**absorbed dose:** amount of energy imparted to a unit mass of matter (nonliving or living). It is expressed in grays (Gy). 1 gray represents 1 joule of energy imparted to 1 kg of matter

**actinides:** see **minor actinides** and **major actinides**

**activation:** action tending to make certain **nuclides radioactive**, particularly within reactor structural materials, when bombarded by **neutrons** or other particles

**activity:** number of **disintegrations** per unit time inside a **radionuclide** or a mixture of radionuclides. Expressed in becquerels (Bq), with 1 Bq being equivalent to one disintegration per second

**adiabatic:** refers to a system in which transformations occur with no exchange of heat with the external medium

**aerosol:** a suspension of very fine solid or liquid particles in a gas

**antineutrino:** antiparticle of a **neutrino**, identical in mass (very low) and with a zero charge

**barriers:** in a nuclear reactor, all the physical elements used to isolate the **radionuclides** in the fuel from the environment. In a **pressurized water reactor**, these elements are the fuel element cladding, followed by the primary circuit containment (including the reactor vessel) and the reactor containment

**benchmark:** reference value

**boiling water reactor (BWR):** reactor in which water is boiled directly in the core

**branching ratio:** the branching ratio of an **isotope** A to an isotope B is the fraction of isotope B formed for a decay of isotope A

**breeder/breeding:** producing more **fissile** fuel than it consumes. The new fissile nuclei are created by **fission neutron** capture by **fertile** nuclei (non fissile in response to **thermal neutrons**) after a certain number of **radioactive disintegrations**

**burnup:** strictly speaking, this represents the percentage of heavy atoms (uranium and plutonium) having undergone **fission** within a given period. Commonly used to determine the quantity of thermal energy per unit mass of fissile material obtained in the reactor between fuel loading and unloading, it is expressed in megawatt·days per tonne (MW·d/t). **Discharge burnup** represents the rate at which the fuel assembly must be definitively removed after several irradiation cycles

**calculation code:** gathering in a computer software package, in the form of encoded mathematical expressions, of a simplified representation (model) of a system or process in order to simulate it

**Čerenkov effect:** visible light emitted when a charged particle passes through a given material at a speed greater than the speed of light in this material. Radiation is emitted in the form of a shock wave accompanying the particle. Thus the decay of **radioactive** nuclei releases electrons at speeds greater than the speed of light in water, with which they interact by transferring their energy to it at the wavelength of blue light. The same phenomenon can occur in material during a **criticality** accident

**chain reaction:** a series of nuclear **fissions** during which the **neutrons** released cause new fissions which in turn generate new neutrons leading to more fissions and so on

**committed dose:** following internal exposure, the cumulative dose received over a period of fifty years (for workers and adults) or up to the age of 70 years (for persons under 20) starting from the year of intake of the **radionuclide**, if it did not disappear earlier as a result of physical decay or biological elimination

**coolant:** fluid (gas or liquid) used to extract the heat produced by **fission**. In a **pressurized water reactor**, water acts as both coolant and **moderator**

**critical:** a system is said to be critical when the number of **neutrons** emitted by **fission** is equal to the number of neutrons disappearing through absorption or leakage. In such cases, the number of fissions observed during successive intervals of time remains constant. **Criticality** is the expression of a precise equilibrium between the neutrons produced through fission and those disappearing through absorption or leakage

**critical mass:** mass of **fissile** material nuclei required for the number of **neutrons** produced to equal the number of neutrons absorbed during a **chain reaction**

**criticality excursion:** rapid growth in the number of **fissions** occurring in a **fissile** medium, also known as **power excursion**

**cross section:** a measure of the probability of an interaction between a particle and a target-nucleus, expressed in **barn** units (1 barn = $10^{-24}$ $cm^2$). In the case of a **neutron**, for example, it defines the probability of interaction between the neutron and the nuclei of the material used to make the different parts of the core

**delayed neutrons: neutrons** emitted by **fission** fragments with an average delay of several seconds after fission. Owing to this time delay, even though they account for less than 1% of emitted neutrons, it is ultimately these neutrons that allow the operation of the reactor

**deterministic calculation** (of neutron variables)**:** numerical solution of the equation governing **neutron transport** in matter after the variables (space, neutron energy and time) have been rendered “discrete”, i.e. converted into distinct quantities

**differential measurement** (of cross section)**:** this type of measurement is used to determine the **cross section** as a function of the different energy levels of the incident **neutron**. An **integral measurement** is used to measure it within a given **neutron spectrum**. The value will thus be averaged out over all neutron energy levels with no means of obtaining the value for an exact energy

**disintegration:** transformation of an unstable nucleus into a stable or unstable nucleus during which the number and nature of the **nucleons** change

**divergence:** the start of the **chain reaction** in a reactor

**dollar:** unit of **reactivity**. The dollar is defined by the ratio of reactivity to the proportion of **delayed neutrons** = 1. It is divided into cents

**dose equivalent rate:** the quantity of **absorbed dose** rate, with the biological effects weighted by *quality factors* varying according to the type of radiation. Expressed in sieverts per second (Sv/s)

**dose rate:** radiation intensity (the energy absorbed by matter per unit mass and time). The legal unit is the **gray** per second (Gy/s)

**electronvolt (eV):** unit of energy used in nuclear physics. 1 eV = $1.6 \cdot 10^{-19}$ joule

**enrichment:** in the case of uranium, process employing various means (gaseous diffusion, ultracentrifugation, selective laser excitation) to increase the concentration of the uranium-235 isotope with regard to the uranium-238 **isotope** which predominates in natural uranium

**epithermal** (neutrons)**:** neutrons located in the 10 **eV** to 20 keV energy range, thus traveling at a greater speed than **thermal neutrons**

**fast neutron reactor (FR):** reactor with no **moderator** in which most fissioning is generated by **neutrons** having energy levels in the same range as when they were produced by **fission**

**fast neutrons: neutrons** released during **fission**, traveling at very high speed (20 000 km/s). Their energy is in the region of 2 million **electronvolts**

**fertile:** refers to a material in which the nuclei yield **fissile** nuclei when they absorb neutrons. This is the case of uranium-238 which yields plutonium-239. When this is not the case, the material is said to be **sterile**

**fissile** (nucleus)**:** nucleus able to undergo **fission** through the absorption of **neutrons**. Strictly speaking, it is not the nucleus called fissile that undergoes fission, but the compound nucleus formed after neutron capture

**fission:** the splitting of a heavy nucleus into two parts, accompanied by the emission of **neutrons**, radiation and the release of a considerable amount of heat

**fission products: nuclides** generated either directly through nuclear **fission**, or indirectly through the **disintegration** of fission fragments

**fusion:** reaction in which two small nuclei join to produce a larger one

**generation time:** average interval between two **fissions**

**half-life:** time in which half the **radioactive** atoms initially present disappear as a result of natural **disintegration**

**heavy nuclei:** name given to **isotopes** with at least 80 protons (i.e. an atomic number of at least 80). All actinides and their daughter products belong to this group

**hybrid system:** system that combines a **spallation neutron** source with a **subcritical** reactor for the **transmutation** of nuclear waste or power production

**incineration** (of nuclear waste)**:** destruction of actinides in a nuclear reactor, in particular **minor actinides**, by **fission** and **neutron** capture

**isotopes:** different forms of a same element with nuclei having the same number of protons but a different number of neutrons

$k_\infty$: see **multiplication factor**

$k_{eff}$: see **multiplication factor**

**kinetics** (reactor...)**:** speed at which changes in power occur

**light water reactors:** family of reactors including **pressurized water reactors** and **boiling water reactors**

**major actinides:** heavy uranium and plutonium nuclei present or produced in nuclear fuel

**material buckling** and **geometric buckling:** in an elementary **neutronics** theory, flux (i.e. the spatial distribution of **neutrons**) is a solution of Laplace's equation. This solution must take into consideration the shape and dimensions of the reactor as well as the characteristics of the material from which the reactor is made. These two aspects can be formulated by an equality expressing the **critical** condition of the system: geometric buckling = material buckling, where the first term is a parameter clarifying geometrical constraints and the second is a parameter summing up the capacity of the material to regenerate neutrons

**metastable state** (isomer)**:** a state in which the nucleus of an atom is "locked" in an excited state (at an energy level above its ground state) for a certain period of time, ranging from a few billionths of a second to several billion years. A single nucleus can have several isomers

**minor actinides:** heavy nuclei formed in a reactor by successive **neutron** capture from fuel nuclei. The main **isotopes** concerned here are neptunium (237), americium (241, 243) and curium (243, 244, 245)

**moderating ratio:** in a reactor, the ratio of the quantity of moderator (water in the case of **PWRs**) to that of fuel

**moderator:** material made from light nuclei that slow down **neutrons** through elastic scattering. The moderator must have a low capture factor in order to avoid "wasting" neutrons, yet be dense enough to slow down the neutrons effectively

**Monte Carlo method:** statistical method used to obtain an approximate value of an integral by using a number of points distributed randomly according to a certain probability. The method consists in repeating the attribution of a numerical value depending on the different stages of a process involving a random element, then calculating an average and its statistical dispersion (reflecting its accuracy) over the obtained values. In particle transport theory in matter, this method entails simulating the displacement of a very large number of particles, taking precise account of geometry and nuclear interactions, then counting the results of interest

**MOX (Mixed Oxides):** mixture of uranium (natural or depleted) and plutonium oxides

**multiplication factor *k*:** mean value of the number of new **fissions** induced by the **neutrons** originating from an initial fission. In multiplication factor evaluations, if neutron leakage to neighboring fuel assemblies or outside the reactor is not taken into consideration, the multiplication factor is qualified as infinite and is noted $k_\infty$. Otherwise, it is qualified as effective and noted $k_{eff}$

**neutrino:** elementary particle with zero charge and very low mass, capable of conveying a large amount of energy

**neutron balance:** the balance of **neutrons** produced and lost by the reactor

**neutron dynamics:** study of the progress of a **neutron** flux in a diffusing and/or absorbing medium

**neutron spectrum:** distribution according to energy of a population of **neutrons** in a reactor core

**neutron:** an uncharged elementary particle with a mass of $1.675 \cdot 10^{-27}$ kg. The nature of this **nucleon** was discovered by the British physicist James Chadwick in 1932. Together with protons, neutrons form atomic nuclei and give rise to **fission** reactions in **fissile** nuclei, thus generating the energy used in nuclear reactors

**neutronics:** the study of the displacement of **neutrons** in **fissile** and non fissile media and the reactions they induce in matter, focusing particularly on their multiplication and their role in initiating and controlling the **chain reaction** in nuclear reactors

**nucleons:** particles making up the nucleus of an atom, i.e. protons and **neutrons**, bonded together by a strong interaction to ensure the cohesion of the nucleus

**nuclide:** nuclear species characterized by its atomic number $Z$ (number of protons), its number of **neutrons** $N$ and its mass number $A$, which is equal to the sum of the protons and neutrons ($A = Z + N$); **radionuclide: radioactive isotope**, sometimes referred to as a radioisotope

**package** (criticality safety)**:** tool intended for use in the calculation of physical variables relevant to nuclear criticality safety (in particular, the **effective multiplication factor**). This tool is made up of nuclear data libraries, **calculation codes** and validated, qualified calculation procedures

**package** (radioactive waste)**:** unit consisting of a transportation, disposal and/or storage container and its clearly defined **radioactive** material content

**poisoning** (of nuclear fuel)**: neutron** capture by certain **fission products** (xenon-135, samarium-149, etc.), that build up during irradiation, thereby deteriorating the **neutron balance**

**poisons** (neutronic)**:** elements with high neutron capture capability used to compensate, at least in part, for the excess **reactivity** of **fissile** media. Four natural elements have particularly strong neutron-absorbing properties: boron (with its $^{10}B$ **isotope**), cadmium, hafnium and gadolinium (with its $^{155}Gd$ and $^{157}Gd$ isotopes). Some poisons are considered “burnable”, as they gradually disappear during combustion in the reactor. **Fission products** are nuclear poisons. They absorb neutrons

**power map:** 3D image obtained using a **calculation code**, representing the power distribution at the different points of a reactor core (e.g. for each fuel assembly)

**pressurized water reactor (PWR):** reactor in which heat is transferred from the core to the heat exchanger *via* water maintained at very high pressure in the primary circuit to prevent it from boiling

**probabilistic calculation** (of neutron variables)**:** use of the **Monte Carlo method** to simulate **neutron** “histories”, from birth to absorption

**prompt neutrons: neutrons** emitted immediately upon **fission**

**radioactivity:** property found in certain natural or artificial elements causing them to emit alpha or beta particles or gamma radiation in a spontaneous manner. More generally speaking, the term refers to radiation emitted during the **disintegration** of an unstable element or **fission**

**radiolysis:** breakdown of matter due to ionizing radiation

**reaction rate:** number of reactions between the **neutrons** and material per unit volume and time

**reactivity coefficient:** variation in the **multiplication factor** due to reactor operation, i.e. changes in temperature and composition due to the release of energy and **neutron** irradiation

**reactivity:** dimensionless quantity used to determine slight variations in the **multiplication factor *k*** around the critical value and defined by $\rho = (k - 1)/k$. As its value is very small, it is usually expressed in hundred thousandths using the unit **pcm** (per cent mille). In a reactor, reactivity is zero when it is **critical**, positive when it is **supercritical** and negative when it is **subcritical**

**reactor coolant:** coolant fluid used to remove heat from the core

**residual power:** thermal power developed by a nuclear reactor on shutdown, due mainly to the **activity** of **fission products**

**resolved resonance:** resonance widened by the energy dispersion linked to the varying degree of measurement accuracy. It can be revealed by **differential cross section measurements**

**resonance:** large **cross section** value for a precise value of incident energy imparted to the nucleus by a **neutron**. Resonance comes from the structure of the energy levels of the compound nucleus

**self-shielding:** in a **thermal neutron** reactor, two mechanisms, qualified as resonance self-shielding phenomena, used to lower the number of **neutrons** involved, in an attempt to prevent disappearance of these neutrons, due to the gigantic **resonant** capture **cross sections** of uranium-238, as they are slowed down by repeated scattering. First, the neutrons are slowed down intermittently by the **moderator**, losing a finite amount of energy each time they are scattered, which allows them to jump over a resonance. Secondly, a heterogeneous structure is adopted, where the area in which the neutrons slow down is separated from that containing the resonant nuclei

**spallation:** nuclear reaction involving a target-heavy nucleus and a particle, usually a proton, accelerated until it reaches an energy level ranging from a few hundred million to several billion **electronvolts**. Through repeated reactions, a beam of these particles can generate, among other things, a large number of **neutrons**. A 1 billion eV proton projected onto a lead target can generate 25 to 30 neutrons

**subcritical:** a system is said to be subcritical when the number of **neutrons** emitted by **fission** is lower than the number of neutrons disappearing as a result of absorption or leakage. In such cases, the number of fissions observed during successive intervals of time decreases

**supercritical:** a system is said to be supercritical when the number of **neutrons** emitted by **fission** is greater than the number of neutrons disappearing as a result of absorption or leakage. In such cases, the number of fissions observed during successive intervals of time increases

**thermal neutrons:** also known as slow **neutrons**, these are neutrons in thermal equilibrium with the material through which they pass at an approximate speed of 2 to 3 km/s. Their energy is less than 1 **electronvolt**

**thermalize:** to slow down **neutrons** to bring them gradually into thermal equilibrium with the reactor material in which they are diffused

**thermohydraulics:** branch of physics concerned with heat transfer and fluid mechanics

**transient:** gradual or sudden, scheduled or unscheduled change in the operating state of a facility. In the nuclear reactor field, a distinction is made between normal transients during which physical parameter values remain within technical specification limits, and abnormal transients that activate protective devices then engineered safety systems

**transmutation:** use of a **neutron**-induced (capture, **fission**) nuclear reaction to transform one **isotope** into another and, more especially, a long-lived **radioactive** isotope into a short-lived or stable isotope

**transport:** movement of **neutrons** in a straight line from their point of emission to their point of observation

**transuranic elements:** all elements with a higher atomic number than uranium. In reactors, heavy nuclei obtained from uranium by **neutron** capture or **radioactive disintegrations** other than **fission** and divided into seven **isotope** families: uranium, neptunium, plutonium, americium, curium, berkelium and californium

**UOX:** standard fuel used in **light water reactors** made from uranium oxide **enriched** with uranium-235

**valley of stability:** line marking the location of stable nuclei in a diagram showing the number of **neutrons** versus the number of protons

**void coefficient:** coefficient reflecting the variation in the **multiplication factor** of a reactor when the **moderator** forms more voids (areas of lesser density such as steam bubbles in water) than normal. If this coefficient is positive, excess steam will lead to increased **reactivity** and, therefore, increased power. On the contrary, if it is negative, excess steam will tend to shut down the reactor

**yield** (of a nuclide)**:** the probability to obtain a nuclide by fission