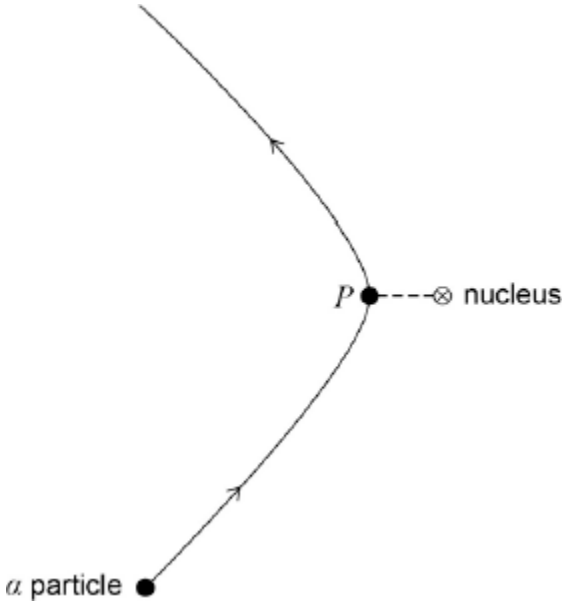
**1** The diagram shows the path of an α particle deflected by the nucleus of an atom. Point P on the path is the point of closest approach of the α particle to the nucleus.




Which of the following statements about the α particle on this path is correct?

**A** Its acceleration is zero at P. ⬭

**B** Its kinetic energy is greatest at P. ⬭

**C** Its potential energy is least at P. ⬭

**D** Its speed is least at P. ⬭

**(Total 1 mark)**

**2** Which of the following best describes the decay constant for a radioisotope?

**A** The reciprocal of the half-life of the radioisotope. ⬭

**B** The rate of decay of the radioisotope. ⬭

**C** The constant of proportionality which links half-life to the rate of decay of nuclei. ⬭

**D** The constant of proportionality which links rate of decay to the number of undecayed nuclei. ⬭

**(Total 1 mark)**

**3** Which of the following is equal to $\frac{\text{radius of a nucleus of } {}^{125}_{51}\text{Sb}}{\text{radius of a nucleus of } {}^{64}_{30}\text{Zn}}$ ??

**A** 1.19 ⬭

**B** 1.25 ⬭

**C** 1.33 ⬭

**D** 1.40 ⬭

**(Total 1 mark)**

**4** After 64 days the activity of a radioactive nuclide has fallen to one sixteenth of its original value.
The half-life of the radioactive nuclide is

**A** 2 days. ⬭

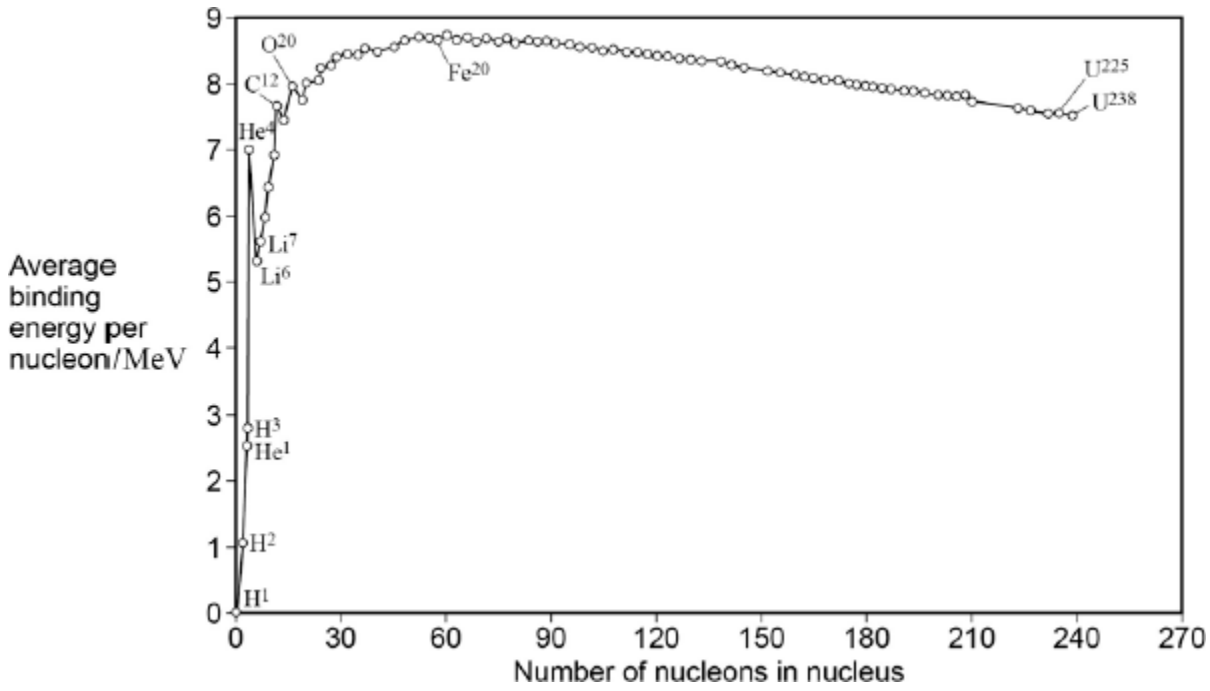
**B** 4 days. ⬭

**C** 8 days. ⬭

**D** 16 days. ⬭

**(Total 1 mark)**

**5** The graph shows how the binding energy per nucleon varies with the nucleon number for stable nuclei.




What is the approximate total binding energy for a nucleus of $^{184}_{74}W$?

**A** 1.28 pJ ⬭

**B** 94.7 pJ ⬭

**C** 103 pJ ⬭

**D** 230 pJ ⬭

**(Total 1 mark)**

**6** In the reaction shown, a proton and a deuterium nucleus, ${}^{2}_{1}\mathrm{H}$, fuse together to form a helium nucleus, ${}^{3}_{2}\mathrm{He}$

$$ {}^{1}_{1}\mathrm{p} + {}^{1}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + \mathrm{Q} $$

What is the value of Q, the energy released in this reaction?

mass of a proton = 1.00728 u

mass of a ${}^{2}_{1}\mathrm{H}$ nucleus = 2.01355 u

mass of a ${}^{3}_{2}\mathrm{He}$ nucleus = 3.01493 u

**A** 5.0 MeV

**B** 5.5 MeV

**C** 6.0 MeV

**D** 6.5 MeV

**(Total 1 mark)**

**7** For a nuclear reactor in which the fission rate is constant, which one of the following statements is correct?

**A** There is a critical mass of fuel in the reactor.

**B** For every fission event, there is, on average, one further fission event.

**C** A single neutron is released in every fission event.

**D** No neutrons escape from the reactor.

**(Total 1 mark)**

**8** The reaction shown below occurs when a proton and a deuterium nucleus, ${}^{2}_{1}\mathrm{H}$, fuse to form a helium nucleus, ${}^{3}_{2}\mathrm{He}$.

$$ {}^{1}_{1}\mathrm{P} \quad + \quad {}^{2}_{1}\mathrm{H} \quad \longrightarrow \quad {}^{3}_{2}\mathrm{He} \quad + \quad Q $$

If the energy released, $Q$, is 5.49 MeV, what is the mass of the helium nucleus?

mass of ${}^{2}_{1}\mathrm{H}$ nucleus = 2.01355 u
mass of proton = 1.00728 u
1u is equivalent to 931.3 Me V

**A** 0.00589 u

**B** 3.01494 u

**C** 3.02083 u

**D** 3.02323 u

**(Total 1 mark)**

**9** Which line, **A** to **D**, in the table gives a combination of materials that is commonly used for moderating, controlling and shielding respectively in a nuclear reactor?

| | **moderating** | **controlling** | **shielding** |
|---|---|---|---|
| **A** | graphite | carbon | lead |
| **B** | cadmium | carbon | concrete |
| **C** | cadmium | boron | lead |
| **D** | graphite | boron | concrete |

**(Total 1 mark)**

**10** Which one of the following statements is **not** true about the control rods used in a nuclear reactor?

**A** They must absorb neutrons.

**B** They must slow down neutrons to thermal speeds.

**C** They must retain their shape at high temperatures.

**D** The length of rod in the reactor must be variable.

**(Total 1 mark)**

**11** The mass of the beryllium nucleus, $^{7}_{4}Be$ , is 7.01473 u. What is the binding energy **per nucleon** of this nucleus?

Use the following data:

mass of proton = 1.00728 u
mass of neutron = 1.00867 u
1u = 931.3 MeV

**A** 1.6 MeV nucleon$^{-1}$

**B** 5.4 MeV nucleon$^{-1}$

**C** 9.4 MeV nucleon$^{-1}$

**D** 12.5 MeV nucleon$^{-1}$

**(Total 1 mark)**

**12** The fusion of two deuterium nuclei produces a nuclide of helium plus a neutron and liberates 3.27 MeV of energy. How does the mass of the two deuterium nuclei compare with the combined mass of the helium nucleus and neutron?

**A** It is $5.8 \times 10^{-30}$ kg greater before fusion.

**B** It is $5.8 \times 10^{-30}$ kg greater after fusion.

**C** It is $5.8 \times 10^{-36}$ kg greater before fusion.

**D** It is $5.8 \times 10^{-36}$ kg greater after fusion.

**(Total 1 mark)**

**13** The mass of the nuclear fuel in a nuclear reactor decreases at a rate of $1.2 \times 10^{-5}$ kg per hour. Assuming 100% efficiency in the reactor what is the power output of the reactor?

**A** 100 MW

**B** 150 MW

**C** 200 MW

**D** 300 MW

**(Total 1 mark)**

**14** The sodium isotope $^{24}_{11}\text{Na}$ is a radioactive isotope that can be produced by bombarding the aluminium isotope $^{27}_{13}\text{Al}$ with neutrons. Which line, **A** to **D**, in the table correctly represents the production of $^{24}_{11}\text{Na}$ from the aluminium isotope $^{27}_{13}\text{Al}$ and its subsequent decay?

| | production | decay |
|---|---|---|
| **A** | $^{27}_{13}\text{Al} + ^{1}_{0}\text{n} \rightarrow ^{24}_{11}\text{Na} + ^{4}_{2}\alpha$ | $^{24}_{11}\text{Na} \rightarrow ^{24}_{12}\text{Mg} + ^{0}_{+1}\beta + \nu$ |
| **B** | $^{27}_{13}\text{Al} + ^{1}_{0}\text{n} \rightarrow ^{24}_{11}\text{Na} + ^{4}_{2}\alpha$ | $^{24}_{11}\text{Na} \rightarrow ^{24}_{12}\text{Mg} + ^{0}_{-1}\beta + \overline{\nu}$ |
| **C** | $^{27}_{13}\text{Al} + ^{1}_{0}\text{n} \rightarrow ^{24}_{11}\text{Na} + ^{3}_{2}\text{He}$ | $^{24}_{11}\text{Na} \rightarrow ^{24}_{12}\text{Mg} + ^{0}_{+1}\beta + \nu$ |
| **D** | $^{27}_{13}\text{Al} + ^{1}_{0}\text{n} \rightarrow ^{24}_{11}\text{Na} + ^{3}_{2}\text{He}$ | $^{24}_{11}\text{Na} \rightarrow ^{24}_{12}\text{Mg} + ^{0}_{-1}\beta + \overline{\nu}$ |

**(Total 1 mark)**

**15** Why is a moderator required in a thermal nuclear reactor?

**A** to prevent overheating of the nuclear core

**B** to absorb surplus uranium nuclei

**C** to shield the surroundings from gamma radiation

**D** to reduce the kinetic energy of fission neutrons

**(Total 1 mark)**

**16** A thermal nuclear reactor is shut down by inserting the control rods fully into the core. Which line, **A** to **D**, shows correctly the effect of this action on the fission neutrons in the reactor?

| | number of fission neutrons | average kinetic energy of fission neutrons |
|---|---|---|
| **A** | reduced | reduced |
| **B** | reduced | unchanged |
| **C** | unchanged | reduced |
| **D** | unchanged | unchanged |

**(Total 1 mark)**

**17** What is the binding energy of the nucleus $^{238}_{92}U$?

Use the following data:

mass of a proton =1.00728 u

mass of a neutron = 1.00867 u

mass of a $^{238}_{92}U$ nucleus = 238.05076 u

1 u = 931.3 MeV

**A** 1685 MeV

**B** 1732 MeV

**C** 1755 MeV

**D** 1802 MeV

**(Total 1 mark)**

**18** In a thermal reactor, induced fission is caused by the $^{235}_{92}U$ nucleus capturing a neutron, undergoing fission and producing more neutrons. Which one of the following statements is true?

**A** To sustain the reaction a large number of neutrons is required per fission.

**B** The purpose of the moderator is to absorb all the heat produced.

**C** The neutrons required for induced fission of $^{235}_{92}U$ should be slow neutrons.

**D** The purpose of the control rods is to slow down neutrons to thermal speeds.

**(Total 1 mark)**

**19** Artificial radioactive nuclides are manufactured by placing naturally-occurring nuclides in a nuclear reactor. They are made radioactive in the reactor as a consequence of bombardment by

**A** $\alpha$ particles.

**B** $\beta$ particles.

**C** protons.

**D** neutrons.

**(Total 1 mark)**

**20** The nuclear fuel, which provides the power output in a nuclear reactor, decreases in mass at a rate of $6.0 \times 10^{-6}$ kg per hour. What is the maximum possible power output of the reactor?

**A** 42 kW

**B** 75 MW

**C** 150 MW

**D** 300 MW

**(Total 1 mark)**

**21** What is the mass difference of the $^{7}_{3}$Li nucleus?

Use the following data:

mass of a proton = 1.00728 u
mass of a neutron = 1.00867 u
mass of $^{7}_{3}$Li nucleus = 7.01436 u

**A** 0.93912 u

**B** 0.04051 u

**C** 0.04077 u

**D** 0.04216 u

**(Total 1 mark)**

**22** The moderator in a nuclear reactor is sometimes made of graphite. What is the purpose of the graphite?

**A** to absorb all the heat produced

**B** to decrease the neutron speeds

**C** to absorb $\alpha$ and $\gamma$ radiations

**D** to prevent the reactor from going critical

**(Total 1 mark)**

**23** The moderator in a nuclear reactor is sometimes made of graphite. What is the purpose of the graphite?

**A** to absorb all the heat produced

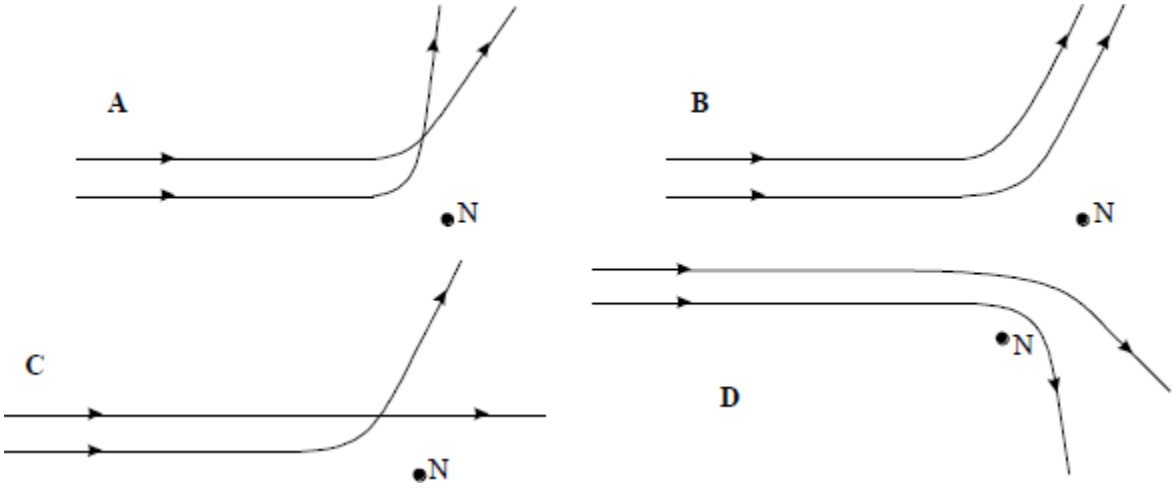
**B** to decrease the neutron speeds

**C** to absorb the $\alpha$ and $\gamma$ radiations

**D** to prevent the reactor from going critical

**(Total 1 mark)**

**24** In the Rutherford alpha particle scattering experiment, alpha particles having the same energy were fired at gold nuclei. The diagrams below are intended to represent encounters between two alpha particles and a gold nucleus N, the alpha particles arriving at different times. Which one best represents the possible encounters?




**(Total 1 mark)**

**25** Which of the following does **not** give a value in seconds?

**A** capacitance × resistance

**B** $\frac{1}{\text{frequency}}$

**C** half-life

**D** $\frac{\text{power}}{\text{work}}$

**(Total 1 mark)**

**26** Nuclear binding energy is

**A** the energy required to overcome the electrostatic force between the protons in the nucleus

**B** energy equivalent of the mass of the protons in the nucleus

**C** the energy equivalent of the mass of all the nucleons in the nucleus

**D** the energy equivalent of the difference between the total mass of the individual nucleons and their mass when they are contained in the nucleus

**(Total 1 mark)**

**27** The actinium series of radioactive decays starts with an isotope of uranium, nucleon (mass) number 235, proton (atomic) number 92.

Which line in the table shows the nucleon number and proton number of the isotope after the emission of 5 $\alpha$ particles and 2 $\beta^-$ particles?

| | Nucleon number | proton number |
|---|---|---|
| **A** | 213 | 82 |
| **B** | 215 | 80 |
| **C** | 215 | 84 |
| **D** | 227 | 87 |

**(Total 1 mark)**

**28** An alpha particle moves at one-tenth the velocity of a beta particle. They both move through the same uniform magnetic field at right angles to their motion.

The magnitude of the ratio $\frac{\text{force on the alpha particle}}{\text{force on the beta particle}}$ is

**A** $\frac{1}{4}$

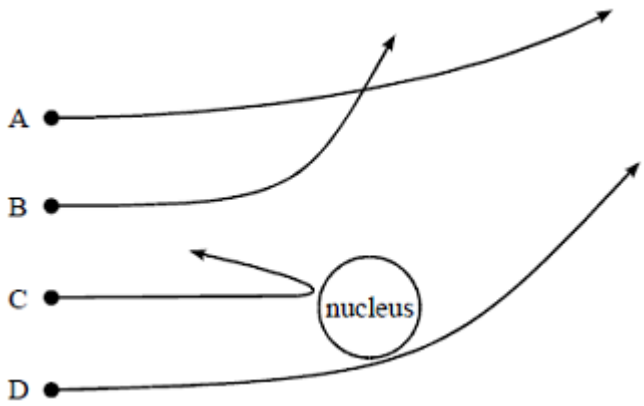
**B** $\frac{1}{5}$

**C** $\frac{1}{10}$

**D** $\frac{1}{20}$

**(Total 1 mark)**

**29** A beam of $\alpha$ particles irradiates a metal foil. The paths of four $\alpha$ particles near the nucleus of a metal atom are shown in the diagram. Which one of the paths must be **incorrect**?




**(Total 1 mark)**

## Mark schemes

| | | |
|---|---|---|
| **1** | D | **[1]** |
| **2** | D | **[1]** |
| **3** | B | **[1]** |
| **4** | D | **[1]** |
| **5** | D | **[1]** |
| **6** | B | **[1]** |
| **7** | B | **[1]** |
| **8** | B | **[1]** |
| **9** | D | **[1]** |
| **10** | B | **[1]** |
| **11** | B | **[1]** |
| **12** | A | **[1]** |
| **13** | D | **[1]** |
| **14** | B | **[1]** |
| **15** | D | **[1]** |
| **16** | B | **[1]** |
| **17** | C | **[1]** |

| | | |
|---|---|---|
| **18** | C | **[1]** |
| **19** | D | **[1]** |
| **20** | C | **[1]** |
| **21** | D | **[1]** |
| **22** | B | **[1]** |
| **23** | B | **[1]** |
| **24** | A | **[1]** |
| **25** | D | **[1]** |
| **26** | D | **[1]** |
| **27** | C | **[1]** |
| **28** | B | **[1]** |
| **29** | D | **[1]** |