Module 6: Nuclear and Particle Physics (part 2)

This section provides knowledge and understanding of the atom, nucleus, fundamental particles, radioactivity, fission and fusion. Nuclear power stations provide a significant fraction of the energy needs of many countries. They are expensive; governments have to make difficult decisions when building new ones. The building of nuclear power stations can be used to evaluate the benefits and risks to society (HSW9). Ethical, environmental and decision making issues may also be discussed (HSW10 and HSW12). The development of the atomic model also addresses issues of scientific development and validation (HSW7, 11).

| Specification reference | Checklist  questions | |
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| 6.4.3 a | Can you define radioactive decay? |  |
| 6.4.3 a | Can you describe the spontaneous and random nature of decay? |  |
| 6.4.3 b i | Can you define α-particles, β-particles and γ-rays? |  |
| 6.4.3 b ii | Can you describe the nature, penetration and range of these radiations, and the techniques used to investigate their absorption? |  |
| 6.4.3 c | Can you demonstrate the nuclear decay equations for alpha, beta-minus and beta-plus decays? |  |
| 6.4.3 c | Can you demonstrate balancing nuclear transformation equations? |  |
| 6.4.3 d | Can you define activity of a source? |  |
| 6.4.3 d | Can you calculate the decay constant λ of an isotope, *A* = λ*N*? |  |
| 6.4.3 e i | Can you calculate the half-life of an isotope, = ln(2)? |  |
| 6.4.3 e ii | Can you describe the techniques used to determine the half-life of an isotope? |  |
| 6.4.3 f i | Can you explain the equations *A* = *A*0*e*−λ*t* and *N* = *N*0*e*−λ*t*? |  |
| 6.4.3 f ii | Can you understand a simulation of radioactive decay? |  |
| 6.4.3 g | Can you demonstrate the graphical methods and spreadsheet modelling of the equation  = −λ*N* for radioactive decay? |  |
| 6.4.3 h | Can you define radioactive dating, such as carbon-dating? |  |

**Homework and Independent Study**

HW: Assessed past-paper questions. Kerboodle online task(s)

Revision: For Module 6.4 topic test (*Nuclear and Particle*)

IS: Textbook summary questions on each sub-topic, to self-assess.

Zig-zag module 6 booklets for revision and IS. *Answers distributed at end of topic.*

Use of online resources including physicandmathstutor.com, Seneca Learning and Kerboodle textbook, Chapter 25. Practise past-paper questions at the end of topic (textbook pages 501-3).

**Key Terms**

**Activity:** The rate of decay of the radioactive nuclei in a given isotope. It is proportional to the total number of nuclei in the sample and is measured in Becquerels.

**Alpha Particles:** A type of particle consisting of two protons and two neutrons. Alpha particles are emitted in alpha decay and are strongly ionising, but weakly penetrating.

**Alpha-Scattering:** An experiment that involved firing alpha particles at a thin gold foil and detecting their subsequent motion. It provided evidence for the currently accepted model of the atom.

**Annihilation:** The process of a particle and its antiparticle colliding and being converted into energy. The energy is released in two photons to conserve momentum.

**Antiparticles:** All particles have a corresponding antiparticle with the same mass but opposite charge and conservation numbers.

**Beta Particles:** An electron or positron. Beta particles are emitted during beta decay and have medium ionising and penetrating capabilities.

**Key Terms (continued)**

**Beta-Minus Decay:** The process of a proton inside a nucleus turning into a neutron, and emitting a beta-minus particle (an electron) and a neutrino.

**Beta-Plus Decay:** The process of a neutron inside a nucleus turning into a proton, and emitting a beta-plus particle (a positron) and a neutrino.

**Binding Energy:** The amount of energy required to split a nucleus into all its separate constituent nucleons. It is equivalent to the mass defect.

**Chain Reaction:** The process of the neutrons released by a fission reaction inducing further fissile nuclei to undergo fission.

**Control Rods:** Rods found in nuclear reactors to absorb neutrons and control the rate of reaction. They can be raised or lowered depending on the rate required.

**Decay Constant:** The probability of decay in a unit time.

**Einstein’s Mass-Energy Equivalence:** Mass and energy are equivalent, with the energy equivalent of a given mass being equal to the product of the mass and the speed of light squared.

**Electron:** A negatively charged fundamental particle found in energy levels surrounding a nucleus.

**Gamma Rays:** A type of radiation emitted in gamma decay. Gamma rays are weakly ionising but very strongly penetrating.

**Hadrons:** A class of subatomic particle that experiences the strong nuclear interaction.

**Half-Life:** The mean time it takes for the number of radioactive nuclei in a sample of an isotope to halve.

**Isotopes:** A form of an element with the same number of protons but different numbers of neutrons.

**Leptons:** A group of elementary subatomic particles, consisting of electrons, muons and neutrinos.

**Mass Defect:** The difference in mass between a nucleus and the sum of the masses of its constituent nucleons.

**Moderator:** A material in nuclear reactors that absorbs energy from fast moving neutrons, to slow them down to speeds that can be absorbed by fissile neutrons to induce fission.

**Neutron:** A neutrally charged nucleon, found in the nucleus of an atom. Neutrons are a form of hadron.

**Nuclear Fission:** The splitting a nucleus, to form two smaller daughter nuclei, neutrons and energy.

**Nuclear Fusion:** The joining of two smaller nuclei to form a larger nucleus and to release energy.

**Nucleon Number:** The sum of the number of protons and neutrons in a given nucleus.

**Positron:** A positively charged particle that is the antiparticle of an electron.

**Proton Number:** The number of protons present in the nucleus of a given element.

**Proton:** A positively charged nucleon, found in the nucleus of an atom. Protons are a form of hadron.

**Quarks:** Fundamental particle that interacts with other quarks via the strong interaction. They change flavour via the weak interaction and annihilate with antiquarks to form photons via the electromagnetic interaction.

**Radioactive Dating:** The use of radioactive isotopes with known half-lives to date objects. The isotope that is usually used is Carbon-14.

**Random Nature of Decay:** Radioactive decay is random - you cannot predict when a nucleus will decay or which nucleus will decay next.

**Strong Nuclear Force:** A force that acts between nucleons in a nucleus to keep it stable. It is attractive at distances of up to 3 fm and repulsive at separations less than 0.5 fm.