25. The nuclear reaction

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

is an example of

A. nuclear fission.

B. radioactive decay.

C. nuclear fusion.

D. artificial transmutation.

26. Degraded energy is energy that is

A. stored in the Earth's atmosphere.

B. available from non-renewable energy sources.

C. converted into work in a cyclical process.

D. no longer available for the performance of useful work.

27. Which of the following correctly describes both the role of the moderator and of the control rods in a nuclear reactor?

	Moderator	Control rods
A.	slows down the neutrons	maintain a constant rate of fission
B.	cools down the reactor	extract thermal energy
C.	cools down the reactor	maintain a constant rate of fission
D.	slows down the neutrons	extract thermal energy

24. The process by which a heavy nucleus splits into two lighter nuclei is known as

A. fission.

B. fusion.

C. radioactive decay.

D. artificial (induced) transmutation.

25. Which of the following correctly shows a renewable and a non-renewable source of energy?

	Renewable	Non-renewable
A.	oil	geothermal
B.	wind	biofuels
C.	ocean waves	nuclear
D.	natural gas	coal

26. Critical mass refers to the amount of fissile material that

A. will allow fission to be sustained.

B. is equivalent to 235 g of uranium.

C. will produce a growing chain reaction.

D. is the minimum mass necessary for fission to take place.

27. The annual variations of solar power incident per unit area at a particular point on the Earth's surface is mainly due to the change in the

A. distance between the Earth and the Sun.

B. angle at which the solar rays hit the surface of the Earth.

C. average albedo of the Earth.

D. average cloud cover of the Earth.

22. Emission and absorption spectra provide evidence for

A. the nuclear model of the atom.

B. natural radioactivity.

C. the existence of isotopes.

D. the existence of atomic energy levels.

23. Which of the following is true in respect of both the Coulomb interaction and the strong interaction between nucleons in an atom?

	Coulomb interaction exists between	**Strong interaction exists between**
A.	protons only	neutrons only
B.	both protons and neutrons	neutrons only
C.	protons only	both protons and neutrons
D.	both protons and neutrons	both protons and neutrons

24. Which of the following correctly identifies the three particles emitted in the decay of the nucleus $^{45}_{20}Ca$ into a nucleus of $^{45}_{21}Sc$?

A. α, β^-, γ

B. $\beta^-, \gamma, \bar{\nu}$

C. $\alpha, \gamma, \bar{\nu}$

D. $\alpha, \beta^-, \bar{\nu}$

21. A particle, of mass m and charge q, moves with velocity v perpendicularly to a magnetic field. The magnitude of the magnetic force acting on the particle at a particular point is F. Which of the following gives the magnitude of the magnetic field strength at that point?

A. $\frac{F}{q}$

B. $\frac{F}{m}$

C. $\frac{F}{v}$

D. $\frac{F}{qv}$

22. Which of the following decay sequences would result in the daughter nucleus having the same proton number as the parent nucleus?

A. Alpha followed by gamma

B. Beta (β^-) followed by gamma

C. Alpha followed by beta (β^-) followed by beta (β^-)

D. Beta (β^-) followed by gamma followed by gamma

23. The difference between the mass of a ${}^{12}_{6}C$ nucleus and the sum of the masses of the individual nucleons is 0.1 u. Which of the following is approximately the binding energy of the nucleus?

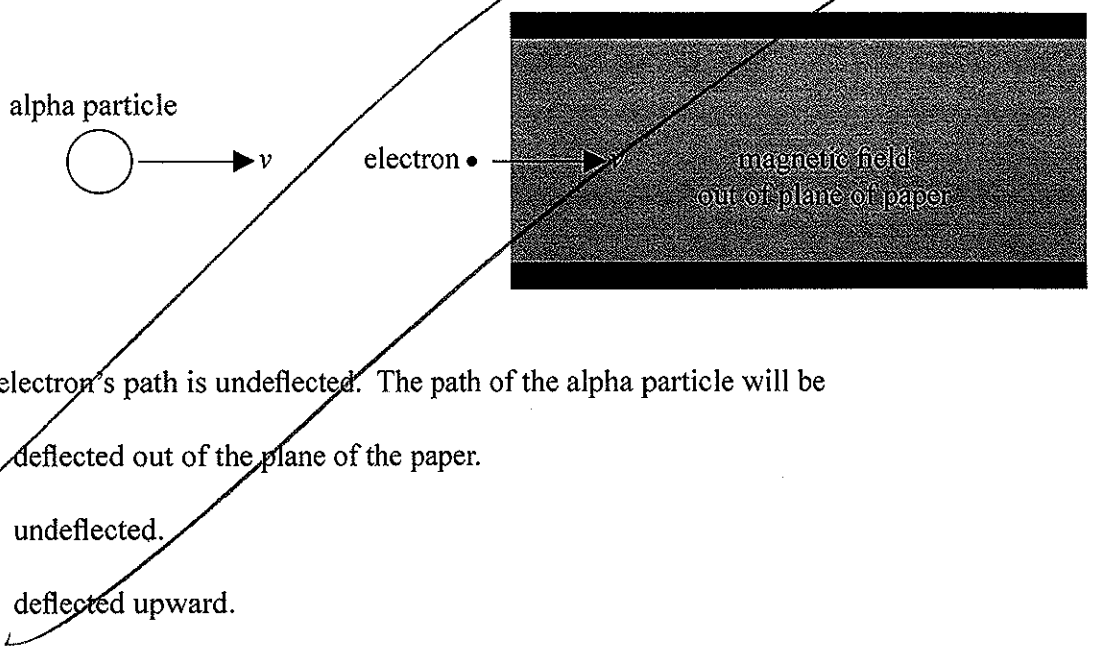
A. 90 MeV

B. 90 MeV c^{-2}

C. 8 MeV

D. 8 MeV c^{-2}

22. An electron enters the vacuum between two oppositely charged plates with velocity v. The electron is followed by an alpha particle moving with the same initial velocity as the electron. A uniform magnetic field is directed out of the plane of the paper.



The electron's path is undeflected. The path of the alpha particle will be

A. deflected out of the plane of the paper.

B. undeflected.

C. deflected upward.

D. deflected downward.

23. The Geiger–Marsden experiment provides evidence for

A. the existence of discrete atomic energy levels.

B. the existence of the neutron.

C. a dense positively charged nucleus.

D. the stability of some nuclei.

24. A radioactive isotope has a half-life of two minutes. A sample contains sixteen grams of the isotope. How much time elapses until one gram of the isotope remains?

A. 6 minutes

B. 8 minutes

C. 10 minutes

D. 12 minutes

(Question B2 continued)

Part 2 Nuclear processes

(a) A nucleus of radium-91 $\left({}^{226}_{91}\text{Ra}\right)$ undergoes alpha particle decay to form a nucleus of radon (Rn).

(i) Identify the proton number and nucleon number of the nucleus of Rn. *[2]*

Proton number: .....

Nucleon number: .....

(ii) The half-life of radium-91 is 1600 years. Determine the length of time taken for 87.5% of the radium to disintegrate. *[2]*

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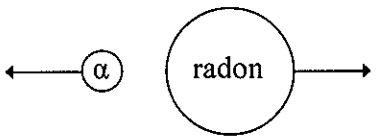
(b) Immediately after the decay of a stationary radium nucleus, the alpha particle and the radon nucleus move off in opposite directions and at different speeds.



Outline the reasons for these observations. *[3]*

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(c) Outline why a beta particle has a longer range in air than an alpha particle of the same energy. *[3]*

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(Question B1 continued)

Part 2 Radioactive decay and binding energy

(a) Describe what is meant by radioactive decay. *[2]*

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(b) A nucleus of thallium-206 (Tl-206) undergoes radioactive decay to a nucleus of lead-206 (Pb-206). In the reaction equation below, identify the proton number Z of lead and the particle x. *[2]*

$$^{206}_{82}\text{Tl} \rightarrow {}^{206}_{Z}\text{Pb} + \beta^- + x$$

Z: .....

x: .....

(c) The mass of a Tl-206 nucleus is $191\,870\,\text{MeV}\,\text{c}^{-2}$. Determine the binding energy per nucleon of Tl-206. *[4]*

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(d) State why the binding energy of Pb-206 is greater than that of Tl-206. *[1]*

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B3. This question is in **two** parts. **Part 1** is about the production of energy in nuclear fission. **Part 2** is about collisions.

Part 1 Production of energy in nuclear fission

(a) A possible fission reaction is

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + x\,{}^{1}_{0}n.$$

(i) State the value of x. *[1]*

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(ii) Show that the energy released when one uranium nucleus undergoes fission in the reaction in (a) is about 2.8×10^{-11} J. *[4]*

Mass of neutron	= 1.00867 u
Mass of U-235 nucleus	= 234.99333 u
Mass of Kr-92 nucleus	= 91.90645 u
Mass of Ba-141 nucleus	= 140.88354 u

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(iii) State how the energy of the neutrons produced in the reaction in (a) is likely to compare with the energy of the neutron that initiated the reaction. *[1]*

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(This question continues on the following page)

(Question B3, part 1 continued)

(b) Outline the role of the moderator. *[2]*

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(c) A nuclear power plant that uses U-235 as fuel has a useful power output of 16 MW and an efficiency of 40 %. Assuming that each fission of U-235 gives rise to 2.8×10^{-11} J of energy, determine the mass of U-235 fuel used per day. *[4]*

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(This question continues on the following page)

(Question B1 continued)

Part 2 Rutherford model of the atom

(a) Most alpha particles used to bombard a thin gold foil pass through the foil without a significant change in direction. A few alpha particles are deviated from their original direction through angles greater than 90°. Use these observations to describe the Rutherford atomic model. *[5]*

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(Question B1, part 2 continued)

(b) The isotope gold-197 $\left({}^{197}_{79}Au\right)$ is stable but the isotope gold-199 $\left({}^{199}_{79}Au\right)$ is not.

(i) Outline, in terms of the forces acting between nucleons, why, for large stable nuclei such as gold-197, the number of neutrons exceeds the number of protons. *[3]*

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(ii) A nucleus of ${}^{199}_{79}\text{Au}$ decays to a nucleus of ${}^{199}_{80}\text{Hg}$ with the emission of an electron and another particle. State the name of this other particle. *[1]*

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B2. This question is in **two** parts. **Part 1** is about power production and global warming. **Part 2** is about electric charge.

Part 1 Power production and global warming

(a) In any cyclical process designed to continuously convert thermal energy to work, some energy is always degraded. Explain what is meant by degraded energy. *[2]*

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(b) A nuclear power station uses uranium-235 (U-235) as fuel. Outline the

(i) processes and energy changes that occur through which thermal energy is produced. *[4]*

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(This question continues on the following page)

(Question B2, part 1 continued)

(ii) role of the heat exchanger of the reactor and the turbine in the generation of electrical energy. *[3]*

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(c) Identify **one** process in the power station where energy is degraded. *[1]*

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(d) The maximum power output of the Drax coal-fired power station in the UK is 4.0 GW. Determine the minimum mass of pure U-235 that would be required by a nuclear power station to provide the same maximum annual energy output as the Drax power station. *[2]*

Energy density of U-235 $= 82\,\text{TJ kg}^{-1}$
1 year $= 3.2\times10^{7}\,\text{s}$

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