I

IAA (indoleacetic acid) *See* AUXIN.

ice *See* WATER.

ice age A period in the earth's history during which ice advanced towards the equator and a general lowering of temperatures occurred. The last major ice age, that of the Pleistocene epoch (sometimes known as the **Ice Age**), ended about 10 000 years ago. At least four major ice advances (glacials) occurred during the Pleistocene; these were separated by interglacials during which the ice retreated and temperatures rose. At present it is not known if the earth is between ice ages or is in an interglacial of the Pleistocene Ice Age. It has been established that ice ages also occurred during the Precambrian (over 500 million years ago) and during the Permo-Carboniferous (about 250 million years ago).

ice point The temperature at which there is equilibrium between ice and water at standard atmospheric pressure (i.e. the freezing or melting point under standard conditions). It was used as a fixed point (0°) on the Celsius scale, but the kelvin and the International Practical Temperature Scale are based on the *triple point of water.

ichthyosaur Any extinct aquatic reptile belonging to the order Ichthyosauria, which lived during the Mesozoic era (250–90 million years ago). The earliest forms resembled lizards with flippers and probably swam in an eel-like fashion. Their successors evolved to become progressively more fishlike, with thickened bodies, finlike fore and hind limbs, and crescent-shaped tails. Fossilized skeletal remains show that the eyes were unusually large and adapted for hunting in poor visibility. Ichthyosaurs typically lived on a diet of squid, and some species attained lengths of over 15 m.

iconoscope A form of television camera tube (*see* CAMERA) in which the beam of light from the scene is focused on to a thin mica plate. One side of the plate is faced with a thin metallic electrode, the other side being coated with a mosaic of small globules of a photoemissive material. The light beam falling on the mosaic causes photoemission of electrons, creating a pattern of positive charges in what is effectively an array of tiny capacitors. A high-velocity electron beam scans the mosaic, discharging each capacitor in turn through the metallic electrode. The resulting current is fed to amplification circuits, the current from a particular section of the mosaic depending on the illumination it has received. In this way the optical information in the light beam is converted into an electrical signal.

ICSH *See* LUTEINIZING HORMONE.

ideal crystal A single crystal with a perfectly regular lattice that contains no impurities, imperfections, or other defects.

ideal gas (perfect gas) A hypothetical gas that obeys the *gas laws exactly. An ideal gas would consist of molecules that occupy negligible space and have negligible forces between them. All collisions made between molecules and the walls of the container or between molecules and other gas molecules would be perfectly elastic, because the molecules would have no means of storing energy except as translational kinetic energy.

ideal solution *See* RAOULT'S LAW.

identical twins (monozygotic twins) Two individuals that develop from a single fertilized egg cell by its division into two genetically identical parts. Each part eventually gives rise to a separate individual and these twins have identical DNA sequences. However, differences in patterns of methylation and acetylation of their DNA can result in differences in gene expression, which may explain observed differences in looks, etc. *Compare* FRATERNAL TWINS.

identity Symbol ≡. A statement of equality that applies for all values of the unknown quantity. For example, $5y \equiv 2y + 3y$.

idiogram *See* KARYOGRAM.

idiosyncrasy An abnormal reaction to a drug or other foreign substance shown by an individual, which is usually genetically determined. An individual that shows im-

munological idiosyncrasy is said to be **hypersensitive** to a particular substance, agent, etc.

IE Ionization energy. *See* IONIZATION POTENTIAL.

Ig *See* IMMUNOGLOBULIN.

IGF (insulin-like growth factor) *See* GROWTH FACTOR.

igneous rocks A group of rocks formed from the crystallization of magma (molten silicate liquid). Igneous rocks form one of the three major rock categories (*see also* METAMORPHIC ROCKS; SEDIMENTARY ROCKS). According to the depth at which the magma solidifies, igneous rocks may be classified as plutonic, hypabyssal, or volcanic. Plutonic rocks solidify slowly at great depth, typically forming large intrusive masses (e.g. batholiths and stocks), and generally have the coarsest texture. Examples of plutonic rocks are granite, syenite, diorite, and gabbro. Volcanic (extrusive) rocks are formed from magma that has been poured out onto the earth's surface; these rocks (e.g. basalt, andesite) are characteristically fine-grained or glassy as a result of their rapid cooling. Hypabyssal rocks (e.g. diorite), which cool at shallower depths than the plutonic, are intermediate in character and medium-grained. They commonly occur in the form of small intrusions, such as dykes and sills. Igneous rocks may also be classified chemically according to their silica content as acidic (over 66% silica), intermediate (55–66%), basic (45–55%), or ultrabasic (under 45%).

ignition temperature **1.** The temperature to which a substance must be heated before it will burn in air. **2.** The temperature to which a *plasma has to be raised in order that nuclear fusion will occur.

ileum The portion of the mammalian *small intestine that follows the *jejunum and precedes the *large intestine. It is a site of digestion and absorption. The internal lining of the ileum bears numerous small outgrowths (*see* VILLUS), which increase its absorptive surface area.

ilium The largest of the three bones that make up each half of the *pelvic girdle. The ilium bears a flattened wing of bone that is attached by ligaments to the sacrum (*see* SACRAL VERTEBRAE). *See also* ISCHIUM; PUBIS.

illuminance (illumination) Symbol *E*. The energy in the form of visible radiation reaching a surface per unit area in unit time; i.e. the luminous flux per unit time. It is measured in *lux (lumens per square metre).

image A representation of a physical object formed by a lens, mirror, or other optical instrument. If the rays of light actually pass through the image, it is called a **real image**. If a screen is placed in the plane of a real image it will generally become visible. If the image is seen at a point from which the rays appear to come to the observer, but do not actually do so, the image is called a **virtual image**. No image will be formed on a screen placed at this point. Images may be **upright** or **inverted** and they may be **magnified** or **diminished**.

image converter An electronic device in which an image formed by invisible radiation (usually gamma rays, X-rays, ultraviolet, or infrared) is converted into a visible image. Commonly the invisible radiation is focused on to a photocathode, which emits electrons when it is exposed to the radiation. These electrons fall on a fluorescent anode screen, after acceleration and focusing by a system of electron lenses. The fluorescent screen produces a visible image. The device is used in fluoroscopes, infrared telescopes, ultraviolet microscopes, and other devices.

imaginary number A number that is a multiple of $\sqrt{-1}$, which is denoted by i; for example $\sqrt{-3} = i\sqrt{3}$. *See also* COMPLEX NUMBER.

imago The adult sexually mature stage in the life cycle of an insect after metamorphosis.

imbibition The uptake of water by substances that do not dissolve in water, so that the process results in swelling of the substance. Imbibition is a property of many biological substances, including cellulose (and other constituents of plant cell walls), starch, and some proteins. It occurs in dry seeds before they germinate and – together with osmosis – is responsible for the uptake of water by growing plant cells.

imides Organic compounds containing the group –CO.NH.CO.– (the **imido group**).

SEE WEB LINKS

- Information about IUPAC nomenclature

imido group *See* IMIDES.

imines Compounds containing the group –NH– in which the nitrogen atom is part of a

ring structure, or the group =NH, in which the nitrogen atom is linked to a carbon atom by a double bond. In either case, the group is referred to as an **imino group**.

SEE WEB LINKS

- Information about IUPAC nomenclature

imino group *See* IMINES.

immersion objective An optical microscope objective in which the front surface of the lens is immersed in a liquid on the cover slip of the microscope specimen slide. Cedar-wood oil (for an **oil-immersion lens**) or sugar solution is frequently used. It has the same refractive index as the glass of the cover slip, so that the object is effectively immersed in it. The presence of the liquid increases the effective aperture of the objective, thus increasing the resolution.

immune response The reaction of the body to foreign or potentially dangerous substances (*antigens), particularly disease-producing microorganisms. *See* IMMUNITY.

immunity The ability of an animal to resist infection or to counter the harmful effects of toxins produced by infecting organisms. Immunity depends on the presence in the body of a range of defensive cells and substances, notably *antibodies and white blood cells (*lymphocytes), which produce an immune response. **Innate** (**inherited** or **natural**) **immunity** is the body's first line of defence and plays a vital role in controlling invading organisms during the early stages of an infection. Phagocytic macrophages can engulf bacteria and other microorganisms and induce them to secrete an array of *cytokines. These substances attract additional immune cells to the site and initiate the process of *inflammation. The *complement system of defensive proteins is also activated. The innate response plays a crucial role in promoting **adaptive** (or **acquired**) **immunity**. Dendritic cells ingest foreign material, such as bacteria and virus particles (*see* ANTIGEN), and present it to T cells as part of the immune response; adaptive immunity can persist throughout the lifetime of the individual. **Active immunity** arises when the body produces antibodies against an invading foreign substance (antigen), either through infection or *immunization. **Humoral immunity** is when B lymphocytes produce free antibodies that circulate in the bloodstream (*see* B CELL); **cell-mediated immunity** is caused by the action of T lymphocytes (*see* T CELL). **Passive immunity** is induced by injection of serum taken from an individual already immune to a particular antigen; it can also be acquired by the transfer of maternal antibodies to offspring via the placenta or breast milk (*see* COLOSTRUM). Active immunity tends to be long-lasting; passive immunity is short-lived. *See also* AUTOIMMUNITY.

SEE WEB LINKS

- A series of colour slides illustrating the working of the immune system, produced by the US National Cancer Institute

immunization The production of *immunity in an individual by artificial means. **Active immunization** (**vaccination**) involves the introduction, either orally or by injection (**inoculation**), of specially treated bacteria, viruses, or their toxins to stimulate the production of *antibodies (*see* VACCINE). **Passive immunization** is induced by the injection of preformed antibodies.

immunoassay Any of various techniques that measure the amount of a particular substance by virtue of its binding antigenically to a specific antibody. In **solid-phase immunoassay** the specific antibody is attached to a solid supporting medium, such as a PVC sheet. The sample is added and any test antigens will bind to the antibody. A second antibody, specific for a different site on the antigen, is added. This carries a radioactive or fluorescent label, enabling its concentration, and thus that of the test antigen, to be determined by comparison with known standards. Variations on this technique include *ELISA and *Western blotting.

immunoglobulin (Ig) One of a group of proteins (*globulins) in the body that act as *antibodies. They are produced by specialized white blood cells called *B cells and are present in blood serum and other body fluids. There are several classes (e.g. IgE, IgG, and IgM) having different functions.

immunosuppression The suppression of an *immune response. Immunosuppression is necessary following organ transplants in order to prevent the host rejecting the grafted organ (*see* GRAFT); it is artificially induced by radiation or chemical agents that inhibit cell division of *lymphocytes. Immunosuppression occurs naturally in certain diseases, notably *AIDS.

impact printer *See* PRINTER.

impedance Symbol *Z*. The quantity that

measures the opposition of a circuit to the passage of a current and therefore determines the amplitude of the current. In a d.c. circuit this is the resistance (R) alone. In an a.c. circuit, however, the *reactance (X) also has to be taken into account, according to the equation: $Z^2 = R^2 + X^2$, where Z is the impedance. The **complex impedance** is given by $Z = R + iX$, where $i = \sqrt{-1}$. The real part of the complex impedance, the resistance, represents the loss of power according to *Joule's law. The ratio of the imaginary part, the reactance, to the real part is an indication of the difference in phase between the voltage and the current.

imperfect fungi *See* DEUTEROMYCOTA.

Imperial units The British system of units based on the pound and the yard. The former f.p.s. system was used in engineering and was loosely based on Imperial units; for all scientific purposes *SI units are now used. Imperial units are also being replaced for general purposes by metric units.

implant Any substance, device, or tissue that is inserted into the body. For example, drug implants and heart pacemakers are typically inserted under the skin.

implantation (nidation) (in embryology) The embedding of a fertilized mammalian egg into the wall of the uterus (womb) where it will continue its development. After fertilization in the fallopian tube the egg passes into the womb in the form of a ball of cells (**blastocyst**). Its outer cells destroy cells of the uterine wall, forming a cavity into which the blastocyst sinks.

implosion An inward collapse of a vessel, especially as a result of evacuation.

imprinting **1.** (in behaviour) A specialized form of learning in which young animals, during a particularly sensitive period in their early development, learn to recognize and approach some large moving object nearby. In nature this is usually the mother, though simple models or individuals of a different species (including humans) may suffice. Imprinting was first described by Konrad *Lorenz, working with young ducks and geese. *See* LEARNING (Feature). **2.** (in genetics) *See* GENE IMPRINTING.

impulse **1.** (in physiology) **(nerve impulse)** The signal that travels along the length of a *nerve fibre and is the means by which information is transmitted through the nervous system. It is marked by the flow of ions across the membrane of the *axon caused by changes in the permeability of the membrane, producing a reduction in potential difference that can be detected as the *action potential. The strength of the impulse produced in any nerve fibre is constant (*see* ALL-OR-NONE RESPONSE). **2.** (in physics) Symbol J. The product of a force F and the time t for which it acts. If the force is variable, the impulse is the integral of $F\mathrm{d}t$ from t_0 to t_1. The impulse of a force acting for a given time interval is equal to the change in momentum produced over that interval, i.e. $J = m(v_1 - v_0)$, assuming that the mass (m) remains constant while the velocity changes from v_0 to v_1.

IMS *See* ION-MOBILITY SPECTROMETRY.

inbreeding Mating between closely related individuals, the extreme condition being self-fertilization, which occurs in many plants and some primitive animals. A population of inbreeding individuals generally shows less variation than an *outbreeding population. Continued inbreeding among a normally outbreeding population leads to **inbreeding depression** (the opposite of *hybrid vigour) and an increased incidence of harmful characteristics. For example, in humans, certain mental and other defects tend to occur more often in families with a history of cousin marriages.

incandescence The emission of light by a substance as a result of raising it to a high temperature. An **incandescent lamp** is one in which light is emitted by an electrically heated filament. *See* ELECTRIC LIGHTING.

incisor A sharp flattened chisel-shaped *tooth in mammals that is adapted for biting food and – in rodents – for gnawing. In humans there are normally two pairs of incisors (central and lateral) in each jaw. *See* PERMANENT TEETH.

inclination **1.** *See* GEOMAGNETISM. **2.** The angle between the orbital plane of a planet, satellite, or comet and the plane of the earth's *ecliptic.

inclusive fitness The quality that organisms attempt (unconsciously) to maximize as the result of natural selection acting on genes that are influential in controlling their behaviour and physiology. It includes the individual's own **reproductive success** (usually taken as the number of its offspring that survive to adulthood) and also the effects of

the individual's actions on the reproductive success of its relatives, because relatives have a higher probability of sharing some identical genes with the individual than do other members of the population. When interactions between relatives are likely to occur (which happens during the lives of many animals and plants) *kin selection will operate.

incoherent scattering *See* COHERENT SCATTERING.

incompatibility **1.** The condition that exists when foreign grafts or blood transfusions evoke a marked *immune response and are rejected. **2.** The phenomenon in which pollen from one flower fails to fertilize other flowers on the same plant (**self-incompatibility**) or on other genetically similar plants. This genetically determined mechanism prevents self-fertilization (breeding between likes) and promotes cross-fertilization (breeding between individuals with different genetic compositions). *See also* ALLOGAMY; FERTILIZATION; POLLINATION.

incomplete dominance The condition that arises when neither *allele controlling a characteristic is dominant and the aspect displayed by the organism results from the partial influence of both alleles. For example, a snapdragon plant with alleles for red and for white flowers produces pink flowers. *Compare* CODOMINANCE.

incubation **1.** The process of maintaining the fertilized eggs of birds and of some reptiles and egg-laying mammals at the optimum temperature for the successful development of the embryos. A period of incubation follows the laying of the eggs and precedes their hatching. **2.** The process of maintaining a *culture of bacteria or other microorganisms at the optimum temperature for growth of the culture. **3.** The phase in the development of an infectious disease between initial infection and the appearance of the first symptoms.

incus (anvil) The middle of the three *ear ossicles of the mammalian middle ear.

indefinite inflorescence *See* RACEMOSE INFLORESCENCE.

indefinite integral *See* INTEGRATION.

indehiscent Describing a fruit or fruiting body that does not open to release its seeds or spores when ripe. Instead, release occurs when the fruit wall decays or, if eaten by an animal, is digested. *Compare* DEHISCENCE.

indene A colourless flammable hydrocarbon, C_9H_8; r.d. 0.996; m.p. –1.8°C; b.p. 182.6°C. Indene is an aromatic hydrocarbon with a five-membered ring fused to a benzene ring. It is present in coal tar and is used as a solvent and raw material for making other organic compounds.

independent assortment The separation of the alleles of one gene into the reproductive cells (gametes) independently of the way in which the alleles of other genes have segregated. By this process all possible combinations of alleles should occur equally frequently in the gametes. In practice this does not happen because alleles situated on the same chromosome tend to be inherited together. However, if the allele pairs *Aa* and *Bb* are on different chromosomes, the combinations *AB*, *Ab*, *aB*, and *ab* will normally be equally likely to occur in the gametes. *See* MEIOSIS; MENDEL'S LAWS.

indeterminacy *See* UNCERTAINTY PRINCIPLE.

index fossil (zone fossil) An animal *fossil of a group that existed continuously during a particular span of geological time and can therefore be used to date the rock in which it is found. Index fossils are found chiefly in sedimentary rocks. They are an essential tool in stratigraphy for comparing the geological ages of sedimentary rock formations. Examples are *ammonites and *graptolites.

indicator A substance used to show the presence of a chemical substance or ion by its colour. **Acid–base indicators** are compounds, such as phenolphthalein and methyl orange, that change colour reversibly, depending on whether the solution is acidic or basic. They are usually weak acids in which the un-ionized form HA has a different colour from the negative ion A^-. In solution the indicator dissociates slightly

$$HA \rightleftharpoons H^+ + A^-$$

In acid solution the concentration of H^+ is high, and the indicator is largely undissociated HA; in alkaline solutions the equilibrium is displaced to the right and A^- is formed. Useful acid–base indicators show a sharp colour change over a range of about 2 pH units. In titration, the point at which the reaction is complete is the **equivalence point** (i.e. the point at which equivalent

quantities of acid and base are added). The **end point** is the point at which the indicator just changes colour. For accuracy, the two must be the same. During a titration the pH changes sharply close to the equivalence point, and the indicator used must change colour over the same range.

Other types of indicator can be used for other reactions. Starch, for example, is used in iodine titrations because of the deep blue complex it forms. **Oxidation–reduction indicators** are substances that show a reversible colour change between oxidized and reduced forms. *See also* ADSORPTION INDICATOR.

indicator species A plant or animal species that is very sensitive to a particular environmental factor, so that its presence (or absence) in an area can provide information about the levels of that factor. For example, some lichens are very sensitive to the concentration of sulphur dioxide (a major pollutant) in the atmosphere. Examination of the lichens present in an area can provide a good indication of the prevailing levels of sulphur dioxide.

indigenous Describing a species that occurs naturally in a certain area, as distinct from one introduced by humans; native.

indigo A blue vat dye, $C_{16}H_{10}N_2O_2$. It occurs as the glucoside **indican** in the leaves of plants of the genus *Indigofera*, from which it was formerly extracted. It is now made synthetically.

indium Symbol In. A soft silvery element belonging to group 13 (formerly IIIB) of the periodic table; a.n. 49; r.a.m. 114.82; r.d. 7.31 (20°C); m.p. 156.6°C; b.p. 2080±2°C. It occurs in zinc blende and some iron ores and is obtained from zinc flue dust in total quantities of about 40 tonnes per annum. Naturally occurring indium consists of 4.23% indium–113 (stable) and 95.77% indium–115 (half-life 6×10^{14} years). There are a further five short-lived radioisotopes. The uses of the metal are small – some special-purpose electroplates and some special fusible alloys. Several semiconductor compounds are used, such as InAs, InP, and InSb. With only three electrons in its valency shell, indium is an electron acceptor and is used to dope pure germanium and silicon; it forms stable indium(I), indium(II), and indium(III) compounds. The element was discovered in 1863 by Ferdinand Reich (1799–1882) and Hieronymus Richter (1824–90).

SEE WEB LINKS

- Information from the WebElements site

indole A yellow solid, C_8H_7N, m.p. 52°C. Its molecules consist of a benzene ring fused to a nitrogen-containing five-membered ring. It occurs in some plants and in coal tar, and is produced in faeces by bacterial action. It is used in making perfumes. Indole has the nitrogen atom positioned next to the fused benzene ring. An isomer with the nitrogen two atoms away from the fused ring is called **isoindole**.

indoleacetic acid (IAA) *See* AUXIN.

induced emission (stimulated emission) The emission of a photon by an atom in the presence of *electromagnetic radiation. The atom can become excited by the absorption of a photon of the right energy and, having become excited, the atom can emit a photon. The rate of absorption is equal to the rate of induced emission, both rates being proportional to the density of photons of the electromagnetic radiation. The relation between induced emission and *spontaneous emission is given by the *Einstein coefficients. The process of induced emission is essential for the operation of *lasers and *masers. *See also* QUANTUM THEORY OF RADIATION.

induced fission *See* NUCLEAR FISSION.

inducer *See* OPERON.

inductance The property of an electric circuit or component that causes an e.m.f. to be generated in it as a result of a change in the current flowing through the circuit (**self-inductance**) or of a change in the current flowing through a neighbouring circuit with which it is magnetically linked (**mutual inductance**). In both cases the changing current is associated with a changing magnetic field, the linkage with which in turn induces the e.m.f. In the case of self inductance, L, the e.m.f., E, generated is given by $E = -L.\mathrm{d}I/\mathrm{d}t$, where I is the instantaneous current and the minus sign indicates that the e.m.f. induced is in opposition to the change of current. In the case of mutual inductance, M, the e.m.f., E_1, induced in one circuit is given by $E_1 = -M.\mathrm{d}I_2/\mathrm{d}t$, where I_2 is the instantaneous current in the other circuit.

induction **1.** (in embryology) The ability of natural stimuli to cause unspecialized embryonic tissue to develop into specialized tis-

sue. **2.** (in obstetrics) The initiation of childbirth by artificial means; for example, by injection of the hormone *oxytocin. **3.** (in physics) A change in the state of a body produced by a field. *See* ELECTROMAGNETIC INDUCTION; INDUCTANCE.

induction coil A type of *transformer used to produce a high-voltage alternating current or pulses of high-voltage current from a low-voltage direct-current source. The induction coil is widely used in spark-ignition *internal-combustion engines to produce the spark in the sparking plugs. In such an engine the battery is connected to the primary winding of the coil through a circuit-breaking device driven by the engine and the e.m.f. generated in the secondary winding of the coil is led to the sparking plugs through the distributor. The primary coil consists of relatively few turns, whereas the secondary consists of many turns of fine wire.

induction heating The heating of an electrically conducting material by *eddy currents induced by a varying electromagnetic field. Induction heating may be an undesirable effect leading to power loss in transformers and other electrical devices. It is, however, useful for melting and heat-treating and in forging and rolling metals, as well as for welding, brazing, and soldering. The material to be heated is inserted into a coil through which an alternating current flows and acts as the short-circuited secondary of a *transformer. Eddy currents induced in the material within the coil cause the temperature of the material to rise.

induction motor *See* ELECTRIC MOTOR.

inductive effect The effect of a group or atom of a compound in pulling electrons towards itself or in pushing them away. Inductive effects can be used to explain some aspects of organic reactions. For instance, electron-withdrawing groups, such as $–NO_2$, –CN, –CHO, –COOH, and the halogens substituted on a benzene ring, reduce the electron density on the ring and decrease its susceptibility to further (electrophilic) substitution. Electron-releasing groups, such as –OH, $–NH_2$, $–OCH_3$, and $–CH_3$, have the opposite effect.

indusium The kidney-shaped covering of the *sorus of certain ferns that protects the developing sporangia. It withers when the sorus ripens to expose the sporangia.

industrial melanism The increase of melanic (dark) forms of an animal in areas darkened by industrial pollution. The example most often quoted is that of the peppered moth (*Biston betularia*), melanic forms of which markedly increased in the industrial north of England during the 19th century. Experiments have shown that the dark forms increase in polluted regions because they are less easily seen by birds against a dark background; conversely the paler forms survive better in unpolluted areas.

inelastic collision A collision in which some of the kinetic energy of the colliding bodies is converted into internal energy in one body so that kinetic energy is not conserved. In collisions of macroscopic bodies some kinetic energy is turned into vibrational energy of the atoms, causing a heating effect. Collisions between molecules of a gas or liquid may also be inelastic as they cause changes in vibrational and rotational *energy levels. In nuclear physics, an inelastic collision is one in which the incoming particle causes the nucleus it strikes to become excited or to break up. **Deep inelastic scattering** is a method of probing the structure of subatomic particles in much the same way as Rutherford probed the inside of the atom (*see* RUTHERFORD SCATTERING). Such experiments were performed on protons in the late 1960s using high-energy electrons at the Stanford Linear Accelerator Centre (SLAC). As in Rutherford scattering, deep inelastic scattering of electrons by proton targets revealed that most of the incident electrons interacted very little and pass straight through, with only a small number bouncing back. This indicates that the charge in the proton is concentrated in small lumps, reminiscent of Rutherford's discovery that the positive charge in an atom is concentrated at the nucleus. However, in the case of the proton, the evidence suggested three distinct concentrations of charge and not one.

inequality A relationship between two quantities in which one of the quantities is not equal to (or not necessarily equal to) the other quantity. If the quantities are a and b, two inequalities exist: a is greater than b, written $a > b$, and a is less than b, i.e. $a < b$. Similar statements can take the form: a is greater than or equal to b, written $a \geq b$, and a is less than or equal to b, which is denoted $a \leq b$. There are many applications of in-

equalities in physical science, an example being the Heisenberg *uncertainty principle.

inert gases *See* NOBLE GASES.

inertia The property of matter that causes it to resist any change in its motion. Thus, a body at rest remains at rest unless it is acted upon by an external force and a body in motion continues to move at constant speed in a straight line unless acted upon by an external force. This is a statement of Newton's first law of motion. The *mass of a body is a measure of its inertia. *See* MACH'S PRINCIPLE; INERTIAL FRAME.

inertial frame A *frame of reference in which bodies move in straight lines with constant speeds unless acted upon by external forces, i.e. a frame of reference in which free bodies are not accelerated. Newton's laws of motion are valid in an inertial system but not in a system that is itself accelerated with respect to such a frame.

inertial mass *See* MASS.

inert-pair effect An effect seen especially in groups 13 and 14 of the periodic table, in which the heavier elements in the group tend to form compounds with a valency two lower than the expected group valency. It is used to account for the existence of thallium(I) compounds in group 13 and lead(II) in group 14. In forming compounds, elements in these groups promote an electron from a filled *s*-level state to an empty *p*-level. The energy required for this is more than compensated for by the extra energy gain in forming two more bonds. For the heavier elements, the bond strengths or lattice energies in the compounds are lower than those of the lighter elements. Consequently the energy compensation is less important and the lower valence states become favoured.

infection The invasion of any living organism by disease-causing microorganisms (*see* PATHOGEN), which proceed to establish themselves, multiply, and produce various symptoms in their host. Pathogens may invade via a wound or (in animals) through the mucous membranes lining the alimentary, respiratory, and reproductive tracts, and may be transmitted by an infected individual, a *carrier, or an arthropod *vector. Symptoms in animals appear after an initial symptomless **incubation period** and typically consist of localized *inflammation, often with pain and fever. Infections are combatted by the body's natural defences (*see* IMMUNITY). Treatment with drugs (*see* ANTIBIOTICS; ANTISEPTIC) is effective against most bacterial, fungal, and protozoan infections; some viral infections respond to *antiviral drugs. *See also* IMMUNIZATION.

inferior Describing a structure that is positioned below or lower than another structure in the body. For example, in flowering plants the ovary is described as inferior when it is located below the other organs of the flower. *Compare* SUPERIOR.

infinite series *See* SERIES.

infinitesimal Vanishingly small but not zero. Infinitesimal changes are notionally made in the *calculus, which is sometimes called the **infinitesimal calculus**.

infinity Symbol ∞. A quantity having a value that is greater than any assignable value. Minus infinity, $-\infty$, is a quantity having a value that is less than any assignable value.

inflammation The defence reaction of tissue to injury, infection, or irritation by chemicals or physical agents. Activated macrophages and other cells in the affected tissue release various substances, including *histamine, *serotonin, *kinins, and *prostaglandins. These cause localized dilatation of blood vessels so that fluid leaks out and blood flow is increased. They also attract white blood cells (neutrophils and monocytes) to the site. Overall, these responses lead to swelling, redness, heat, and often pain. White blood cells, particularly *phagocytes, enter the tissue and an immune response is stimulated (*see* IMMUNITY). A gradual healing process usually follows.

inflation *See* EARLY UNIVERSE.

inflationary universe *See* EARLY UNIVERSE.

inflection A point on a curve at which the tangent changes from rotation in one direction to rotation in the opposite direction. If the curve $y = f(x)$ has a stationary point $dy/dx = 0$, there is either a maximum, minimum, or inflection at this point. If $d^2y/dx^2 = 0$, the stationary point is a point of inflection.

inflorescence A particular arrangement of flowers on a single main stalk of a plant. There are many different types of inflorescence, which are classified into two main groups depending on whether the tip of the flower axis goes on producing new flower buds during growth (*see* RACEMOSE INFLORES-

CENCE) or loses this ability (*see* CYMOSE INFLORESCENCE).

information technology *See* IT.

information theory The branch of mathematics that analyses information mathematically. Several branches of physics have been related to information theory. For example, an increase in *entropy has been expressed as a decrease in information. It has been suggested that it may be possible to express the basic laws of physics using information theory. *See also* LANDAUER'S PRINCIPLE; ZEILINGER'S PRINCIPLE.

infradian rhythm *See* BIORHYTHM.

infrared astronomy The study of radiation from space in the infrared region of the spectrum (*see* INFRARED RADIATION). Some infrared radiation is absorbed by water and carbon dioxide molecules in the atmosphere but there are several narrow atmospheric *windows in the near-infrared (1.15–1.3 μm, 1.5–1.75 μm, 2–2.4 μm, 3.4–4.2 μm, 4.6–4.8 μm, 8–13 μm, and 16–18 μm). Longer wavelength observations must be made from balloons, rockets, or satellites. Infrared sources are either thermal, i.e. emitted by the atoms or molecules of gases or dust particles in the temperature range 100–3000 K, or electronic, i.e. emitted by high-energy electrons interacting with magnetic fields as in *synchrotron radiation. Detectors are either modified reflecting *telescopes or solid-state photon detectors, usually incorporating photovoltaic devices (*see* PHOTOELECTRIC EFFECT).

infrared radiation (IR) Electromagnetic radiation with wavelengths longer than that of red light but shorter than radiowaves, i.e. radiation in the wavelength range 0.7 micrometre to 1 millimetre. It was discovered in 1800 by William Herschel (1738–1822) in the sun's spectrum. The natural vibrational frequencies of atoms and molecules and the rotational frequencies of some gaseous molecules fall in the infrared region of the electromagnetic spectrum. The infrared absorption spectrum of a molecule is highly characteristic of it and the spectrum can therefore be used for molecular identification. Glass is opaque to infrared radiation of wavelength greater than 2 micrometres and other materials, such as germanium, quartz, and polyethene, have to be used to make lenses and prisms. Photographic film can be made sensitive to infrared up to about 1.2 μm.

infrared spectroscopy (IR spectroscopy) A technique for chemical analysis and the determination of structure. It is based on the principles that molecular vibrations occur in the infrared region of the electromagnetic spectrum and functional groups have characteristic absorption frequencies. The frequencies of most interest range from 2.5 to 16 μm; however, in IR spectroscopy it is common to use the reciprocal of the wavelength, and thus this range becomes 4000–625 cm^{-1}. Examples of typical vibrations are centred on 2900 cm^{-1} for C–H stretching in alkanes, 1600 cm^{-1} for N–H stretching in amino groups, and 2200 cm^{-1} for C≡C stretching in alkynes. In an IR spectrometer there is a source of IR light, covering the whole frequency range of the instrument, which is split into two beams of equal intensity. One beam is passed through the sample and the other is used as a reference against which the first is then compared. The spectrum is usually obtained as a chart showing absorption peaks, plotted against wavelength or frequency. The sample can be a gas, liquid, or solid.

infrasound Soundlike waves with frequencies below the audible limit of about 20 hertz.

ingestion (feeding) A method of *heterotrophic nutrition in which food is taken into an organism and subsequently digested (*see* DIGESTION). Ingestion is the principal mechanism of animal nutrition. *See also* MACROPHAGOUS; MICROPHAGOUS.

inhalation *See* INSPIRATION.

inheritance The transmission of particular characteristics from generation to generation by means of the *genetic code, which is transferred to offspring in the gametes. *See also* MENDEL'S LAWS.

inhibition **1.** (in chemistry) A reduction in the rate of a catalysed reaction by substances called **inhibitors**. Inhibitors may work by poisoning catalysts for the reaction or by removing free radicals in a chain reaction. **Enzyme inhibition** affects biochemical reactions, in which the catalysts are *enzymes. **Competitive inhibition** occurs when the inhibitor molecules resemble the substrate molecules and bind to the *active site of the enzyme, so preventing normal enzymatic activity. Competitive inhibition can be reversed by increasing the concentration of the substrate. In **noncompetitive inhibition**

the inhibitor binds to a part of the enzyme or *enzyme–substrate complex other than the active site, known as an **allosteric site**. This deforms the active site so that the enzyme cannot catalyse the reaction. Noncompetitive inhibition cannot be reversed by increasing the concentration of the substrate. The toxic effects of many substances are produced in this way. Inhibition by reaction products (**feedback inhibition**) is important in the control of enzyme activity. *See also* ALLOSTERIC ENZYME. **2.** (in physiology) The prevention or reduction of the activity of effectors (such as muscles) by means of certain nerve impulses. Inhibitory activity often provides a balance to stimulation of a process; for example, the impulse to stimulate contraction of a voluntary muscle may be accompanied by an inhibitory impulse to prevent contraction of its antagonist.

inhibitory postsynaptic potential (IPSP) The electric potential that is generated in a postsynaptic neuron when an inhibitory neurotransmitter (such as gamma-aminobutyric acid) is released into the synapse and causes a slight increase in the potential difference across the postsynaptic membrane. This makes the neuron less likely to transmit an impulse. *Compare* EXCITATORY POSTSYNAPTIC POTENTIAL.

initial One of a group of cells (or, in lower plants, a single cell) that divides to produce the cells of a plant tissue or organ. The cells of the apical meristem, cambium, and cork cambium are initials.

initiation codon *See* START CODON.

innate behaviour An inherited pattern of behaviour that appears in a similar form in all normally reared individuals of the same sex and species. *See* INSTINCT.

inner Describing a chemical compound formed by reaction of one part of a molecule with another part of the same molecule. Thus, a lactam is an inner amide; a lactone is an inner ester.

inner ear The structure in vertebrates, surrounded by the temporal bone of the skull, that contains the organs of balance and hearing. It consists of soft hollow sensory structures (the **membranous labyrinth**), containing fluid (**endolymph**), surrounded by fluid (**perilymph**), and encased in a bony cavity (the **bony labyrinth**). It consists of two chambers, the *sacculus and *utriculus, from which arise the *cochlea and *semicircular canals respectively.

inner transition series *See* TRANSITION ELEMENTS.

innervation The supply of nerve fibres to and from an organ.

innominate artery A short artery that branches from the aorta to divide into the *subclavian artery (the main artery to the arm) and the right *carotid artery (which supplies blood to the head).

innominate bone One of the two bones that form each half of the *pelvic girdle in adult vertebrates. This bone is formed by the fusion of the *ilium, *ischium, and *pubis.

inoculation **1.** *See* VACCINE. **2.** The placing of a small sample of microorganisms or any other type of cell into a *culture medium so that the cells can grow and proliferate.

inoculum A small amount of material containing bacteria, viruses, or other microorganisms that is used to start a culture.

inorganic chemistry The branch of chemistry concerned with compounds of elements other than carbon. Certain simple carbon compounds, such as CO, CO_2, CS_2, and carbonates and cyanides, are usually treated in inorganic chemistry.

inositol A cyclic alcohol, $C_6H_{12}O_6$, that is a constituent of certain cell phosphoglycerides. It is sometimes classified as a member of the vitamin B complex but it can be synthesized by many animals and it is not regarded as an essential nutrient in humans. **Phosphatidyl inositol**, a constituent of plasma membranes, is a precursor of the intracellular messenger molecules, **inositol 1,4,5-trisphosphate** (**IP_3**) and **diacylglycerol**; these are produced in response to the binding of substances, e.g. serotonin, to their receptors on the cell surface. These pathways mediate such cellular events as smooth muscle contraction, adrenaline secretion, and histamine secretion.

Insecta *See* HEXAPODA.

insecticide *See* PESTICIDE.

Insectivora An order of small, mainly nocturnal, mammals that includes the hedgehogs, moles, and shrews. They have long snouts covered with stiff tactile hairs and their teeth are specialized for seizing and crushing insects and other small prey. The

insectivores have changed very little since they evolved in the Cretaceous period, 130 million years ago.

insectivore An animal that eats insects, especially a mammal of the order Insectivora (hedgehogs, shrews, etc.).

insectivorous plant *See* CARNIVOROUS PLANT.

insertion **1.** (of muscles) *See* VOLUNTARY MUSCLE. **2.** (in genetics) A *point mutation in which an extra nucleotide base is added to the DNA sequence. This results in the misreading of the base sequence during the *translation stage of protein synthesis.

insertion sequence *See* TRANSPOSON.

insight learning A form of learning in which an animal responds to new situations by adapting experiences gained in other contexts. Insight learning requires an animal to solve problems by viewing a situation as a whole instead of relying wholly on trial-and-error learning. Chimpanzees are capable of insight learning. *See* LEARNING (Feature).

insolation (from *in*coming *sol*ar radi*ation*) The solar radiation that is received at the earth's surface per unit area. It is related to the *solar constant, the duration of daylight, the altitude of the sun, and the latitude of the receiving surface. It is measured in MJ m^{-2}.

inspiration (inhalation) The process by which gas is drawn into the lungs through the trachea (*see* RESPIRATORY MOVEMENT). In mammals the rib cage is raised by contraction of the external *intercostal muscles and the muscles of the diaphragm. These actions enlarge the thorax, so that pressure in the lung cavity is reduced below atmospheric pressure, which causes an influx of air until the pressures are equalized. *Compare* EXPIRATION.

inspiratory centre *See* VENTILATION CENTRE.

instantaneous value The value of any varying quantity at a specified instant.

instar A stage in the larval development of an insect between two moults (ecdyses). There are usually a number of larval instars before the pupal stage and metamorphosis.

instinct An innate tendency to behave in a particular way, which does not depend critically on particular learning experiences for its development and therefore is seen in a similar form in all normally reared individuals of the same sex and species. Much instinctive behaviour takes the form of **fixed action patterns**. These are movements that – once started – are performed in a stereotyped way unaffected by external stimuli. For example, a frog's prey-catching tongue flick is performed in the same way whether or not anything is caught. Some complex instinctive behaviour, however, requires some learning by the animal before it is perfected. Birdsong, for example, consists of an innate component that is modified and made more complex by the influence of other birds, the habitat, etc.

insulator A substance that is a poor conductor of heat and electricity. Both properties usually occur as a consequence of a lack of mobile electrons. *See* ENERGY BANDS.

insulin A protein hormone, secreted by the β (or B) cells of the *islets of Langerhans in the pancreas, that promotes the uptake of glucose by body cells, particularly in the liver and muscles, and thereby controls its concentration in the blood. Insulin was the first protein whose amino-acid sequence was fully determined (in 1955). Underproduction of insulin results in the accumulation of large amounts of glucose in the blood and its subsequent excretion in the urine. This condition, known as **diabetes mellitus**, can be treated successfully by insulin injections.

insulin-like growth factor (IGF) *See* GROWTH FACTOR.

integer Any one of the positive or negative whole numbers.

integral calculus *See* CALCULUS.

integrand *See* INTEGRATION.

integrated circuit A miniature electronic circuit produced within a single crystal of a *semiconductor, such as silicon. They range from simple logic circuits, little more than 1 mm square, to large-scale circuits measuring up to 8 mm square and containing a million or so transistors (active components) and resistors or capacitors (passive components). They are widely used in memory circuits, microcomputers, pocket calculators, and electronic watches on account of their low cost and bulk, reliability, and high speed. They are made by introducing impurities into specific regions of the semiconductor crystal by a variety of techniques.

integration **1.** (in physiology) The coordi-

nation within the brain of separate but related nervous processes. For example, sensory information from the inner ear and the eye are both necessary for the sense of balance. These stimuli must be integrated by the brain not only with each other but also with various motor nerves, which coordinate the muscles that control posture. **2.** (in mathematics) The process of continuously summing changes in a function f(x). It is the basis of the integral *calculus and the opposite process to *differentiation. The function to be integrated is called the **integrand** and the result of integration on the integrand is called the **integral**. For example, the integration of f(x) is written $\int f(x)dx$, the differential dx being added to indicate that f(x) must be integrated with respect to x. To complete the integration, a **constant of integration**, C, must be added where no interval over which the integration takes place is given. This is called an **indefinite integral**. If the interval is specified, e.g.

$$\int_a^b (x)dx,$$

no constant of integration is required and the result is a **definite integral**. This means that f(x) is to be integrated between the values $x = +r$ and $x = -r$.

integument **1.** The outermost body layer of an animal, characteristically comprising a layer of living cells – the *epidermis – together with a superficial protective coat, which may be a secreted hardened *cuticle, as in arthropods, or dead keratinized cells, as in vertebrates (*see* SKIN). **2.** The outer protective covering of a plant *ovule. It is perforated by a small pore, the *micropyle. Usually two integuments are present in angiosperms and one in gymnosperms. After fertilization the integuments form the *testa of the seed.

intelligence The coordination of *memory, *learning, and reasoning in animals. Intelligence has also been defined as the ability of an animal to form associative links between events or objects of which it has had no previous experience (*see* INSIGHT LEARNING). In humans intelligence is generally expressed as an **intelligence quotient** (**IQ**): the mental age of the subject (as measured by standard tests) divided by his or her real age $\times 100$.

intensity **1.** The rate at which radiant energy is transferred per unit area. *See* RADIANT INTENSITY. **2.** The rate at which sound energy is transferred as measured relative to some reference value. *See* DECIBEL. **3.** Magnetic intensity. *See* MAGNETIC FIELD. **4.** Electric intensity. *See* ELECTRIC FIELD. **5.** *See* LUMINOUS INTENSITY.

intensive variable A quantity in a *macroscopic system that has a well defined value at every point inside the system and that remains (nearly) constant when the size of the system is increased. Examples of intensive variables are the pressure, temperature, density, specific heat capacity at constant volume, and viscosity. An intensive variable results when any *extensive variable is divided by an arbitrary extensive variable such as the volume. A macroscopic system can be described by one extensive variable and a set of intensive variables.

interaction An effect involving a number of bodies, particles, or systems as a result of which some physical or chemical change takes place to one or more of them. *See also* FUNDAMENTAL INTERACTIONS.

interactome All the interactions that occur between the various molecules produced by an organism, in all its cells and tissues and at all stages of its life. Of central significance are the interactions of proteins – the protein interactome – because these are the molecules encoded by the organism's genes and are fundamental to all other cellular processes. Determining which proteins form complexes, or bind together in some way, enables researchers to identify the components of the complex pathways and networks that govern different aspects of cellular functioning and potentially play a role in health and disease.

intercalation cell A type of secondary cell in which layered electrodes, usually made of metal oxides or graphite, store positive ions between the crystal layers of an electrode. In one type, lithium ions form an intercalation compound with a graphite electrode when the cell is charged. During discharge, the ions move through an electrolyte to the other electrode, made of manganese oxide, where they are more tightly bound. When the cell is being charged, the ions move back to their positions in the graphite. This backwards and forwards motion of the ions has led to the name **rocking-chair cell** for this type of system. Such cells have the advantage that only minor physical changes occur to the electrodes during the charging and discharging processes and the electrolyte is not decomposed but simply serves as a con-

ductor of ions. Consequently, such cells can be recharged many more times than, say, a lead-acid accumulator, which eventually suffers from degeneration of the electrodes. **Lithium cells**, based on this principle, have been used in portable electronic equipment, such as camcorders. They have also been considered for use in electric vehicles.

intercalation compound A type of compound in which atoms, ions, or molecules are trapped between layers in a crystal lattice. There is no formal chemical bonding between the host crystal and the trapped molecules (*see also* CLATHRATE). Such compounds are formed by *lamellar solids and are often nonstoichiometric; examples are graphitic oxide (graphite–oxygen) and the mineral *muscovite.

intercellular (in biology) Located or occurring between cells. *Compare* INTRACELLULAR.

intercostal muscles The muscles located between the *ribs, surrounding the lungs. Comprising the superficial **external intercostal muscles** and the deep **internal intercostal muscles**, they play an essential role in breathing (*see* EXPIRATION; INSPIRATION).

interference The interaction of two or more wave motions affecting the same part of a medium so that the instantaneous disturbances in the resultant wave are the vector sum of the instantaneous disturbances in the interfering waves.

The phenomenon was first described by Thomas Young in 1801 in light waves; it provided strong evidence for the wave theory of light. In the apparatus known as **Young's slits**, light is passed from a small source through a slit in a screen and the light emerging from this slit is used to illuminate two adjacent slits on a second screen. By allowing the light from these two slits to fall on a third screen, a series of parallel interference fringes is formed. Where the maximum values of the two waves from the slits coincide a bright fringe occurs (**constructive interference**) and where the maxima of one wave coincide with the minima of the other dark fringes are produced (**destructive interference**). (In Young's original experiment, two pinholes were used rather than slits). *Newton's rings are also an interference effect. Because *lasers produce *coherent radiation they are also used to produce interference effects, one application of their use being *holography. *See also* INTERFEROMETER.

interferometer An instrument designed to produce optical *interference fringes for measuring wavelengths, testing flat surfaces, measuring small distances, etc. *See also* ECHELON; FABRY–PÉROT INTERFEROMETER; MICHELSON–MORLEY EXPERIMENT. In astronomy, radio interferometers are one of the two basic types of *radio telescopes.

interferon (IFN) Any of a number of proteins (*see* CYTOKINE) that increase the resistance of cells to attack by viruses. In humans, three groups of interferons have been discovered: α-interferons from white blood cells; β-interferons from connective tissue fibroblasts; and γ-interferons from T cells and *natural killer cells (NK cells). α- and β-interferons induce intrinsic resistance to viral infection in all cells by triggering the expression of genes that encode antiviral proteins. Moreover, they activate NK cells, which selectively kill virus-infected cells, and promote synthesis of MHC proteins by all cell types (*see* HISTOCOMPATIBILITY), thereby protecting uninfected cells from attack by the NK cells. The actions of γ-interferon include macrophage activation, increasing the expression of MHC molecules, and suppression of helper *T cells. It is produced by cytotoxic T cells. Interferons are produced commercially for therapeutic purposes using genetically engineered bacteria or human tissue culture.

interhalogen A chemical compound formed between two *halogens. Interhalogens are highly reactive and volatile, made by direct combination of the elements. They include compounds with two atoms (ClF, IBr, etc.), four atoms (ClF_3, IF_3, etc.), six atoms (BrF_5, IF_5, etc.) and IF_7 with eight atoms.

interleukin Any of several *cytokines that are produced by leucocytes. **Interleukin-1** (**IL-1**) is secreted by antigen-activated macrophages and activates *T cells. **Interleukin-2** (**IL-2**) stimulates the proliferation of T cells, which also secrete it. **Interleukin-3** is a growth factor for haemopoietic cells, and **interleukin-4** induces B cells to proliferate and produce antibodies. Nearly 30 interleukins are now known to exist, and some are manufactured using recombinant DNA technology, for use as therapeutic agents.

intermediate bond *See* CHEMICAL BOND.

intermediate coupling *See* J-J COUPLING.

intermediate frequency *See* HETERODYNE; SUPERHETERODYNE RECEIVER.

intermediate neutron A *neutron with kinetic energy in the range 10^2–10^5 electronvolts ($1.6 \times 10^{-17} - 1.6 \times 10^{-14}$ joule).

intermediate vector boson *See* W BOSON; Z BOSON.

intermetallic compound A compound consisting of two or more metallic elements present in definite proportions in an alloy.

intermolecular forces Weak forces occurring between molecules. *See* VAN DER WAALS' FORCE; HYDROGEN BOND.

internal-combustion engine A *heat engine in which fuel is burned in combustion chambers within the engine rather than in a separate furnace (as with the steam engine). The first working engine was the four-stroke **Otto engine** produced in 1876 by Nikolaus Otto (1832–91). In this type of engine a piston descends in a cylinder, drawing in a charge of fuel and air through an inlet valve; after reaching the bottom of its stroke the piston rises in the cylinder with the valves closed and compresses the charge; at or near the top of its stroke the charge is ignited by a spark and the resulting increase in pressure from the explosion forces the piston down again; on the subsequent upstroke the exhaust valve opens and the burnt gases are pushed out of the combustion chamber. The cycle is then repeated. Otto's engine used gas as a fuel; however, the invention of the carburettor and the development of the oil industry at the end of the 19th century enabled the Otto engine to become the source of power for the emerging motor car. A variation of the Otto four-stroke engine is the two-stroke engine that has no complicated valve system, the explosive charge entering and leaving the cylinder through ports in the cylinder that are covered and uncovered by the moving piston.

An alternative to the Otto engine, especially for heavy vehicles where weight is not a problem, is the compression-ignition **Diesel engine** invented by Rudolf Diesel (1858–1913) in about 1896. In this type of engine there are no sparking plugs; instead air is compressed in the cylinder, causing its temperature to rise to about 550°C. Oil is then sprayed into the combustion chamber and ignites on contact with the hot air. While the spark-ignition petrol engine typically works on a *compression ratio of 8 or 9 to 1, the Diesel engine has to have a compression ratio of between 15 and 25 to 1. This requires a much heavier, and therefore more expensive, engine. *See also* GAS TURBINE.

internal conversion A process in which an excited atomic nucleus (*see* EXCITATION) decays to the *ground state and the energy released is transferred by electromagnetic coupling to one of the bound electrons of that atom rather than being released as a photon. The coupling is usually with an electron in the K-, L-, or M-shell of the atom, and this **conversion electron** is ejected from the atom with a kinetic energy equal to the difference between the nuclear transition energy and the binding energy of the electron. The resulting ion is itself in an excited state and usually subsequently emits an Auger electron (*see* AUGER EFFECT) or an X-ray photon.

internal energy Symbol U. The total of the kinetic energies of the atoms and molecules of which a system consists and the potential energies associated with their mutual interactions. It does not include the kinetic and potential energies of the system as a whole nor their nuclear energies or other intra-atomic energies. The value of the absolute internal energy of a system in any particular state cannot be measured; the significant quantity is the change in internal energy, ΔU. For a closed system (i.e. one that is not being replenished from outside its boundaries) the change in internal energy is equal to the heat absorbed by the system (Q) from its surroundings, less the work done (W) by the system on its surroundings, i.e. $\Delta U = Q - W$. *See also* ENERGY; HEAT; THERMODYNAMICS.

internal environment The conditions that prevail within the body of an organism, particularly with respect to the composition of the *tissue fluid. The concept of an internal environment was first proposed by the French physiologist Claude Bernard (1813–78), who stated that maintenance of a constant internal environment was necessary for the survival of an organism in a varying external environment. Selective absorption of materials across plasma membranes plays a large part in controlling the internal environment of both animals and plants. Animals in addition can regulate their body fluids by the action of hormones and the nervous system. *See* HOMEOSTASIS.

internal resistance The resistance within a source of electric current, such as a cell or generator. It can be calculated as the difference between the e.m.f. (E) and the potential difference (V) between the terminals divided by the current being supplied (I), i.e. $r = (E - V)/I$, where r is the internal resistance.

international candle A former unit of *luminous intensity. It has now been replaced by the *candela, to which it is approximately equal.

international date line An imaginary line on the earth's surface that joins the north and south poles and approximately follows the 180° meridian through the Pacific Ocean. This line has been agreed internationally to mark the beginning and end of a day. A traveller moving towards the east, against the sun's apparent movement, gains 1 hour for every 15° of longitude; westward he loses time at the same rate. In crossing the dateline therefore he is deemed to compensate for this by losing or gaining (respectively) one day. The 180° meridian was chosen as the date line by the International Meridian Conference in 1884.

International Nucleotide Sequence Database Collaboration (INSDC) A collaborative venture that effectively divides up the task of collecting, updating, and storing the nucleotide sequence data reported by researchers throughout the world. It comprises three databases, which exchange information on a daily basis; these are GenBank, run by the US National Institutes of Health, the DNA Data Bank of Japan (DDBJ), and the Nucleotide Sequence Database of the European Molecular Biology Laboratory (EMBL). Information from the entire collection can be accessed via any one of the partner organizations.

International Practical Temperature Scale *See* TEMPERATURE SCALES.

International Space Station A space-based scientific research facility constructed in earth orbit at an altitude of 350 km from prefabricated modules and components. It is a joint project involving the space agencies of the United States, Russia, Japan, Canada, and the ten member nations of the European Space Agency, with additional contributions from Brazil and Italy. Assembly of the station began in 1998 and was scheduled to be completed by 2011. It has been crewed continuously since November 2000.

international system *See* HERMANN–MAUGUIN SYSTEM.

Internet (Net) The global network that links most of the world's computer networks. It does not offer services to users, but serves primarily to interconnect other networks on which services are located. These include basic services for *electronic mail, the transfer of computer files, and remote log-in, and high-level services including the *World Wide Web. The Internet is informal, with a minimal level of administration by governing bodies.

internode **1.** (in botany) The part of a plant stem between two *nodes. **2.** (in neurology) The myelinated region of a nerve fibre between two nodes of Ranvier. *See* MYELIN SHEATH.

interoceptor A *receptor that detects stimuli from the internal environment of an organism. *Chemoreceptors that detect changes in the levels of oxygen concentration in the blood are examples. *Compare* EXTEROCEPTOR.

interphase The period following the completion of *cell division, when the nucleus is not dividing. During this period changes in both the nucleus and the cytoplasm result in the complete development of the daughter cells. *See* CELL CYCLE.

interplanetary space (interplanetary medium) The space occupied by the sun and the planets, dwarf planets, asteroids, comets, *trans-Neptunian objects, and all other bodies within the *solar system. Apart from these, the **interplanetary matter** that saturates this region of space consists mostly of the energetic particles that make up the *solar wind. The solar wind consists primarily of protons emerging from the sun at a rate of about 10^9 kilograms per second. At the earth's distance from the sun the particle density is only a few particles per cm^3. Apart from this very tenuous gas, there are also dust particles in interplanetary space, largely believed to originate in the belt of asteroids. Particles weighing about 1 g produce visible meteors in the earth's atmosphere; micrometeorites as small as 1 nanogram can be detected by their impact on spacecraft.

interpolation An *approximation technique for finding the value of a function or a measurement that lies within known values. If the values $f(x_0)$, $f(x_1)$, …, $f(x_n)$ of a function f of a variable x are known in the interval

$[x_0,x_n]$, the value of $f(x)$ for a value of x inside the interval $[x_0,x_n]$ can be found by interpolation. One method of interpolation, called **linear interpolation** for $x_0 < x < x_1$, gives:

$$f(x) \cong f(x_0) + [f(x_1) - f(x_0)]\ (x - x_0)/(x_1 - x_0),$$

which is derived using the assumption that between the points x_0 and x_1, the graph of the function $f(x)$ can be regarded as a straight line. More complicated methods of interpolation exist, using more than two values for the function. The techniques used for interpolation are usually much better than the techniques used in *extrapolation.

intersex An organism displaying characteristics that are intermediate between those of the typical male and typical female of its species. For example, a human intersex may have testes that fail to develop, so that although he is technically a man he has the external appearance of a woman. Intersexes may be produced in various ways; for example, by malfunctioning of the sex hormones. *See also* HERMAPHRODITE.

interspecific competition *See* COMPETITION.

interstellar molecules *See* ASTROCHEMISTRY.

interstellar space (interstellar medium) The space between the stars. The **interstellar matter** that occupies this space constitutes several percent of the Galaxy's total mass and it is from this matter that new stars are formed. The matter is primarily hydrogen, in which a number of other molecules and radicals have been detected, together with small solid dust grains. On average the density of matter in interstellar space is about 10^6 hydrogen atoms per cubic metre, but the gas is not uniformly distributed, being clumped into **interstellar clouds** of various sizes and densities.

interstitial *See* CRYSTAL DEFECT (Feature).

interstitial cell A cell that forms part of the connective tissue (the **interstitium**) between other tissues and structures, especially any of the cells of the *testis that lie between the seminiferous tubules and secrete androgens in response to stimulation by interstitial-cell-stimulating hormone (*see* LUTEINIZING HORMONE).

interstitial-cell-stimulating hormone *See* LUTEINIZING HORMONE.

interstitial compound A compound in which ions or atoms of a nonmetal occupy interstitial positions in a metal lattice. Such compounds often have metallic properties. Examples are found in the *carbides, *borides, and *silicides.

intervertebral disc Any of the discs of cartilage that separate the bones of the *vertebral column. The intervertebral discs allow the vertebral column a certain degree of flexibility and they also absorb shock.

intestinal juice (succus entericus) A slightly alkaline liquid containing mucus that is secreted into the lumen of the small intestine from the cells that line the *crypts of Lieberkühn. Together with pancreatic juice, the intestinal juice provides an alkaline environment that helps in the absorption of digested food molecules entering the small intestine in chyme from the stomach.

intestine The portion of the *alimentary canal posterior to the stomach. Its major functions are the final digestion of food matter from the stomach, the absorption of soluble food matter, the absorption of water, and the production of *faeces. *See* LARGE INTESTINE; SMALL INTESTINE.

intracellular (in biology) Located or occurring within cells. *Compare* INTERCELLULAR.

intraspecific competition *See* COMPETITION.

intrinsic factor *See* VITAMIN B COMPLEX.

intrinsic semiconductor *See* SEMICONDUCTOR.

intron (intervening sequence) A nucleotide sequence in a gene that does not code for the gene product (*compare* EXON). Introns, which occur principally in eukaryotes, are transcribed into messenger *RNA but are subsequently removed from the transcript before translation (*see* GENE SPLICING). Their functional significance is still subject to debate.

intrusion An upwelling of *magma or other molten rock into an existing rock. The intrusion may force its way through or follow such weaknesses as joints and bedding planes. The heat of the molten intrusion may bring about changes in the composition of the country rock it invades. There are various kinds of igneous intrusions, including *batholiths, *dykes, laccoliths, sills, and *xenoliths.

inulin A polysaccharide, made up from fructose molecules, that is stored as a food reserve in the roots or tubers of many plants, such as the dahlia.

Invar A trade name for an alloy of iron (63.8%), nickel (36%), and carbon (0.2%) that has a very low *expansivity over a a restricted temperature range. It is used in watches and other instruments to reduce their sensitivity to changes in temperature.

inverse Compton effect The gain in energy of low-energy photons when they are scattered by free electrons of much higher energy. As a consequence, the electrons lose energy. The effect is thought to be important in certain astrophysical processes. *See also* COMPTON EFFECT; GZK LIMIT.

inverse functions If $y = f(x)$ and a function can be found so that $x = g(y)$, then $g(y)$ is said to be the inverse function of $f(x)$. If y is a trigonometrical function of the angle x, say $y = \sin x$, then x is the **inverse trigonometrical function** of y, written $x = \arcsin y$ or $\sin^{-1} y$. Similarly, the other trigonometrical functions form the inverse trigonometrical functions $\cos^{-1} y$, $\tan^{-1} y$, $\cot^{-1} y$, $\sec^{-1} y$, and $\mathrm{cosec}^{-1} y$. **Inverse hyperbolic functions** are also formed in this way, e.g. $\mathrm{arcsinh}\, y$ or $\sinh^{-1} y$, $\cosh^{-1} y$, and $\tanh^{-1} y$.

inverse-square law A law in which the magnitude of a physical quantity is proportional to the reciprocal of the square of the distance from the source of that property. *Newton's law of gravitation and *Coulomb's law are both examples.

inversion **1.** (in chemistry) A chemical reaction involving a change from one optically active configuration to the opposite configuration. The Walden inversion is an example. *See* NUCLEOPHILIC SUBSTITUTION. **2.** (in genetics) A *chromosome mutation caused by reversal of part of a chromosome, so that the genes within that part are in inverse order. Inversion mutations usually occur during *crossing over in meiosis. **3.** (in genetics) A *point mutation caused by the reversal of two or more bases in the DNA sequence within a gene.

inversion layer *See* TRANSISTOR.

inversion temperature *See* JOULE–THOMSON EFFECT.

invertebrate Any animal that lacks a vertebral column (backbone). Invertebrates include all nonchordate animals as well as the more primitive chordates (*see* CHORDATA).

in vitro Describing biological processes that are made to occur outside the living body, in laboratory apparatus (literally 'in glass', i.e. in a test tube). In *in vitro* fertilization, mature egg cells are removed from the ovary of a woman unable to conceive normally and fertilized externally; the resultant blastocyst is implanted into her uterus. *Compare* IN VIVO.

in vivo Describing biological processes as they are observed to occur in their natural environment, i.e. within living organisms. *Compare* IN VITRO.

involucre A protective structure in some flowering plants and bryophytes. In flowering plants it consists of a ring of *bracts arising beneath the flower cluster of those species with a *capitulum (i.e. members of the dandelion family) or an *umbel (i.e. members of the carrot family). In mosses and liverworts the involucre is a projection of tissue from the thallus that arches over the developing *archegonium.

involuntary (in biology) Not under the control of the will of an individual. Involuntary responses by muscles, glands, etc., occur automatically when required; many such responses, such as gland secretion, heartbeat, and peristalsis, are controlled by the *autonomic nervous system and effected by *involuntary muscle.

involuntary muscle (smooth muscle) Muscle whose activity is not under the control of the will; it is supplied by the *autonomic nervous system. Involuntary muscle comprises long spindle-shaped cells without striations. These cells occur singly, in groups, or as sheets in the skin, around hair follicles, and in the digestive tract, respiratory tract, urinogenital tract, and the circulatory system. The cells contract slowly in spontaneous rhythms or when stretched; they may show sustained contraction (tonus) for long periods without fatigue. *Compare* CARDIAC MUSCLE; VOLUNTARY MUSCLE.

involute *See* EVOLUTE.

involution **1.** A decrease in the size of an organ or the body. It may be associated with functional decline, as occurs in the ageing process, or follow enlargement, as when the uterus returns to its normal size after preg-

nancy. **2.** The turning or rolling inwards of cells that occurs during the development of some vertebrate embryos.

iodic acid Any of various oxoacids of iodine, such as iodic(V) acid and iodic(VII) acid. When used without an oxidation state specified, the term usually refers to iodic(V) acid (HIO_3).

iodic(V) acid A colourless or very pale yellow solid, HIO_3; r.d. 4.63; decomposes at 110°C. It is soluble in water but insoluble in pure ethanol and other organic solvents. The compound is obtained by oxidizing iodine with concentrated nitric acid, hydrogen peroxide, or ozone. It is a strong acid and a powerful oxidizing agent.

iodic(VII) acid (periodic acid) A hygroscopic white solid, H_5IO_6, which decomposes at 140°C and is very soluble in water, ethanol, and ethoxyethane. Iodic(VII) acid may be prepared by electrolytic oxidation of concentrated solutions of iodic(V) acid at low temperatures. It is a weak acid but a strong oxidizing agent.

iodide *See* HALIDE.

iodine Symbol I. A dark violet nonmetallic element belonging to group 17 of the periodic table (*see* HALOGENS); a.n. 53; r.a.m. 126.9045; r.d. 4.94; m.p. 113.5°C; b.p. 184.35°C. The element is insoluble in water but soluble in ethanol and other organic solvents. When heated it gives a violet vapour that sublimes. Iodine is required as a trace element (*see* ESSENTIAL ELEMENT) by living organisms; in animals it is concentrated in the thyroid gland as a constituent of thyroid hormones. The element is present in sea water and was formerly extracted from seaweed. It is now obtained from oil-well brines (displacement by chlorine). There is one stable isotope, iodine–127, and fourteen radioactive isotopes. It is used in medicine as a mild antiseptic (dissolved in ethanol as **tincture of iodine**), and in the manufacture of iodine compounds. Chemically, it is less reactive than the other halogens and the most electropositive (metallic) halogen. It was discovered in 1812 by Bernard Courtois (1777–1838).

SEE WEB LINKS

- Information from the WebElements site

iodine(V) oxide (iodine pentoxide) A white solid, I_2O_5; r.d. 4.799; decomposes at 300–350°C. It dissolves in water to give iodic(V) acid and also acts as an oxidizing agent.

iodine value A measure of the amount of unsaturation in a fat or vegetable oil (i.e. the number of double bonds). It is obtained by finding the percentage of iodine by weight absorbed by the sample in a given time under standard conditions.

iodoethane (ethyl iodide) A colourless liquid *haloalkane, C_2H_5I; r.d. 1.9; m.p. –108°C; b.p. 72°C. It is made by reacting ethanol with a mixture of iodine and red phosphorus.

iodoform *See* TRIIODOMETHANE.

iodoform test *See* HALOFORM REACTION.

iodomethane (methyl iodide) A colourless liquid haloalkane, CH_3I; r.d. 2.28; m.p. –66.45°C; b.p. 42.4°C. It can be made by reacting methanol with a mixture of iodine and red phosphorus.

ion An atom or group of atoms that has either lost one or more electrons, making it positively charged (a cation), or gained one or more electrons, making it negatively charged (an anion). *See also* IONIZATION.

ion channel A protein that spans a cell membrane to form a water-filled pore through which ions can pass in or out of the cell or cell compartment. Ion channels are found in the plasma membrane and in certain internal cell membranes. They vary in how they open and close and in their selectivity to different ions: some may be specific for one particular ion, whereas others may admit two or more similar ions (e.g. K^+ and Na^+). The electrical and chemical environment inside cells, including the resting potential, is determined largely by the numbers, types, and activity of the cell's ion channels; they play a crucial role in the excitability of nerve and muscle cells.

ion engine A type of jet-propulsion engine that may become important for propelling or controlling spacecraft. It consists of a unit producing a beam of ions, which are accelerated by an electric or electromagnetic field. Reaction forces from the high-speed ions causes propulsion in much the same way as that caused by exhaust gas of a rocket. However, a separate beam of electrons or ions of opposite polarity to the propelling beam must also be ejected from the engine to enable recombination to take place behind the vehicle (to avoid the vehicle

becoming charged). Ion engines provide high *specific impulse and therefore low propellant consumption. The three main components of an ion engine are the power generator, the propellant feed, and the thruster. The power generator may be a nuclear reactor or a solar-energy collector. If it is the former, a gas turbine is coupled to the reactor and the turbine drives an electric generator. A solar-energy unit provides electricity direct. The propellant chosen needs to have an ion of medium mass (low mass for high specific impulse, high mass for high thrust) and a low first *ionization potential. Caesium and mercury are materials currently envisaged as suitable propellants. The thruster consists of an ionizer to produce the ions, an accelerator to provide and shape the accelerating field, and a neutralizer (usually an electron emitter) to neutralize the fast-moving ion beam after ejection.

ion exchange The exchange of ions of the same charge between a solution (usually aqueous) and a solid in contact with it. The process occurs widely in nature, especially in the absorption and retention of water-soluble fertilizers by soil. For example, if a potassium salt is dissolved in water and applied to soil, potassium ions are absorbed by the soil and sodium and calcium ions are released from it.

The soil, in this case, is acting as an ion exchanger. Synthetic **ion-exchange resins** consist of various copolymers having a cross-linked three-dimensional structure to which ionic groups have been attached. An **anionic resin** has negative ions built into its structure and therefore exchanges positive ions. A **cationic resin** has positive ions built in and exchanges negative ions. Ion-exchange resins, which are used in sugar refining to remove salts, are synthetic organic polymers containing side groups that can be ionized. In anion exchange, the side groups are ionized basic groups, such as $-NH_3^+$ to which anions X^- are attached. The exchange reaction is one in which different anions in the solution displace the X^- from the solid. Similarly, cation exchange occurs with resins that have ionized acidic side groups such as $-COO^-$ or $-SO_2O^-$, with positive ions M^+ attached.

Ion exchange also occurs with inorganic polymers such as *zeolites, in which positive ions are held at sites in the silicate lattice. These are used for water-softening, in which Ca^{2+} ions in solution displace Na^+ ions in the zeolite. The zeolite can be regenerated with sodium chloride solution. **Ion-exchange membranes** are used as separators in electrolytic cells to remove salts from sea water (*see also* DESALINATION) and in producing deionized water. Ion-exchange resins are also used as the stationary phase in **ion-exchange chromatography**.

ionic bond *See* CHEMICAL BOND.

ionic crystal *See* CRYSTAL.

ionic product The product of the concentrations of ions present in a given solution taking the stoichiometry into account. For a sodium chloride solution the ionic product is $[Na^+][Cl^-]$; for a calcium chloride solution it is $[Ca^{2+}][Cl^-]^2$. In pure water, there is an equilibrium with a small amount of self-ionization:

$$H_2O \rightleftharpoons H^+ + OH^-$$

The equilibrium constant of this dissociation is given by

$$K_W = [H^+][OH^-]$$

since the concentration $[H_2O]$ can be taken as constant. K_W is referred to as the ionic product of water. It has the value 10^{-14} $mol^2\ dm^{-6}$ at 25°C. In pure water (i.e. no added acid or added alkali) $[H^+] = [OH^-] = 10^{-7}$ mol dm^{-3}. *See also* SOLUBILITY PRODUCT; PH SCALE.

ionic radius A value assigned to the radius of an ion in a crystalline solid, based on the assumption that the ions are spherical with a definite size. X-ray diffraction can be used to measure the internuclear distance in crystalline solids. For example, in NaF the Na – F distance is 0.231 nm, and this is assumed to be the sum of the Na^+ and F^- radii. By making certain assumptions about the shielding effect that the inner electrons have on the outer electrons, it is possible to assign individual values to the ionic radii – Na^+ 0.096 nm; F^- 0.135 nm. In general, negative ions have larger ionic radii than positive ions. The larger the negative charge, the larger the ion; the larger the positive charge, the smaller the ion.

ionic strength Symbol *I*. A function expressing the effect of the charge of the ions in a solution, equal to the sum of the molality of each type of ion present multiplied by the square of its charge:

$$I = \Sigma m_i z_i^2.$$

ion implantation The technique of im-

planting ions in the lattice of a semiconductor crystal in order to modify its electronic properties. It is used as an alternative to diffusion, or in conjunction with it, in the manufacture of integrated circuits and solid-state components.

ionization The process of producing *ions. Certain molecules (*see* ELECTROLYTE) ionize in solution; for example, *acids ionize when dissolved in water (*see also* SOLVATION):

$$HCl \rightarrow H^+ + Cl^-$$

Electron transfer also causes ionization in certain reactions; for example, sodium and chlorine react by the transfer of a valence electron from the sodium atom to the chlorine atom to form the ions that constitute a sodium chloride crystal:

$$Na + Cl \rightarrow Na^+Cl^-$$

Ions may also be formed when an atom or molecule loses one or more electrons as a result of energy gained in a collision with another particle or a quantum of radiation (*see* PHOTOIONIZATION). This may occur as a result of the impact of *ionizing radiation or of thermal ionization and the reaction takes the form

$$A \rightarrow A^+ + e$$

Alternatively, ions can be formed by electron capture, i.e.

$$A + e \rightarrow A^-$$

ionization chamber An instrument for detecting *ionizing radiation. It consists of two electrodes contained in a gas-filled chamber with a potential difference maintained between them. Ionizing radiation entering the chamber ionizes gas atoms, creating electrons and positive ions. The electric field between the electrodes drives the electrons to the anode and the positive ions to the cathode. This current is, in suitable conditions, proportional to the intensity of the radiation. *See also* GEIGER COUNTER.

ionization energy (IE) *See* IONIZATION POTENTIAL.

ionization gauge A vacuum gauge consisting of a three-electrode system inserted into the container in which the pressure is to be measured. Electrons from the cathode are attracted to the grid, which is positively biased. Some pass through the grid but do not reach the anode, as it is maintained at a negative potential. Some of these electrons do, however, collide with gas molecules, ionizing them and converting them to positive ions. These ions are attracted to the anode; the resulting anode current can be used as a measure of the number of gas molecules present. Pressure as low as 10^{-6} pascal can be measured in this way.

ionization potential (IP) Symbol *I*. The minimum energy required to remove an electron from a specified atom or molecule to such a distance that there is no electrostatic interaction between ion and electron. Originally defined as the minimum potential through which an electron would have to fall to ionize an atom, the ionization potential was measured in volts. It is now, however, defined as the energy to effect an ionization and is conveniently measured in electronvolts (although this is not an SI unit).

The energy to remove the least strongly bound electron is the **first ionization potential**. Second, third, and higher ionization potentials can also be measured, although there is some ambiguity in terminology. Thus, in chemistry the second ionization potential is often taken to be the minimum energy required to remove an electron from the singly charged ion; the second IP of lithium would be the energy for the process

$$Li^+ \rightarrow Li^{2+} + e$$

In physics, the second ionization potential is the energy required to remove an electron from the next to highest energy level in the neutral atom or molecule; e.g.

$$Li \rightarrow Li^{*+} + e,$$

where Li^{*+} is an excited singly charged ion produced by removing an electron from the K-shell.

SEE WEB LINKS

- Values for ionization energies of neutral atoms at the NIST website

ionizing radiation Radiation of sufficiently high energy to cause *ionization in the medium through which it passes. It may consist of a stream of high-energy particles (e.g. electrons, protons, alpha-particles) or short-wavelength electromagnetic radiation (ultraviolet, X-rays, gamma-rays). This type of radiation can cause extensive damage to the molecular structure of a substance either as a result of the direct transfer of energy to its atoms or molecules or as a result of the secondary electrons released by ionization (*see* SECONDARY EMISSION). In biological tissue the effect of ionizing radiation can be very serious, usually as a consequence of the ejection of an electron from a water mol-

ecule and the oxidizing or reducing effects of the resulting highly reactive species:

$2H_2O \rightarrow e^- + H_2O^* + H_2O^+$

$H_2O^* \rightarrow .OH + .H$

$H_2O^+ + H_2O \rightarrow .OH + H_3O^+$

where the dot before a radical indicates an unpaired electron and * denotes an excited species.

ion-microprobe analysis A technique for analysing the surface composition of solids. The sample is bombarded with a narrow beam (as small as 2 µm diameter) of high-energy ions. Ions ejected from the surface by sputtering are detected by mass spectrometry. The technique allows quantitative analysis of both chemical and isotopic composition for concentrations as low as a few parts per million.

ion-mobility spectrometry (IMS) A technique for detecting low concentrations of specific compounds, based on the rate at which their ions migrate through an electric field. The instrument operates in the gas phase at atmospheric pressure. The sample vapour enters an ionizing region, where ions can be produced by a variety of methods. In compact instruments the source is usually a small amount of radioactive material. The ions are allowed in pulses into a drift tube, where they move to a detector under the influence of a homogeneous electric field. The rate of movement depends on the way the ions interact with neutral molecules in the tube and this depends on the ion's size and shape. The spectrum is a plot of detector signal against time, and is characteristic of the sample being ionized. Ion-mobility spectrometers are compact, sensitive, and fast-acting. They are widely used in screening for drugs and explosives at airports, border crossings, etc. often the technique is to wipe a swab over luggage and place it in the instrument. More sophisticated instruments combine IMS with gas chromatography or mass spectrometry. The technique is sometimes referred to as **gas-phase electrophoresis**.

ionomer A thermoplastic resin with ionic bonds between the polymer chains.

ionosphere *See* EARTH'S ATMOSPHERE; RADIO TRANSMISSION.

ionospheric wave *See* RADIO TRANSMISSION.

ion pair A pair of oppositely charged ions produced as a result of a single ionization; e.g.

$HCl \rightarrow H^+ + Cl^-$.

Sometimes a positive ion and an electron are referred to as an ion pair, as in

$A \rightarrow A^+ + e^-$.

ion pump A type of *vacuum pump that can reduce the pressure in a container to about 1 nanopascal by passing a beam of electrons through the residual gas. The gas is ionized and the positive ions formed are attracted to a cathode within the container where they remain trapped. The pump is only useful at very low pressures, i.e. below about 1 micropascal. The pump has a limited capacity because the absorbed ions eventually saturate the surface of the cathode. A more effective pump can be made by simultaneously *sputtering a film of metal, so that fresh surface is continuously produced. The device is then known as a **sputter-ion pump**.

ion trap A device used to trap ions by electrical or magnetic fields (or a combination of both). There are a number of types. The **Paul trap** has a ring electrode with a hyperbolic section and two hyperbolic end caps. Ions are trapped in an oscillating field produced by applying an oscillating voltage (about 1 MHz) between the ring electrode and the end caps. The device was invented in the 1950s by the German physicist Wolfgang Paul (1913–93). The **Penning trap** has a similar geometry and operation, but there is also a positive direct voltage (about 100 V) on the cap electrodes with respect to the ring electrode, and an axial magnetic field (about 5 tesla) to confine the particles. This type of trap was developed in 1959 by the German–American physicist Hans Dehmelt (1922–). He named it after Frans Penning, who had invented the *Penning gauge, which also uses a magnetic field. Ion traps can be used for storing and investigating the properties of ions and other charged particles and can also be used in *mass spectrometry.

IP *See* IONIZATION POTENTIAL.

IP_3 *See* INOSITOL.

IR *See* INFRARED RADIATION.

iridium Symbol Ir. A silvery metallic *transition element (*see also* PLATINUM METALS); a.n. 77; r.a.m. 192.20; r.d. 22.42; m.p. 2410°C; b.p. 4130°C. It occurs with platinum and is

mainly used in alloys with platinum and osmium. The element forms a range of iridium(III) and iridium(IV) complexes. It was discovered in 1804 by Smithson Tennant (1761–1815).

SEE WEB LINKS

- Information from the WebElements site

iridium anomaly The occurrence of unusually high concentrations of the relatively scarce metal iridium at the boundaries of certain geological strata. Two such layers have been discovered, one at the end of the Cretaceous, 65 million years ago, and the second at the end of the Eocene, 34 million years ago. One theory to account for these suggests that on each occasion a huge iridium-containing meteorite may have collided with the earth, producing a cloud of dust that settled out to form an iridium-rich layer. The environmental consequences of such an impact, notably in causing a general warming of the earth by the *greenhouse effect, may have led to the extinction of the dinosaurs at the end of the Cretaceous and the extinction of many radiolarians at the end of the Eocene. *See* ALVAREZ EVENT.

iris **1.** (in anatomy) The pigmented ring of muscular tissue, lying between the cornea and the lens, in the eyes of vertebrates and some cephalopod molluscs. It has a central hole (the **pupil**) through which light enters the eye and it contains both circular and radial muscles. Reflex contraction of the former occurs in bright light to reduce the diameter of the pupil; contraction of the radial muscles in dim light increases the pupil diameter and therefore the amount of light entering the eye. Colour is determined by the amount of the pigment melanin in the iris. Blue eyes result from relatively little melanin; grey and brown eyes from increasingly larger amounts. **2.** (in physics) *See* DIAPHRAGM.

iron Symbol Fe. A silvery malleable and ductile metallic *transition element; a.n. 26; r.a.m. 55.847; r.d. 7.87; m.p. 1535°C; b.p. 2750°C. The main sources are the ores *haematite (Fe_2O_3), *magnetite (Fe_3O_4), limonite ($FeO(OH)_nH_2O$), ilmenite ($FeTiO_3$), siderite ($FeCO_3$), and pyrite (FeS_2). The metal is smelted in a *blast furnace to give impure *pig iron, which is further processed to give *cast iron, *wrought iron, and various types of *steel. The pure element has three crystal forms: **alpha-iron**, stable below 906°C with a body-centred-cubic structure; **gamma-iron**, stable between 906°C and 1403°C with a nonmagnetic face-centred-cubic structure; and **delta-iron**, which is the body-centred-cubic form above 1403°C. Alpha-iron is ferromagnetic up to its Curie point (768°C). The element has nine isotopes (mass numbers 52–60), and is the fourth most abundant in the earth's crust. It is required as a trace element (*see* ESSENTIAL ELEMENT) by living organisms. Iron is quite reactive, being oxidized by moist air, displacing hydrogen from dilute acids, and combining with nonmetallic elements. It forms ionic salts and numerous complexes with the metal in the +2 or +3 oxidation states. Iron(VI) also exists in the ferrate ion FeO_4^{2-}, and the element also forms complexes in which its oxidation number is zero (e.g. $Fe(CO)_5$).

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iron(II) chloride A green-yellow deliquescent compound, $FeCl_2$; hexagonal; r.d. 3.16; m.p. 670°C. It also exists in hydrated forms: $FeCl_2.2H_2O$ (green monoclinic; r.d. 2.36) and $FeCl_2.4H_2O$ (blue-green monoclinic deliquescent; r.d. 1.93). Anhydrous iron(II) chloride can be made by passing a stream of dry hydrogen chloride over the heated metal; the hydrated forms can be made using dilute hydrochloric acid or by recrystallizing with water. It is converted into iron(III) chloride by the action of chlorine.

iron(III) chloride A black-brown solid, $FeCl_3$; hexagonal; r.d. 2.9; m.p. 306°C; decomposes at 315°C. It also exists as the hexahydrate $FeCl_3.6H_2O$, a brown-yellow deliquescent crystalline substance (m.p. 37°C; b.p. 280–285°C). Iron(III) chloride is prepared by passing dry chlorine over iron wire or steel wool. The reaction proceeds with incandescence when started and iron(III) chloride sublimes as almost black iridescent scales. The compound is rapidly hydrolysed in moist air. In solution it is partly hydrolysed; hydrolysis can be suppressed by the addition of hydrochloric acid. The compound dissolves in many organic solvents, forming solutions of low electrical conductivity: in ethanol, ethoxyethane, and pyridine the molecular weight corresponds to $FeCl_3$ but is higher in other solvents corresponding to Fe_2Cl_6. The vapour is also dimerized. In many ways the compound resembles aluminium chloride, which it may replace in Friedel–Crafts reactions.

iron(II) oxide A black solid, FeO; cubic; r.d. 5.7; m.p. 1420°C. It can be obtained by heating iron(II) oxalate; the carbon monoxide formed produces a reducing atmosphere thus preventing oxidation to iron(III) oxide. The compound has the sodium chloride structure, indicating its ionic nature, but the crystal lattice is deficient in iron(II) ions and it is nonstoichiometric. Iron(II) oxide dissolves readily in dilute acids.

iron(III) oxide A red-brown to black insoluble solid, Fe_2O_3; trigonal; r.d. 5.24; m.p. 1565°C. There is also a hydrated form, $Fe_2O_3.xH_2O$, which is a red-brown powder; r.d. 2.44–3.60. (*See* RUSTING.)

Iron(III) oxide occurs naturally as *haematite and can be prepared by heating iron(III) hydroxide or iron(II) sulphate. It is readily reduced on heating in a stream of carbon monoxide or hydrogen.

iron pyrites *See* PYRITE.

ironstone A sedimentary rock so-called because of its content of iron, usually in the form of the minerals haematite, limonite, or pyrite, which sometimes give the surface of the rock a typical rusty colour. It is found in beds, layers, or nodules. The iron minerals often take the form of small spherical oolites embedded in the rock.

iron(II) sulphate An off-white solid, $FeSO_4.H_2O$; monoclinic; r.d. 2.970. There is also a heptahydrate form, $FeSO_4.7H_2O$; blue-green monoclinic; r.d. 1.898; m.p. 64°C. The heptahydrate is the best known iron(II) salt and is sometimes called **green vitriol** or **copperas**. It is obtained by the action of dilute sulphuric acid on iron in a reducing atmosphere. The anhydrous compound is very hygroscopic. It decomposes at red heat to give iron(III) oxide, sulphur trioxide, and sulphur dioxide. A solution of iron(II) sulphate is gradually oxidized on exposure to air, a basic iron(III) sulphate being deposited.

iron(III) sulphate A yellow hygroscopic compound, $Fe_2(SO_4)_3$; rhombic; r.d. 3.097; decomposes above 480°C. It is obtained by heating an aqueous acidified solution of iron(II) sulphate with hydrogen peroxide:

$$2FeSO_4 + H_2SO_4 + H_2O_2 \rightarrow Fe_2(SO_4)_3 + 2H_2O$$

On crystallizing, the hydrate $Fe_2(SO_4)_3.9H_2O$ is formed. The acid sulphate $Fe_2(SO_4)_3.H_2SO_4.8H_2O$ is deposited from solutions containing a sufficient excess of sulphuric acid.

irradiance Symbol *E*. The *radiant flux per unit area reaching a surface; in SI units it is measured in watts per square metre ($W\ m^{-2}$). Irradiance refers to electromagnetic radiation of all kinds, whereas *illuminance refers only to visible radiation.

irradiation Exposure to any form of radiation; often exposure to *ionizing radiation is implied. *See also* FOOD PRESERVATION.

irrational number A number that cannot be expressed as the ratio of two integers. An irrational number may be a *surd, such as $\sqrt{2}$ or $\sqrt{3}$, which can be expressed to any desired degree of accuracy but cannot be assigned an exact value. Alternatively, it may be a *transcendental number, such as π or e. *Compare* RATIONAL NUMBER.

irreversibility The property of a system that precludes a change to the system from being a *reversible process. The paradox that although the equations describing the bodies in a system, such as Newton's laws of motion, Maxwell's equation, or Schrödinger's equation are invariant under *time reversal, events involving systems made up from large numbers of these bodies are not reversible. The process of scrambling an egg is an example. The resolution of this paradox requires the concept of *entropy using *statistical mechanics. Irreversibility occurs in the transition from an ordered arrangement to a disordered arrangement, which is a natural trend, since changes in a closed system occur in the direction of increasing entropy. Irreversibility also occurs in processes that violate T symmetry. According to the *CPT theorem, processes that violate CP also violate T and hence are irreversible. This has been observed in some weak interactions.

irreversible reaction *See* CHEMICAL REACTION.

irrigation The provision of water for crops by artificial methods; for example by constructing ditches, pipe systems, and canals. Irrigation can lead to problems when the water leaches trace elements from the soil; selenium, for example, can be toxic to both local fauna and flora. Irrigation can also increase the salinity of the soil, if diverted rivers are used to provide the water. Evaporation of surface water leaves a crust of salt, which can drain down to deeper layers of the soil.

irritability *See* SENSITIVITY.

IR spectroscopy *See* INFRARED SPECTROSCOPY.

ischium The most posterior of the three bones that make up each half of the *pelvic girdle. *See also* ILIUM; PUBIS.

isentropic process Any process that takes place without a change of *entropy. The quantity of heat transferred, δQ, in a reversible process is proportional to the change in entropy, δS, i.e. $\delta Q = T\delta S$, where T is the thermodynamic temperature. Therefore, a reversible *adiabatic process is isentropic, i.e. when δQ equals zero, δS also equals zero.

Ising model A simplified model of a magnetic system consisting of an array of magnetic spins. Spins may have one of two values and interactions occur with nearest neighbours. There are also random thermal fluctuations depending on the temperature of the system. At low temperatures there is a net magnetization as a result of alignment of spins. At high temperature there is no net magnetization. The model was first proposed by the German physicist Ernst Ising (1900–98), who studied the one-dimensional case in 1924. The two-dimensional case for a square lattice was solved exactly by Lars Onsager in 1944. Only approximate solutions have been found for three-dimensional models. The Ising model is very important in statistical mechanics and can be used to investigate other types of phase transition.

ISIS/Draw A commonly used chemical drawing program for 2D and 3D structures, copyright of MDL Information Systems, Inc. The program has certain additional features including calculation of molecular weight, calculation of percentages of elements present, IUPAC name generation, and viewing in RasMol.

SEE WEB LINKS

- A limited version of ISIS/Draw at the Elsevier MDL website (free registration required)

islets of Langerhans Small groups of cells in the pancreas that function as an endocrine gland. The alpha (or A) cells secrete the hormone *glucagon, the beta (or B) cells secrete *insulin, and the D cells secrete *somatostatin. The islets are named after their discoverer, the German anatomist and microscopist Paul Langerhans (1847–88).

iso- Prefix denoting that a compound is an isomer, e.g. isopentane ($CH_3CH(CH_3)C_2H_5$, 2-methylbutane) is an isomer of pentane. *See* ISOMERISM.

isobar **1.** A line on a map or chart that joins points or places that have the same atmospheric pressure. **2.** A curve on a graph representing readings taken at constant pressure. **3.** One of two or more nuclides that have the same number of nucleons but different *atomic numbers. Radium–88, actinium–89, and thorium–90 are isobars as each has a *nucleon number of 228.

isobaric spin *See* ISOTOPIC SPIN.

isocline A line on a map or chart joining points or places of equal magnetic dip (*see* GEOMAGNETISM).

isocyanate *See* CYANIC ACID.

isocyanic acid *See* CYANIC ACID.

isocyanide *See* ISONITRILE.

isocyanide test A test for primary amines by reaction with an alcoholic solution of potassium hydroxide and trichloromethane.

$$RNH_2 + 3KOH + CHCl_3 \rightarrow RNC + 3KCl + 3H_2O$$

The isocyanide RNC is recognized by its unpleasant smell. This reaction of primary amines is called the **carbylamine reaction**.

isodiaphere One of two or more nuclides in which the difference between the number of neutrons and the number of protons is the same. A nuclide and its product after losing an *alpha particle are isodiapheres.

isodynamic line A line on a map or chart joining points or places at which the total strengths of the earth's magnetic field are equal (*see* GEOMAGNETISM).

isoelectric point The pH of a medium at which a protein carries no net charge and therefore will not migrate in an electric field. Proteins precipitate most readily at their isoelectric points; this property can be utilized to separate mixtures of proteins or amino acids.

isoelectronic Describing compounds that have the same numbers of valence electrons. For example, nitrogen (N_2) and carbon monoxide (CO) are isoelectronic molecules.

isoenzyme *See* ISOZYME.

isogamy Sexual reproduction involving the production and fusion of gametes that are similar in size and structure. It occurs in

some protoctists, e.g. certain protozoans and algae. *Compare* ANISOGAMY.

isogonal line A line on a map or chart joining points or places of equal magnetic declination (*see* GEOMAGNETISM).

isoindole *See* INDOLE.

isolating mechanism Any of the biological properties of organisms that prevent interbreeding (and therefore exchange of genetic material) between members of different species that inhabit the same geographical area. These mechanisms include **seasonal isolation**, in which the *breeding seasons of the different populations do not overlap; and **behavioural isolation**, in which different *courtship behaviour in the populations ensures that mating takes place only between members of the same species. Both these are examples of **premating mechanisms**. **Postmating mechanisms** include hybrid infertility and inviability.

isoleptic complex A metal complex in which all the ligands are the same.

isoleucine *See* AMINO ACID.

isomerase Any of a class of *enzymes that catalyse the rearrangement of the atoms within a molecule, thereby converting one isomer into another.

isomerism **1.** (in chemistry) The existence of chemical compounds (**isomers**) that have the same molecular formulae but different molecular structures or different arrangements of atoms in space. In **structural isomerism** the molecules have different molecular structures: i.e. they may be different types of compound or they may simply differ in the position of the functional group in the molecule. Structural isomers generally have different physical and chemical properties. In **stereoisomerism**, the isomers have the same formula and functional groups, but differ in the arrangement of groups in space. Optical isomerism is one form of this (*see* OPTICAL ACTIVITY). Another type is **cis–trans isomerism** (formerly **geometrical isomerism**), in which the isomers have different positions of groups with respect to a double bond or central atom (see illustration overleaf).

Octahedral complexes can display cis–trans isomerism if they have formulae of the type MX_2Y_4. Octahedral complexes with formulae of the type MX_3Y_3 can display a different type of isomerism. If the three X ligands are in a plane that includes the metal atom and the three Y ligands are in a different plane at right angles, then the structure is a **mer-isomer** (meridional). If the three X ligands are all on one face of the octahedron and the three Y ligands are on an opposite face, then it is a **fac-isomer** (facial). See illustration overleaf. *See also* AMBIDENTATE; E–Z CONVENTION. **2.** (in physics) The existence of atomic nuclei that have the same atomic number and the same mass number but different energy states.

isomers *See* ISOMERISM.

isometric **1.** (in technical drawing) Denoting a projection in which the three axes are equally inclined to the surface of the drawing and lines are drawn to scale. **2.** (in crystallography) Denoting a system in which the axes are perpendicular to each other, as in cubic crystals. **3.** (in physics) Denoting a line on a graph illustrating the way in which temperature and pressure are interrelated at constant volume.

isomorphism The existence of two or more substances (**isomorphs**) that have the same crystal structure, so that they are able to form *solid solutions.

isonitrile (isocyanide; carbylamine) An organic compound containing the group –NC, in which the bonding is to the nitrogen atom.

SEE WEB LINKS

- Information about IUPAC nomenclature

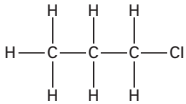
iso-octane *See* OCTANE; OCTANE NUMBER.

isopoly compound *See* CLUSTER COMPOUND.

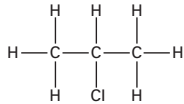
isoprene A colourless liquid diene, $CH_2{:}C(CH_3)CH{:}CH_2$. The systematic name is **2-methylbuta-1,3-diene**. It is the structural unit in *terpenes and natural *rubber, and is used in making synthetic rubbers.

isospin *See* ISOTOPIC SPIN.

isostasy The theoretical equilibrium that tends to exist in the earth's crust. If this equilibrium is disturbed, for example as a result of erosion or deposition, compensatory movements in the earth's crust occur: areas of deposition sink, whereas areas of erosion rise. Continental ice sheets have been an important cause of isostatic movements of the earth's crust. The growth of ice sheets and the resulting additional mass of the ice is compensated by the downward

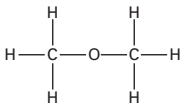


1-chloropropane

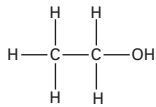


2-chloropropane

structural isomers in which the functional group has different positions

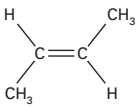


methoxymethane

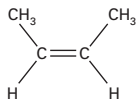


ethanol

structural isomers in which the functional groups are different

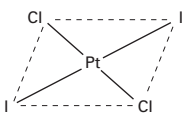


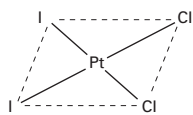
trans-but-2-ene



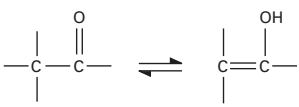
cis-but-2-ene

cis–trans isomers in which the groups are distributed on a double bond





cis–trans isomers in a square-planar complex



keto form enol form

keto–enol tautomerism

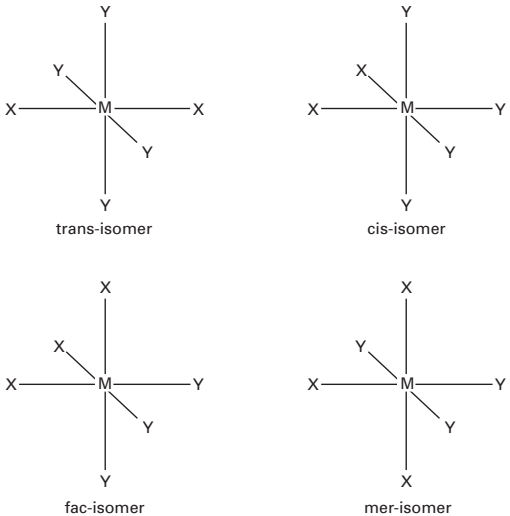
Isomerism.

deflection of the lithospheric plate and the displacement of asthenospheric material (*see* ASTHENOSPHERE) beneath it. When the ice melts, the displaced material flows back causing the overlying lithospheric plate to rise.

isotactic polymer *See* POLYMER.

isotherm **1.** A line on a map or chart joining points or places of equal temperature. **2.** A curve on a graph representing readings taken at constant temperature (e.g. the relationship between the pressure and volume of a gas at constant temperature).

isothermal process Any process that



Isomerism.

takes place at constant temperature. In such a process heat is, if necessary, supplied or removed from the system at just the right rate to maintain constant temperature. *Compare* ADIABATIC PROCESS.

isotone One of two or more nuclides that contain the same number of neutrons but different numbers of protons. The naturally occurring isotones, for example, strontium–88 and yttrium–89 (both with 50 neutrons), give an indication of the stability of certain nuclear configurations.

isotonic Describing solutions that have the same osmotic pressure.

isotope One of two or more atoms of the same element that have the same number of protons in their nucleus but different numbers of neutrons. Hydrogen (1 proton, no neutrons), deuterium (1 proton, 1 neutron), and tritium (1 proton, 2 neutrons) are isotopes of hydrogen. Most elements in nature consist of a mixture of isotopes. *See* ISOTOPE SEPARATION.

SEE WEB LINKS

- Isotopic compositions at the NIST website

isotope separation The separation of the *isotopes of an element from each other on the basis of slight differences in their physical properties. For laboratory quantities the most suitable device is often the mass spectrometer. On a larger scale the methods used include gaseous diffusion (widely used for separating isotopes of uranium in the form of the gas uranium hexafluoride), distillation (formerly used to produce heavy water), electrolysis (requiring cheap electrical power), thermal diffusion (formerly used to separate uranium isotopes, but now considered uneconomic), centrifuging, and laser methods (involving the excitation of one isotope and its subsequent separation by electromagnetic means).

isotopic number (neutron excess) The difference between the number of neutrons in an isotope and the number of protons.

isotopic signature The relative proportions of certain isotopes in a sample of tissue, water, air or other material. In biology the proportions of stable isotopes of common elements in organic matter, especially carbon, nitrogen, and oxygen, can provide useful clues about growing conditions, lifestyle, and metabolism of the organism from which the material was derived. Differences in the relative tissue abundance of the natural stable isotopes of carbon (i.e. ^{12}C and ^{13}C), oxygen (^{16}O and ^{18}O) and nitrogen

(^{14}N and ^{15}N) reflect their differing availability in the environment or in the diet, or some form of selective metabolism by the organism. So, for example, human hair samples with differing isotopic signatures can indicate the dietary preferences of the individuals.

isotopic spin (isospin; isobaric spin) A quantum number applied to hadrons (*see* ELEMENTARY PARTICLES) to distinguish between members of a set of particles that differ in their electromagnetic properties but are otherwise apparently identical. For example if electromagnetic interactions and weak interactions are ignored, the proton cannot be distinguished from the neutron in their strong interactions: isotopic spin was introduced to make a distinction between them. The use of the word 'spin' implies only an analogy to angular momentum, to which isotopic spin has a formal resemblance.

isotropic Denoting a medium whose physical properties are independent of direction. *Compare* ANISOTROPIC.

isozyme (isoenzyme) One of several forms of an enzyme in an individual or population that catalyse the same reaction but differ from each other in such properties as substrate affinity and maximum rates of enzyme–substrate reaction (*see* MICHAELIS–MENTEN CURVE).

IT (information technology) The use of computers and telecommunications equipment (with their associated microelectronics) to send, receive, store and manipulate data. The data may be textual, numerical, audio or video, or any combination of these. *See also* WORLD WIDE WEB.

iteration The process of successive approximations used as a technique for solving a mathematical problem. The technique can be used manually but is widely used by computers.

IUPAC International Union of Pure and Applied Chemistry. An international nongovernmental body formed in 1919 to foster worldwide communications in chemical science, both academic and industrial. IUPAC is the international authority defining recommended terminology, atomic weights, isotopic abundances, and other data.

SEE WEB LINKS

- The IUPAC home page

IUPAP International Union of Pure and Applied Physics. An international nongovernmental body formed in 1922 to stimulate and promote international cooperation in physics. IUPAP fosters the preparation and publication of tables of physical constants and promotes international agreements on the use of symbols, units, nomenclature, and standards.

SEE WEB LINKS

- The IUPAP home page