Topic 26 Particle physics

Summary

- An atom consists of a nucleus containing protons and neutrons surrounded by orbiting electrons.
- Most of the mass of an atom is contained in its nucleus.
- An atom is neutral as it contains an equal number of protons and electrons.
- Atoms which have gained or lost electrons are charged, and are called ions.
- The nucleon number A of a nucleus is the number of nucleons (protons and neutrons) in the nucleus.
- The proton number Z of a nucleus is the number of protons in the nucleus; hence the number of neutrons in the nucleus is $A - Z$.
- A nucleus (chemical symbol X) may be represented by:

$$^{\text{nucleon number}}_{\text{proton number}}\text{X}$$

- Isotopes are different forms of the same element, that is, nuclei with the same proton number but with different nucleon numbers.
- An α-particle is a helium nucleus (two protons and two neutrons).
- A β-particle is a fast-moving electron.
- γ -radiation consists of short-wavelength electromagnetic waves.
- In nuclear notation the emissions are represented as: α-particle $^{4}_{2}\text{He}$; β^--particle $^{0}_{-1}\text{e}$ or β^+-particle $^{0}_{+1}\text{e}$; γ-radiation $^{0}_{0}\gamma$.
- α-emission reduces the nucleon number of the parent nucleus by 4, and reduces the proton number by 2.
- β-emission causes no change to the nucleon number of the parent nucleus, and increases or decreases the proton number by 1.
- γ-emission causes no change to nucleon number or proton number of the parent nucleus.
- Radioactive decay is a spontaneous, random process.
- The Rutherford α-particle experiment confirmed the nuclear model of the atom: the atom consists of a small, positively-charged nucleus, surrounded by negatively-charged electrons in orbit about the nucleus and that the vast majority of the mass of the atom is in the nucleus.
- The diameter of the nucleus is about 10^{-15} m; the diameter of the atom is about 10^{-10} m.
- Electron diffraction gives evidence for the regular arrangement of atoms in crystals, and allows the measurement of the distance between planes of atoms in solids.
- For every type of subatomic particle there is an antimatter particle which has the same mass but opposite electrical charge.
- The antiparticle of the electron is called the positron.
- Protons and neutrons are hadrons and are affected by the strong force.
- During hadron reactions, charge and strangeness are conserved.
- The simple quark model has three flavours of quark (up, down and strange) together with their antiquarks.
- Protons are composed of quarks up, up and down, and neutrons of quarks up, down and down.
- Electrons and neutrinos are leptons which are fundamental particles and are affected by a weak interaction.
- During β^- decay: $^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e}$ (electron) + $^{0}_{0}\bar{\nu}$ (antineutrino)
- During β^+ decay: $^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{n} + {}^{0}_{1}\text{e}$ (positron) + $^{0}_{0}\nu$ (neutrino)
- The energy of subatomic particles is often measured in eV or MeV.

Definitions and formulae

- Atoms are composed of neutrons and protons in a central nucleus with orbiting electrons.
- The nucleus is very small compared to the size of the atom (most of the atom is empty space).
- The positive charge of the atom is found in the nucleus as is the vast majority of the atom's mass.
- Nucleon number *A* is the number of protons and neutrons (nucleons) in a nucleus.
- Proton (atomic) number *Z* is the number of protons in a nucleus.
- Isotopes are nuclei that have same number of protons but a different number of neutrons

$^{\text{nucleon number}}_{\text{proton number}}\text{X} = {}^{A}_{Z}\text{X}$ is the notation used for the representation of nuclides

- A nuclide is one type of nucleus which has the same number of protons and the same number of neutrons.
- In nuclear reactions, nucleon number, proton number and mass–energy are all conserved.
- An α-particle is identical to the nucleus of a helium atom.
- In α-decay the proton number of the nucleus decreases by two, and the nucleon number decreases by four.
- β-particles are fast moving electrons either positive or negative.
- In β^- decay (negative electron) a daughter nuclide is formed with the proton number increased by one, but with the same nucleon number.
- In β^- emission a neutron in the nucleus forms a proton, a negative electron and an antineutrino.
- In β^+ decay (positive electron) a daughter nuclide is formed with the proton number decreased by one, but with the same nucleon number.
- In β^+ emission a proton in the nucleus forms a neutron, a positive electron and a neutrino.
- γ-radiation is part of the electromagnetic spectrum with wavelengths between 10^{-11} m and 10^{-13} m.
- In γ-emission no particles are emitted and there is therefore no change to the proton number or nucleon number of the parent nuclide.
- The quark model for hadrons: flavours of quark are up (u), down (d) and strange (s) and their respective antiquarks.
- Protons are composed of quarks up, up and down and neutrons of quarks up, down and down.
- Protons and neutrons are hadrons and are affected by the strong force.
- Electrons and neutrinos are leptons, fundamental particles and are affected by a weak interaction.
- During β^--decay: ${}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + {}^{0}_{-1}\text{e}$ (electron) + ${}^{0}_{0}\bar{\nu}$ (antineutrino)
- During β^+decay: ${}^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{n} + {}^{0}_{1}\text{e}$ (positron) + ${}^{0}_{0}\nu$ (neutrino)