1 The nuclear reaction represented by the equation

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{94}_{39}\mathrm{Y} + {}^{139}_{53}\mathrm{I} + 3\,{}^{1}_{0}\mathrm{n}$$

takes place in the core of a nuclear reactor at a power station.

(a) Describe how this reaction can lead to a chain reaction.

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..... **[1]**

(b) Explain the role of fuel rods, control rods and a moderator in a nuclear reactor.

In your answer you should make clear how chain reactions are controlled in the reactor.

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..... **[5]**

(c) In the nuclear reactor of a power station, each fission reaction of uranium produces 3.2×10^{-11} J of energy. The electrical power output of the power station is 3.0 GW. The efficiency of the system that transforms nuclear energy into electrical energy is 22%. Calculate

(i) the total power output of the reactor core

power output = ... W **[1]**

(ii) the total energy output of the reactor core in one day

1 day = 8.64×10^4 s

energy output = ... J **[1]**

(iii) the mass of uranium-235 converted in one day. The mass of a uranium-235 nucleus is 3.9×10^{-25} kg.

mass = ... kg **[2]**

(d) Discuss the physical properties of nuclear waste that makes it dangerous.

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..... **[2]**

2 **(a)** In experiments carried out to determine the nature of atoms, alpha particles were fired at thin metal foils. Describe how the alpha-particle scattering experiments provide evidence for the existence, charge and size of the nucleus.

In your answer, you should make clear how your conclusions link with your observations.

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(b) Describe the nature and range of the **three** forces acting on the protons and neutrons in the nucleus.

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(c) The radius of a $^{235}_{92}U$ nucleus is 8.8×10^{-15} m. The average mass of a nucleon is 1.7×10^{-27} kg.

(i) Estimate the average density of this nucleus.

density = ... kg m^{-3} **[3]**

(ii) State one assumption made in your calculation.

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..... **[1]**

[Total: 14]

3 **(a)** Describe the process of induced nuclear fission.

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(b) Explain how nuclear fission can provide energy.

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(c) Suggest a suitable material which can be used as a moderator in a fission reactor and explain its role.

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[Total: 7]

4 **(a)** A sample of a radioactive isotope contains 4.5×10^{23} active undecayed nuclei. The half-life of the isotope is 12 hours. Calculate

(i) the initial activity of the sample

activity = ... s^{-1} **[2]**

(ii) the number of active nuclei of the isotope remaining after 36 hours

number = ... **[1]**

(iii) the number of active nuclei of the isotope remaining after 50 hours.

number = ... **[2]**

(b) Explain why the activity of a radioactive material is a major factor when considering the safety precautions in the disposal of nuclear waste.

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[Total: 7]

5 There are two types of beta decay, beta-plus and beta-minus. An isotope of carbon $^{15}_{6}C$ decays by beta emission into an isotope of nitrogen $^{15}_{7}N$. An isotope of phosphorus $^{30}_{15}P$ decays by beta emission into an isotope of silicon $^{30}_{14}Si$.

(a) Complete the following decay equations for the carbon and phosphorus isotopes.

(i) carbon decay

$$^{15}_{6}C \rightarrow {}^{\cdots}_{\cdots}e + {}^{\cdots}_{\cdots}N + \ldots\ldots$$

(ii) phosphorus decay

$$^{30}_{15}P \rightarrow {}^{\cdots}_{\cdots}e + {}^{\cdots}_{\cdots}Si + \ldots\ldots$$

[3]

(b) State the two beta decays in terms of a quark model of the nucleons.

(i) beta-plus decay

(ii) beta-minus decay

[2]

(c) Name the force responsible for beta decay.

..... **[1]**

[Total: 6]