Questions

Q1.

The fuel used in a nuclear fission reactor is uranium.
Which of the following is required for fission to proceed?

☒ **A** Neutrons must be removed from the reactor core.

☒ **B** The reactor core must be very hot.

☒ **C** The uranium nuclei must absorb neutrons.

☒ **D** The uranium nuclei must absorb protons.

(Total for question = 1 mark)

Q2.

In both nuclear fission and nuclear fusion there are changes in the binding energy per nucleon.
This releases energy.

Which row of the table correctly shows the change in binding energy per nucleon for both processes?

	Nuclear fission	Nuclear fusion
☒ **A**	decrease	decrease
☒ **B**	decrease	increase
☒ **C**	increase	decrease
☒ **D**	increase	increase

(Total for question = 1 mark)

Q3.

A number of conditions must be met if the fusion of hyrdrogen nuclei is to occur. Which condition, in a sample of hydrogen, is **not** neccesary for nuclear fusion to occur

☒ **A** very high density

☒ **B** very high mass

☒ **C** very high pressure

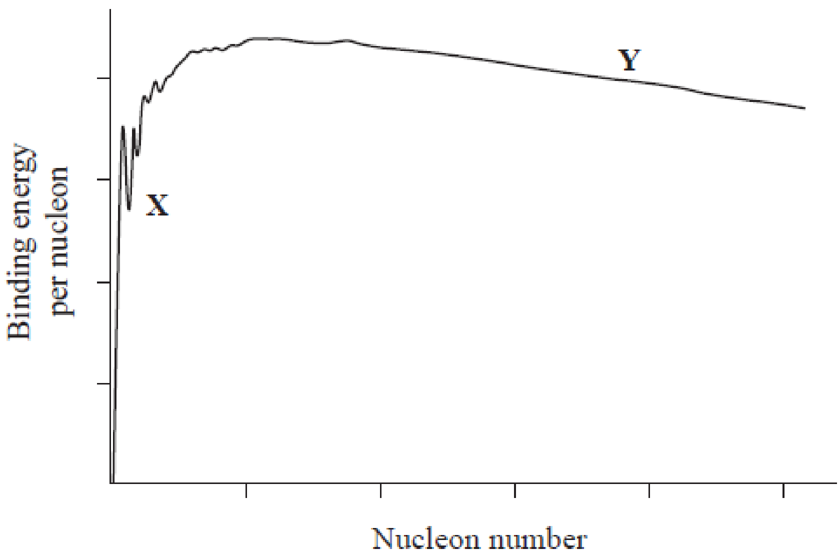
☒ **D** very high temperature

(Total for question = 1 marks)

Q4.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

The diagram shows binding energy per nucleon against nucleon number for atomic nuclei.



Which line of the table correctly identifies the process that would increase stability for nuclei in the positions indicated by X and Y?

		X	Y
☒	**A**	nuclear fission	nuclear fission
☒	**B**	nuclear fission	nuclear fusion
☒	**C**	nuclear fusion	nuclear fission
☒	**D**	nuclear fusion	nuclear fusion

(Total for question = 1 mark)

Q5.

At the Culham Centre for Fusion Energy (CCFE) experiments are carried out to investigate nuclear fusion and the properties of plasmas. A plasma consists of ionised gas, containing positive ions and electrons.

In a fusion experiment at CCFE, ions of two isotopes of hydrogen fuse to produce helium ions and fast-moving neutrons.

Fusion occurs naturally in the core of stars.

Explain why very high densities of matter and very high temperatures are needed to bring about and maintain nuclear fusion in stars.

(2)

....

....

....

....

....

....

(Total for question = 2 marks)

Q6.

State what is meant by binding energy.

(2)

....

....

....

....

(Total for question = 2 marks)

Q7.

Nuclear fusion involves small nuclei joining to make larger nuclei. Nuclear fission involves large nuclei splitting to become smaller nuclei. Both of these processes release energy.

Explain the conditions required to bring about and maintain nuclear fusion.

(3)

....

....

....

....

....

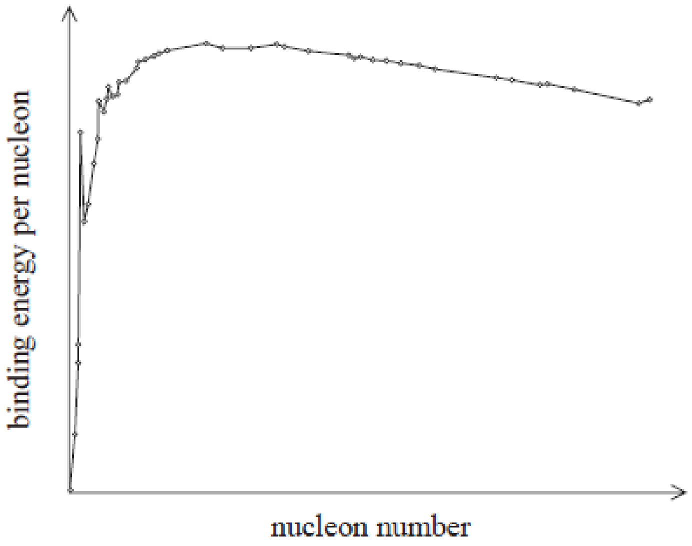
....

(Total for question = 3 marks)

Q8.

Nuclear fusion involves small nuclei joining to make larger nuclei. Nuclear fission involves large nuclei splitting to become smaller nuclei. Both of these processes release energy.

The graph shows how the binding energy per nucleon varies with nucleon number for a range of isotopes.



Use the binding energy per nucleon curve to explain how fusion and fission both release energy.

(3)

....

....

....

....

....

....

(Total for question = 3 marks)

Q9.

In a nuclear fission reaction in power station, a slow-moving neutron is absorbed by a nucleus of U-235
The fission reaction produces nuclei of barium-141 and krypton-92

The equation for the reaction is:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3 \times ^{1}_{0}n$$

Use the data in the table to calculate the energy, in joules, released in this fission reaction.

(3)

	Mass/u
neutron	1.008665
uranium-235	235.0439
barium-141	140.9144
krypton-92	91.9262

....

....

....

....

....

....

....

....

Energy = ... J

(Total for question = 5 marks)

Q10.

The photograph shows a tea cup on a saucer.

A student notices that walking with this sort of tea cup when it is filled with tea is particularly difficult to do without spilling it.

While walking, the tea starts to oscillate from side to side in the cup, rapidly increasing in amplitude and spilling over the edge.

The student develops the hypothesis that spillage occurs most when the frequency of the steps taken by a person matches the natural frequency of oscillation of tea in the cup.

(a) Explain whether the student's hypothesis is supported by relevant physics.

(4)

....

....

....

....

....

....

....

....

(Total for question = 4 marks)

Q11.

Phosphogypsum is a by-product in the manufacture of fertiliser. It is slightly radioactive because of the presence of radium-226, a radioisotope with a half-life of 1600 years.

It must be stored securely as long as the activity of the radium-226 it contains is greater than 0.4 Bq per gram of phosphogypsum.

Radium-226 decays to radon-222 by alpha emission.

Determine the energy released in MeV in the decay of a single nucleus of radium-226.

(5)

mass of radium-226 nucleus = 225.97713 u
mass of radon-222 nucleus = 221.97040 u
mass of α particle = 4.00151 u

....

....

....

....

....

....

....

....

....

....

Energy released = ... MeV

(Total for question = 5 marks)

Q12.

The photograph shows a vase made of uranium glass. Uranium glass is radioactive.

Uranium glass usually contains a maximum of 2% uranium. Uranium glass made in the early part of the 20th century can contain up to 25% uranium.

A uranium nucleus decays to thorium by emission of an alpha particle.

It can be assumed that all the energy of the decay is transferred to kinetic energy of the alpha particle.

Calculate the speed of the emitted alpha particle.

mass of uranium nucleus = 238.0003 u
mass of thorium nucleus = 233.9942 u
mass of alpha particle = 4.0015 u

(5)

....

....

....

....

....

....

....

....

....

....

Speed of alpha particle = ...

(Total for question = 5 marks)

Q13.

At the Culham Centre for Fusion Energy (CCFE) experiments are carried out to investigate nuclear fusion and the properties of plasmas. A plasma consists of ionised gas, containing positive ions and electrons.

In a fusion experiment at CCFE, ions of two isotopes of hydrogen fuse to produce helium ions and fast-moving neutrons.

$$^{2}_{1}\text{H} + ^{3}_{1}\text{H} \rightarrow ^{4}_{2}\text{He} + ^{1}_{0}\text{n}$$

Show that a single fusion reaction releases about 3×10^{-12} J of energy.

mass of $^{2}_{1}\text{H}$ = 2.013553 u

mass of $^{3}_{1}\text{H}$ = 3.015501 u

mass of $^{4}_{2}\text{He}$ = 4.001506 u

mass of $^{1}_{0}\text{n}$ = 1.008665 u

(4)

....

....

....

....

....

....

....

....

(Total for question = 4 marks)

Q14.

* The energy radiated by stars is released by nuclear fusion.

Explain the conditions required to bring about and maintain nuclear fusion in stars.

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

(Total for question = 6 marks)

Q15.

In 2012, building commenced on the International Thermonuclear Experimental Reactor (ITER) in France. The aim is for this fusion reactor to be working by 2020.

(a) (i) Describe the process of nuclear fusion.

(2)

....

....

....

....

(ii) Explain why it is difficult to maintain the conditions needed for nuclear fusion in a reactor.

(2)

....

....

....

....

....

(b) Explain why the fusion of hydrogen nuclei should release energy.

(2)

....

....

....

....

(Total for question = 6 marks)

Q16.

Radium is a radioactive element . The most common isotope of radium has a half-life of almost two thousand years. A sample of radium can remain at a higher temperature than its surroundings for a long period of time.

Explain how a sample of radium is able to release significant amounts of energy over a long period of time.

(6)

....

....

....

....

....

....

....

....

....

....

....

....

....

....

(Total for question = 6 marks)

Q17.

(a) In 1939 Hans Bethe published a paper describing the fusion processes in stars.

In the proton-proton cycle, hydrogen is converted to helium in stages. The nuclear equation below represents one of the stages.

$$^{7}_{3}\text{Li} + ^{\dots}_{\dots}\text{X} \rightarrow 2 \times ^{4}_{2}\text{He}$$

(i) Complete the equation and identify X.

(2)

X is ....

(ii) Calculate, in joules, the energy emitted in this stage of the cycle.

(3)

	Mass / MeV/c^2
Proton	938.3
Neutron	939.6
Helium	3727.4
Lithium	6533.8

....

....

....

....

....

....

Energy = ... J

(b) In 1967 Bethe received a Nobel Prize in Physics for his work on understanding the fusion processes in stars.

Explain why sustainable fusion has not yet been achieved for the generation of electrical power.

(4)

....

....

....

....

....

....

....

Q18.

An old type of camping lamp used a 'gas mantle'. The gas mantle is heated by the gas flame on the lamp and emits a bright white light. Gas mantles used to contain thorium-230.

Thorium-230 decays by alpha emission to form an isotope of radium. A student keeps a radioactive gas mantle in a sealed polythene bag. The student suggests that over a period of a year a significant volume of helium gas will be collected, since an alpha particle is a helium nucleus.

A particular gas mantle contains 5.18×10^{-5} g of thorium-230.

(i) Show that the activity of the thorium-230 in the mantle is about 4.0×10^{4} Bq.

230 g of thorium-230 contains 6.02×10^{23} atoms

half-life of thorium-230 = 75 400 years

number of seconds in 1 year = 3.15×10^{7}

(4)

....

....

....

....

....

....

....

....

(ii) Determine the volume of helium gas that could be collected in a year as a result of alpha emission.

Assume that the temperature is 22.0 °C and the pressure is 1.00×10^{5} Pa.

(4)

....

....

....

....

....

....

....

....

Volume = ...

(iii) Calculate the root mean square speed of the atoms in the helium gas at a temperature of 22.0 °C.

(3)

....

....

....

....

....

Root mean square speed = ...

(Total for question = 11 marks)

Q19.

Electrical power generated by nuclear fission makes an important contribution to world energy needs. However Rutherford, who is credited with the discovery and first splitting of the nuclear atom, later said:

"The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine."

Rutherford carried out experiments that involved firing alpha particles at nitrogen atoms.

(a) (i) Complete the equation for the interaction between nitrogen and alpha particles.

(1)

$$^{14}_{7}\text{N} + ^{4}_{2}\alpha \rightarrow ^{\dots}_{\dots}\text{O} + ^{1}_{\dots}\text{p}$$

(ii) This interaction requires a small energy input. Other similar nuclear reactions may give an energy output of no more than 20 MeV, giving some justification to Rutherford's statement. Suggest why Rutherford's statement eventually turned out to be very inaccurate.

(1)

....

....

....

(b) Uranium-235 is able to undergo fission when it absorbs a neutron to become uranium-236. The equation below shows a possible fission reaction

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{92}_{36}Kr + ^{141}_{56}Ba + 3 \times ^{1}_{0}n$$

Use the data in the table to show that the energy released by the fission of one uranium nucleus is about 170 MeV.

Isotope	Mass / 10^{-27} kg
^{235}U	390.29989
^{141}Ba	233.99404
^{92}Kr	152.64708
^{1}n	1.67493

(4)

....

....

....

....

....

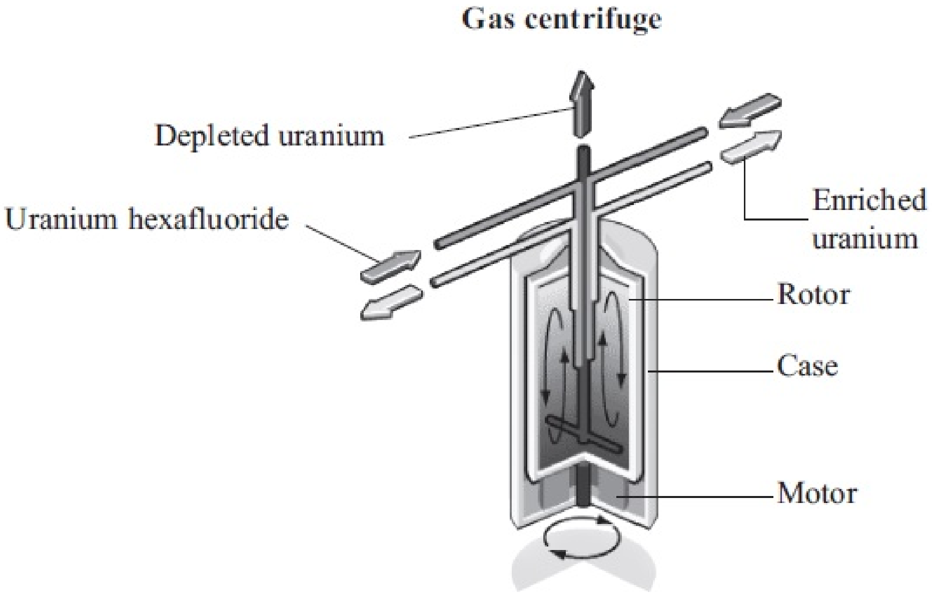
....

....

....

(c) Naturally occurring uranium is more than 99% uranium-238. Fuel for a fission reactor requires at least 3% of the uranium to be uranium-235.

Uranium hexafluoride gas is used during the uranium enrichment process. It is fed into a centrifuge, and a rotating cylinder (rotor) sends the uranium-238 to the outside of the cylinder, where it can be drawn off, while the uranium-235 diffuses to the center of the cylinder.



(i) Give **one** similarity and **one** difference between the nuclei of uranium-238 and uranium-235.

(2)

Similarity

....

Difference

....

(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute

Calculate the centripetal acceleration at the rim of the motor.

(2)

....

....

....

....

Centripetal acceleration = ...

(iii) The rotor is subjected to huge forces because of the high spin rate.

Give **two** mechanical properties essential for the material from which the rotor is made.

(2)

Property 1

....

Property 2

....

(d) The waste heat from some power stations is transfered to water.

The San Onofre Nuclear Generating Station in California has reactors with a total output power of 2200 MW. These reactors circulate sea water at an average mass flow rate of 7.0×10^4 kg s^{-1}. The water is heated to approximately 11 K above the input temperature as it flows through condensers, before being discharged back into the ocean.

Show that the rate at which energy is removed from the reactors is about 3000 MW, and hence estimate a value for the efficiency of the electrical power generation process.

specific heat capacity of the sea water = 3990 J kg^{-1} K^{-1}

(4)

....

....

....

....

....

....

....

....

Efficiency = ...

(Total for question = 16 marks)