

> Glossary

absolute zero the temperature at which everything would be in its lowest energy state: 0 K or $-273.15\text{ }^{\circ}\text{C}$. The absolute scale of temperature (Kelvin scale of temperature) starts at absolute zero.

accuracy how close a measurement is to the actual value of a particular quantity.

Acid deposition a more general term than acid rain that refers to any process in which acidic substances (particles, gases and precipitation) leave the atmosphere to be deposited on the surface of the Earth – it can be divided into wet deposition (acid rain, fog and snow) and dry deposition (acidic gases and particles).

acid dissociation constant (K_a) equilibrium constant for the dissociation of a weak acid. In general, for the dissociation of acid HA, $\text{HA}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{A}^-(\text{aq})$, the expression for the acid dissociation constant is

$$K_a = \frac{[\text{A}^-(\text{aq})][\text{H}^+(\text{aq})]}{[\text{HA}(\text{aq})]}$$

The higher the value of K_a , the stronger the acid.

acid rain rain with a pH of less than 5.6. It is caused by atmospheric pollution.

activation energy (E_a) the minimum energy that colliding particles must have before collision results in a chemical reaction.

addition polymerisation a large number of monomers are joined together into a polymer chain; no other groups are lost in the process. Alkenes (containing $\text{C}=\text{C}$) undergo addition polymerisation.

addition reaction in organic chemistry, a reaction in which a molecule is added to a compound containing a multiple bond without the loss of any other groups.

adsorption the tendency of atoms/molecules/ions to 'bond' to a surface either through a chemical or a physical interaction.

aliphatic organic compounds not containing a phenyl group.

alkali a base that is dissolved in water to form a solution containing hydroxide ions.

alkali metals the elements in Group 1 of the periodic table.

allotropes different forms of the same element, e.g. diamond, graphite and fullerene are allotropes of carbon.

alloy mixture of two or more metals or of a metal with a non-metal.

amphiprotic a substance that can donate a proton (acting as a Brønsted–Lowry acid) and accept a proton (acting as a Brønsted–Lowry base), e.g. HCO_3^- .

amphoteric a substance that can act as an acid and a base.

anion a negative ion. It can be formed when an atom gains (an) electron(s) so that the ion has more electrons (–) than protons (+).

anode the electrode at which oxidation occurs.

aromatic in organic chemistry, aromatic compounds are those that contain a phenyl group.

Arrhenius equation an equation that models the variation of the rate constant with temperature:

$$k = Ae^{\frac{-E_a}{RT}}$$

' A ' is the pre-exponential factor or A -factor or Arrhenius A factor and contains information related to the frequency of collisions and the orientation of the collisions.

atom the smallest part of an element that can still be recognised as the element. In the simplest model of the atom, the electrons orbit around the central nucleus; the nucleus is made up of protons and neutrons (except for a hydrogen atom, which has no neutrons).

atom economy a measure of how efficient a particular reaction is in converting as much of the starting materials as possible into useful products.

$$\text{atom economy} = \frac{\text{molar mass of desired product}}{\text{total molar mass of all reactants}} \times 100\%$$

The higher the atom economy, the greener the process, because more of the starting materials end up in the desired product.

atomic number (Z) the number of protons in the nucleus of an atom.

atomic radius half the internuclear distance between two atoms of the same element which are covalently bonded. Atomic radius is usually called ‘covalent radius’ in more advanced work. It is also possible for an element to have a ‘van der Waals radius’.

Aufbau principle the process of putting electrons into atoms to generate the electron configuration.

average bond enthalpy the average quantity of energy required to break one mole of covalent bonds, in a gaseous molecule under standard conditions; ‘average’ refers to the fact that the bond enthalpy is different in different molecules and, therefore, the value quoted is the average quantity of energy to break a particular bond in a range of molecules.

Avogadro constant has the same numerical value as the Avogadro number but units of mol^{-1} , i.e. $6.02 \times 10^{23} \text{ mol}^{-1}$. The symbol L or N_A is used for the Avogadro constant.

Avogadro number 6.02×10^{23} . This is the number of defined particles in 1 mol of substance.

Avogadro’s law equal volumes of ideal gases measured at the same temperature and pressure contain the same number of molecules.

base ionisation constant (K_b) equilibrium constant for the ionisation of a weak base, B, which ionises according to the equation:
 $\text{B(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{BH}^+(\text{aq}) + \text{OH}^-(\text{aq})$

$$K_b = \frac{[\text{BH}^+(\text{aq})][\text{OH}^-(\text{aq})]}{[\text{B(aq)}]}$$

The higher the value of K_b , the stronger the base.

biodegradable can be broken down by microorganisms in the environment.

biofuel a fuel produced from organic matter obtained from plants, or waste material of plant/animal origin, e.g. ethanol (from the fermentation of sugar cane/corn starch), biogas (from decaying matter) and biodiesel (from vegetable oils).

biomass material of plant or animal origin that is used for fuel. The biomass can be burned directly (e.g. wood) or converted into biofuels.

boiling point the temperature at which a liquid boils under a specific set of conditions – usually we will be considering the boiling point at atmospheric pressure.

Bohr model of the atom atoms consist of a central nucleus with electrons moving around the nucleus in

circular orbits. The energy of an electron in a particular orbit (energy level/shell) is constant. Only certain orbits (energy levels/shells) can exist so the electron within an atom can only have certain amounts of energy.

bond enthalpy the enthalpy change when one mole of covalent bonds, in a gaseous molecule, is broken under standard conditions. Bond breaking requires energy (endothermic), ΔH is positive; bond making releases energy (exothermic), ΔH is negative.

bond order the number of covalent bonds between two atoms. A single bond has a bond order of 1. A double bond a bond order of 2, and a triple bond a bond order of 3. When molecules/ions are best described as resonance hybrids, the bond orders will involve fractions.

Born–Haber cycle an enthalpy level diagram breaking down the formation of an ionic compound into a series of simpler steps.

Brønsted–Lowry definition of acids and bases an acid is a proton (H^+) donor; a base is a proton (H^+) acceptor.

buffer solution a solution that resists changes in pH when small amounts of acid or alkali are added.

calibration curve a graph relating a particular variable to concentration from which concentrations of unknown solutions can be determined. It is constructed by measuring a particular property (e.g. absorbance) of solutions of known concentrations.

calorimetry experimental determination of the heat given out/taken in during chemical reactions/physical processes.

carbocation an organic molecular species with a positive charge on a carbon atom.

carbon footprint a measure of the quantity of greenhouse gases (primarily carbon dioxide and methane) emitted as a result of human activities.

carbon neutral a process/fuel which results in no net release of carbon dioxide, or other greenhouse gases, into the atmosphere.

catalyst a substance that increases the rate of a chemical reaction without itself being used up in the reaction. A catalyst acts by allowing the reaction to proceed by an alternative pathway of lower activation energy.

cathode the electrode at which reduction occurs.

cation a positive ion. It can be formed when an atom loses (an) electron(s) so that the ion has more protons (+) than electrons (−).

chain reaction a process in which one initial event causes a large number of subsequent reactions – the reactive species is regenerated in each cycle of reactions.

charge density the charge on an ion divided by its volume. The higher the charge or the smaller the ion, the greater the charge density.

chemical properties how a substance behaves in chemical reactions.

chemical shift (δ) The horizontal scale in an NMR spectrum that indicates the chemical environment of a proton (^1H) or group of protons. The value is a ratio and is expressed in ppm. Chemical shift values for protons in different environments are given in the IB data booklet.

chiral a molecule is chiral if mirror images are non-superimposable. To be chiral, the molecule must possess a chirality (chiral) centre and not have a centre of symmetry.

chirality centre (chiral centre) a carbon atom with four different atoms or groups attached to it (sometimes called an asymmetric carbon atom) that makes a molecule chiral.

cis–trans isomerism where two compounds have the same structural formula, but the groups are arranged differently in space around a double bond or a ring.

closed system a system where there is no exchange of matter with the surroundings.

collision theory a model that is used to explain the variation of rate of reaction. A reaction can occur only when two particles collide in the correct orientation and with $E \geq E_a$.

complex ion an ion formed when a central transition metal atom/ion is bonded to ligands, e.g. $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$. The ligands form coordination bonds to the transition metal atom/ion.

compound a pure substance formed when two or more elements combine chemically in a fixed ratio.

concentration quantity of solute dissolved in a unit volume of solution; the volume that is usually taken is 1 dm^3 (one litre); the quantity of solute may be expressed in g or mol, so the units of concentration are g dm^{-3} or mol dm^{-3} .

condensation polymerisation monomers, each containing two functional groups, join together to form a long chain, with the elimination of a small molecule, such as water or hydrogen chloride, each time two monomers join together.

condensed structural formula shows how the atoms are joined together in a molecule but does not show all of the bonds, e.g. $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$.

conjugate acid–base pair two species that differ by one proton (H^+). When an acid donates a proton, it forms its conjugate base (CH_3COO^- is the conjugate base of CH_3COOH); when a base gains a proton, it forms its conjugate acid (H_3O^+ is the conjugate acid of H_2O).

continuous spectrum a spectrum consisting of all frequencies/wavelengths of light.

convergence limit the point in a line emission spectrum where the lines merge to form a continuum. In the emission spectrum of hydrogen, the frequency of the convergence limit in the series of lines where the electron falls down to $n = 1$, may be used to determine the ionisation energy of hydrogen.

coordination bond a type of covalent bond in which both electrons come from the same atom. Also called a dative bond or coordinate covalent bond.

coordination number in an ionic crystal, it is the number of nearest neighbours, of opposite charge, for an ion in a crystal. For a molecular entity/complex ion, it is the number of atoms that the central atom/ion is bonded to.

covalent bond the electrostatic attraction between a shared pair of electrons and the nuclei of the atoms making up the bond.

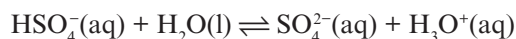
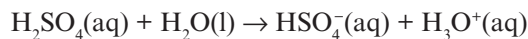
covalent network structure the structure of substances such as diamond and graphite that contain an extended network of covalently bonded atoms and not individual molecules. This is also called a giant covalent structure.

degenerate a set of orbitals with the same energy.

delocalisation the sharing of a pair of electrons between three or more atoms.

diamagnetism a magnetic property of atoms/ions/molecules caused by the presence of paired electrons – diamagnetic substances are repelled slightly by a magnetic field.

diprotic acid H_2SO_4 is a diprotic acid, as it can dissociate to form two protons per molecule:



ductile can be drawn out into wires.

dynamic equilibrium in a reversible reaction (process), macroscopic properties (all concentrations of reactants and products) are constant and the rate of the forward reaction is equal to the rate of the reverse reaction.

effective nuclear charge the nuclear charge experienced by electrons when shielding is taken into account.

$$\text{effective nuclear charge} = \text{actual nuclear charge} - \text{shielding effect}$$

electrochemical cells a device that interconverts chemical energy and electrical energy. These are of two main types:

- voltaic cell: chemical energy is converted into electrical energy – a chemical reaction produces electrical energy
- electrolytic cell: electrical energy is converted into chemical energy – electricity is used to bring about a chemical reaction.

electrochemical series metals can be arranged in an electrochemical series in order of how readily they are oxidised to an aqueous positive ion. The standard electrode potential (*standard reduction potential* in the IB data booklet) is a measure of this and metals can be arranged in order from the most negative standard electrode potential (most readily oxidised/strongest reducing agent/most reactive) to least negative/most positive standard electrode potential (least readily oxidised/weakest reducing agent/least reactive).

electrolysis the breaking down of a substance (in molten state or solution) by the passage of electricity through it.

electrolyte a solution, or a molten compound, that will conduct electricity due to the presence of ions that are free to move towards the electrodes.

electron domain a lone pair, the electron pair that makes up a single bond or the electron pairs that together make up a multiple bond. Each single, double or triple bond counts as one electron domain when working out shapes of molecules.

electronegativity a measure of the attraction of an atom in a molecule for the electron pair in the covalent bond of which it is a part. A more electronegative atom attracts electrons more strongly.

electrophile a reagent (a positively charged ion or the positive end of a dipole) that is attracted to regions of high electron density and accepts a pair of electrons to form a covalent bond. An electrophile is a Lewis acid.

electrophilic addition an addition reaction where the initial attack on the organic molecule is by an electrophile. Alkenes (and alkynes) undergo electrophilic addition reactions.

electrophilic substitution substitution reaction where the initial attack on the organic molecule is by an electrophile. Benzene undergoes electrophilic substitution.

electroplating the process of coating an object with a thin layer of a metal using electrolysis.

electrostatic attraction attraction between positive and negative charges.

element a chemical substance that cannot be broken down into a simpler substance by chemical means. Each atom has the same number of protons in the nucleus.

emission spectrum electromagnetic radiation given out when an electron in an atom falls from a higher energy level to a lower one. Only certain frequencies of electromagnetic radiation are emitted – a line spectrum. Each atom has a different emission spectrum. For hydrogen, the emission spectrum in the visible region consists of a series of coloured lines that get closer together at higher frequency.

empirical formula the simplest whole number ratio of the elements present in a compound.

enantiomers the non-superimposable mirror images of a chiral molecule.

endothermic reaction a chemical reaction in which heat is taken in from the surroundings – the reaction vessel gets colder; ΔH for an endothermic reaction is positive.

end point in a titration, the point at which an indicator changes colour.

enthalpy change (ΔH) the heat energy exchanged with the surroundings at constant pressure.

entropy (S) a measure of the disorder of a system (how the matter is dispersed/distributed) or how the available energy is distributed among the particles.

Standard entropy (S^\ominus) is the entropy of a substance at 100 kPa and 298.15 K; units are $\text{J K}^{-1} \text{mol}^{-1}$. ΔS^\ominus is the entropy change under standard conditions – a positive value indicates an increase in entropy, i.e., the system becomes more disordered/the energy becomes more spread out (less concentrated).

equilibrium a reversible reaction will eventually reach a state of equilibrium. At this point, all concentrations are constant (macroscopic properties are constant). See also *dynamic equilibrium*.

equilibrium law / equilibrium constant the ratio of the concentrations (raised to the powers of the coefficients in the stoichiometric equation) of products to reactants at equilibrium is equal to the equilibrium constant, K .

So, for the reaction: $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$

$$K = \frac{[\text{HI}(\text{g})]^2}{[\text{H}_2(\text{g})][\text{I}_2(\text{g})]}$$

equivalence point in a titration, the point at which equivalent numbers of moles of acid and alkali have been added.

excited state an energy state for an atom (or molecule) that has higher energy than the ground state.

exothermic reaction a chemical reaction that results in the release of heat to the surroundings – the reaction vessel gets hotter; ΔH for an exothermic reaction is negative.

experimental (or actual) yield the amount/mass of desired product actually formed in a reaction.

first electron affinity enthalpy change when one electron is added to each atom in one mole of gaseous atoms under standard conditions: $\text{X}(\text{g}) + \text{e}^- \rightarrow \text{X}^-(\text{g})$. The first electron affinity is exothermic for virtually all elements.

first ionisation energy the minimum amount of energy required to remove an electron from a gaseous atom/the energy required to remove one electron from each atom in one mole of gaseous atoms under standard conditions. The energy for the process: $\text{M}(\text{g}) \rightarrow \text{M}^+(\text{g}) + \text{e}^-$.

formal charge (FC) the charge that an atom in a molecule/ion would have if we assumed that the electrons in a covalent bond were equally shared between the atoms that are bonded – i.e., we assume that all atoms have the same electronegativity. Formal charge arises when there is a charge on an ion and/or when coordination bonds are formed. The two electrons

in a coordination bond are shared equally between the donating atom (which, therefore, has a formal charge of +1) and the receiving atom (which then has a formal charge of –1).

fossil fuels fuels formed from things that were once alive and have been buried underground for millions of years, e.g. coal, oil and gas.

fragmentation pattern the series of peaks in a mass spectrum formed by ions that have been generated when the molecular ion breaks apart in the mass spectrometer.

fuel something that is burnt to produce energy.

fuel cell a type of electrochemical cell that uses the reaction between a fuel (such as hydrogen or methanol) and an oxidising agent (e.g. oxygen) to produce electrical energy directly. It uses a continuous supply of reactants from an external source.

full structural formula shows *all* atoms and *all* bonds in a molecule. This is also called a displayed or graphic formula.

functional group an atom or group of atoms that gives an organic molecule its characteristic chemical properties. A functional group also influences the physical properties of a compound.

giant structure one in which bonding extends fairly uniformly throughout the whole structure; there are no individual molecules, e.g. an ionic crystal or diamond.

Gibbs energy change (ΔG) (sometimes called the free energy change) ΔG is related to the entropy change of the universe and can be defined using the equation $\Delta G = \Delta H - T\Delta S$. For a reaction to be spontaneous, ΔG for the reaction must be negative. ΔG^\ominus is the standard Gibbs energy change.

ground state the lowest possible energy state for an atom (or molecule).

group vertical column in the periodic table. These are numbered from 1 to 18, including the transition element groups.

heat the energy that flows from something at a higher temperature to something at a lower temperature because of the temperature difference between them.

Hess's law the enthalpy change accompanying a chemical reaction is independent of the pathway between the initial and final states.

heterogeneous mixture a mixture of two or more substances, that does not have uniform composition and consists of separate phases. A heterogeneous mixture can be separated by mechanical means. An example is a mixture of two solids.

heterolytic fission a covalent bond breaks so that both electrons go to the same atom.

homogeneous mixture a mixture of two or more substances with the same (uniform) composition throughout the mixture – it consists of only one phase. Examples are solutions or a mixture of gases.

homologous series a series of compounds with the same functional group, in which each member differs from the next by $\text{—CH}_2\text{—}$.

homolytic fission a covalent bond breaks such that one electron goes back to each atom making up the original covalent bond.

Hund's rule electrons fill orbitals of the same energy (degenerate orbitals) to give the maximum number of electrons with the same spin.

hybridisation the mixing of atomic orbitals when a compound forms to produce a new set of orbitals (the same number as originally), which are better arranged in space for covalent bonding.

hydrocarbon a compound containing carbon and hydrogen only.

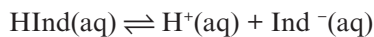
hydrogenation addition of hydrogen (H_2) to a compound containing multiple bonds.

hydrogen bonding an intermolecular force resulting from the interaction of a lone pair on a very electronegative atom (N/O/F) in one molecule with an H atom attached to N/O/F in another molecule. These forces may also occur between atoms in different parts of the same molecule.

hydrolysis a reaction in which a covalent bond in a molecule is broken by reaction with water; most commonly, hydrolysis reactions occur when a molecule is reacted with aqueous acid or aqueous alkali.

ideal gas a theoretical model that approximates the behaviour of real gases. It can be defined in terms of macroscopic properties (a gas that obeys the equation $PV = nRT$) or in terms of microscopic properties (the main assumptions that define an ideal gas on a microscopic scale are that the molecules are point masses – their volume is negligible compared with the volume of the container – and that there are no intermolecular forces except during a collision).

indicator an acid–base indicator has different colours, according to the pH of the solution. Indicators are usually weak acids (HInd); they dissociate according to the following equation:



colour I colour II

the ionised (Ind^-) and un-ionised (HInd) forms must have different colours. Indicators may also be weak bases.

initiation step the step that starts off the chain reaction in a radical substitution reaction. It involves an increase in the number of radicals.

intermolecular forces forces between molecules. These include London forces, permanent dipole–permanent dipole interactions and hydrogen bonding.

intramolecular forces forces within a molecule – usually covalent bonding.

ion a charged particle that is formed when an atom (or molecular entity) loses or gains electron(s); a positive ion is formed when an atom loses (an) electron(s) and a negative ion is formed when an atom gains (an) electron(s).

ionic bonding the electrostatic attraction between oppositely charged ions.

ionisation energy see first ionisation energy.

ion product constant of water (K_w) an equilibrium constant for the dissociation of water:

$$K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})]$$

K_w has a value of 1.0×10^{-14} at 25°C . The ion product constant is also known as the ionic product constant.

isoelectronic species with the same number of electrons.

isotopes different atoms of the same element with different mass numbers, i.e., different numbers of neutrons in the nucleus. Isotopes have the same chemical properties but different physical properties.

kinetic energy the energy a body has because of its motion; $E_k = \frac{1}{2}mv^2$.

lattice enthalpy see standard lattice enthalpy

lattice usually used when describing crystals – a structure with a regular, repeating (3D) arrangement.

leaving group an atom/ion/group of atoms that is lost from the substrate when a bond is broken in a reaction.

Le Chatelier's principle if a system at equilibrium is subjected to some change, the position of equilibrium will shift in order to minimise the effect of the change.

Lewis definition of acids and bases an acid is an electron-pair acceptor; a base is an electron-pair donor.

Lewis (electron dot) formula a diagram showing all the valence (outer-shell) electrons in a molecule (or ion). Also called a Lewis structure.

ligand negative ion or neutral molecule that uses lone pairs of electrons to bond to a transition element ion to form a complex ion. Coordination bonds are formed between the ligand and the transition element ion.

limiting reactant the reactant that is used up first in a chemical reaction; when the amount in moles of each species is divided by their coefficient in the stoichiometric equation, the limiting reactant is the one with the lowest number; all other reactants are in excess.

line spectrum the emission spectrum of an atom consists of a series of lines; only certain frequencies/wavelengths of light are present.

lone pair of electrons a pair of electrons in the outer shell of an atom that is not involved in covalent bonding.

London (dispersion) forces intermolecular forces resulting from temporary (instantaneous) dipole-induced dipole interactions.

malleable can be hammered into different shapes.

Markovnikov's rule 'rule' that can be used to predict the major product when HX adds to an unsymmetrical alkene. When H—X adds across the double bond of an alkene, the H atom becomes attached to the C atom that has the larger number of H atoms already attached.

mass number (*A*) the total number of protons plus neutrons in the nucleus of an atom.

Maxwell-Boltzmann distribution a graph showing the distribution of molecular kinetic energies in a sample of gas at a particular temperature.

metallic bonding the electrostatic attraction between the positive ions in a metallic lattice and the delocalised electrons.

metalloid elements, such as Si, Ge and Sb, that have some of the properties of both metals and non-metals or properties that are intermediate between those of a metal and non-metal.

mixture two or more substances mixed together. The components of a mixture can be mixed together in any

proportion (although there are limits for solutions). The components of a mixture are not chemically bonded together, and so, retain their individual properties. The components of a mixture can be separated from each other by physical processes.

mobile phase the phase that moves in chromatography, e.g. the solvent moving up the paper in paper chromatography.

molar mass (*M*) the mass that contains 1 mol of particles (atoms, molecules, ions) and is the A_r or M_r in grams of the substance. The units of molar mass are g mol^{-1} .

molar volume the volume occupied by one mole of a gas; the molar volume of an ideal gas at STP is $22.7 \text{ dm}^3 \text{ mol}^{-1}$.

mole the unit of the amount of substance. The amount of substance that contains the Avogadro number (6.02×10^{23}) of particles (atoms, ions, molecules, etc.)

molecular formula the total number of atoms of each element present in a molecule of the compound. The molecular formula is a multiple of the empirical formula.

molecularity the number of reactant 'molecules' that take part in a particular elementary step in a reaction mechanism.

molecule an electrically neutral particle consisting of two or more atoms chemically bonded together.

monomer a molecule from which a polymer chain may be built up, e.g. ethene is the monomer for polyethene.

monoprotic acid HCl is a monoprotic acid as it dissociates to form one proton per molecule.

neutralisation reaction a chemical reaction in which an acid reacts with a base/alkali to form a salt plus water. Neutralisation reactions are exothermic.

noble gases the elements in Group 18 of the periodic table.

non-renewable energy sources sources of energy that are finite – they will eventually run out, e.g. coal.

nucleophile a molecule or a negatively charged ion, possessing a lone pair of electrons, which is attracted to a more positively charged region in a molecule (region with lower electron density) and donates a lone pair of electrons to form a covalent (coordination) bond. A nucleophile is a Lewis base.

nucleophilic substitution a type of reaction in organic chemistry in which initial attack on the molecule is by a nucleophile and the nucleophile replaces an atom/group, e.g. when a halogenoalkane is attacked by an OH^- nucleophile, the OH replaces the halogen atom.

octet rule electrons will be shared so that the central atom has eight electrons in its outer (valence) shell. There are, however, many exceptions to the octet rule.

optical isomerism optical isomers (enantiomers) rotate the plane of plane-polarised light in opposite directions (by the same amount as long as concentrations are equal). Optical isomers have the same molecular and structural formula, but groups are arranged differently in space and the individual optical isomers are non-superimposable mirror images of each other.

optically active a substance is optically active/demonstrates optical activity if it rotates the plane of polarisation of plane-polarised light.

orbital a region of space in which there is a high probability of finding an electron; it represents a discrete energy level. There are s, p, d and f orbitals. One orbital can contain a maximum of two electrons.

orbital diagrams diagrams that show the electron configuration of atoms/ions using arrows (electrons) in boxes (orbitals).

order of a reaction the power of the concentration of a particular reactant in the experimentally determined rate equation. e.g. in the rate equation: $\text{rate} = k[\text{A}]^m[\text{B}]^n$, the order with respect to A is m and the order with respect to B is n .

overall order of reaction the sum of the powers of the concentration terms in the experimentally determined rate equation. e.g. in the rate equation: $\text{rate} = k[\text{A}]^m[\text{B}]^n$, the overall order is $m + n$.

oxidation a process which involves a loss of electrons or an increase in oxidation state. Oxidation can also be defined in terms of the gain of oxygen or the loss of hydrogen, but these are less general definitions.

oxidation state (oxidation number) the degree of oxidation of an atom in terms of counting electrons. It is a purely formal concept that regards all compounds as ionic and assigns charges to the components accordingly; it provides a guide to the distribution of electrons in covalent compounds.

oxidising agent (oxidant) oxidises other species and, in the process, is itself reduced; an oxidising agent takes electrons away from another species.

paramagnetism a magnetic property of atoms/ions/molecules caused by the presence of unpaired electrons – paramagnetic substances are attracted by a magnetic field.

partition the tendency of a solute to distribute itself between two immiscible solvents due to its solubility in each.

Pauli exclusion principle two electrons in the same orbital must have opposite spins.

percentage yield the percentage yield compares the actual, experimental, yield and the theoretical, maximum, yield:

$$\% \text{ yield} = \frac{\text{experimental yield}}{\text{theoretical yield}} \times 100$$

period horizontal row in the periodic table. Hydrogen and helium are in Period 1.

pH a measure of the concentration of H^+ ions in an aqueous solution; it can be defined as the negative logarithm to base ten of the hydrogen ion concentration in aqueous solution:

$$\text{pH} = -\log_{10} [\text{H}^+(\text{aq})]$$

pH range of an indicator the pH range over which intermediate colours for an indicator can be seen because comparable amounts of the un-ionised and ionised forms are present.

photon particle of electromagnetic radiation. The energy of a photon is proportional to the frequency of the electromagnetic radiation and inversely proportional to its wavelength.

physical properties properties such as melting point, solubility and electrical conductivity, relating to the physical state of a substance and the physical changes it can undergo.

pi (π) bond bond formed by the sideways overlap/combination of parallel p orbitals; the electron density in the pi bond lies above and below the internuclear axis.

plane-polarised light light that vibrates in one plane only. Enantiomers rotate the plane of plane-polarised light in opposite directions.

polar molecule molecule in which one end is slightly positive relative to the other. Whether a molecule is polar or not depends on the differences in electronegativity of the atoms and the shape of the molecule.

polyamide a polymer where the monomers are linked together by amide functional groups. They are formed in condensation polymerisation reactions.

polyester a polymer where the monomers are linked together by ester functional groups. They are formed in condensation polymerisation reactions.

polymerisation the process of joining together a large number of monomers to form a long chain molecule (polymer). There are two types of polymerisation: addition and condensation.

polymers long-chain molecules, usually based on carbon, which are formed when smaller molecules (monomers) join together.

position of equilibrium the relative amounts of reactants and products present in a system at equilibrium.

primary cell a cell (battery) that cannot usually be recharged by connecting to an electricity supply – the reaction in the cell is non-reversible. A voltaic cell is also referred to as a primary cell on the IB syllabus.

propagation step a step in a radical substitution reaction that involves production of products and no change in the number of radicals.

racemic mixture (racemate) an equimolar mixture of the two enantiomers of a chiral compound; it has no effect on plane-polarised light – it is optically inactive.

radical a molecular entity (atom or group of atoms) with an unpaired electron. Radicals are very reactive because of this unpaired electron.

random error uncertainty in a measurement due to the limitations of the measuring apparatus and other uncontrollable variables that are inevitable in any experiment. The effects of random uncertainties should mean that the measurements taken will be distributed either side of the mean, i.e. fluctuations will be in both directions. The effect of random uncertainties can be reduced by repeating the measurements more often, but random uncertainties can never be completely eliminated.

rate-determining step the slowest step in a reaction mechanism. It is the step with the highest activation energy.

rate constant (k) a constant of proportionality relating the concentrations in the experimentally determined rate expression to the rate of a chemical reaction. The rate constant is only a constant for a particular reaction at a particular temperature.

rate equation (rate expression/rate law) an experimentally determined equation that relates the rate of reaction to the concentrations of substances in the reaction mixture, e.g. $\text{rate} = k[\text{A}]^m[\text{B}]^n$.

rate of reaction the speed at which reactants are used up or products are formed or, more precisely, the change in concentration of reactants or products per unit time:

$$\text{average rate} = \frac{\text{change in concentration}}{\text{time}}$$

It could also be defined in terms of change in mass or volume etc. over time.

reaction quotient (Q) the ratio of the concentrations of the reactants and products (raised to the appropriate powers) at any point in time. An expression for Q is exactly the same as that for the equilibrium constant, except that the concentrations are not equilibrium concentrations.

So, for the reaction: $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$

$$Q = \frac{[\text{HI}(\text{g})]^2}{[\text{H}_2(\text{g})][\text{I}_2(\text{g})]}$$

redox reaction a reaction involving both oxidation and reduction; if one species is oxidised, another species must be reduced.

reducing agent (reductant) reduces other species and, in the process, is itself oxidised; a reducing agent gives electrons to another species.

reduction a process that involves gain of electrons or decrease in oxidation state. Reduction can also be defined in terms of the loss of oxygen or the gain of hydrogen, but these are less general definitions.

reflux a technique for heating volatile substances in a laboratory. The flask has a condenser attached vertically. The vapours cool in the condenser and condense so that they run back into the flask without escaping.

relative atomic mass (A_r) the average mass of the naturally occurring isotopes of an element relative to the mass of $\frac{1}{12}$ of an atom of carbon-12.

relative formula mass if a compound contains ions, the relative formula mass is the average mass of the formula unit relative to the mass of $\frac{1}{12}$ of an atom of carbon-12.

relative molecular mass (M_r) the average mass of a molecule of a compound relative to the average mass of $\frac{1}{12}$ of an atom of carbon-12; M_r is the sum of the relative atomic masses of the individual atoms making up a molecule.

renewable energy sources sources of energy that are naturally replenished – they will not run out, e.g. solar energy or wind power.

repeating unit (repeat unit) of a polymer the basic unit from which the whole polymer chain can be made up.

resonance energy the difference in energy between the actual (delocalised) structure of a molecule and the energy of a theoretical resonance structure. Used as a term to describe the ‘extra’ stability arising from delocalisation.

resonance hybrid the actual structure of a molecule/ion for which resonance structures can be drawn can be described as a resonance hybrid made up of contributions (not necessarily equal) from all possible resonance structures.

resonance structure one of several Lewis formulas that can be drawn for some molecules/ions.

R_F (retardation factor) value in chromatography:

$$R_F = \frac{\text{distance solute moves}}{\text{distance solvent front moves}}$$

reversible reaction a reaction that can go either way; the reactants become the products, but the products of the reaction can also react to re-form the reactants. The symbol \rightleftharpoons shows that a reaction is reversible. A reversible reaction will eventually reach a state of equilibrium.

salt a compound formed when the hydrogen ion (H^+) in an acid is replaced by a metal ion (or ammonium ion).

salt bridge completes the circuit in a voltaic cell by providing an electrical connection between two half-cells, allowing ions to flow into or out of the half-cells to balance out the charges in the half-cells. A salt bridge contains a concentrated solution of an ionic salt, such as KCl.

saturated when referring to organic compounds, it is a compound containing only single bonds between carbon atoms.

saturated solution a solution that contains the maximum amount of dissolved solute at a particular temperature.

secondary cell a cell (battery) that can be recharged by connecting to an electricity supply, and is often called a rechargeable battery. The chemical reactions in a rechargeable battery are reversible and can be reversed by connecting them to an electricity supply.

serial dilutions successive dilutions of a solution.

shielding the ability of electrons (usually those in inner shells) to shield/screen/insulate other electrons from the attractive force of the nucleus.

sigma (σ) bond bond formed by the axial (head-on) overlap/combination of atomic orbitals. The electron density in a sigma bond lies mostly along the axis joining the two nuclei.

skeletal formula a representation of the structure of a molecule that shows only the bonds in the carbon skeleton and any groups joined to the carbon skeleton. The carbon atoms are not shown explicitly nor are hydrogen atoms joined to carbon.

S_N1 a unimolecular nucleophilic substitution reaction – only one species is involved in the rate-determining step. The main mechanism for nucleophilic substitution in tertiary halogenoalkanes.

S_N2 a bimolecular nucleophilic substitution reaction – two species are involved in the rate-determining step. The main mechanism for nucleophilic substitution in primary halogenoalkanes.

solute a substance that is dissolved in another (the solvent) to form a solution.

solution that which is formed when a solute dissolves in a solvent.

solvent a substance that dissolves another substance (the solute); the solvent should be present in excess of the solute.

specific energy the energy released from a fuel per unit mass of fuel consumed.

specific heat capacity the energy required to raise the temperature of 1 g of substance by 1 K (1 °C). It can also be defined as the energy to raise the temperature of 1 kg of substance by 1 K. Specific heat capacity has units of $J\ g^{-1}\ K^{-1}$ or $J\ g^{-1}\ ^\circ C^{-1}$. Units that are also encountered are $kJ\ kg^{-1}\ K^{-1}$ or $J\ kg^{-1}\ K^{-1}$.

spectrochemical series a series of ligands arranged in order of the extent to which they cause splitting of d orbitals in a transition metal complex ion.

spontaneous reaction a reaction that occurs without any outside influence, i.e., no input of energy. ΔG is negative for a spontaneous reaction.

stability usually refers to the relative energies of reactants and products – if the products are at lower enthalpy (energy) than the reactants, then they are more stable. It is also possible to define *kinetic* stability.

standard cell potential the electromotive force (voltage) produced when two half-cells are connected under standard conditions (all concentrations 1 mol dm^{-3} and pressure 100 kPa). This drives the movement of electrons through the external circuit from the negative electrode to the positive electrode.

standard conditions a common set of conditions used to compare enthalpy changes; the pressure is 100 kPa and for reactions involving solutions, all solutions should have a concentration of 1 mol dm^{-3} . A temperature is not stated in the definition and should be specified – when it is not specified, we will assume in this course that it is 298.15 K (25°C). All substances must be in their standard state.

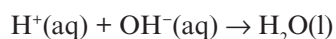
standard electrode potential the electromotive force (voltage) of a half-cell connected to a standard hydrogen electrode, measured under standard conditions; all solutions must be of concentration 1 mol dm^{-3} and pressure must be 100 kPa . A standard electrode potential is always quoted for the reduction reaction.

standard enthalpy change of atomisation ($\Delta H_{\text{at}}^\ominus$) the enthalpy change when one mole of gaseous atoms is formed from an element in its standard state under standard conditions.

standard enthalpy change of combustion ($\Delta H_{\text{c}}^\ominus$) the enthalpy change when one mole of a substance is completely burnt in oxygen under standard conditions.

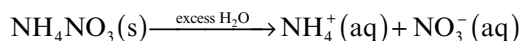
standard enthalpy change of formation ($\Delta H_{\text{f}}^\ominus$) the enthalpy change when one mole of a substance is formed from its elements in their standard states under standard conditions. $\Delta H_{\text{f}}^\ominus$ for any element in its standard state is zero.

standard enthalpy change of neutralisation ($\Delta H_{\text{n}}^\ominus$) the enthalpy change when one mole of H_2O molecules is formed when an acid (H^+) reacts with an alkali (OH^-) under standard conditions, i.e.



standard enthalpy change of reaction ($\Delta H_{\text{r}}^\ominus$) the enthalpy change (heat given out or taken in) when molar amounts of reactants, as shown in the stoichiometric equation, react together under standard conditions.

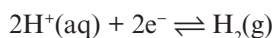
standard enthalpy change of solution ($\Delta H_{\text{sol}}^\ominus$) the enthalpy change when one mole of solute is dissolved in excess solvent to form a solution of ‘infinite dilution’ under standard conditions, e.g.



‘infinite dilution’ means that any further dilution of the solution produces no further enthalpy change, i.e., the solute particles are assumed not to interact with each other in the solution.

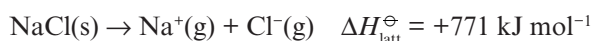
standard hydrogen electrode the standard half-cell relative to which standard electrode potentials are measured. Hydrogen gas at 100 kPa (1 bar) pressure is bubbled around a platinum electrode of very high surface area in a solution of H^+ ions of concentration 1 mol dm^{-3} .

The reaction occurring in this half-cell is



and this is assigned a standard electrode potential (E^\ominus) of 0.00 V .

standard lattice enthalpy ($\Delta H_{\text{latt}}^\ominus$) the enthalpy change when one mole of ionic compound is broken apart into its constituent gaseous ions under standard conditions, e.g., for NaCl :



Lattice enthalpy can be defined in either direction, i.e. as the making or breaking of the lattice, but in the IB syllabus it is usually defined in terms of breaking apart the lattice.

standard solution a solution of known concentration.

standard state the pure substance at 100 kPa and a specified temperature (assume 298.15 K if one is not given). It is often used to refer the state in which a substance exists under standard conditions, e.g. at 298.15 K for iodine it is $\text{I}_2(\text{s})$ but for nitrogen it is $\text{N}_2(\text{g})$.

standard temperature and pressure (STP) 273.15 K , 100 kPa pressure.

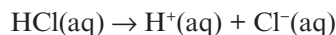
state symbols are used to indicate the physical state of an element or compound: (aq) = aqueous (dissolved in water); (g) = gas; (l) = liquid; (s) = solid.

stationary phase in chromatography, the phase that does not move; this may be the water coating the fibres in paper chromatography or the solid adsorbent in thin-layer chromatography.

stereochemical formula a diagram of a molecule that shows the spatial arrangement of the atoms/groups. Solid wedges show a bond coming out of the plane of the paper/screen and dashed wedges shows bonds going into the plane.

stereoisomers molecules with the same molecular formula and structural formula, but the atoms are arranged differently in space; *cis-trans* isomers and optical isomers are stereoisomers.

strong acid an acid, such as HCl , H_2SO_4 , HNO_3 , that dissociates completely in aqueous solution:



strong base a base that ionises completely in aqueous solution; strong bases are the Group 1 hydroxides (LiOH , NaOH , etc.) and Ba(OH)_2 .

structural isomers two or more compounds that have the same molecular formula but different structural formulas, i.e., the atoms are joined together in a different way.

sub-level/subshell an orbital (in the case of s) or a group of degenerate orbitals (for p, d, f) in an atom, that make up part of a main energy level/shell. The p sub-level/subshell is made up of the p_x , p_y and p_z orbitals.

substitution reaction a reaction in which one atom or group is replaced by another atom or group.

substrate the main chemical species that undergoes a reaction and is transformed into something else.

systematic error an error introduced into an experiment due to the apparatus used or the procedure. Systematic errors result in a loss of accuracy, i.e., the measured value being further away from the true value. Systematic errors are always in the same direction. The effect of a systematic error cannot be reduced by repeating the readings.

temperature a measure of the average kinetic energy of particles.

termination step the step that ends a radical substitution chain reaction – it involves a decrease in the number of radicals.

theoretical yield the maximum possible amount/mass of the desired product formed in a reaction.

thermoplastic a type of polymer that softens when it is heated and hardens when it is cooled; it can be repeatedly heated and cooled and remoulded into different shapes.

thermoset polymer material with extensive cross-linking that cannot be remoulded.

titration a technique that involves adding measured volumes of a solution (from a burette) to another solution to determine the amounts that react exactly with each other.

transition metals/elements the elements in the central part (d block) of the periodic table. There are various ways of defining a transition element. IUPAC definition: ‘an element whose atoms have an incomplete (partially filled) d sub-shell or forms positive ions with an incomplete (partially filled) d sub-shell’.

transition state (activated complex) a local maximum on an energy profile/the highest energy species on the reaction pathway between reactants/intermediates and intermediates/products.

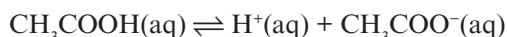
unpaired electron an electron in an orbital by itself – it is not paired with another electron of the opposite spin.

unsaturated organic compounds containing multiple bonds between carbon atoms. This term is usually just applied to compounds containing $\text{C}=\text{C}$ and $\text{C}\equiv\text{C}$ and not to compounds containing multiple bonds to other atoms, e.g. $\text{C}=\text{O}$.

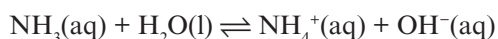
van der Waals forces the collective name given to the forces between molecules and includes London (dispersion) forces, dipole–dipole interactions and dipole–induced dipole interactions but not hydrogen bonding and ion–dipole interactions.

water of crystallisation water that is present in definite proportions in the crystals of hydrated salts, e.g. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$. The water may or may not be directly bonded to the metal (in hydrated copper sulfate, four water molecules are bonded to the copper ion and one is not). When the crystals dissolve in water, the water of crystallisation just becomes part of the solvent.

weak acid an acid, such as a carboxylic acid (ethanoic acid, propanoic acid, etc.) or carbonic acid (H_2CO_3), that dissociates only partially in aqueous solution:



weak base a base that ionises only partially in aqueous solution, e.g., ammonia and amines:



yield the amount/mass of the desired product obtained from a chemical reaction. See also *experimental (or actual) yield*, *percentage yield* and *theoretical yield*.