CAMBRIDGE INTERNATIONAL AS & A LEVEL • PHYSICS 9702

Topical Questions

Unit 11: Nuclear Physics

Past Papers 2021 – 2025

QUESTION PAPER 33 Questions

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Question 1

(a) Complete Table 6.1 to show the masses (in terms of the unified atomic mass unit u) and charges (in terms of the elementary charge *e*) of α, β^+ and β^- particles.

Table 6.1

	mass / u	charge / *e*
α-particle		
β^+ particle		
β^- particle		

[4]

(b) Carbon-14 is radioactive and decays by emission of β^- particles.

(i) Nuclei do not contain β^- particles.

Explain the origin of the β^- particle that is emitted from the nucleus during β^- decay.

.....

.....

..... [1]

(ii) State the change in the quark composition of a carbon-14 nucleus when it emits a β^- particle.

..... [1]

(iii) Suggest why the β^- particles are emitted with a range of different energies.

.....

.....

.....

..... [2]

[Total: 8]

Question 2

A stationary nucleus P of mass 243 u decays by emitting an α-particle of mass 4 u to form a different nucleus Q, as illustrated in Fig. 7.1.

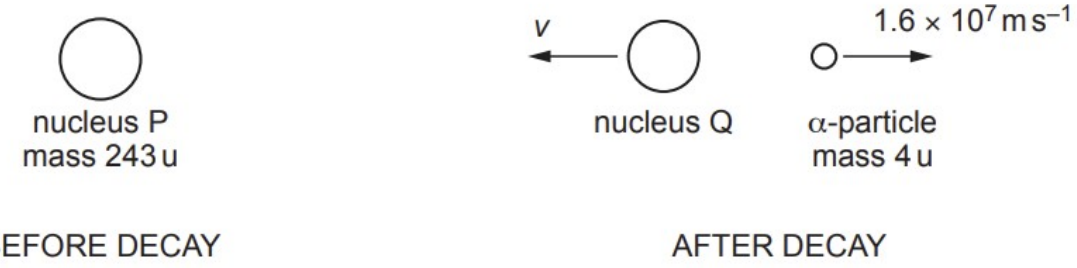

Fig. 7.1

The initial speed of the α-particle is $1.6 \times 10^7\,\text{m s}^{-1}$.

(a) Use the principle of conservation of momentum to explain why the initial velocities of nucleus Q and the α-particle must be in opposite directions.

.....

.....

.....

..... [2]

(b) Determine the initial speed v of nucleus Q.

v = ... m s^{-1} [2]

(c) Calculate the initial kinetic energy, in MeV, of the α-particle.

kinetic energy = ... MeV [3]

(d) A graph of number of neutrons N against proton number Z is shown in Fig. 7.2.

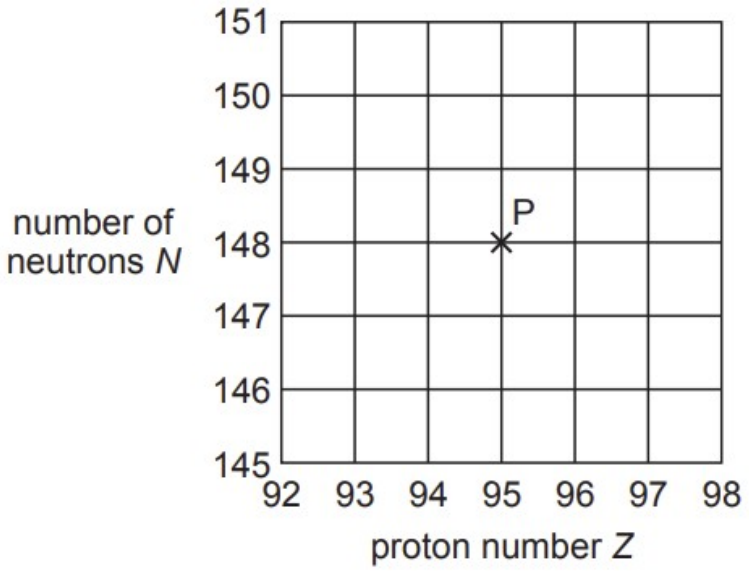

Fig. 7.2

The graph shows a cross that represents nucleus P.

A nucleus R has a nucleon number of 242 and is an isotope of nucleus P.

Nucleus R decays by emitting a β^- particle to form a different nucleus S.

(i) On Fig. 7.2, draw a cross to represent:

1. nucleus R (label this cross R)

2. nucleus S (label this cross S).

[2]

(ii) State the name of the other lepton, in addition to the β^- particle, that is emitted during the decay of nucleus R.

..... [1]

[Total: 10]

Question 3

(a) A proton in a nucleus decays to form a neutron and a β^+ particle.

(i) State the name of another lepton that is produced in the decay.

..... [1]

(ii) State the name of the interaction (force) that gives rise to this decay.

..... [1]

(iii) State which of the three particles (proton, neutron or β^+ particle) has the largest ratio of charge to mass.

..... [1]

(iv) Use the quark model to show that the charge on the proton is $+e$, where e is the elementary charge.

[2]

(v) The quark composition of the proton is changed during the decay.

Describe the change to the quark composition.

.....

..... [1]

(b) A nucleus X ($^{12}_{6}X$) and a nucleus Y ($^{16}_{8}Y$) are accelerated by the same uniform electric field.

(i) Determine the ratio

$$\frac{\text{electric force acting on nucleus X}}{\text{electric force acting on nucleus Y}}.$$

ratio = ... [2]

(ii) Determine the ratio

$$\frac{\text{acceleration of nucleus X due to the field}}{\text{acceleration of nucleus Y due to the field}}.$$

ratio = ... [1]

(iii) Nucleus X is at rest in the uniform electric field at time $t = 0$.

The field causes nucleus X to accelerate so that it moves through the field.

On Fig. 6.1, sketch the variation with time t of the acceleration a of nucleus X due to the field.

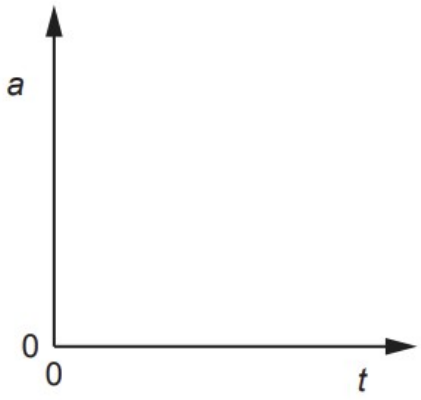

Fig. 6.1

[1]

[Total: 10]

Question 4

(a) One of the results of the α-particle scattering experiment is that a very small minority of the α-particles are scattered through angles greater than 90°.

State what may be inferred about the structure of the atom from this result.

.....

.....

.....

..... [2]

(b) An α-particle is made up of other particles. One of these particles is a proton.

State and explain whether a proton is a fundamental particle.

.....

..... [1]

(c) A radioactive source produces a beam of α-particles in a vacuum. The average current produced by the beam is 6.9×10^{-9}A.

Calculate the average number of α-particles passing a fixed point in the beam in a time of 1.0 minute.

number = ... [3]

(d) The α-particles in the vacuum in **(c)** enter a uniform electric field. The α-particles enter the field with their velocity in the same direction as the field.

State and explain whether the magnitude of the acceleration of an α-particle due to the field decreases, increases or stays constant as the α-particle moves through the field.

.....

.....

..... [2]

(e) A nucleus X is an isotope of a nucleus Y. The mass of nucleus X is greater than that of Y.

Both of the nuclei are in the same uniform electric field.

State and explain whether the magnitude of the electric force acting on nucleus X is greater than, less than or the same as that acting on nucleus Y.

.....

.....

..... [2]

[Total: 10]

Question 5

(a) The results of the α-particle scattering experiment provide evidence for the structure of the atom.

Result 1: The vast majority of the α-particles pass straight through the metal foil or are deviated by small angles.

Result 2: A very small minority of α-particles is scattered through angles greater than 90°.

State what may be inferred (deduced) from:

(i) result 1

.....

..... [1]

(ii) result 2.

.....

.....

..... [2]

(b) A radioactive decay sequence contains four nuclei, P, Q, R and S, as shown.

$$^{218}_{84}\text{P} \rightarrow {}^{214}_{82}\text{Q} \rightarrow {}^{214}_{83}\text{R} \rightarrow \text{S}$$

Nucleus S is an isotope of nucleus P.

(i) Determine the proton number and the nucleon number of nucleus S.

proton number = ...

nucleon number = ...

[2]

(ii) The quark composition of a nucleon in Q changes as Q decays to form R.

Describe this change to the quark composition of the nucleon.

.....

..... [1]

[Total: 6]

Question 6

(a) A lepton is an example of a fundamental particle.

State what is meant by fundamental particle.

.....

..... [1]

(b) A lambda particle Λ^0 is a hadron that consists of an up (u) quark, a down (d) quark and a strange (s) quark.

Show that the charge on the Λ^0 particle is zero.

[2]

(c) The Λ^0 particle is unstable. It can decay into a neutron (n) and a pion (π^0) as shown by

$$\Lambda^0 \longrightarrow n + \pi^0.$$

The π^0 particle consists of an up quark and an up antiquark.

(i) Compare the properties of an up quark and an up antiquark.

.....

.....

..... [2]

(ii) Explain why the neutron is classed as a baryon and the π^0 particle is classed as a meson.

.....

.....

..... [2]

[Total: 7]

Question 7

(a) Describe the structure of an **atom** of uranium-238, $^{238}_{92}U$.

.....

.....

..... [2]

(b) The decay of uranium-238 is shown by the equation

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + X.$$

For nucleus X, calculate the ratio, in $C\,kg^{-1}$, of

$$\frac{\text{charge}}{\text{mass}}.$$

ratio = ... $C\,kg^{-1}$ [3]

(c) Two particles P and Q each consist of three quarks. These quarks are up (u) or down (d) quarks.

Particle P has no overall charge.

Particle Q has an overall charge of +2*e*, where *e* is the elementary charge.

State the quark composition of:

(i) particle P

..... [1]

(ii) particle Q.

..... [1]

[Total: 7]

Question 8

(a) The nuclide $^{14}_{6}C$ (carbon-14) is unstable and undergoes β^- decay, emitting a high-energy electron and an antineutrino to form a new nuclide X. The equation for this decay is shown.

$$^{14}_{6}C \rightarrow \text{.....}^{\text{.....}}_{\text{.....}}X + \text{.....}^{\text{.....}}_{\text{.....}}e^- + {}^{0}_{0}\bar{\nu}$$

Complete the equation. [2]

(b) **(i)** State the equation for β^- decay in terms of the fundamental particles involved.

[1]

(ii) Use your equation from **(b)(i)** to show how charge is conserved in β^- decay.

[1]

(c) Neutrinos were first proposed to exist more than 20 years before they were directly detected, in order to explain a particular experimental observation about β-decay.

(i) State an observation about β-decay that is explained by the existence of neutrinos.

.....

.....

..... [1]

(ii) Suggest how the existence of neutrinos explains the observation in **(c)(i)**.

.....

.....

..... [1]

[Total: 6]

(ii) Use your equation from **(b)(i)** to show how charge is conserved in β^- decay.

[1]

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(i) State an observation about β-decay that is explained by the existence of neutrinos.

.....

.....

..... [1]

(ii) Suggest how the existence of neutrinos explains the observation in **(c)(i)**.

.....

.....

..... [1]

[Total: 6]

Question 9

(a) A nucleus of caesium-137 ($^{137}_{55}Cs$) decays by emitting a β^- particle to produce a nucleus of an element X and an antineutrino. The decay is represented by

$$^{137}_{55}Cs \rightarrow {}^{Q}_{S}X + {}^{P}_{R}\beta^- + {}^{0}_{0}\bar{\nu}.$$

(i) State the number represented by each of the following letters.

P .....

Q .....

R .....

S .....

[2]

(ii) State the name of the class (group) of particles that includes the β^- particle and the antineutrino.

..... [1]

(b) A particle Y has a quark composition of ddd where d represents a down quark.

A particle Z has a quark composition of $\bar{u}d$ where $\bar{u}$ represents an up antiquark.

(i) Show that the charges of particles Y and Z are equal.

[2]

(ii) State and explain which particle is a meson and which particle is a baryon.

meson: .....

.....

baryon: .....

.....

[2]

[Total: 7]

Question 10

(a) Fluorine-18 ($^{18}_{9}F$) is an isotope that decays to an isotope of oxygen (O) by the emission of a β^+ particle.

(i) Complete the nuclear equation for the decay, including all the particles involved.

$$^{18}_{9}F \rightarrow$$

[3]

(ii) A quark in the fluorine-18 nucleus changes flavour during the decay. State this change of flavour.

..... quark to ..... quark. [1]

(b) A hadron has a charge of –2*e*, where *e* is the elementary charge.

(b) A hadron has a charge of –2*e*, where *e* is the elementary charge.

(i) State and explain whether the hadron is a meson or a baryon.

.....

.....

..... [2]

(ii) State a possible quark composition for the hadron.

.....

..... [1]

[Total: 7]

Question 11

(a) A nucleus of sodium-22 ($^{22}_{11}$Na) decays by emitting a β^+ particle. A different nucleus is formed by the decay.

(i) State the name of another lepton that is produced by the decay.

..... [1]

(ii) Determine the nucleon number and the proton number of the nucleus that is formed by the decay.

nucleon number = ...

proton number = ...

[2]

(iii) The quark composition of a nucleon in the sodium-22 nucleus is changed during the decay.

Describe the change to the quark composition of the nucleon.

.....

..... [1]

(b) A baryon consists of quarks that are the same flavour (type). The charge of the baryon is $-2e$, where e is the elementary charge.

(i) Calculate, in terms of e, the charge of each quark.

charge = ... e [1]

(ii) State a possible flavour (type) of the quarks.

..... [1]

[Total: 6]

Question 12

(a) The results of the α-particle scattering experiment led to the development of the nuclear model for the atom.

State the results that suggested that most of the mass of the atom is concentrated in a very small region and most of the atom is empty space.

.....

.....

.....

..... [2]

(b) State the composition of γ-radiation.

..... [1]

(c) Table 7.1 lists the names of three particles and possible classifications for them.

Table 7.1

particle name	classification		
	baryon	hadron	lepton
neutrino			
neutron			
positron			

Complete Table 7.1 by placing ticks (✓) in the boxes to indicate the classifications that apply to each particle. [2]

(d) The discovery of a particle with an unusual charge was an important step in the development of the theory of quarks. The particle is a hadron with a mass of 2.19×10^{-27} kg and a charge of $+2e$, where e is the elementary charge.

(i) Calculate the mass, in u, of the particle. Give your answer to three significant figures.

mass = ... u [1]

(ii) Determine a possible quark composition of a hadron with a charge of $+2e$.
Explain your reasoning.

[2]

[Total: 8]

Question 13

(a) In the following list, underline **all** the particles that are **not** fundamental.

antineutrino baryon nucleon positron [1]

(b) A nucleus of thorium-230 ($^{230}_{90}$Th) decays in stages, by emitting α-particles and β^- particles, to form a nucleus of lead-206 ($^{206}_{82}$Pb).

Determine the total number of α-particles and the total number of β^- particles that are emitted during the sequence of decays that form the nucleus of lead-206 from the nucleus of thorium-230.

number of α-particles = ...

number of β^- particles = ...
[2]

(c) A meson has a charge of $-1e$, where e is the elementary charge. The quark composition of the meson includes a charm antiquark.

State and explain a possible flavour (type) of the other quark in the meson.

.....

..... [2]

[Total: 5]

Question 14

(a) The nuclide $^{23}_{12}Mg$ is an isotope of magnesium that undergoes β^+ decay to form a new nuclide X according to the equation

$$^{23}_{12}Mg \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}X + {}^{\cdots\cdots}_{\cdots\cdots}\beta^+ + {}^{0}_{0}\nu.$$

Four numbers are missing from the equation.

(i) For the nuclide $^{23}_{12}Mg$, state what is represented by the numbers 23 and 12.

23 represents: .....

12 represents: .....

[2]

(ii) Complete the equation by inserting the missing numbers. [2]

(iii) State the name of the group (class) of fundamental particles to which the positron and neutrino belong.

..... [1]

Question 15

An isolated stationary nucleus X decays by emitting an α-particle to form a nucleus Y.

Nucleus Y and nucleus Z are isotopes of the same element.

(a) By comparing the number of protons in each nucleus, state and explain whether the charge of nucleus Y is less than, greater than or the same as the charge of:

(i) nucleus Z

.....

..... [1]

(ii) nucleus X.

.....

.....

..... [2]

(b) Use the principle of conservation of momentum to explain why nucleus Y cannot be stationary immediately after the decay of nucleus X.

.....

.....

.....

..... [2]

[Total: 5]

Question 16

(a) Nucleus P and nucleus Q are isotopes of the same element.

Nucleus Q is unstable and emits a β^- particle to form nucleus R.

(i) For nuclei P and Q, compare:

- the number of protons

.....

- the number of neutrons.

.....

[2]

(ii) When nucleus Q decays to form nucleus R, the quark composition of a nucleon changes.

State the change to the quark composition of the nucleon.

..... [1]

(iii) State the name of another particle that must be emitted from nucleus Q in addition to the β^- particle.

..... [1]

(b) A hadron consists of two charm quarks and one bottom quark.

Determine, in terms of the elementary charge *e*, the charge of the hadron.

charge = ... *e* [2]

[Total: 6]

Question 17

(a) Table 7.1 shows incomplete data for three flavours (types) of quark. The elementary charge is e.

Table 7.1

flavour	quark		antiquark	
	symbol	charge / e	symbol	charge / e
up	u	$+\frac{2}{3}$	$\bar{u}$	
down	d		$\bar{d}$	
charm	c		$\bar{c}$	

Complete Table 7.1 by inserting the missing charges. [2]

(b) Using the symbols given in Table 7.1, state a possible quark combination for the following hadrons:

(i) a neutral baryon

..... [1]

(ii) a meson with a charge of $+e$.

..... [1]

(c) Quarks are fundamental particles.

Electrons are in another group (class) of fundamental particle.

(i) State the name of this group.

..... [1]

(ii) State the name of another particle in this group.

..... [1]

[Total: 6]

Question 18

(a) Nuclei X and Y are different isotopes of the same element.

Nucleus X is unstable and emits a β^+ particle to form nucleus Z.

By comparing the number of protons in each nucleus, state and explain whether the charge of nucleus X is less than, the same as or greater than the charge of:

(i) nucleus Y

.....

..... [1]

(ii) nucleus Z.

.....

.....

..... [2]

(b) Hadrons can be divided into two groups (classes), P and Q. Group P is baryons.

(i) State the name of group Q.

..... [1]

(ii) Describe, in general terms, the quark structure of hadrons that belong to group Q.

.....

..... [1]

[Total: 5]

Question 19

(a) Compare an α-particle with a β^+ particle in terms of their masses and charges.

.....

.....

.....

.....

..... [3]

(b) Nucleus P undergoes α-decay to form nucleus Q. Nucleus Q then undergoes a further decay to form nucleus R. The proton and nucleon numbers of P and R are shown in Fig. 6.1.

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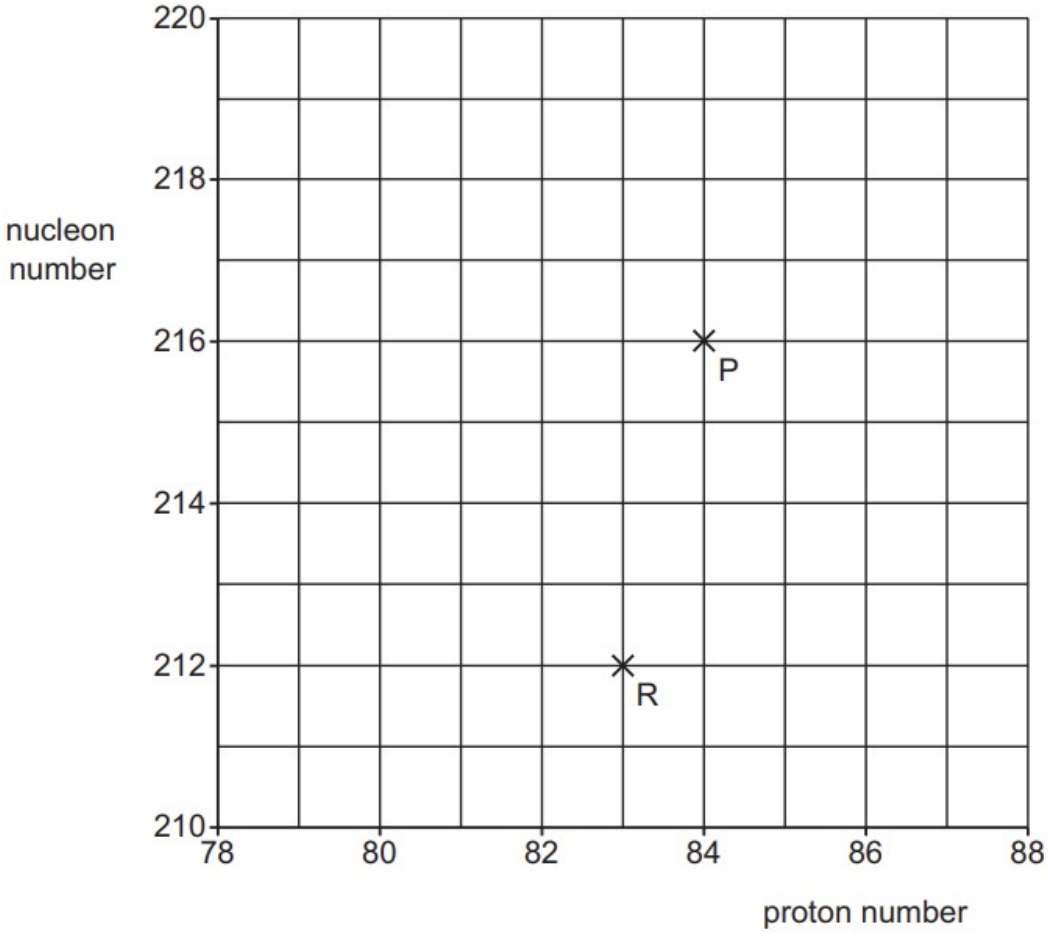

Fig. 6.1

(i) On Fig. 6.1, draw a cross (×) to show the proton number and nucleon number of Q. Label your cross Q. [1]

(ii) State the names of the particles emitted as Q decays to form R.

.....

..... [2]

(c) Before the α-decay, P is travelling at a constant velocity. After the decay, Q has a velocity of $1.3 \times 10^5\,m\,s^{-1}$ at an angle of 68° to the original path of P.
The α-particle has a velocity of $150 \times 10^5\,m\,s^{-1}$ at an angle of θ to the original path of P, as shown in Fig. 6.2.

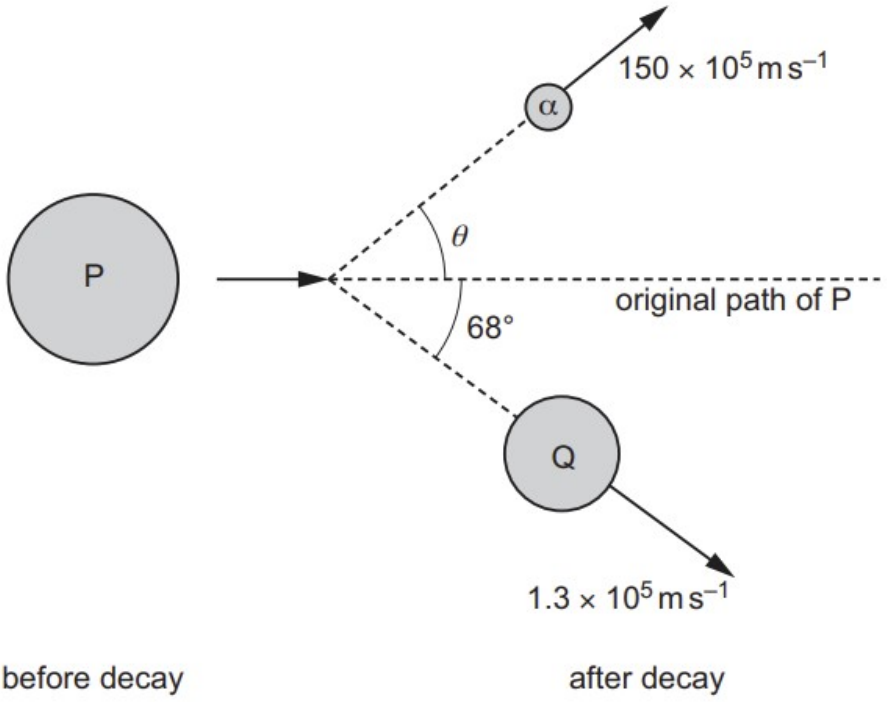

Fig. 6.2 (not to scale)

(i) Use the principle of conservation of momentum to determine θ.

θ = ...° [3]

(ii) Calculate the kinetic energy of the α-particle.

kinetic energy = ... J [2]

[Total: 11]

Question 20

(a) Complete Table 7.1 to show the charges, in terms of the elementary charge *e*, on each of the flavours of quark and antiquark shown.

Table 7.1

flavour	charge / *e*	
	quark	antiquark
up		
down		
strange		

[3]

(b) **(i)** State the name of the class (group) of fundamental particles to which baryons and mesons belong.

..... [1]

(ii) Compare baryons and mesons in terms of their constituent particles.

.....

.....

..... [2]

(c) Describe β^+ decay in terms of the fundamental particles involved.

.....

.....

.....

..... [2]

[Total: 8]

Question 21

Nuclei of an isotope of copper (Cu) each have 29 protons and 37 neutrons. This isotope is a β^- emitter.

(a) State the nuclide notation in the form ${}^{A}_{Z}X$ for this nucleus of copper.

[1]

(b) The energy spectrum of the β^- radiation emitted by a sample of this isotope is shown in Fig. 7.1.

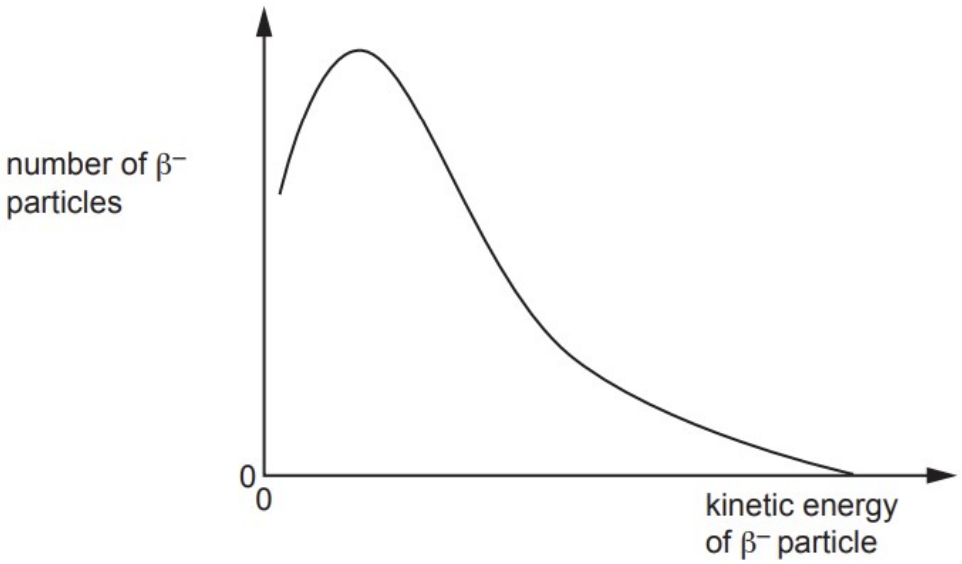

Fig. 7.1

(i) Use Fig. 7.1 to explain why other particles apart from the β^- particles must be emitted during this decay.

.....

.....

.....

.....

..... [3]

(ii) State the name of the other particle emitted during the decay of this isotope.

..... [1]

(iii) The copper isotope decays to an isotope of zinc (Zn).

Give the radioactive decay equation for this decay. Include the nucleon and proton numbers of **all** the particles involved.

[3]

[Total: 8]

Question 22

A particle Q and a particle R are each composed of one quark and one antiquark.

(a) State the name of the class (group) of particles that includes Q and R.

..... [1]

(b) Q has a charge of $-1e$, where e is the elementary charge. R has a charge of 0.

Complete Table 7.1 to show a possible second quark in each of Q and R.

Table 7.1

	charge	first quark	second quark
Q	$-1e$	strange	
R	0	anti-up	

[2]

[Total: 3]

Question 23

Nuclei of an isotope of samarium (Sm) each contain 62 protons and 85 neutrons.

(a) State the nuclide notation in the form ${}^{A}_{Z}X$ for this isotope of samarium.

[1]

(b) This isotope of samarium is radioactive and decays by emitting particles. Gamma-radiation is **not** emitted. The energy spectrum of the emitted particles is shown in Fig. 6.1.

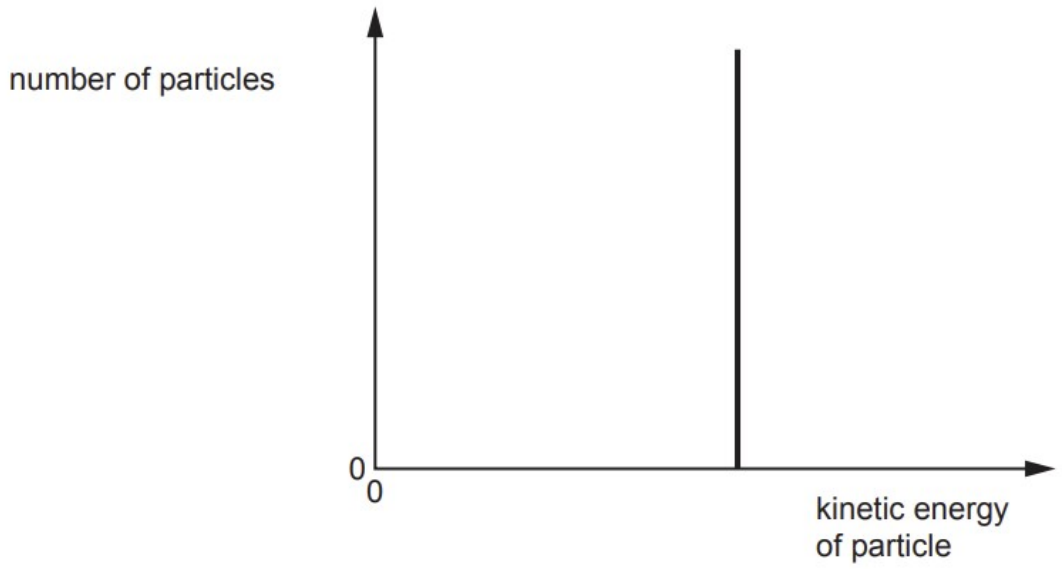

Fig. 6.1

Fig. 6.1

(i) Explain how Fig. 6.1 shows that this isotope of samarium emits α-particles and does **not** emit β-particles.

.....

.....

.....

..... [2]

(ii) This isotope of samarium decays to an isotope of neodymium (Nd).

Give the radioactive decay equation for this decay. Include the nucleon and proton numbers of **all** the particles involved.

[2]

(c) A baryon is composed of three quarks which all have different flavours. The baryon has a charge of 0.

Two of the quarks in the baryon are an up quark and a bottom quark.

(i) Determine, in terms of the elementary charge *e*, the charge on the third quark in the baryon.

charge = ... *e* [2]

(ii) State a possible flavour for the third quark in the baryon.

..... [1]

[Total: 8]

Question 24

(a) State the name of the class (group) of fundamental particles that contains a neutrino.

..... [1]

(b) A hadron P has a charge of +1*e*, where *e* is the elementary charge. The hadron P is composed of a down antiquark and only one other quark.

(i) Identify a possible flavour for this other quark.

..... [1]

(ii) State what type of hadron is P.

..... [1]

(c) Nucleus Q undergoes radioactive decay to form nucleus R, emitting an antineutrino and another particle X, as shown in the decay equation.

$$Q \longrightarrow R + X + \overline{\nu}$$

(i) State what particle is represented by X.

..... [1]

(ii) Compare the nucleon numbers of Q and R.

..... [1]

(iii) Compare the charges of Q and R.

..... [1]

[Total: 6]

Question 25

The nuclide ${}^{3}_{1}H$ is an isotope of hydrogen that is called tritium.

(a) (i) Determine the numbers of protons, neutrons and electrons in a neutral atom of tritium.

number of protons = ...

number of neutrons = ...

number of electrons = ...

[2]

(ii) Draw a labelled diagram to represent a simple model of the arrangement of the protons, neutrons and electrons in a tritium atom.

[2]

(b) Tritium is radioactive and undergoes β^- decay to form an isotope of helium (He). Gamma radiation is not emitted during this decay.

(i) Complete the equation to represent the radioactive decay of tritium.

$$ {}^{3}_{1}H \rightarrow {}^{\ldots\ldots}_{\ldots\ldots}He + {}^{\ldots\ldots}_{\ldots\ldots}\beta + {}^{0}_{0}X $$

[2]

(ii) State the name of particle X.

..... [1]

(c) Determine the quark composition of a tritium nucleus.

.....

..... [2]

[Total: 9]

Question 26

(a) State what is meant by a fundamental particle.

.....

..... [1]

(b) **(i)** Particle Q is a meson with a charge of 0.

Determine a possible quark composition for Q.

..... [2]

(ii) Particle Q has a mass of 0.67 u and a kinetic energy of 2.1×10^{-16} J.

Calculate the speed of particle Q.

speed = ... $m s^{-1}$ [3]

(c) Radium-228 ($^{228}_{88}Ra$) is a radioactive nuclide.

(i) State the number of electrons in a neutral atom of radium-228.

number of electrons = ... [1]

(ii) A nucleus of radium-228 undergoes a series of decays to form nucleus X.
During the process, 5 α-particles and 4 β^- particles are emitted.

Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

[Total: 9]

Question 27

The nuclide ${}^{3}_{1}H$ is an isotope of hydrogen that is called tritium.

(a) (i) Determine the numbers of protons, neutrons and electrons in a neutral atom of tritium.

number of protons = ...

number of neutrons = ...

number of electrons = ...

[2]

(ii) Draw a labelled diagram to represent a simple model of the arrangement of the protons, neutrons and electrons in a tritium atom.

[2]

(b) Tritium is radioactive and undergoes β^- decay to form an isotope of helium (He). Gamma radiation is not emitted during this decay.

(i) Complete the equation to represent the radioactive decay of tritium.

$$ {}^{3}_{1}H \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}He + {}^{\cdots\cdots}_{\cdots\cdots}\beta + {}^{0}_{0}X $$

[2]

(ii) State the name of particle X.

..... [1]

(c) Determine the quark composition of a tritium nucleus.

.....

..... [2]

[Total: 9]

Question 28

Fig. 6.1 shows four alpha particles W, X, Y and Z moving towards a gold nucleus that is in thin gold foil.

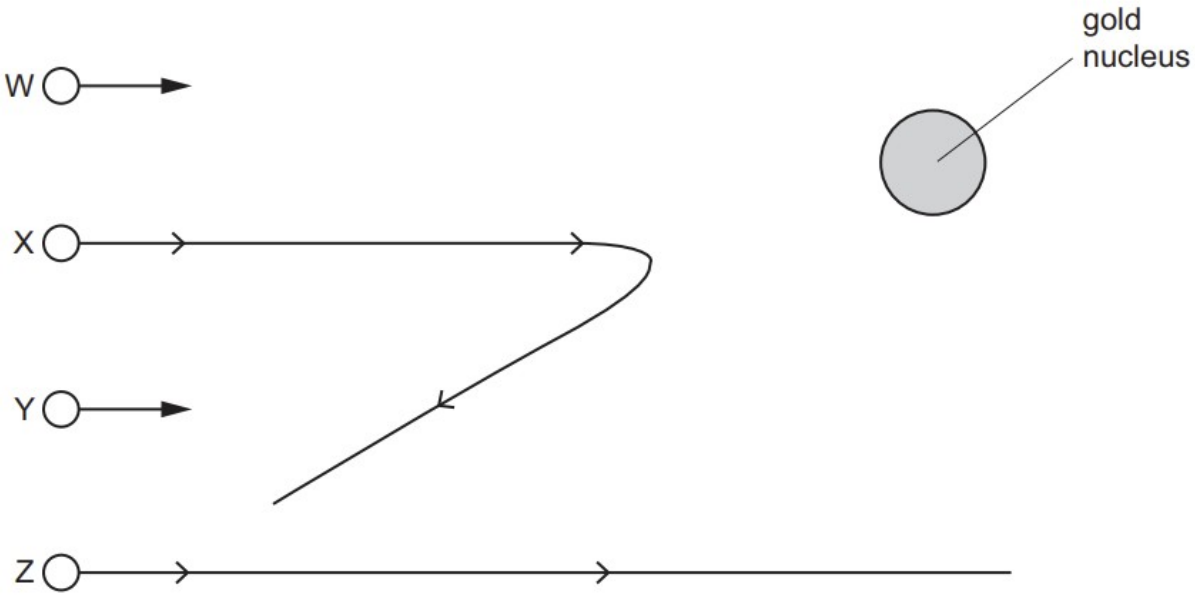

Fig. 6.1 (not to scale)

(a) (i) The paths of particles X and Z are shown.

Complete Fig. 6.1 to show possible paths for particles W and Y. [3]

(ii) Describe what may be inferred about the structure of an atom from the path of particle X.

.....

.....

..... [1]

(iii) When a beam containing many alpha particles is incident on thin gold foil, nearly all of the alpha particles follow paths that are similar to the path of particle Z.

Describe what may be inferred from this about the structure of an atom.

.....

.....

..... [1]

(b) State the mass and the charge, in terms of the atomic mass unit u and the elementary charge *e*, of an alpha particle.

mass = ... u

charge = ... *e*

[2]

(c) There are two types of hadron.
The hadrons that are in alpha particles are each composed of three quarks.

(i) State the name of this type of hadron.

..... [1]

(ii) Show, by reference to their constituent quarks, that the hadrons in an alpha particle have charges of either zero or +1*e*.

[2]

[Total: 10]

Question 29

(a) Nitrogen-12 ($^{12}_{7}N$) is an unstable isotope of nitrogen that decays by the emission of radiation to carbon-12 ($^{12}_{6}C$).

Complete the full nuclear equation for the decay, including all the particles involved.

$$^{12}_{7}N \rightarrow$$

[3]

(b) Hydrogen-1 ($^{1}_{1}H$) is an isotope of hydrogen. An atom of hydrogen-1 comprises a proton with an orbiting electron.

An antiparticle equivalent of hydrogen-1 comprises an antiproton with an orbiting positron. The antiquarks in the antiproton are the antiparticles of the quarks in a proton.

(i) State the charge on the positron in terms of the elementary charge *e*.

charge = ... *e* [1]

(ii) State the group (class) of fundamental particle to which the positron belongs.

..... [1]

(ii) State the group (class) of fundamental particle to which the positron belongs.

..... [1]

(iii) In Table 7.1, state the flavour and charge of the three antiquarks that comprise the antiproton.

Table 7.1

flavour	charge / *e*

[3]

[Total: 8]

Question 30

(a) State what is meant by a fundamental particle.

.....

..... [1]

(b) A nucleus X has 14 nucleons and p protons. The ratio of charge to mass for nucleus X is $4.1 \times 10^7\,\text{C kg}^{-1}$.

(i) Determine p.

p = ... [3]

(ii) Nucleus X undergoes β^- decay to form nucleus Z.

Complete the equation representing this decay.

$$^{14}_{\ldots\ldots}X \rightarrow {}^{\ldots\ldots}_{\ldots\ldots}Z + {}^{\ldots\ldots}_{\ldots\ldots}\ldots\ldots + {}^{\ldots\ldots}_{\ldots\ldots}\ldots\ldots$$

[3]

(c) A sample of a radioactive substance emits particles that are positively charged and have a continuous range of kinetic energies.

State and explain whether the nuclei in the sample are undergoing α-decay, β^+ decay or β^- decay.

.....

.....

.....

.....

.....

..... [2]

[Total: 9]

Question 31

(a) An antiparticle equivalent of the neutron is called the antineutron. The quarks in the antineutron are the antiparticles of the quarks in a neutron.

The elementary charge is *e*.

In Table 8.1, state the flavour and charge of the three antiquarks that comprise the antineutron.

Table 8.1

flavour	charge / *e*

[3]

(b) In β^- decay, a neutron decays to form a proton.

Theory predicts that an antineutron should decay to form an antiproton. A particle and an antiparticle should also be observed.

Suggest the names of the particle and the antiparticle.

particle: .....

antiparticle: .....

[2]

[Total: 5]

Question 32

(a) State the names of **two** different leptons.

1 .....

2 .....

[2]

(b) In the following list, underline all the particles that are hadrons.

antineutrino beta-plus meson neutron

[1]

(c) By reference to quark composition, show that the charge of a proton is $+1.6 \times 10^{-19}$ C.

[2]

[Total: 5]

Question 33

An isolated stationary nucleus Q decays into nucleus R and an α-particle. The α-particle has speed $1.5 \times 10^7\,\text{m s}^{-1}$.

(a) Complete the equation for this decay.

$$^{\ldots\ldots}_{88}\text{Q} \rightarrow ^{222}_{\ldots\ldots}\text{R} + ^{4}_{2}\alpha$$

[1]

(b) By considering momentum, calculate the speed of nucleus R after the decay.

speed = ... m s^{-1} [3]

(c) State **three** quantities that are conserved during the decay.

1 .....

2 .....

3 .....

[3]

[Total: 7]

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