



Theme E

Nuclear and Quantum

HL Only

#	Physical Quantity	Definition
E.1 Structure of the Atom - Includes HL Section		
1	Nuclide	" Is a nucleus with a particular number of protons and neutrons."
2	The Nucleon Number, A	" Is the number of protons and neutrons in the nucleus of an atom; it determines the mass of the nucleus."
3	The Atomic Number, Z	" Is the number of protons in the nucleus of an atom; it determines the total charge of a nucleus."
4	The Neutron Number, N	" Is the number of neutrons in the nucleus of an atom and is given by $N = A - Z$."
5	Isotopes	" Are atoms of the same atomic number, Z, but with different number of neutrons, i.e. different nucleon numbers."
6	Elementary Particle	" A particle is called elementary if it is not made out of any smaller component particles. It has no internal structure."
7	Diffusion	" Is the random movement of particles from a place of high concentration to places of lower concentration."
8	Ionization Energy	" Is the energy that must be supplied to an atom so that an electron will be knocked-off from the atom."
9	Ground State	" Is the lowest possible energy level of an atom. It has a principal quantum number of 1."
10	Continuous Spectrum	" Is a spectrum in which light is spread smoothly over a broad band of wavelengths (or frequencies). A hot metal produces a continuous spectrum."
11	Emission Spectrum	" Is a line spectrum in which discrete bright lines are set against a dark background. A hot gas produces an emission spectrum."
12	Absorption Spectrum	" Is a line spectrum in which discrete dark lines are set against an otherwise continuous background."
13	Photon	" Is a quantum of light or other electromagnetic radiation. It has zero mass and carries a quantum of energy and momentum."
14	Strong Nuclear Force	" Is a Fundamental force that is responsible for attracting nucleons together inside the nucleus. It is a short-range attractive force ($\sim 10^{-15}$ m).
15	Angular Momentum, mvr	" Is the vector product of the momentum of a particle (mv) and the radius of the motion r."
16	Bohr's First Assumption	" The angular momentum (mvr) of an electron in a stationary state on a stable orbit is quantized in integral values of $h/2\pi$."
E.2 Quantum Physics - HL Only		
17	Quantum Mechanics	" Represent the mathematical aspects of Quantum Physics."
18	The Photoelectric Effect	" Is the emission of electrons from a metallic surface when light or other forms of electromagnetic radiation are incident on the surface."
19	Photoelectrons	" Are electrons that are ejected from a surface due to a photoelectric effect."
20	Threshold or Critical Frequency	" Is the minimum frequency of light required to liberate an electron from the surface of a metal."
21	Work Function, ϕ	" Is the minimum amount of energy needed to completely free an electron from an atom of the photo-surface."
22	Quantum Efficiency	" Is the fraction of photons that eject electrons out of photo-surface at a certain wavelength."



23	Photoelectric Equation	" States that the maximum kinetic energy of an emitted photoelectron is the difference between the incident photon's energy and the work function, Φ : $E_{\max} = hf - \Phi$."
24	Stopping Voltage	" Is the voltage at which the current becomes zero and the kinetic energy of the emitted electrons is maximum."
25	de Broglie's Hypothesis	" There is a wave-like nature associated with every moving particle, of wavelength equals to Planck's constant divided by the momentum of the particle."
26	Compton Effect (Scattering)	" Is the increase in wavelength (decrease in energy) of high-frequency photons when they collide with electrons. It is considered as evidence for the particle nature of electromagnetic radiation."

E.3 Radioactive Decay - Includes HL Section

27	Radionuclide (radioisotope)	" Is a nuclide that is unstable and undergoes radioactive decay."
28	Radioactivity	" Is the spontaneous disintegration of an unstable nucleus to form a more stable nucleus, resulting in the emission of a radioactive ionizing particle (alpha, beta or gamma)."
29	Background Radiation	" Is the radiation that is presented in the environment at a particular location. The sources include radioactive materials in rocks, soil and building materials, as well as cosmic radiation from space and any radiation escaping from artificial sources."
30	G-M (Geiger-Muller) Tube	" Is a metal cylinder filled with a low-pressure gas, when ionized by certain radiation. The tube is used as a counter for the radioactive decays."
31	Transmutation	" Is the changing of one element into another by radioactive decay, nuclear bombardment, or similar processes."
32	Neutrino	" Is a low-mass, and very weakly interacting uncharged particle emitted during the beta-positive decay."
33	Antineutrino	" Is a low-mass, and very weakly interacting uncharged particle emitted during the beta-negative decay."
34	Annihilation	" When a particle interacts with its anti-particle, their mass annihilate and totally converted to electromagnetic energy."
35	Positron	" Is the antiparticle of the electron. It has the same mass but with a positive charge."
36	Decay Series	" Is a series of nuclides linked in a chain by radioactive decay. Each nuclide in the chain decays to the next until a stable nuclide is reached."
37	Activity (Count Rate)	" Is the number of decays of a radioactive element per second, measured in Becquerels (Bq)."
38	Half Life - Def.1	" Is the time taken for half the number of nuclei in a sample of radioactive isotope to decay into nuclei of another element."
39	Half Life - Def.2	" Is the interval of time after which the activity of a radioactive sample is reduced by a factor of 2."
40	Carbon Dating	" Using the radioactive decay of Carbon-14 to estimate the age of once-living material."
41	Binding Energy - Def.1	" Is defined as the minimum amount of work required to completely separate the nucleons of a nucleus."
42	Binding Energy - Def.2	" Is the amount of energy released when a nucleus is formed from its constituent nucleons."
43	Unified Atomic Mass Unit, amu	" It is defined as one-twelfth of the rest mass of an unbound atom of carbon-12 in its nuclear and electronic ground state, having a value of $1.660\ 539\ 066\ 60 \times 10^{-27}$ Kg."
44	The Mass Defect	" Is the difference in mass between a nucleus and the total mass of its nucleons if they were separated. Equivalent to the nuclear binding energy."
45	Alpha Particle Spectrum	" Is the range of discrete energies possessed by alpha particles emitted from the same radionuclide."
46	Gamma Ray Spectrum	" Is the range of discrete energies possessed by photons emitted from the same radionuclide."
47	Beta Particle Spectra	" Is the continuous range of different energies possessed by beta particles emitted from the same radionuclide."
48	The Decay Constant, λ	" Is defined as the probability of decay of an unstable nucleus per unit time. Unit: s^{-1} ."
49	The Law of Radioactive Decay	" States that the rate of decay is proportional to the number of undecayed nuclei, $\Delta N/\Delta t = -\lambda N$."



E.4 Fission

50	Nuclear Fission	" Is a nuclear reaction in which a heavy (massive) nucleus splits into more stable lighter nuclei whose total binding energy is greater than the binding energy of the initial nucleus, with the release of energy."
51	Nuclear Fusion	" Is a nuclear reaction in which two light (low mass) nuclei combine to form a more stable heavier nucleus whose binding energy is greater than the combined binding energies of the initial nuclei, with the release of energy."
52	Fission Fragments	" Are the nuclei produced in a fission reaction."
53	Spontaneous Fission	" Is the process in which a heavy nucleus splits into two almost equal smaller nuclei without absorbing a neutron."
54	Neutron-Induced Fission	" Is the process in which a heavy nucleus absorbs a slow-moving neutron, becomes unstable and then the nucleus splits."
55	Fissile Nuclide	" Is one that is capable of sustaining a nuclear fission chain reaction. Uranium-235 is the world's only naturally occurring nuclide that is fissile. There are other fissile nuclides (e.g. Plutonium-239) but they are not found naturally: they need to be produced in nuclear reactors."
56	Thermal Neutrons	" Are neutrons that are in equilibrium with matter at about room temperatures. Their typical speed is $\sim 2 \text{ km.s}^{-1}$."
57	Fuel Enrichment	" Is the process of boosting the ratio of U-235 in a sample to around 3% to 5% before it can be used as fuel in a nuclear power station."
58	Fuel Rods	" Are tubes containing the fuel. In nuclear power stations U-235 or Pu-239 are the nuclides mostly used as the fuel."
59	Critical Mass	" Is the minimum mass of Uranium-235 that must be present to ensure a self-sustaining nuclear chain reaction."
60	The Moderator	" Is the material surrounding the fuel rods (graphite) in order to slow down the speed of the neutrons so they can be absorbed by the Uranium fuel and cause fission."
61	The Coolant	" Is the substance by which heat exchange occurs in order to extract the heat energy from the moderator to the turbines in a closed system. The coolant is water under pressure in case of PWR (Pressurized Water Reactors) and carbon dioxide gas in case of AGR (Advanced Gas-cooled Reactors)."
62	Control Rods	" Are rods introduced into the moderator to control (adjust) the rate of reaction by being lowered or raised from the reactor core. They are usually made of Boron, which absorbs neutrons strongly."
63	Meltdown	" Is the meltdown of the fuel rods as a result of overheat and poor control of the nuclear reactions. In this case, the fuel cannot be removed and may cause the pressure vessel to burst sending radioactive material into the atmosphere."
64	Shielding	" Is a protective barrier formed by layers of very thick reinforced concrete around the nuclear reactor vessel to ensure the absorption of dangerous radiations. The reactor vessel itself is made of thick steel to withstand the high temperatures and pressures present in the reactor."
65	Nuclear Waste	" Are radioactive materials associated with the production of nuclear power that are no longer useful, and which may have to be stored safely underground in strong and secure containers for a long period of time."

E.5 Fusion and Stars

66	Star	" Is a massive sphere of plasma held together by the forces of gravity and because of the high temperatures, thermonuclear fusion occurs and radiation is emitted."
67	Effective Temperature	" Is the name given to the surface temperature calculated assuming the star behaves as perfect black body."
68	Interstellar Matter	" Is a low-density matter that exists in the space between stars, commonly described as 'dust and gas'. It is composed mainly of Hydrogen (70% by mass) and Helium (28% by mass) while the remaining 2% is other elements of the remnants of exploded old stars."
69	A Nebula (plural Nebulae)	" Is a vast, identifiable cloud of dust and gases (mostly hydrogen and helium) in the space in between stars. The dust consists of compounds of carbon, oxygen, silicon, as well as molecular hydrogen."
70	Main-Sequence Star	" Is a stable star that is undergoing nuclear fusion of hydrogen into helium. Our Sun is a typical main-sequence star."
71	The p-p Chain (proton-proton Cycle)	" Is the simplest nuclear fusion process which occur in stellar cores of stars on the main sequence. Its net effect is to convert four hydrogen nuclei into one helium-4 nucleus. It is the fusion reaction which occurs in the core of the Sun."



72	The CNO Cycle	" Is the second fusion reaction which occurs in stellar cores of stars on the main sequence. Its net effect is also to convert four hydrogen nuclei into one helium-4 nucleus, but it uses Carbon, Nitrogen and Oxygen nuclei as catalysts. As a consequence of the stronger repulsive Coulomb forces between the higher ionized carbon, nitrogen and oxygen nuclei, as compared to the p-p chain nuclei, the CNO cycle is only dominant in the more massive stars, greater than $1.5M_{\odot}$, whose core temperatures are greater than 17 million Kelvin."
73	Stellar Equilibrium	" Is the balance between the effects of radiation pressure acting outwards against the gravitational forces acting inwards."
74	Lifetime (of Main-Sequence Star)	" Is the duration for which a star is fusing hydrogen into helium, emitting radiation and maintaining stellar equilibrium."
75	The Hertzsprung-Russell Diagram	" An HR diagram is a diagram that displays a certain order in the apparent diversity of stars by plotting the luminosity of stars versus their surface temperatures. Temperature is plotted increasing to the left on the horizontal axis."
76	Red Giants (and Super Giants)	" Are relatively cool stars that are formed by the increased rate of nuclear fusion that occurs because of the greater temperatures created in the collapse of main-sequence stars at the end of their lifetimes."
77	White Dwarf	" The end result of the explosion of a red giant. A small, dense star in which no nuclear reactions take place. It is very hot but its small size gives it a very low luminosity."
78	Black Dwarf	" Is the remnant of a white dwarf after it has cooled down. It has very low luminosity."
79	The Triple-Alpha Process	" Is a fusion reaction that occurs in the core of stars which have left the main sequence of the H-R diagram and its net effect is to convert three helium-4 nuclei into one carbon-12 nucleus. It is the final fusion reaction for those main sequence stars with a mass smaller than eight solar masses, which end up as white dwarfs surrounded by a planetary nebula."
80	Planetary Nebula	" Is a short-lived diffuse cloud of ionized gas emitted from the outer layers of a red giant star at the end of its life time."
81	Pauli Exclusion Principle	" States that fermions (electrons and quarks) in the same state cannot occupy the same place in space."
82	Electron Degeneracy	" Is a process occurring within white dwarf stars that keep them stable and stops them collapsing."
83	Supernova	" Is the sudden and very luminous explosion of a red supergiant star, resulting in neutron star or black hole."
84	Instability Strip	" Is a region of the Hertzsprung-Russell diagram containing pulsating, variable stars."
85	Neutron Star	" If the original mass of the star was between 8 and 20 solar masses, the remaining core after the supernova will form a neutron star which is very dense."
86	Black Hole	" If the original mass of the star was greater than 20 solar masses, the remaining core after the supernova will form a black hole. The latter is extremely dense remnant where gravitational forces are so great that even light cannot escape."
87	Stellar Parallax	" Is a geometrical method of determining the distance to a nearby star from measurement of its parallax angle."
88	The Parallax Angle - Def.1	" Is the angle, at the position of a star, that is subtended by a distance equal to the radius of the Earth's orbit around the sun."
89	The Parallax Angle (Annual Parallax) - Def.2	" Is half the angle subtended between the two extreme positions of the Earth in its orbit."
90	The Parsec	" Is the distance to a star whose annual parallax is 1 arc-second."
91	Arc-second	" Is an angle which is $1/3600$ of one degree."
92	A Light Year, ly	" Is the distance travelled in a vacuum by light in one year. Thus $1 \text{ ly} = 9.46 \times 10^{15} \text{ m}$."
93	The Astronomical Unit, AU	" Is the average distance between Earth and the Sun. $1 \text{ AU} = 1.50 \times 10^{11} \text{ m}$ approximately."
94	Neutron Capture	" Is a nuclear reaction in which a neutron is absorbed by a nucleus to form a more massive nucleus."
95	Nucleosynthesis	" Is the creation of new nuclides (elements) from existing, less massive, nuclei."