AQA Examination-style questions

1 (a) In a nuclear reactor, some of the $^{238}_{92}U$ nuclei absorb neutrons to become uranium $^{239}_{92}U$ nuclei. These nuclei decay in two stages to become nuclei of the plutonium isotope $^{239}_{94}Pu$.

(i) Write down an equation to represent the formation of a $^{239}_{92}U$ nucleus from a $^{238}_{92}U$ nucleus.

(ii) What types of particles are emitted when a $^{239}_{92}U$ nucleus decays to form a $^{239}_{94}Pu$ nucleus? *(3 marks)*

(b) The THORP reprocessing plant at Sellafield is used to recover uranium and plutonium from spent fuel rods. In addition to reprocessing nuclear waste from the UK, it also reprocesses waste from nuclear reactors in other countries as well as from the UK. Uranium-238 and plutonium-239 can both be used in a type of nuclear reactor called a *fast breeder* reactor, although this type of reactor has not yet been fully appraised in terms of reliability and safety. By using such reactors in the future, the lifetime of the world's reserves of uranium would be extended from a few hundred years to several thousand years. Plutonium can also be used to make nuclear bombs. Discuss the arguments for and against reprocessing nuclear waste. *(5 marks)*

2 (a) In the context of an atomic nucleus,

(i) state what is meant by *binding energy*, and explain how it arises,

(ii) state what is meant by *mass difference*,

(iii) state the relationship between binding energy and mass difference. *(4 marks)*

(b) Calculate the average binding energy per nucleon, in MeV nucleon^{-1}, of the zinc nucleus $^{64}_{30}Zn$.

mass of $^{64}_{30}Zn$ atom = 63.929 15 u *(5 marks)*

(c) Why would you expect the zinc nucleus to be very stable? *(1 mark)*

AQA, 2004

3 (a) (i) Describe the physical process of *nuclear fusion*.

(ii) Describe the physical process of *nuclear fission*.

(iii) Explain why each of these processes releases energy. *(6 marks)*

(b) Energy is also released by radioactive decay, such as the decay of radon-220 as represented by the equation

$$^{220}_{86}Rn \longrightarrow ^{216}_{84}Po + \alpha$$

Calculate the energy released, in J, by the decay of one nucleus of radon-220.

mass of ^{220}Rn nucleus = 219.964 10 u

mass of ^{216}Po nucleus = 215.955 72 u

mass of α particle = 4.001 50 u *(3 marks)*

AQA, 2007

4 (a) A solar panel of area 2.5 m^2 is fitted to a satellite in orbit above the Earth. The panel produces a current of 2.4 A at a potential difference of 20 V when solar radiation is incident normally on it.

(i) Calculate the electrical power output of the panel.

(ii) Solar radiation on the satellite has an intensity of 1.4 kW m^{-2}. Calculate the efficiency of the panel. *(4 marks)*

(b) The back-up power system in the satellite is provided by a radioactive isotope enclosed in a sealed container which absorbs the radiation from the isotope. Energy from the radiation is converted to electrical energy by means of a thermoelectric module.

(i) The isotope has an activity of 1.1×10^{14} Bq and produces α particles of energy 5.1 MeV. Show that the container absorbs energy from the α particles at a rate of 90 J s^{-1}.

(ii) The isotope has a half-life of 90 years. Calculate the decay constant λ of this isotope.

(iii) The mass number of the isotope is 239. Calculate the mass of isotope needed for an activity of 1.1×10^{14} Bq. *(7 marks)*

AQA, 2003

5 **Figure 1** shows the general relationship between the nuclear binding energy per nucleon (B) and nucleon number (A).

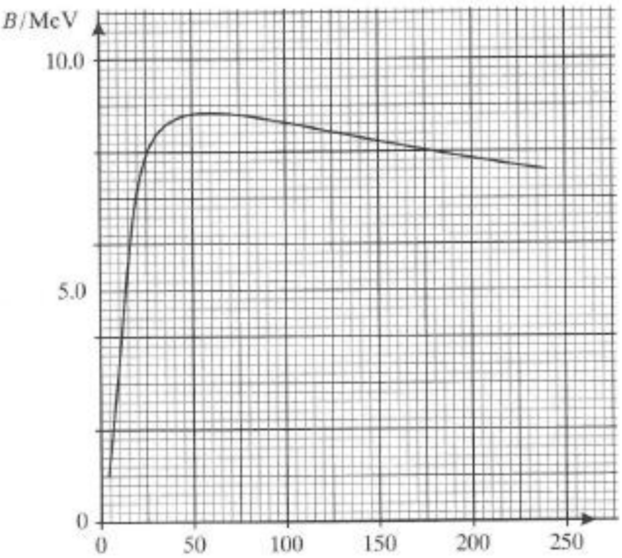

Figure 1

(a) (i) Copy **Figure 1** and mark with the letter S to show the nucleon number and the nuclear binding energy per nucleon for the nuclide with the most stable nuclear structure.

(ii) Write down the nucleon number and the nuclear binding energy per nucleon for this nuclide.

(iii) Calculate the total binding energy of this nuclide. *(3 marks)*

(b) A fusion reaction in which two protons combine to form a deuterium nucleus is summarised by the equation:

$$^{1}_{1}H + ^{1}_{1}H \longrightarrow ^{2}_{1}H + ^{0}_{1}e + \nu + 1.44\,\text{MeV}$$

(i) What do the symbols $^{0}_{1}e$ and ν represent?

(ii) By considering charge, baryon number and lepton number for each side of the equation, show that this reaction satisfies the conservation laws for these quantities.

(iii) Subsequently two γ-ray photons are released, each with an energy of 0.51 MeV. Calculate the wavelength of these photons. *(18 marks)*

(c) With reference to **Figure 1** explain why the fission of a heavy nucleus is likely to release more energy than when a pair of light nuclei undergo nuclear fusion. You may wish to sketch the general shape of **Figure 1** in order to aid your explanation. *(5 marks)*

AQA, 2004

6 (a) With reference to the process of nuclear fusion, explain why energy is released when two small nuclei join together, and why it is difficult to make two nuclei come together. *(3 marks)*

(b) A fusion reaction takes place when two deuterium nuclei join, as represented by

$$^{2}_{1}H + ^{2}_{1}H \longrightarrow ^{3}_{2}He + ^{1}_{0}n$$

mass of ^{2}H nucleus = 2.01355 u

mass of ^{3}He nucleus = 3.01493 u

Calculate:

(i) the mass difference produced when two deuterium nuclei undergo fusion,

(ii) the energy released, in J, when this reaction takes place. *(3 marks)*

AQA, 2003

7 (a) In the context of the processes that occur in a nuclear power reactor, explain what is meant by:

(i) thermal neutrons,

(ii) induced fission,

(iii) a self-sustaining chain reaction. *(5 marks)*

(b) (i) Describe the process of moderation that takes place in an operational reactor.

(ii) How is the fission rate controlled in a power reactor? *(7 marks)*

8 (a) When a fuel rod has been in use in a nuclear reactor for several years, it produces less output power and presents a greater hazard than it did when first installed. Explain why this is so. *(3 marks)*

(b) Describe how the spent fuel rods are handled and processed after they have been removed from a nuclear reactor. Indicate how the active wastes are dealt with in order to reduce the hazards they could present to future generations. *(5 marks)*