AQA – Nuclear physics – A2 Physics P2

1. June/2021/Paper_7408_2/No.06

0 6 . 1 Explain, in terms of binding energy, why energy can be released when two nuclei undergo nuclear fusion.

[2 marks]

0 6 . 2 During the collapse of a supermassive star, helium-3 and oxygen-17 fuse to release energy. The equation for this reaction is

$$^{3}_{2}\mathrm{He} + ^{17}_{8}\mathrm{O} \rightarrow ^{20}_{10}\mathrm{Ne}$$

Table 2 gives data for these nuclei.

Table 2

Nucleus	Mass / u
$^{3}_{2}\mathrm{He}$	3.01603
$^{17}_{8}\mathrm{O}$	16.99913
$^{20}_{10}\mathrm{Ne}$	19.99244

Calculate, in J, the energy released when this reaction occurs.

[2 marks]

energy released = _____ J

0 6 . 4 $^{3}_{2}\mathrm{He}$ can undergo fusion reactions with either $^{34}_{16}\mathrm{S}$ or $^{17}_{8}\mathrm{O}$ at the same temperature in a star.

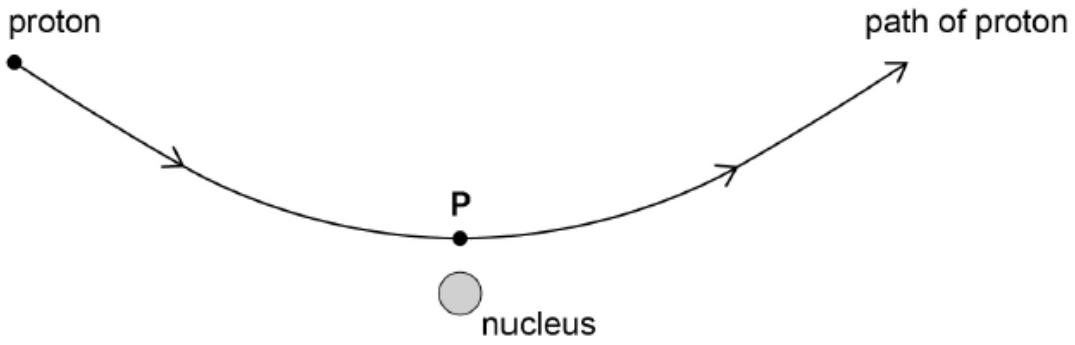
The nucleus has properties that depend on its proton number and its nucleon number. These properties affect the fusion reaction.

Discuss, for this star, how these properties affect the rate of fusion of $^{34}_{16}\mathrm{S}$ with $^{3}_{2}\mathrm{He}$ compared to the rate of fusion of $^{17}_{8}\mathrm{O}$ with $^{3}_{2}\mathrm{He}$.

[3 marks]

2. June/2021/Paper_7408_2/No.26

The diagram shows the path of a proton being deflected by the nucleus of an atom.
Point **P** is the position of the proton when it is closest to the nucleus.



What is **not** true about the proton along its path at **P**?

[1 mark]

A Its rate of change of momentum is at a minimum. ⬭

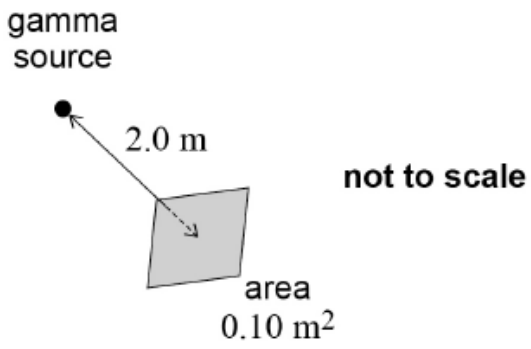
B Its kinetic energy is at a minimum. ⬭

C Its potential energy is at a maximum. ⬭

D Its acceleration is at a maximum. ⬭

3. June/2021/Paper_7408_2/No.27

The diagram shows an area of $0.10\ m^2$ normal to a line connecting it to a point source of gamma radiation. The source emits photons uniformly in all directions.
The area and the source are separated by a distance of $2.0\ m$.



The source emits 5000 gamma photons per second.

How many photons pass through the area every second?

[1 mark]

A 500 ⬭

B 250 ⬭

C 10 ⬭

D 2.5 ⬭

4. June/2021/Paper_7408_2/No.28

X and **Y** are two radioactive nuclides. **X** has a half-life of 3.0 minutes and **Y** has a half-life of 9.0 minutes.

Two freshly prepared samples of **X** and **Y** start decaying at the same time.
After 18 minutes the number of radioactive nuclei in both samples is the same.
The sample of **Y** initially contained N radioactive nuclei.

What was the initial number of radioactive nuclei in the sample of **X**?

[1 mark]

A $4N$ ⬭

B $16N$ ⬭

C $32N$ ⬭

D $64N$ ⬭

5. June/2021/Paper_7408_2/No.29

What is the main purpose of a moderator in a thermal nuclear reactor?

[1 mark]

A to shield the surroundings from ionising radiations ⬭

B to decrease the number of fission chain reactions ⬭

C to decrease neutron speeds ⬭

D to prevent the core from overheating ⬭

6. June/2021/Paper_7408_2/No.30

In the core of a nuclear reactor, the mass of fuel decreases at a rate of 9.0×10^{-6} kg hour^{-1} due to nuclear reactions.

What is the maximum power output of the reactor?

[1 mark]

A 2.3×10^{8} W ⬭

B 1.4×10^{11} W ⬭

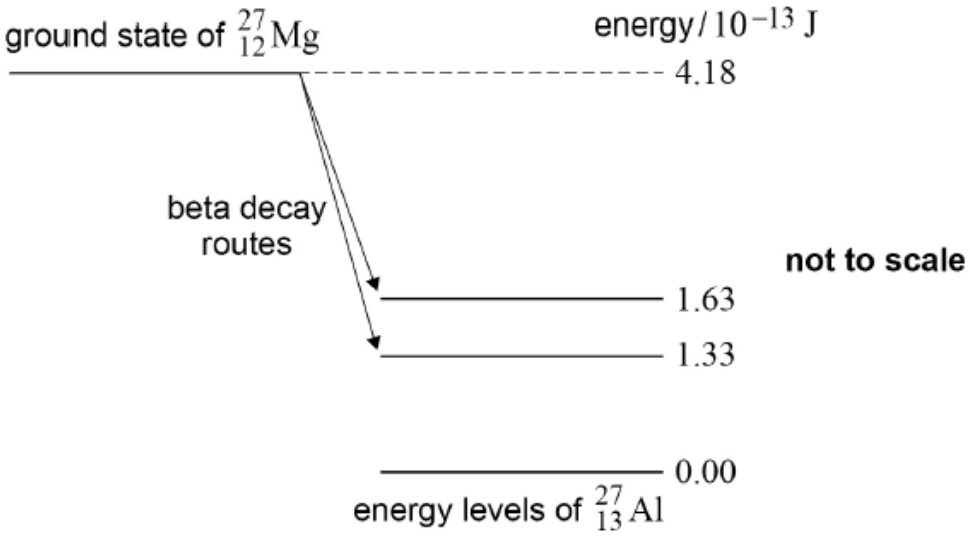
C 8.1×10^{11} W ⬭

D 2.9×10^{15} W ⬭

7. June/2021/Paper_7408_2/No.31

$^{27}_{12}\text{Mg}$ can decay by beta minus emission to one of two possible excited states of $^{27}_{13}\text{Al}$.

Both excited states decay by the emission of a gamma photon directly to the ground state.



The diagram shows the energy levels and two routes for the beta decay.

One route results in the emission of a gamma photon with a higher frequency than the other photon.

What is the maximum possible kinetic energy for the beta particle emitted in this route?

[1 mark]

A 1.33×10^{-13} J ⬭

B 1.63×10^{-13} J ⬭

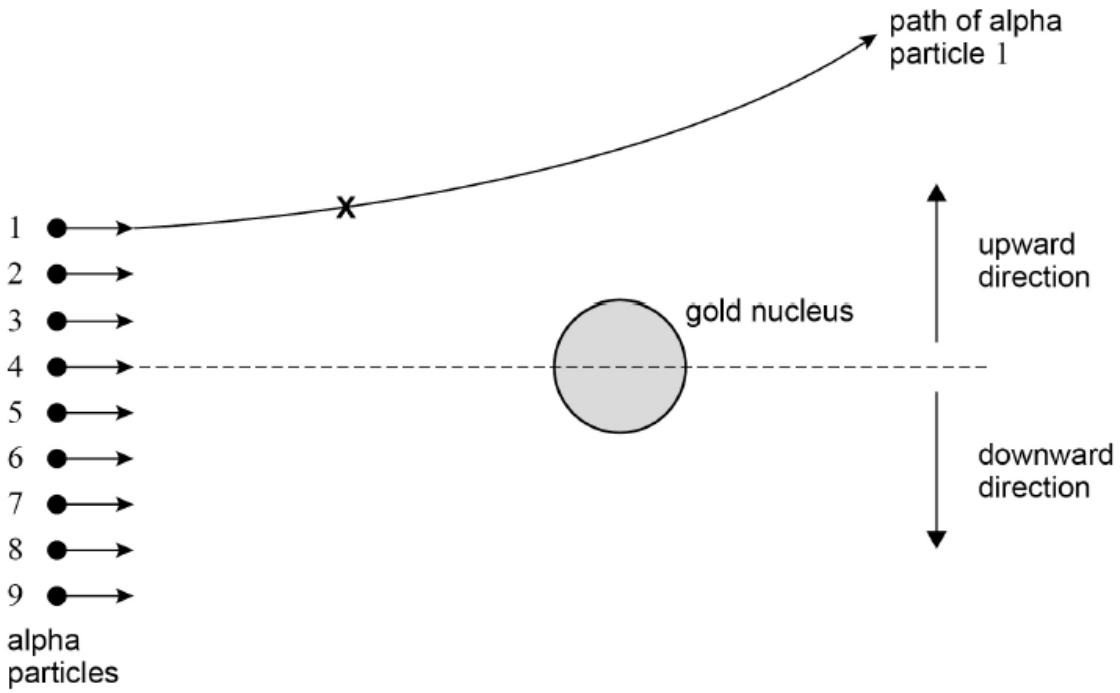
C 2.55×10^{-13} J ⬭

D 2.85×10^{-13} J ⬭

8. June/2020/Paper_7408_2/No.05

0 5 **Figure 11** shows alpha particles all travelling in the same direction at the same speed.
The alpha particles are scattered by a gold ($^{197}_{79}Au$) nucleus.
The path of alpha particle **1** is shown.

Figure 11



0 5 . 1 State the fundamental force involved when alpha particle **1** is scattered by the nucleus in **Figure 11**.

[1 mark]

_____

0 5 . 2 Draw an arrow at position **X** on **Figure 11** to show the direction of the rate of change in momentum of alpha particle **1**

[1 mark]

0 5 . 3 Suggest **one** of the alpha particles in **Figure 11** which may be deflected downwards with a scattering angle of $90°$

Justify your answer.

[2 marks]

alpha particle number = _____

_____

_____

_____

_____

0 5 . 4 Alpha particle **4** comes to rest at a distance of 5.5×10^{-14} m from the centre of the $^{197}_{79}Au$ nucleus.

Calculate the speed of alpha particle **4** when it is at a large distance from the nucleus. Ignore relativistic effects.

mass of alpha particle = 6.8×10^{-27} kg

[3 marks]

speed = _____ $m\ s^{-1}$

0 5 . 5 The nuclear radius of $^{197}_{79}\mathrm{Au}$ is 6.98×10^{-15} m.

Calculate the nuclear radius of $^{107}_{47}\mathrm{Ag}$.

[2 marks]

radius = _____ m

0 5 . 6 All nuclei have approximately the same density.

State **one** conclusion about the nucleons in a nucleus that can be deduced from this fact.

[1 mark]

_____

_____

_____

_____

9. June/2020/Paper_7408_2/No.06

0 6 A thermal nuclear reactor uses enriched uranium as its fuel.
This is fuel in which the ratio of U-235 to U-238 has been artificially increased from that found in naturally-occurring ore.

0 6 . 1 Describe what happens when neutrons interact with U-235 and U-238 nuclei in a thermal nuclear reactor.

[3 marks]

0 6 . 2 The amounts of U-235 and U-238 in the ore decrease due to radioactive decay at different rates.

A sample of uranium ore today contains 993 g of U-238
The mass of U-238 in this sample was greater 2.00×10^9 years ago.

Show that the mass of U-238 in this sample at that time was about 1.4 kg.

decay constant of U-238 = 1.54×10^{-10} year^{-1}

[2 marks]

0 6 . 3 A thermal nuclear reactor requires a minimum of 3.0% of its uranium mass to be U-235

The ratio of U-235 to U-238 in the ore has changed over time.
2.00×10^9 years ago, the sample in Question **06.2** contained 52 g of U-235

Deduce whether the sample had a high enough U-235 content to be used in a reactor 2.00×10^9 years ago.

[1 mark]

10. June/2020/Paper_7408_2/No.28

A point source emits gamma radiation. The intensity I of the radiation is measured at different distances d from the source.

Which graph will show a straight line through the origin?

[1 mark]

A I plotted against d ⬭

B I plotted against d^2 ⬭

C I plotted against d^{-1} ⬭

D I plotted against d^{-2} ⬭

11. June/2020/Paper_7408_2/No.29

The number of parent nuclei in a sample of a radioactive element is N at time t.
The radioactive element has a half-life $t_{\frac{1}{2}}$

The rate of decay is proportional to

[1 mark]

A N ⬭

B t ⬭

C $\frac{1}{t}$ ⬭

D $t_{\frac{1}{2}}$ ⬭

12. June/2020/Paper_7408_2/No.30

The table shows the masses of three particles.

Particle	Mass / u
proton	1.00728
neutron	1.00867
nucleus of lithium $^{7}_{3}\mathrm{Li}$	7.01436

What is the mass difference of a $^{7}_{3}\mathrm{Li}$ nucleus?

[1 mark]

A 4.99841 u ⬭

B 0.04216 u ⬭

C 0.04147 u ⬭

D 0.04077 u ⬭

13. June/2020/Paper_7408_2/No.31

The mass of the fuel in a fission reactor decreases at a rate of 6.0×10^{-6} kg hour^{-1}.

What is the maximum possible power output of the reactor?

[1 mark]

A 75 MW ⬭

B 150 MW ⬭

C 300 MW ⬭

D 9000 MW ⬭