

Glossary of Terms

Adiabatic process

A process that takes place without heat entering or leaving the system.

Alternating current

Electric current that flows for an interval of time (half-period) in one direction and then flows for the same time in the opposite direction. The normal waveform is sinusoidal.

Anion

Ion in an electrolyte that carries a negative charge and that migrates towards the anode under the influence of a potential gradient. See **Anode**, **Ion**.

Anode

An electrode at which an oxidation process, *i.e.*, loss of electrons, is occurring. During electrolysis, the anode is the positive electrode. In a fuel cell, the anode is the negative electrode where hydrogen is consumed.

Aquifer

Underground water-bearing, porous rock strata that yield economic supplies of water, sometimes heated, to wells or springs.

Band gap energy

The energy gap, generally measured in electron volts (eV), between the top of the valence band and the bottom of the conduction band in a crystalline solid. See **Conduction band**, **Energy band**, **Valence band**.

Barrel

A measure of crude oil (petroleum), approximately 159 litres.

Battery electric vehicle (BEV)

A vehicle driven by an electric motor that is powered by rechargeable batteries.

Battery pack

A number of batteries connected together to provide the required power and energy for a given application.

Bio-energy

Energy derived from combustible waste materials or crops.

Biofuel

A gaseous, liquid or solid fuel that is derived from a biological source.

Biogas

A mixture of methane and carbon dioxide that results from the anaerobic decomposition of waste matter.

Biomass

The term used to describe all biologically produced matter at the end of its life. This includes both waste matter and crops that are specially grown as a source of energy.

Bipolar plates

The components of a fuel cell that act as the current collector for the positive electrode in one cell and for the negative electrode in the adjacent cell and also serve to join the cells electrically. The cells in a stack are series-connected and so allow the voltage to be built up.

Carbon footprint

A measure of the impact of human activities on the environment in terms of the amount of greenhouse gases produced; expressed as tonnes of carbon dioxide or carbon emitted, usually on a yearly basis.

Carnot cycle

The most efficient cycle of operation for a reversible heat engine. It consists of four operations, as in the four-stroke internal combustion engine, namely: isothermal expansion, adiabatic expansion, isothermal compression and adiabatic compression to the initial state.

Catalyst

A substance that increases the rate of a chemical reaction, but that is not itself permanently changed.

Cathode

An electrode at which a reduction process, *i.e.*, gain of electrons, is occurring. During electrolysis the cathode is the negative electrode. In a fuel cell, the cathode is the positive electrode where oxygen is consumed.

Cation

Ion in an electrolyte that carries a positive charge and that migrates towards the cathode under the influence of a potential gradient. See **Cathode**, **Ion**.

Chemical reactor

Engineering equipment in which a chemical reaction takes place.

Clathrates

Crystalline compounds formed between certain gases (*e.g.*, carbon dioxide, hydrogen sulfide, methane) and water at low temperatures and high pressures.

Climate change

A change of climate, attributed directly or indirectly to human activity, that alters the composition of the global atmosphere and is in addition to natural climate variability observed over comparable time periods. See **Global warming**.

Coal gas

A fuel gas, which is usually rich in hydrogen, produced when coal is heated in the absence of air (so-called ‘destructive distillation’ or ‘pyrolysis’). It is a by-product in the preparation of coke and coal tar. Coal gas was a major source of energy in the late 19th and early 20th centuries and was also known as ‘town gas’. The use of this gas declined with the increasing availability of natural gas. See **Pyrolysis**.

Cogeneration

See **Combined heat and power (CHP) system**.

Combined-cycle gas turbine (CCGT)

The technology employed in a natural gas-fired power station. The gas is first burnt in a gas turbine and the waste heat contained in the exhaust gases is then recovered and used to raise steam to drive a steam turbine.

Combined heat and power (CHP) system

An installation where there is simultaneous generation of usable heat and power (usually electricity) in a single process. The term is synonymous with cogeneration.

Conduction band

Partially filled or empty energy levels in a crystalline solid where electrons are free to move and thus allow the solid to conduct an electrical current.

Critical point (of a gas/liquid)

The temperature and pressure at and above which the gaseous and liquid states of a substance are indistinguishable.

Current density

In an electrochemical cell, the current flowing per unit electrode area.

Direct current

Electric current that flows in one direction only, although it may have appreciable pulsations in its magnitude.

Drive-train

The elements of the propulsion system that deliver mechanical energy from the power source to drive the wheels of a given vehicle.

Electric vehicle (EV)

A vehicle propelled by an electric motor.

Electrochemical capacitor

A capacitor that stores charge in the form of ions (rather than electrons), adsorbed on materials of high surface area. The ions undergo redox reactions

during charge and discharge. Also known as electrochemical double-layer capacitors, supercapacitors and ultracapacitors. See **Redox reaction**.

Electrode

An electronic conductor that acts as a source or sink of electrons that are involved in electrochemical reactions.

Electrode potential

The voltage developed by a single electrode, either positive or negative. The algebraic difference in voltage of any pair of electrodes of opposite polarity equals the cell voltage.

Electrolysis

The production of a chemical reaction by passing a direct electric current through an electrolyte.

Electrolyte

A chemical that conducts electricity by means of positive or negative ions. Electrolytes are solids, molten ionic compounds or solutions containing ions, *i.e.*, solutions of ionic salts or of compounds that ionize in solution.

Electrolytic cell

An electrochemical cell, which consists of a positive and a negative electrode and an electrolyte, through which an externally generated electric current is passed in order to produce an electrochemical reaction. See **Positive electrode**, **Negative electrode**, **Electrolyte**.

Electrolyzer

An electrochemical plant designed to effect the process of electrolysis.

Energy efficiency

The ratio of the energy output from a device to the energy input.

Endothermic reaction

A chemical reaction in which heat is absorbed. See **Enthalpy**.

Energy

The ability to do work or produce heat (measured in joules).

Energy band

The range of energies that electrons can have in a solid. In a single atom, electrons exist in discrete energy levels. In a crystal, where large numbers of atoms are held closely together in a lattice, electrons are influenced by a number of adjacent nuclei and the sharply defined energy levels of the atoms become bands of allowed energy that are separated by bands of forbidden values. In a metal, there is a continuous energy band.

Energy crops

Trees, grasses and other vegetation grown specially for use as a fuel or for extracting plant oils or alcohols that may be used as fuels in internal combustion engines.

Energy density

Stored energy per unit volume, usually expressed in MJ m⁻³ or kWh m⁻³.

Enthalpy

A thermodynamic quantity (H) equal to the total energy of a system when it is at constant pressure. The gain or loss of energy by a system when it reacts at constant pressure is expressed by the change in enthalpy, symbolized by ΔH . When all the energy change appears as heat (Q), the change in enthalpy is equal to the heat of reaction at constant pressure, *i.e.*, $\Delta H=Q$. The values of ΔH and Q are negative for exothermic reactions (heat evolved from system) and positive for endothermic reactions (heat absorbed by system).

Entropy

A thermodynamic quantity representing the amount of energy in a system that is no longer available to do useful work. When a closed system undergoes a reversible change, the entropy change (ΔS) equals the energy lost from or transferred to, the system by heat (Q) divided by the absolute temperature (T) at which this occurs, *i.e.*, $\Delta S=Q/T$. At constant pressure, the amount of heat (Q) is equal to the change in enthalpy (ΔH). For a more detailed explanation, see **Box 4.2, Chapter 4**.

Equilibrium potential

See **Reversible potential**.

Equilibrium voltage

See **Reversible voltage**.

Exothermic reaction

A chemical reaction in which heat is evolved. See **Enthalpy**.

Fermi level

The energy level in a semiconductor where there is a 0.5 probability of finding an electron.

Fossil fuels

Carbonaceous deposits (solid, liquid or gaseous) that derive from the decay of vegetable matter over geological time spans.

Free energy of formation

See **Gibbs free energy** and **Box 4.2, Chapter 4**.

Fuel cell

An electrochemical device for generating low-voltage direct current electricity from a fuel (often hydrogen) and air or oxygen.

Galvanic cell

An electrochemical cell in which chemical energy is converted into electrical energy on demand; more commonly known as a 'battery'. See **Fuel cell**.

Gasification

A special type of pyrolysis where thermal decomposition takes place in the presence of a small amount of air or oxygen. See **Coal gas, Pyrolysis**.

Gettering

The removal of residual gas from a moderate vacuum by absorption into, or reaction with, a reactive species such as a metal.

Gibbs free energy

The energy liberated or absorbed in a reversible process at constant pressure and constant temperature. The change in free energy, ΔG , in a chemical reaction is given by $\Delta G = \Delta H - T\Delta S$, where ΔH is the change in enthalpy, ΔS is the change in entropy and T is the temperature. This is known as the Gibbs equation. See **Enthalpy**, **Entropy**.

Global warming

The observed and projected increases in the average temperature of the Earth's atmosphere and oceans.

Green electricity

Electricity generated from renewable energy sources, which include carbon-neutral biomass. (Note: nuclear energy, which does not liberate carbon dioxide, is sometimes counted as a form of green electricity.)

Greenhouse gases

Those gaseous constituents of the Earth's atmosphere, both natural and anthropogenic, that absorb and re-emit infrared radiation.

Higher heating value of a fuel (HHV)

The maximum heat of combustion (MJ kg^{-1}) of a fuel, based on complete combustion to carbon dioxide and water at 25 °C.

Hybrid electric vehicle (HEV)

A vehicle that has two power sources, often a conventional engine together with a battery or fuel cell that provides electric propulsion through an electric motor.

Hydrothermal reservoir

An aquifer containing water or brine at more than 100 °C and therefore pressurized.

Integrated gasification combined cycle (IGCC)

A technology employed in some coal-fired power stations. Instead of feeding pulverized coal directly to the boilers to raise steam, it is first converted to a gaseous mixture of carbon monoxide, hydrogen and nitrogen that is then combusted in a gas turbine.

Internal resistance

The opposition to current flow that results from the various electronic and ionic resistances within an electrochemical or photo-electrochemical cell.

Ion

An atom that has lost or gained one or more orbiting electrons and thus becomes electrically charged.

Ionization

Any process by which an atom, molecule or ion gains or loses electrons.

Isoelectronic compounds

Compounds with the same number of electrons.

Isothermal process

A process that takes place without change in temperature.

Joule–Thompson cooling

The cooling of a gas by allowing it to expand without gaining any external heat.

Latent heat

The heat absorbed or released by a substance when it changes state (*e.g.*, from solid to liquid or vice versa) at constant temperature and pressure. The term **Specific latent heat** denotes the heat absorbed or released per unit mass of a substance during the course of its change of state.

Lower heating value of a fuel (LHV)

The heat of combustion (MJ kg^{-1}) of a fuel, based on complete combustion to carbon dioxide and steam at $100\text{ }^{\circ}\text{C}$.

Maximum power point

The point on the current–voltage curve for a photovoltaic cell at which the cell generates maximum power.

Megawatt (MW)

Unit of energy equal to 10^6 W. MW_e denotes electrical output and MW_{th} denotes thermal heat output.

Membrane–electrode assembly

A component of a fuel cell that consists of a polymer membrane electrolyte coated with (or sandwiched between) positive and negative electrodes and then placed between bipolar plates.

Monopolar

The conventional method of constructing an electrolyzer (or battery) in which component cells are joined in parallel and have their electrodes at the same common potential.

Negative electrode

The electrode in an electrochemical cell that has the lower potential.

***n*-type semiconductor**

A semiconductor in which electrical conduction is due mainly to the movement of electrons.

Oil

In this book, oil and petroleum are used synonymously for crude (unrefined) oil.

Oil sands

A mixture of sand, clay, water and bitumen from which oil may be recovered and refined.

Oil shale

Rocks rich in organic material (kerogen) from which petroleum may be recovered by dry distillation.

Open-circuit voltage

The voltage of a power source, such as a battery, fuel cell or photo-electrochemical cell, when there is no net current flow.

Overpotential

The shift in the potential of an electrode from its equilibrium value as a result of current flow.

Peak power

The sustained pulsed power that is obtainable from a fuel cell or battery under specified conditions, usually measured in watts over a period of 30 s.

Petrol

Term used in the UK for a light hydrocarbon liquid fuel for spark-ignition internal combustion engines. Other terms for such fuel are gas(oline) and motor spirit.

Petroleum

See **Oil**.

Photo-electrochemical cell

Solar cells that extract electrical energy from light, including visible light. Each cell consists of a photo-sensitive electrode and a conducting counter electrode immersed in an electrolyte. Some photo-electrochemical cells simply produce a direct current, whereas others liberate hydrogen in a process similar to the conventional electrolysis of water.

Photolysis

A chemical reaction (often a decomposition) caused by exposure to light.

Photosynthesis

The chemical process by which green plants synthesize organic compounds from carbon dioxide and water in the presence of sunlight.

Photovoltaic (PV) cell

A semiconductor device for converting light energy into low-voltage, direct current electricity.

pH

A measure of the acidity/alkalinity (basicity) of a solution. The pH scale extends from 0 to 14 (in aqueous solutions at room temperature). A pH value of 7 indicates a neutral solution. A pH value of less than 7 indicates an acidic solution; the acidity increases with decreasing pH value. A pH value of more than 7 indicates an alkaline solution; the basicity or alkalinity increases with increasing pH value.

Physisorption

Adsorption of gases on solid surfaces whereby the bonding is by means of a weak intermolecular (van der Waals) attraction rather than by chemical bonding.

Positive electrode

The electrode in an electrochemical cell that has the higher potential.

Power density

The power output of an energy device per unit volume, usually expressed in terms of $W L^{-1}$ or $W dm^{-3}$.

Producer gas

A mixture of carbon monoxide and nitrogen made by passing air over very hot carbon. Usually some steam is added to the air and the mixture then contains hydrogen. The gas is used as a fuel in some industrial processes.

***p*-type semiconductor**

A semiconductor in which electrical conduction is due mainly to the movement of positively charged holes.

Pyrolysis

Thermal decomposition of a substance at elevated temperatures in the absence of air or oxygen.

Quantum yield

For photocells, the fractional number of electrons generated per photon incident on the cell or the ratio of the number of photon-induced reactions occurring to total number of incident photons.

Redox reaction

A chemical reaction that involves the transfer of an electron from one species (which is thereby oxidized) to another (which is thereby reduced). The species are known as redox reagents.

Regenerative braking

The recovery of some fraction of the energy normally dissipated during braking of a vehicle and its return to a battery or some other energy-storage device.

Renewable energy (Renewables)

All natural energy forms that do not derive from the combustion of fossil fuels.

Reversible potential

The potential of an electrode when there is no net current flowing through the cell.

Reversible voltage

The difference in the reversible potentials of the two electrodes that make up the cell.

Sensible heat

The heat absorbed by a substance that gives rise to an increase in temperature of the substance. See **Latent heat**.

Separator

An electronically non-conductive, but ion-permeable, component of a battery or fuel cell that prevents electrodes of opposite polarity from making contact.

Sequestration

The capture of carbon dioxide from streams of mixed gases and its subsequent indefinite storage.

Solar array

An assembly of solar panels electrically connected together.

Solar-thermal plant

A large-area assembly of mirrors to focus solar radiation to a point where a solar furnace may be used to raise steam, heat liquids or carry out chemical reactions.

Specific energy

Stored energy per unit mass, expressed in MJ kg⁻¹, Wh kg⁻¹ or kWh kg⁻¹.

Specific power

The power output of a battery or fuel cell per unit mass, usually expressed in W kg⁻¹.

Standard cell voltage

The reversible voltage of an electrochemical cell with all active materials in their standard states. See **Reversible voltage**.

Standard electrode potential

The reversible potential of an electrode with all the active materials in their standard states. Usual standard states specify a pressure of 101.325 kPa for gases and unit activity for elements, solids and 1 mol dm⁻³ solutions – all at a temperature of 298.15 K. See **Reversible potential**.

Steam reforming

The reaction of fossil fuels with steam at high temperature to generate a mixture of hydrogen and carbon monoxide.

Stoichiometry

The branch of chemistry concerned with the relative proportions in which atoms or molecules react together to form chemical compounds; derivative: **stoichiometric**.

Sustainable energy ('sustainability')

A set of energy technologies that meets humanity's needs on an indefinite basis without producing irreversible environmental effects. (Note: various definitions exist in the literature, but they all convey the same message.)

Synthesis gas ('syngas')

A mixture of carbon monoxide and hydrogen made by reacting natural gas with steam and air or oxygen.

Synthetic natural gas

Methane produced by the catalytic reaction of carbon monoxide with hydrogen or from coal by reaction with hydrogen.

Thermocline

The depth in the ocean where the temperature changes abruptly between surface warm water and deep cold water.

Thermohaline circulation

A natural oceanic phenomenon whereby cold water in the Arctic/North Atlantic sinks to the ocean floor and then circulates at depth around the world, to surface eventually in the Indian and Pacific oceans some hundreds of years later. This circulation is sometimes called the **Ocean conveyor belt**, the **Great ocean conveyer**, the **Global conveyor belt**, or, most commonly, the **Meridional overturning circulation** (often abbreviated as **MOC**).

Thermolysis

The dissociation or decomposition of a molecule by heat.

Town gas

See **Coal gas**.

Traction battery

A battery designed to provide motive power.

Valence band

The range of energy levels of electrons that bind atoms of a crystal together. When electrons are excited from the valence band to the conduction band, the resulting electron hole is mobile and gives rise to p-type conduction in the valence band. See **Conduction band**, **Energy band**.

Voltaic efficiency

The ratio, usually expressed as a percentage, of the average voltage during discharge to the average voltage during charge.

Water gas

A mixture of carbon monoxide and hydrogen produced by passing steam over hot carbon (coke). The reaction is strongly endothermic but may be combined with the exothermic reaction for producer gas. See **Producer gas**, **Steam reforming**, **Water-gas shift reaction**.

Water-gas shift reaction

The reaction of water gas with steam to yield hydrogen and carbon dioxide.

Wind farm

A collection of wind turbines, grouped together to form a single generating unit.