A COMPREHENSIVE DICTIONARY OF CHEMISTRY

Chief Editor & Compiler:
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Preface

Chemistry is the subject which is involved in every kind of element which we are able to see or not, tangible or intangible. In a way this subject concerns everybody. The dictionary, which we are presenting, takes care of this fact. This dictionary is formulated in such a way that every kind of reader, be a student, a teacher, a researcher or any other who is remotely concerned with the subject will find it useful. The presentation of facts is simple and non-technical. Besides defining the terms we have also provided pictorial presentation of many terms, which will help the reader to extract the crust of the definition. Apart from that these images are a kind of supplementary definitions for a particular term. These are used as a tool to enhance the reader's knowledge with some extra information. The images also provide spatial distribution of some compound, their crystal structure, their orientations in three-dimensional space, etc. This dictionary contains more than 2000 terms. All the definitions are well researched, simple and exhaustive. It provides all sorts of information concerning chemistry, and related subjects. All possible information is included with utmost accuracy.

This dictionary has been developed with great deal of effort, with lot of hard work in developing the contents. A response for this effort is greatly anticipated.
With this we hope readers will enjoy reading this dictionary and found it more information than any other existing ones.

■ **μ**
the letter "μ" when used as a prefix before a unit symbol indicates a multiplier of 10^{-6}. Abbreviation of "micro".

■ **μA**
symbol and abbreviation of microampere (= 10^{-6} ampere, one millionth of an ampere).

■ **μC**
symbol and abbreviation of microcoulomb (= 10^{-6} coulomb, one millionth of a coulomb).

■ **μF**
symbol and abbreviation of microfarad (= 10^{-6} farad, one millionth of a farad).

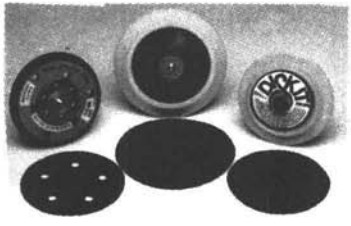
■ **μV**
symbol and abbreviation of microvolt (= 10^{-6} volt, one millionth of a volt).

■ **2D scenario**
the old term used to describe these compounds was 'Geometrical Isomer'. It is still commonly encountered, especially in older text books and those trained from them. It is however an unnecessary complication as the term diastereomer adequately describes such compounds.

These two compounds are clearly not mirror images (2D enantiomers) but are still stereoisomers of each other. They are therefore 2D diastereomers.

■ **3D scenario**
the α-amino acid 2-amino-3-methylpentanoic acid has 2 asymmetric centres indicated by the asterisks. (A maximum of 2^n different compounds, where n = number of chiral centres exist).

■ **abrasive**
a very hard, brittle, heat-resistant substance that is used to grind the edges or rough surfaces of an object. boron carbide, diamond, and corundum are abrasives.



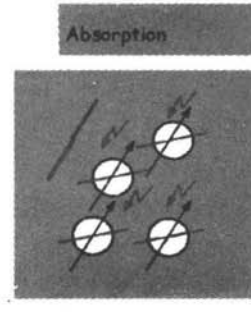
■ **absolute error**
absolute uncertainty. The uncertainty in a measurement, expressed with appropriate units. For example, if three replicate weights for an object are 1.00 g, 1.05 g, and 0.95 g.

the absolute error can be expressed as ± 0.05 g. Absolute error is also used to express inaccuracies; for example, if the "true value" is 1.11 g and the measured value is 1.00 g, the absolute error could be written as 1.00 g - 1.11 g = -0.11 g. Note that when absolute errors are associated with indeterminate errors , they are preceded with "±"; when they are associated with determinate errors , they are preceded by their sign.

■ **absolute temperature**
temperature measured on a scale that sets absolute zero as zero. In the SI system, the kelvin scale is used to measure absolute temperature.

■ **absolute zero**
(0 K), the temperature at which the volume of an ideal gas becomes zero; a theoretical coldest temperature that can be approached but never reached. Absolute zero is zero on the Kelvin scale, -273.15°C on the Celsius scale, and -459.67°F on the Fahrenheit scale.

■ **absorption**
1. penetration of molecules into the bulk of a solid or liquid, forming either a solution or compound. Absorption can be a chemical process (a strong solution of NaOH absorbs CO_2 from the air) or a physical process (palladium absorbs hydrogen gas).
2. capture and transformation of energy by a substance; for example, copper looks reddish because it absorbs blue light. An absorbent captures another material and distributes it throughout; an adsorbent captures another material and distributes it on its surface only.



■ **absorption spectrum**
a plot that shows how much radiation a substance absorbs at different wavelengths. Absorption spectra are unique for each element and compound and

they are often used as chemical "fingerprints" in analytical chemistry. The spectrum can represented by a plot of either absorbance or transmittance versus wavelength, frequency, or wavenumber.

■ **accuracy**

accuracy is the correctness of a single measurement. The accuracy of a measurement is assessed by comparing the measurement with the true or accepted value, based on evidence independent of the measurement. The closeness of an average to a true value is referred to as "trueness".

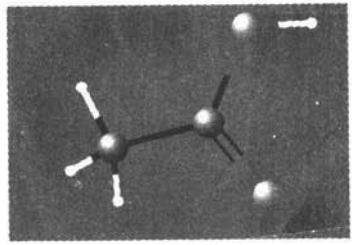
■ **acetate**

(CH_3COO-, $C_2H_3O_2$-) acetate ion.

1. an ion formed by removing the acidic hydrogen of acetic acid, $HC_2H_3O_2$.
2. a compound derived by replacing the acidic hydrogen in acetic acid.
3. a fiber made of cellulose acetate.

■ **acetic acid**

CH_3COOH, $HC_2H_3O_2$, ethanoic acid; vinegar acid; methanecarboxylic acid. A simple organic acid that gives vinegar its characteristic odour and flavour. Glacial acetic acid is pure acetic acid.



■ **achiral**

the opposite of 'Chiral'. An achiral molecule has a superimposable (identical) mirror image. It is optically inactive.

■ **acid**

Latin. word acidus, meaning sour.

1. a compound which releases hydrogen ions (H^+) in solution (Arrhenius).
2. a compound containing detachable hydrogen ions (Bronsted-Lowry).
3. a compound that can accept a pair of electrons from a base (Lewis).

■ **acid anhydride**

non-metallic oxides or organic compounds that react with water to form acids. For example,

SO_2, CO_2, P_2O_5, and SO_3 are the acid anhydrides of sulphurous, carbonic, phosphoric, and sulphuric acids, respectively. Acetic anhydride $(CH_3CO)_2O$ reacts with water to form acetic acid.

■ **acid dissociation constant**
symbolised as K_a. Also known as acid ionisation constant. The equilibrium constant for the dissociation of an acid into a hydrogen ion and an anion. For example, the acid dissociation constant for acetic acid is the equilibrium constant for $HC_2H_3O_2(aq) \rightarrow H^+(aq) + C_2H_3O_2^-(aq)$, which is Ka à $[H^+][C_2H_3O_2^-]/[HC_2H_3O_2]$.

■ **acid halide**
acid chloride; acyl halide; acyl chloride. Compounds containing a carbonyl group bound to a halogen atom.

■ **acidbase indicator**
a weak acid that has acid and base forms with sharply different colours. Changes in pH around the acid's pK_a are "indicated" by colour changes.

■ **acidulant**
a substance added to food or beverages to lower pH and to impart a tart, acid taste. Phosphoric acid is an acidulant added to cola drinks.

■ **actinide**
elements 89-102 are called actinides. Electrons added during the Aufbau construction of actinide atoms go into the 5f subshell. Actinides are unstable and undergo radioactive decay. The most common actinides on Earth are uranium and thorium.

■ **activated charcoal**
also known as activated carbon; active carbon. A porous form of carbon that acts as a powerful adsorbent, used to decolourise liquids, recover solvents, and remove toxins from water and air.

■ **activated complex**
transition state. An intermediate structure formed in the conversion of reactants to products. The activated complex is the structure at the maximum energy point along the reaction path; the activation energy is the difference between the energies of the activated complex and the reactants.

■ **activation energy**
for the forward reaction is the energy required to go from reactants to the transition state. The activation energy for the reverse reaction is the energy required to go from products to the transition state.

■ **activity**
an effective concentration used in thermodynamic calculations in place of the actual concentration to allow equations developed for ideal solutions to be used to treat real solutions.

■ **addition compound**
an addition compound contains two or more simpler compounds that can be packed in a definite ratio into a crystal. A dot is used to separate the compounds in the formula. For example, $ZnSO_4 \cdot 7\ H_2O$ is an addition compound of zinc sulphate and water. This represents a compound, and not a mixture, because there is a definite 1:7 ratio of zinc sulphate to water in the compound. Hydrates are a common type of addition compound.

■ **adhesion**
attraction between different substances on either side of a phase boundary.

■ **adiabat**
a line on an indicator diagram that represents an adiabatic process.

■ **adiabatic**
adiabatic process; isentropic process. A process that neither absorbs nor releases energy into the surroundings. For example, a chemical reaction taking place in a closed thermos bottle can be considered adiabatic. Very fast processes can often be considered adiabatic with respect to heat exchange with the surroundings, because heat exchange is not instantaneous.

■ **adsorbent**
a substance that collects molecules of another substance on its surface. For example, gases that make water taste bad are strongly adsorbed on activated charcoal granules in water filters.

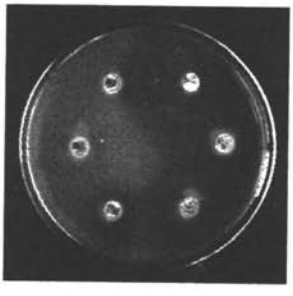
■ **adsorption**
adsorption is collection of a substance on the surface of a

solid or a liquid. For example, gases that make water taste bad are strongly adsorbed on charcoal granules in water filters.

■ **aeration**
preparation of a saturated solution of air gases by either spraying the solution in air or by bubbling air through it.

■ **aerosol**
a colloid in which solid particles or liquid droplets are suspended in a gas. Smoke is an example of a solid aerosol; fog is an example of a liquid aerosol.

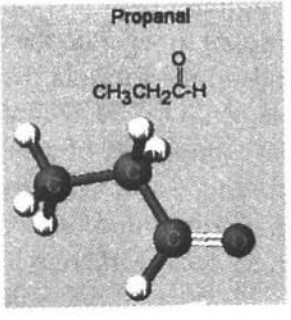
■ **agar**
a gel made from seaweed used to make salt bridges.



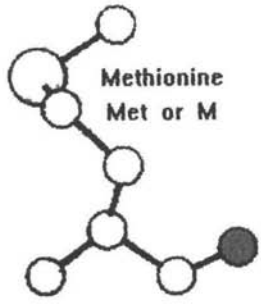
■ **-al**
a suffix added to the systematic names of organic compounds that contain an aldehyde group -(C=O)-H. For example, the systematic name of acetaldehyde, CH_3CHO, is ethanal.

■ **alcohol**
an alcohol is an organic compound with a carbon bound to a hydroxyl group. Examples are methanol, CH_3OH; ethanol, CH_3CH_2OH; propanol, $CH_3CH_2CH_2OH$. Compounds with -OH attached to an aromatic ring are called phenols rather than alcohols.

■ **aldehyde**
an aldehyde is an organic compound with a carbon bound to a -(C=O)-H group. Examples are formaldehyde (HCHO), acetaldehyde, CH_3CHO, and benzaldehyde, C_6H_6CHO.



■ **aliphatic**
an organic compound that does not contain ring structures.



■ **aliquot**
a sample of precisely determined amount taken from a material.

■ **alkali metal**
(alkaline earth metal) alkali metal element. The Group 1 elements, lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), and francium (Fr) react with cold water for form strongly alkaline hydroxide solutions, and are referred to as "alkali metals". Hydrogen is not considered an alkali metal, despite its position on some periodic tables.

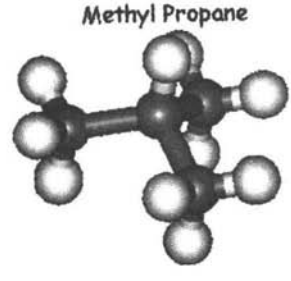
■ **alkaline**
having a pH greater than 7.

■ **alkaline earth**
an oxide of an alkaline earth metal , which produces an alkaline solution in reaction with water.

■ **alkaline earth metal**
(alkali metal) The Group 2 elements, beryllium (Be), magnesium (Mg), calcium (Ca), strontium (Sr), barium (Ba), and radium (Ra) form alkaline oxides and hydroxides and are called "alkaline earth metals".

■ **alkalinity**
a measure of a material's ability to neutralise acids . Alkalinities are usually determined using titration.

■ **alkane**
paraffin. Compare with hydrocarbon and alkene. A series of organic compounds with general formula C_nH_{2n+2}. Alkane names end with -ane. Examples are propane (with n=3) and octane (with n=8).



■ **alkene**
a compound that consists of only carbon and hydrogen, that contains at least one carbon-car-

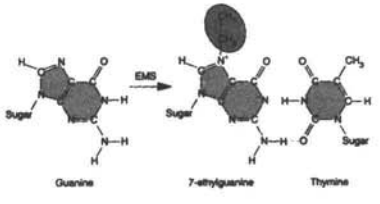
bon double bond. Alkene names end with -ene. Examples are ethylene ($CH_2=CH_2$); 1-propene ($CH_2=CH_2CH_3$), and 2-octane ($CH_3CH_2=CH_2(CH_2)_4CH_3$).

■ **alkoxide**

($RO^- M^+$) alkoxide ion. An ionic compound formed by removal of hydrogen ions from the hydroxyl group in an alcohol using reactive metals, e.g. sodium. For example, potassium metal reacts with methanol (CH_3OH) to produce potassium methoxide ($KOCH_3$).

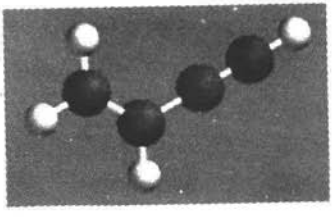
■ **alkyl**

($-C_nH_{2n+1}$) alkyl group. A molecular fragment derived from an alkane by dropping a hydrogen atom from the formula. Examples are methyl (CH_3) and ethyl (CH_2CH_3).



■ **alkyne**

a compound that consists of only carbon and hydrogen, that contains at least one carbon-carbon triple bond. Alkyne names end with -yne. Examples are acetylene (CHCH); 1-propyne ($CH_2CH_2CH_3$), and 2-octyne ($CH_3CH_2CH_2(CH_2)_4CH_3$).



■ **allo**

a prefix that designates the more stable of a pair of geometric isomers. allo- is sometimes used less precisely to designate isomers or close relatives of a compound.

■ **allobar**

a form of an element that has isotopic abundances that are different from the naturally occuring form. For example, "depleted" uranium has had most of the uranium-235 removed, and is an allobar of natural uranium.

■ **allomer**

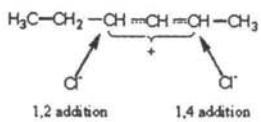
allomerism. Substances with different chemical composition but the same crystalline form.

■ **allotrope**
allotropy; allotropic; allotropism. Compare with isotope and polymorph . Some elements occur in several distinct forms called allotropes. Allotropes have different chemical and physical properties. For example, graphite and diamond are allotropes of carbon.

■ **alloy**
alloying; alloyed. Compare with amalgam . A mixture containing mostly metals. For example, brass is an alloy of copper and zinc. Steel contains iron and other metals, but also carbon.

■ **allyl**
allylic; allyl group; allyl radical. A molecular fragment derived by removing a methyl hydrogen from propene (-CH2-CH_2=CH_2). For example, "allyl chloride" is 3-chloropropene, Cl-CH_2-CH_2=CH_2.

Allyl cation

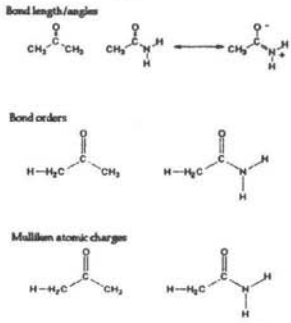


■ **alpha particle**
($^4_2$He) a particle that is commonly ejected from radioactive nuclei, consisting of two protons and two neutrons. Alpha particles are helium nuclei. Alpha particles have a mass of 6.644 655 98 × 10^{-27} kg or 4.001 506 1747 atomic mass units.

■ **alpha ray**
(a -ray) alpha radiation. A stream of alpha particles. Alpha rays rapidly dissipate their energy as they pass through materials, and are far less penetrating than beta particles and gamma rays .

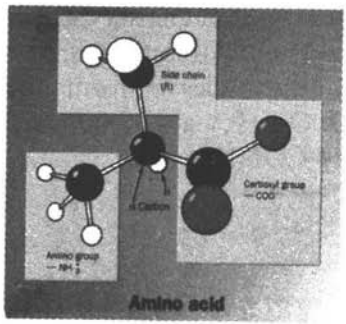
■ **amalgam**
an alloy that contains mercury.

■ **amide**
an amide is an organic compound that contains a carbonyl group bound to nitrogen: . The simplest amides are formamide ($HCONH_2$) and acetamide (CH_3CONH_2).



■ **amine**
compare with ammine. An amine is an organic compound that contains a nitrogen atom bound only to carbon and possibly hydrogen atoms. Examples are methylamine, CH_3NH_2; dimethylamine, CH_3NHCH_3; and trimethylamine, $(CH_3)_3N$.

■ **amino acid**
amino acids are molecules that contain at least one amine group ($-NH_2$) and at least one carboxylic acid group (-COOH). When these groups are both attached to the same carbon, the acid is an -amino acid. -amino acids are the basic building blocks of proteins.



■ **ammine**
a metal ion complex containing ammonia as a ligand. The ammonia nitrogen is bound directly to a metal ion in ammines; amines differ in that the ammonia nitrogen is directly bound to a carbon atom.

■ **ammonia**
$-NH_3$, pure NH_3 is a colourless gas with a sharp, characteristic odour. It is easily liquified by pressure, and is very soluble in water. Ammonia acts as a weak base . Aqueous solutions of ammonia are (incorrectly) referred to as "ammonium hydroxide".

■ **ammonium ion**
NH_4^+, ammonium. NH_4^+ is a cation formed by neutralisation of ammonia , which acts as a weak base.

■ **amorphous**
a solid that does not have a repeating, regular three-dimensional arrangement of atoms, molecules, or ions.

■ **ampere**
the SI unit of electric current , equal to flow of 1 coulomb of charge per second. An ampere is the amount of current necessary to produce a force of 0.2 micronewtons per meter between two arbitrarily long, arbitrarily thin wires, placed parallel in a vacuum and exactly 1

m apart. Named for 19th century physicist André Marie Ampère.

■ **amphiprotic solvent**
solvents that exhibit both acidic and basic properties; amphiprotic solvents undergo autoprotolysis. Examples are water, ammonia, and ethanol.

■ **amphoteric**
a substance that can act as either an acid or a base in a reaction. For example, aluminium hydroxide can neutralise mineral acids ($Al(OH)_3 + 3\ HCl$ ® $AlCl_3 + 3\ H_2O$) or strong bases ($Al(OH)_3 + 3\ NaOH$ ® $Na_3AlO_3 + 3\ H_2O$).

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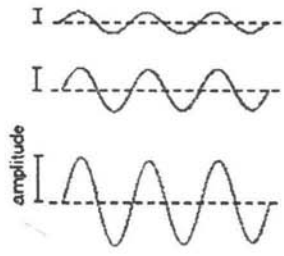
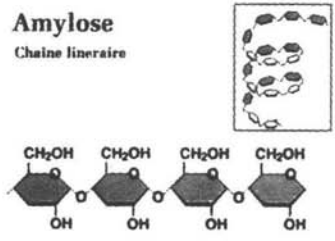
or
strong bases ($Al(OH)_3 + 3\ NaOH \rightarrow Na_3AlO_3 + 3\ H_2O$).

■ **amplitude**
the displacement of a wave from zero. The maximum amplitude for a wave is the height of a peak or the depth of a trough, relative to the zero displacement line.



■ **amylopectin**
a component of starch that is very large with molecular weights of up to 1,500,000. It has a branched structure because of 1,6- glycosidic linkages which occur in addition to the 1,4-linkages. Branching occurs at every 20th to 25th glucose molecule.

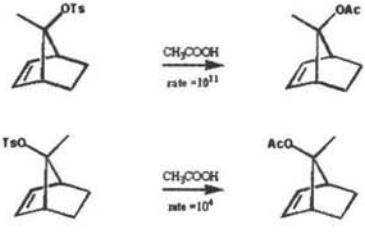
■ **amylose**
a component of starch that is smaller than amylopectin and is relatively unbranched.



■ **analysis**
chemical analysis. Determination of the composition of a sample.

■ **analyte**
an analyte is the sample constituent whose concentration is sought in a chemical analysis.

■ **anchimeric assistance**
anchimeric assistance is the term used to describe a reaction when the rate of the reaction is increased due to neighbouring group participation. For example the difference in rate of acetate substitution in the following reactions is 10^7. If the first reaction was over in 10 minutes the second would take 190 years to reach completion. In this example the electrons in the sigma-bond are responsible for neighbouring group participation which enhances the rate. N.B. The stereochemistry is not inverted in these reactions because of the double Walden inversion that is occurring.



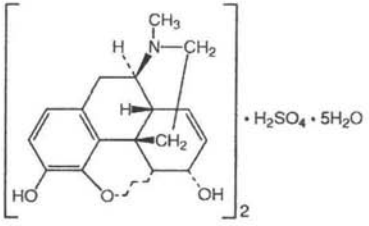
■ **angle strain**
also referred to as 'Baeyer Strain'. Angle strain results when the bond angle is distorted from the normal bonding angle. For example in cyclopropane the bond angle is required to be 60°, which represents a large deviation from the ideal tetrahedral angle of 109.5° for an sp^3 hybridised carbon. This deviation causes strain.
In cyclobutane and cyclopentane the angle strain is minimised by ring puckering, while for cyclohexane there is no angle strain.

■ **Angstrom**
Å, Ångstrom units. A non-SI unit of length used to express wavelengths of light, bond lengths, and molecular sizes. 1 Å = 10^{-10} m = 10^{-8} cm.

■ **angular momentum quantum number**
also known as azimuthal quantum number; orbital angular momentum quantum number. A quantum number that labels the subshells of an atom. Sometimes called the orbital angular momentum quantum number, this quantum number dictates orbital shape. can take on val-

ues from 0 to n-1 within a shell with principal quantum number n.

■ **anhydrous**
anhydrous compound; anhydride. A compound with all water removed, especially water of hydration. For example, strongly heating copper(II) sulphate pentahydrate ($CuSO_4 \cdot 5H_2O$) produces anhydrous copper(II) sulphate ($CuSO_4$).

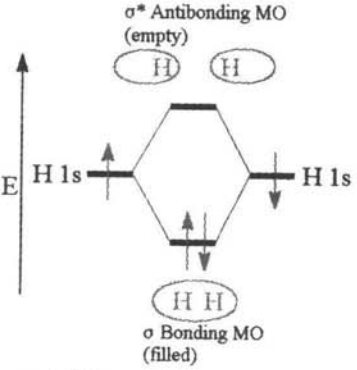


■ **anion**
an anion is a negatively charged ion. Non-metals typically form anions.

■ **anode**
the electrode at which oxidation occurs in a cell. Anions migrate to the anode.

■ **anodise**
to coat a metal with a protective film by electrolysis.

■ **antibonding orbital**
a molecular orbital that can be described as the result of destructive interference of atomic orbitals on bonded atoms. Antibonding orbitals have energies higher than the energies its constituent atomic orbitals would have if the atoms were separate.



■ **antichlor**
a chemical compound that reacts with chlorine-based bleaches to stop the bleaching. Thiosulphate compounds are antichlors.

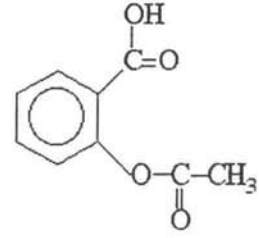
■ **anticlinal**
when the X-C-C-Y dihedral (sometimes called 'torsional') angle is between 90° and 150° or -90° and -150° (210° to 270°) the conformer is called anticlinal.

■ **antioxidant**
antioxidants are compounds that slow oxidation processes that degrade foods, fuels, rubber, plastic, and other materials. Antioxidants like butylated hydroxyanisole (BHA) are added to food to prevent fats from becoming rancid and to minimise decomposition of vitamins and essential fatty acids; they work by scavenging destructive free radicals from the food.

■ **antiozonant**
substances that reverse or prevent severe oxidation by ozone. Antiozonants are added to rubber to prevent them from becoming brittle as atmospheric ozone reacts with them over time. Aromatic amines are often used as antiozonants.

■ **antiperiplanar**
when the X-C-C-Y dihedral (sometimes called 'torsional') angle is between 150° and 210° the conformer is called antiperiplanar. The most frequently cited example has X and Y directly opposite in a fully staggered conformation (i.e. 180°).

■ **antipyretic**
a substance that can lessen or prevent fever.



■ **Antoine equation**
a simple 3-parameter fit to experimental vapour pressures measured over a restricted temperature range: log P = A-B/T+C where A, B, and C are "Antoine coefficients" that vary from substance to substance. Sublimations and vapourisations of the same substance have separate sets of Antoine coefficients, as do components in mixtures. The Antoine equation is accurate to a few percent for most volatile substances (with vapour pressures over 10 Torr).

■ **aprotic solvent**
a solvent that does not act as an acid or as a base; aprotic solvents don't undergo autoprotolysis. Examples are pentane, pet ether, and toluene.

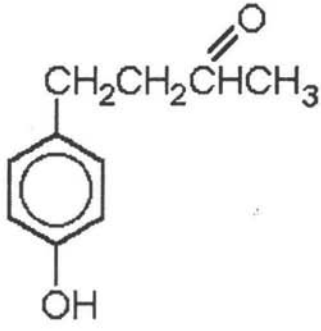
■ **aqua regia**
a mixture of nitric and hydrochloric acids, usually 1:3 or 1:4 parts HNO_3 to HCl, used to dissolve gold.

■ **aqueous**
a substance dissolved in water.

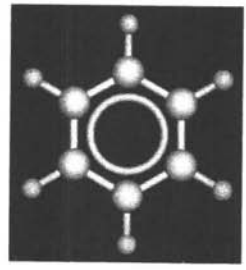
■ **aqueous solution**
a solution in which water is the dissolving medium or solvent.

■ **arene**
hydrocarbon that contains at least one aromatic ring.

■ **aromatic compound**
a compound containing an aromatic ring. Aromatic compounds have strong, characteristic odours.



■ **aromatic ring**
an exceptionally stable planar ring of atoms with resonance structures that consist of alternating double and single bonds, e. g. benzene:



■ **Arrhenius equation**
in 1889, Svante Arrhenius explained the variation of rate constants with temperature for several elementary reactions using the relationship $k = A \exp(-E_a/RT)$ where the rate constant k is the total frequency of collisions between reaction molecules A times the fraction of collisions $\exp(-E_a/RT)$ that have an energy that exceeds a threshold activation energy E_a at a temperature of T (in kelvins). R is the universal gas constant.

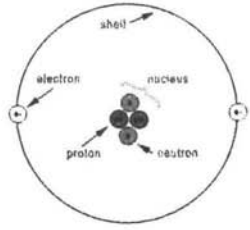
■ **aryl**
a molecular fragment or group attached to a molecule by an atom that is on an aromatic ring.

■ **asymmetric centre**
when an sp^3 hybridised centre, generally Carbon with Phosphorus and Nitrogen being the most commonly encountered exceptions, possesses 4 different groups attached to it the centre is said to be asymmetric (i.e. without symmetry).

■ **atmosphere**
(atm) a unit of pressure, equal to a barometer reading of 760 mm Hg. 1 atmosphere is 101325 pascals and 1.01325 bar.

■ **atom**
an atom is the smallest particle of an element that retains the chemical properties of the element. Atoms are electrically neutral, with a positively charged nucleus that binds one or more electrons in motion around it.

The Atom



■ **atomic mass unit**
a unit of mass equal to 1/12 the mass of a carbon-12 nucleus, which is $1.660\ 538\ 73 \times 10^{-27}$ kg $\pm$ $0.000\ 000\ 13 \times 10^{-27}$ kg Abbreviated as amu or u. Sometimes called the dalton, after John Dalton, architect of the first modern atomic theory.

■ **atomic nucleus**
a tiny, incredibly dense positively charged mass at the heart of the atom. The nucleus is composed of protons and neutrons (and other particles). It contains almost all of the mass of the atom but occupies only a tiny fraction of the atom's volume.

■ **atomic number**
the number of protons in an atomic nucleus . The atomic number and the element symbol are two alternate ways to label an element. In nuclide symbols , the atomic number is a leading subscript; for example, in $^{12}_{6}C$, the "6" is the atomic number.

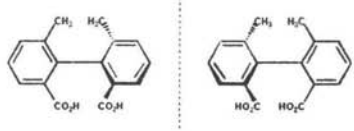
■ **atomic orbital**
a wave function that describes the behaviour of an electron in an atom.

■ **atomic radius**
metallic radius; covalent radius; atomic radii. Compare with ionic radius. One half the distance between nuclei of atoms of the same element, when the atoms are bound by a single covalent bond or are in a metallic crystal. The radius of atoms obtained from covalent bond lengths is called the covalent radius; the radius from interatomic distances in metallic crystals is called the metallic radius.

■ **atomic theory**
an explanation of chemical properties and processes that assumes that tiny particles called atoms are the ultimate building blocks of matter.

■ **atomic weight**
atomic mass. The average mass of an atom of an element, usually expressed in atomic mass units . The terms mass and weight are used interchangeably in this case. The atomic weight given on the periodic table is a weighted average of isotopic masses found in a typical terrestrial sample of the element.

■ **atropisomer**
an atropisomer is a special case where the molecule can be equally well described as a 'Conformational Isomer' and a 'Configurational Isomer'. They result from 'Restricted Rotation' about a single bond. The two molecules below represent non-superimposable mirror images of each other, 'Enantiomers', due to restricted rotation. The class of compounds are known as atropisomers.



■ **atto**
prefix used in the SI system meaning "multiply by 10^{-18}". For example, 3 am means 3×10^{-18} meters.

■ **Aufbau principle**
an approximate procedure for writing the ground state electronic configuration of atoms. The configuration of an atom is obtained by inserting one electron into the configuration of the atom immediately to its left on the periodic table. The electron is inserted into the

subshell indicated by the element's period and block.

■ **autoignition temperature**
minimum temperature at which the vapour/air mixture over a liquid spontaneously catches fire.

■ **autoprotolysis**
autoionisation; autoionisation constant; autoprotolysis constant. Transfer of a hydrogen ion between molecules of the same substance, e. g. the autoprotolysis of methanol (2 CH_3OH à $CH_3OH_2^+ + CH_3O^-$). Autoprotolysis of water into hydronium ions and hydroxide ions results in equilibrium concentrations that satisfy $K_w = [H_3O^+][OH^-]$, where the autoprotolysis constant K_w is equal to 1.01×10^{-14} at 25°C.

■ **autoxidation**
oxidation caused by exposure to air. Rust is an example of autoxidation. Autoxidation makes ether taken from half-filled bottles very dangerous, because air oxidises ether to highly explosive organic peroxides.

■ **average bond enthalpy**
average enthalpy change per mole when the same type of bond is broken in the gas phase for many similar substances.

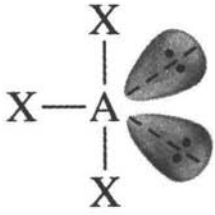
■ **Avogadro**
Italian chemist and physicist Amadeo Avogadro (1776-1856) proposed a correct molecular explanation for Gay-Lussac's law of combining volumes . His work provided a simple way to determine atomic weights and molecular weights of gases.

■ **Avogadro number**
(N_A, L) Avogadro's number; Avogadro constant. The number of particles in one mole, equal to $6.02214199 \times 10^{23}$ mol^{-1} ($\pm$ 0.00000047 mol^{-1}).

■ **Avogadro's law**
equal volumes of an ideal gas contain equal numbers of molecules, if both volumes are at the same temperature and pressure. For example, 1 L of ideal gas contains twice as many molecules as 0.5 L of ideal gas at the same temperature and pressure.

■ **axial**
an atom, bond, or lone pair that is perpendicular to equatorial atoms, bonds, and lone pairs in

a trigonal bipyramidal molecular geometry.



■ **azeotrope**
azeotropic mixture; azeotropy. A solution that does not change composition when distilled. For example, if a 95% (w/w) ethanol solution in water is boilled, the vapour produced also is 95% ethanol- and it is not possible to obtain higher percentages of ethanol by distillation.

■ **azo**
azo compound; azo group; azo dye. The azo group has the general structure Ar-N=N-Ar', where Ar and Ar' indicate substituted aromatic rings. Compounds containing the azo compounds are often intensely coloured and are economically important as dyes. Methyl orange is an example of an azo dye.

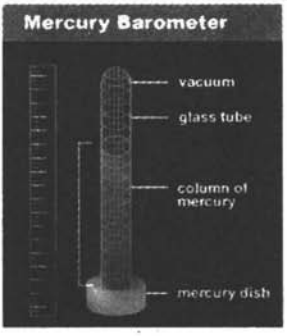
■ **balanced equation**
balanced. a description of a chemical reaction that gives the chemical formulas of the reactants and the products of the reaction, with coefficients introduced so that the number of each type of atom and the total charge is unchanged by the reaction. For example, a balanced equation for the reaction of sodium metal (Na(s)) with chlorine gas ($Cl_2(g)$) to form table salt (NaCl(s)) would be 2 Na(s) + $Cl_2(g)$ ® 2 NaCl(s), NOT Na(s) + $Cl_2(g)$ = NaCl(s).

■ **Balmer series**
balmer lines. A series of lines in the emission spectrum of hydrogen that involve transitions to the n=2 state from states with n>2.

■ **band spectrum**
band spectra. Compare with line spectrum and continuous spectrum. An emission spectrum that contains groups of sharp peaks that are so close together that they are not distinguishable separately, but only as a "band".

■ **bar**
unit of pressure . 1 bar = 10^5 pascals = 1.01325 atmospheres

■ **barometer**
compare with manometer. An instrument that measures atmospheric pressure. A mercury barometer is a closed tube filled with mercury inverted in a mercury reservoir. The height of the mercury column indicates atmospheric pressure (with 1 atm = 760 mm of mercury). An aneroid barometer consists of an evacuated container with a flexible wall. When atmospheric pressure changes, the wall flexes and moves a pointer which indicates the changing pressure on a scale.



■ **base**
1. a compound that reacts with an acid to form a salt.
2. a compound that produces hydroxide ions in aqueous solution (Arrhenius).
3. a molecule or ion that captures hydrogen ions.(Bronsted-Lowry).
4. a molecule or ion that donates an electron pair to form a chemical bond.(Lewis).

■ **base hydrolysis constant**
(K_b) base ionisation constant; basic hydrolysis constant. Compare with acid dissociation constant. The equilibrium constant for the hydrolysis reaction associated with a base. For example, K_b for ammonia is the equilibrium constant for $NH_3(aq) + H_2O \rightarrow NH_4^+(aq) + OH^-(aq)$, or $Kb = [NH_4^+][OH^-]/[NH_3]$.

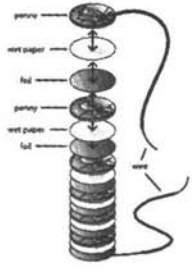
■ **base unit**
base units are units that are fundamental building blocks in a system of measurement. There are seven base units in the SI system.

■ **basis function**
a mathematical function that can be used to build a description of wavefunctions for electrons in atoms or molecules.

■ **basis set**
a set of mathematical functions that are combined to approximate the wavefunctions for

electrons in atoms and molecules.

■ **battery**
a group of voltaic cells connected in series.



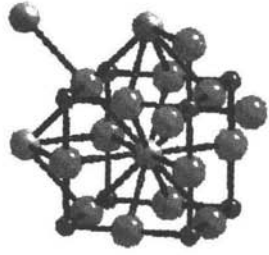
Battery

■ **battery acid**
a solution of approximately 6M sulphuric acid used in the lead storage battery.

■ **beta particle**
(ß-) an electron emitted by an unstable nucleus , when a neutron decays into a proton and an electron. In some cases, beta radiation consists of positrons ("antielectrons" which are identical to electrons but carry a +1 charge.") Note that beta particles are created in nuclear decay; they do not exist as independent particles within the nucleus.

■ **bimolecular step**
two species are reacting and form the transition state.

■ **binary compound**
compare with compound . A compound that contains two different elements. NaCl is a binary compound; NaClO is not.



■ **biochemistry**
the chemistry of living things, including the structure and function of biological molecules and the mechanism and products of their reactions.

■ **bleach**
a dilute solution of sodium hypochlorite or calcium hypochlorite which kills bacteria and destroys coloured organic materials by oxidising them.

■ **block**
a region of the periodic table that corresponds to the type of subshell (s, p, d, or f) being

filled during the Aufbau construction of electron configurations.

■ **Bohr atom**
bohr's theory; Bohr's atomic theory; Bohr model. A model of the atom that explains emission and absorption of radiation as transitions between stationary electronic states in which the electron orbits the nucleus at a definite distance. The Bohr model violates the Heisenberg uncertainty principle, since it postulates definite paths and momenta for electrons as they move around the nucleus. Modern theories usually use atomic orbitals to describe the behaviour of electrons in atoms.

■ **boiling point**
(bp) standard boiling point; normal boiling point. The temperature at which the vapour pressure of a liquid is equal to the external pressure on the liquid. The standard boiling point is the temperature at which the vapour pressure of a liquid equals standard pressure.

■ **boiling point elevation**
the boiling point of a solution is higher than the boiling point of the pure solvent. Boiling point elevation is a colligative property.

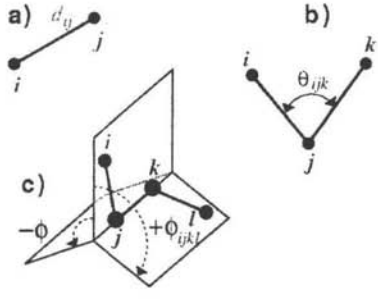
■ **Boltzmann constant**
(k) Boltzmann's constant, a fundamental constant equal to the ideal gas law constant divided by Avogadro's number , equal to 1.3805×10^{-23} J K^{-1}.

■ **Boltzmann equation**
a statistical definition of entropy, given by $S = k \ln W$, where S and k are the entropy and Boltzmann's constant, respectively, and W is the probability of finding the system in a particular state.

■ **bond energy**
compare with bond enthalpy. Energy change per mole when a bond is broken in the gas phase for a particular substance.

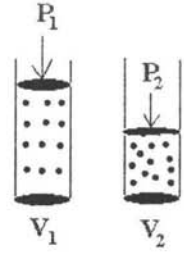
■ **bond enthalpy**
compare with average bond enthalpy. Enthalpy change per mole when a bond is broken in the gas phase for a particular substance.

■ **bond length**
the average distance between the nuclei of two bonded atoms in a stable molecule.



■ **bond order**
1. in Lewis structures, the number of electron pairs shared by two atoms.
2. in molecular orbital theory, the net number of electron pairs in bonding orbitals (calculated as half the difference between the number of electrons in bonding orbitals and the number of electrons in antibonding orbitals.

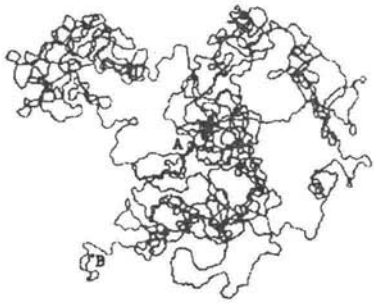
■ **Boyle's law**
the pressure of a ideal gas is inversely proportional to its volume, if the temperature and amount of gas is held constant. Doubling gas pressure halves gas volume, if temperature and amount of gas don't change. If the initial pressure and volume are P_1 and V_1 and the final pressure and volume are P_2V_2, then $P_1V_1 = P_2V_2$ at fixed temperature and gas amount.



■ **Brönsted acid**
compare with acid. A material that gives up hydrogen ions in a chemical reaction.

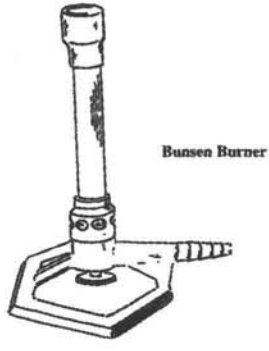
■ **Brönsted base**
compare with base A material that accepts hydrogen ions in a chemical reaction.

■ **Brownian motion**
Brownian movement. Small particles suspended in liquid move spontaneously in a random fashion. The motion is caused by unbalanced impacts of molecules on the particle. Brownian motion provided strong circumstantial evidence for the existence of molecules.



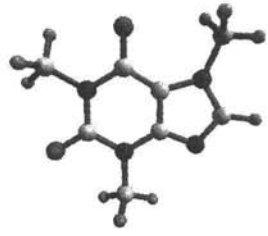
■ **buffer**
pH buffer; buffer solution. A solution that can maintain its pH value with little change when acids or bases are added to it. Buffer solutions are usually prepared as mixtures of a weak acid with its own salt or mixtures of salts of weak acids. For example, a 50:50 mixture of 1 M acetic acid and 1 M sodium acetate buffers pH around 4.7.

■ **Bunsen burner**
a gas burner with adjustable air intake, commonly used in laboratories.



■ **Bürgi-Dunitz angle**
the Bürgi-Dunitz angle or Bürgi-Dunitz trajectory as it is sometimes called represents the angle that a nucleophile attacks an sp^2 hybridised centre, such as that in a carbonyl system. The angle of attack is approximately 109°, not 180° as if often depicted.

■ **caffeine**
($C_8H_{10}N_4O_2$) methyltheobromine; guaranine; 1,3,7-trimethylxanthine; 1,3,7-trimethyl-2,6-dioxopurine. A substance found in tea, coffee, and cola that acts as a stimulant. It is extremely soluble in supercritical fluid carbon dioxide and somewhat soluble in water; aqueous solutions of caffeine quickly break down.

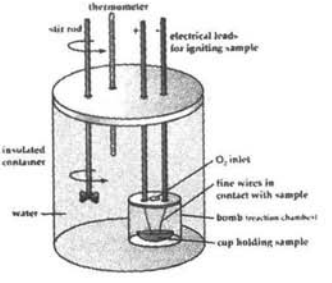


■ **calibration**
calibration is correcting a measuring instrument by measuring values whose true values are

known. Calibration minimises systematic error.

■ **calorie**
the amount of heat required to raise the temperature of 1 g of water at 14.5°C to 15.5°C. One calorie is equivalent to exactly 4.184 J.

■ **calorimeter**
an insulated vessel for measuring the amount of heat absorbed or released by a chemical or physical change.



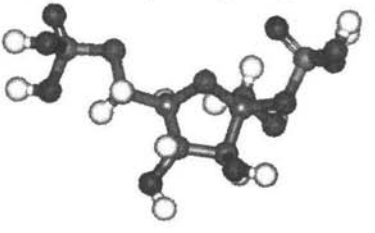
■ **calorimetry**
experimental determination of heat absorbed or released by a chemical or physical change.

■ **calutron**
a device that separates isotopes (e. g. ^{235}U from ^{238}U) by ionising the sample, accelerating the ions in a strong electric field, and then passing them through a strong magnetic field. The magnetic field bends the trajectories of the ions with high charge-to-mass ratio more, allowing ions to be separated by mass and collected.

■ **carbocation**
an electron deficient carbon with only three single bonds. It is positively charged. A primary carbocation is bonded to only one other carbon, a secondary carbocation is bonded to two other carbon atoms and a tertiary carbocation is bonded to three other carbon atoms. The tertiary carbocation is most stable due to the stabilising effect of the alkyl groups which donate electrons to stabilise the ion.

■ **carbohydrate**
a polyhydroxyl aldehyde or a polyhydroxyl ketone. Many of these compounds are commonly called sugars.

Fructose-2,6-bisphosphate



■ **carbonate hardness**
carbonate water hardness. Compare with water hardness. Water hardness due to the presence of calcium and magnesium carbonates and bicarbonates. The "noncarbonate hardness" is due mostly to calcium and magnesium sulphates, chlorides, and nitrates.

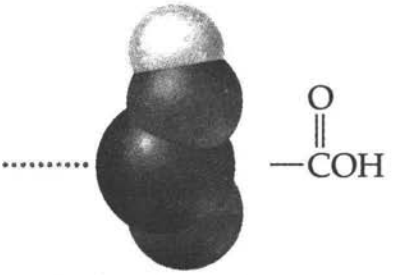
■ **carbonyl**
carbonyl group. A divalent group consisting of a carbon atom with a double-bond to oxygen. For example, acetone (CH_3-(C=O)-CH_3) is a carbonyl group linking two methyl groups. Also refers to a compound of a metal with carbon monoxide, such as iron carbonyl, $Fe(CO)_5$.

Carbonyl

Ketone, located in a carbon chain

Aldehyde, located at the end of a chain

■ **carboxylic acid**
carboxyl; carboxyl group. A carboxylic acid is an organic molecule with a -(C=O)-OH group. The group is also written as -COOH and is called a carboxyl group. The hydrogen on the -COOH group ionises in water; carboxylic acids are weak acids. The simplest carboxylic acids are formic acid (H-COOH) and acetic acid (CH_3-COOH).



Carboxylic acid group

■ **carotene**
carotene is an unsaturated hydrocarbon pigment found in many plants. Carotene is the basic building block of vitamin A.

■ **catalyst**
catalyse; catalysis. A substance that increases the rate of a chemical reaction, without being consumed or produced by the reaction. Catalysts speed both the forward and reverse reactions, without changing the position of equi-

librium. Enzymes are catalysts for many biochemical reactions.

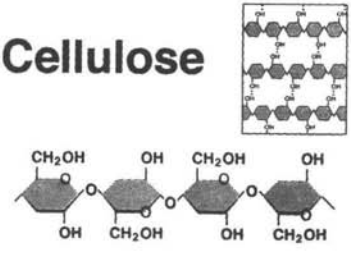
■ **cathode**
compare with anode The electrode at which reduction occurs.

■ **cathode ray**
a negatively charged beam that emanates from the cathode of a discharge tube. Cathode rays are streams of electrons.

■ **cation**
compare with anion A cation is a positively charged ion. Metals typically form cations.

■ **cell potential**
the driving force in a voltaic cell that pulls electrons from the reducing agent in one compartment to the oxidising agent in the other; also called electromotive force; represented by the symbol E. To calculate E, one must add the half-cell potentials of the oxidation and reduction half-reactions.

■ **cellulose**
a long polymer of glucose that contains beta-1,4-glycoside bonds.



■ **celsius**
(°C) Celsius temperature scale; Celsius scale. A common but non-SI unit of temperature, defined by assigning temperatures of 0°C and 100°C to the freezing and boiling points of water, respectively.

■ **centi**
(c) Prefix used in the SI system meaning "one hundredth of". For example 1 cm means "one hundredth of a meter"; 2.3 cg could also be written "2.3 $\times 10^{-2}$ g" or "0.023 g".

■ **cgs**
compare with SI . An older metric system of units that uses

centimeters, grams, and seconds as base units.

■ **Charles' law**
the volume of a gas is directly proportional to its temperature in kelvins, if pressure and amount of gas remain constant. Doubling the kelvin temperature of a gas at constant pressure will double its volume. If V_1 and T_1 are the initial volume and temperature, the final volume and temperature ratio $V_2/T_2 = V_1/T_1$ if pressure and moles of gas are unchanged.

■ **chelate**
a stable complex of a metal with one or more polydentate ligands. For example, calcium complexes with EDTA to form a chelate.

■ **chemical bond**
bond; bonding; chemical bonding. A chemical bond is a strong attraction between two or more atoms. Bonds hold atoms in molecules and crystals together. There are many types of chemical bonds, but all involve electrons which are either shared or transferred between the bonded atoms.

■ **chemical change**
reaction; chemical reaction. Compare with physical change . A chemical change is a dissociation, recombination, or rearrangement of atoms.

■ **chemical equation**
a compact notation for describing a chemical change. The formulas of the reactants are added together on the left hand side of the equation; the formulas of the products are added together on the right side. Coefficients are inserted before the formulas to ensure that the equation is balanced . The phase in which each substance is found is usually indicated in parentheses after each formula. For example, $2\ H_2(g) + O_2(g) = 2\ H_2O(g)$ indicates that 2 moles of hydrogen gas combine with one mole of oxygen gas to produce two moles of steam.

■ **chemical property**
chemical properties. Compare with physical property . Measurement of a chemical property involves a chemical change . For example, determining the flammability of gasoline involves burning it,

producing carbon dioxide and water.

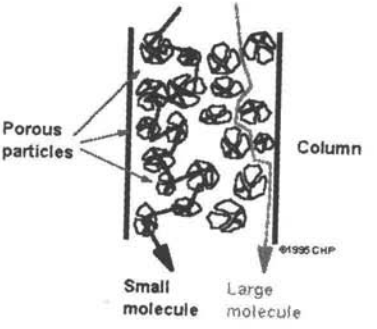
■ **chemistry**
the study of matter and its transformations.

■ **chiral**
derived from the Greek word *'cheir'*, meaning hand. A molecule is chiral if it cannot be superimposed on its mirror image. The opposite of 'Chiral' is 'Achiral'. A chiral molecule is optically active.

■ **chiral centre**
a centre that confers chirality to a molecule. Often used synonomously with the term 'Asymmetric Centre'. However, a centre can be asymmetric without being chiral. For example, *meso*-tartaric acid contains two asymmetric centres, but no chiral centres. The molecule is achiral due to an internal plane of symmetry.

■ **chirality**
handedness, the quality of having non-superimposable mirror images.

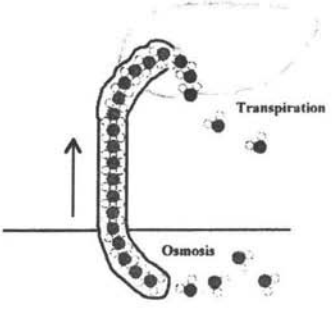
■ **chromatography**
chromatography is a method for separating mixtures based on differences in the speed at which they migrate over or through a stationary phase.



■ **Clausius-Clapeyron equation**
the Clausius-Clapeyron equation predicts the temperature dependence of vapour pressures of pure liquids or solids: $\ln (P/P^\circ) = H R (1/T^\circ - 1/T)$ where P is the vapour pressure, P° is a vapour pressure at a known temperature T°, H is an enthalpy of vapourisation if the substance is a liquid or an enthalpy of sublimation if it's a solid, R is the ideal gas law constant, and T is the temperature (in kelvins).

■ **closed system**
a system which can exchange only energy with its surroundings.

■ **cohesion**
compare with adhesion. Attraction between like molecules.

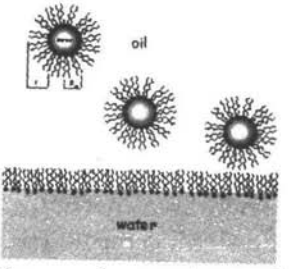


■ **colligative property**
colligative; colligative properties. Properties of a solution that depend on the number of solute molecules present, but not on the nature of the solute. Osmotic pressure, vapour pressure, freezing point depression, and boiling point elevation are examples of colligative properties.

■ **collision frequency**
collision frequencies; frequency of collision. The average number of collisions that a molecule undergoes each second.

■ **collision theory**
collision model. A theory that explains reaction rates in terms of collisions between reactant molecules.

■ **colloid**
a colloid is a heterogeneous mixture composed of tiny particles suspended in another material. The particles are larger than molecules but less than 1 μm in diameter. Particles this small do not settle out and pass right through filter paper. Milk is an example of a colloid. The particles can be solid, tiny droplets of liquid, or tiny bubbles of gas; the suspending medium can be a solid, liquid, or gas (although gas-gas colloids aren't possible).



■ **column chromatography**
column chromatography is a method for separating mixtures. A solution containing the mixture is passed through a narrow tube packed with a stationary phase . Different substances in the mixture have different affinities for the stationary phase, and so move through the tube at different

rates. This allows the substances in the mixture to be detected or collected separately as they reach the end of the tube

■ **combination reaction**
a reaction in which two or more substances are chemically bonded together to produce a product. For example,
$2\ Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$
is a combination reaction.

■ **combustion**
combustion reaction. A chemical reaction between a fuel and an oxidising agent that produces heat (and usually, light). For example, the combustion of methane is represented as
$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O$.

■ **combustion reaction**
the vigorous and exothermic reaction that takes place between certain substances, particularly organic compounds, and oxygen.

■ **complete ionic equation**
total ionic equation. Compare with net ionic equation . A balanced equation that describes a reaction occurring in solution, in which all strong electrolytes are written as dissociated ions.

■ **compound**
compare with element and mixture. A compound is a material formed from elements chemically combined in definite proportions by mass. For example, water is formed from chemically bound hydrogen and oxygen. Any pure water sample contains 2 g of hydrogen for every 16 g of oxygen.

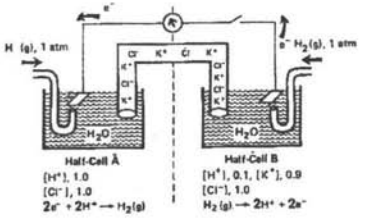
■ **computational chemistry**
a branch of chemistry concerned with the prediction or simulation of chemical properties, structures, or processes using numerical techniques.

■ **computer assisted drug design**
using computational chemistry to discover, enhance, or study drugs and related biologically active molecules.

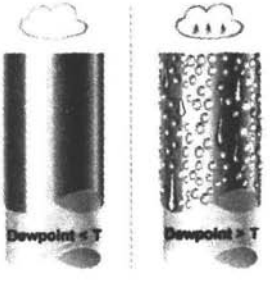
■ **concentration**
compare with dilution . 1. A measure of the amount of substance present in a unit amount of mixture. The amounts can be expressed as moles , masses, or volumes. 2. The process of in-

creasing the amount of substance in a given amount of mixture.

■ **concentration cell**
a voltaic cell in which both compartments contain the same components, but at different concentrations.



■ **condensation**
1. the conversion of a gas into a liquid is called condensation. Condensation usually occurs when a gas is cooled below its boiling point.
2. a reaction that involves linking of two molecules with the elimination of water (or another small molecule).



■ **configurational isomers**
configurational isomers have the same molecular formula and differ in only configuration about a chiral centre or double bond. There are two types of configurational isomers, they are 'Enantiomers' and 'Diastereomers'.

■ **conformational isomers**
conformational isomers or conformers have the same molecular fomula and are related by rotation around a single bond. For example, the different conformations of Butane (C_4H_{10}) represent different conformers. Each conformation will have an energy associated with it and the lower energy conformations will be preferred.
Sometimes the barrier to rotation is great enough that the different conformers are able to be distinguished. The energy barrier to rotation needs to be 80 kJ/mol or greater for this to be observed. For example, consider 6,6'-dimethylbiphenyl-2,2'-dicarboxylic acid. Rotation about the C-C single bond is prevented by the unfavourable interaction of the methyl and acid groups on adjacent rings

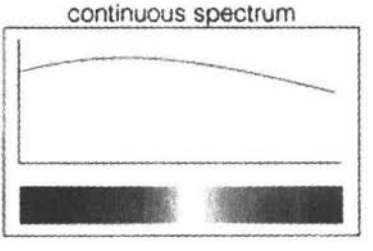
which must pass each other for complete rotation to occur. In this case two conformers, which happen to be non-superimposable mirror images of each other (enantiomers), are possible. Such compounds are termed 'Atropisomers' and represent a case where they can be described as both configurational isomers and conformational isomers.

■ **conformers**
molecular arrangements that differ only by rotations around single bonds. For example, the "boat" and "chair" forms of cyclohexane are conformers.

■ **congener**
1. elements belonging to the same group on the periodic table. For example, sodium and potassium are congeners.
2. compounds produced by identical synthesis reactions and procedures constitutional isomers also known as Structural Isomers, constitutional isomers are compounds that have different atom connectivities. The molecules, 2-Methyl pentane and 3-Methyl pentane are examples of constitutional isomers.

■ **constructive interference**
compare with destructive interference. When the peaks and troughs of two interfering waves match, the amplitudes add to give the resultant wave a higher amplitude.

■ **continuous spectrum**
compare with line spectrum and band spectrum. A plot of the relative absorbance or intensity of emitted light vs. wavelength or frequency that shows a smooth variation, rather than a series of sharp peaks or bands.



■ **conversion factor**
a conversion factor is a fraction that relates one unit to another. Multiplying a measurement by a conversion factor changes the units of the measurement. For example, since 1 in = 2.54 cm, to convert 10 inches to centimeters, (10 in)=2.54 cm/1 in= 25.4 cm.

■ **coordination number**
the number of bonds formed by the central atom in a metal-ligand complex.

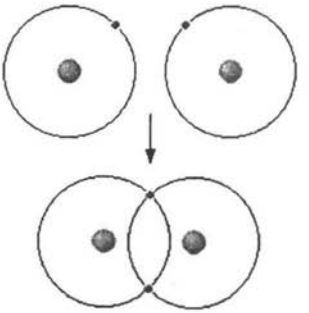
■ **copolymer**
a polymer composed of two or more different monomers. The different monomers can be linked randomly, or in repeating sequences, or in blocks, or as side chains off the main chain.

■ **core electron**
compare with valence electron. Electrons occupying completely filled shells under the valence shell.

■ **corrosion**
corrode. Corrosion is a reaction that involves action of an oxidising agent on a metal. The oxidising agent is often oxygen dissolved in water.

■ **coulomb**
(C) the SI unit of electric charge, equal to the amount of charge delivered by a current of 1 ampere running for 1 second. One mole of electrons has a charge of about 96487 C.

■ **covalent bond**
covalent; covalently bound. Compare with covalent compound and ionic bond. A covalent bond is a very strong attraction between two or more atoms that are sharing their electrons. In structural formulas, covalent bonds are represented by a line drawn between the symbols of the bonded atoms.



Covalent bond

■ **covalent compound**
molecular compound. Compare with ionic bond and ionic compound . A compound made of molecules - not ions. The atoms in the compound are bound together by shared electrons. Also called a molecular compound.

■ **Cram's Rule**
Cram's rule allows you to predict the stereochemical outcome of certain reactions.
In the addition of a nucleophile to a carbonyl carbon the stere-

ochemistry of the major product may be successfully predicted. The nucleophile will attack the electropositive carbonyl centre at the Bürgi-Dunitz angle of about 109°. As depicted below, attack from one face of the double bond (the *Si* face in this instance) is far more likely on steric grounds than attack at the alternative *Re* face.

The diastereoselectivity stems from the fact that a carbonyl group will react in the conformation in which the largest substituent is ***anti*** to the Oxygen of the C=O group. The attack of a nucleophile then takes place from the least hindered side of the molecule.

Often confused with the D/L system of nomenclature to which it has absolutely no relationship. The d stand for dextro or 'dextrorotatory' and simply signifies that plain polarised light is rotated to the right (clockwise). The l stands for laevo or 'laevorotatory' and signifies that the molecule rotates plane polarised to the left (anticlockwise). The system is outdated and largely replaced with the (+)/(-) nomenclature.

■ **critical molar volume**
(V_c) The molar volume at the critical point.

■ **critical point**
critical state. State at which two phases of a substance first become indistinguishable. For example, at pressures higher than 217.6 atm and temperatures above 374°C, the meniscus between steam and liquid water will vanish; the two phases become indistinguishable and are referred to as a supercritical fluid.

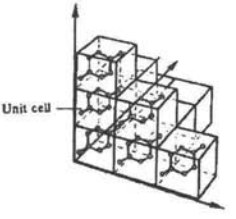
■ **critical pressure**
(P_c) the pressure at the critical point.

■ **critical temperature**
(T_c) the temperature at the critical point. A gas above the critical temperature will never condense into a liquid, no matter how much pressure is applied. Most substances have a critical temperature that is about 1.5 to 1.7 times the standard boiling point, in kelvin.

■ **crystal**
a sample of a crystalline solid that has a regular shape bound by plane surfaces (facets) that intersect at characteristic

angles. The shape results from the arrangement of the substances atoms, ions, or molecules. Most crystals contain defects that can strongly affect their optical and electrical properties.

A Crystal Structure



■ crystal field splitting energy
ligands complexed to a metal ion will raise the energy of some of its d orbitals and lower the energy of others. The difference in energy is called the crystal field splitting energy.

■ crystal field theory
crystal field. The colour, spectra, and magnetic properties of metal-ligand complexes can be explained by modeling the effect of ligands on metal's d orbital energies.

■ crystalline solid
crystalline. Compare with amorphous A solid that has a repeating, regular three-dimensional arrangement of atoms, molecules, or ions.

■ crystallisation
fractional crystallisation; crystallisation. The process of forming pure crystals by freezing a liquid, evaporating a solution, or precipitating a solid from solution. Impurities remain in the liquid, so crystallisation is often to purify solid substances.

■ cupric
(Cu^{2+}) cupric ion. Deprecated. 1. the copper(II) ion, Cu^{2+}. 2. a compound that contains copper in the +2 oxidation state.

■ cuprous
(Cu^{+}) cuprous ion. Deprecated. 1. the copper(I) ion, Cu^{+}. 2. a compound that contains copper in the +1 oxidation state.

■ current
the amount of charge carried per unit time.

■ cyanide process
a method for separating a metal from an ore. Crushed ore is treated with cyanide ion to produce a soluble metal cyanide complex. The complex is

washed out of the ore and reduced to metallic form using an active metal (usually zinc).

■ d

d-isomer. Compare with L-Prefix used to designate a dextrorotatory enantiomer.

■ D/L

confusing and outdated system of nomenclature for assigning absolute stereochemistry to an asymmetric centre.

The system has nothing to do with optical rotation and should not be confused with the '*d/l*' system of nomenclature.

The D and L assignments are related back to glyceraldehyde.It has been almost universally replaced with the unambiguous *R/S* system devised by Cahn, Ingold and Prelog, although it is still often encountered when dealing with carbohydrates and α-amino acids.

■ Dalton's law

Dalton's law of partial pressure. The total pressure exerted by a mixture of gases is the sum of the pressures that each gas would exert if it were alone. For example, if dry oxygen gas at 713 torr is saturated with water vapour at 25 torr, the pressure of the wet gas is 738 torr.

■ decomposition

decompose; decomposable; decomposition reaction. Compare with synthesis . A reaction in which a compound is broken down into simpler compounds or elements. Compounds sometimes decompose if heated strongly or if subjected to a strong electric current (electrolysis).

■ degenerate

degenerate orbital. A set of orbitals are said to be degenerate if they all have the same energy. This degeneracy can sometimes be "lifted" by external electric or magnetic fields.

■ density

(ñ ,d) Compare with specific gravity . Mass of a substance per unit volume. Saying "the density of mercury is 13.55 g/cm^3 " is the same as saying "the mass of exactly 1 cm3 of mercury is 13.55 g".

■ dependent variable

compare with independent variable . A dependent variable changes in response to changes

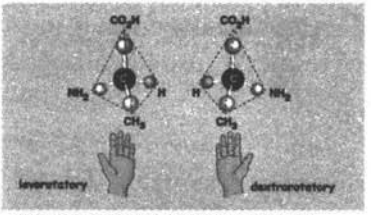
in independent variables . For example, in an experiment where the vapour pressure of a liquid is measured at several different temperatures, temperature is the independent variable and vapour pressure is the dependent variable.

■ **derived unit**
derived units are units constructed from the SI system's base units . For example, the SI unit for density is kg/m^3, derived from the base units kg and m.

■ **destructive interference**
compare with constructive interference. When the peaks of one wave match the troughs of another, the waves interfere destructively. The amplitudes of the interfering waves cancel to give the resultant wave a lower amplitude.

■ **deuterium**
(D, 2H) An isotope of hydrogen that contains one neutron and one proton in its nucleus.

■ **dextrorotatory**
pertains to optical rotation and indicates the molecule rotates plane polarised light clockwise or (+).

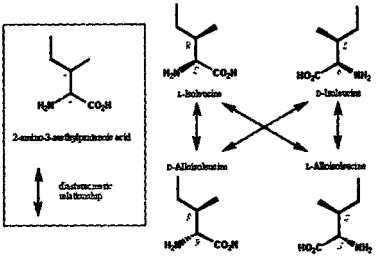


(c) Enantiomers: variation in spatial arrangement around an asymmetric carbon, resulting in molecules that are mirror images, like left and right hands. Enantiomers cannot be superimposed on each other.

■ **dialysis**
dialysis is the separation of components in a mixture by passing them across a semipermeable membrane.

■ **diamagnetism**
diamagnetic. Compare with paramagnetism. Diamagnetic materials are very weakly repelled by magnetic fields. The atoms or molecules of diamagnetic materials contain no unpaired spins.

■ **diastereomers**
diastereomers are stereoisomers that are not related as mirror images. The term is equally valid for both 3D and 2D molecules. Diastereomers differ in both their physical and chemical properties.



■ **diastereotopic**

the concept of Diastereotopicity is a natural extension of 'Enantiotopicity'. If a chiral centre already exists in the molecule being examined, then replacement of alternate X groups with a Y group will produce a pair of diastereomeric compounds. Thus the term Diastereotopic. The concept can be extended to include the diastereotopic faces of a double bond. When a chiral centre already exists in the compound then recation at the two distinct faces of the double bond will produce diastereomers. Because the energies of the diastereomeric transitions states are not equal one product will usually predominate, this may be predicted by employing 'Cram's Rule'.

■ **diatomic molecule**

compare with binary compound and polyatomic molecule . A molecule that contains only two atoms. All of the noninert gases occur as diatomic molecules; e. g. hydrogen, oxygen, nitrogen, fluorine, and chlorine are H_2, O_2, N_2, F_2, and Cl_2, respectively.

■ **diazonium salt**

a diazonium salt is a compound with general form Ar-N N+X-, where Ar represents a substituted benzene ring and X- is a halide ion such as chloride. Diazonium salts are unstable and explosive in dry form. They are used to manufacture many different organic compounds, including azo dyes.

■ **diazotisation**

diazotisation is a reaction that converts an $-NH_2$ group connected to a phenyl ring to a diazonium salt. For example, Diazotisation reactions are extremely useful in organic synthesis. The nitrous acid provides NO^+ which replaces a hydrogen on the $-NH_3+$ group to produce $-NH_2NO^+$ and water; a second water is eliminated to produce the $-N_2^+$ group.

■ **dichloromethane**
(CH_2Cl_2) Dichloromethane (CH_2Cl_2) is an organic solvent often use to extract organic substances from samples. It is toxic but much less so than chloroform or carbon tetrachloride, which were previously used for this purpose.

■ **diffraction**
diffract. Compare with effusion. The ability of a wave to bend around the edges of obstacles or holes. The effect is most noticeable when the obstacle or hole is comparable to the size of the wavelength.

■ **diffusion**
diffuse. Compare with effusion The mixing of two substances caused by random molecular motions. Gases diffuse very quickly; liquids diffuse much more slowly, and solids diffuse at very slow (but often measurable) rates. Molecular collisions make diffusion slower in liquids and solids.

■ **diffusion rate**
rate of diffusion. Compare with effusion . The number of randomly moving molecules that pass through a unit area per second. Diffusion rates are fastest when a large concentration difference exists on either side of the unit area. Diffusion rates increase with temperature, and decrease with increasing pressure, molecular weight, and molecular size.

■ **dihedral angle**
the dihedral angle or torsion angle (Ø) is the angle between two planes defined by the atoms ABCD. It is most commonly encountered when considering Newman projections.

■ **dilution**
adding solvent to a solution to lower its concentration.

■ **dipole-dipole interaction**
dipole-dipole force. Electrostatic attraction between oppositely charged poles of two or more dipoles.

■ **disaccharides**
a carbohydrate made up of two monosaccharide units. Two common disaccharides are sucrose and lactose.

■ **displacement**
displacement reaction; replacement reaction; replacement. A reaction in which a fragment of one reactant is replaced by an-

other reactant (or by a fragent of another reactant). Displacement reactions have the same number of products as reacdomoic acid.
domoic acid is a toxic amino acid produced by certain species of algae. Domoic acid binds to a receptor that helps nerve cells control the flow of ions across their cell membranes. The receptor no longer works correctly, and the uncontrolled flux of ions damages and eventually kills the nerve cell.

■ **double displacement**
double displacement reaction; double replacement; double replacement reaction; double exchange; exchange; metathesis. A double displacement or metathesis is a reaction in which two reactants trade fragments: $AB + CD \rightarrow AC + BD$. Most commonly, the fragments are ions, e. g. $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$.

■ **dry cell**
Leclanché cell. A electrolytic cell that uses a moist paste rather than a liquid as an electrolyte. Flashlight batteries are dry cells with a zinc cup for an anode, a carbon rod for a cathode, and a paste made of powdered carbon, NH_4Cl, $ZnCl_2$, and MnO_2 for an electrolyte.

■ **ductile**
ductility. Compare with malleable . Capable of being drawn into wire. Metals are typically ductile materials.

■ **dynamic equilibrium**
equilibrium. Compare with position of equilibrium. Dynamic equilibrium is established when two opposing processes are occuring at precisely the same rate, so that there is no apparent change in the system over long periods of time.

■ **dyne**
(dyn) the unit of force in the obsolete cgs system of units. A dyne is the force required to

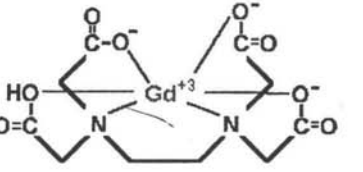
accelerate a 1 g mass by 1 cm/s per second.

■ **E/Z**
the system of nomenclature used to distinguish between 2D 'Diastereomers'. The Cahn, Ingold, Prelog 'Sequence Rules' are used to prioritise the substituents at the two ends of the double bond. If the 2 highest priority groups are on the same side then the descriptor *Z* is used to describe the stereochemistry. If the 2 highest priority groups are on opposite sides then the descriptor *E* is used to describe the stereochemistry.
Z - cis - seqcis - derived form the German *Zuzammen* meaning together.
E - trans - seqtrans - derived form the German *Entgegen* meaning opposite.

■ **ebulliometry**
ebulliometric. Determination of average molecular weight of a dissolved substance from the boiling point elevation of the solution.

■ **EDTA**
ethylenediaminetetracetic acid; versine. A polydentate ligand that tightly complexes certain metal ions. EDTA is used as a blood preservative by complexing free calcium ion (which promotes blood clotting). EDTA's ability to bind to lead ions makes it useful as an antidote for lead poisoning.

Gd-EDTA



■ **effective collisons**
collision between molecules resulting in a reaction; one in which the molecules collide with proper relative orientations and sufficient energy to react.

■ **effective molality**
the sum of the molalities of all solute particles in a solution.

■ **effective nuclear charge**
the nuclear charge experienced by the outermost electrons of an atom; the actual nuclear charge minus the effects of shielding due to inner-shell electrons. Example: Set of dx_2-y_2 and dz_2 orbitals; those d orbit-

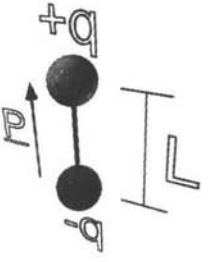
als within a set with lobes directed along the x-, y-, and z-axes.

■ **efflorescent**
efflorescence; effloresing. Compare with deliquescent and hygroscopic . Efflorescent substances lose water of crystallisation to the air. The loss of water changes the crystal structure, often producing a powdery crust.

■ **effusion**
effuse. Compare with diffusion and diffraction . Gas molecules in a container escape from tiny pinholes into a vacuum with the same average velocity they have inside the container. They also move in straight-line trajectories through the pinhole.

■ **electric charge**
charge. a property used to explain attractions and repulsions between certain objects. Two types of charge are possible: negative and positive. Objects with different charge attract; objects with the same charge repel each other.

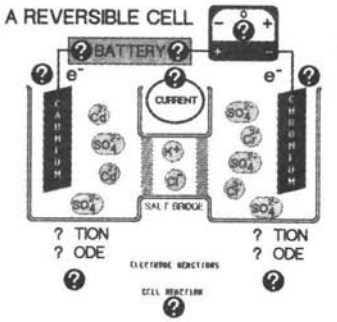
■ **electric dipole**
dipole. an object whose centres of positive and negative charge do not coincide. For example, a hydrogen chloride (HCl) molecule is an electric dipole because bonding electrons are on average closer to the chlorine atom than the hydrogen, producing a partial positive charge on the H end and a partial negative charge on the Cl end.



■ **electric dipole moment**
(μ) dipole moment. A measure of the degree of polarity of a polar molecule. Dipole moment is a vector with magnitude equal to charge separation times the distance between the centres of positive and negative charges. Chemists point the vector from the positive to the negative pole; physicists point it the opposite way. Dipole moments are often expressed in units called Debyes.

■ **electrical conductivity**
ability to conduct electricity.

■ **electrochemical cell**
electric cell. a device that uses a redox reaction to produce electricity, or a device that uses electricity to drive a redox reaction in the desired direction.

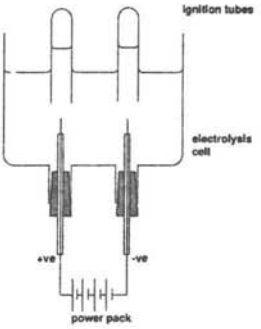


■ **electrochemistry**
study of chemical changes produced by electrical current and the production of electrically by chemical reactions.

■ **electrode**
any terminal that conducts an electric current into or away from various conducting substances in a circuit (such as the anode or cathode of a battery).

■ **electrode potentials**
potentials, E, of half-reactions as reductions versus the standard hydrogen electrode.

■ **electrolysis**
the process of driving a redox reaction in the reverse direction by passage of an electric current through the reaction mixture.



■ **electrolyte**
a substance that dissociates fully or partially into ions when dissolved in a solvent, producing a solution that conducts electricity.

■ **electrolytic cells**
electrochemical cells in which electrical energy causes nospontaneous redox reactions to occur. An electrochemical cell in which chemical reactions are forced to occur by the application of an outside source of electrical energy.

■ **electrolytic conduction**
conduction of electrical current by ions through a solution or pure liquid.

■ **electromagnetic radiation**
electromagnetic wave. A wave that involves perpendicular oscillations in the electric and magnetic fields, moving at a speed of 2.99792458×10^8 m/s in a vacuum away from the source. gamma rays, x-rays, ultraviolet light, visible light, infrared radiation, and radio waves are all electromagnetic waves.

■ **electromotive series**
the relative order of tendencies for elements and their simple ions to act as oxidising or reducing agents; also called the activity series.

■ **electron**
(e-) Compare with proton and neutron. A fundamental consituent of matter, having a negative charge of 1.602 176 462×10^{-19} coulombs $\pm$ 0.000 000 063 $\times 10^{-19}$ coulombs and a mass of 9.109 381 88 $\times 10^{-31}$ kg $\pm$ 0.000 000 72 $\times 10^{-31}$ kg.

■ **electron affinity**
the amount of energy absorbed in the process in which an electron is added to a neutral isolated gaseous atom to form a gaseous ion with a 1- charge; has a negative value if energy is released.

■ **electron configuration**
electronic configuration. A list showing how many electrons are in each orbital or subshell. There are several notations. The subshell notation lists subshells in order of increasing energy, with the number of electrons in each subshell indicated as a superscript. For example, $1s^2\ 2s^2\ 2p^3$ means "2 electrons in the 1s subshell, 2 electrons in the 2s subshell, and 3 electrons in the 2p subshell.

■ **electron deficient compounds**
compounds that contain at least one atom (other than H) that shares fewer than eight electrons.

■ **electronegativity**
compare with ionisation energy and electron affinity. Electronegativity is a measure of the attraction an atom has for bonding electrons. Bonds between atoms with different electronegativities are polar, with the bonding electrons spending more time on average around the atom with higher electronegativity.

■ **electronic geometry**
the geometric arrangement of orbitals containing the shared and unshared electron pairs surrounding the central atom of a molecule or polyatomic ion.

■ **electronic transition**
the transfer of an electron from one energy level to another.

■ **electrophile**
a species that loves electrons. Since the electrons are negatively charged, electrophiles are positively charged or bear a partial positive charge. Examples are carbocations or protons.

■ **electrophile**
positively charged or electron-deficient.

■ **electrophoresis**
a technique for separation of ions by rate and direction of migration in an electric field.

■ **electrorefining**
electrorefining is a method for purifying a metal using electrolysis . An electric current is passed between a sample of the impure metal and a cathode when both are immersed in a solution that contains cations of the metal. Metal is stripped off the impure sample and deposited in pure form on the cathode.

■ **element**
compare with compound and mixture An element is a substance composed of atoms with identical atomic number . The older definition of element (an element is a pure substance that can't be decomposed chemically) was made obsolete by the discovery of isotopes.

■ **element symbol**
an international abbreviation for element names, usually consisting of the first one or two distinctive letters in element name. Some symbols are abbreviations for ancient names.

■ **elementary reaction**
compare with net chemical reaction. A reaction that occurs in a single step. Equations for elementary reactions show the actual molecules, atoms, and ions that react on a molecular level.

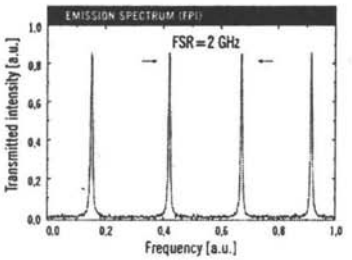
■ **elementary step**
reaction mechanisms are broken down into elementary steps. For each step the the reactants are directly involved in forming the transition state. Therefore

a rate law can be written from an elementary step but not from an overall reaction.

■ **eluant or eluent**
the solvent used in the process of elution, as in liquid chromatography.

■ **eluate**
solvent (or mobile phase) which passes through a chromatographic column and removes the sample components from the stationary phase.

■ **emission spectrum**
spectrum associated with emission of electromagnetic radiation by atoms (or other species) resulting from electronic transitions from higher to lower energy states.



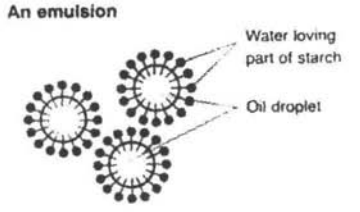
■ **emollient**
a substance added to a formulation that gives it softening ability. For example, oils that can soften skin are added as emollients in some skin creams.

■ **empirical formula**
simplest formula. Compare with molecular formula . Empirical formulas show which elements are present in a compound, with their mole ratios indicated as subscripts. For example, the empirical formula of glucose is CH_2O, which means that for every mole of carbon in the compound, there are 2 moles of hydrogen and one mole of oxygen.

■ **empirical temperature**
a property that is the same for any two systems that are in thermodynamic equilibrium with each other.

■ **emulsifying agent**
a sustance that coats the particles of the dispersed phase and prevents coagulation of colloidal particles; an emulsifier.

■ **emulsion**
compare with colloid. A colloid formed from tiny liquid droplets suspended in another, immiscible liquid. Milk is an example of an emulsion.



■ **enantiomeric excess**
enantiomeric excesses are generally expressed as a percentage and tell the reader the extent to which one enantiomer is present compared to the other. For example a 50% e.e. indicates that one enantiomer is present at 75% while the other is at 25%, that is a ratio of 75:25. The actual ratio of enantiomers is readily determined given an e.e.
The e.e, in virtually all cases, corresponds to the optical purity of a sample. For example a sample of 90% e.e would have an optical rotation 90% of the value expected for the pure major enantiomer.

■ **enantiomers**
enantiomers are a pair of non superimposable mirror images. The term is used almost exclusively for 3D stereoisomers, but can be extended to describe 2D molecules.

■ **enantiotopic**
in a prochiral molecule, replacement of the alternate X groups with another group Y, assumed to be of higher priority than X but of lower priority than the other two substituents, results in enantiomeric compounds being produced. The X groups in such a molecule are termed 'Enantiotopic'.
The terms pro-*R* and pro-*S* indicate that replacement of the group labelled such would lead to the *R* or *S* enantiomer respectively.
In the case of 2D chirality what we are talking about is reaction at enantiotopic faces. The term used to describe the Prochiral faces are '*Re*' and '*Si*'. Attack at opposing faces produces enantiomeric compounds.

■ **end point**
the point at which an indicator changes colour and a titration is stopped.

■ **endergonic**
refers to a reaction for which the free energy of the system increases; G is positive for an endergonic reaction.

■ **endothermic**
endothermic reaction; endothermic process. Compare with exothermic. A process that absorbs heat. The enthalpy change for an endothermic process has a positive sign.

■ **endothermicity**
the absorption of heat by a system as the process occurs.

■ **endpoint**
end point. Compare with equivalence point . The experimental estimate of the equivalence point in a titration.

■ **energy**
compare with heat and work. Energy is an abstract property associated with the capacity to do work.

■ **ensemble**
the set of atoms or molecules comprising the system.

■ **enthalpy**
(H) enthalpy change. Compare with heat. Enthalpy (H) is defined so that changes in enthalpy (H) are equal to the heat absorbed or released by a process running at constant pressure. While changes in enthalpy can be measured using calorimetry, absolute values of enthalpy usually cannot be determined. Enthalpy is formally defined as H ® U + PV, where U is the internal energy, P is the pressure, and V is the volume.

■ **enthalpy of atomisation**
atomisation enthalpy; heat of atomisation. The change in enthalpy that occurs when one mole of a compound is converted into gaseous atoms. All bonds in the compound are broken in atomisation and none are formed, so enthalpies of atomisation are always positive.

■ **enthalpy of combustion**
(H_c) heat of combustion. The change in enthalpy when one mole of compound is completely combusted. All carbon in the compound is converted to $CO_2(g)$, all hydrogen to $H_2O()$, all sulphur to $SO_2(g)$, and all nitrogen to $N_2(g)$.

■ **enthalpy of formation**
the enthalpy change when 1 mole of a substance is formed from the elements in their standard states; represented by the symbol H_f; also called heat of formation.

■ **enthalpy of fusion**
(H_{fus}) heat of fusion; molar heat of fusion; molar enthalpy of fusion. The change in enthalpy when one mole of solid melts to form one mole of liquid. Enthalpies of fusion are always positive because melting involves overcoming some of the intermolecular attractions in the solid.

■ **enthalpy of hydration**
(H_{hyd}) hydration enthalpy; heat of hydration. The change in enthalpy for the process. A(g) ®A(aq)where the concentration of A in the aqueous solution approaches zero. Enthalpies of hydration for ions are always negative because strong ion-water attractions are formed when the gas-phase ion is surrounded by water.

■ **enthalpy of reaction**
(H_{rxn}) heat of reaction. The heat absorbed or released by a chemical reaction running at constant pressure.

■ **enthalpy of sublimation**
(H_{sub}) heat of sublimation. The change in enthalpy when one mole of solid vapourises to form one mole of gas. Enthalpies of sublimation are always positive because vapourisation involves overcoming most of the intermolecular attractions in the sublimation.

■ **enthalpy of vapourisation**
(H_{vap}) heat of vapourisation. The change in enthalpy when one mole of liquid evaporates to form one mole of gas. Enthalpies of vapourisation are always positive because vapourisation involves overcoming most of the intermolecular attractions in the liquid.

■ **entropy**
(S) entropy is a measure of energy dispersal. Any spontaneous change disperses energy and increases entropy overall. For example, when water evaporates, the internal energy of the water is dispersed with the water vapour produced, corresponding to an increase in entropy.

■ **environmental chemistry**
chemical ecology. The study of natural and man-made substances in the environment, including the detection, monitoring, transport, and chemical

transformation of chemical substances in air, water, and soil.

■ **enzyme**
protein or protein-based molecules that speed up chemical reactions occurring in living things. Enzymes act as catalysts for a single reaction, converting a specific set of reactants (called substrates) into specific products. Without enzymes life as we know it would be impossible.

■ **equation of state**
an equation that describes the behaviour of matter in a given state; the Van der Waals equation describes the behaviour of the gaseous state.

■ **equilibrium**
the point in a reaction at which the free energies of the reactants and products are equal; at this point G = 0.

■ **equilibrium constant**
a constant represented by the symbol K which is defined as the product of the equilibrium concentrations of the products, each raised to the power that corresponds to its coefficient in the balanced equation, divided by the product of the equilibrium concentrations of reactants, each raised to the power that corresponds to its coefficient in the balanced equation. The magnitude of K is a measure of the extent to which a reaction occurs.

■ **equilibrium or chemical equilibrium**
a state of dynamic balance in which the rates of forward and reverse reactions are equal; the state of a system when neither forward or reverse reaction is thermodynamically favoured.

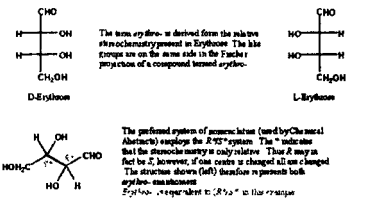
■ **equivalence point**
compare with end point . The equivalence point is the point in a titration when enough titrant has been added to react completely with the analyte.

■ **equivalent**
compare with normality
1. the amount of substance that gains or loses one mole of electrons in a redox reaction.
2. the amount of substances that releases or accepts one mole of hydrogen ions in a neutralisation reaction.
3. the amount of electrolyte that carries one mole of positive or

negative charge, for example, 1 mole of $Ba^{2+}(aq)$ is 2 equivalents of $Ba^{2+}(aq)$.

■ **equivalent weight**
an oxidising or reducing agent, who's mass gains (oxidising agents) or loses (reducing agents) 6.022×10^{23} electrons in a redox reaction. The mass of an acid or base that furnishes or reacts with 6.022×10^{23} H_3O^+ or OH^- ions.

■ **erythro-**
the term *erythro-* belongs to an outdated system of nomenclature used to describe the relative stereochemistry of 2 adjacent chiral centres. In a Fischer projection the *erythro-* isomer has identical (or at least similar) substituents on adjacent chiral centres on the same side. The system is awkward and confusing when applied to non-carbohydrate molecules or molecules with multiple adjacent chiral centres. There are also multiple and contradicting definitions for the term and as such it should not be used. The preferred system of nomenclature in these cases uses *R*/S** system.



■ **essential oil**
a plant extract that has a distinctive odour or flavour.

■ **ester**
an ester is a compound formed from an acid and an alcohol. In esters of carboxylic acids, the -COOH group and the -OH group lose a water and become a -COO- linkage: R-COOH + R'-OH = R-COO-R' + H_2O where R and R' represent organic groups.

■ **ether**
compound in which an oxygen atom is bonded to two alkyl or two aryl groups, or one alkyl and one aryl group.

■ **eutectic mixture**
a mixture of two or more substances with melting point lower than that for any other mixture of the same substances.

■ **eutrophication**
the undesirable overgrowth of vegetation caused by high con-

centrates of plant nutrients in bodies of water.

■ **evaporation rate**
the rate at which a particular substance will vapourise (evaporate) when compared to the rate of a known substance such as ethyl ether. This term is especially useful for health and fire-hazard considerations.

■ **evaporisation**
vapourisation of a liquid below its boiling point.

■ **evaporate**
to convert a liquid into a gas.

■ **evaporation**
vapourisation. Conversion of a liquid into a gas.

■ **excited state**
compare with ground state. An atom or molecule which has absorbed energy is said to be in an excited state. Excited states tend to have short lifetimes; they lose energy either through collisions or by emitting photons to "relax" back down to their ground states.

■ **excitotoxin**
an excitotoxin is a toxic molecule that stimulates nerve cells so much that they are damaged or killed. Domoic acid and glutamate are examples of excitotoxins.

■ **exergonic**
refers to a reaction for which the free energy of the system decreases; G is negative for an exergonic reaction.

■ **exothermic**
exothermic reaction; exothermic process. Compare with endothermic. A process that releases heat. The enthalpy change for an exothermic process is negative. Examples of exothermic processes are combustion reactions and neutralisation reactions.

■ **exothermicity**
the release of heat by a system as a process occurs.

■ **experiment**
an experiment is direct observation under controlled conditions. Most experiments involve carefully changing one variable and observing the effect on another variable (for example, changing temperature of a water sample and recording the change volume that results).

■ **experimental yield**
actual yield. Compare with theoretical yield and percent yield . The measured amount of product produced in a chemical reaction.

■ **explosive**
a chemical or compound that causes a sudden, almost instantaneous release or pressure, gas, heat and light when subjected to sudden shock, pressure, high temperature or applied potential.

■ **explosive limits**
the range of concentrations over which a flammable vapour mixed with proper ratios of air will ignite or explode if a source of ignitions is provided.

■ **extensive property**
extensive; extensive properties. Compare with intensive property . A property that changes when the amount of matter in a sample changes. Examples are mass, volume, length, and charge.

■ **extraction**
a technique for separating components in a mixture that have different solubilities . For example, caffeine can be separated from coffee beans by washing the beans with supercritical fluid carbon dioxide; the caffeine dissolves in the carbon dioxide but flavour compounds do not. Vanillin can be extracted from vanilla beans by shaking the beans with an organic solvent, like ethanol.

■ **extrapolate**
to estimate the value of a result outside the range of a series of known values. Technique used in standard additions calibration procedure.

■ **f orbital**
an orbital with angular momentum quantum number = 2. The f orbitals generally have 3 nuclear nodes and rather complex shapes.

■ **faraday**
one faraday of electricity corresponds to the charge on 6.022 x 10^{23} electrons, or 96,487 coulombs.

■ **faraday's law of electrolysis**
one equivalent weight of a substance is produced at each electrode during the passage of 96,487 coulombs of charge through an electrolytic cell.

■ **fast neutron**
a neutron ejected at high kinetic energy in a nuclear reaction.

■ **fat**
solid triester of glycerol and (mostly) saturated fatty acids.

■ **fatty acid**
fatty acids are carboxylic acids with long hydrocarbon side chains. Most natural fatty acids have hydrocarbon chains that don't branch; any double bonds occurring in the chain are cis isomers (side chains are attached on the same side of the double bond).

■ **femto**
(f) Prefix used in the SI system meaning "multiply by 10^{-15}". For example 22 fg means 22×10^{-15} g.

■ **ferric**
ferric ion. Deprecated.
1. the iron(III) ion, Fe^{3+}.
2. a compound that contains iron in the +3 oxidation state.

■ **ferroin**
a blood-red complex of Fe^{2+} ion with 1,10-phenanthroline, used as a redox indicator. Ferroin changes from red to pale blue when oxidised.

■ **ferromagnetism**
the ability of a substance to become permanently magnetized by exposure to an external magnetic field.

■ **ferrous**
ferrous ion. Deprecated.
1. the iron(II) ion, Fe^{2+}.
2. a compound that contains iron in the +2 oxidation state.

■ **film badge**
a small patch of photographic film worn on clothing to detect and measure accumulated incident ionising radiation.

■ **first ionisation energy**
(IE,IP) first ionisation potential. Compare with second ionisation energy, adiabatic ionisation energy, vertical ionisation energy, electronegativity, and electron affinity. The energy needed to remove an electron from an isolated, neutral atom.

■ **first law of thermodynamics**
the first law states that energy cannot be created or destroyed. Many equivalent statements are possible, including: Internal energy changes depend only on the initial and final states of the

system, not on the path taken. The work done during an adiabatic process depends only on the initial and final states of the system, and not on the path taken. The internal energy change for any cyclic process is zero.

■ **first order reaction**
compare with zero order reaction and second order reaction. The sum of concentration exponents in the rate law for a first order reaction is one. Many radioactive decays are first order reactions.

■ **Fischer Projection**
Fischer projections represent a standard way for drawing organic molecules. In the Fischer projection lines horizontal to the viewer (i.e. across the page) are thought of as coming out of the page whereas vertical lines (i.e. up and down the page) are thought of as going into the page.
The Fischer projection is often used to depict carbohydrates.

■ **flammable**
a liquid as defined by NFPD and DOT as having a flash point below 37.8°C (100°F).

■ **flash point**
compare with auto-ignition temperature .The temperature when vapour pressure of a substance becomes high enough to allow the air/vapour layer over the substance to be ignited. Ether and acetone have flash points below room temperature, which makes them very dangerous.

■ **flotation**
method by which hydrophobic (water-repelling) particles of an ore are separated from hydrophilic (water-attracting) particles of a metallurgical pretreatment process.

■ **fluids**
substances that flow freely; gases and liquids.

■ **fluorescence**
absorption of high energy radiation by a substance and subsequent emission of visible light.

■ **flux**
a substance added to react with the charge, or a product of its reduction, in metallurgy; usually added to lower a melting point.

■ **foam**
compare with colloid. A colloid in which bubbles of gas are suspended in a solid or liquid. Aerogel (solid smoke) and Styrafoam are examples of solid foams; whipped cream is an example of a liquid foam.

■ **forbidden zone**
a relatively large energy separation between an insulator's highest filled electron energy band and the next higher energy vacant band. Beginning in the fourth energy level, a set of seven degenerate orbitals per energy level, higher in energy than s, p, and d orbitals of the same energy level.

■ **formal charge**
a method of counting electrons in a covalently bonded molecule or ion; counts bonding electrons as though they were equally shared between the two atoms.

■ **formation**
formation reaction. A reaction that forms one mole of a compound from its elements in their most stable forms. For example, the formation reaction for water is
$H_2(g) + \frac{1}{2}O_2 \rightarrow H_2O$

■ **formula**
combination of symbols that indicates the chemical composition of a substance.

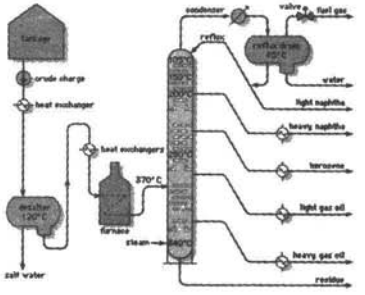
■ **formula unit**
compare with empirical formula . One formula weight of a compound

■ **formula weight**
formula mass. Compare with molecular weight and empirical formula. The formula weight is the sum of the atomic weights of the atoms in an empirical formula. Formula weights are usually written in atomic mass units (u).

■ **fossil fuels**
substances consisting largely of hydrocarbons, derived from decay of organic materials under geological conditions of high pressure and temperature (metamorphism) include coal, petroleum, natural gas, peat and oil shale.

■ **fractional distillation**
compare with distillation. A technique for separation of liquid mixtures by distillation that uses a tower attached to a flask containing the mixture

to perform multiple distillations. vapour moving up the column condenses on packing material inside the column, trickles down the column, and again vapourises. The more



volatile component can then be drawn off at the top of the component, while the less volatile component remains at the bottom.

■ **fractional precipitation**
removal of some ions from solution by precipitation while leaving other ions with similar properties in solution.

■ **Frasch process**
method by which elemental sulphur is mined or extracted. Sulphur is melted with superheated water (at 170°C under high pressure) and forced to the surface of the earth as a slurry.

■ **free energy**
energy that is actually available to do useful work. A decrease in free energy accompanies any spontaneous process. Free energy does not change for systems that are at equilibrium.

■ **free energy change**
the indicator of spontaneity of a process at constnt T and P. If delta-G is negative, the process is spontaneous.

■ **free energy, Gibbs free energy**
the thermodynamic state function of a system that indicates the amount of energy available for the system to do useful work at constant T and P.

■ **free radical**
a free radical is a molecule with an odd number of electrons. Free radicals do not have a completed octet and often undergo vigorous redox reactions. Free radicals produced within cells can react with membranes, enzymes, and genetic material, damaging or even killing the cell. Free radicals have been implicated in a number of degenerative conditions, from

natural aging to Alzheimer's disease.

■ **freezing point**
(mp) standard melting point; normal melting point; melting point. the temperature at which the vapour pressure of a liquid is equal to the vapour pressure of the corresponding solid form. The liquid and solid forms can coexist at equilibrium at the freezing point. The standard melting point is the melting point at standard pressure.

■ **freezing point depression**
(T_{fp}) the freezing point of a solution is always lower than the freezing point of the pure solvent. The freezing point depression is roughly proportional to the molality of solute particles in the solution. Freezing point depression is an example of a colligative property of a solution.

■ **frequency**
compare with wavelength. The number of cycles of a wave that move past a fixed observation point per second. The SI unit of frequency is the Hertz (Hz).

■ **fuel cells**
voltaic cells in which the reactants (usually gases) are supplied continuously. A voltaic cell that converts the chemical energy of a fuel and an oxidising agent directly into electriacl energy on a continuous basis.

■ **functional group**
a substructure that imparts characteristic chemical behaviours to a molecule, for example, a carboxylic acid group.

■ **furanose ring**
a five-membered cyclic hemiacetal or hemiketal of a carbohydrate.

■ **galvanic cell**
see voltaic cell.

■ **galvanising**
placing a thin layer of zinc on a ferrous material to protect the underlying surface from corrosion.

■ **gamma ray**
high energy electromagnetic radiation. A highly penetrating type of nuclear radiation similar to x-ray radiation, except that it comes from within the nucleus of an atom and has a higher energy. Energywise, very

similar to cosmic ray except that cosmic rays originate from outer space.

■ **gangue**
sand, rock, and other impurities surrounding the mineral of interest in an ore.

■ **gas**
gases; vapour. Matter in a form that has low density, is easily compressible and expandable, and expands spontaneously when placed in a larger container. Molecules in a gas move freely and are relatively far apart. "vapour" often refers to a gas made of a substance that is usually encountered as a liquid or solid; for example, gaseous H_2O is called "water vapour".

■ **Gauche**
probably derives from the French word for 'crooked'. A gauche conformation represents an energy minimum, but is not the lowest possible energy in the system. This may be attributed to the anti conformer.

■ **Geiger counter**
a gas filled tube which discharges electriaclly when ionising radiation passes through it.

■ **gel**
compare with colloid. A gell is a sol in which the solid particles fuse or entangle to produce a rigid or semirigid mixture. For example, gelatin dissolved in water produces a sol of protein molecules. When the gelatin is cooked, the protein chains entangle and crosslink, forming a gel which is a mesh of solid protein with trapped pockets of liquid inside. Fruit jellies are also gels.

■ **gem-dimethyl group**
two methyl groups of the same carbon atom.

■ **geminal**
geminal (gem) is a term used to describe a relative 1,1-disubstitution. For example the hydrogen atoms in dichloromethane may be described as geminal, as may the two chlorine atoms. A geminal or gem diol has two alcohol groups attached in a 1,1-relationship relative to each other.

■ **geochemistry**
geological chemistry. The study of materials and chemical reac-

tions in rocks, minerals, magma, seawater, and soil.

■ **geometric isomers**
geometric or also called cis-trans isomers are stereoisomers in molecules with restricted rotation about a bond. Cycloalkanes and alkenes form cis-trans isomers due to the restriction of rotation about the double bond or due to the restriction in a ring. In order for an alkene to freely rotate, the pi bond must be broken. This process has a high activation energy and does not occur at room temperature. Cis isomers have the two substituents on each of the carbons of the double bond on the same side, whereas in the trans isomer they are on opposite sides. The expression cis and trans only applies to alkenes or cycloalkanes if one of the substituents on each of the carbons are the same. If there are three or four different substituents, E,Z or R,S nomenclature must be used.

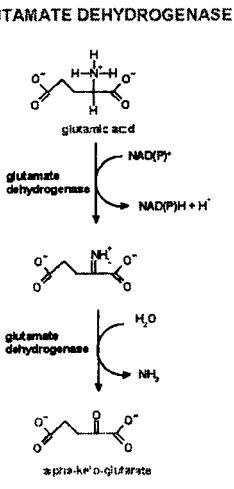
■ **geometrical isomers**
compounds with different arrangements of groups on either side of a bond with restricted rotation, such as a double bond or a single bond in a ring; for example cis-trans isomers of certain alkenes. Stereoisomers that are not mirror images of each other; also known as position isomers.

■ **Gibbs free energy**
(G) Gibbs' free energy. A thermodynamic property devised by Josiah Willard Gibbs in 1876 to predict whether a process will occur spontaneously at constant pressure and temperature. Gibbs free energy G is defined as $G = H - \Delta TS$ where H, T and S are the enthalpy, temperature, and entropy. Changes in G correspond to changes in free energy for processes occuring at constant temperature and pressure; the Gibbs free energy change corresponds to the maximum non-expansion work that can be obtained under these conditions. The sign of ΔG is negative for all spontaneous processes and zero for processes at equilibrium.

■ **Gibbs free energy of formation**
(G_f) Gibbs' free energy of formation. The change in Gibbs

free energy that accompanies the formation of one mole of a compound from its elements in their most stable form.

■ **glutamate**
ionic salts of glutamic acid used as flavour enhancers in many foods. Glutamate is usually manufactured by acid hydrolysis of vegetable proteins. Besides being a basic building block of proteins, glutamate functions as a neurotransmitter



that helps neurons grow new connections; as such, glutamate plays an important role in learning and memory. At high concentrations, glutamate can function as an excitotoxin.

■ **glutamate receptors**
glutamate receptors are protein molecules that helps gate the flow of ions across a nerve cell's membrane. They play a role in the formation of new connections between nerve cells (and so, in learning and memory). The receptors are normally activated by aspartate and glutamate. In amnesic shellfish poisoning, domoic acid acts as an excitotoxin that very strongly activates some of these receptors, preventing their proper functioning.

■ **glyceride**
monoglyceride; diglyceride; triglyceride. Glycerides are fats and oils that are esters of glycerol with one or more fatty acids. Monoglycerides, diglycerides, and triglycerides contain one, two, and three fatty acids linked to the glycerol, respectively.

■ **glycerol**
$hOCH_2CH(OH)CH_2OH$, Glycerol is a small molecule with three alcohol groups. It is

a basic building block of fats and oils.

■ **glycogen**
a polymer of glucose that is built like amulopectin except that it is larger and even more branched. Branching occurs at every 10th to 18th glucose molecule.

■ **Graham's law**
the rates of effusion of gases are inversely proportional to the square roots of their molecular weights or densities.

■ **gram**
a metric unit of mass, equal to 1/1000 of a kilogram . Kilograms are the base SI units for mass, not grams.

■ **greenhouse effect**
trapping of heat at the surface of the earth by carbon dioxide and water vapour in the atmosphere.

■ **gross error**
compare with systematic error , random error and mistake . Gross errors are undetected mistakes that cause a measurement to be very much farther from the mean measurement than other measurements.

■ **ground state**
compare with excited state. The lowest energy state for an atom or molecule. When an atom is in its ground state, its electrons fill the lowest energy orbitals completely before they begin to occupy higher energy orbitals, and they fill subshells in accordance with Hund's rule.

■ **group**
1. a substructure that imparts characteristic chemical behaviours to a molecule, for example, a carboxylic acid group. (also: functional group).
2. a vertical column on the periodic table, for example, the halogens. Elements that belong to the same group usually show chemical similarities, although the element at the top of the group is usually atypical.

■ **Haber process**
a process for the catalysed industrial production of ammonia from N_2 and H_2 at high temperature and pressure.

■ **half-cell**
compartment in which the oxidation or reduction half-reaction occurs in a voltaic cell.

■ **half-life**
the time required for half of a reactant to be converted into product(s). The time required for half of a given sample to undergo radioactive decay.

■ **half-reaction**
either the oxidation part or the reduction part of a redox reaction.

■ **halide**
halide ion. A compound or ion containing fluorine, chlorine, bromine, iodine, or astatine.

■ **halogen**
group VIIA; group 18. An element of group VIIA (a. k. a. Group 18). The name means "salt former"; halogens react with metals to form binary ionic compounds. Fluorine (F), chlorine (Cl), bromine (Br), iodine (I), and astatine (At) are known at this time.

■ **hard water**
water containing Fe^{3+}, Ca^{2+}, and Mg^{2+} ions, which forms precipates with soap.

■ **heat**
energy transferred between two objects because of a temperature difference; the thermal motion of atoms and molecules. For chemical systems the sign for heat flow into the system is positive, because this process increases the internal energy of the system. Heat flowing out of the system is defined to be negative, since this process decreases the internal energy of the system.

■ **heat capacity**
the amount of energy required to raise the temperature of an object by one degree Celsius (or Kelvin); it is represented by the symbol C and is given in units of J/K.

■ **heat of condensation**
the amount of heat that must be removed from one gram of a vapour at it's condensation point to condense the vapour with no change in temperature.

■ **heat of crystallisation**
the amount of heat that must be removed from one gram of a liquid at its freezing point to freeze it with no change in temperature.

■ **heat of fusion**
the amount of heat required to melt one gram of solid at its melting point with no change in temperature. Usually expressed

in J/g. The molar heat of fusion is the amount of heat required to melt one mole of a solid at its melting point with no change in temperature and is usually expressed in kJ/mol.

■ **heat of hydration**
the enthalpy change associated with placing gaseous molecules or ions in water.

■ **heat of solution**
the amount of heat absorbed in the formation of solution that contains one mole of solute; the value is positive if heat is absorbed (endothermic) and negative if heat is released (exothermic).

■ **heat of vapourisation**
the amount of heat required to vapourise one gram of a liquid at its boiling point with no change in temperature. Usually expressed in J/g. The molar heat of vapourisation is the amount of heat required to vapourise one mole of liquid at its boiling point with no change in temperature and usually expressed ion kJ/mol.

■ **heat of vapourisation**
the energy required to vapourise one mole of a liquid at a pressure of one atmosphere.

■ **heating curve**
a plot of temperature verses time for a substance where energy is added at a constant rate.

■ **heavy water**
(D_2O) Water that contains 2H, rather than 1H. Heavy water is about 11% denser than ordinary water.

■ **heavy water**
water containing deuterium, a heavy isotope of hydrogen.

■ **Heisenberg uncertainty principle**
it is impossible to determine accurately both the momentum and position of an electron simultaneously.

■ **Helmholtz free energy**
a thermodynamic property that can be used to predict whether a process will occur spontaneously at constant volume and temperature. Helmholtz free energy A is defined as $A = U - \Delta TS$ where U, T and S are the internal energy, temperature, and entropy. Changes in A correspond to changes in free energy for processes occuring at constant temperature and vol-

ume. The sign of AA is negative for spontaneous processes and zero for processes at equilibrium.

■ **Henry's law**
Henry's law constant. Henry's law predicts that the solubility (C) of a gas or volatile substance in a liquid is proportional to the partial pressure (P) of the substance over the liquid: P = k C where k is called the Henry's law constant and is characteristic of the solvent and the solute.

■ **hertz**
(Hz, s^{-1}) frequency. The SI unit of frequency, equal to one cycle of the wave per second (s^{-1}).

■ **Hess's law**
law of constant heat summation; Hess's law of heat summation. The heat released or absorbed by a process is the same no matter how many steps the process takes. For example, given a reaction A B, Hess's law says that H for the reaction is the same whether the reaction is written as A C B or as A B. This is the same as writing that H(A B) = H(A C) + H(C B).

■ **heterocyclic**
heterocycle; heterocyclic ring. An organic group or molecule containing rings with at least one noncarbon atom on the ring.

■ **heterocyclic amine**
amine in which the nitrogen is part of a ring.

■ **heterogeneous catalysis**
a form of catalysis in which the catalyst is in different physical state than the reactants.

■ **heterogeneous catalyst**
a catalyst that exists in a different phase (solid, liquid or gas) from the reactants; a contact catalyst.

■ **heterogeneous equilibria**
equilibria involving species in more than one phase.

■ **heterogeneous mixture**
heterogeneous. Compare with homogeneous mixture , solution , element , and compound . A sample of matter consisting of more than one pure substance and more than one phase . Blood, protoplasm, milk, chocolate, smoke, and chicken soup are examples of heterogeneous mixtures.

■ **heteronuclear**
consisting of different elements.

■ **high performance liquid chromatography**
HPLC. An efficient form of column chromatography that pumps a liquid solution of the sample at very high pressure through a column packed with a stationary phase made of very tiny particles. The high pressure pumps required make HPLC an expensive technique.

■ **high spin complex**
high-spin complex. A metal-ligand complex with the same number of unpaired electrons as the uncomplexed metal ion. When a weak ligand complexes the metal ion, the crystal field splitting is small and the electrons can still occupy all of the d orbitals without pairing.

■ **homogeneous catalysis**
a form of catalysis in which the catalyst is in the same physical state than the reactants, for example reactants and catalyst are all gases.

■ **homogeneous catalyst**
a catalyst that exists in the same phase (solid, liquid or gas) as the reactants.

■ **homogeneous equilibria**
equilibria involving only one species in a single phase. For example, all gases, all liquids or all solids.

■ **homogeneous mixture**
solution. Compare with heterogeneous mixture , element and compound . A sample of matter consisting of more than one pure substance with properties that do not vary within the sample.

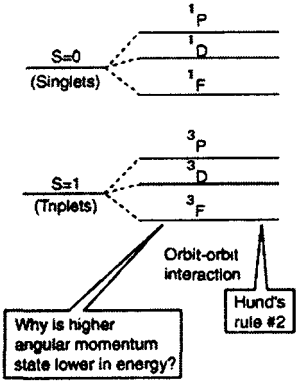
■ **homolog**
homologue; homologous; homologous series. A compound belonging to a series of compounds that differ by a repeating group. For example, propanol ($CH_3CH_2CH_2OH$), n-butanol ($CH_3CH_2CH_2CH_2OH$), and n-pentanol ($CH_3CH_2CH_2CH_2CH_2OH$) are homologs; they belong to a homologous series $CH_3(CH_2)_nOH$.

■ **homologous series**
a series of compounds in which each member differs from the next by a specific number and kind of atoms.

■ **homonuclear**
consisting of only one element.

■ **humectant**
a substance that absorbs or retains moisture, added to a product to keep it from drying out.

■ **Hund's rule**
rule of maximum multiplicity. A rule of thumb stating that subshells fill so that the number of unpaired spins is maximized, or "spread them out and line them up."



■ **hybridisation**
mixing a set of atomic orbitals to form a new set of atomic orbitals with the same total electron capacity and with properties and energies intermediate between those of the original unhybridised orbitals.

■ **hydrate**
compare with addition compound . A hydrate is an addition compound that contains water in weak chemical combination with another compound. For example, crystals of $CuSO_4 \cdot 5\ H_2O$ (copper sulphate pentahydrate) are made of regularly repeating units, each containing 5 molecules of water weakly bound to a copper(II) ion and a sulphate ion.

■ **hydrate isomers**
isomers of crystalline complexes that differ in whether water is present inside or outside the coordination sphere.

■ **hydration**
reaction of a substance with water.

■ **hydration energy**
the energy change accompanying the hydration of a mole of gase and ions.

■ **hydrazine**
(NH_2NH_2) a colourless, fuming, corrosive liquid that is a powerful reducing agent. NH_2NH_2 is used in jet and rocket fuels, and as an intermediate in the manufacture of agricultural, textile, photographic, and industrial chemicals.

■ **hydride**
a binary compound of hydrogen.

■ **hydrocarbon**
compare with alkane, alkene, alkyne, and organic. Hydrocarbons are organic compounds that contain only hydrogen and carbon. The simplest hydrocarbons are the alkanes.

■ **hydrogen bond**
hydrogen bonding. an especially strong dipole-dipole force between molecules X-H...Y, where X and Y are small electronegative atoms (usually F, N, or O) and ... denotes the hydrogen bond. Hydrogen bonds are responsible for the unique properties of water and they loosely pin biological polymers like proteins and DNA into their characteristic shapes.

■ **hydrogenation**
the reaction in which hydrogen adds across a double or triple bond.

■ **hydrogen-oxygen fuel cell**
fuel cell in which hydrogen is the fuel (reducing agent) and oxygen is the oxidising agent.

■ **hydrolysis**
the reaction of a substance with water or its ions.

■ **hydrolysis constant**
an equilibrium constant for a hydrolysis reaction.

■ **hydrometer**
an instrument for measuring the specific gravity of liquids. A hydrometer is a weight with a vertical scale attached. When placed into a liquid, the hydrometer bobs upright, and sinks to a certain level. The specific gravity or solution composition can be read from the liquid level on the vertical scale. Hydrometers are often calibrated in degrees Baumé.

■ **hydronium ion**
(H_3O^+) hydronium. the H_3O^+ ion, formed by capture of a hydrogen ion by a water molecule. A strong covalent bond is formed between the hydrogen ion and water oxygen; all hydrogen ions in aqueous solution are bound inside hydronium ions.

■ **hydrophilic**
hydrophilicity; hydrophilic group. A polar molecule or group that can form strong hydrogen bonds with water.

■ **hydrophilic colloids**
colloidal particles that repel water molecules.

■ **hydrophobic**
hydrophobicity; hydrophobic group. A nonpolar molecule or group that has little affinity for water. Hydrophobic groups on molecules in solution tend to turn in on themselves or clump together with other hydrophobic groups because they are unable to disrupt the network of strong hydrogen bonds in the water around them.

■ **hydroxide**
(OH^-) hydroxide ion. Compare with hydroxyl .
1. the OH^- ion.
2. compounds containing the OH^- ion.

■ **hygroscopic**
able to absorb moisture from air. For example, sodium hydroxide pellets are so hygroscopic that they dissolve in the water they absorb from the air.

■ **hygroscopicity**
the ability of a substance to absorb moisture from air. For example, sodium hydroxide pellets are so hygroscopic that they dissolve in the water they absorb from the air.

■ **hypertonic**
compare with osmotic pressure Describes a solution which has higher osmotic pressure than some other solution (usually, higher osmotic pressure than cell or body fluids). Freshwater fish die if placed in seawater because the seawater is hypertonic, and causes water to leave the cells in fish's body.

■ **hypothesis**
hypotheses. Compare with theory . A hypothesis is a conjecture designed to guide experimentation. Hypotheses are extremely useful in problem solving, and are essential in developing new theories.

■ **hypotonic**
compare with osmotic pressure Describes a solution which has lower osmotic pressure than some other solution (usually, lower osmotic pressure than cell or body fluids). Washing your contact lenses with distilled water rather than saline is painful because distilled water is hypotonic; it causes water to move

into cells, and they swell and burst.

■ **ideal gas**
ideal gases; perfect gas; ideal gas law. A gas whose pressure P, volume V, and temperature T are related by PV = nRT, where n is the number of moles of gas and R is the ideal gas law constant . Ideal gases have molecules with negligible size, and the average molar kinetic energy of an ideal gas depends only on its temperature. Most gases behave ideally at sufficiently low pressures.

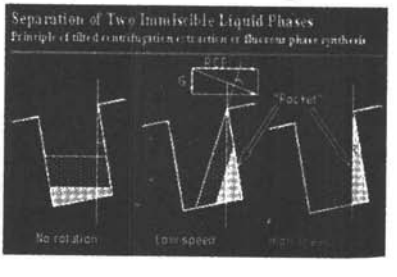
■ **ideal gas law**
the product of pressure and the volume of an ideal gas is directly proportional to the number of moles of the gas and the absolute temperature.

■ **ideal gas law constant**
(R) ideal gas constant; universal gas constant. A constant R equal to PV/(nT) for ideal gases , where the pressure, volume, moles, and temperature of the gas are P, V, n, and T, respectively. The value and units of R depend on the units of P, V, and T. Commonly used values and units of R include: 82.055 cm^3 atm K^{-1} mol^{-1}; 0.082055 L atm mol^{-1} K^{-1}; 8.31434 J mol^{-1} K^{-1}; 1.9872 cal K^{-1} mol^{-1}; 8314.34 L Pa mol^{-1} K^{-1}; 8.31434 Pa m^3 mol^{-1} K^{-1}.

■ **ideal solution**
all molecules in an "ideal solution" interact in exactly the same way; the solvent-solvent, solvent-solute, and solute-solute intermolecular forces are all equivalent. Ideal solutions obey Raoult's law exactly. Real solutions behave ideally only when they are very dilute.

■ **ideal solution**
a solution that obeys Raoult's Law exactly.

■ **immiscible**
immiscibility. Compare with miscible and partial miscibility. Two liquids are considered "immiscible" or unmixable if shaking equal volumes of the liquids together results in a meniscus visible between two layers of liquid. If the liquids are completely immiscible, the volumes



of the liquid layers are the same as the volumes of liquids orginally added to the mixture.

■ **impedance**
impedance is the analogue of the resistance or resistivity when applied to alternating current. That is, it is a measure of a material's inability to carry the electrical current. In many materials, the impedance varies as the frequency of the applied electrical potential changes, due to the properties of the conducting liquid or solid. In electrochemistry, the impedance of the electrodes is also frequency dependent.

■ **incomplete octet**
1.an atom with less than eight electrons in its valence shell.
2.an atom with less than eight total bonding and nonbonding electrons in a Lewis structure, for example, B in BH_3 has an incomplete octet.

■ **independent variable**
compare with dependent variable . An independent variable that can be set to a known value in an experiment. Several independent variables may be controlled in an experiment. For example, in an experiment where the vapour pressure of a liquid is measured at several different temperatures, temperature is the independent variable and vapour pressure is the dependent variable.

■ **indicator**
a substance that undergoes an sharp, easily observable change when conditions in its solutions change.

■ **indicator diagram**
PV diagram. A plot of pressure vs. volume. Lines or curves on the indicator diagram represent processes. The areas under curves on the indicator diagram are equal to the work released by the process.

■ **indicators**
for acid-base titrations, organic compounds that exhibit different colors in solutions of different acidities; used to determine the point at which reaction between two solutes is complete.

■ **indirect electrolysis**
the production of chemicals in an electrolytic cell through intermediate electrolysis products. It is often used in the oxidation/reduction of organic

compounds that would otherwise react very slowly at the electrode surface. An intermediate oxidising/reducing agent is produced at the electrode surface and the agent reacts with the organic in the bulk solution. The agent is continuously regenerated by the electrolysis. A typical oxidising agent is the ferric (tri-valent iron) ion, and an example of the reducing agent is the cerous (tri-valent cerium) ion. The reactive intermediate is often called a "mediator," and the overall reaction a "mediated reaction."

■ **inductive effect**
inductance effect. An inductive effect is the polarisation of a chemical bond caused by the polarisation of an adjacent bond. (Field effects are polarisation caused by nonadjacent bonds).

■ **inert electrode**
an electrode that serves only as a source or sink for electrons without playing a chemical role in the electrode reaction. Noble metals, mercury, and carbon are typically used as inert electrodes. The "inert" nature of the electrode can sometimes be questioned. While the electrode may not take part in the reaction as a reactant or product, it still can act as an electrocatalyst.

■ **inert pair**
Valence electrons in an s orbital penetrate to the nucleus better than electrons in p orbitals, and as a result they're more tightly bound to the nucleus and less able to participate in bond formation. A pair of such electrons is called an "inert pair". The inert pair effect explains why common ions of Pb are Pb^{4+} and Pb^{2+}, and not just Pb^{4+} as we might expect from the octet rule.

■ **inert's-pair effect**
characteristic of the post-transition minerals; tendency of the outermost s electrons to remain non-ionised or un shared in compounds.

■ **infrared radiation**
(IR) infrared. Electromagnetic radiation with wavelength longer than visible light but shorter than that of microwaves. Infrared radiation is produced by hot objects; absorption of infrared radiation causes chemical bonds to vibrate.

■ **infrared spectroscopy**
IR spectroscopy. A technique for determining the structure (and sometimes concentration) of molecules by observing how infrared radiation is absorbed by a sample.

■ **inhibitor**
a chemical that stops (or at least decreases the rate of) a chemical reaction.

■ **inhibitory catalyst**
an inhibitor, a catalyst that decreases the rate of reaction.

■ **inner orbital complex**
valence bond designation for a complex in which the metal ion utilises d orbitals for one shell inside the outermost occupied shell in its hybridisation.

■ **innersphere charge transfer reaction**
a charge-transfer reaction with the reactants in direct contact with each other, without any intervening solvent molecules. Note that a "reactant" can also be an electrode. Contrast with outer-sphere charge-transfer reaction.

■ **inorganic chemistry**
the study of inorganic compounds , specifically their structure, reactions, catalysis, and mechanism of action.

■ **inorganic compound**
inorganic. Compare with organic. A compound that does not contain carbon chemically bound to hydrogen. Carbonates, bicarbonates, carbides, and carbon oxides are considered inorganic compounds, even though they contain carbon.

■ **insoluble**
insolubility. Compare with soluble . Refers to a substance that does not dissolve in a solvent to any significant degree. Compounds with solubilities of less than 1 g per litre of water are often referred to as 'insoluble', even though they do dissolve to a small extent.

■ **insoluble compound**
a very slightly soluble compound.

■ **insulator**
poor electric and heat conductor.

■ **insulator (electrical)**
a material that will not carry any electrical current. It has zero conductivity and infinite resistivity.

■ **integrated rate equation**
an equation giving the concentration of a reactant remaining after a specified time; has different mathematical form for different orders of reactants.

■ **integrated rate law**
rate laws like $d[A]/dt = -k[A]$ give instantaneous concentration changes. To find the change in concentration over time, the instantaneous changes must by added (integrated) over the desired time interval. The rate law $d[A]/dt = -k[A]$ can be integrated from time zero to time t to obtain the integrated rate law $\ln([A]/[A]_o = -kt$, where $[A]_o$ is the initial concentration of A.

■ **intensive property**
intensive; intensive properties. Compare with extensive property . A property that does not change when the amount of sample changes. Examples are density, pressure, temperature, colour.

■ **interconnect**
an electrically conductive structural part that connects series-connected cells in a fuel cell stack.

■ **interference**
interfering. Compare with constructive interference and destructive interference. The amplitudes of waves moving into the same region of space add to produce a single resultant wave. The resultant wave can have higher or lower amplitude than the component waves.

■ **intermediate**
a molecular or ionic species that is formed (directly or indirectly) from the reactants and reacts further (directly or indirectly) to form the products of the reaction. It does not accumulate during the course of the reaction.

■ **intermediate species**
species formed in a reaction consisting of more than one step. An intermediate is produced in one reaction and consumed in the following reaction.

■ **intermolecular force**
an attraction or repulsion between molecules. Intermolecular forces are much weaker than chemical bonds. Hydrogen bonds, dipole-dipole interactions, and London forces are

examples of intermolecular forces.

■ **internal electrolyte**
the electrolyte solution inside a reference electrode assembly such as the silver/silver-chloride electrode. (Also called "filling solution.") Internal electrolytes are used also in membrane electrodes. Contrast with external electrolyte.

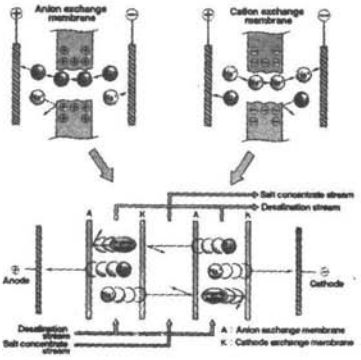
■ **internal energy**
(U, E) compare with enthalpy and energy. Internal energy (U) is defined so that changes in internal energy (U) are equal to the heat absorbed or released by a process running at constant volume. While changes in internal energy can be measured using calorimetry, absolute values of internal energy usually cannot be determined. Changes in internal energy are equal to the heat transferred plus the work done for any process.

■ **internal reference electrode**
a reference electrode used inside a membrane electrode assembly as an electrical contact, with stable potential, to the internal electrolyte.

■ **ion**
an atom or molecule that has acquired a charge by either gaining or losing electrons. An atom or molecule with missing electrons has a net positive charge and is called a cation ; one with extra electrons has a net negative charge and is called an anion.

■ **ion exchange**
ion exchange resin; ion exchanger. Ion exchange is a method of separating ions from a solution by reversibly binding them onto a resin that has charged sites on its surface. Ion exchangers are used to remove metal ions from drinking water.

■ **ion exchange membrane**
a plastic sheet formed from ion-exchange resin. The utility of such membranes is based on their property that they are permeable preferentially only to either positive ions (cation-exchange membrane) or to negative ions (anion-exchange membrane).



■ **ion product for water**
equilibrium constant for the ionisation of water, $K_w = [H_3O^+][OH^-] = 1.00 \times 10^{-14}$ at 25 °C.

■ **ionexchange resin**
a polymeric resin that contains electrically charged fragments ("fixed ions") permanently attached to the polymer backbone, electrical neutrality is achieved by attached mobile "counterions" in the solution phase the resin is immersed into. A practical use of such resin is the removal of unwanted ions from a solution by replacing them with other ions. e.g., a cation exchange resin containing fixed negative charges with attached mobile sodium ions can be used to remove "hardness" from water if the calcium and magnesium ions are more strongly attracted to the resin and therefore will replace the sodium ions. Eventually all the sodium ions will go into solution and the ion-exchange process terminates. The resin can be regenerated by soaking in a high concentration sodium salt solution. Such process can also be used to remove unwanted ions from polluted water streams.

■ **ionic bond**
ionically bound; ionic bonding. Compare with covalent bond. An attraction between ions of opposite charge. Potassium bromide consists of potassium ions (K^+) ionically bound to bromide ions (Br^-). Unlike covalent bonds, ionic bond formation involves transfer of electrons, and ionic bonding is not directional.

■ **ionic bonding**
chemical bonding resulting from the transfer of one or more electrons from one atom or a group of atoms to another.

■ **ionic compound**
salt. Compare with covalent compound and ionic bond. A

compound made of distinguishable cations and anions, held together by electrostatic forces.

■ **ionic compounds**
compounds containing predominantly ionic bonding.

■ **ionic conductor**
a material that conducts electricity with ions as charge carriers.

■ **ionic current**
electrical current with ions as charge carriers.

■ **ionic dissociation**
ionise; ionisation. When ionic substances dissolve, their ions are surrounded by solvent molecules and separated from each other. This phenomena is also called ionisation.

■ **ionic equation**
complete ionic equation . Compare with net ionic equation and molecular equation . An ionic equation is a balanced chemical equation in which strong electrolytes are written as dissociated ions. For example, $Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$ is an ionic equation; $AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$ is not.

■ **ionic geometry**
the arrangement of atoms (not lone pairs of electrons) about the central atom of a polyatomic ion.

■ **ionic liquid**
a liquid containing mostly ions, a molten salt in which the molecules are fully (or almost fully) dissociated. Contrast with electrolyte solution in which the dissociated salt is dissolved in a solvent, with the solvent not (or only slightly) dissociated. Corresponding examples are molten sodium chloride (table salt) and aqueous solution of sodium chloride, respectively.

■ **ionic mobility**
a quantitative measure of an ion's ability to move under the influence of a potential difference in solution. It is the speed of movement under the influence of unit potential difference. While the mobility is defined in terms electromigration, it also affects the speed of diffusion.

■ **ionic radius**
compare with atomic radius . The radii of anions and cations in crystalline ionic compounds,

as determined by consistently partitioning the centre-to-centre distance of ions in those compounds.

■ **ionics**
part (sub-discipline) of electrochemistry that deals with the behaviour of ions in liquid solutions, ionic liquids, and solids ("solid-state ionics").

■ **ionisation energy**
(IE,IP) ionisation potential. Compare with adiabatic ionisation energy, vertical ionisation energy, electronegativity, and electron affinity. The energy needed to remove an electron from a gaseous atom or ion.

■ **ionisation**
in aqueous solution, the process in which a molecular compound reacts with water and forms ions.

■ **ionisation constant**
equilibrium constant for the ionisation of a weak electrolyte.

■ **ionisation energy**
the minimum amount of energy required to remove the most loosely held electron of an isolated gaseous atom or ion.

■ **ionisation isomers**
isomers that result from the interchange of ions inside and outside the coordination sphere.

■ **ionselective electrode**
an electrode or electrode assembly with a potential that is dependent on the concentration of an ionic species in the test solution and is used for electroanalysis. Ion-selective electrodes are often membrane type electrodes. Abbreviated as "ISE."

■ **IR (drop) compensation**
some potentiostats are equipped with an optional ir compensation. The potentiostat electronically corrects for the solution ir drop and the potential of the working electrode is controlled (at least in principle) at the correct value. Unfortunately, most potentiostats become unstable at full compensation, so one can only make a partial compensation, resulting in an uncompensated ir drop and an error in the potential control. The user must provide the solution resistance value, though some potentiostat setups will measure it automati-

cally. Contrast with ir (drop) correction.

■ **IR (drop) correction**
a numerical correction of measured potential of the working electrode for the solution IR drop. (One must know the value of the current and the value of the resistance of the electrolyte between the working and the reference electrodes.) It cannot be simply stated whether this correction is positive or negative because of the contradictory conventions used for the anodic and cathodic currents. In either case, the absolute value of the corrected potential must be smaller than that of the uncorrected potential. Contrast with ir (drop) compensation.

■ **IR drop**
the electrical potential difference between the two ends of a conducting phase during a current flow. It is the product of the current (I) and the resistance (R) of the conductor. In electrochemistry, it refers to the solution IR drop, or to the ohmic loss in an electrochemical cell.

■ **irreversible electrode**
an electrode with an irreversible electrode reaction.

■ **irreversible electrode reaction**
a qualitative term for a slow electrode reaction. An electrode reaction having a small exchange current density. Opposite: reversible electrode reaction.

■ **irreversible process**
any real process; when a system undergoes the changes State 1 -> State 2 -> State 1 by any real pathway, the universe is different that before the cyclic process took place in the system.

■ **ISE**
stands for ion-selective electrode.

■ **isobar**
compare with isotope .
1. a contour line that corresponds to values measured at identical pressures. For example, curves on a plot of gas volumes measured at different temperatures in an open container are isobars.
2. nuclides that have the same isotopic mass but different atomic number.

■ **isobaric**
having constant pressure.

■ **isochore**
a contour line that corresponds to values measured at identical volumes. For example, a curve on a plot of gas pressure measured at different temperatures in a rigid container is an isochore.

■ **isochoric**
having constant volume.

■ **isoelectric**
having the same electronic configurations.

■ **isoelectric focusing**
a variation of the electrophoretic separation technique. The separation of molecules occurs in a combination of potential an pH gradients resulting in sharper separations compared to simple electrophoresis.

■ **isoelectronic**
refers to a group of atoms or ions having the same number of electrons. For example, F^-, Ne, and Na^+ are isoelectronic.

■ **isolated system**
a system which can exchange neither mass nor energy with its surroundings.

■ **isomers**
different compounds with the same molecular formula. This is a very broad term and encompasses all of the different types of isomers. To call something an isomer is analogous to saying that it is related without saying how it is related.

■ **isomorphous**
refers to crystals having the same atomic arrangement.

■ **isotherm**
a contour line that corresponds to values measured at identical temperatures. For example, curves on a plot of gas pressure measured at different volumes in a constant temperature bath are isotherms.

■ **isothermal**
having constant temperature.

■ **isotope**
isotopic; isotopy. Compare with isomer , allotrope , isobar , and isotone . Atoms or ions of an element with different numbers of neutrons in their atomic nucleus . Isotopes have the same atomic number but different mass number . Isotopes have very similar chemical

properties but sometimes differ greatly in nuclear stability.

■ **isotopic abundance**
compare with natural abundance . The fraction of atoms of a given isotope in a sample of an element .

■ **isotopic mass**
isotopic masses. The mass of a single atom of a given isotope , usually given in daltons.

■ **IUPAC**
International Union of Pure and Applied Chemistry, an organisation which sets international standards for chemical nomenclature , atomic weights , and the names of newly discovered elements.

■ **joule**
(J), the SI unit of energy, equal to the work required to move a 1 kg mass against an opposing force of 1 newton . 1 J = 1 kg m^2 s^{-2} = 4.184 calories.

■ **k**
the letter "k" when used as a prefix before a unit symbol indicates a multiplier of 10^3. Symbol of "kilo". e.g., kÙ = 10^3 ohm, one kiloohm, one thousand ohms. (The symbol is the letter "k" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)

■ **K capture**
absorption of a K shell (n=1) electron by a proton as it is converted to a neutron.

■ **kA**
symbol and abbreviation of kiloampere (= 10^3 A, one thousand amperes).

■ **kelvin**
(K) the SI base unit of temperature, defined by assigning 273.16 K to the temperature at which steam, ice, and water are at equilibrium (called the triple point of water). The freezing point of water is 273.15 K.

■ **ketone**
(R-CO-R') An organic compound that contains a carbonyl group. For example, methyl ethyl ketone is $CH_3COCH_2CH_3$ is used in some adhesives.

■ **kilo**
when used as a prefix before a unit name it indicates a multiplier of 10^3. e.g., kiloohm = 10^3 ohm, one thousand ohms. Symbol: "k".

■ **kilo ohm**
10^3 ohm, symbol: "kΩ" (one thousand ohms).

■ **kilogram**
(kg) The kilogram (kg) is the base unit of mass in the SI system of units. The standard kilogram is a 1 kg corrosion resistant platinum/iridium cylinder, carefully preserved in the suburbs of Paris (with a backup copy kept in Gaithersburg, Maryland.) Efforts are underway to replace these artifacts by redefining the kilogram as the mass of a certain number of silicon atoms.

■ **kinetic energy**
compare with potential energy. The energy an object possesses by virtue of its motion. An object of mass m moving at velocity v has a kinetic energy of $\frac{1}{2}mv^2$.

■ **kinetic molecular theory**
this theory assumes that molecules must collide in order to react. The more collisions the more likely it is for a reaction to occur. However, depending on the conditions, only a small fraction of the collisions are effective in producing a reaction. There are several constraints. In order for a reaction to occur, bonds initially are broken, which requires energy. This energy depends on the type of the reaction and comes from the kinetic energies that the molecules possess before the collision. It is called the activation energy. Increasing the temperature increases the kinetic energies and more collisions will occur. In addition, at a higher temperature a greater number of the reacting molecules might possess an energy equal to or greater than the activation energy. However the molecules must also collide in a specific orientation, called the steric factor in order for a reaction to occur. A reaction will only be successful, if the collision has enough energy to be either equal to or greater than the activation energy and if the orientation of the collision allows for correct bond formation. These factors are in the Arrhenius equation:
$k = zp$
The rate constant k is proportional to the Arrhenius factor A. A is the product of the collision frequency z, and the steric fac-

tor p. The fraction of collisions with sufficient energy to produce a reaction are in the term of the equation.

■ **kinetic-molecular theory**
a theory, that attempts to explain macroscopic observations on gases in microscopic or molecular terms.

■ **kinetics**
chemical kinetics is a scientific discipline dedicated to the study of the rates of chemical reactions. How fast is a reaction proceeding in time, and what is affecting the rate.

■ **K_w**
symbol for the autoprotolysis constant for water, equal to 1.01×10^{-14} at 25°C.

■ **kWh**
symbol and abbreviation of kilowatt-hour (= 10^3 Wh, one thousand watt-hours).

■ **kΩ**
symbol and abbreviation of kiloohm (= 10^3 ohm, one thousand ohms). (The symbol is the letter "k" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)

■ **L**
L-isomer. Compare with D-Prefix used to designate a levorotatory enantiomer.

■ **lanthanide**
compare with actinide and inner transition metals. Elements 57-70 are called lanthanides. Electrons added during the Aufbau construction of lanthanide atoms go into the 4f subshell.

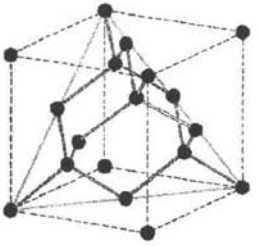
■ **lanthanide contraction**
an effect that causes sixth period elements with filled 4f subshells to be smaller than otherwise expected. The intervention of the lanthanides increases the effective nuclear charge, which offsets the size increase expected from filling the n=6 valence shell. As a consequence, sixth period transition metals are about the same size as their fifth period counterparts.

■ **lanthanides**
elements 58 to 71 (after lanthanum).

■ **latent heat**
heat that is absorbed without causing a rise in temperature. For example, "latent heat of vapourisation" refers to the

amount of heat required to convert a liquid to vapour at a particular temperature.

■ **lattice**
a regular array of ions or atoms.



■ **law**
natural law; scientific law. Natural laws summarise patterns that recur in a large amount of data. Unlike human laws, natural laws don't forbid or permit; they describe.

■ **law of combining volumes**
Gay-Lussac's law. When gases react, they do so in a definite proportion by volume, if the volumes are measured at the same pressure and temperature. For example, in the reaction $N_2(g) + 3\ H_2(g) = 2\ NH_3(g)$, 3 litres of hydrogen will react with 1 litre of nitrogen to give 2 litres of ammonia if all volumes are measured at the same temperature and pressure.

■ **law of conservation of mass**
there is no change in total mass during a chemical change. The demonstration of conservation of mass by Antoine Lavoisier in the late 18th century was a milestone in the development of modern chemistry.

■ **law of conservation of matter**
there is no detectable change in the quantity of matter during an ordinary chemical reaction.

■ **law of conservation of matter and energy**
the total amount of matter and energy available in the universe is fixed.

■ **law of definite proportions**
when two pure substances react to form a compound, they do so in a definite proportion by mass. For example, when water is formed from the reaction between hydrogen and oxygen, the 'definite proportion' is 1 g of H for every 8 g of O.

■ **law of multiple proportions**
when one element can combine with another to form more than one compound, the mass ratios of the elements in the compounds are simple whole-number ratios of each other. For example, in CO and in CO_2, the oxygen-to-carbon ratios are 16:12 and 32:12, respectively. Note that the second ratio is exactly twice the first, because there are exactly twice as many oxygens in CO_2 per carbon as there are in CO.

■ **law of partial pressures (Dalton's law)**
the total pressure exerted by a mixture of gases is the sum of the partial pressures of the individual gases.

■ **Le chatelier's principle**
states that a system at equilibrium, or striving to attain equilibrium, responds in such a way as to counteract any stress placed upon it. If a stress (change of conditions) is applied to a system at equilibrium, the system shifts in the direction that reduces stress.

■ **lead acid battery**
a rechargeable battery. During discharging, the reaction on the positive electrode is the conversion of lead dioxide to lead sulphate, while on the negative electrode it is the conversion of metallic lead to lead sulphate. The reactions are reversed during charging. The current collector can be lead in both electrodes. The electrolyte is sulphuric acid. While it is one of the earliest practical storage batteries (1866), it is still very widely used today, e.g. as automobile starter battery.

■ **lead storage battery**
a battery (used in cars) in which the anode is lead, the cathode is lead coated with lead dioxide, and the electrolyte is a sulphuric acid solution.

■ **Leclanche cell (battery)**
one of the earliest practical non-rechargeable batteries (Georges-Lionel Leclanche, 1866). It uses a zinc anode (negative electrode) and a manganese dioxide cathode (positive electrode) with ammonium chloride solution as electrolyte. The initially liquid electrolyte

was later "immobilised," and this system became the first dry cell. It is still widely used.

■ **leveling agent, leveler**
small amounts of (usually organic) compounds added to an electroplating solution that changes the mechanism of the plating to produce a metal deposit smoother than the original substrate.

■ **leveling effect**
effect by which all acids stronger than the acid that is characteristic of the solvent react with solvent to produce that acid; similar statement applies to bases. The strongest acid (base) that can exist in a given solvent is the acid (base) characteristic of the solvent.

■ **Levich equation**
an equation that describes the effect of several variables (rotation rate, solution concentration, etc) on the current at a rotating-disk electrode.

■ **laevorotatory**
compare with dextrorotatory. Having the property of rotating plane-polarised light counterclockwise.

■ **Lewis acid**
any species that can accept a share in an electron pair.

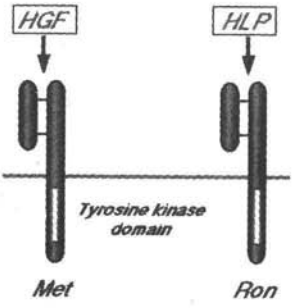
■ **Lewis base**
any species that can make available a share in an electron pair.

■ **Lewis dot formula (electron dot formula)**
representation of a molecule, ion or formula unit by showing atomic symbols and only outer shell electrons.

■ **Lewis structure**
electron dot structure; dot structure. A model pioneered by Gilbert N. Lewis and Irving Langmuir that represents the electronic structure of a molecule by writing the valence electrons of atoms as dots. Pairs of dots (or lines) wedged between atoms represent bonds; dots drawn elsewhere represent nonbonding electrons.

■ **ligand**
1. in inorganic chemistry, a molecule or ion that binds to a metal cation to form a complex. 2 in biochemistry, a molecule that binds to a receptor, having a biological effect

Ligand-Receptor Specificity



■ **limit of quantitation** (LOD) quantitative detection limit; limit of determination. The smallest detectable concentration an analytical instrument can determine at a given confidence level. IUPAC defines the quantitative detection limit as Cld = ks/m, where k is 10, s is the standard deviation of instrument readings taken on a "blank" (a solution with zero concentration of analyte), and m is the slope of a plot of instrument response vs. concentration, as calculated by linear regression.

■ **limiting current density** the maximum current density that can be achieved for an electrode reaction at a given concentration of the reactant in the presence of a large excess of supporting electrolyte. The mass transport occurs exclusively through diffusion in the diffusion layer, driven by the concentration difference of the reactant between the edge of the diffusion layer and the electrode surface. As the current density is increased (usually by changing the electrode potential), the surface concentration of the reactant must decrease so that the concentration difference driving the diffusion can increase and provide the required flux of the reactant. However, the surface concentration obviously cannot decrease below zero, thereby a situation is reached when further change of the electrode potential cannot increase the reactant flux, and correspondingly the current density. The concept of "limiting current density" is valid even in the absence of supporting electrolyte. However, the situation is more complex in this case because electromigrational effects must also be taken into consideration.

■ **limiting reactant** limiting reagent. The reactant that limits the amount of product produced in a chemical re-

action. For example, mixing one mole of $H_2(g)$ with one mole of O_2 produces one mole of steam ($H_2O(g)$), with half a mole of $O_2(g)$ remaining. The hydrogen gas limits the amount of steam produced in this case.

■ **line spectrum**
line spectra; line emission spectrum. Compare with band spectrum and continuous spectrum. A emission spectrum that contains very sharp peaks, corresponding to transitions between states in free atoms. For example, the line spectrum of hydrogen contains 4 sharp lines in the visible part of the spectrum.

■ **linear accelerator**
a device used for accelerating charged particles along a straight line path.

■ **linkage isomers**
isomers in which a particular ligand bonds to a metal ion through different donor atoms.

■ **liquefaction**
the transformation of a gas into a liquid.

■ **liquid**
a state of matter that has a high density and is incompressible compared to a gas. Liquids take the shape of their container but do not expand to fill the container as gases do. Liquids diffuse much more slowly than gases.

■ **liquid aerosol**
colloidal suspension of liquid in gas.

■ **liquid junction potential**
a potential difference between two solutions of different compositions separated by a membrane type separator. The simplest example is the case of two solutions containing the same salt in different concentrations. The salt will diffuse from the higher concentration side to the lower concentration side. However, the diffusion rate of the cation and the anion of the salt will very seldom be exactly the same. Let us assume for this example that the cations move faster; consequently, an excess positive charge will accumulate on the low concentration side, while an excess negative charge will accumulate on the high concentration side of the junction due to the slow moving anions. This sets up a potential difference that will start

an electromigration of the ions that will increase the net flux of the anions and decrease the net flux of the cations. In steady-sate conditions, the two ions will move at the same speed and a potential difference will be created between the two solutions. This "steady-sate" potential difference seems constant, but this is misleading because it slowly changes as the concentrations between the two solutions equalise. The diffusion process will "eventually" result in equal concentrations of the salt in the two solutions separated by the membrane, and the liquid-junction potential will vanish. For a simple case, the value of the liquid junction potential can be calculated by the so called "Henderson" equation.

■ **litmus**
a mixture of pigments extracted from certain lichens that turns blue in basic solution and red in acidic solution.

■ **litmus paper**
litmus test. Paper impregnated with litmus, usually cut in narrow strips. Dipping red litmus paper into a basic solution turns it blue; dipping blue litmus paper into an acidic solution turns it red.

■ **load**
a device that consumes electrical power, e.g. a motor or a light bulb.

■ **load leveling**
an energy management system in which energy is produced even when there is no demand for it, and it is stored. This stored energy can later be released during high demand. This way the production capacity of the system can be less than the peak demand (load).

■ **london dispersion forces**
the forces that exist in nonpolar molecules that involve an accidental dipole that induces a momentary dipole in a neighbor.

■ **london force**
dispersion force. An intermolecular attractive force that arises from a cooperative oscillation of electron clouds on a collection of molecules at close range.

■ **lone pair**
pair of electrons residing on one atom and not shared by other atoms; unshared pair.

■ **low spin complex**
low-spin complex. Compare with high spin complex. A metal-ligand complex with fewer unpaired electrons than the uncomplexed metal ion. When a strong ligand complexes the metal ion, the crystal field splitting is large and some electrons pair rather than occupying the higher energy d orbitals.

■ **luggin tip (luggin capillary) (luggin probe)**
a salt bridge with a thin, capillary tip at one end. This can be useful for minimising the solution ir drop by placing the fine capillary tip very close to the surface of the working electrode, when the salt bridge is used to connect the working and reference electrode compartments of a three-electrode cell. The solution distance causing the ir drop can be easily limited to a few millimeters; and, in specially designed cells, often to a much smaller distance.

■ **m**
the letter "m" when used as a prefix before a unit symbol indicates a multiplier of 10^{-3}. Symbol of "milli". e.g., mV = 10^{-3} volt, one millivolt, one thousandth of a volt.

■ **M**
the letter "M" when used as a prefix before a unit symbol indicates a multiplier of 10^{6}. Abbreviation of "meg" or "mega". e.g., MÙ = 10^{6} ohm, one megohm, one million ohms. (The symbol is the letter "M" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.) The letter "M" is also used to denote the molar concentration. The difference in meaning should be quite clear from the context of usage.

■ **mA**
symbol and abbreviation of milliampere (= 10^{-3} ampere, one thousandth of an ampere).

■ **macrostate**
a time-average of many microstates; this is a state of the system that can actually be observed.

■ **magnetic quantum number**
(m) Quantum number that labels different orbitals within a subshell. m can take on values from - to +. The number of

orbitals in a subshell is the same as the number of possible m values.

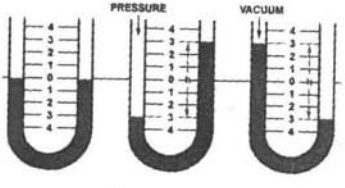
■ **magnetoelectrochemistry**
electrochemical phenomena occurring under the influence of magnetic field.

■ **main group elements**
elements of the s and p blocks.

■ **maintenance free battery**
a rechargeable battery which does not require periodic "topping up" (addition of water) to maintain electrolyte volume.

■ **malleable**
malleability. Compare with ductile . Capable of being hammered into sheets. Metals are typically malleable materials.

■ **manometer**
compare with barometer . An instrument for measuring gas pressures. A mercury or oil manometer measures gas pressure as the height of a fluid column the gas sample is able to support. Open manometers measure gas pressure relative to atmospheric pressure.



■ **mass**
(m) compare with weight . Mass is a measure of the tendency of an object to resist acceleration. It's harder to roll a tractor trailer than a roller skate; the tractor trailer has a far greater mass.

■ **mass action expression**
for a reversible reaction, aA + bB ® cC + dD the product of the concentrations of the products (species on the right), each raised to the power that corresponds to its coefficient in the balanced chemical equation, divided by the product of the concentrations of reactants (species on the left), each raised to the power that corresponds to its coefficient in the balanced chemical equation. At equilibrium the mass action expression is equal to K.

■ **mass deficiency**
the amount of matter that would be converted into energy if an atom were formed from constituent particles.

■ **mass number**
(M,A) compare with atomic number and atomic weight . The total number of protons and neutrons in an atom or ion. In nuclide symbols the mass number is given as a leading superscript. In isotope names (e. g. carbon-14, sodium-23) the mass number is the number following the element name.

■ **mass percentage**
((w/w)%) mass percentages express the concentration of a component in a mixture or an element in a compound. For example, household bleach is 5.25% NaOCl by mass, meaning that every 100 g of bleach contains 5.25 g of NaOCl. Mass percentage can be calculated as 100% times the mass of a component divided by the mass of the mixture containing the component.

■ **mass spectrometer**
an instrument that measures the masses and relative abundances of a sample that has been vapourised and ionised.

■ **mass spectrometry**
mass spectroscopy. (of elements) a method for experimentally determining isotopic masses and isotopic abundances . A sample of an element is converted into a stream of ions and passed through an electromagnetic field. Ions with different charge-to-mass ratios are deflected by different amounts, and strike different spots on a film plate or other detector. From the position of the spots, the mass of the ions can be determined; from the intensity of the spot, the relative number of ions (the isotopic abundance) can be determined.

■ **mass spectrum**
mass spectra. a plot showing the results of a mass spectrometry experiment, which shows the presence of particles with different masses as a series of sharp, separate peaks. The position of the peaks on the x-axis indicates the mass of the particles; the peak heights indicate the relative abundance of the particles.

■ **mass transport**
the phenomenon of movement (transportation) of mass (e.g.,

chemical compounds, ions) from one part of the system to another. Most of the time this occurs through diffusion and convection. Under special circumstances it can also occur through electromigration since the movement of the electrically charged ions also carries mass with them (e.g., ionic current through an ion-exchange membrane. The mass transport and the charge transport are typically "decoupled" in electrochemistry; that is, the reacting species and the charge carrying species are not necessarily identical. e.g., one would intuitively assume that during electroplating of copper from a solution of copper sulphate all the mass and charge required for the electrode reaction at the cathode would be carried by the copper cations in the solution. That is not the case at all. In the presence of a large excess of supporting electrolyte, all the current is carried by electromigration of the ions of the supporting electrolyte (both in the bulk solution and in the diffusion layer) while all the mass is carried by the copper ions by convection in the bulk solution and by diffusion in the diffusion layer. In the absence of any supporting electrolyte, all the mass is still carried by the copper ions, while the current is divided between the copper cations and the sulphate anions according to the ratio of their transport numbers (both in the bulk electrolyte and in the diffusion layer). The situation is maybe more self-explanatory in the case of an electrically neutral molecule reactant that cannot carry any current.

■ **matter**

matter is anything that has mass. Air, water, coffee, fire, human beings, and stars are matter. Light, X-rays, photons, gravitons, information, and love aren't matter.

■ **measurement**

measurement is the collection of quantitative data. Measurement involves comparison of the quantity of interest with a standard called a unit. The comparison is never perfect. As a result, measurements always include error. You must consider the reliability of the measurement when using it to make

decisions or estimate other quantities.

■ **mechanical recharging**
restoring the capacity (charging) of a rechargeable battery by replacing the spent electrode(s) with a fresh one.

■ **mechanism**
the sequence of steps by which reactants are converted into products.

■ **medicinal chemistry**
a branch of chemistry concerned with the discovery, design, synthesis , and investigation of biologically active compounds and reactions that these compounds undergo in living things.

■ **meg or mega**
when used as a prefix before a unit name it indicates a multiplier of 10^6. e.g., megaohm = 10^6 ohm, one million ohms. Symbol: "M".

■ **megawatt**
10^6 watt, symbol: "MW" (one million watts).

■ **megohm**
10^6 ohm, symbol: "MΩ" (one million ohms). (The symbol is the letter "M" followed by the "Greek capital omega" letter, some browsers unfortunately do not support this.)

■ **melting point**
the temperature at which liquid and solid coexist in equilibrium; also the freezing point.

■ **membrane electrode**
an ion-selective electrode assembly terminating in an ion permeable (e.g., ion-exchange) membrane sensing element. The membrane separates the internal filling solution (that contains a fixed concentration of the ion to be detected) and the test solution. The potential across the membrane depends on the concentration ratio of the ion in the two solutions. The assembly also contains an internal reference electrode immersed in the filling solution, serving as an electrical contact with a stable potential. The potential of this assembly is then measured against an external reference electrode immersed in the test solution.

■ **memory effect**
a phenomenon in which a rechargeable battery discharged repeatedly to the same, but less than 100%, depth of discharge

temporarily (or permanently) loses the rest of its capacity for consequent charging.

■ **meniscus**
meniscuses; menisci. A phase boundary that is curved because of surface tension.

■ **meso compounds**
when an internal plane of symmetry exists within a diastereomer then the mirror image compound is superimposable on the original. As such it is not an 'Enantiomer'. The term used to describe such compounds is MESO. Meso compounds are 'Achiral', they are optically inactive.

■ **metal**
metallic. Compare with non-metal and metalloid. A metal is a substance that conducts heat and electricity, is shiny and reflects many colours of light, and can be hammered into sheets or drawn into wire. Metals lose electrons easily to form cations. About 80% of the known chemical elements are metals.

■ **metal deposition/dissolution**
a class of electrode reactions involving oxidation/reduction of a solid metal and its dissolved ion. e.g., if a copper metal rod is immersed in a copper sulphate solution, the copper cations can be cathodically reduced to copper metal, or the copper metal can be anodically oxidised to copper ions. Compare with a redox reaction where both the oxidised and the reduced species are in solution. The terms "electrodeposition" and "electrodissolution" are often used to describe these reactions. These reactions are used in many technologies, such as electroplating, electrowinning, and electrorefining. And also in electrogravimetry.

■ **metallic bonding**
bonding within metals due to the electrical attraction of positively charges metal ions for mobile electrons that belong to the crystal as a whole.

■ **metallic conduction**
conduction of electrical current through a metal or along a metallic surface.

■ **metalloids**
elements with properties intermediate between metals and

nonmetals: B, Al, Si, Ge, As, Sb, Te, Po, and At.

■ **metallurgy**
refers to the overall processes by which metals are extracted from ores.

■ **metathesis reactions**
reactions in which two compounds react to form two new compounds, with no changes in oxidation number. Reactions in which the ions of two compounds exchange partners.

■ **meter**
(m) metre. The meter is the basic unit of length in the SI system of units, defined as the distance light travels through a vacuum in exactly 1/299792458 seconds. 1 m = 39.37 inches. Meters are abbreviated as "m" in measurements.

■ **method of initial rates**
method of determining the rate-law expression by carrying out a reaction with different initial concentrations and analyzing the resultant changes in initial rates.

■ **methyl**
(-CH_3) a group -CH_3, derived from methane. For example, CH3Cl is "methyl chloride" (systematic name: chloromethane); CH_3OH is "methyl alcohol" (systematic name: methanol).

■ **micro**
(μ) micro. Prefix used in the SI system meaning "one millionth of". For example 1 μm means "one millionth of a meter"; 3.1 μL means "3.1 $\times$ 10^{-6} L".

■ **microstate**
each arrangement of the ensemble; every possible arrangement of the atoms or molecules in the system.

■ **microwave**
microwave radiation. Electromagnetic radiation with wavelength between 3 mm and 30 cm.

■ **milli**
(m) Prefix used in the SI system meaning "one thousandth of". For example 1 mL means "one thousandth of a litre"; 1 mg means "one thousandth of a gram".

■ **miscibility**
the ability of one liquid to mix with (dissolve in) another liquid.

■ **miscible**
miscibility; liquid miscibility. Compare with immiscible and partial miscibility. Two liquids are considered "miscible" or mixable if shaking them together results in a single liquid phase, with no meniscus visible between layers of liquid.

■ **mistake**
blunder. Compare with systematic error , random error and gross error . A mistake is a measurement which is known to be incorrect due to carelessness, accidents, or the ineptitude of the experimenter. It's important to distinguish mistakes from errors: mistakes can be avoided. Errors can be minimised but not entirely avoided, because they are part of the process of measurement. Data that is mistaken should be discarded. Data that contains errors can be useful, if the sizes of the errors can be estimated.

■ **mixed glyceride**
compare with glyceride. A diglyceride or triglyceride that contains more than one type of fatty acid connected to glycerol via an ester linkage. Natural oils and fats usually contain several different mixed glycerides.

■ **mixture**
a sample of matter composed of two or more substances, each of which retains its identity and properties.

■ **moderator**
a substance such as hydrogen, deuterium, oxygen or paraffin capable of slowing fast nuetrons upon collision.

■ **molality**
(m) Compare with molarity Concentration measured as moles of solute per kilogram of solvent. For example, a 1 m NaCl solution contains 1 mole of NaCl per kilogram of water. Molalities are preferred over molarities in experiments that involve temperature changes of solutions, e. g. calorimetry and freezing point depression experiments.

■ **molar**
1. of or pertaining to moles .
2. an synonym for molarity ; for example, a "six molar solution of hydrochloric acid" contains 6 moles of HCl per litre of solution.

■ molar heat capacity
atomic heat capacity. Compare with molar heat capacity and specific heat . The heat required to raise the temperature of one mole of a substance by 1°C is called the molar heat capacity of the substance. Molar heat capacity is an intensive property with SI system units of J mol^{-1} K^{-1}. The molar heat capacity of elements is sometimes called the "atomic heat capacity".

■ molar volume
the volume occupied by one mole of a material. For example, the molar volume of an ideal gas at STP is 22.4 L/mol.

■ molarity
(M) molar concentration. Concentration of a solution measured as the number of moles of solute per litre of solution. For example, a 6 M HCl solution contains 6 moles of HCl per litre of solution.

■ mole
(mol) The mole is the SI unit for amount of substance. 1 mole of particles is equal to the number of atoms in exactly 12 g of carbon-12. 1 mole of molecules has a mass equal to the molecular weight in grams.

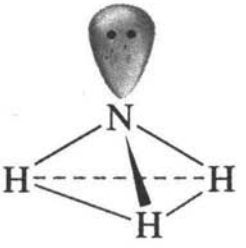
■ mole fraction
concentration of a substance in a mixture measured as moles of the substance per mole of mixture. For example, the mole fraction of oxygen in air is about 0.21, which means that 1 mol of air contains about 0.21 mol O_2.

■ molecular equation
compare with ionic equation .A molecular equation is a balanced chemical equation in which ionic compounds are written as neutral formulas rather than as ions. For example,
$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$
is a molecular equation;
$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl\text{-}(aq) \rightarrow AgCl(s) + Na^+(aq) + NO3^-(aq)$ is not.

■ molecular formula
formula; chemical formula. Compare with empirical formula . A notation that indicates the type and number of atoms in a molecule. The molecular formula of glucose is $C_6H_{12}O_6$, which indicates that a molecule of glucose contains 6 atoms of

carbon, 12 atoms of hydrogen, and 6 atoms of oxygen.

■ **molecular geometry**
1. the three-dimensional shape of a molecule. For example, methane (CH_4) has a tetrahedral molecular geometry.

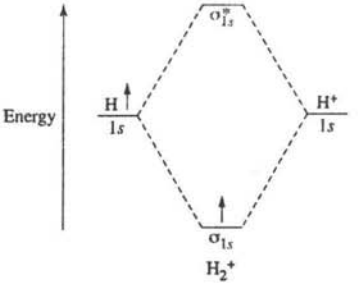


VSEPR notation: AX_3E

2. the study of molecular shapes.

■ **molecular model**
stick model; ball and stick model; spacefilling model. A representation of a molecule. The model can be purely computational or it can be an actual physical object. Stick models show bonds, ball-and-stick models show bonds and atoms, and spacefilling models show relative atomic sizes.

■ **molecular orbital**
compare with atomic orbital and orbital. A wavefunction that describes the behaviour of an electron in a molecule. Molecular orbitals are usually spread across many atoms in the molecule, and they are often described as a combination of atomic orbitals on those atoms.



■ **molecular orbital theory**
a theory of chemical bonding based upon the postulated existence of molecular orbitals.

■ **molecular sieve**
a material that contains many small cavities interconnected with pores of precisely uniform size. Zeolites are an example. Molecular sieves adsorb molecules that are small enough to pass through their pore systems- especially water. They are often used as drying agents, and to separate large molecules from smaller ones in prepara-

tory work and in exclusion chromatography.

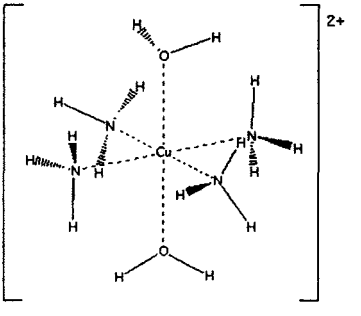
■ **molecular weight**
molecular mass. Compare with formula weight and molecular formula . The average mass of a molecule, calculated by summing the atomic weights of atoms in the molecular formula . Note that the words mass and weight are often used interchangeably in chemistry

■ **molecularity of a rection**
the number of species forming the transition state.

■ **molecule**
compare with atom and ion . The smallest particle of an element or compound that retains the chemical properties of the element or compound. A molecule is a collection of chemically bound atoms with characteristic composition and structure. Making or breaking bonds in a molecule changes it into a new molecule. Ionic compounds are not composed of molecules, because there is no distinct collection of ions that are chemically bound in the crystal.

■ **momentum**
(p) momentum is a property that measures the tendency of a moving object to keep moving in the same direction. Increasing the speed of an object increases its momentum, and a heavy object will have more momentum than a lighter one moving at the same speed. For a particle with mass m and velocity v, the momentum of the particle is mv.

■ **monodentate**
a ligand that has only one atom that coordinates directly to the central atom in a complex. For example, ammonia and chloride ion are monodentate ligands of copper in the complexes $[Cu(NH_3)_6]_2^+$ and $[CuCl_6]_2^+$



■ **monomer**
a small molecule that is linked with large numbers of other

small molecules to form a chain or a network (polymer).

■ **monoprotic acid**
acid that can form only one hydronium ion per molecule; may be strong or weak. Acid that contains one ionisable hydrogen atom per formula unit.

■ **monosaccharides**
the simplest carbohydrates.

■ **mother nuclide**
nuclide that undergoes nuclear decay.

■ **MSDS**
Material Safety Data Sheet. Safety information sheet for a particular substance that lists physical properties, hazards, cleanup and disposal procedures, fire and explosion data, and protective equipment required.

■ **MSG**
monosodium Glutamate. MSG is monosodium glutamate, used as a flavour enhancer in many foods.

■ **multiple bond**
sharing of more than one electron pair between bonded atoms. A double bond consists of two shared pairs of electrons; a triple bond consists of three shared pairs.

■ **mutarotation**
name given to the phenomenon that occurs when glucose is dissolved in water. There is an equilibrium that is formed between the open-chain form and the alpha and beta pyranose forms. The beta is the most stable conformation because it puts the -OH in an equatorial position and thus most of the glucose in the aqueous solution is in the beta form.

■ **nano**
(n) Prefix used in the SI system meaning "multiply by 10^{-9}". For example 1 nm means "0.000000001 m"; 2.8 ng could also be written "2.8×10^{-9} g".

■ **native state**
refers to the occurrence of an element in an uncombined or free state in nature.

■ **natural abundance**
compare with isotopic abundance . The average fraction of atoms of a given isotope of an element on Earth.

■ **natural gas**
a mixture of methane and other gases, found trapped over pe-

troleum deposits under the earth.

■ **natural radioactivity**
spontaneous decomposition of an atom.

■ **Nernst equation**
an equation defining the equilibrium potential of an electrode. The potential is the sum of the standard electrode potential and a correction term for the deviation from unit concentrations of the reactant and the product of the electrode reaction in the solution; if the "reduced" form is a metal, a pure metal (not alloyed with other metals) is considered to be at unit concentration. The correction term is the product of the "Nernst slope" and the logarithm of the ratio of the concentrations (strictly speaking, activities) of the oxidised species and the reduced species. At room temperature, the Nernst slope is 0.05916 volt divided by the number of electrons transferred during the reaction. e.g., for a simple metal deposition/dissolution reaction the slope is 0.05916 for a single charged metal cation, 0.00296 volt for a double charged ion, etc.

■ **Nernstian behaviour**
an electrode is said to behave "nernstially" if the equilibrium electrode potential obeys the Nernst equation when the concentration (strictly speaking, activity) of a species involved in the electrode reaction changes. Opposite: non-Nernstian behaviour.

■ **net ionic equation**
equation that results from canceling spectator ions and eliminating brackets from a total ionic equation.

■ **network covalent solid**
network covalent substance. A substance which consists of an array of atoms held together by an array of covalent bonds. A crystal of a network covalent solid is actually a single, gigantic molecule. Diamond and quartz are examples.

■ **neurotransmitter**
neurotransmitters are molecules that are used to carry signals from one neuron to another. One neuron releases the neurotransmitter near another neuron's receptors. The neurotransmitter diffuses across the gap between the neurons

and locks into a receptor site on the surface of the downstream neuron. This induces a change in the downstream neuron.

■ **neutral**
1 having no net electrical charge. Atoms are electrically neutral; ions are not.
2 a solution containing equal concentrations of H^+ and OH^-

■ **neutralisation**
1. the reaction of an acid and a base to form a "neutral" (pH = 7) solution.
2. the removal of electrical charge to produce a "neutral" (electrically uncharged) particle or object.

■ **neutralisation reaction**
neutralisation; acid-base reaction. A chemical change in which one compound aquires H^+ from another. The compound that receives the hydrogen ion is the base; the compound that surrenders it is an acid.

■ **neutron**
(n, 10n) compare with proton and electron . An elementary particle found the atomic nucleus of all stable atoms except the hydrogen-1 atom. Neutrons have no charge and have a mass of 1.008665 daltons.

■ **Newman Projection**
a method of drawing different 'Conformations' of organic structures in which the observer positions themselves such that they are looking along a bond. This is generally a C-C single-bond. For example the fully staggered conformation of 3-Bromo-penatan-2-ol, looking along the C2-C3 bond appears as shown.
The method is particularly useful when considering the relative energy of the different conformations. For example consider butane. The highest energy state occurring when the two methyl groups are eclipsing one another (*'syn*-periplanar') while the lowest energy state occurs when the two methyl groups are staggered and as far away from each other as possible (*'anti*-periplanar'). The diagram also shows the gauche ('synclinal') and an 'anticlinal' conformation.

■ **Newtonian fluid**
compare with non-Newtonian fluid. A fluid whose viscosity doesn't depend on gradients in

flow speed. Gases and low-molecular weight liquids are usually Newtonian fluids.

■ **NHE**
stands for "normal hydrogen electrode," which is an alternative name for the standard hydrogen electrode.

■ **nickel-cadmium cell (nicad battery)**
a dry cell in which the anode is Cd, the cathode is NiO_2, and the electrolyte is basic.

■ **nitric acid**
(HNO_3) aqua fortis. A corrosive liquid with a sharp odour that acts as a strong acid when dissolved in water. Nitric acid is used to synthesise ammonium nitrate for fertilisers, and is also used in the manufacture of explosives, dyes, and pharmaceuticals. Salts of nitric acid are called nitrates.

■ **nitrogen cycle**
the complex series of reactions by which nitrogen is slowly but continually recycled in the atmosphere, lithosphere and hydrosphere.

■ **nitrogenases**
a class of enzymes found in bacteria within root nodules in some plants, which catalyse reactions by which N2 molecules from the air are converted to ammonia.

■ **noble gas core**
([X], where X is the symbol of an inert gas element) core configuration. Compare with valence shell. All completely filled shells underneath the valence shell.

■ **noble gases (rare gases)**
elements of the periodic Group 0; also called rare gases; formerly called inert gases, He,Ne,Ar, Kr, Xe, Rn.

■ **noble metal**
a metal that resists oxidation (corrosion) in air, and therefore retains its metallic luster. Examples are platinum and gold. These metals have high positive standard electrode potentials and are the lowest ones on the electromotive series. Contrast with active metal.

■ **nodal plane**
a region in which the probability of finding an electron is zero.

■ **node**
a point, region, or surface where the amplitude of a standing wave is zero. The probabil-

ity of finding an electron at an orbital node is zero.

■ **nomenclature**
a system for naming things. For example, "organic nomenclature" is the system used to name organic compounds.

■ **nonaqueous solution**
a solution with the solvent anything but water (e.g., organic or inorganic liquid, molten salt). Contrast with: aqueous solution.

■ **nonbonding orbital**
a molecular orbital derived only from an atomic orbital of one atom; lends neither stability nor instability to a molecule or ion when populated with electrons.

■ **nonelectrolyte**
a substance whose aqueous solutions do not conduct electricity.

■ **nonmetal**
(metal,metalloid) non-metal. A nonmetal is a substance that conducts heat and electricity poorly, is brittle or waxy or gaseous, and cannot be hammered into sheets or drawn into wire. Nonmetals gain electrons easily to form anions. About 20% of the known chemical elements are nonmetals.

■ **non-Nernstian behaviour**
an electrode is said to behave "non-Nernstially" if the equilibrium electrode potential does not obey the Nernst equation when the concentration (strictly speaking, activity) of a species involved in the electrode reaction changes. Opposite: Nernstian behaviour.

■ **non-Newtonian fluid**
compare with Newtonian fluid. A fluid whose viscosity changes when the gradient in flow speed changes. Colloidal suspensions and polymer solutions like ketchup and starch/water paste are non-Newtonian fluids.

■ **non-ohmic resistance (behaviour)**
a system or system element is behaving "non-ohmically" if it does not follow Ohm's law. That is, the value of the resistance depends on the current or the potential. Opposite: ohmic behaviour. The resistance can be formally defined as the differential of the potential with respect of the current. In the

case of Ohm's law, this is the constant value of the resistance. In electrochemistry, a typical "non-ohmic" element is the charge-transfer resistance. The charge-transfer reaction can be considered a circuit element because it requires a certain amount of overpotential to force through a current. However, the pertinent relation here is the Tafel law (at least at relatively large overpotentials), and the differential of the current (that is the resistance) is a function of the current itself.

■ **nonparticulate**
not composed of distinct particles.

■ **nonpolar**
having a relatively even or symmetrical distribution of charge

■ **nonpolar bond**
covalent bond in which electron density is symmetrically distributed.

■ **nonpolar molecule**
a molecule in which the centre of positive charge and the centre of negative charge coincide. Examples are CCl_4 and CO_2; counterexamples are $CHCl_3$ and H_2O.

■ **nonpolarisable electrode**
an electrode that is not easily polarisable. That is, the potential of the electrode will not change significantly from its equilibrium potential with the application of even a large current density. The reason for this behaviour is that the electrode reaction is inherently fast (has a large exchange current density).

■ **non-rechargeable battery**
a battery in which the chemical reaction system providing the electrical current is not easily "chemically" reversible. It provides current until all the chemicals placed in it during manufacture are used up. It is discarded after a single discharge. Also called "primary" battery or cell. Contrast with rechargeable battery. This battery always operates as a galvanic cell. Consequently, the anode is the negative electrode, while the cathode is the positive electrode.

■ **normal electrode potential**
alternative name for standard electrode potential.

■ **normal hydrogen electrode**
alternative name for standard hydrogen electrode. Abbreviated as "NHE."

■ **normality**
(N) normal. Compare with molarity and equivalent A measure of solution concentration, defined as the number of equivalents of solute per litre of solution.

■ **nuclear binding energy**
energy equivalent of the mass deficiency; energy released in the formation of an atom from the subatomic particles.

■ **nuclear fission**
the process in which a heavy nucleus splits into nuclei of intermediate masses and one or more protons are emitted.

■ **nuclear reaction**
involves a change in the composition of a nucleus and can evolve or absorb an extraordinarily large amount of energy.

■ **nuclear reactor**
a system in which controlled nuclear fisson reactions generate heat energy on a large scale, which is subsequently converted into electrical energy.

■ **nucleation**
the process of providing sites for
1. new bubbles to form in a liquid that is boiling or supersaturated with gas;
2. new droplets to condense from a supersaturated vapour, or
3. new crystals to form in a supersaturated solution. Nucleation sites can be scratches in a surface, dust particles, seed crystals, and so on.

■ **nucleon**
compare with proton , neutron and atomic nucleus . A proton or a neutron in the atomic nucleus.

■ **nucleophile**
a species that loves a nucleus. Since nuclei are positively charged, nucleophiles are negatively charged or bear a partial negative charge. Examples are lone pairs or a hydroxide ion.

■ **nucleus**
the very small, very dense, positively charged centre of an atom containing protons and neutrons, as well as other subatomic particles.

■ **nuclide**
compare with atomic nucleus and nuclide symbol . An atom or ion with a specified mass number and atomic number. For example, uranium-235 and carbon-14 are nuclides.

■ **nuclide symbol**
compare with atomic nucleus , nuclide and element symbol . A symbol for an nuclide that contains the mass number as a leading superscript and the atomic number as a leading subscript. For ions, the ionic charge is given as a trailing superscript. For example, the nuclide symbol for the most common form of the chloride ion is $^{35}_{17}Cl^-$, where 35 is the mass number, 17 is the atomic number, and the charge on the ion is -1. The atomic number is sometimes omitted from nuclide symbols.

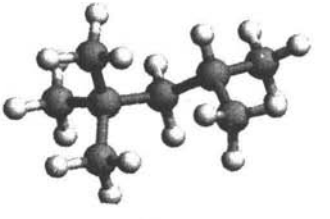
■ **nuclides**
refers to different atomic forms of all elements in contrast to isotopes, which refer only to different atomic forms of a single element.

■ **nV**
symbol and abbreviation of nanovolt(= 10^{-9} volt, one billionth of a volt).

■ **ocp**
stands for open-circuit potential.

■ **octahedral**
a term used to describe molecules and polyatomic ions that have one atom in the centre and six atoms at the corners of a octahedron.

■ **octane**
(C_8H_{18}) Compare with alkane and hydrocarbon. Flammable liquid compounds found in petroleum and natural gas. There are 18 different octanes- they have different structural formulas but share the molecular formula C_8H_{18}. Octane is used as a fuel and as a raw material for building more complex organic molecules. It is the eighth member of the alkane series.



■ **octane number**
a number that indicates how smoothly a gasoline burns.

■ **octet**
a set of eight valence electrons.

■ **octet rule**
a guideline for building Lewis structures that states that atoms tend to gain, lose, or share valence electrons with other atoms in a molecule until they hold or share eight valence electrons. The octet rule almost always holds for carbon, nitrogen, oxygen, and fluorine; it is regularly violated for other elements.

■ **OCV**
stands for open circuit voltage.

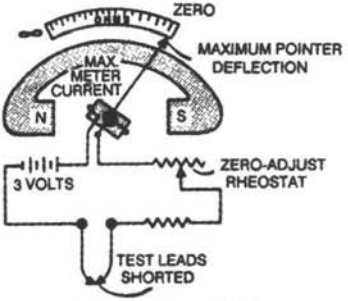
■ **OER**
stands for oxygen evolution reaction.

■ **ohm**
measurement unit of the electrical resistance. Symbol: "Ù". (The symbol is the "Greek capital omega" letter, some browsers unfortunately do not support this.)

■ **ohmic loss**
the total IR drop in an electrochemical cell, including the IR drop in the solution between the electrodes and in any separator.

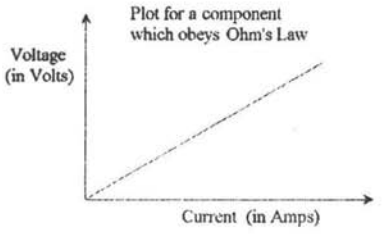
■ **ohmic resistance (behaviour)**
a system or system element is behaving "ohmically" if it follows Ohm's law. That is, the value of the resistance is independent of the current and the potential. Typically, metals and electrolyte solutions are "ohmic." Opposite: non-ohmic behaviour.

■ **ohmmeter**
instrument used for the measurement of electrical resistance.



Simple Ohmmeter Circuit.

■ **Ohm's law**
the relation amongst the current flowing through a resistor and the potential difference between the two ends of the resistor. The potential difference is equal to the product of the current and the resistance (volt = ampere times ohm).



■ **oil**
liquid triester of glycerol and unsaturated fatty acids.

■ **open circuit voltage**
the cell voltage under zero current conditions. Abbreviated as "ocv."

■ **open sextet**
refers to species that have only six electrons in the highest energy level of the central element (many Lewis acids).

■ **open system**
a system which can exchange both matter and energy with its surroundings.

■ **optical activity**
optically active. A substance that is capable of rotating plane-polarised light. Molecules of an optically active substance cannot be superimposed on their own mirror images, just as your left hand cannot be superimposed on your right when both are held palm-down.

■ **optical isomers**
stereoisomers that differ only by being nonsuperimposable mirror images of each other, like right and left hands, also called enantiomers.

■ **optically active**
optical activity refers to the ability of a molecule to rotate plane polarised light. All 3D chiral molecules have this ability. The signs (+) and (-) refer to the direction (right and left respectively) that the plane of polarised light is rotated. There is NO relationship between the direction of rotation and the absolute stereochemistry (*R* and *S*) of a molecule.
Generally the wavelength used is 589 nm which is the D-line of sodium and as such the measure is often refered to as an $[\alpha]_D$ (alpha-D).
It is vital to quote both the solvent used and concentration when reporting an optical rotation. The rotation of a molecule may change sign and magnitude in different solvents and at different concentrations. For example, (*S*)-2-Ethyl-2-methyl

succinic acid has a rotation that may be 0, +ve or -ve, depending on the concentration at which it is run.

■ **orbital**
a wavefunction that describes what an electron with a given energy is doing inside an atom or molecule.

■ **order**
order of reaction; reaction order. The order of a reaction is the sum of concentration exponents in the rate law for the reaction. For example, a reaction with rate law d[C]/dt = k[A]2[B] would be a third order reaction. Noninteger orders are possible.

■ **ore**
a natural deposit containing a mineral of an element to be extracted.

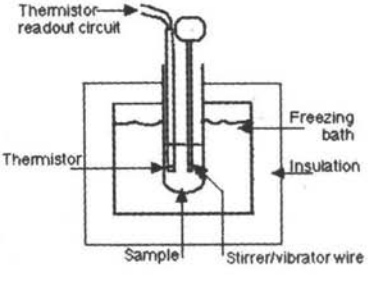
■ **organic**
organic compound. Compare with inorganic compound Compounds that contain carbon chemically bound to hydrogen. They often contain other elements (particularly O, N, halogens, or S). Organic compounds were once thought to be produced only by living things. We now know that any organic compound can be synthesised in the laboratory (although this can be extremely difficult in practice!).

■ **organic chemistry**
the study of compounds that contain carbon chemically bound to hydrogen, including synthesis, identification, modelling, and reactions of those compounds.

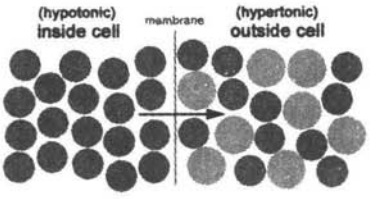
■ **orp electrode**
stands for oxidation/reduction potential electrode.

■ **ORR**
stands for oxygen reduction reaction.

■ **osmometry**
compare with osmosis Determination of the average molecular weight of a dissolved substance from measurements of osmotic pressure.



■ **osmosis**
compare with reverse osmosis Passage of solvent molecules from a dilute solution through a semipermeable membrane to a more concentrated solution.



■ **osmotic pressure**
the pressure that develops in a solution separated from a solvent by a membrane permeable only to the solvent.

■ **Ostwald process**
a process for the industrial production of nitrogen oxide and nitric acid from ammonia and oxygen.

■ **outer orbital complex**
valence bond designation for a complex in which the metal ion utilises d orbitals in the outermost (occupied) shell in hybridisation.

■ **outersphere charge transfer reaction**
a charge-transfer reaction with the reactants separated from each other by some solvent molecules due to the solvation of the reactants. Note that a "reactant" can also be an electrode. Contrast with innersphere charge-transfer reaction.

■ **overcharging**
during the charging of a rechargeable battery, eventually enough electrical charge is supplied to convert all the active material stored in the electrodes. If charging continues, the battery is said to be "overcharged." It very much depends on the battery system whether overcharging is detrimental to the battery or not.

■ **overlap**
the interaction of orbitals on different atoms in the same region of space.

■ **overpotential**
the difference in the electrode potential of an electrode between its equilibrium potential and its operating potential when a current is flowing. The overpotential represents the extra energy needed (an energy loss that appears as heat) to force the electrode reaction to proceed at a required rate (or its equivalent current density).

Consequently, the operating potential of an anode is always more positive than its equilibrium potential, while the operating potential of a cathode is always more negative than its equilibrium potential. The overpotential increases with increasing current density. The value of the overpotential also depends on the "inherent speed" of the electrode reaction: a slow reaction (with small exchange current density) will require a larger overpotential for a given current density than a fast reaction (with large exchange current density). Also referred to as "polarisation" of the electrode. An electrode reaction always occurs in more than one elementary step, and there is an overpotential associated with each step. Even for the simplest case, the overpotential is the sum of the concentration overpotential and the activation overpotential.

■ **overvoltage**
the difference between the cell voltage (with a current flowing) and the open-circuit voltage (ocv). The overvoltage represents the extra energy needed (an energy loss that appears as heat) to force the cell reaction to proceed at a required rate. Consequently, the cell voltage of a galvanic cell (e.g., a rechargeable battery during discharging) is always less than its ocv, while the cell voltage of an electrolytic cell (e.g., a rechargeable battery during charging) is always more than its ocv. Occasionally also referred to as "polarisation" of the cell. The overvoltage is the sum of the overpotentials of the two electrodes of the cell and the ohmic loss of the cell. Unfortunately, the terms "overvoltage" and "overpotential" are sometimes used interchangeably.

■ **oxidant**
alternative expression for oxidising agent.

■ **oxidation**
oxidise; oxidising; oxidised. Compare with reduction Oxidation is the loss of one or more electrons by an atom, molecule, or ion. Oxidation is accompanied by an increase in oxidation number on the atoms, molecules, or ions that lose electrons.

■ **oxidation number**
oxidation state; positive valence. A convention for representing a charge of an atom embedded within a compound, if the compound were purely ionic. For example, H_2O is a covalent compound; if it were ionic, the hydrogens would be H^+ (oxidation number +1) and the oxygen would be O^{2-} (oxidation number -2). Oxidation number rises for at least one atom in a compound that is oxidised; oxidation number becomes smaller if the compound is reduced.

■ **oxidation/reduction potential**
a measure of the oxidation/reduction capability of a solution. It is a redox potential measured with an inert electrode. An oxidising solution (e.g., one saturated with oxygen) has a more positive potential than a reducing solution (e.g., one saturated with hydrogen).

■ **oxidation/reduction potential electrode**
a measuring electrode used for the determination of the oxidation/reduction potential of a solution. Abbreviated as "ORP."

■ **oxidation-reduction reactions**
reactions in which oxidation and reduction occur; also called redox reactions.

■ **oxide**
a binary compound of oxygen.

■ **oxidising agent**
oxidant; oxidiser. Compare with reducing agent. A reactant that removing electrons from other reactants in a chemical reaction. Oxidising agents cause other substances to be oxidised in chemical reactions while they themselves are reduced. For example, nitrate ion is an oxidising agent in the following reaction:
$Cu(s) + 4\ H^+(aq) + 2\ NO^{3-}(aq) \rightarrow Cu^{2+}(aq) + 2\ H_2O + 2\ NO_2(g)$ Copper gets oxidised (its oxidation number goes from 0 to +2) while the nitrogen gets reduced (from +5 in nitrate to +4 in nitrogen dioxide).

■ **oxidising agent**
a substance that is affecting oxidation by accepting electrons

from another substance. Also called "oxidant."

■ **oxygen evolution reaction**
an electrode reaction in which oxygen gas is produced at the anode of an electrolytic cell by the oxidation of hydroxyl (OH^-) ions or the oxidation of the water molecules of an aqueous solution. Abbreviated as "oer." It is the reverse reaction of oxygen reduction.

■ **oxygen reduction reaction**
an electrode reaction in which oxygen gas is reduced at the cathode of an electrochemical cell. The product of the reduction can be hydroxyl (OH^-) ions or water molecules (or occasionally hydrogen peroxide molecules). Abbreviated as "orr." It is the reverse reaction of oxygen evolution. It is a very important and much studied electrode reaction because it occurs at the cathode of practically all fuel cells and it occurs at the cathode of many (though not all) corrosion cells.

■ **packedbed electrode**
an electrode assembly consisting of loosely packed small particles of the electrode material (e.g., some metal or carbon) with the electrolyte flowing through the bed. This type of electrode is especially useful for removing small traces of impurities from the solution by electrolysis (e.g., waste treatment) because the solution is well stirred and it contacts a large surface of the electrode material.

■ **pairing**
a favourable interaction of two electrons with opposite m, values in the same orbital.

■ **pairing energy**
energy required to pair two electrons in the same orbital.

■ **paraffin**
paraffin wax.
1 a waxy substance that is a mixture of alkanes with chains containing 18 to 36 carbon atoms.
2 an alkane.

■ **parallelcoupled cells**
individual electrochemical cells can be combined in assemblies by parallel or series coupling (or a combination of the two). In case of "parallel" coupling, the positive electrode of every cell is connected together and

the negative electrode of every cell is connected together, resulting in two external terminals. The voltage of every cell must be identical in parallel coupled assemblies. The overall current passing through the assembly is the sum of the individual cell currents, while the assembly voltage is identical to the individual cell voltage. Parallel coupling is often used in batteries. Cell lines and stacks can also be parallel coupled. Contrast with series coupling.

■ **paramagnetism**
paramagnetic. Compare with diamagnetism and ferromagnetism. Paramagnetic materials are attracted to a magnetic field due to the presence of least one unpaired spin in their atoms or molecules.

■ **partial current (density)**
the two current densities at which the electrode reaction is proceeding in the anodic and cathodic directions at an electrode potential. The actual (net) current density is the algebraic sum of the two partial current densities (one is considered positive the other negative). Electrode reactions are typically "chemically" reversible, that is, they can proceed both in forward and reverse direction. At equilibrium, the reaction is proceeding at equal rate in both directions , the "anodic partial current density" and the "cathodic partial current density" are equal and the net current density is zero. When the electrode is polarised, the partial current densities are unequal and the net current density is not zero. If the electrode is negatively polarised, the cathodic reaction speeds up (compared with its rate at equilibrium), while the anodic reaction slows down and a net cathodic current density results (and vice versa for anodic polarisation).

■ **partial miscibility**
partially miscible. Compare with miscible and immiscible Two liquids are considered partially miscible if shaking equal volumes of the liquids together results in a meniscus visible between two layers of liquid, but the volumes of the layers are not identical to the volumes of the liquids originally added.

■ **partial pressures**
the independent pressure exerted by different gases in a mixture.

■ **particulate**
composed of distinct particles. Smoke is particulate; pure gases are not.

■ **particulate matter**
fine divided solid particles suspended in polluted air.

■ **parts per million**
(ppm) concentration expressed as parts of solute per million parts of solution. Usually refers to parts per million by mass. For example, a 10 ppm NaCl solution can be written as: 10 mg NaCl/kg solution, 10 μg NaCl/g solution, 10 ng NaCl/mg solution. In very dilute aqueous solutions, ppm is approximately equal to mg solute per litre of solution.

■ **pascal**
(Pa) the SI unit of pressure, equal to a force of one newton per square meter. 101325 pascals = 1 atmosphere ; 10^5 pascals = 1 bar.

■ **passivation**
the formation of a thin adherent film or layer on the surface of a metal or mineral that acts as a protective coating to protect the underlying surface from further chemical reaction, such as corrosion, electrodissolution, or dissolution. The passive film is very often, though not always, an oxide. A passivated surface is often said to be in a "passive state." The surface oxidation can result from chemical or electrochemical (anodic) oxidation. During anodic passivation, using linear-sweep voltammetry, the current first increases with potential, then falls to a very small value.

■ **passivation potential**
the most negative electrode potential at which a passivating film is formed electrochemically. It is equal to or more positive than the equilibrium potential of formation of the compound (usually oxide) constituting the passive film. Usually the current goes through a maximum at the passivation potential during linear-sweep voltammetry. Also called the "Flade" potential.

■ **path function**
a property that is dependent on the path taken.

■ **Pauli exclusion principle**
no two electrons in the same atom may have identical sets of four quantum numbers.

■ **Pauli principle**
exclusion principle; Pauli exclusion; Pauli exclusion principle. No two electrons in an atom can have the same set of 4 quantum numbers. Because the n, , and m quantum numbers address a particular orbital, and because the ms quantum number has only two possible values, the Pauli principle says that a maximum of two electrons can occupy an atomic orbital- and these electrons must have opposite spins.

■ **peak power**
the maximum output that a battery or other power supply can produce without damage. Peak power capability is typically well beyond the continuous reliable power capability and should only be used infrequently.

■ **PEM**
stands for either polymer-electrolyte membrane or proton-exchange membrane.

■ **penetration**
compare with shielding. Electrons in penetrating orbitals can reach the nucleus. The n and quantum numbers determine how well an orbital penetrates. Lower n and lower values mean better penetration. A low n value means the orbital is small. A low value means the orbital has fewer nuclear nodes (planes that pass through the nucleus where the probability of locating the electron is zero). In order of decreasing penetration, the subshells are s > p > d > f. A 1s orbital penetrates better than a 2s orbital.

■ **percent by mass**
100% times the actual yield divided by theoretical yield.

■ **percent composition**
the mass percent of each element in a compound.

■ **percent purity**
the percent of a specified compound or element in an impure sample.

■ **percent yield**
percentage yield. Compare with theoretical yield and actual yield . Percent yield equals

experimental yield divided by theoretical yield times 100%.

■ **percentage ionisation**
the percentage of the weak electrolyte that ionises in a solution of given concentration.

■ **perfect crystal**
a crystal with no defects or impurities, made of completely identical repeating subunits. Further, a perfect crystal has only one possible arrangement of subunits, with every subunit making exactly the same contribution to the total energy of the crystal.

■ **period**
rows in the periodic table are called periods. For example, all of the elements in the second row are referred to as 'second period elements'. All elements currently known fall in the first seven periods.

■ **periodic law**
the periodic law states that physical and chemical properties of the elements recur in a regular way when the elements are arranged in order of increasing atomic number.

■ **periodic table**
an arrangement of the elements according to increasing atomic number that shows relationships between element properties.

■ **periodic trend**
a regular variation in element properties with increasing atomic number that is ultimately due to regular variations in atomic structure.

■ **periodicity**
regular periodic variations of properties of elements with atomic number (and position in the periodic table).

■ **permanent hardness**
permanent water hardness. Compare with temporary hardness and water hardnessn Water hardness that remains after boiling the water, mainly due to dissolved calcium sulphate. Chlorides also contribute to permanent hardness.

■ **permselectivity**
the permeation of certain ions in preference to other ions through an ion-exchange membrane.

■ **peroxide**
a compound containing oxygen in the -1 oxidation state. Metal peroxides contain the peroxide ion, O_2^{2-}

■ **pH**
a measure of the acidity/alkalinity (basicity) of a solution. The pH scale extends from 0 to 14 (in aqueous solutions at room temperature). A pH value of 7 indicates a neutral (neither acidic nor basic) solution. A pH value of less than 7 indicates an acidic solution, the acidity increases with decreasing pH value. A pH value of more than 7 indicates a basic solution, the basicity or alkalinity increases with increasing pH value. The pH of a solution is equal to the negative, ten-based logarithm of the activity of the hydrogen ions in the solution. Neutral water dissociates into equal amounts of hydrogen (H^+) cations and hydroxyl (OH^-) anions. As the product of the concentrations (activities) of the two ions is always a constant 10^{-14}, water has a pH of 7. In acidic solutions the hydrogen ions are in excess, while in basic solutions the hydroxyl ions are in excess.

■ **pH electrode**
an electrode assembly with a pH dependent potential. A variety of different electrodes can be used for this purpose, the most common one is the glass electrode.

■ **pH meter**
volt meter that measures the electrical potential difference between a pH electrode and a reference electrode and displays the result in terms of pH value of the sample solution in which they are immersed.

■ **pharmacognosy**
identification, isolation, and characterisation of biologically active substances in living things.

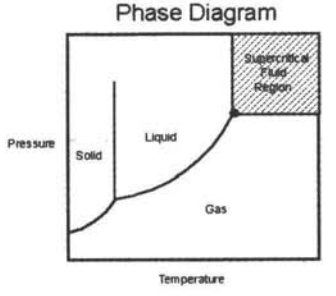
■ **pharmacology**
the study of drugs, which includes determination of biological activity, biological effects, breakdown and synthesis, and delivery.

■ **phase**
in phase; out of phase; wave phase.

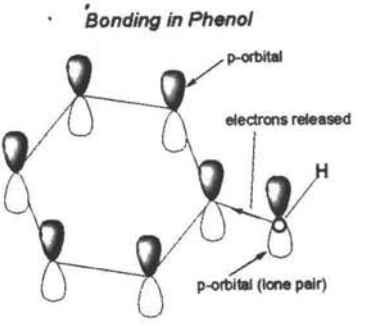
1. a phase is a part of a sample of matter that is in contact with other parts but is separate from them. Properties within a phase are homogeneous (uniform). For example, oil and vinegar salad dressing contains two phases: an oil-rich liquid, and a vinegar-rich liquid. Shaking the bottle breaks the phases up into tiny droplets, but there are still two distinct phases.
2. in wave motion, phase is the fraction of a complete cycle that has passed a fixed point since the current cycle began. The phase is often expressed as an angle, since a full cycle is 360°; two waves are "in phase" if the peaks of one wave align with the peaks of the other; they are "out of phase" if the peaks of one wave align with the troughs of the other.

■ **phase boundary**
a phase boundary is a surface where two samples of matter with different properties are in contact. The surface of a gas bubble in water or the surface of a crystal are examples of phase boundaries.

■ **phase diagram**
phase map. A map that shows which phases of a sample are most stable for a given set of conditions. Phases are depicted as regions on the map; the borderlines between regions correspond to conditions where the phases can coexist in equilibrium.



■ **phenol**
a group or molecule containing a benzene ring that has a hydroxyl group substituted for a ring hydrogen.



■ **phenolphthalein**
an organic compound used as an acid-base indicator. The compound is colourless in acidic solution and pink in basic solution (with the transition occuring around pH 8.3). Phenolpthalein was used for many years as a laxative in very low concentrations- high concentrations are toxic!

■ **phenyl**
a molecular group or fragment formed by abstracting or substituting one of the hydrogen atoms attached to a benzene ring.

■ **photochemical oxidants**
photochemically produced oxidising agents capable of causing damage to plants and animals.

■ **photochemical smog**
a brownish smog occurring in urban areas receiving large amounts of sunlight; caused by photochemical (light-induced) reactions among nitrogen oxides, hydrocarbons and other components of polluted air that produce photochemical oxidants.

■ **photoelectric effect**
ejection of electrons from an atom or molecule that has absorbed a photon of sufficient energy. The photoelectric effect is the operating principle behind "electric eyes"; it is experimental evidence for particle-like behaviour of electromagnetic radiation.

■ **photoelectrochemical cell**
a galvanic cell in which usable current and voltage are simultaneously produced upon absorption of light by at least one of the electrodes. Also called "photogalvanic cell."

■ **photoelectrochemistry**
chemistry resulting from the interaction of light with electrochemical systems.

■ **photoelectrolytic cell**
an electrolytic cell in which the production of chemicals is caused by or speeded up by the absorption of light by at least one of the electrodes. The process occurring in such cell is called "photoelectrosynthesis."

■ **photoelectron**
an electron ejected from an atom or molecule that has absorbed a photon.

■ **photoelectrosynthesis**
production of chemicals in a photoelectrolytic cell, where the production is caused by or speeded up by the absorption of light by at least one of the electrodes.

■ **photon**
(h) quantum; quanta. A discrete packet of energy associated with electromagnetic radiation. Each photon carries energy E proportional to the frequency of the radiation: $E = h\bar{\nu}$, where h is Planck's constant.

■ **physical change**
compare with chemical change . A change which does not transform one substance into another. For example, freezing water is a physical change because both water and ice are H_2O. However, electrolysis of water would not be a physical change because passing a strong electric current through water can decompose it into H_2 and O_2.

■ **physical chemistry**
chemical physics. A branch of chemistry that studies chemical phenomena from a physical and mathematical perspective. Physical chemistry includes chemical thermodynamics, kinetics, spectroscopy, quantum chemistry, and statistical mechanics.

■ **physical property**
physical properties. Compare with chemical property . Measurement of a physical property may change the arrangement but not the structure of the molecules of a material. Examples of physical properties are density, colour, boiling point, volume, temperature, and mass.

■ **pi bond**
(bond) compare with sigma bond. In the valence bond theory, a pi bond is a valence bond formed by side-by-side overlap of p orbitals on two bonded atoms. In most multiple bonds, the first bond is a sigma bond and all of the others are pi bonds.

■ **pickling**
process for removal of oxide scales from metal surfaces in preparation for electroplating. Typically, the metal is immersed in hot, strongly acidic solution that dissolves the oxide scales.

The solution usually also contains some corrosion inhibitor to avoid dissolution of the metal itself.

■ **pico**
(p) Prefix used in the SI system meaning "multiply by 10^{-12}". For example, 3 pm means 3×10^{-12} meters.

■ **pile**
an archaic name for a battery or other series-coupled electrochemical cells.

■ **Pitzer Strain**
another name used to describe torsional Strain.

■ **Planck's constant**
(h) a proportionality constant that relates the energy carried by a photon to its frequency. Planck's constant has a value of 6.6262×10^{-34} J s.

■ **plane polarised light**
light which is passed through a filter which blocks out all the light except that which ocillates in one plane.

■ **plasma**
1. in biology, the fluid in which blood cells or lymph cells are suspended.
2. a gas like state of matter consisting of positively charged ions, free electrons, and neutral particles. Plasma is found in stars, the sun, the solar wind, lightning, and fire.

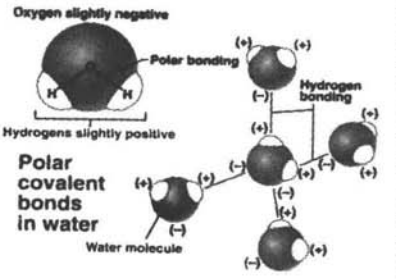
■ **plate**
electrode structures in rechargeable batteries are sometimes called "plates."

■ **platinised platinum electrode**
a platinum metal electrode that is covered with a rough, large surface area platinum coating. The purpose is to produce an electrode with a large true area that will be relatively non polarisable.

■ **platinum black**
a rough, large surface area platinum coating usually deposited on a platinum metal electrode.

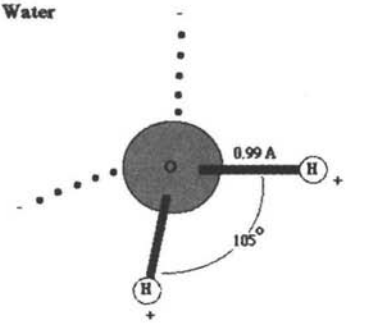
■ **poise**
(P) a cgs unit of resistance to fluid flow (viscosity). If a force of 1 dyne is needed to force two fluid layers with 1 cm_2 area that are 1 cm apart past each other at a speed of 1 cm/s, the liquid has a viscosity of 1 poise.

■ **polar bond**
compare with covalent bond and ionic bond. A bond involving electrons that are unequally shared. Polar bonds can be thought of as intermediate between the extremes represented



by covalent bonds and ionic bonds.

■ **polar molecule**
polar. Compare with covalent compound, ionic compound and polar bond. An asymmetric molecule containing polar bonds. H_2O, NH_3, and HCl are examples of polar molecules. Non-examples are CO2, CCl_4, and BCl_3 which contain polar bonds but are nonpolar because they have symmetric shapes. Alkanes are usually asymmetric but are nonpolar because they contain no polar bonds. Polar molecules are electric dipoles and they attract each other via dipole-dipole forces.



■ **polarimeter**
a device used to measure optical activity.

■ **polarisability**
of orbitals means that the electron cloud can be shifted towards a positive charge or away from a negative charge due to electrostatic attraction and repulsion.

■ **polarisable electrode**
an electrode that is easily polarisable. That is, the potential of the electrode will change significantly from its equilibrium potential with the application of even a small current density. The reason for this behaviour is that the electrode reaction is inherently slow (has a small exchange current den-

sity). Opposite: non-polarisable electrode.

■ **polarisation**
the change of potential of an electrode from its equilibrium potential upon the application of a current. Somewhat confusingly, the term "polarisation" is often also used in place of overvoltage.

■ **polarisation curve**
alternative name for current-potential plot.

■ **polarising power**
means that a charged species such as a proton can attract negatively charged electrons which causes a shift in the orbital. The higher the positive charge and the smaller the smaller the size, the greater the polarising power of the species.

■ **polarity**
indicates the sign of the potential of an electrode, that is, it can be negative or positive.

■ **polarogram**
the graphical representation of the result of polarography.

■ **polarograph**
an instrument used in carrying out polarographic analysis.

■ **polarography**
a classical electroanalytical technique discovered in 1922 by J. Heyrovsky, for which he was awarded the Nobel Prize for Chemistry in 1959. Essentially, it is linear-sweep voltammetry using a dropping-mercury electrode for working electrode and a large mercury pool as counter electrode.

■ **pole**
alternative name of a terminal.

■ **polyatomic ion**
compare with molecule , ion and polyatomic molecule . A polyatomic ion is a charged particle that contains more than two covalently bound atoms.

■ **polyatomic molecule**
compare with polyatomic ion and diatomic molecule . A polyatomic molecule is an uncharged particle that contains more than two atoms.

■ **polydentate**
polydentate ligand. A ligand that has more than one atom that coordinates directly to the central atom in a complex. Polydentate ligands are called chelating agents when two or more coordinating atoms are

attached to the same metal ion in a complex. For example, EDTA or ethylenediaminotetracetic acid is a hexadentate ligand of calciumion.

■ **polyene**
a compound that contains more than one double bond per molecule.

■ **polymer**
a large molecule consisting of chains or rings of linked monomer units, usually characterised by high melting and boiling points.

■ **polymer electrolyte membrane**
an ion-exchange membrane that is used both as a "separator" and as the electrolyte in some fuel cells. Abbreviated as "PEM."

■ **polymerisation**
a process that links smaller molecules together to form a larger molecule.

■ **polymerise**
to link smaller molecules together to form a larger molecule.

■ **polymorph**
polymorphism; polymorphic. Compare with isotope and allotrope . Solid substances that occur in several distinct forms. Polymorphs have different chemical and physical properties. allotropes are polymorphs of elements.

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■ **polymorphous**
refers to substances that crystallise in more than one crystalline arrangement.

■ **polyprotic acid**
an Acid that can form two or more hydronium ions per molecule; often a least one step of ionisation is weak.

■ **polysaccharide**
long chains of monosaccharides.

■ **porous disk**
a disk in a tube connecting two different solutions in a

voltaic cell that allows ion flow without extensive mixing of the solutions; similar to a salt bridge.

■ **porous electrode**
an electrode consisting of a highly porous solid. This is often used in fuel cells with gaseous reactants. In this case, the charge-transfer reaction proceeds mainly at the triple interface formed by the electrode material, the electrolyte, and the gaseous reactant. The pores of the structure are partly filled by the electrolyte and partly by the gas. A porous electrode provides a much larger area for reaction than a solid electrode with the gas bubbled around it. A porous electrode can also be used as a flow-through electrode.

■ **positional probability**
a type of probability that depends on the number of arrangements in space that yield a particular state.

■ **positron**
a Nuclear particle with the mass of an electron but opposite charge.

■ **pot**
an alternative name of an industrial electrolytic cell used in aluminium production.

■ **potential difference**
electrical potential difference. Work that must be done to move an electric charge between specified points. Electric potential differences are measured in volts.

■ **potential energy**
compare with kinetic energy . energy an object possesses by virtue of its position. For example, lifting a mass mby h meters increases its potential energy by mgh, where g is the acceleration due to gravity.

■ **potential of zero charge**
the electrode potential where the charge in the electrical double layer is zero. Abbreviated as "pzc."

■ **potential pH diagram**
a diagram often used in the field of corrosion to indicate the corrosion tendency and stability of a metal in aqueous solutions. The equilibrium potential of the metal is plotted against the pH of the solution, usually for a series of concentrations of the

metal ion. The curves demarcate potential-pH domains where a species of the metal is predominant in equilibrium, this can be the metal, its ion, oxide, or hydroxide. In simplified version, the diagram can indicate the potential-pH domains where the metal is immune to corrosion, corrodes, or passivates. The diagrams must be used with some caution because they represent equilibrium conditions and the corrosion tendency is also influenced by kinetic effects. Also called "Pourbaix diagram."

■ **potential ramp technique**
alternative name for voltammetry.

■ **potential step voltammetry**
alternative name for chronoamperometry.

■ **potential sweep technique**
alternative name for voltammetry.

■ **potentiodynamic technique**
alternative name for linear-sweep voltammetry. This expression is primarily used in the field of corrosion

■ **potentiokinetic technique**
alternative name for linear-sweep voltammetry. This expression is primarily used in the field of corrosion.

■ **potentiometer**
can be used in more than one meaning:
1. a continuously variable resistor. More precisely, a resistor with continuously variable tap. This can provide three resistance values, a fixed resistance between the two end connectors, and two variable resistances, one between either end connector and the variable tap connector. The sum of the two variable resistances is the fixed resistance.
2. a somewhat archaic measurement system, based on a resistor with a continuously variable tap, that can be used to measure the electromotive force of electrochemical cells that can be easily polarised by current. It uses a comparison technique to compare a "standard" voltage source to the unknown, under conditions of practically zero current. It is seldom used today because high input resistance voltmeters and electrometers are readily available.

■ **potentiometry**
an electroanalytical technique based on the measurement of the electromotive force of an electrochemical cell comprised of a measuring and a reference electrode. The simplest example of a measuring electrode is a metal electrode whose potential depends on the concentration of the cation of the electrode metal.

■ **potentiostat**
an electronic instrument that controls the electrical potential between the working and reference electrodes of a three-electrode cell at a preset value. It forces whatever current is necessary to flow between the working and counter electrodes to keep the desired potential, as long as the needed cell voltage and current do not exceed the compliance limits of the potentiostat.

■ **potentiostatic technique**
an electrochemical measuring technique for electrochemical analysis or for the determination of the kinetics and mechanism of electrode reactions based on the control of the electrode potential.

■ **power**
the rate at which energy is supplied. Power has define[SI] units of J/s, sometimes called "Watts" (W).

■ **power density**
characteristic parameter of a battery indicating its electrical power per unit weight or volume. The terminology is not strictly defined. Weight based power density is often called "specific power" or "gravimetric power density." Volume based power density is often called "power density" or "volumetric power density. The power density is typically expressed as watt/kilogram or watt/litre.

■ **precipitate**
ppt. An insoluble substance that has been formed from substances dissolved in a solution. For example, mixing silver nitrate and sodium chloride solutions produces a precipitate, insoluble silver chloride (along with soluble sodium nitrate.

■ **precipitation**
precipitation is the conversion of a dissolved substance into

insoluble form by chemical or physical means.

■ **precision**
reproducibility. Compare with accuracy . Precision is reproducibility. Saying "These measurements are precise" is the same as saying, "The same measurement was repeated several times, and the measurements were all very close to one another".

■ **pressure**
(P) force per unit area. The SI unit of pressure is the pascal, defined as one newton per square meter. Other common pressure units are the atmosphere , the bar , and the Torr.

■ **pressure rise coefficient**
a measure of a diffuser's ability to increase the pressure of the fluid, is defined as the ratio of the actual pressure rise in the diffuser to the pressure rise that would be realised if the process were isentropic.

■ **pressure transducers**
are made of semiconductor materials such as silicon and convert the pressure effect to an electrical effect such as a change in voltage, resistance, or capacitance. Pressure transducers are smaller and faster, and they are more sensitive, reliable, and precise than their mechanical counterparts.

■ **primary or fundamental dimensions**
such as mass m, length L, time t, and temperature *T*, are the basis for the derivation of secondary dimensions.

■ **primary standard**
a substance of a known high degree of purity that undergoes one invariable reaction with the other reactant of interest.

■ **primary voltaic cells**
voltaic cells that cannot be recharged; no further chemical reaction is possible once the reactants are consumed.

■ **principal quantum number**
(n) the quantum number that determines the size and (in hydrogen atoms) the energy of an orbital. n is used to label electron shells. n may take on integer values from 1 to infinity.

■ **principle of corresponding states**
is the fact that compressibility factor Z for all gases is approximately the same at the same

reduced pressure and temperature.

■ **process**
is any change that a system undergoes from one equilibrium state to another. To describe a process completely, one should specify the initial and final states of the process, as well as the path it follows, and the interactions with the surroundings.

■ **process heat**
is required energy input in the form of heat for many industrial processes. The process heat is often obtained as heat transfer from high-pressure, high-temperature steam. Some industries that rely heavily on process heat are chemical, pulp and paper, oil production and refining, steel making, food processing, and textile industries.

■ **prochiral**
a 3D molecule is termed prochiral if replacement of one of the substituents at a particular centre would render that centre chiral.
The X groups in such a molecule are termed 'Enantiotopic', as replacement of the alternative X group would lead to enantiomers being produced.
Prochirality also exists in 2D space. Here we are considering enantiotopic faces. The two faces of ethanal (acetaldehyde) are prochiral and reaction at one face results in a compound enantiomeric with the one produced by reaction at the other face. If a molecule is 2D chiral it will exhibit prochirality.

■ **products**
are the components that exist after the reaction in a combustion process.

■ **propane**
(C_3H_8) compare with alkane and hydrocarbon. A colourless, odourless, flammable gas, found in petroleum and natural gas. It is used as a fuel and as a raw material for building more complex organic molecules. Propane is the third member of the alkane series.

■ **propellant**
1 a mixture of fuel and oxidising agent that reacts to produce a high-energy stream of product gases that can produce thrust.
2. a compressed gas used to push a material through a

nozzle, forming an aerosol or a foam. For example, nitrogen or propane are used as propellants for shaving cream; nitrous oxide is used as a propellant for whipped cream.

■ **property**
is any characteristic of a system. Some familiar properties are pressure P, temperature T, volume V, and mass m. The list can be extended to include less familiar ones such as viscosity, thermal conductivity, modulus of elasticity, thermal expansion coefficient, electric resistivity, and even velocity and elevation.

■ **propulsive efficiency**
of an aircraft turbojet engine is the ratio of the power produced to propel the aircraft and the thermal energy of the fuel released during the combustion process.

■ **propulsive power**
is the power developed from the thrust of the aircraft gas turbines and is the propulsive force (thrust) times the distance this force acts on the aircraft per unit time, that is, the thrust times the aircraft velocity.

■ **proton**
(p^+) compare with electron and neutron . An elementary particle found the atomic nucleus with a positive charge equal and opposite that of the electron . Protons have a mass of 1.007276 daltons.

■ **proton donor**
acid. compare with base Because a free H^+ ion is technically a bare proton, acids are sometimes referred to as "proton donors" because they release hydrogen ions in solution. The term "proton donor" is misleading, since in aqueous solution, the hydrogen ion is never a bare proton- it's covalently bound to a water molecule as an H_3O^+ ion. Further, acids don't "donate" protons; they yield them to bases with a stronger affinity for them.

■ **pseudobinaryionic compounds**
compounds that contain more than two elements but are named like binary compounds.

■ **pseudocore**
electrons in d or f subshells which are outside the noble gas core.

■ **pseudo-reduced specific volume**
VR is used with the generalised compressibility chart to determine the third property when P and V, or T and V, are given instead of P and T.

■ **psychrometric chart**
presents the properties of atmospheric air at a specified pressure and two independent intensive properties. The psychrometric chart is a plot of absolute humidity versus dry-bulb temperature and shows lines of constant relative humidity, wet-bulb temperature, specific volume, and enthalpy for the atmospheric air.

■ **pump**
is a device that increases the pressure of liquids very much as compressors increase the pressure of gases.

■ **pure substance**
substance. a sample of matter that cannot be separated into simpler components without chemical change. Physical changes can alter the state of matter but not the chemical identity of a pure substance. Pure substances have fixed, characteristic elemental compositions and properties.

■ **pure substance**
is a substance that has a fixed chemical composition throughout.

■ **P-V-T surface**
is a three-dimensional surface in space which represents the P-V-T behaviour of a substance. All states along the path of a quasi-equilibrium process lie on the P-V-T surface since such a process must pass through equilibrium states. The single-phase regions appear as curved surfaces on the P-V-T surface, and the two-phase regions as surfaces perpendicular to the P-T plane.

■ **pyranose ring**
a six-membered cyclic hemiacetal or ketal.

■ **pyrophoric**
pyrophoric solid. Catches fire spontaneously when exposed to air at normal room temperature. For example, powdered potassium metal is pyrophoric.

■ **qualitative analysis**
compare with quantitative analysis . A chemical analysis

that detects the presence of a substance in a sample.

■ **quantum**
quanta. a discrete packet of energy.

■ **quantum mechanics**
quantum theory. a branch of physics that describes the behaviour of objects of atomic and subatomic size.

■ **quantum number**
indices that label quantised energy states. Quantum numbers are used to describe the state of a confined electron, e.g. an electron in an atom.

■ **quasi-static, or quasi-equilibrium, process**
is a process which proceeds in such a manner that the system remains infinitesimally close to an equilibrium state at all times. A quasi-equilibrium process can be viewed as a sufficiently slow process that allows the system to adjust itself internally so that properties in one part of the system do not change any faster than those at other parts.

■ **R*/S***
a system of nomeclature that replaces terms such as *erythro-* and *threo-*. Based around the Cahn, Ingold, Prelog system with the * indicating that the stereochemistry is only relative. Thus a compound designated as (2*R**, 3*R**, 4*S**) represents two enantiomeric compounds. That is, it represents both (2*R*, 3*R*, 4*S*) and (2*S*, 3*S*, 4*R*).

■ **R/S**
the letters used to assign absolute stereochemistry based on the 'Cahn, Ingold, Prelog' 'Sequence Rules'. After assigning priorities to the substitutuents around an asymmetric centre the molecule is viewed such that the bond from the asymmetric centre to the substituent of lowest priority (4) is going away from the viewer, or into the page.
If the remaining three groups from highest to lowest priority (1-2-3) appear clockwise then the asymmetric centre is designated as *R*.
If the remaining three groups from highest to lowest priority (1-2-3) appear anticlockwise then the asymmetric centre is designated as *S*.

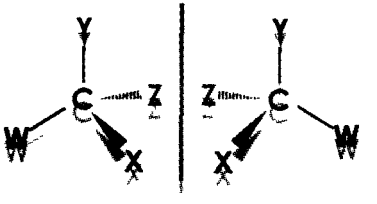
■ **Racemic**
when a mixture contains equal amounts of both enantiomers

(50:50) it is racemic. If the mixture contains any other ratio of enantiomers then it is termed 'Scalemic'.

When a compound exhibits 2D chirality it has two distinct, 'Prochiral', faces. These are designated *Re* or *Si* and are assigned by the familiar Cahn, Ingold, Prelog 'Sequence Rules'.

Re is equivalent to *R*, i.e. a clockwise rotation from highest to lowest priority.

Si is equivalent to *S*, i.e. an anticlockwise rotation from highest to lowest priority.



■ **racemic mixture**
a 50:50 mixture of two enantiomers (such a mixture does not rotate plane-polarised light).

■ **radiation**
is the transfer of energy due to the emission of electromagnetic waves (or photons).

■ **radical**
an atom or group of atoms that contains one or more unpaired electrons (usually very reactive species).

■ **radioactive dating**
method of dating ancient objects by determining the ratio of amounts of mother and daughter nuclides present in an object and relating the ratio to the object?s age via half-life calculations.

■ **radioactive tracer**
a small amount of radioisotope replacing a nonradioactive isotope of the element in a compound whose path (for example, in the body) or whose decomposition products are to be monitored by detection of radioctivity; also called a radioactive label.

■ **radioactivity**
radiation; radioactive. Spontaneous emission of particles or high-energy electromagnetic radiation from the nuclei of unstable atoms. "Radiation" refers to the emissions, and "radioactive source" refers to the source of the radiation.

■ **ramjet engine**
is a properly shaped duct with no compressor or turbine, and is sometimes used for high-speed propulsion of missiles and aircraft. The pressure rise in the engine is provided by the ram effect of the incoming high-speed air being rammed against a barrier. Therefore, a ramjet engine needs to be brought to a sufficiently high speed by an external source before it can be fired.

■ **random error**
indeterminate error. Compare with systematic error , gross error and mistake . Random errors are errors that affect the precision of a set of measurements. Random error scatters measurements above and below the mean, with small random errors being more likely than large ones.

■ **Rankine cycle**
is the ideal cycle for vapour power plants. The ideal Rankine cycle does not involve any internal irreversibilities and consists of the following four processes: 1-2 Isentropic compression in a pump.
2-3 Constant pressure heat addition in a boiler.
3-4 Isentropic expansion in a turbine.
4-1 Constant pressure heat rejection in a condenser.

■ **Rankine cycle with reheat**
is a modification of the Rankine cycle in which the steam is expanded in the turbine in two stages and reheated in between. Reheating is a practical solution to the excessive moisture problem in the lower-pressure stages of turbines, and it is used frequently in modern steam power plants.

■ **Rankine scale**
named after William Rankine (1820-1872) is the thermodynamic temperature scale in the English system. The temperature unit on this scale is the rankine, which is designated by R.

■ **Raoult's law**
applies to a gas-liquid mixture when a gas is highly soluble in a liquid (such as ammonia in water) and relates the mole fractions of the species of a two-phase mixture in the liquid and

gas phases in an approximate manner.

■ **rate constant**
(k) a rate constant is a proportionality constant that appears in a rate law. For example, k is the rate constant in the rate law d[A]/dt = k[A]. Rate constants are independent of concentration but depend on other factors, most notably temperature.

■ **rate law**
a rate law or rate equation relates reaction rate with the concentrations of reactants, catalysts, and inhibitors. For example, the rate law for the one-step reaction A + Bà C is d[C]/dt = k[A][B].

■ **rate of heat transfer**
is the amount of heat transferred per unit time.

■ **rate of reaction**
change in the concentration of a reactant or product per unit time.

■ **rate-determining step**
the slowest step in a mechanism; the step that determines the overall rate of reaction.

■ **rate-law expression**
equation relating the rate of a reaction to the concentrations of the reactants and the specific rate of the constant.

■ **Rayleigh line**
is the locus of all states for frictionless flow in a constant-area duct with heat transfer plotted on a T-s diagram.

■ **reactants**
are the components that exist before the reaction in a combustion process.

■ **reaction mechanism**
mechanism. a list of all elementary reactions that occur in the course of an overall chemical reaction.

■ **reaction quotient**
a constant represented by the symbol Q which is defined as the product of the concentrations of the products, each raised to the power that corresponds to its coefficient in the balanced equation, divided by the product of the concentrations of reactants, each raised to the power that corresponds to its coefficient in the balanced equation . At equilibrium con-

ditions Q=K, the equilibrium constant.

■ **reaction rate**
a reaction rate is the speed at which reactants are converted into products in a chemical reaction. The reaction rate is given as the instantaneous rate of change for any reactant or product, and is usually written as a derivative (e.g. d[A]/dt) with units of concentration per unit time (e.g. mol L^{-1} s^{-1}).

■ **reaction stoichiometry**
description of the quantitative relationships among substances as they participate in chemical reactions.

■ **rearrangement reaction**
a reaction in which a reactant and product are isomers of each other. Chemical bonds within the reactant are broken and reformed to produce the product.

■ **redox indicator**
oxidation-reduction indicator. An organic molecule that has reduced and oxidised forms with different colours; interconversion of the reduced and oxidised forms of the indicator must be reversible. Ferroin is an example.

■ **redox reaction**
electrochemical reaction; oxidation-reduction reaction; redox. A reaction that involves transfer of electrons from one substance to another. Redox reactions always involve a change in oxidation number for at least two elements in the reactants.

■ **redox titration**
oxidation-reduction titration. A titration based on a redox reaction. For example, iron in water can be determined by converting dissolved iron to Fe^{2+} and titrating the solution with potassium permanganate ($KMnO_4$), a powerful oxidising agent.

■ **reduced pressure**
pR is the ratio of the pressure to the critical pressure.

■ **reduced temperature**
T_R is the ratio of the temperature to the critical temperature.

■ **reducing agent**
reductant. Compare with oxidising agent. A reducing agent is a substance that reduce another substance by supplying electrons to it. Reducing agents cause other substances to be reduced in chemical reactions

while they themselves are oxidised. For example, tin(II) is a reducing agent in the following reaction: $Sn^{2+}(aq) + 2 Fe^{3+}(aq) \rightarrow Sn^{4+}(aq) + 2 Fe^{2+}(aq)$.

■ **reduction**
in a narrow sense, oxidation means the reaction of a substance with oxygen. Hydrogen can react with oxygen to be oxidised to water. Hydrocarbon fuels (gasoline, natural gas, etc) can react with oxygen to be oxidised to carbon dioxide and water. Iron can react with oxygen to be oxidised to "rust." During oxidation, the oxygen itself is being reduced. Oxidation and reduction always occur simultaneously. During these reactions, electrons are transferred from the substance that is oxidised to the oxygen. In a wider sense, all electron-transfer reactions are considered oxidation/reduction. The substance gaining electrons ("oxidising agent" or "oxidant") is oxidising the substance that is losing electrons ("reducing agent" or "reductant"). In the process, the "oxidising agent" is itself reduced by the "reducing agent." Consequently, the reduction process is sometimes called "electronation," and the oxidation process is called "de-electronation."

■ **reduction**
reduce; reduced; reducing. Compare with oxidation. Reduction is gain of one or more electrons by an atom, molecule, or ion. Reduction is accompanied by a decrease in oxidation number.

■ **reduction potential**
the tendency of a substance to be reduced; this value is measured relative to the standard hydrogen electrode which is defined as zero. The more positive the number the stronger the tendency for the species to be reduced. Sometimes oxidation potentials are used. They simply are the reverse of the reduction potential and refer to the oxidation reaction.

■ **reference state**
is chosen to assign a value of zero for a convenient property or properties at that state.

■ **refrigerant**
is the working fluid used in the refrigeration cycle.

■ **refrigerants**
are the working fluids used in the refrigeration cycles.

■ **refrigerator**
is a cyclic device which causes the transfer of heat from a low-temperature region to a high-temperature region. The objective of a refrigerator is to maintain the refrigerated space at a low temperature by removing heat from it.

■ **refrigerator coefficient of performance**
is the efficiency of a refrigerator, denoted by COP_R, and expressed as desired output divided by required input or $COP_R = Q_L / W_{net, in}$.

■ **refrigerators**
are cyclic devices which allow the transfer of heat from a low-temperature medium to a high-temperature medium.

■ **regeneration**
is a process during which heat is transferred to a thermal energy storage device (called a regenerator) during one part of the cycle and is transferred back to the working fluid during another part of the cycle.

■ **regenerator effectiveness**
is the extent to which a regenerator approaches an ideal regenerator and is defined as the ratio of the heat transfer to the compressor exit gas to the maximum possible heat transfer to the compressor exit gas.

■ **relative error**
relative uncertainty. Compare with absolute error . The uncertainty in a measurement compared to the size of the measurement. For example, if three replicate weights for an object are 2.00 g, 2.05 g, and 1.95 g, the absolute error can be expressed as ± 0.05 g and the relative error is ± 0.05 g / 2.00 g = 0.025 = 2.5%

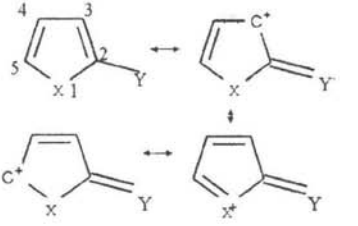
■ **relative humidity**
is a measure of the amount of moisture the air holds relative to the maximum amount the air can hold at the same temperature. The relative humidity can be expressed as the ratio of the vapour pressure to the saturation pressure of water at that temperature.

■ **relative pressure**
p_r is defined as the quantity $\exp(s°/R)$ and is a dimensionless quantity that is a function of temperature only since $s°$ depends on temperature alone. Relative pressure is used in isentropic processes of ideal gases where variable specific heats are required.

■ **relative specific volume**
v_r is defined as the quantity T/P_r is a function of temperature only and P_r is the relative pressure. Relative specific volume is used in isentropic processes of ideal gases where variable specific heats are required.

■ **relative standard deviation**
(RSD) Compare with standard deviation . The relative standard deviation is a measure of precision , calculated by dividing the standard deviation for a series of measurements by the average measurement.

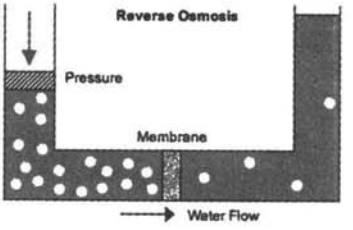
■ **resonance**
description of the ground state of a molecule with delocalised electrons as an average of several Lewis structures. The actual ground state doesn't switch rapidly between the separate structures: it is an average.



■ **resonance effect**
mesomeric effect. If electron density at a particular point in a molecule is higher or lower than what you'd expect from a single Lewis structure, and various canonical structures can be drawn to show how electron delocalisation will explain the discrepancy, the difference in electron density is called a "resonance effect" or "mesomeric effect" .

■ **restricted rotation**
when the energy barrier to rotation about a single bond is of the order of 80 kJ/mol or greater, complete rotation about the bond is prohibited. Instead partial rotation between the high-energy states occurs. This is termed restricted rotation.

■ **reverse osmosis**
compare with osmosis Solvent molecules flow spontaneously from a dilute solution through a semipermeable membrane to a more concentrated solution (osmosis). In reverse osmosis, pressure is applied to the more concentrated solution to force the flow of solvent to go from more concentrated to more dilute solution. Reverse osmosis



is used to produce fresh water from sea water.

■ **reversed Carnot cycle**
is a reversible cycle in which all four processes that comprise the Carnot cycle are reversed during operation. Reversing the cycle will also reverse the directions of any heat and work interactions. The result is a cycle that operates in the counterclockwise direction.

■ **reversible electrode**
an electrode with a reversible electrode reaction.

■ **reversible electrode reaction**
a qualitative term for a fast electrode reaction. There are, unfortunately, several meanings attributed to the term "reversibility," resulting in possibly confusing situation. An electrode reaction is considered reversible in the "electrochemical sense" if the reaction is fast, that is, if the exchange current density of the electrode reaction is large. In contrast, in the "chemical sense," reversibility indicates that the reaction can proceed both in forward and backward (reverse) direction. Also called Nernstian reaction. Opposite: irreversible electrode reaction. Both of the above described meanings of reversibility are different from the meaning in the "thermodynamic sense."

■ **reversible hydrogen electrode**
a commonly used reference electrode. A hydrogen electrode immersed directly into the electrolyte of the electro-

chemical cell and usually (unless otherwise sated) operated with one atmosphere pressure hydrogen gas. The equilibrium potential depends on the hydrogen ion concentration (strictly speaking, activity) of the cell electrolyte.

■ **reversible process**
a cyclic process carried out by a hypothetical pathway, which leaves the universe exactly the same as it was before the process; no real process is reversible. For chemical systems we consider a process at equilibrium to be reversible. Examples are phase transitions that occur at the melting point or boiling point temperatures at 1 atm pressure.

■ **reversible reaction**
reactions that do not go to completion and occur in both the forward and reverse direction.

■ **reversible steady-flow work**
is defined as the negative of the integral of the specific volume-pressure product. The larger the specific volume, the larger the reversible work produced or consumed by the steady-flow device. Therefore, every effort should be made to keep the specific volume of a fluid as small as possible during a compression process to minimise the work input and as large as possible during an expansion process to maximise the work output.

■ **reversible work**
w_{rev} is defined as the maximum amount of useful work that can be produced (or the minimum work that needs to be supplied) as a system undergoes a process between the specified initial and final states. Reversible work is determined from the exergy balance relations by setting the exergy destroyed equal to zero. The work W in that case becomes the reversible work.

■ **rocket**
is a device where a solid or liquid fuel and an oxidiser react in the combustion chamber. The high-pressure combustion gases are then expanded in a nozzle. The gases leave the rocket at very high velocities, producing the thrust to propel the rocket.

■ **rotating disk electrode**
a specialised hydrodynamic electrode used in the study of the kinetics and mechanism of electrode reactions and in electroanalysis for ensuring a known and controllable flow of solution over the electrode. The flow control is achieved by using a flat disc electrode that is rotated in the solution resulting in a defined hydrodynamic boundary layer. The current can be calculated using the Levich equation. Abbreviated as "RDE."

■ **rotating ring disk electrode**
a variant of the rotating-disk electrode which includes a second electrode - a concentric ring electrode - that is placed outside the disk and used to analyse the species generated on the disk. The ring is electrically insulated from the disk so that their potentials can be controlled independently. Abbreviated as "RRDE."

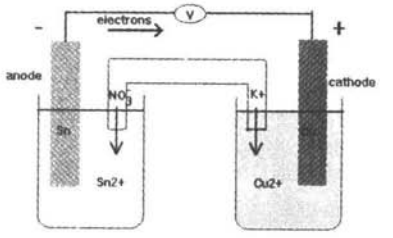
■ **rotating wire electrode**
an electrode made of metal wire (often platinum) rotated about its axis at a known and constant velocity. It is used in the study of the kinetics and mechanism of electrode reactions and in electroanalysis.

■ **roughness factor**
the ratio between the true electrode area and the geometric electrode area.

■ **s orbital**
a spherically symmetrical atomic orbital; one per energy level.

■ **salt bridge**
an ionically conducting path between separate compartments of an electrochemical cell. Often the working and reference (and occasionally even the counter) electrodes are in completely separate compartments and the required conducting path between them is provided by a tubing filled with highly conducting electrolyte solution. A common arrangement for a "salt bridge" is an inverted "U" shaped glass tubing with its ends dipped into the solutions of the two cell compartments; however, other materials and shapes are also used. The salt bridge may contain any conducting solution, but very often a highly concentrated po-

tassium chloride solution (often immobilised by some gelling agent) is used.



■ **sand equation**
an equation relating current density, transition time, and concentration of the reactant in a chronopotentiometric experiment, assuming that the current is sufficiently large to immediately result in diffusion limiting conditions. The equation is valid only for planar electrodes in unstirred solution. The product of the current density and the square root of the transition time divided by the concentration is a constant. The constant is proportional to the square root of the diffusion coefficient of the reactant. Because the equation was derived for an unstirred solution, it ceases to be valid once natural convection starts.

■ **saponification**
hydrolysis of esters in the presence of strong soluable bases.

■ **SATP**
standard ambient pressure and temperature. Compare with STP and standard state .Used to describe a substance at standard pressure and a temperature of 25°C (298.15 K).

■ **saturated air**
is air which can hold no more moisture. Any moisture introduced into saturated air will condense.

■ **saturated fat**
compare with unsaturated fat. A lipid that contains no carbon-carbon double bonds. Animal fats like butter and lard are composed of saturated fat. Saturated fats tend to be waxy or greasy solids.

■ **saturated hydrocarbons**
hydrocarbons that contain only single bonds. They are also called alkanes or paraffin hydrocarbons.

■ **saturated liquid**
is a liquid that is about to vapourise.

■ **saturated liquid line**
is the saturated liquid states connected by a line that meets the saturated vapour line at the critical point, forming a dome.

■ **saturated liquid-vapour mixture**
is a mixture of the liquid and vapour phases that coexist in equilibrium.

■ **saturated liquid-vapour mixture region, or the wet region**
is all the states that involve both the liquid and vapour phases in equilibrium and are located under the dome.

■ **saturated solution**
compare with supersaturated solution A solution which does not dissolve any more solute. When a saturated solution is placed in contact with additional solute, solute neither dissolves nor is deposited from a saturated solution.

■ **saturated vapour**
is a vapour that is about to condense.

■ **saturated vapour line**
is the saturated vapour states connected by a line that meets the saturated liquid line at the critical point, forming a dome.

■ **saturation pressure**
P_{sat} is called the pressure at which a pure substance changes phase at a given temperature.

■ **saturation temperature**
T_{sat} is the temperature at which a pure substance changes phase at a given pressure.

■ **scalemic**
any ratio of enantiomers which is not 'Racemic'.

■ **SCE**
stands for "saturated calomel electrode."

■ **scientific notation**
exponential notation. A system for reporting very small or very large numbers by writing the number as a decimal number between 1 and 10, multiplied by a power of 10. For example, 602000000000000000000000 is written in scientific notation as 6.02×10^{23}. 0.000323 is written in scientific notation as 3.23×10^{-4}

■ **scramjet engine**
is essentially a ramjet in which air flows through at supersonic

speeds (above the speed of sound).

■ **sealed battery**
a battery which can be operated without regard to position.

■ **second**
the second (s) is the base unit of time in the SI system of units, defined as the duration of 9,192,631,770 cycles of the radiation associated with a certain colour of light emitted by the caesium atom.

■ **second ionisation energy**
(IE,IP) second ionisation potential. Compare with first ionisation energy, adiabatic ionisation energy, vertical ionisation energy, electronegativity, and electron affinity. The energy needed to remove an electron from an isolated +1 ion. The third ionisation energy would be the energy required to remove an electron from an isolated +2 ion, and so on.

■ **second law of thermodynamics**
the second law states that every spontaneous process causes a net increase in the entropy of the universe. Many alternative statements are possible, including: Heat cannot be converted to work via an isothermal cycle. Heat cannot be converted to work with 100% efficiency. Heat cannot flow from a cold object to a warmer object without doing outside work.

■ **second order reaction**
compare with zero order reaction and first order reaction. A reaction with a rate law that is proportional to either the concentration of a reactant squared, or the product of concentrations of two reactants.

■ **secondary current distribution**
a current distribution that is controlled by the resistivity of the solution and the charge-transfer resistance of the electrode reaction occurring on the working electrode. That is, a current distribution taking into effect the activation overpotential. A large charge-transfer resistance (that is, a slow reaction), compared to the solution resistance, tends to make the current distribution more uniform. This still ignores the effect of the concentration overpotential.

■ **secondary dimensions, or derived dimensions**
such as velocity, energy E, and volume V, are expressed in terms of the primary dimensions.

■ **secondary standard**
a solution that has been titrated against a primary standard. A standard solution is a secondary standard.

■ **secondary voltaic cells**
voltaic cells that can be recharged; original reactanats can be regenerated be reversing the direction of the current flow.

■ **second-law efficiency**
is the ratio of the actual thermal efficiency to the maximum possible (reversible) thermal efficiency under the same conditions. The second-law efficiency of various steady-flow devices can be determined from its general definition, ς_{II} = (exergy recovered)/(exergy supplied).

■ **sedimentation**
separation of a dense material (usually a solid) from a less dense material (usually a liquid) by allowing the denser material to settle out of the mixture

■ **sedimentation potential**
an electrical potential difference that arises when small suspended particles move through a liquid (e.g., forced by gravity). Also called "Dorn potential.

■ **Seebeck effect results when**
two wires made from different metals are joined at both ends (junctions), form a closed circuit, and one of the ends is heated. As a result of the applied heat a current flows continuously in the circuit. The Seebeck effect is named in honour of Thomas Seebeck, who made its discovery in 1821.

■ **self discharge**
a slow discharging of a battery without being connected to an external load. This is caused partly by impurities and side reactions (reactions other than the cell reaction) and partly by the imperfect separation of the active chemicals in the battery causing a slow "direct" reaction between them. The rate of the self discharge determines the shelf life of a non-rechargeable battery.

■ **semiconductor**
a substance that does not conduct electricity at low temperatures but does so at higher temperatures.

■ **semipermeable membrane**
a membrane that allows some but not all of the components in a mixture to pass through it. Semipermeable membranes are used in dialysis.

■ **sensible energy**
is the portion of the internal energy of a system associated with the kinetic energies of the molecules.

■ **separator**
a thin structural material (usually a sheet) used to separate the electrolyte of a divided electrochemical cell into two or more compartments. A separator is typically either a membrane or a diaphragm. The distinction between these two separators is somewhat blurred. A membrane typically has very small pores that permit only diffusional or conductive motion of the solvent or the electrolyte from one compartment to another. A diaphragm has larger pores so that it permits the flow of the electrolyte solution from one compartment to another but still restricts the complete intermixing the two solutions.

■ **sequence rules**
in order to unambiguously assign the stereochemistry to a molecule, Cahn, Ingold and Prelog developed a series of sequence rules. These rules allow the absolute (*R/S*) stereochemistry and relative (*E/Z*) stereochemistry of molecules to be assigned and may be summarised as follows;
Rule 1: Atoms of higher atomic number take precedence over those of lower atomic number. For isotopes the higher atomic weight takes precedence. Lone pair electrons have the lowest priority.
$I > Br > Cl > P > O > N > {}^{13}C > {}^{12}C > {}^{3}H > H >$
Rule 2: If the atoms attached to the chiral centre or double bond are the same then the priority is determined by the atomic number of the atoms which are attached to them. This process is continued until priority is determined.
Rule 3: In groups containing multiple bonds, then for the

purposes of determining priority the atom at the end of the bond is duplicated or triplicated as required.
Rule 4: When the difference between substituents is in configuration then $R > S$ and *cis* $(Z) >$ *trans* (E).

■ **series coupled cells**
individual electrochemical cells can be combined in assemblies by series or parallel coupling (or a combination of the two). In case of "series" coupling, the positive electrode of one cell is connected to the negative electrode of the next cell, and so on. The assembly has only two external terminals. The overall voltage of the assembly is the sum of the individual cell voltages, while the current passing through every cell (and the assembly) is the same. Series coupling can be used in a number of assemblies, such as battery, cell line, and stack. Contrast with parallel coupling.

■ **shaft work**
is energy transmitted by a rotating shaft and is the related to the torque T applied to the shaft and the number of revolutions of the shaft per unit time.

■ **shallow discharge**
discharge of a rechargeable battery using only a small portion of its total rated capacity. Contrast with deep discharge.

■ **shape change**
the change in shape of an electrode of a rechargeable battery due to movement of the active (reacting) material during charge/discharge cycling.

■ **SHE**
stands for standard hydrogen electrode.

■ **shelf life**
the time period a non-rechargeable battery can be stored after manufacturing so that it still can provide a required amount of electricity when connected to a load. The shelf life of modern batteries is many years.

■ **shell**
compare with subshell. A set of electrons with the same principal quantum number. The number of electrons permitted in a shell is equal to $2n^2$. A shell contains n2 orbitals, and n subshells.

■ **shielding**
compare with penetration. Electrons in orbitals with high penetration can shield the nucleus from less penetrating electrons. Because they are closer to the nucleus on average, they repel those farther away and lessen the effective nuclear charge for the more distant electrons.

■ **shielding effect**
electrons in filled sets of s , p orbitals between the nucleus and outer shell electrons shield the outer shell electrons somewhat from the effect of protons in the nucleus; also called screening effect.

■ **short circuit current**
the initial current resulting from discharging a battery through a load of negligible resistivity.

■ **SI**
systeme Internationale; International System. Le Systéme Internationale (SI) is a system of units introduced to remove barriers to international trade, based on the older metric system. It is now used in science and technical communications worldwide.

■ **siemens**
the measurement unit of electrical conductance. Symbol: "S". The reciprocal of ohm, and sometimes called "mho."

■ **sigma bond**
(bond) compare with pi bond. In the valence bond theory, a sigma bond is a valence bond that is symmetrical around the imaginary line between the bonded atoms. Most single bonds are sigma bonds.

■ **sigma orbital**
molecular orbital resulting from head-on overlap of two atomic orbitals.

■ **significant figure**
significant digit; significant. A convention for recording measurements. Measurements are rounded so that they contain only the digits up to and including the first uncertain digit, when the number is written in scientific notation.

■ **silicones**
polymeric organo-silicon compounds; contain individual or cross-linked Si-O chains or rings in which some oxygens of SiO_4 tetrahedral are replaced by other groups.

■ **silver/silverchloride electrode**
a commonly used reference electrode. The electrode assembly consists of a silver metal electrode in contact with solid silver chloride (usually as a coating on the silver metal) immersed in an aqueous chloride salt solution saturated with silver chloride. All these are contained in a small vessel, typically made of glass tubing. The internal electrolyte of the reference electrode assembly and the external electrolyte into which the whole assembly is immersed are in ionic contact through a separator. A typical separator is a small porous ceramic plug sealed into the end of the glass tubing. The operating principle of this electrode is that of an electrode of the second kind. The equilibrium electrode potential is a function of the chloride concentration of the internal electrolyte ("filling solution"). The most commonly used electrolyte is 4 molar potassium chloride, producing a potential of 0.222 volt against the standard hydrogen electrode at 25 °C. Occasionally, other concentrations of potassium chloride or other chloride salts are used.

■ **simple compressible system**
is a system in which there is the absence of electrical, magnetic, gravitational, motion, and surface tension effects. These effects are due to external force fields and are negligible for most engineering problems.

■ **simple cooling**
is the process of lowering the temperature of atmospheric air when no moisture is removed.

■ **simple heating**
is the process of raising the temperature of atmospheric air when no moisture is added.

■ **simultaneous reactions**
are chemical reactions that involve two or more reactions occurring at the same time.

■ **single bond**
covalent bond resulting from the sharing of two electrons (one pair) between two atoms.

■ **SLI battery**
stands for "starting, lighting, ignition." A rechargeable battery used in automobiles for starting the engine and to pro-

vide power while the engine is not running.

■ **sling psychrometer**
is a device with both a dry-bulb thermometer and a wet-bulb temperature mounted on the frame of the device so that when it is swung through the air both the wet-and dry-bulb temperatures can be read simultaneously.

■ **SMDE**
stands for static-mercury-drop electrode.

■ **soap**
a salt of a fatty acid. For example, sodium stearate is a soap made by neutralising stearic acid. Commercial soaps are mixtures of fatty acid salts.

■ **sol**
a colloid with solid particles suspended in a liquid. Examples are protoplasm, starch in water, and gels.

■ **solid**
a solid is a relatively dense, rigid state of matter, with a definite volume and shape. Molecules in solids are often packed close together in regularly repeating patterns, and vibrate around fixed positions.

■ **solid oxide fuel cell**
a fuel cell that employs a solid, ionically conductive material as electrolyte. Due to the typically low ionic conductivity of solid oxides, these fuel cells must operate at very high temperatures.

■ **solid phase**
has molecules arranged in a three-dimensional pattern (lattice) that is repeated throughout. Because of the small distances between molecules in a solid, the attractive forces of molecules on each other are large and keep the molecules at fixed positions.

■ **solubilising group**
a group or substructure on a molecule that increases the molecule's solubility. solubilising groups usually make the molecule they are attached to ionic or polar. For example, hydrocarbon chains can be made water-soluble by attaching a carboxylic acid group to the molecule.

■ **solubility**
solubilities; equilibrium solubility; solubleness. The solubility of a substance is its con-

centration in a saturated solution. Substances with solubilities much less than 1 g/100 mL of solvent are usually considered insoluble. The solubility is sometimes called "equilibrium solubility" because the rates at which solute dissolves and is deposited out of solution are equal at this concentration.

■ **solubility product**
the solubility of slightly soluble salts is often expressed as the product of the solubility concentrations of its ions. e.g., the solubility product of silver chloride is the product of the concentrations of the silver and chloride ions in the saturated solution of this salt. The significance of the solubility product is that its value cannot be exceeded even in the presence of other dissolved salts. Consequently, the solubility of silver chloride is less in a solution containing potassium chloride than in pure water. This is because in the calculation of the solubility product one must use the "total" chloride concentration in the solution, therefore a silver concentration lower than in water is needed to satisfy a constant solubility product. The solubility (the saturated solution concentration) of the salt, in the absence of any other dissolved species in the solution, is the square root of the solubility product for a salt like the silver chloride. Strictly speaking, activities should be used instead of concentrations.

■ **solubility product constant**
equilibrium constant that applies to the dissolution of a slightly soluble compound.

■ **solubility product principle**
the solubility product constant expression for a slightly soluble compound is the product of the concentrations of the constituent ions, each raised to the power that corresponds to the number of ions in one formula unit.

■ **soluble**
compare with insoluble . Capable of being dissolved in a solvent (usually water).

■ **soluble salt**
an ionic compound that dissolves in a solvent (usually water).

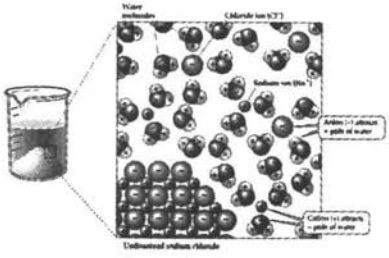
■ **solute**
a substance dissolved in a solvent to make a solution.

■ **solution**
homogeneous mixture. Compare with heterogeneous mixture . A sample of matter consisting of more than one pure substance with properties that do not vary within the sample. Also called a homogeneous mixture.

■ **solution IR drop**
the IR drop in the electrolyte solution of a three-electrode cell between the working and the reference electrodes. This ir drop (which is expressed as a potential) is always included in the measured potential of the working electrode. Therefore, it is important to minimise this error, and to place the reference electrode as close as possible to the working electrode. It is also called "ohmic overpotential (or polarisation)" or "resistance overpotential (or polarisation)." One can correct for the IR drop to obtain the real electrode potential, or in some cases one can compensate for the ir drop during potential control. During the measurement of an electromotive force (potential measurement without any current flowing), the IR drop is always zero, and the position of the reference electrode is immaterial.

■ **solvation**
ions in solution are always surrounded by solvent molecules. A few of these molecules will be more or less strongly attached to the ion (mainly because of the attraction of the charged ion and the dipole of the solvent molecule) and this assembly may be considered as a single unit for some purposes. e.g., the solvent molecules will move together with the ion during diffusion and electromigration. The number of solvent molecules so attached to an ion is called the "solvation number." The surface of an electrode also can, and usually is, solvated. Since the electrodes usually have some excess charge they also attract the solvent dipoles, and the electrode

surface is usually covered by a monolayer of strongly oriented solvent molecules. Under certain extreme conditions, a solution can contain free electrons that are stabilised by solvation. The solvation number is not very exactly defined since its value may depend on the measurement technique.



■ **solvent**
the dispersing medium of a solution.

■ **solvent extraction**
solvent extraction is a method for separating mixtures by exploiting differences in the solubilities of the components. For example, a coffee machine extracts the soluble components of ground coffee with water, and leaves the insoluble components behind. The sample is shaken or mixed with solvent (or with two immiscible solvents) to effect the separation. The "like dissolves like" is a useful guide for selecting solvents to use in the extraction. Non-polar substances are usually successfully extracted into non-polar solvents like hexane or methylene chloride. Polar and ionic substances are often extracted with water.

■ **solvolysis**
the reaction of a substance with the solvent in which it is dissolved.

■ **sonic flow**
occurs when a flow has a Mach number $M = 1$.

■ **sonoelectrochemistry**
electrochemical phenomena occurring under the influence of sound waves (typically ultrasound).

■ **sorption**
compare with adsorption and absorption . Assimilation of molecules of one substance by a material in a different phase. Adsorption (sorption on a surface) and absorption (sorption into bulk material) are two types of sorption phenomena

■ **spark-ignition (SI) engines**
are reciprocating engines in which the combustion of the air-

fuel mixture is initiated by a spark plug.

■ **specific conductance**
the quantitative and characteristic measure of the conductivity of a given substance. This characteristic constant is the numerical value of the conductivity between two opposite sides of a unit cube (usually a cube of one centimeter) of the substance. Also called "specific conductivity."

■ **specific gravity**
specific gravities. Compare with density. The mass of a unit volume of a substance relative to the mass of a unit volume of water. Temperature must be specified when reporting specific gravities, since the density of the substance and of water change with temperature. Specific gravities are often reported relative to water at 4°C; at that temperature, water has a density of 1.00000 g/mL and the specific gravity of a substance is equal to its density in g/mL.

■ **specific gravity, or relative density**
is defined as the ratio of the density of a substance to the density of some standard substance at a specified temperature (usually water at 4°C, for which the density is 1000 kg/m^3).

■ **specific heat**
compare with heat capacity
The heat required to raise the temperature of 1 g of a substance by 1°C is called the specific heat of the substance. Specific heat is an intensive property with units of J g^{-1} K^{-1}.

■ **specific heat at constant pressure**
C_p as the energy required to raise the temperature of the unit mass of a substance by one degree as the pressure is maintained constant. C_p is a measure of the variation of enthalpy of a substance with temperature. C_p can be defined as the change in the enthalpy of a substance per unit change in temperature at constant pressure.

■ **specific heat at constant volume**
C_v is the energy required to raise the temperature of the unit mass of a substance by one degree as the volume is maintained constant. C_v is related to

the changes in internal energy. It would be more proper to define C_v as the change in the internal energy of a substance per unit change in temperature at constant volume.

■ **specific heat capacity**
the amount of energy required to raise the temperature of one gram of a substance by one degree Celsius (or Kelvin).

■ **specific heat ratio**
k, is defined as the ratio C_p/C_v.

■ **specific heats for solids and liquids**
or incompressible substances, are equal.

■ **specific properties**
are extensive properties per unit mass. Some examples of specific properties are specific volume (v=V/m) and specific total energy (e= E/m).

■ **specific rate constant**
an experimentally determined (proportionality) constant, which is different for different reactions and which changes only with temperature; k in the rate-law expression: Rate = k [A] x [B]v.

■ **specific resistance**
the quantitative and characteristic measure of the resistivity of a given substance. This characteristic constant is the numerical value of the resistivity between two opposite sides of a unit cube (usually a cube of one centimeter) of the substance. Also called "specific resistivity."

■ **specific volume**
compare with density. The volume of a unit mass of substance. For example, the specific volume of water at 4°C is 1.00000 mL/g. Specific volume is the reciprocal of density.

■ **specific weight**
w is the weight of a unit volume of a substance and is determined from the product of the local acceleration of gravity and the substance density.

■ **spectator ion**
a spectator ion is an ion that appears as both a reactant and a product in an ionic equation. For example, in the ionic equation
$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + Na^+(aq) + NO^{3-}(aq)$ the so-

dium and nitrate ions are spectator ions.

■ **spectral line**
any of a number of lines corresponding to definite wavelengths of an atomic emission or absorption spectrum; represents the energy difference between two energy levels.

■ **spectrochemical series**
arrangement of ligands in order of increasing ligand field strength.

■ **spe.ctroelectrochemistry**
the simultaneous application of electrochemical and optical spectroscopic techniques to investigate a phenomenon.

■ **spectrophotometry**
determination of the concentration of a material in a sample by measurement of the amount of light the sample absorbs.

■ **spectroscopy**
spectrometry; spectroscopic. Spectroscopy is analysis of the interaction between electromagnetic radiation and matter. Different types of radiation interact in characteristic ways with different samples of matter; the interaction is often unique and serves as a diagnostic "fingerprint" for the presence of a particular material in a sample. Spectroscopy is also a sensitive quantitative technique that can determine trace concentrations of substances.

■ **spectrum**
1. a sequence of colours produced by passing light through a prism or diffraction grating.
2. a range of wavelengths of electromagnetic radiation.
3. a plot that shows how some intensity-related property of a beam of radiation or particles depends on another property that is related to dispersal of the beam by a prism, a magnet, or some other device. For example, a plot of light absorbance vs. wavelength is an absorption spectrum; a plot of ion abundance vs. mass is a mass spectrum.

■ **spin**
electrons have an intrinsic angular momentum that is similar to what would be observed if they were spinning. Electron spin is sometimes called a "twoness" property because it can have two values, referred to as "spin up" and "spin down".

Nuclei can have spins of their own.

■ **spin pair**
paired spins; electron pair; paired electrons. Compare with unpaired spin. Two electrons with opposite spins, usually occupying the same orbital.

■ **spontaneous**
spontaneity; spontaneous process; spontaneous reaction. A spontaneous process occurs because of internal forces; no external forces are required to keep the process going, although external forces may be required to get the process started. For example, the burning of wood is spontaneous once the fire is started. The combination of water and carbon dioxide to reform the wood and oxygen is not spontaneous!

■ **spontaneous process**
a process that occurs without outside intervention. Spontaneity is independent of rate. To be spontaneous a process must increase the entropy of the universe.

■ **spray pond**
is a pond where warm water is sprayed into the air and is cooled by the air as it falls into the pond. Spray ponds require 25 to 50 times the area of a cooling tower because water loss due to air drift is high.

■ **spring work**
is the work done to change the length of a spring.

■ **square planar**
a term used to describe molecules and polyatomic ions that have one atom in the centre and four atoms at the corners of a square.

■ **square planar complex**
complex in which the metal is in the centre of a square plane, with ligand donor atoms at each of the four corners.

■ **stable form of an element**
is the chemically stable form of that element at 25° C and 1 atm. Nitrogen, for example, exists in diatomic form (N_2) at 25° C and 1 atm. Therefore, the stable form of nitrogen at the standard reference state is diatomic nitrogen N_2, not monatomic nitrogen N.

■ **stack**
a series-coupled assembly of cells, a term used primarily for fuel cells.

■ **stagnation**
(or total) temperature is the temperature an ideal gas will attain when it is brought to rest adiabatically.

■ **stagnation enthalpy**
represents the total energy of a flowing fluid stream per unit mass and represents the enthalpy of a fluid when it is brought to rest adiabatically with no work. The stagnation enthalpy equals the static enthalpy when the kinetic energy of the fluid is negligible.

■ **stagnation pressure**
is the pressure a fluid attains when brought to rest isentropically. For ideal gases with constant specific heats, the stagnation pressure is related to the static pressure of the fluid through the isentropic process equation relating pressure and temperature.

■ **stagnation properties**
are the properties of a fluid at the stagnation state. These properties are called stagnation temperature, stagnation pressure, stagnation density, etc. The stagnation state and the stagnation properties are indicated by the subscript 0.

■ **standard cell**
a non-rechargeable cell (battery) whose emf is accurately known and remains sufficiently constant. It is less and less used nowadays because the availability of electronic voltage standards.

■ **standard deviation**
(s,BESD,) the standard deviation is a statistical measure of precision. The best estimate of the standard deviation s for small data sets is calculated using where xi is the measurement from the i-th run, x-bar is the mean of all the measurements, and N is the number of measurements. For very large data sets, the standard deviation is the root-mean-square deviation from the true mean, and is usually written as to distinguish it from the best estimate standard deviation s used for small data sets.

■ **standard electrode potential**
the equilibrium potential of an electrode when both the oxidised and the reduced spe-

cies are present in unit concentration (strictly speaking, activity) in the solution; if the "reduced" form is a metal, a pure metal (not alloyed with other metals) is considered to be at unit concentration. The standard potentials are always expressed against the standard hydrogen electrode the potential of which is zero "by definition." Standard potentials are a function of the temperature, they are usually tabulated for 25 °C. Also called "normal electrode potential." The standard potential is the electromotive force of an electrochemical cell comprised of the electrode in question and the standard hydrogen electrode. Strictly speaking, one must use unit activities rather than concentrations.

■ **standard electrode potential**
by convention , potential, E_o, of a half-reaction as a reduction relative to the standard hydrogen electrode when all species are present at unit activity.

■ **standard electrodes**
half-cells in which the oxidised and reduced forms of a species are present at unit activity; 1.0M solutions of dissolved ions, 1.0atm partial pressure of gases, and pure solids and liquids.

■ **standard enthalpy change**
(H°) standard enthalpy. Compare with enthalpy change . A change in enthalpy associated with a reaction or transformation involving substances in their standard states.

■ **standard enthalpy of formation**
($H_f°$) standard heat of formation; heat of formation; enthalpy of formation. The change in enthalpy when one mole of compound is formed from its elements in their most stable form and in their standard states.

■ **standard enthalpy of reaction**
($H_{rxn}°$) standard heat of reaction. A change in enthalpy associated with a reaction involving substances in their standard states.

■ **standard entropy**
the absolute entropy of a substance in its standard state at 298 K.

■ **standard entropy of reaction**
($S_{rxn}°$) entropy of reaction. A change in entropy associated with a reaction involving substances in their standard states . A superscript circle (°) distinguishes standard enthalpy changes from enthalpy changes which involve reactants and products that are not in their standard states.

■ **standard hydrogen electrode**
the most fundamental reference electrode in electrochemistry. "By definition" its equilibrium potential is considered zero at any temperature, because this electrode was chosen as an arbitrary zero point for electrode potentials. A zero point is needed since the potential of a single electrode cannot be measured, only the difference of two electrode potentials is measurable. All electrode potentials are expressed on this "hydrogen scale." It is a hydrogen electrode with an electrolyte containing unit concentration of hydrogen ions and saturated with hydrogen gas at unit atmosphere pressure. This electrode can be somewhat inconvenient to use because of the need to supply hydrogen gas. Therefore, other reference electrodes (e.g., calomel or silver/silver chloride) are often used instead, but the measured electrode potentials can be converted to the "hydrogen scale." Abbreviated as "SHE." Also called "normal hydrogen electrode." Strictly speaking, one must use unit activity rather than concentration of hydrogen ions and unit fugacity rather than unit pressure of hydrogen gas.

■ **standard molar enthalphy of formation**
the amount of heat absorbed in the formation of one mole of a substance in a specified state from its elements in their standard states.

■ **standard molar entropy**
($S°$) the entropy of one mole of a substance in its standard state.

■ **standard molar volume**
the volume occupied by one mole of an ideal gas under standard conditions; 22.4liters.

■ **standard pressure**
(P° or P_o) standard pressure is a pressure of 1 bar. Before 1982, the standard pressure was 1 atm (1 atm = 1.01325 bar).

■ **standard reaction**
a reaction in which the numbers of moles of reactants shown in the balanced equation, all in their standard states, are completely converted to the numbers of moles of products shown in the balanced equation, also sall at their standard state.

■ **standard reference state**
for the properties of chemical components is chosen as 25°C (77°F) and 1 atm. Property values at the standard reference state are indicated by a superscript (°) (such as $h^\circ$and u°).

■ **standard solution**
a solution of precisely known concentration.

■ **standard state**
(° or o) a set of conditions defined to allow convenient comparison of thermodynamic properties. The standard state for a gas is the the state of the pure substance in the gaseous phase at the standard pressure , with the gas behaving ideally. The standard state for liquids and solids is the state of the most stable form of the substance at the standard pressure. Temperature is not included in the definition of standard state and must be specified, but when not given a temperature of 25°C is usually implied.

■ **standard-state Gibbs function change**
is the difference between the sum products of the stoichiometric coefficients and the Gibbs function of a component at 1 atm pressure and temperature T for the products and reactants in the stoichiometric reaction.

■ **starch**
a polymer of glucose that has alpha-1,4-glycoside linkages.

■ **state**
of a system not undergoing any change gives a set of properties that completely describes the condition of a system. At this point, all the properties can be

measured or calculated throughout the entire system.

■ **state function**
a property that depends only on the condition or "state" of the system , and not on the path used to obtain the current conditions. Energy, enthalpy, temperature, volume, pressure, and temperature are examples of state functions; heat and work are examples of non-state functions.

■ **state of matter**
there are three common states of matter: gases , liquids , and solids . States of matter differ in the way the molecules are arranged at the molecular level, but not in the structure of the molecules themselves. Other states (the plasma and Bose-Einstein condensate states) are uncommon on Earth.

■ **state postulate**
specifies the number of properties required to fix the state of a system: The state of a simple compressible system is completely specified by two independent, intensive properties.

■ **stationary phase**
a stationary phase is a substance that shows different affinities for different components in a sample mixture in a separation of the mixture by chromatography . The mobile phase (a solution containing the sample) flows over or through the stationary phase to effect the separation.

■ **stationary systems**
are systems that do not involve any changes in their velocity or elevation during a process.

■ **statistical thermodynamics**
an approach to thermodynamics more elaborate than classical thermodynamics, is based on the average behaviour of large groups of individual particles.

■ **steady**
implies no change with time. The opposite of steady is unsteady, or transient.

■ **steady-flow devices**
operate for long periods of time under the same conditions.

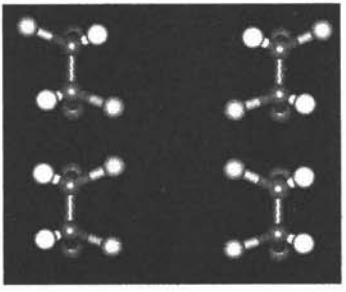
■ **steady-flow process**
is defined as a process during which a fluid flows through a control volume steadily. That is, the fluid properties can change from point to point within the

control volume, but at any fixed point they remain the same during the entire process.

■ **steam generator**
is the combination of a boiler and a heat exchanger section (the superheater), where steam is superheated.

■ **steam power plant**
is an external-combustion engine in which steam (water) is the working fluid. That is, combustion takes place outside the engine, and the thermal energy released during this process is transferred to the steam as heat. A turbine in the power plant converts some of the energy of the steam into rotating shaft work.

■ **stereoisomers**
are molecules with the same order of attachment of atoms, but a different orientation of the atoms in space. It is the broad category which contains both 'Enantiomers' and 'Diastereomers'.



■ **Stirling cycle**
is made up of four totally reversible processes:
1-2 *T constant* expansion (heat addition from the external source).
2-3 *v constant* regeneration (internal heat transfer from the working fluid to the regenerator).
3-4 *T constant* compression (heat rejection to the external sink).
4-1 *v constant* regeneration (internal heat transfer from the regenerator back to the working fluid).

■ **stoichiometric (theoretical) reaction**
is the balance reaction equation for a chemical equilibrium reaction.

■ **stoichiometric air or theoretical air**
is the minimum amount of air needed for the complete combustion of a fuel. When a fuel is completely burned with theoretical air, no uncombined oxygen will be present in the product gases.

■ **stoichiometric coefficients**
are the mole numbers in the stoichiometric (theoretical) reaction.

■ **stoichiometric combustion or theoretical combustion**
is the ideal combustion process during which a fuel is burned completely with theoretical air.

■ **stoichiometry**
1. ratios of atoms in a compound.
2. ratios of moles of compounds in a reaction.
3. a branch of chemistry that quantitatively relates amounts of elements and compounds involved in chemical reactions, based on the law of conservation of mass and the law of definite proportions .

■ **STP**
standard temperature and pressure. Compare with SATP and standard state .Used to describe a substance at standard pressure and a temperature of 0°C (273.15 K).

■ **stripping**
stripping is a technique for removing volatile components in a mixture by bubbling a stream of an chemically unreactive gas (like nitrogen) through the sample, and then 'scrubbing' the nitrogen through a solution or solid adsorbent that can recover the volatile materials.

■ **stroke**
is the distance between the top dead centre and the bottom dead centre is the largest distance that the piston can travel in one direction within a cylinder.

■ **strong acid**
compare with weak acid . A strong acid is an acid that completely dissociates into hydrogen ions and anions in solution. Strong acids are strong electrolytes . There are only six common strong acids: HCl (hydrochloric acid), HBr (hydrobromic acid), HI (hydroiodic acid), H_2SO_4 (sulphuric acid), $HClO_4$ (perchloric acid), and HNO_3 (nitric acid).

■ **strong base**
a strong base is an base that completely dissociates into ions in solution. Strong bases are strong electrolytes . The most common strong bases are alkali metal and alkaline earth metal hydroxides.

■ **strong electrolyte**
compare with weak electrolyte, a strong electrolyte is a solute

that completely dissociates into ions in solution. Solutions of strong electrolytes conduct electricity. Most soluble ionic compounds are strong electrolytes.

■ **strong field ligand**
ligand that exerts a strong crystal or ligand electrical field and generally forms low spin complexes with metal ions when possible.

■ **strong ligand**
strong field ligand. Compare with weak ligand. A ligand that causes a large crystal field splitting which results in a low-spin complex.

■ **structural formula**
compare with molecular formula and empirical formula . A structural formula is a diagram that shows how the atoms in a molecule are bonded together. Atoms are represented by their element symbols and covalent bonds are represented by lines. The symbol for carbon is often not drawn. Most structural formulas don't show the actual shape of the molecule (they're like floor plans that show the layout but not the 3D shape of a house).

■ **structural isomers**
are organic compounds that have the same som formula, meaning the same number of carbons , hydrogens or other type ot atoms. They differ from each other in the way the atoms are connected. Examples are n-butane and 2-methylpropane or ethanol and dimethylether.

■ **subcooled liquid**
has a temperature less than the saturation temperature corresponding to the pressure.

■ **sublimation**
sublimate; sublimating. Conversion of a solid directly into a gas, without first melting into a liquid.

■ **sublimation line**
separates the solid and vapour regions on the phase diagram.

■ **subshell**
sublevel. A set of electrons with the same azimuthal quantum number. The number of electrons permitted in a subshell is equal to 2 + 1.

■ **subsonic flow**
occurs when a flow has a Mach number $M < 1$.

■ **substance**
any kind of matter all specimens of which have the same chemical composition and physical properties.

■ **substitution reaction**
a reaction in which an atom or a group of atoms is replaced by another atom or group of atoms.

■ **sugar**
a carbohydrate with a characteristically sweet taste. Sugars are classified as monosaccharides , disaccharides , or trisaccharides.

■ **supercooled liquids**
liquids that, when cooled, apparently solidify but actually continue to flow very slowly under the influence of gravity.

■ **supercooling**
supercooled; supercool. Liquids at temperatures below their normal freezing points are said to be "supercooled".

■ **supercritical fluid**
a fluid state that occurs when the pressure and temperature exceed the substance's critical pressure and critical temperature. Supercritical fluids fill their containers like gases but dissolve substances like liquids, which makes them very useful as solvents. Their density and other properties are intermediate between gases and liquids.

■ **superheated vapour**
is a vapour that is not about to condense (not a saturated vapour). A superheated vapour has a temperature greater than the saturation temperature for the pressure.

■ **superheated vapour region**
is all the superheated states located to the right of the saturated vapour line and above the critical temperature line.

■ **superoxide**
superoxide ion. A binary compound containing oxygen in the -½ oxidation state. For example, KO_2 is potassium superoxide, an ionic compound containing the superoxide ion, O^{2-}

■ **supersaturated solution**
supersaturated. A supersaturated solution has concentration of solute that is higher than its solubility. A crystal of solute dropped into a supersaturated solution grows; excess solute is

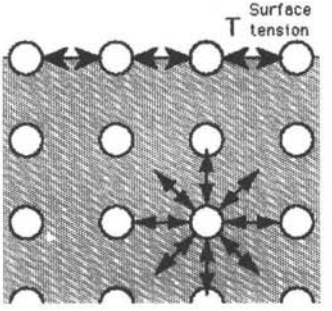
deposited out of the solution until the concentration falls to the equilibrium solubility.

■ **supersaturated steam**
is steam that exists in the wet region without containing any liquid. This phenomenon would exist due to the supersaturation process.

■ **supersaturation**
is the phenomenon owing to steam flowing through a nozzle with the high velocities and exiting the nozzle in the saturated region. Since the residence time of the steam in the nozzle is small, and there may not be sufficient time for the necessary heat transfer and the formation of liquid droplets, the condensation of the steam may be delayed for a little while.

■ **supersonic flow**
occurs when a flow has a Mach number $M > 1$.

■ **surface tension**
is the force per unit length used to overcome the microscopic forces between molecules at the liquid-air interfaces.



■ **surfactant**
a material that spreads along a surface, changing the properties of the surface. For example, soap spreads over a water surface and lowers its surface tension.

■ **surroundings**
everything in the universe surrounding a thermodynamic system.

■ **surroundings work**
is the work done by or against the surroundings during a process.

■ **suspension**
a heterogeneous mixture in which solute-like particles settle out of solvent-like phase some time after their introduction.

■ **synclinal**
when the X-C-C-Y dihedral (sometimes called 'torsional')

angle is between 30° and 90° or -30° and -90° (270° to 330°) the conformer is called synclinal. The most frequently cited example of a synclinal conformer is the 'Gauche' conformer where the dihedral angle is 60°.

■ **synperiplanar**
when the X-C-C-Y dihedral (sometimes called 'torsional') angle is between -30° and 30° (270° to 330°) the conformer is called anticlinal. The most frequently cited example of a synperiplanar conformer is a fully eclipsed conformer where the angle between X and Y is 0°.

■ **synthesis**
synthesise; synthetic reaction. Compare with decomposition . Formation of a complex product from simpler reactants. For example, water can be synthesised from oxygen and hydrogen gas:
$H_2(g) + ½O2(g) \rightarrow H_2O$

■ **system**
that part of the universe on which attention is to be focused.

■ **systematic error**
determinate error. Compare with random error , gross error and mistake . Systematic errors have an identifiable cause and affect the accuracy of results.

■ **tautomer**
a structure formed by facile motion of a hydrogen from one site to another within the same molecule.

■ **Tds relations**
relate the *Tds* product to other thermodynamic properties. The first Gibbs relation is $Tds = du + Pdv$. The second Gibbs relation is $Tds = dh - vdP$.

■ **temperature**
compare with heat and thermodynamic temperature . Temperature is an intensive property associated with the hotness or coldness of an object. It determines the direction of spontaneous heat flow (always from hot to cold).

■ **temporary hardness**
temporary water hardness. Compare with permanent hardness and water hardness. The component of total water hardness that can be removed by boiling the water. $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$

are responsible for temporary hardness.

■ **teratogen**
a substance that can cause deformities in embryos. Dioxin is a teratogen.

■ **ternary acid**
a ternary compound containing H, O, and another element, often a nonmetal.

■ **ternary compound**
a compound consisting of three elements; may be ionic or covalent.

■ **tetrahedral**
a term used to describe molecules and polyatomic ions that have one atom in centre and four atoms at the corners of a tetrahedron.

■ **theoretical yield**
maximum amount of a specified product that could be obtained from specified amounts of reactants, assuming complete consumption of limiting reactant according to only one reaction and complete recovery of product. (Compare with Actual Yield).

■ **theory**
theories. compare with hypothesis. Theories are well-established explanations for experimental data. To become established, the theory must experimentally tested by many different investigators. Theories usually can not be proven; a single contrary experiment can disprove a theory.

■ **therm**
of natural gas is an amount of energy equal to 29.3 kWh.

■ **thermal cracking**
decomposition by heating a substance in the presence of a catalyst and in the absence of air.

■ **thermal efficiency**
is a measure of the performance of a heat engine and is the fraction of the heat input to the heat engine that is converted to net work output.

■ **thermal efficiency of a heat engine**
is the fraction of the thermal energy supplied to a heat engine that is converted to work.

■ **thermal efficiency of a power plant**
is defined as the ratio of the shaft work output of the tur-

bine to the heat input to the working fluid.

■ **thermal efficiency ς_{th}**
is the ratio of the net work produced by a heat engine to the total heat input, $\varsigma_{th} = W_{net}/Q_{in}$.

■ **thermal energy**
energy an object possesses by virtue of its temperature. For example, 1 g of water at 15°C has 4.184 J more energy than 1 g of water at 14°C.

■ **thermal energy reservoir**
or just a reservoir is a hypothetical body with a relatively large thermal energy capacity (mass specific heat) that can supply or absorb finite amounts of heat without undergoing any change in temperature.

■ **thermal equilibrium**
means that the temperature is the same throughout the entire system.

■ **thermochemical equation**
an compact equation representing a chemical reaction that describes both the stoichiometry and the energetics of the reaction. For example, the thermochemical equation
$CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(g),\ H = -2220$ kJ
means "When one mole of gaseous CH4 is burned in two moles of oxygen gas, one mole of CO_2 gas and 2 moles of steam are produced, and 2220 kilojoules of heat are released."

■ **thermochemistry**
the study of heat absorbed or released during chemical changes.

■ **thermodynamic equilibrium**
a system is at thermodynamic equilibrium if the energy it gains from its surroundings is exactly balanced by the energy it loses, no matter how much time is allowed to pass.

■ **thermodynamic system**
is defined as a quantity of matter or a region in space chosen for study.

■ **thermodynamic temperature**
scale is a temperature scale that is independent of the properties of the substances that are used to measure temperature. This temperature scale is called the Kelvin scale, and the temperatures on this scale are called absolute temperatures. On the Kelvin scale, the temperature

ratios depend on the ratios of heat transfer between a reversible heat engine and the reservoirs and are independent of the physical properties of any substance.

■ **thermodynamic temperature scale**
is a temperature scale that is independent of the properties of any substance or substances.

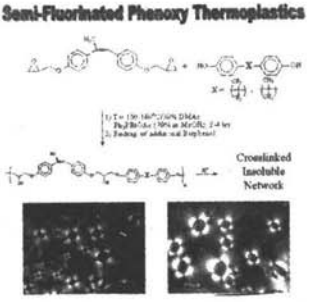
■ **thermodynamics**
can be defined as the science of energy. Energy can be viewed as the ability to cause changes. The name *thermodynamics* stems from the Greek words *therme* (heat) and *dynamis* (power), which is most descriptive of the early efforts to convert heat into power. Today the same name is broadly interpreted to include all aspects of energy and energy transformations, including power production, refrigeration, and relationships among the properties of matter.

■ **thermoelectric refrigerator**
is a refrigerator using electric energy to directly produce cooling without involving any refrigerants and moving parts.

■ **thermometry**
the science of temperature measurement.

■ **thermonuclear energy**
energy from nuclear fusion reactions.

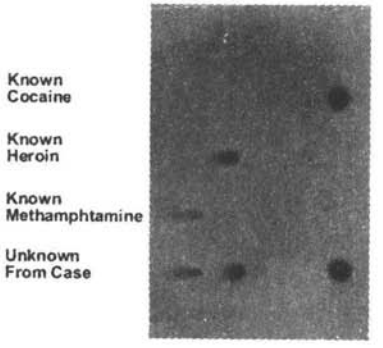
■ **thermoplastic**
compare with thermosetting, A



polymer that softens or melts on heating, and becomes rigid again on cooling. Thermoplastic polymer chains are not crosslinked. Polystyrene is a thermoplastic.

■ **thermosetting**
thermosetting plastic. Compare with thermoplastic A polymer that solidifies on heating and cannot be remelted. The setting action results from crosslinking of the polymer chains at high temperature- a process that is not reversed by cooling and reheating.

■ **thin layer chromatography**
a technique for separating components in a mixture on the basis of their differing polarities. A spot of sample is placed on a flat sheet coated with silica and then carried along by a solvent



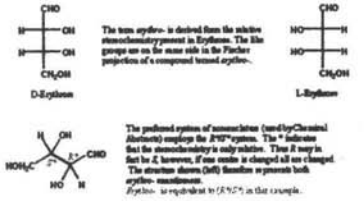
that soaks the sheet. Different components will move different distances over the surface. TLC is a useful screening technique in clinical chemistry; for example, it can be used to detect the presence of drugs in urine.

■ **thio**
a prefix that means, "replace an oxygen with sulphur". For example, sulphate ion is SO_4^{2-}; thiosulphate ion is $S_2O_3^{2-}$. Cyanate ion is OCN^-; thiocyanate ion is SCN^-.

■ **third law of thermodynamics**
the entropy of a perfect crystal at 0 K is zero.

■ **thixotropic fluid**
thixotropy. A liquid that becomes less viscous when stirred. Paint and printing inks are thixotropic fluids; they are formulated so that they flow more freely when brushed or rolled.

■ **threo-**
the term *threo-* belongs to an outdated system of nomenclature used to describe the relative stereochemistry of 2 adjacent chiral centres. In a Fischer projection the *threo-* isomer has identical (or at least similar) substituents on adjacent chiral centres on opposite sides. The system is awkward and confusing when applied to non-carbohydrate molecules or molecules with multiple adjacent chiral centres. There are also multiple and contradicting definitions for the term and as such it should not be used.. The preferred system of nomenclature in these cases uses *R*/S** system.



■ **throat**
of a converging-diverging nozzle is located at smallest flow area.

■ **throttling valves**
are any kind of flow-restricting devices that cause a significant pressure drop in the fluid. Some familiar examples are ordinary adjustable valves, capillary tubes, and porous plugs. Unlike turbines, they produce a pressure drop without involving any work. The pressure drop in the fluid is often accompanied by a large drop in temperature, and for that reason throttling devices are commonly used in refrigeration and air-conditioning applications. The magnitude of the temperature drop (or, sometimes, the temperature rise) during a throttling process is governed by a property called the Joule-Thomson coefficient.

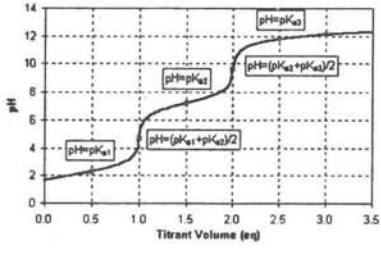
■ **thrust**
is the unbalanced force developed in a turbojet engine that is caused by the difference in the momentum of the low-velocity air entering the engine and the high-velocity exhaust gases leaving the engine, and it is determined from Newton's second law.

■ **titrant**
the substance that quantitatively reacts with the analyte in a titration . The titrant is usually a standard solution added carefully to the analyte until the reaction is complete. The amount of analyte is calculated from the volume of titrant required for complete reaction.

■ **titration**
a procedure for determining the amount of some unknown substance (the analyte) by quantitative reaction with a measured volume of a solution of precisely known concentration (the titrant).

■ **titration curve**
a plot that summarises data collected in a titration . A linear titration curve plots moles of analyte (or, some quantity

proportional to moles of analyte) on the Y axis, and the volume of titrant added on the X axis. Nonlinear plots use the log of the concentration of the analyte instead. Nonlinear titration curves are often used for neutralisation titrations (pH vs. mL NaOH solution). Logs are used to exaggerate the rate of change of concentration on the plot, so that the endpoint can be determined from the point of maximal slope.



■ **ton of refrigeration**
is the capacity of a refrigeration system equivalent to the energy that can freeze 1 ton (2000 lbm) of liquid water at 0 °C (32 °F) into ice at 0°C in 24 h. One ton of refrigeration is equivalent to 211 kJ/min or 200 Btu/min. The cooling load of a typical 200-m^2 (2153-ft^2) residence is in the 3-ton (10-kW) range.

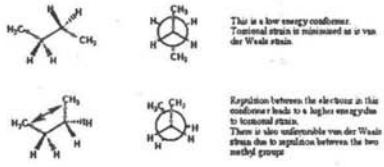
■ **top dead centre**
(TDC) is the position of the piston when it forms the smallest volume in the cylinder.

■ **topping cycle**
is a power cycle operating at high average temperatures that rejects heat to a power cycle operating at lower average temperatures.

■ **torr**
torr; mm Hg. Compare with barometer and pressure. A unit of pressure, defined so that 760 Torr is exactly 1 atmosphere. A Torr is equivalent to 1 mm Hg on barometer readings taken at 0°C; at other temperatures, the conversion from mm Hg to Torr is approximately p(Torr) = p(mm Hg) × (1 - 1.8×10^{-4}t), where t is in °C.

■ **torsional strain**
torsional strain (also known as Pitzer Strain) is a result of twisting about a single bond and is best understood in terms of the repulsion between the electrons in the bonds. When the 'dihedral angle' is such that it results in eclipsing conformations the strain and hence the energy of

that conformation increases. A dihedral angle that results in a staggered conformation has lower torsional strain and is therefore of lower energy.



■ **total energy**
of a system is the sum of the numerous forms of energy such as thermal, mechanical, kinetic, potential, electric, magnetic, chemical, and nuclear, and their constituents. The total energy of a system on a unit mass basis is denoted by*e* and is defined as E/m.

■ **total energy of a flowing fluid**
is the sum of the enthalpy, kinetic, and potential energies of the flowing fluid.

■ **total ionic equation**
equation for a chemical reaction written to show the predominant form of all species in aqueous solution or in contact with water.

■ **totally reversible process,**
a process which involves no irreversibilities within the system or its surroundings. A totally reversible process involves no heat transfer through a finite temperature difference, no non-quasi-equilibrium changes, and no friction or other dissipative effects.

■ **toxicology**
the study of poisons, including identification, isolation, biological effects, mechanism of action, and development of antidotes.

■ **transition metal**
transition element; outer transition element. An element with an incomplete d subshell. Elements which have common cations with incomplete d subshells are also considered transition metals. Elements with incomplete f subshells are sometimes called "inner transition elements".

■ **transition state**
the state of highest energy during a reaction. Also called activated complex. During the transition state bond breaking and bond formation occurs.

■ **transition state theory**
theory of reaction rates that states that reactants pass through high-energy transition states before forming products.

■ **transsonic flow**
occurs when a flow has a Mach number $M = 1$ (approx.).

■ **trap**
is a device that allows condensed steam to be routed to another heater or to the condenser. A trap allows the liquid to be throttled to a lower-pressure region but traps the vapour. The enthalpy of steam remains constant during this throttling process.

■ **triglyceride**
a triglyceride is an ester of glycerol and three fatty acids. Most animal fats are composed primarily of triglycerides. In the structures below, 'R' represents the fatty acids attached to the glycerol. The fatty acids can be the same or different.

■ **triple bond**
a covalent bond that involves 3 bonding pairs. In the valence bond theory, one of the bonds in a triple bond is a sigma bond and the other two are pi bonds . For example, the central bond in acetylene is a triple bond: H-C-C-H.

■ **triple line**
is the locus of the conditions where all three phases of a pure substance coexist in equilibrium. The states on the triple line of a substance have the same pressure and temperature but different specific volumes.

■ **triple point**
of water is the state at which all three phases of water coexist in equilibrium.

■ **trueness**
compare with accuracy . Trueness is the closeness of an average measurement to a "true" value, while accuracy is the closeness of a single measurement to the true value.

■ **turbine**
is a device that produces shaft work due to a decrease of enthalpy, kinetic, and potential energies of a flowing fluid.

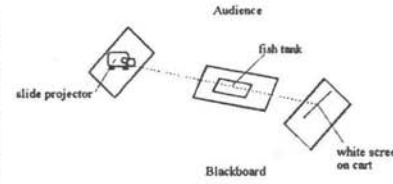
■ **turbofan (or fan-jet) engine**
is the most widely used engine in aircraft propulsion. In this engine a large fan driven by the turbine forces a consider-

able amount of air through a duct (cowl) surrounding the engine. The fan exhaust leaves the duct at a higher velocity, enhancing the total thrust of the engine significantly. A turbofan engine is based on the principle that for the same power, a large volume of slower-moving air will produce more thrust than a small volume of fast-moving air. The first commercial turbofan engine was successfully tested in 1955.

■ **turboprop engine**
uses propellers powered by the aircraft turbine to produce the aircraft propulsive power.

■ **two-stroke engines**
execute the entire cycle in just two strokes: the power stroke and the compression stroke.

■ **Tyndall effect**
light passing through a colloid is scattered by suspended particles. The light beam becomes clearly visible; this phenomenon is called the Tyndall effect. For example, car headlight beams can be seen in fog, but the beams are invisible in clear air.



■ **ultraviolet light**
ultraviolet; ultraviolet radiation; ultraviolet region; UV. Electromagnetic radiation with wavelength longer than that of x-rays but shorter than that of visible light. Ultraviolet light can break some chemical bonds and cause cell damage.

■ **uncertainty principle**
Heisenberg's uncertainty principle; Heisenberg principle; indeterminacy; indeterminancy principle. The exact momentum and exact location of a particle cannot be specified. Werner Heisenberg stated that the product of uncertainties in location and momentum measurements can never be smaller than h/4, where h is Planck's constant.

■ **uniform**
implies no change with location over a specified region.

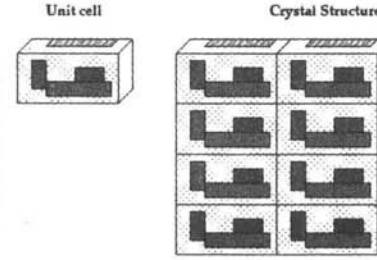
■ **uniform-flow process**
involves the following idealisation: The fluid flow at any inlet or exit is uniform and steady, and thus the fluid properties do not change with time or position over the cross section of an inlet or exit. If they do change with time, the fluid properties are averaged and treated as constants for the entire process.

■ **unimolecular reaction**
a reaction that involves isomerisation or decomposition of a single molecule.

■ **unimolecular step**
a reaction involving one species.

■ **unit**
a standard for comparison in measurements. For example, the meter is a standard length which may be compared to any object to describe its length.

■ **unit cell**
the simplest arrangement of atoms or molecules that regularly repeats in a crystal structure.



■ **units**
are the arbitrary magnitudes assigned to the dimensions.

■ **universal gas constant**
ru is the same for all substances and its value is 8.314 kJ/kmol·K and 1.986 Btu/lbmol·R.

■ **unpaired spin**
unpaired electron. Compare with paired spin. A single electron occupying an orbital.

■ **unsaturated compound**
an organic compound with molecules containing one or more double bonds.

■ **unsaturated fat**
compare with saturated fat. A lipid containing one or more carbon-carbon double bonds. Unsaturated fats tend to be oily liquids and are obtained from plants.

■ **unsteady-flow**
or transient-flow, processes are processes that involve changes within a control volume with time.

■ **useful work**
w_u is the difference between the actual work W and the surroundings work W_{surr}.

■ **useful work potential**
is the maximum possible work that a system will deliver as it undergoes a reversible process from the specified initial state to the state of its environment, that is, the dead state.

■ **utilisation factor**
is a measure of the energy transferred to the steam in the boiler of a steam power plant that is utilised as either process heat or electric power. Thus the utilisation factor is defined for a cogeneration plant as the ratio of the sum of the net work output and the process heat to the total heat input.

■ **vacuum cooling**
is a way to cool a substance by reducing the pressure of the sealed cooling chamber to the saturation pressure at the desired low temperature and evaporating some water from the products to be cooled. The heat of vapourisation during evaporation is absorbed from the products, which lowers the product temperature.

■ **vacuum freezing**
is the application of vacuum cooling when the pressure (actually, the vapour pressure) in the vacuum chamber is dropped below 0.6 kPa, the saturation pressure of water at 0°C.

■ **vacuum pressure**
is the pressure below atmospheric pressure and is measured by a vacuum gage that indicates the difference between the atmospheric pressure and the absolute pressure.

■ **valence**
the number of hydrogen atoms that typically bond to an atom of an element. For example, in H_2O, oxygen has a valence of 2; carbon in CH_4 has a valence of four.

■ **valence bond**
in the valence bond theory, a valence bond is a chemical bond formed by overlap of half-filled atomic orbitals on two different atoms.

■ **valence bond theory**
assumes that covalent bonds are formed when atomic orbitals on different atoms overlap and the electrons are shared.

■ **valence electron**
electrons that can be actively involved in chemical change; usually electrons in the shell with the highest value of n. For example, sodium's ground state electron configuration is $1s^2\ 2s^2\ 2p^6\ 3s^1$; the 3s electron is the only valence electron in the atom. Germanium (Ge) has the ground state electron configuration $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^2$; the 4s and 4p electrons are the valence electrons.

■ **valence shell**
the shell corresponding to the highest value of principal quantum number in the atom. The valence electrons in this shell are on average farther from the nucleus than other electrons; they are often directly involved in chemical reaction.

■ **valence shell electron pair repulsion theory**
assumes that electron pairs are arranged around the central element of a molecule or polyatomic ion so that there is maximum separation (and minimum repulsion) among regions of high electron density.

■ **Van der Waals equation**
a semiempirical equation that describes the relationship between pressure (P), volume (V), temperature (T), and moles of gas (n) for a real gas. The equation is $(P + n^2a/V^2)(V - nb) = nRT$, where a and b are constants that include the effects of molecular attractions and molecular volume. a and b are usually fitted to experimental data for a particular gas.

■ **Van der Waals force**
a force acting between nonbonded atoms or molecules. Includes dipole-dipole, dipole-induced dipole, and London forces.

■ **Van der Waals radius**
Van der Waals radii. One half the distance between two nonbonded atoms, when attractive and repulsive forces between the atoms are balanced.

■ **Van der Waals Strain**
Van der Waals strain is the strain caused by the mutual repulsion of atoms when

bought close to each other. The *syn*-1,3-diaxial interactions observed in cyclohexanes is an example of van der Waals strain and explains why bulky groups prefer to sit in an equatorial positon.

■ **Van't hoff equation**
is the expression of the variation of the equilibrium constant with temperature in terms of the enthalpy of reaction at temperature T.

■ **vapour**
a gas formed by boiling or evaporating a liquid.

■ **vapour pressure**
is usually considered to be the partial pressure of water vapour in atmospheric air.

■ **vapour pressure lowering**
vapour pressure depression; vapour pressure depression. A colligative property of solutions. The vapour pressure of a solution is always lower than the vapour pressure of the pure solvent; the ratio of solution to pure solvent vapour pressures is approximately equal to the mole fraction of solvent in the solution.

■ **vapour-compression refrigeration cycle**
is the most frequently used refrigeration cycle and involves four main components: a compressor, a condenser, an expansion valve, and an evaporator.

■ **vapourisation line**
separates the liquid and vapour regions on the phase diagram.

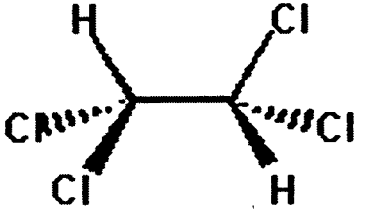
■ **variable**
compare with independent variable and dependent variable A quantity that can have many possible values. In designing experiments, variables that affect measurements must be identified and controlled. For example, an experiment that measures reaction rates must control temperature, because temperature is a variable that can change the rate of reaction. Theories usually can not be proven; a single contrary experiment can disprove a theory.

■ **velocity coefficient**
a parameter that is used to express the performance of a nozzle, is defined as the ratio of the actual velocity at nozzle exit to the velocity at nozzle exit for isentropic flow from the same

inlet state to the same exit pressure.

■ **velocity of sound**
is the velocity at which an infinitesimally small pressure wave travels through a medium.

■ **vicinal**
vicinal (vic) is a term used to describe a relative 1,2-disubstitution. The hydrogen atoms in 1,1,2,2-tetrahydroethane can be described as being vicinal to each other.



■ **vinyl**
polyethylene. A polymer made by linking ethylene ($CH_2=CH_2$) or substituted ethylene molecules together.

■ **virial equations of state**
is an equation of state of a substance expressed in a series form as P = RT/v + a(T)/v2 + b(T)/v3 + c(T)/v4 + d(T)/v5 +...where the coefficients a(T), b(T), c(T), and so on, are functions of temperature alone and are called virial coefficients.

■ **viscosity**
coefficient of viscosity. The resistance a liquid exhibits to flow. Experimentally, the frictional force between two liquid layers moving past each other is proportional to area of the layers and the difference in flow speed between them. The constant of proportionality is called "viscosity" or "coefficient of viscosity", and is given the symbol . The time required for a liquid to drain out of a capillary tube is directly proportional to its viscosity. The poise is a non-SI unit frequently used to express viscosities.

■ **visible light**
visible light is electromagnetic radiation with a wavelength between 400 and 750 nm.

■ **vitamin**
a substance that is critical for proper functioning of a living organism that the organism is unable to produce in sufficient quantities for itself.

■ **volt**
the unit of electrical potential defined as one joule of work per coulomb of charge transferred.

■ **voltage**
potential difference between two electrodes; a measure of the chemical potential for a redox reaction to occur.

■ **voltaic cell**
a device in which chemical energy from a spontaneous redox reaction is changed to electrical energy that can be used to do work; also called a galvanic cell.

■ **voltaic pile**
an early battery consisting of disks of dissimilar metals (usually zinc and copper) separated by moist paper or cloth soaked in an electrolyte solution.

■ **voltammeter**
an instrument for measuring voltages and amperages.

■ **voltmeter**
an instrument that measures cell potential by drawing electric current through a known resistance.

■ **volume expansivity**
(also called the coefficient of volumetric expansion) relates how volume changes when temperature changes when pressure is held constant.

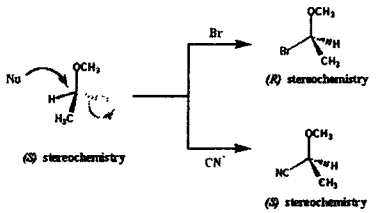
■ **volume flow rate**
is the volume of the fluid flowing through a cross section per unit time.

■ **volume fraction**
of a gas component in a gas mixture is the ratio of the component volume to the mixture volume. Note that for an ideal-gas mixture, the mole fraction, the pressure fraction, and the volume fraction of a component are identical.

■ **volume percentage**
((v/v)%) Volume percentages express the concentration of a component in a mixture or an element in a compound. For example, 95% ethanol by volume contains 95 mL of ethanol in 100 mL of solution (not in 100 mL of water).

■ **Walden Inversion**
in an S_{N2} reaction at an asymmetric centre the optical integrity of the molecule is retained (i.e. the molecule does not racemise as is the case in an S_{N1} reaction). The nucleophile attacks such that the orientation of the nucleophile to the other substituents is inverted with

respect to that of the leaving group.
This does not mean that the stereochemistry is inverted as that will depend on the priority of the nucleophile and leaving group. In the example below



Walden inversion has occurred in both cases, however, the absolute stereochemistry has only inverted in one case.

■ **waste heat**
is energy that must be dissipated to the atmosphere from a process such as the heat transferred from condensing steam in the condenser of a steam power plant.

■ **water gas**
blue gas; synthesis gas. A fuel gas used in industrial synthesis of organic chemicals, and in welding, glassmaking, and other high-temperature industrial applications. Water gas made by passing steam over a bed of hot coal or coke. It consists mainly of of carbon monoxide (CO) and hydrogen (H_2), contaminated with small amounts of CO_2, N_2, CH_4, and O_2

■ **water hardness**
hard water, compare with water softener. Hard water is water contaminated with compounds of calcium and magnesium. Dissolved iron, manganese, and strontium compounds can also contribute to the "total hardness" of the water, which is usually expressed as ppm $CaCO_3$. Water with a hardness over 80 ppm $CaCO_3$ is often treated with water softeners, since hard water produces scale in hot water pipes and boilers and lowers the effectiveness of detergents.

■ **water of crystallisation**
water of hydration. Water that is stoichiometrically bound in a crystal; for example, the waters in copper sulphate pentahydrate.

■ **water softener**
soft water; water softening. Compare with water hardness A material that lowers water

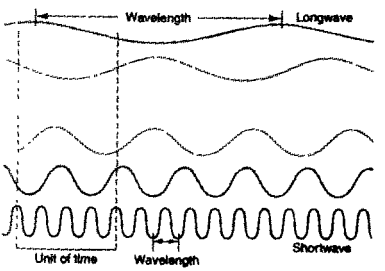
hardness when dissolved in water. For example, sodium carbonate ("washing soda") softens water by precipitating Ca^{2+} ions as $CaCO_3$. Zeolites soften water by exchanging Ca^{2+} ions with Na_+ ions.

■ **water softening**
compare with water softener and water hardness Removal of Ca^{2+} and Mg^{2+} from water to prevent undesirable precipitation reactions from occurring in plumbing, pools, washwater, and boilers.

■ **wave**
an oscillating motion that moves outward from the source of some disturbance (ripples running away from a pebble tossed in a pond). Waves transmit the energy of the disturbance away from its source.

■ **wavefunction**
a mathematical function that gives the amplitude of a wave as a function of position (and sometimes, as a function of time and/or electron spin). Wavefunctions are used in chemistry to represent the behaviour of electrons bound in atoms or molecules.

■ **wavelength**
the distance between adjacent peaks (or adjacent troughs) on a wave. Varying the wavelength of light changes its colour; varying the wavelength of sound changes its pitch.



■ **wax**
an ester formed from long-chain fatty acids and alcohols that is usually solid at room temperature.

■ **weak acid**
compare with strong acid An acid that only partially dissociates into hydrogen ions and anions in solution. Weak acids are weak electrolytes. Recognise weak acids by learning the six common strong acids; any acid that doesn't appear on the list of strong acids is usually a weak acid.

■ **weak base**
compare with strong base. base that only partially dissociates into ions in solution. Weak bases are weak electrolytes. Ammonia is an example of a weak base; the reaction $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$ is reversible.

■ **weak electrolyte**
compare with strong electrolyte . A weak electrolyte is a solute that incompletely dissociates into ions in solution. For example, acetic acid partially dissociates into acetate ions and hydrogen ions, so that an acetic acid solution contains both molecules and ions. A solution of a weak electrolyte can conduct electricity, but usually not as well as a strong electrolyte because there are fewer ions to carry the charge from one electrode to the other.

■ **weak ligand**
weak field ligand. Compare with strong field ligand A ligand that causes a small crystal field splitting which results in a high-spin complex.

■ **weight**
(W) compare with mass . Weight is the force exerted by an object in a gravitational field. The weight of an object (W) arises from its mass (m): $W = mg$ where g is the acceleration due to gravity (about 9.8 m/s^2 on Earth).

■ **wet cooling tower**
is essentially a semi-enclosed evaporative cooler.

■ **wet-bulb temperature**
is temperature measured by using a thermometer whose bulb is covered with a cotton wick saturated with water and blowing air over the wick.

■ **wetting**
covering with a surface with thin film of liquid. Liquid beads up on a surface if it cannot wet it.

■ **Wilson line**
is the locus of points where condensation will take place regardless of the initial temperature and pressure as steam flows through a high-velocity nozzle. The Wilson line is often approximated by the 4 percent moisture line on the *h-s* diagram for steam. Therefore, steam flowing through a high-

velocity nozzle is assumed to begin condensation when the 4 percent moisture line is crossed.

■ **work**
compare with heat . Work is the energy required to move an object against an opposing force. Work is usually expressed as a force times a displacement. Dropping a stone from a window involves no work, because there is no force opposing the motion (unless you consider air friction...). Pushing against a stone wall involves no work, unless the stone wall actually moves.

■ **working fluid**
is the fluid to and from which heat and work is transferred while undergoing a cycle in heat engines and other cyclic devices.

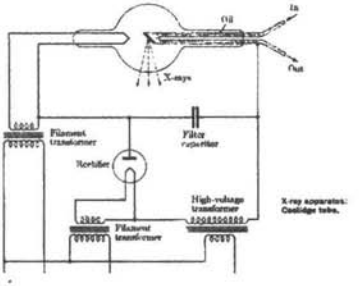
■ **X ray**
a very high energy form of electromagnetic radiation (though not as high energy as gamma rays). X-rays typically have wavelengths from a few picometers up to 20 nanometers. X-rays easily penetrate soft tissue, which makes them useful in medical imaging and in radiation therapy.

■ **X ray crystallography**
determination of three dimensional arrangement of atoms in a crystal by analysis of x-ray diffraction patterns.

■ **X ray diffraction pattern**
interference patterns created by x-rays as they pass through a solid material. Studying x-ray diffraction patterns gives detailed information on the three-dimensional structure of crystals, surfaces, and atoms.

■ **X ray spectrum**
x-ray spectra. A set of characteristic x-ray frequencies or wavelengths produced by a substance used as a target in an x-ray tube. Each element has a characteristic x-ray spectrum, and there is a strong correlation between atomic number and the frequencies of certain lines in the x-ray spectrum.

■ **X ray tube**
a cathode ray tube that focuses energetic streams of electrons on a metal target, causing the metal to emit x-rays.



■ **xenon**
xe. Element 54, a colourless, inert gas used to fill cathode ray tubes.

■ **yield**
experimental yield; actual yield. Compare with theoretical yield and percent yield . The amount of product actually obtained in a chemical reaction.

■ **-yl**
a suffix indicating a molecular fragment or group; e. g. a methyl group ($-CH_3$) derived from methane (CH_4)

■ **zeolite**
addition compounds of the type $Na_2O \cdot Al_2O_3 \cdot n\ SiO_2 \cdot m\ H_2O$, with calcium sometimes replacing or present with the sodium. The sodium in the zeolite exchanges with calcium in water, making zeolites useful for water softening. The porous structure of zeolites also makes them effective molecular sieves used as gas adsorbents and drying agents. Artificial zeolites are used as ion exchange resins.

■ **zero order reaction**
compare with first order reaction and second order reaction A reaction with a reaction rate that does not change when reactant concentrations change.

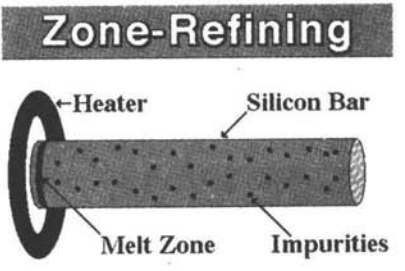
■ **zero point energy**
a minimum possible energy for an atom or molecule predicted by quantum mechanics. Electrons stay in motion and bonds continue to vibrate even at absolute zero because of zero point energy.

■ **zeroth law of thermodynamics**
states that if two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other. By replacing the third body with a thermometer, the zeroth law can be restated as two bodies are in thermal

equilibrium if both have the same temperature reading even if they are not in contact.

■ **zincography**
process of etching unprotected parts of a zinc plate with strong acids to produce a printing surface.

■ **zone refining**
a method for purifying solids based on the fact that solutes tend to concentrate in the liquid when a solution is frozen. A solid bar is drawn slowly over a heat source and melted in a narrow band; impurities are carried along in the melted band until the end of the bar is reached.



■ **zwitterion**
a particle that contains both positively charged and negatively charged groups. For example, amino acids (NH_2-CHR-COOHcan form zwitterions ($+NH_3$-CHR-COO-).

Notes

Notes