CAMBRIDGE INTERNATIONAL AS & A LEVEL PHYSICS · 9702

PHYSICS



EXAM QUESTION PACK

11 PARTICLE PHYSICS

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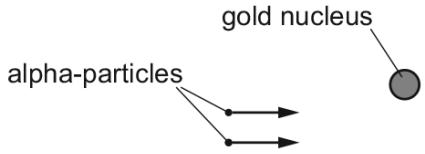
Chapter 13

Particle and nuclear physics

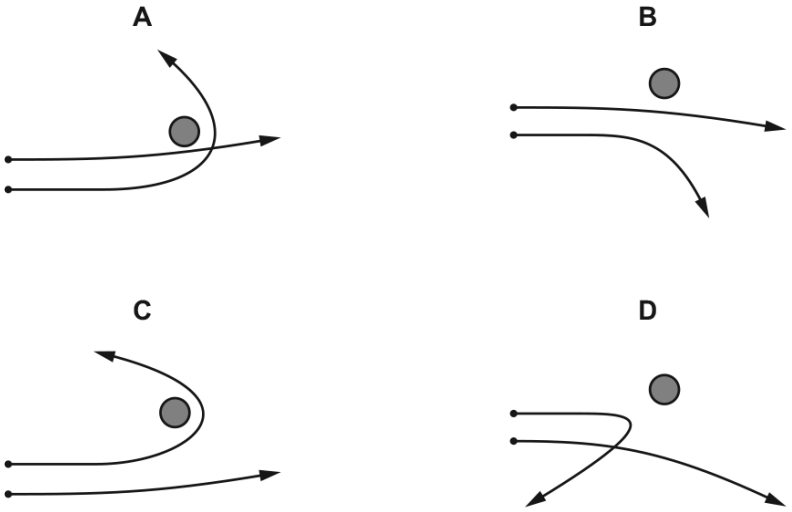
13.1 Atoms, nuclei and radiation

1309. 9702_m20_qp_12 Q: 38

Two alpha-particles with the same kinetic energy are moving towards, and are then deflected by, a gold nucleus.



Which diagram could show the paths of the two alpha-particles?



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1310. 9702_s20_qp_11 Q: 39

An element has two isotopic forms.

What are the nuclear arrangements of these two isotopes?

A They have different nucleon numbers and different proton numbers.

B They have different nucleon numbers but the same proton number.

C They have the same nucleon number and the same proton number.

D They have the same nucleon number but different proton numbers.

1311. 9702_s20_qp_12 Q: 39

An unstable nucleus goes through successive decays to become a final, stable nucleus.

The initial nucleus and the final nucleus are isotopes of each other.

How many α and β^- particles could have been emitted during the decay sequence?

	particle	
	α	β^-
A	1	0
B	1	2
C	2	0
D	2	1

1312. 9702_s20_qp_13 Q: 39

Radiation from a radioactive source has a range of a few millimetres in air and can be deflected by an electric field.

Which type of radiation is being emitted?

A α-radiation

B β^- radiation

C β^+ radiation

D γ-rays

1313. 9702_m19_qp_12 Q: 39

A neutron ${}^{1}_{0}n$ is fired at a ${}^{235}_{92}U$ nucleus. The neutron is absorbed by the nucleus which then splits to form nuclei of ${}^{141}_{56}Ba$ and ${}^{92}_{36}Kr$.

What is the number of neutrons emitted when the ${}^{235}_{92}U$ nucleus splits?

A 0 **B** 1 **C** 2 **D** 3

1314. 9702_m19_qp_12 Q: 40

Which word equation represents β^+ decay?

A proton → neutron + electron + electron antineutrino

B proton → neutron + electron + electron neutrino

C proton → neutron + positron + electron antineutrino

D proton → neutron + positron + electron neutrino

1315. 9702_s19_qp_11 Q: 39

Which statement about the alpha-particle scattering experiment provides evidence for the existence of the nucleus?

A A tiny proportion of the alpha-particles are deflected through large angles.

B Slower alpha-particles are deflected through larger angles.

C The kinetic energies of the deflected alpha-particles are unchanged.

D The number of alpha-particles deflected depends on the thickness of the foil.

1316. 9702_s19_qp_12 Q: 38

A nucleus of francium-221 $({}^{221}_{87}Fr)$ decays into a nucleus of bismuth-209 $({}^{209}_{83}Bi)$ in several steps.

Which particles could be emitted?

A 2 α-particles and 4 β^- particles

B 2 α-particles and 4 β^+ particles

C 3 α-particles and 2 β^- particles

D 3 α-particles and 2 β^+ particles

1317. 9702_s19_qp_13 Q: 39

What is a correct estimate of the order of magnitude of the diameter of a typical atomic nucleus?

A 10^{-14} m **B** 10^{-18} m **C** 10^{-22} m **D** 10^{-26} m

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1318. 9702_w19_qp_11 Q: 39

An unstable nucleus of an element decays by emitting an α-particle or a β^- particle to become a nucleus of a different element. This nucleus is also unstable and also emits an α-particle or a β^- particle. The process continues until an isotope of the original element is produced.

What is the minimum possible number of these particles emitted?

A 2 **B** 3 **C** 4 **D** 5

1319. 9702_w19_qp_12 Q: 38

The table gives some data relating to four neutral (uncharged) atoms W, X, Y and Z.

	W	X	Y	Z
nucleon (mass) number	16	17	17	18
total number of particles (protons, neutrons and electrons) in the atom	24	26	25	28

Two of the atoms are isotopes of the same element.

What is the proton number of this element?

A 7 **B** 8 **C** 9 **D** 10

1320. 9702_w19_qp_12 Q: 39

What is **not** a fundamental particle?

A electron

B neutrino

C neutron

D positron

1321. 9702_w19_qp_13 Q: 39

A radioactive nucleus emits an α-particle or a β^- particle, creating a product nucleus.

Which decay could create the product nucleus stated?

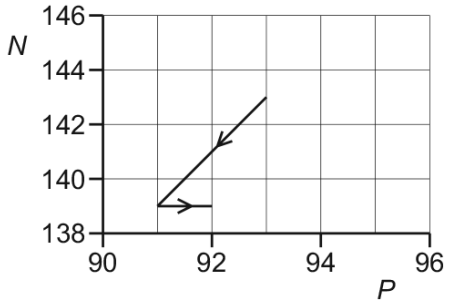
	radioactive nucleus	decay	product nucleus
A	$^{226}_{88}Ra$	α	$^{224}_{86}Rn$
B	$^{238}_{92}U$	α	$^{242}_{94}Pu$
C	$^{228}_{88}Ra$	β^-	$^{228}_{87}Fr$
D	$^{231}_{90}Th$	β^-	$^{231}_{91}Pa$

1322. 9702_m18_qp_12 Q: 39

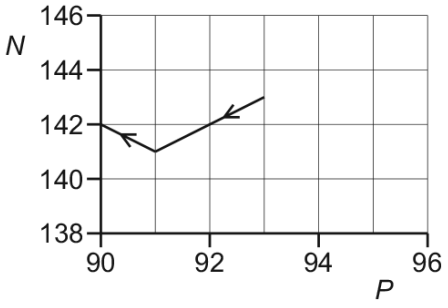
A nucleus of neptunium-236 contains 93 protons and 143 neutrons. This nucleus decays with the emission of an α-particle. The nucleus formed then emits a β^- particle.

Which diagram shows the changes in the number P of protons and the number N of neutrons in these nuclei?

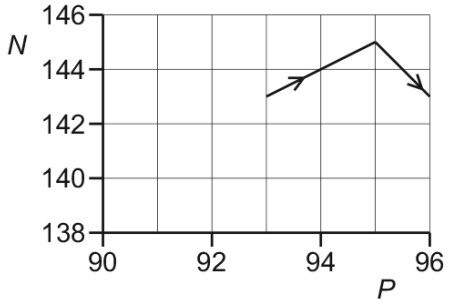
A



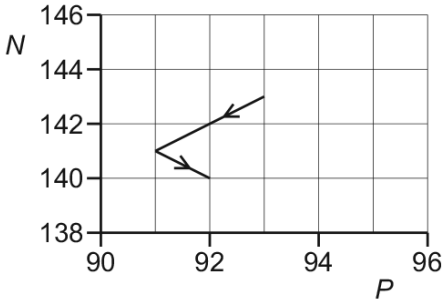
B



C



D



1323. 9702_s18_qp_11 Q: 40

What is the correct equation for β^+ decay?

A neutron $\rightarrow$ proton + electron + electron antineutrino

B neutron $\rightarrow$ proton + electron + electron neutrino

C proton $\rightarrow$ neutron + positron + electron antineutrino

D proton $\rightarrow$ neutron + positron + electron neutrino

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1324. 9702_s18_qp_12 Q: 38

In the α-particle scattering experiment, a beam of α-particles is aimed at a thin gold foil. Most of the α-particles go straight through or are deflected by a small angle. A very small proportion are deflected through more than 90°, effectively rebounding towards the source of the α-particles.

Which conclusion about the structure of atoms **cannot** be drawn from this experiment alone?

A Most of the atom is empty space.

B Most of the mass of an atom is concentrated in the nucleus.

C The nucleus contains both protons and neutrons.

D The nucleus is charged.

1325. 9702_s18_qp_12 Q: 39

Radon-211, $^{211}_{86}\text{Rn}$, francium-210, $^{210}_{87}\text{Fr}$, and radium-212, $^{212}_{88}\text{Ra}$, are three nuclides.

How many neutrons does each nuclide have in its nucleus?

	radon-211	francium-210	radium-212
A	86	87	88
B	125	123	124
C	211	210	212
D	297	297	300

1326. 9702_s18_qp_13 Q: 39

A nucleus of magnesium-23 undergoes β^+ decay, as represented by the nuclear equation shown.

$$^{23}_{12}\text{Mg} \rightarrow \text{X} + \beta^+ + \nu_e$$

What is nucleus X?

A $^{22}_{11}\text{Na}$ **B** $^{22}_{13}\text{Al}$ **C** $^{23}_{11}\text{Na}$ **D** $^{23}_{13}\text{Al}$

1327. 9702_w18_qp_11 Q: 39

A nucleus emits a β^- particle.

What is the change to the proton number and to the nucleon number of the nucleus?

	proton number	nucleon number
A	–1	+1
B	0	–1
C	+1	–1
D	+1	0

1328. 9702_w18_qp_12 Q: 39

A proton in a nucleus undergoes β^+ decay. One of the products is a neutron.

What are the other products?

A an electron and a neutrino

B an electron and an antineutrino

C a positron and a neutrino

D a positron and an antineutrino

1329. 9702_w18_qp_13 Q: 38

A neutron collides with a nucleus of uranium-235. One possible nuclear reaction that results is represented by the equation

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{154}_{60}\mathrm{Nd} + {}^{80}_{32}\mathrm{Ge} + \mathrm{x}$$

where x represents one or more particles.

What does x represent?

A one neutron

B two electrons

C two neutrons

D two protons

1330. 9702_w18_qp_13 Q: 39

A nucleus Q has the notation ${}^{y}_{x}\mathrm{Q}$.

Which of the following is an isotope of Q?

A ${}^{y-1}_{x}\mathrm{Q}$ **B** ${}^{y}_{x-1}\mathrm{Q}$ **C** ${}^{y}_{x+1}\mathrm{Q}$ **D** ${}^{y-1}_{x+1}\mathrm{Q}$

1331. 9702_m17_qp_12 Q: 38

Which row describes the relative ionizing power and the relative penetration power per unit length in air of α-particles and γ-rays?

	α-particles	γ-rays
A	least ionizing	least penetrating
B	least penetrating	most ionizing
C	most ionizing	most penetrating
D	most penetrating	least ionizing

1332. 9702_s17_qp_11 Q: 38

The table lists the nucleon number and the proton number of various nuclei. The nuclei are represented by the letters L to T.

nucleus	nucleon number	proton number
L	227	89
M	226	89
N	225	89
O	227	90
P	226	90
Q	225	90
R	227	91
S	226	91
T	225	91

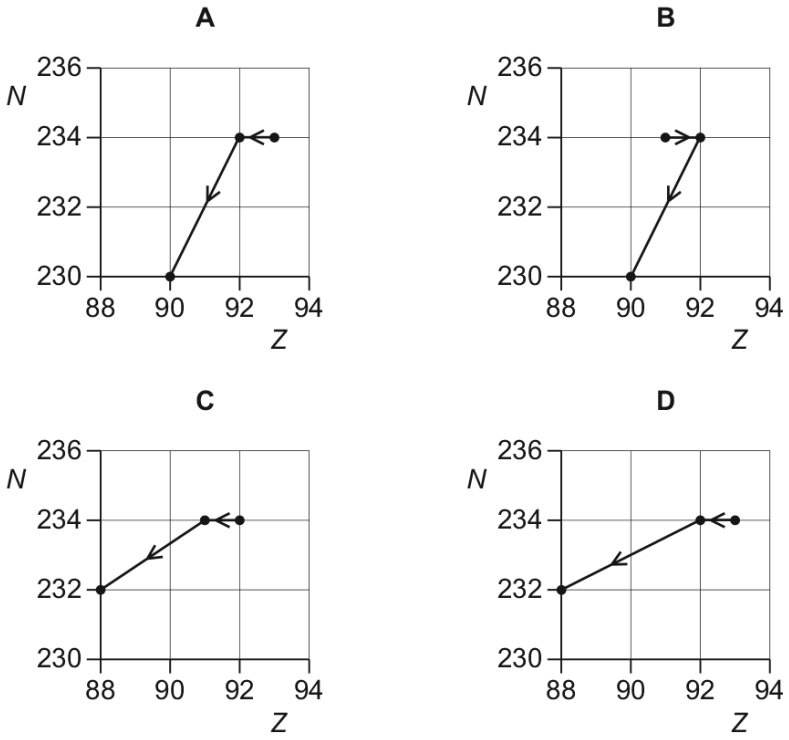
Which row in the following table correctly shows three nuclei of the same element, and three nuclei that have the same number of neutrons?

	same element	same number of neutrons
A	L M N	R P N
B	M P S	R S T
C	O P Q	M P S
D	R P N	O P Q

1333. 9702_s17_qp_11 Q: 39

A radioactive nucleus is formed by β^- decay. This nucleus then decays by α-emission.

Which graph of nucleon number N plotted against proton number Z shows the β^- decay followed by the α-emission?



1334. 9702_s17_qp_12 Q: 38

In a television programme to illustrate scientific models, a presenter fires a gun many times at a bale of hay. Two small cannon balls are embedded within the hay some distance apart from each other.

The hay bale measures approximately 2 m × 2 m × 2 m and the cannon balls are made of iron, approximately spherical, and about 5 cm in diameter.

What might the presenter be illustrating?

A α-particle scattering

B β^- decay

C conservation of momentum

D double-slit interference

1335. 9702_s17_qp_12 Q: 39

A certain nuclide, uranium-235, has nucleon number 235, proton number 92 and neutron number 143. Data on four other nuclides are given below.

Which nuclide is an isotope of uranium-235?

	nucleon number	proton number	neutron number
A	235	91	144
B	236	92	144
C	237	94	143
D	238	95	143

1336. 9702_s17_qp_13 Q: 37

A nucleus of uranium-238, $^{238}_{92}\mathrm{U}$, decays in a series of steps to form a nucleus of lead-206, $^{206}_{82}\mathrm{Pb}$, as shown.

$$^{238}_{92}\mathrm{U} \rightarrow \ldots\ldots\ldots\ldots \rightarrow {}^{206}_{82}\mathrm{Pb}$$

An α-particle or a β^- particle is emitted during each step.

What is the total number of β^- particles that are emitted?

A 6 **B** 8 **C** 10 **D** 16

1337. 9702_s17_qp_13 Q: 38

Which statement about α-particles is correct?

A α-particles emitted from a single radioactive isotope have a continuous distribution of energies.

B α-particles have less ionising power than β-particles.

C The charge of an α-particle is $+1.60 \times 10^{-19}\,\mathrm{C}$.

D The speeds of α-particles can be as high as $1.5 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

1338. 9702_s17_qp_13 Q: 39

The nuclear equation shown has a term missing.

$$^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta + ...$$

What is represented by the missing term?

A an antineutrino

B an electron

C a neutrino

D a positron

1339. 9702_w17_qp_11 Q: 39

An astatine nucleus has a nucleon number of 218 and a proton number of 85. It decays to form a polonium nucleus, emitting a β^- particle and an α-particle in the process.

What are the nucleon number and the proton number of this polonium nucleus?

	nucleon number	proton number
A	214	83
B	214	84
C	215	83
D	216	82

1340. 9702_w17_qp_12 Q: 39

The diagram shows a sequence of radioactive decays involving three α-particles and a β^- particle.

$$^{237}_{93}Np \xrightarrow{\alpha} Q \xrightarrow{\beta^-} R \xrightarrow{\alpha} S \xrightarrow{\alpha} T$$

What is nuclide T?

A $^{225}_{88}Ra$ **B** $^{231}_{88}Ra$ **C** $^{225}_{90}Th$ **D** $^{229}_{90}Th$

1341. 9702_w17_qp_13 Q: 39

Each option shows the number of neutrons, protons and electrons in two atoms, some of which are ionised.

Which pair of atoms in the table are isotopes of the same element?

	neutron	proton	electron
A	20 20	17 19	20 20
B	28 28	23 24	23 24
C	34 36	29 29	29 28
D	40 42	32 31	32 32

1342. 9702_m16_qp_12 Q: 38

A sample of an isotope emits β^- particles.

The emitted β^- particles have a range of energies.

What must also be emitted?

A antineutrinos

B neutrinos

C antineutrons

D neutrons

1343. 9702_m16_qp_12 Q: 39

A nucleus of magnesium decays into a nucleus of sodium by emitting a β^+ particle. The decay is represented by the equation shown.

$$^{23}_{12}\text{Mg} \rightarrow {}^{P}_{Q}\text{Na} + {}^{0}_{+1}\beta$$

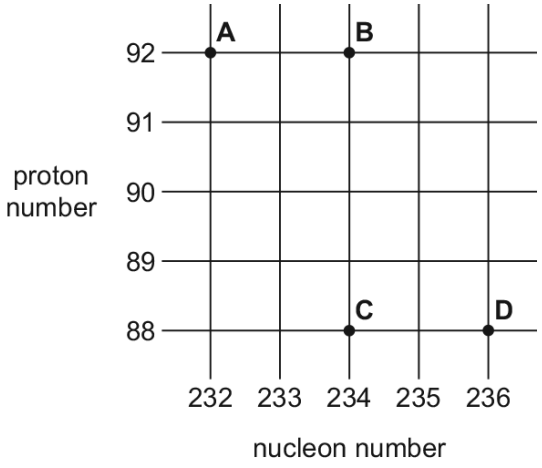
What are the values of P and Q?

	P	Q
A	22	11
B	22	13
C	23	11
D	23	13

1344. 9702_m16_qp_12 Q: 40

Thorium-234 ($^{234}_{90}$Th) decays by β^- emission into a daughter product which in turn decays by a further β^- emission into a granddaughter product.

Which letter in the diagram represents the granddaughter product?



1345. 9702_s16_qp_11 Q: 39

Which word equation represents β^+ decay?

A proton → neutron + electron + electron antineutrino

B proton → neutron + electron + electron neutrino

C proton → neutron + positron + electron antineutrino

D proton → neutron + positron + electron neutrino

1346. 9702_s16_qp_11 Q: 40

Which statement about the alpha-particle scattering experiment provides evidence for the existence of the nucleus?

A A tiny proportion of the alpha-particles are deflected through large angles.

B Slower alpha-particles are deflected through larger angles.

C The kinetic energies of the deflected alpha-particles are unchanged.

D The number of alpha-particles deflected depends on the thickness of the foil.

1347. 9702_s16_qp_12 Q: 38

The gold nucleus $^{185}_{79}Au$ undergoes alpha decay.

What are the nucleon number and proton number of the nucleus formed by this decay?

	nucleon number	proton number
A	183	79
B	183	77
C	181	77
D	181	75

1348. 9702_s16_qp_13 Q: 38

A nitrogen-13 nucleus $^{13}_{7}N$ undergoes beta decay.

In the equations below, ν and $\bar{\nu}$ represent a neutrino and antineutrino respectively and γ represents a photon of gamma radiation.

Which equation represents this decay?

A $^{13}_{7}N \rightarrow {}^{13}_{6}C + \beta^{-} + \bar{\nu} + \gamma$

B $^{13}_{7}N \rightarrow {}^{13}_{6}C + \beta^{-} + \nu + \gamma$

C $^{13}_{7}N \rightarrow {}^{13}_{6}C + \beta^{+} + \bar{\nu} + \gamma$

D $^{13}_{7}N \rightarrow {}^{13}_{6}C + \beta^{+} + \nu + \gamma$

1349. 9702_s16_qp_13 Q: 39

Radon $^{222}_{86}Rn$ is the start of a decay chain that forms bismuth $^{214}_{83}Bi$ by α and β^{-} emission.

For the decay of each nucleus of radon, how many α particles and β^{-} particles are emitted?

	α particles	β^{-} particles
A	1	1
B	2	1
C	1	2
D	2	2

1350. 9702_w16_qp_11 Q: 39

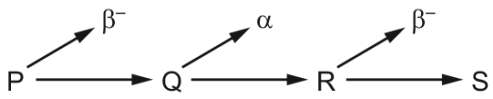
What are the correct descriptions of a γ-ray and a β^- particle?

	γ-ray	β^- particle
A	high-speed electron	electromagnetic radiation
B	electromagnetic radiation	helium-4 nucleus
C	electromagnetic radiation	high-speed electron
D	high-speed electron	helium-4 nucleus

1351. 9702_w16_qp_11 Q: 40

In a radioactive decay series, three successive decays each result in a particle being emitted.

The first decay results in the emission of a β^- particle. The second decay results in the emission of an α particle. The third decay results in the emission of another β^- particle.



Nuclides P and S are compared.

Which statement is correct?

A P and S are identical in all respects.

B P and S are isotopes of the same element.

C S is a different element of lower atomic number.

D S is a different element of reduced mass.

1352. 9702_w16_qp_12 Q: 39

The calcium nuclide $^{42}_{20}Ca$ is formed by β^- decay.

What are the nucleon (mass) number and proton (atomic) number of the unstable nuclide that underwent β^- decay to form the calcium nuclide?

	nucleon number	proton number
A	41	19
B	41	21
C	42	19
D	42	21

1353. 9702_w16_qp_13 Q: 39

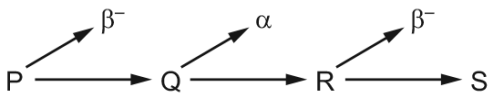
What are the correct descriptions of a γ-ray and a β^- particle?

	γ-ray	β^- particle
A	high-speed electron	electromagnetic radiation
B	electromagnetic radiation	helium-4 nucleus
C	electromagnetic radiation	high-speed electron
D	high-speed electron	helium-4 nucleus

1354. 9702_w16_qp_13 Q: 40

In a radioactive decay series, three successive decays each result in a particle being emitted.

The first decay results in the emission of a β^- particle. The second decay results in the emission of an α particle. The third decay results in the emission of another β^- particle.



Nuclides P and S are compared.

Which statement is correct?

A P and S are identical in all respects.

B P and S are isotopes of the same element.

C S is a different element of lower atomic number.

D S is a different element of reduced mass.

1355. 9702_s15_qp_11 Q: 39

When α-particles are directed at gold leaf

1 almost all α-particles pass through without deflection,

2 a few α-particles are deviated through large angles.

What are the reasons for these effects?

	1	2
A	most α-particles have enough energy to pass right through the gold leaf	gold is very dense so a few low energy α-particles bounce back from the gold surface
B	most α-particles miss all gold atoms	a few α-particles bounce off gold atoms
C	the gold nucleus is very small so most α-particles miss all nuclei	occasionally the path of an α-particle is close to a nucleus
D	the positive charge in an atom is not concentrated enough to deflect an α-particle	occasionally an α-particle experiences many small deflections in the same direction

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1356. 9702_s15_qp_11 Q: 40

The nuclide $^{222}_{86}\text{Rn}$ decays in a sequence of stages to form the nuclide $^{206}_{82}\text{Pb}$.

Four of the nuclides formed in the sequence are α-particle emitters. The others are β-particle emitters.

How many nuclides formed in the decay sequence are β-particle emitters?

A 2 **B** 4 **C** 8 **D** 12

1357. 9702_s15_qp_12 Q: 38

An experiment in which α-particles were deflected by a gold foil produced new insights into the structure of the atom.

Which conclusion can be drawn from the results of the experiment?

A Atomic nuclei occupy a very small fraction of the volume of an atom.

B Electrons orbit the atomic nucleus.

C Some atoms of the same element contain different numbers of neutrons.

D The atomic nucleus contains protons and neutrons.

1358. 9702_s15_qp_12 Q: 39

A radioactive substance contains a number of identical nuclei that emit β-particles.

Which property of these nuclei remains unaltered by the emission?

A charge

B neutron number

C nucleon number

D proton number

1359. 9702_s15_qp_12 Q: 40

A uranium-238 nucleus, $^{238}_{92}\mathrm{U}$, undergoes nuclear decays to form uranium-234, $^{234}_{92}\mathrm{U}$.

Which series of decays could give this result?

A emission of four β-particles

B emission of four γ-rays

C emission of one α-particle and two β-particles

D emission of two α-particles and eight β-particles

1360. 9702_s15_qp_13 Q: 38

Nucleus P decays in two stages to produce nucleus Q.

Which decay sequence will result in the highest number of neutrons in nucleus Q?

A an α-particle followed by a β-particle

B an α-particle followed by a γ-ray

C a β-particle followed by another β-particle

D a β-particle followed by a γ-ray

1361. 9702_s15_qp_13 Q: 39

A neutral atom has a nucleus given by the symbol $^{133}_{55}Cs$.

How many protons, neutrons and electrons are in this atom?

	protons	neutrons	electrons
A	55	78	55
B	55	133	55
C	78	55	78
D	133	55	133

1362. 9702_s15_qp_13 Q: 40

The nuclear equation for a fission reaction is shown below.

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{93}_{X}Rb + {}^{141}_{55}Cs + Y\,{}^{1}_{0}n$$

What are the values of X and Y?

	X	Y
A	37	0
B	37	1
C	37	2
D	38	2

13.2 Fundamental particles

1363. 9702_m20_qp_12 Q: 39

The equation represents the decay of a nucleus X to a nucleus Y.

$$^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + p + q$$

What are particles p and q?

	p	q
A	β^- particle	neutron
B	β^- particle	proton
C	β^+ particle	antineutrino
D	β^+ particle	neutrino

1364. 9702_m20_qp_12 Q: 40

Which row gives the correct type and quark composition for the named particle?

	particle	type	quark composition
A	neutron	hadron	u u d
B	neutron	lepton	u d d
C	proton	hadron	u u d
D	proton	lepton	u d d

key
u = up quark
d = down quark

1365. 9702_s20_qp_11 Q: 40

A hadron has a charge +*e*, where *e* is the elementary charge.

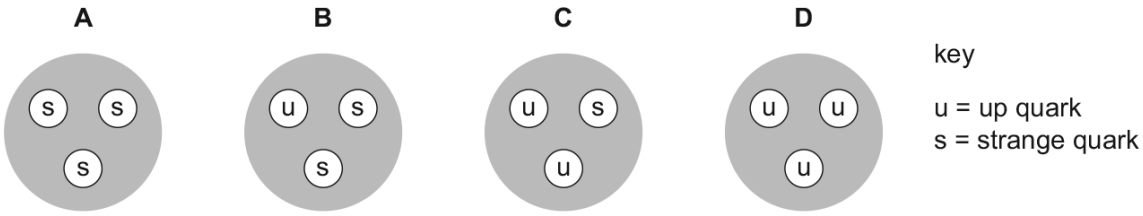
Which combination of up (u) and down (d) quarks could form this hadron?

A ddd **B** udd **C** uud **D** uuu

1366. 9702_s20_qp_12 Q: 40

A hadron has a charge of –*e* and is composed of three quarks.

What could be the quark composition of the hadron?



1367. 9702_s20_qp_13 Q: 40

Which equation describes the process of β^+ decay?

key:

u = up quark

d = down quark

ν = (electron) neutrino

$\bar{\nu}$ = (electron) antineutrino

A $ddu \rightarrow uud + \beta^+ + \nu$

B $ddu \rightarrow uud + \beta^+ + \bar{\nu}$

C $uud \rightarrow ddu + \beta^+ + \nu$

D $uud \rightarrow ddu + \beta^+ + \bar{\nu}$

1368. 9702_s19_qp_11 Q: 40

Some particles are a combination of three quarks.

Which combination of quarks would **not** result in a particle with a charge of either $+1.6 \times 10^{-19}$ C or zero?

A up, down, down

B up, strange, strange

C up, up, down

D up, up, up

1369. 9702_s19_qp_12 Q: 39

Which equation describes the changes to the quark composition of a nucleus and the lepton emission during the process of β^+ decay?

A down $\rightarrow$ up + positron + electron neutrino

B down $\rightarrow$ up + positron + electron antineutrino

C up $\rightarrow$ down + positron + electron neutrino

D up $\rightarrow$ down + positron + electron antineutrino

1370. 9702_s19_qp_12 Q: 40

There are protons, neutrons and electrons in the simple model of an atom.

To which class (group), hadron or lepton, do these particles belong?

	hadron	lepton
A	electron	proton and neutron
B	neutron	proton and electron
C	proton and electron	neutron
D	proton and neutron	electron

1371. 9702_s19_qp_13 Q: 40

Which statement describes β^- decay in terms of a simple quark model?

A A down quark changes to an up quark, and an electron and an electron antineutrino are emitted.

B A down quark changes to an up quark, and a positron and an electron neutrino are emitted.

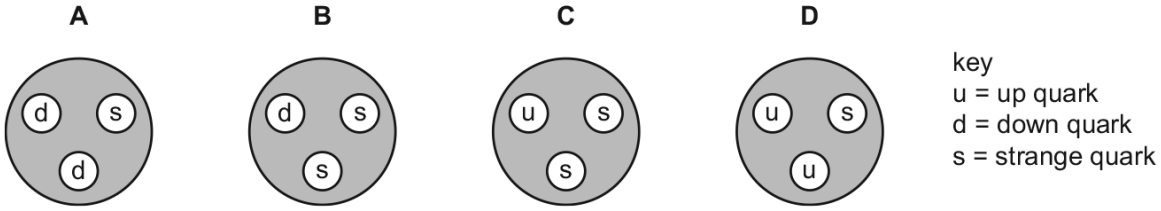
C An up quark changes to a down quark, and an electron and an electron antineutrino are emitted.

D An up quark changes to a down quark, and a positron and an electron neutrino are emitted.

1372. 9702_w19_qp_11 Q: 40

The diagrams show the quark composition of four different hadrons. One of the hadrons is a Σ^+ particle. It has a charge of $+e$, where e is the elementary charge.

Which hadron could be the Σ^+ particle?



1373. 9702_w19_qp_12 Q: 40

An unstable nucleus decays and emits a β^- particle.

Which changes, if any, occur to the quark composition of the nucleus?

	quark changes	
	up quarks	down quarks
A	+1	0
B	+1	–1
C	–1	+1
D	0	+1

1374. 9702_w19_qp_13 Q: 40

Which statement is correct?

A Electrons and neutrinos are fundamental particles.

B Electrons and neutrinos are hadrons.

C Protons and neutrons are leptons.

D Protons and neutrons are quarks.

1375. 9702_m18_qp_12 Q: 40

An isolated neutron decays to produce a proton, a β^- particle and an antineutrino.

Which row gives the quark composition of the neutron and the proton and the type of force that gives rise to this reaction?

	quark composition		type of force
	neutron	proton	
A	down, down, up	down, up, up	strong interaction
B	down, down, up	down, up, up	weak interaction
C	down, up, up	down, down, up	strong interaction
D	down, up, up	down, down, up	weak interaction

1376. 9702_s18_qp_11 Q: 38

Which elementary particle is a lepton?

A proton

B neutron

C electron

D quark

1377. 9702_s18_qp_11 Q: 39

How many down quarks are in a nucleus of hydrogen-3, $^{3}_{1}\mathrm{H}$?

A 2 **B** 3 **C** 4 **D** 5

1378. 9702_s18_qp_12 Q: 40

A neutron is composed of one up (u) quark and two down (d) quarks. When the neutron decays to a proton, there is β-emission.

What is the change in the quark structure of the neutron due to the β-emission?

(The symbol for a neutrino is ν_e and for an antineutrino is $\overline{\nu_e}$.)

A $\mathrm{d} \rightarrow \mathrm{u} + \beta^- + \nu_e$

B $\mathrm{d} \rightarrow \mathrm{u} + \beta^- + \overline{\nu_e}$

C $\mathrm{u} \rightarrow \mathrm{d} + \beta^+ + \nu_e$

D $\mathrm{u} \rightarrow \mathrm{d} + \beta^+ + \overline{\nu_e}$

1379. 9702_s18_qp_13 Q: 40

Which list contains only leptons?

A electron, neutrino, positron

B electron, neutrino, proton

C electron, proton, neutron

D neutrino, neutron, positron

1380. 9702_w18_qp_11 Q: 40

How many up quarks and how many down quarks are in a nucleus of the nuclide $^{37}_{17}Cl$?

	up quarks	down quarks
A	51	60
B	54	57
C	57	54
D	60	51

1381. 9702_w18_qp_12 Q: 40

A certain type of hadron has zero charge. It is composed of a down quark, a strange quark and one other quark.

What could be the other quark?

A up

B down

C strange

D anti-strange

1382. 9702_w18_qp_13 Q: 40

In β^- decay, a neutron inside a nucleus changes to a proton.

Which statement describes the quark composition of the nucleus during the decay?

A The number of down quarks decreases by one.

B The number of down quarks increases by one.

C The number of down quarks stays the same.

D The number of up quarks stays the same.

1383. 9702_m17_qp_12 Q: 39

A nucleus of sodium-21, $^{21}_{11}\text{Na}$, decays to form a new nucleus containing 10 protons and 11 neutrons.

Which leptons are emitted from the sodium-21 nucleus during the decay?

A a positron and an antineutrino

B a positron and a neutrino

C an electron and an antineutrino

D an electron and a neutrino

1384. 9702_m17_qp_12 Q: 40

A neutron decays to form a proton.

Which particle is **not** involved in the decay process?

A antineutrino

B down quark

C positron

D up quark

1385. 9702_s17_qp_11 Q: 40

What are the structures of the proton and of the neutron in terms of quarks?

	proton		neutron	
	up quark	down quark	up quark	down quark
A	1	1	2	2
B	1	2	2	1
C	2	1	1	2
D	2	2	1	1

1386. 9702_s17_qp_12 Q: 40

During β^- decay, which change takes place to the quark composition of the nucleus that emits the β^- particle, and which other particle is emitted?

	quark change	other particle emitted
A	down to up	antineutrino
B	down to up	neutrino
C	up to down	antineutrino
D	up to down	neutrino

1387. 9702_s17_qp_13 Q: 40

Which particle is a fundamental particle?

A electron

B hadron

C neutron

D proton

1388. 9702_w17_qp_11 Q: 40

What is the quark composition of a hydrogen-3 nucleus, ${}^{3}_{1}\mathrm{H}$?

	number of quarks	
	up	down
A	4	5
B	5	4
C	5	7
D	7	5

1389. 9702_w17_qp_12 Q: 40

Which combination of up (u) and down (d) quarks forms a neutron?

A u u u **B** u u d **C** u d d **D** d d d

1390. 9702_w17_qp_13 Q: 40

Which combination of up (u) and down (d) quarks forms a proton?

A u u u **B** u u d **C** u d d **D** d d d

1391. 9702_s16_qp_11 Q: 38

Which statement describes β^- decay in terms of a simple quark model?

A A down quark changes to an up quark and emits an electron and an electron antineutrino.

B A down quark changes to an up quark and emits a positron and an electron neutrino.

C An up quark changes to a down quark and emits an electron and an electron antineutrino.

D An up quark changes to a down quark and emits a positron and an electron neutrino.

1392. 9702_s16_qp_12 Q: 39

Which row gives the correct classification of protons, electrons and neutrinos?

	protons	electrons	neutrinos
A	hadrons	leptons	hadrons
B	hadrons	leptons	leptons
C	leptons	hadrons	hadrons
D	leptons	hadrons	leptons

1393. 9702_s16_qp_12 Q: 40

Which equation represents β^+ decay?

A neutron $\rightarrow$ proton + positron + antineutrino

B neutron $\rightarrow$ proton + positron + neutrino

C proton $\rightarrow$ neutron + positron + antineutrino

D proton $\rightarrow$ neutron + positron + neutrino

1394. 9702_s16_qp_13 Q: 40

The magnitude of the charge on the proton may be regarded as +1 unit. On this basis, the charges on the up (u) quark, down (d) quark and their antiquarks ($\bar{u}$ and $\bar{d}$) are not whole units.

Which row in the table shows the correct values for the charges on the u, d, $\bar{u}$ and $\bar{d}$ quarks?

	u	d	$\bar{u}$	$\bar{d}$
A	$+\frac{2}{3}$	$-\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$
B	$-\frac{2}{3}$	$+\frac{1}{3}$	$+\frac{2}{3}$	$-\frac{1}{3}$
C	$+\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{2}{3}$	$+\frac{1}{3}$
D	$-\frac{2}{3}$	$+\frac{1}{3}$	$-\frac{2}{3}$	$+\frac{1}{3}$

1395. 9702_w16_qp_11 Q: 38

What is a proton?

A a hadron

B a particle consisting of two down quarks and one up quark

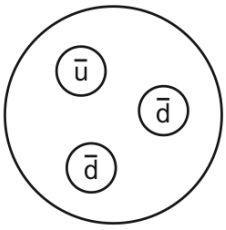
C a positive fundamental particle

D a positive lepton

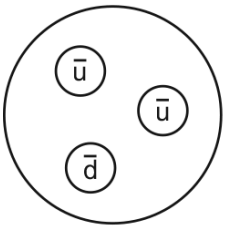
1396. 9702_w16_qp_12 Q: 40

Which diagram represents the structure of an antineutron?

A



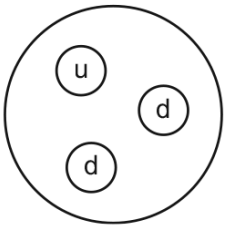
B



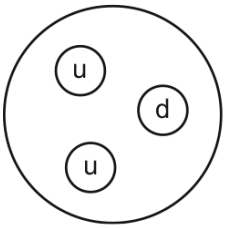
key

u	up quark
d	down quark
$\bar{u}$	up antiquark
$\bar{d}$	down antiquark

C



D



1397. 9702_w16_qp_13 Q: 38

What is a proton?

A a hadron

B a particle consisting of two down quarks and one up quark

C a positive fundamental particle

D a positive lepton

Chapter 13

Particle and nuclear physics

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13.1 Atoms, nuclei and radiation

250. 9702_s20_qp_21 Q: 6

(a) Two horizontal metal plates are separated by a distance of 2.0 cm in a vacuum, as shown in Fig. 6.1.

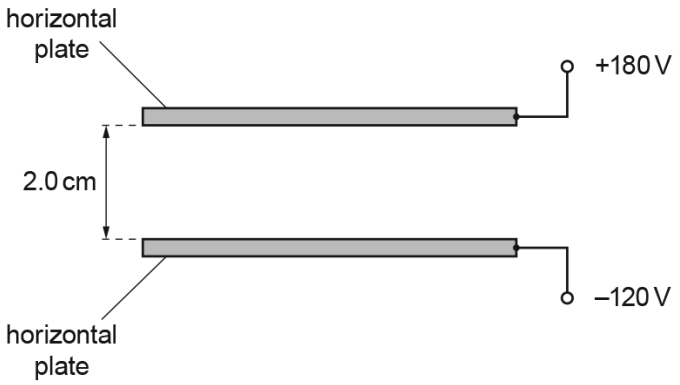


Fig. 6.1

The top plate has an electric potential of +180 V and the bottom plate has an electric potential of –120 V.

(i) Determine the magnitude of the electric field strength between the plates.

electric field strength = ... NC^{-1} [2]

(ii) State the direction of the electric field.

..... [1]

(b) An uncharged atom of uranium-238 ($^{238}_{92}U$) has a change made to its number of orbital electrons. This causes the atom to change into a new particle (ion) X that has an overall charge of +2*e*, where *e* is the elementary charge.

(i) Determine the number of protons, neutrons and electrons in the particle (ion) X.

number of protons = ...

number of neutrons = ...

number of electrons = ...

[3]

(ii) The particle (ion) X is in the electric field in **(a)** at a point midway between the plates.

Determine the magnitude of the electric force acting on X.

force = ... N [2]

(iii) The nucleus of uranium-238 ($^{238}_{92}$U) decays in stages, by emitting α-particles and β^- particles, to form a nucleus of thorium-230 ($^{230}_{90}$Th).

Calculate the total number of α-particles and the total number of β^- particles that are emitted during the decay of uranium-238 to thorium-230.

number of α-particles = ...

number of β^- particles = ...
[2]

[Total: 10]

---

251. 9702_w20_qp_23 Q: 7

Two vertical metal plates are separated by a distance *d* in a vacuum, as shown in Fig. 7.1.

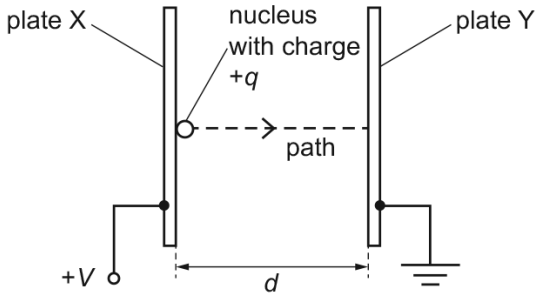


Fig. 7.1 (not to scale)

The potential difference (p.d.) between the plates is *V*. A nucleus with charge +*q* is initially at rest on plate X. The nucleus is accelerated by the uniform electric field from plate X along a horizontal path to plate Y.

(a) State expressions, in terms of some or all of *d*, *q* and *V*, for:

(i) the magnitude of the electric field strength

electric field strength = ... [1]

(ii) the magnitude of the electric force acting on the nucleus

force = ... [1]

(iii) the kinetic energy of the nucleus when it reaches plate Y.

kinetic energy = ... [1]

(b) State the change, if any, in the kinetic energy of the nucleus on reaching plate Y when the following separate changes are made.

(i) The distance *d* is halved, but the p.d. *V* remains the same.

..... [1]

(ii) The nucleus is replaced by a different nucleus that is an isotope of the original nucleus with fewer neutrons.

..... [1]

(c) The nucleus is carbon-14 ($^{14}_{6}C$). This nucleus decays to form a new nucleus by releasing a β^- particle and only one other particle of negligible mass.

(i) Calculate the nucleon number and the proton number of the **new** nucleus.

nucleon number = ...

proton number = ...
[1]

(ii) State the name of the particle of negligible mass.

..... [1]

[Total: 7]

---

252. 9702_w19_qp_22 Q: 7

A nucleus of plutonium-238 ($^{238}_{94}Pu$) decays by emitting an α-particle to produce a new nucleus X and 5.6 MeV of energy. The decay is represented by

$$^{238}_{94}Pu \longrightarrow X + \alpha + 5.6\,MeV.$$

(a) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...
[2]

(b) Calculate the number of plutonium-238 nuclei that must decay in a time of 1.0 s to produce a power of 0.15 W.

number = ... [2]

[Total: 4]

---

253. 9702_w19_qp_23 Q: 7

A stationary nucleus of a radioactive isotope X decays by emitting an α-particle to produce a nucleus of neptunium-237 and 5.5 MeV of energy. The decay is represented by

$$X \longrightarrow {}^{237}_{93}Np + \alpha + 5.5\,MeV.$$

(a) Calculate the number of protons and the number of neutrons in a nucleus of X.

number of protons = ...

number of neutrons = ...
[2]

(b) Explain why the energy transferred to the α-particle as kinetic energy is less than the 5.5 MeV of energy released in the decay process.

.....

..... [1]

(c) A sample of X is used to produce a beam of α-particles in a vacuum. The number of α-particles passing a fixed point in the beam in a time of 30 s is 6.9×10^{11}.

(i) Calculate the average current produced by the beam of α-particles.

current = ... A [2]

(ii) Determine the total power, in W, that is produced by the decay of 6.9×10^{11} nuclei of X in a time of 30 s.

power = ... W [2]

[Total: 7]

254. 9702_m18_qp_22 Q: 6

A sample of a radioactive isotope emits a beam of β^- radiation.

(a) State the change, if any, to the number of neutrons in a nucleus of the sample that emits a β^- particle.

.....[1]

(b) The number of β^- particles passing a fixed point in the beam in a time of 2.0 minutes is 9.8×10^{10}.

Calculate the current, in pA, produced by the beam of β^- particles.

current = ... pA [3]

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

.....

.....

.....

.....[2]

[Total: 6]

255. 9702_w18_qp_21 Q: 5

(a) State what is meant by an *electric field*.

.....

..... [1]

(b) A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

Show that

$$a = \frac{Eq}{m}.$$

[2]

(c) A stationary nucleus X decays by emitting an α-particle to form a nucleus of plutonium, $^{240}_{94}\text{Pu}$, as shown.

$$\text{X} \longrightarrow {}^{240}_{94}\text{Pu} + \alpha$$

(i) Determine the number of protons and the number of neutrons in nucleus X.

number of protons = ...

number of neutrons = ...

[2]

(ii) The total mass of the plutonium nucleus and the α-particle is less than that of nucleus X. Explain this difference in mass.

.....

.....

.....

..... [2]

(iii) The plutonium nucleus and the α-particle are both accelerated by the same uniform electric field.

Use the expression in **(b)** to determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particle}}{\text{acceleration of the plutonium nucleus}}.$$

ratio = ... [2]

[Total: 9]

256. 9702_w18_qp_23 Q: 5

A particle of mass m and charge q is in a uniform electric field of strength E. The particle has acceleration a due to the field.

(a) Show that

$$\frac{q}{m} = \frac{a}{E}.$$

[2]

(b) The particle has a charge of $4e$ where e is the elementary charge. The electric field strength is $3.5 \times 10^4\,\text{V m}^{-1}$. The acceleration of the particle is $1.5 \times 10^{12}\,\text{m s}^{-2}$.

Use the expression in **(a)** to show that the mass of the particle is 9.0 u.

[2]

(c) The particle is a nucleus. State the number of protons and the number of neutrons in the nucleus.

number of protons = ...

number of neutrons = ...
[1]

(d) A second nucleus that is an isotope of the nucleus in **(c)** is in the same uniform electric field.

State and explain whether the electric field produces, for the two nuclei, the same magnitudes of

(i) force,

.....

.....[1]

(ii) acceleration.

.....

.....[1]

[Total: 7]

257. 9702_m17_qp_22 Q: 7

A nucleus of bismuth-212 ($^{212}_{83}$Bi) decays by the emission of an α-particle and γ-radiation.

(a) State the number of protons and the number of neutrons in the nucleus of bismuth-212.

number of protons = ...

number of neutrons = ...
[1]

(b) The γ-radiation emitted from the nucleus has a wavelength of 3.8 pm.

Calculate the frequency of this radiation.

frequency = ... Hz [3]

(c) Explain how a single beam of α-particles and γ-radiation may be separated into a beam of α-particles and a beam of γ-radiation.

.....

.....

.....

.....[2]

(d) The α-particle emitted from the bismuth nucleus has an initial kinetic energy of 9.3×10^{-13} J. As the α-particle moves through air it causes the removal of electrons from atoms. The α-particle loses energy and is stopped after removing 1.8×10^{5} electrons as it moved through the air.

Determine the energy, in eV, needed to remove one electron.

energy = ... eV [2]

[Total: 8]

258. 9702_w17_qp_23 Q: 7

(a) A nucleus X decays by emitting a β^+ particle to form a new nucleus, $^{23}_{11}\text{Na}$.

State the number of nucleons and the number of neutrons in nucleus X.

number of nucleons = ...

number of neutrons = ...
[2]

(b) State one similarity and one difference between a β^+ particle and a β^- particle.

similarity: .....

difference: .....
[2]

[Total: 4]

---

259. 9702_s15_qp_22 Q: 7

A uranium-235 nucleus absorbs a neutron and then splits into two nuclei. A possible nuclear reaction is given by

$$^{235}_{92}\mathrm{U} + {}^{a}_{b}\mathrm{n} \rightarrow {}^{93}_{37}\mathrm{Rb} + {}^{c}_{d}\mathrm{X} + 2{}^{a}_{b}\mathrm{n} + \text{energy.}$$

(a) State the constituent particles of the uranium-235 nucleus.

..... [1]

(b) Complete Fig. 7.1 for this reaction.

	value
a	
b	
c	
d	

[3]

Fig. 7.1

(c) Suggest a possible form of energy released in this reaction.

..... [1]

(d) Explain, using the law of mass-energy conservation, how energy is released in this reaction.

.....

.....

..... [2]

260. 9702_s15_qp_23 Q: 7

The equation represents the spontaneous radioactive decay of a nucleus of bismuth-212.

$$^{212}_{83}\mathrm{Bi} \longrightarrow \mathrm{X} + {}^{208}_{81}Tl + 6.2\,\mathrm{MeV}$$

(a) (i) Explain the meaning of *spontaneous* radioactive decay.

.....

.....[1]

(ii) State the constituent particles of X.

.....[1]

(b) (i) Use the conservation of mass-energy to explain the release of 6.2 MeV of energy in this reaction.

.....

.....

.....[2]

(ii) Calculate the energy, in joules, released in this reaction.

energy = ... J [1]

261. 9702_w15_qp_21 Q: 7

Two parallel, vertical metal plates in a vacuum are connected to a power supply and a switch, as shown in Fig. 7.1.

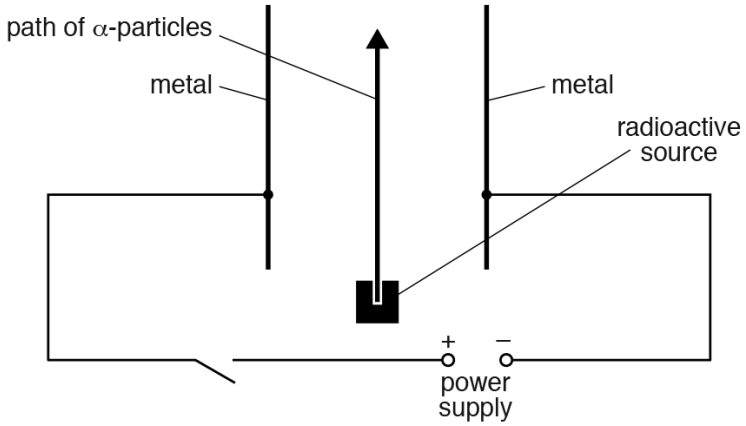


Fig. 7.1

A radioactive source emitting α-particles is placed below the plates. The path of the α-particles is shown on Fig. 7.1. The switch is closed producing a potential difference (p.d.) across the plates. This gives rise to a uniform electric field between the plates.

The separation of the plates is 12 mm.

(a) (i) On Fig. 7.1, draw the path of the α-particles. [1]

(ii) Explain why the metal plates are placed in a vacuum.

.....

..... [1]

(iii) Calculate the p.d. required to produce an electric field of 140 MV m^{-1}.

p.d. = ... MV [2]

(b) The α-particle source is replaced by a β-particle source. By reference to the properties of α-radiation and β-radiation, suggest three possible differences in the deflection observed with β-particles.

1. .....

.....

2. .....

.....

3. .....

.....

[3]

(c) Complete Fig. 7.2 to show the changes in the proton number Z and the nucleon number A of different radioactive nuclei when either an α-particle or a β-particle is emitted.

emitted particle	change in Z	change in A
α-particle		
β-particle		

Fig. 7.2

[1]

262. 9702_w15_qp_22 Q: 8

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

State two results and the associated conclusions.

result 1: .....

.....

conclusion 1: .....

.....

result 2: .....

.....

conclusion 2: .....

.....

[4]

(b) In a model of a copper atom of the isotope $^{63}_{29}Cu$, the atom and its nucleus are assumed to be spherical.

The diameter of the nucleus is 2.8×10^{-14} m. The diameter of the atom is 2.3×10^{-10} m.

Calculate the ratio

$$\frac{\text{density of the nucleus}}{\text{density of the atom}}.$$

ratio = ...[3]

263. 9702_w15_qp_23 Q: 8

(a) State the quantities, other than momentum, that are conserved in a nuclear reaction.

.....

.....[2]

(b) A stationary nucleus of uranium-238 decays to a nucleus of thorium-234 by emitting an α-particle. The kinetic energy of the α-particle is 6.69×10^{-13} J.

(i) Show that the kinetic energy E_k of a mass m is related to its momentum p by the equation

$$E_k = \frac{p^2}{2m}.$$

[1]

(ii) Use the conservation of momentum to determine the kinetic energy, in keV, of the thorium nucleus.

kinetic energy = ... keV [3]

13.2 Fundamental particles

264. 9702_m20_qp_22 Q: 7

(a) State and explain whether a neutron is a fundamental particle.

.....

..... [1]

(b) A proton in a stationary nucleus decays.

(i) State the **two** leptons that are produced by the decay.

.....

..... [2]

(ii) Part of the energy released by the decay is given to the two leptons.

State **two** possible forms of the remainder of the released energy.

.....

..... [2]

[Total: 5]

---

265. 9702_s20_qp_22 Q: 7

(a) A nucleus of an element X decays by emitting a β^+ particle to produce a nucleus of potassium-39 ($^{39}_{19}K$) and a neutrino. The decay is represented by

$$^{Q}_{S}X \rightarrow {}^{39}_{19}K + {}^{P}_{R}\beta^+ + {}^{0}_{0}\nu.$$

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

P .....

Q .....

R .....

S .....

[2]

(ii) State the name of the interaction (force) that gives rise to β^+ decay.

..... [1]

(b) A hadron is composed of three identical quarks and has a charge of +2*e*, where *e* is the elementary charge.

Determine a possible type (flavour) of the quarks.
Explain your working.

.....

..... [2]

[Total: 5]

266. 9702_s20_qp_23 Q: 7

A potential difference is applied between two horizontal metal plates that are a distance of 6.0 mm apart in a vacuum, as shown in Fig. 7.1.

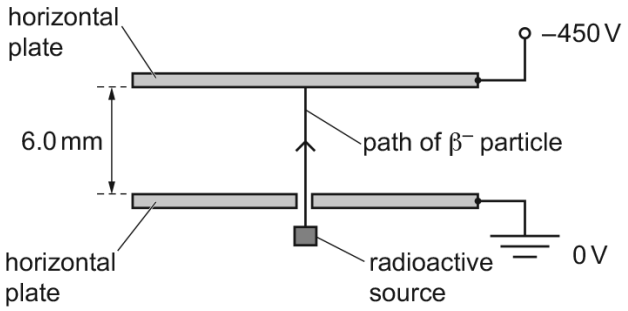


Fig. 7.1

The top plate has a potential of –450 V and the bottom plate is earthed. Assume that there is a uniform electric field produced between the plates.

A radioactive source emits a β^- particle that travels through a hole in the bottom plate and along a vertical path until it reaches the top plate.

(a) (i) Determine the magnitude and the direction of the electric force acting on the β^- particle as it moves between the plates.

magnitude of force = ... N

direction of force .....

[4]

(ii) Calculate the work done by the electric field on the β^- particle for its movement from the bottom plate to the top plate.

work done = ... J [2]

(b) The β^- particle is emitted from the source with a kinetic energy of 3.4×10^{-16} J.

Calculate the speed at which the β^- particle is emitted.

speed = ... $m\,s^{-1}$ [2]

(c) The β^- particle is produced by the decay of a neutron.

(i) Complete the equation below to represent the decay of the neutron.

$$^{1}_{0}n \rightarrow {}^{0}_{-1}\beta^- + {}^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots + {}^{\cdots\cdots}_{\cdots\cdots}\cdots\cdots$$

[2]

(ii) State the name of the group (class) of particles that includes:

1. neutrons

.....

2. β^- particles.

.....

[2]

[Total: 12]

---

267. 9702_w20_qp_21 Q: 8

(a) State a similarity and a difference between a down quark and a down antiquark.

similarity: .....

difference: .....

[2]

(b) For a nucleus of aluminium-25 ($^{25}_{13}Al$):

(i) state the number of protons and the number of neutrons

number of protons = ...

number of neutrons = ...
[1]

(ii) show that the charge is 2.1×10^{-18} C.

[1]

(c) The nucleus in **(b)** is moved along a straight line from point A to point B in a uniform horizontal electric field in a vacuum, as shown in Fig. 8.1.

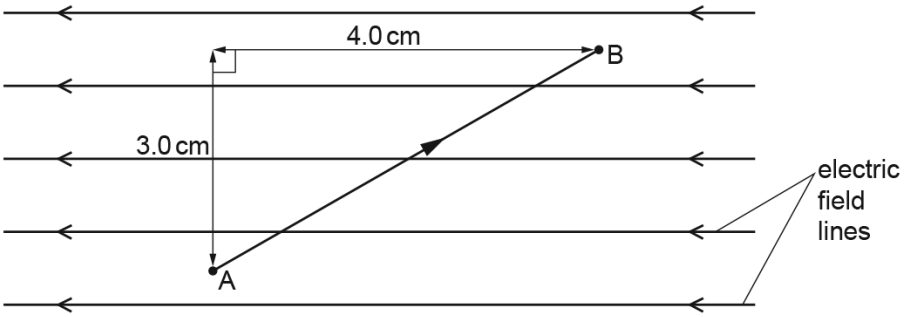


Fig. 8.1

The electric field strength is 11 kV m^{-1}.

Calculate the work done to move the charge from A to B.

work done = ... J [3]

[Total: 7]

268. 9702_w20_qp_22 Q: 7

(a) State a similarity and a difference between an up quark and an up antiquark.

similarity: .....

difference: .....
[2]

(b) Fig. 7.1 shows an electron in an electric field, in a vacuum, at an instant when the electron is stationary.

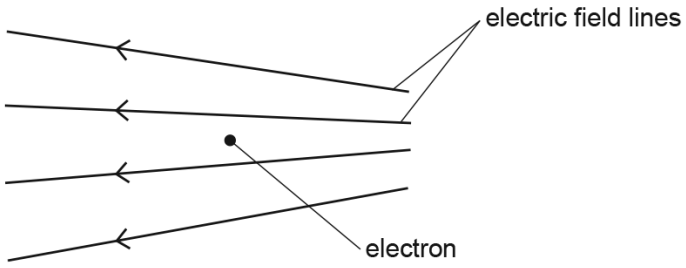


Fig. 7.1

(i) On Fig. 7.1, draw an arrow to show the direction of the electric force acting on the stationary electron. [1]

(ii) The electric field causes the electron to move from its initial position.

Describe and explain the acceleration of the electron due to the field, as the electron moves through the field.

.....

.....

.....

..... [2]

(iii) A stationary α-particle is now placed in the same electric field at the same initial position that was occupied by the electron.

Compare the initial electric force acting on the α-particle with the initial electric force that acted on the electron.

.....

.....

.....

..... [2]

[Total: 7]

269. 9702_m19_qp_22 Q: 7

(a) The names of four particles are listed below.

alpha beta-plus neutron proton

State the name(s) of the particle(s) in this list that:

(i) are not fundamental

.....[1]

(ii) do not experience an electric force when situated in an electric field

.....[1]

(iii) has the largest ratio of charge to mass.

.....[1]

(b) A hadron has a charge of $+e$ where e is the elementary charge. The hadron is composed of only two quarks. One of these quarks is an antidown ($\bar{d}$) quark. By considering charge, state and explain the name (flavour) of the other quark.

.....

.....[3]

[Total: 6]

270. 9702_s19_qp_21 Q: 7

(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) A hadron has an overall charge of $+e$, where e is the elementary charge. The hadron contains three quarks. One of the quarks is a strange (s) quark.

(i) State the charge, in terms of e, of the strange (s) quark.

charge = ... [1]

(ii) The other two quarks in the hadron have the same charge as each other.

By considering charge, determine a possible type (flavour) of the other two quarks. Explain your working.

.....

.....[2]

[Total: 5]

271. 9702_s19_qp_22 Q: 6

(a) State what is meant by a *field line* (*line of force*) in an electric field.

.....

.....[1]

(b) An electric field has two different regions X and Y. The field strength in X is less than that in Y. Describe a difference between the pattern of field lines (lines of force) in X and in Y.

.....

.....[1]

(c) A particle P has a mass of 0.15 u and a charge of $-1e$, where e is the elementary charge.

(i) Particle P and an α-particle are in the same uniform electric field. Calculate the ratio

$$\frac{\text{magnitude of acceleration of particle P}}{\text{magnitude of acceleration of } \alpha\text{-particle}}.$$

ratio = ... [3]

(ii) Particle P is a hadron composed of only two quarks. One of them is a down (d) quark.

By considering charge, determine a possible type (flavour) of the other quark.
Explain your working.

.....

.....[3]

[Total: 8]

272. 9702_s19_qp_23 Q: 7

A sample of a radioactive substance may decay by the emission of either α-radiation or β-radiation and/or γ-radiation.

State the type of radiation, one in each case, that:

(a) consists of leptons

.....[1]

(b) contains quarks

.....[1]

(c) cannot be deflected by an electric field

.....[1]

(d) has a continuous range of energies, rather than discrete values of energy.

.....[1]

[Total: 4]

273. 9702_w19_qp_21 Q: 7

(a) The decay of a nucleus $^{35}_{18}Ar$ by β^+ emission is represented by

$$^{35}_{18}Ar \rightarrow X + \beta^+ + Y.$$

A nucleus X and two particles, β^+ and Y, are produced by the decay.

State:

(i) the proton number and the nucleon number of nucleus X

proton number = ...

nucleon number = ...
[1]

(ii) the name of the particle represented by the symbol Y.

..... [1]

(b) A hadron consists of two down quarks and one strange quark.

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

charge = ... [2]

[Total: 4]

274. 9702_s18_qp_21 Q: 7

A β^- particle from a radioactive source is travelling in a vacuum with kinetic energy 460 eV. The particle enters a uniform electric field at a right-angle and follows the path shown in Fig. 7.1.

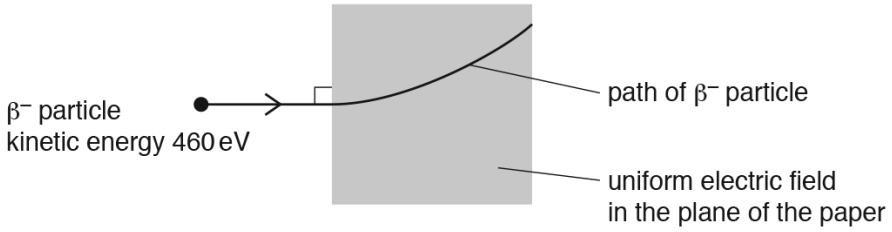


Fig. 7.1

(a) The direction of the electric field is in the plane of the paper.
On Fig. 7.1, draw an arrow to show the direction of the electric field. [1]

(b) Calculate the speed of the β^- particle before it enters the electric field.

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

(c) Other β^- particles from the same radioactive source travel outside the electric field along the same incident path as that shown in Fig. 7.1.

State and briefly explain whether those β^- particles will all follow the same path inside the electric field.

.....

.....

.....

.....[2]

[Total: 6]

275. 9702_s18_qp_22 Q: 7

A stationary nucleus X decays to form nucleus Y, as shown by the equation

$$X \longrightarrow Y + \beta^- + \bar{\nu}.$$

(a) In the above equation, draw a circle around all symbols that represent a lepton. [1]

(b) State the name of the particle represented by the symbol $\bar{\nu}$.

.....[1]

(c) Energy is released during the decay process. State the form of the energy that is gained by nucleus Y.

.....[1]

(d) By comparing the compositions of X and Y, state and explain whether they are isotopes.

.....

.....

.....[2]

(e) The quark composition of one nucleon in X is changed during the emission of a β^- particle. Describe this change to the quark composition.

.....

.....[1]

[Total: 6]

276. 9702_s18_qp_23 Q: 7

A graph of nucleon number A against proton number Z is shown in Fig. 7.1.

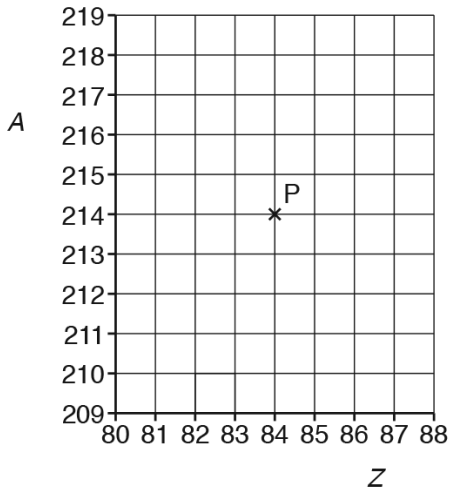


Fig. 7.1

The graph shows a cross (labelled P) that represents a nucleus P.

Nucleus P decays by emitting an α particle to form a nucleus Q.
Nucleus Q then decays by emitting a β^- particle to form a nucleus R.

(a) On Fig. 7.1, use a cross to represent

(i) nucleus Q (label this cross Q), [1]

(ii) nucleus R (label this cross R). [1]

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

.....[1]

(c) The quark composition of one nucleon in Q is changed during the emission of the β^- particle. Describe this change to the quark composition.

.....

.....[1]

[Total: 4]

277. 9702_w18_qp_22 Q: 8

(a) In the following list, underline all particles that are leptons.

antineutrino positron proton quark [1]

(b) A stationary nucleus of magnesium-27, $^{27}_{12}Mg$, decays by emitting a β^- particle and γ radiation. An incomplete equation to represent this decay is

$$^{27}_{12}Mg \longrightarrow X + \beta^- + \gamma.$$

(i) State the nucleon number and the proton number of nucleus X.

nucleon number = ...

proton number = ...
[2]

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

.....[1]

(iii) State **two** possible reasons why the sum of the kinetic energy of the β^- particle and the energy of the γ radiation is less than the total energy released during the decay of the magnesium nucleus.

1. .....

.....

2. .....

.....
[2]

[Total: 6]

278. 9702_s17_qp_21 Q: 7

(a) Use the quark model to show that

(i) the charge on a proton is $+e$,

.....[1]

(ii) the charge on a neutron is zero.

.....[1]

(b) A nucleus of $^{90}_{38}Sr$ decays by the emission of a β^- particle. A nucleus of $^{64}_{29}Cu$ decays by the emission of a β^+ particle.

(i) In Fig. 7.1, state the nucleon number and proton number for the nucleus produced in each of these decay processes.

	nucleus formed by β^- decay	nucleus formed by β^+ decay
nucleon number		
proton number		

Fig. 7.1 [1]

(ii) State the name of the force responsible for β decay.

.....[1]

(iii) State the names of the leptons produced in each of the decay processes.

β^- decay: .....

β^+ decay: .....
[1]

[Total: 5]

279. 9702_s17_qp_22 Q: 8

(a) Describe **two** differences between the decay of a nucleus that emits a β^- particle and the decay of a nucleus that emits a β^+ particle.

1. .....

.....

2. .....

.....

[2]

(b) In a simple quark model there are three types of quark. State the composition of the proton and of the neutron in terms of these three quarks.

proton: .....

neutron: .....

[1]

[Total: 3]

---

280. 9702_s17_qp_23 Q: 7

(a) The following particles are used to describe the structure of an atom.

electron neutron proton quark

Underline the fundamental particles in the above list. [1]

(b) The following equation represents the decay of a nucleus of $^{60}_{27}Co$ to form nucleus Q by β^- emission.

$$^{60}_{27}Co \rightarrow {}^{A}_{B}Q + \beta^- + x$$

(i) Complete Fig. 7.1.

	value
A	
B	

Fig. 7.1

[1]

(ii) State the name of the particle x.

.....[1]

[Total: 3]

---

281. 9702_w17_qp_21 Q: 8

A neutron within a nucleus decays to produce a proton, a β^- particle and an (electron) antineutrino.

$$n \longrightarrow p + \beta^- + \bar{\nu}$$

(a) Use the quark composition of the neutron to show that the neutron has no charge.

[3]

(b) Complete Fig. 8.1 by giving appropriate values of the charge and the mass of the proton, the β^- particle and the (electron) antineutrino.

	proton	β^- particle	antineutrino
charge			
mass			

Fig. 8.1

[2]

[Total: 5]

282. 9702_w17_qp_22 Q: 7

A stationary nucleus X decays by emitting a β^+ particle to form a nucleus of carbon-13 (${}^{13}_{6}C$). An incomplete equation to represent this decay is

$$X \rightarrow {}^{13}_{6}C + \beta^+.$$

(a) State the name of the class (group) of particles that includes β^+.

.....[1]

(b) For nucleus X, state the number of

protons, ...

neutrons. ..... [1]

(c) The carbon-13 nucleus has a mass of 2.2×10^{-26} kg. Its kinetic energy as a result of the decay process is 0.80 MeV.

Calculate the speed of this nucleus.

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

(d) Explain why the sum of the kinetic energies of the carbon-13 nucleus and the β^+ particle cannot be equal to the total energy released by the decay process.

.....

.....[1]

[Total: 6]

283. 9702_m16_qp_22 Q: 6

A neutron decays by emitting a β^- particle.

(a) Complete the equation below for this decay.

$$^{1}_{0}n \rightarrow \overset{\cdots\cdots}{\cdots\cdots}\ \cdots\cdots + \overset{\cdots\cdots}{\cdots\cdots}\ \beta^- + \overset{\cdots\cdots}{\cdots\cdots}\ \bar{\nu}$$

[2]

(b) State the name of the particle represented by the symbol $\bar{\nu}$.

..... [1]

(c) State the name of the class (group) of particles that includes β^- and $\bar{\nu}$.

..... [1]

(d) State

(i) the quark structure of the neutron,

..... [1]

(ii) the change to the quark structure when the neutron decays.

.....

..... [1]

[Total: 6]

284. 9702_s16_qp_21 Q: 7

(a) Give one example of

a hadron: .....

a lepton: .....
[1]

(b) Describe, in terms of the simple quark model,

(i) a proton,

.....[1]

(ii) a neutron.

.....[1]

(c) Beta particles may be emitted during the decay of an unstable nucleus of an atom. The emission of a beta particle is due to the decay of a neutron.

(i) Complete the following word equation for the particles produced in this reaction.

neutron $\longrightarrow$ ..... + ... + ... [1]

(ii) State the change in quark composition of the particles during this reaction.

.....[1]

[Total: 5]

285. 9702_s16_qp_22 Q: 8

(a) State the name of the class (group) to which each of the following belongs:

electron .....

neutron .....

neutrino .....

proton .....

[2]

(b) A proton may decay into a neutron together with two other particles.

(i) Complete the following to give an equation that represents this proton decay.

$$^{1}_{1}p \rightarrow \text{.....}^{\text{.....}}_{\text{.....}}n + \text{.....}^{\text{.....}}_{\text{.....}} + \text{.....}^{\text{.....}}_{\text{.....}}$$

[2]

(ii) Write an equation for this decay in terms of quark composition.

[1]

(iii) State the name of the force responsible for this decay.

.....[1]

[Total: 6]

286. 9702_s16_qp_23 Q: 8

(a) Distinguish between an α-particle and a β^+-particle.

.....

.....

.....

.....

.....[3]

(b) State the equation that shows the decay of a particle in a nucleus that results in β^+ emission. All particles in the equation should be shown in the notation that is usually used for the representation of nuclides.

[2]

(c) **(i)** State the quark composition of

1. a proton,

.....

2. a neutron.

.....
[2]

(ii) Use the quark model to explain the charge on a proton.

.....

.....

.....[1]

[Total: 8]

---

287. 9702_w16_qp_21 Q: 7

(a) State **one** difference between a hadron and a lepton.

.....

.....[1]

(b) **(i)** State the quark composition of a proton and of a neutron.

proton: .....

neutron: .....
[2]

(ii) Use your answer in **(i)** to determine the quark composition of an α-particle.

quark composition: .....[1]

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

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

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

State what may be inferred from

(i) result 1,

.....

.....[1]

(ii) result 2.

.....

.....

.....

.....[2]

[Total: 7]

288. 9702_w16_qp_22 Q: 6

(a) State **one** difference between a hadron and a lepton.

.....

.....[1]

(b) A proton within a nucleus decays to form a neutron and two other particles. A partial equation to represent this decay is

$$^{1}_{1}\text{p} \rightarrow {}^{1}_{0}\text{n} + {}^{\cdots\cdots}_{\cdots\cdots} \cdots\cdots + {}^{\cdots\cdots}_{\cdots\cdots} \cdots\cdots$$

(i) Complete the equation. [2]

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

.....[1]

(iii) State three quantities that are conserved in the decay.

1. .....

2. .....

3. .....

[3]

(c) Use the quark composition of a proton to show that it has a charge of $+e$, where e is the elementary charge.

Explain your working.

[3]

[Total: 10]

289. 9702_w16_qp_23 Q: 7

(a) State **one** difference between a hadron and a lepton.

.....

.....[1]

(b) **(i)** State the quark composition of a proton and of a neutron.

proton: .....

neutron: .....
[2]

(ii) Use your answer in **(i)** to determine the quark composition of an α-particle.

quark composition: .....[1]

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

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

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

State what may be inferred from

(i) result 1,

.....

.....[1]

(ii) result 2.

.....

.....

.....

.....[2]

[Total: 7]

Chapter 16

Particle and nuclear physics

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397. 9702_s20_qp_41 Q: 11

An electron, at rest, has mass m_e and charge $-q$.

A positron is a particle that, at rest, has mass m_e and charge $+q$.

A positron interacts with an electron. The electron and the positron may be considered to be at rest.
The outcome of this interaction is that the electron and the positron become two gamma-ray (γ-ray) photons, each having the same energy.

(a) Calculate, for one of the γ-ray photons:

(i) the photon energy, in J

energy = ... J [2]

(ii) its momentum.

momentum = ... Ns [2]

(b) State and explain the direction, relative to each other, in which the γ-ray photons are emitted.

.....

.....

.....

..... [2]

[Total: 6]

398. 9702_s20_qp_42 Q: 12

(a) State what is meant by the *mass defect* of a nucleus.

.....

.....

..... [2]

(b) Some masses are shown in Table 12.1.

Table 12.1

	mass / u
proton $^{1}_{1}p$	1.007 276
neutron $^{1}_{0}n$	1.008 665
helium-4 ($^{4}_{2}He$) nucleus	4.001 506

Show that:

(i) the energy equivalence of 1.00 u is 934 MeV

[2]

(ii) the binding energy per nucleon of a helium-4 nucleus is 7.09 MeV.

[2]

(c) Isotopes of hydrogen have binding energies per nucleon of less than 3 MeV.

Suggest why a nucleus of helium-4 does not spontaneously break down to become nuclei of hydrogen.

.....

.....

..... [2]

[Total: 8]

399. 9702_s20_qp_43 Q: 11

An electron, at rest, has mass m_e and charge $-q$.

A positron is a particle that, at rest, has mass m_e and charge $+q$.

A positron interacts with an electron. The electron and the positron may be considered to be at rest.
The outcome of this interaction is that the electron and the positron become two gamma-ray (γ-ray) photons, each having the same energy.

(a) Calculate, for one of the γ-ray photons:

(i) the photon energy, in J

energy = ... J [2]

(ii) its momentum.

momentum = ... N s [2]

(b) State and explain the direction, relative to each other, in which the γ-ray photons are emitted.

.....

.....

.....

..... [2]

[Total: 6]

400. 9702_m19_qp_42 Q: 12

The incomplete nuclear equation for one possible reaction that takes place in the core of a nuclear reactor is

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{139}_{57}\text{La} + {}^{95}_{42}\text{Mo} + 2\,{}^{1}_{0}\text{n} + \ldots\ldots\ldots\ldots$$

(a) **(i)** State the name given to this type of nuclear reaction.

..... [1]

(ii) Complete the nuclear equation. [2]

(b) The mass defect for the reaction is 0.223 u.

(i) Calculate the energy, in J, equivalent to 0.223 u.

energy = ... J [2]

(ii) Suggest **two** forms of the energy released in this reaction.

1. .....

.....

2. .....

..... [2]

[Total: 7]

401. 9702_w19_qp_41 Q: 12

One possible nuclear reaction that takes place is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{95}_{42}Mo + ^{139}_{57}La + 2^{1}_{0}n + 7^{0}_{-1}e$$

Data for nuclei in this reaction are given in Fig. 12.1.

nucleus	mass/u	total mass of separate nucleons/u	mass defect/u	binding energy per nucleon/MeV
$^{95}_{42}Mo$	94.906	95.765	0.859	8.443
$^{139}_{57}La$	138.906	140.125	1.219	8.189
$^{235}_{92}U$	235.044	236.909	1.865	.....

Fig. 12.1

(a) Show that the energy equivalent to a mass of 1.00 u is 934 MeV.

[2]

(b) **(i)** Use data from Fig. 12.1 to calculate the binding energy per nucleon of a nucleus of uranium-235 ($^{235}_{92}U$). Complete Fig. 12.1.

[2]

(ii) The nucleon number of an isotope of the element rutherfordium is 267.

State whether the binding energy per nucleon of this isotope will be greater than, equal to or less than the binding energy per nucleon of uranium-235.

..... [1]

(c) Calculate the total energy, in MeV, released in this nuclear reaction.

energy = ... MeV [2]

(d) The nuclei in 1.2×10^{-7} mol of uranium-235 all undergo this reaction in a time of 25 ms.

Calculate the average power release during the time of 25 ms.

power = ... W [3]

[Total: 10]

---

402. 9702_w19_qp_43 Q: 12

One possible nuclear reaction that takes place is

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{95}_{42}Mo + ^{139}_{57}La + 2^{1}_{0}n + 7_^{0}_{-1}e$$

Data for nuclei in this reaction are given in Fig. 12.1.

nucleus	mass/u	total mass of separate nucleons/u	mass defect/u	binding energy per nucleon/MeV
$^{95}_{42}Mo$	94.906	95.765	0.859	8.443
$^{139}_{57}La$	138.906	140.125	1.219	8.189
$^{235}_{92}U$	235.044	236.909	1.865	.....

Fig. 12.1

(a) Show that the energy equivalent to a mass of 1.00 u is 934 MeV.

[2]

(b) **(i)** Use data from Fig. 12.1 to calculate the binding energy per nucleon of a nucleus of uranium-235 ($^{235}_{92}U$). Complete Fig. 12.1.

[2]

(ii) The nucleon number of an isotope of the element rutherfordium is 267.

State whether the binding energy per nucleon of this isotope will be greater than, equal to or less than the binding energy per nucleon of uranium-235.

..... [1]

(c) Calculate the total energy, in MeV, released in this nuclear reaction.

energy = ... MeV [2]

(d) The nuclei in 1.2×10^{-7} mol of uranium-235 all undergo this reaction in a time of 25 ms.

Calculate the average power release during the time of 25 ms.

power = ... W [3]

[Total: 10]

---

403. 9702_m18_qp_42 Q: 3

(a) A mass is undergoing simple harmonic motion with amplitude x_0. The maximum velocity of the mass has magnitude v_0.

On Fig. 3.1, show the variation with displacement x of the velocity v of the mass.

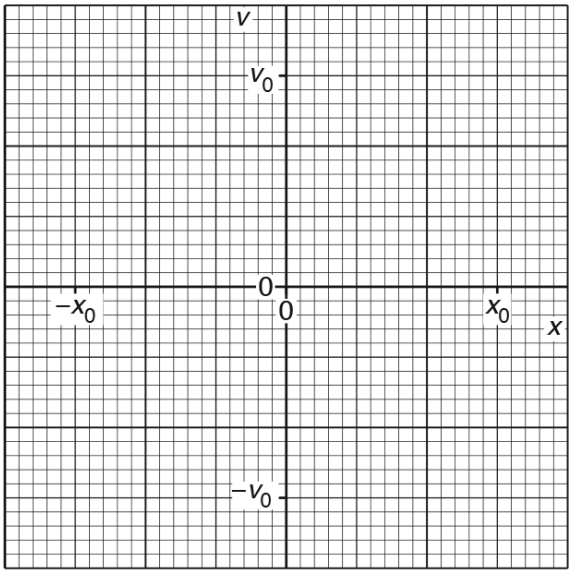


Fig. 3.1

[2]

(b) A straight stiff wire carries a constant current in a region of uniform magnetic flux density.

The angle θ between the direction of the current and the direction of the magnetic field is varied. The maximum force on the wire is F_0.

On Fig. 3.2, show the variation with angle θ of the force F on the wire for values of θ between 0° and 90°.

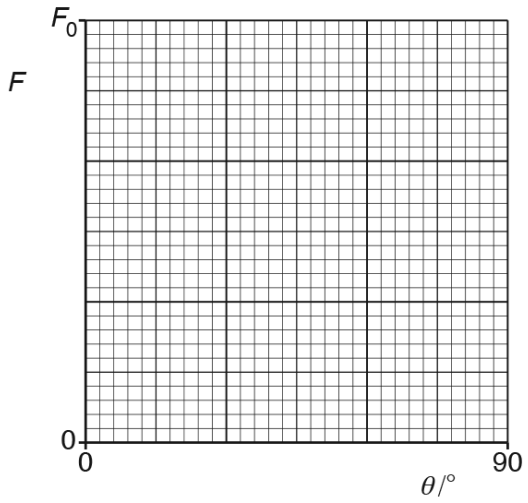


Fig. 3.2

[2]

STEMUP.CO.UK

(c) A sinusoidal supply has frequency 250 Hz and r.m.s. potential difference 2.8 V.

On the axes of Fig. 3.3, show quantitatively the variation with time t of the voltage V for one cycle of the varying voltage.

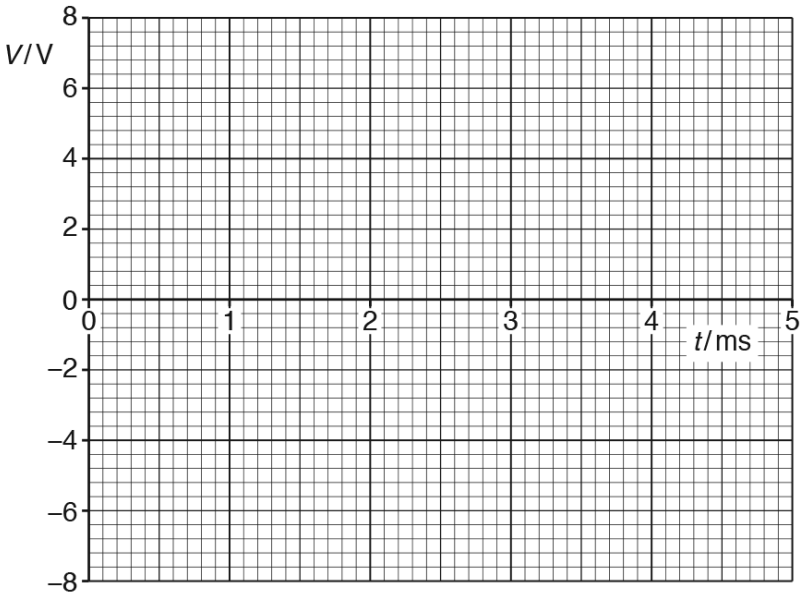


Fig. 3.3

[2]

(d) One particular fission reaction may be represented by the equation

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

The variation with nucleon number A of the binding energy per nucleon B_E is shown in Fig. 3.4.

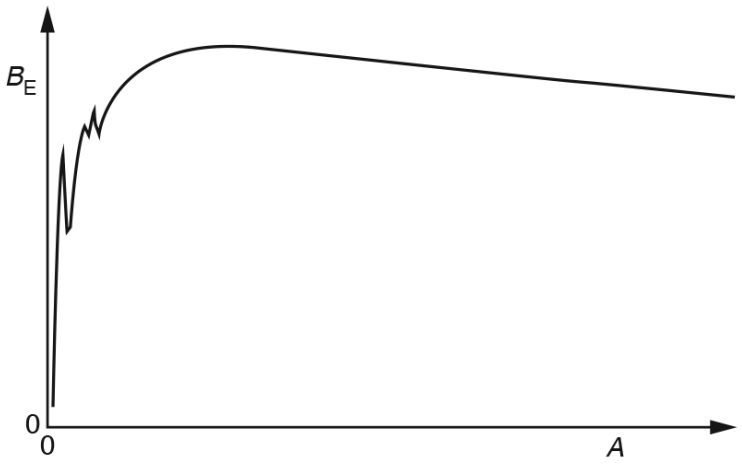


Fig. 3.4

On Fig. 3.4, mark on the line the position of

(i) the nucleus $^{235}_{92}\text{U}$ (label this point U),

(ii) the nucleus $^{141}_{56}\text{Ba}$ (label this point Ba),

(iii) the nucleus $^{92}_{36}\text{Kr}$ (label this point Kr).

[2]

[Total: 8]

404. 9702_w18_qp_41 Q: 11

A stationary isolated nucleus emits a γ-ray photon of energy 0.51MeV.

(a) State what is meant by a *photon*.

.....

.....

.....[2]

(b) For the γ-ray photon, calculate

(i) its wavelength,

wavelength = ... m [2]

(ii) its momentum.

momentum = ...Ns [2]

(c) **(i)** For this nucleus, determine the change in mass Δm during the decay that gives rise to the energy of the γ-ray photon.

Δm = ... kg [2]

(ii) Explain why, after the decay, the nucleus is no longer stationary.

.....

.....

.....[1]

[Total: 9]

---

405. 9702_w18_qp_42 Q: 12

(a) State what is meant by *nuclear fusion* and *nuclear fission*.

nuclear fusion: .....

.....

.....

nuclear fission: .....

.....

.....

[3]

(b) A nuclear reaction which may, in the future, be used for the generation of electrical energy is

$$^{2}_{1}\mathrm{H} + ^{3}_{1}\mathrm{H} \rightarrow ^{4}_{2}\mathrm{He} + \mathrm{x}.$$

(i) Name the particle x.

.....[1]

(ii) Data for the binding energy per nucleon E_B of some nuclei are given in Fig. 12.1.

		binding energy per nucleon $E_B / 10^{-13}$ J
deuterium	$^{2}_{1}\mathrm{H}$	1.7813
tritium	$^{3}_{1}\mathrm{H}$	4.5285
helium	$^{4}_{2}\mathrm{He}$	11.3290

Fig. 12.1

1. State the binding energy per nucleon of x.

binding energy per nucleon = ... J

2. Calculate the energy change that takes place in this reaction.

energy change = ... J
[3]

(iii) Use your answer in **(ii) part 2** to determine the energy release when 2.0 g of deuterium ($^{2}_{1}\mathrm{H}$) reacts with 3.0 g of tritium ($^{3}_{1}\mathrm{H}$).

energy = ... J [1]

[Total: 8]

406. 9702_w18_qp_43 Q: 11

A stationary isolated nucleus emits a γ-ray photon of energy 0.51MeV.

(a) State what is meant by a *photon*.

.....

.....

.....[2]

(b) For the γ-ray photon, calculate

(i) its wavelength,

wavelength = ... m [2]

(ii) its momentum.

momentum = ...N s [2]

(c) **(i)** For this nucleus, determine the change in mass Δm during the decay that gives rise to the energy of the γ-ray photon.

$\Delta m =$ ..... kg [2]

(ii) Explain why, after the decay, the nucleus is no longer stationary.

.....

.....

.....[1]

[Total: 9]

---

407. 9702_m17_qp_42 Q: 12

(a) Define the *binding energy* of a nucleus.

.....

.....

.....[2]

(b) A stationary nucleus of uranium-238 ($^{238}_{92}$U) decays to form a nucleus of thorium-234 ($^{234}_{90}$Th). An α-particle and a gamma-ray photon are emitted. The equation representing the decay is

$$^{238}_{92}\text{U} \rightarrow {}^{234}_{90}\text{Th} + {}^{4}_{2}\text{He} + {}^{0}_{0}\gamma$$

The masses of the nuclei are given in Fig. 12.1.

nucleus	mass/u
uranium-238	238.05076
thorium-234	234.04357
helium-4	4.00260

Fig. 12.1

(i) State the relationship between the binding energies of the nuclei that is consistent with this reaction being energetically possible.

.....

.....[1]

(ii) Calculate, for this reaction,

1. the change, in u, of the mass,

change of mass = ...u [1]

2. the total energy, in J, released.

energy = ...J [2]

(iii) State and explain whether the energy of the gamma-ray photon is equal to the energy released in the reaction.

.....

.....

.....[2]

[Total: 8]

---

408. 9702_s17_qp_41 Q: 12

One possible nuclear reaction that takes place in a nuclear reactor is given by the equation

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{95}_{42}\text{Mo} + {}^{139}_{57}\text{La} + 2{}^{1}_{0}\text{n} + x\,{}^{0}_{-1}\text{e}$$

Data for the nuclei and particles are given in Fig. 12.1.

nucleus or particle	mass / u
$^{235}_{92}$U	235.123
$^{95}_{42}$Mo	94.945
$^{139}_{57}$La	138.955
$^{1}_{0}$n	1.00863
$^{0}_{-1}$e	5.49×10^{-4}

Fig. 12.1

(a) Determine, for this nuclear reaction, the value of x.

$x =$ .....[1]

(b) **(i)** Show that the energy equivalent to 1.00 u is 934 MeV.

[3]

(ii) Calculate the energy, in MeV, released in this reaction. Give your answer to three significant figures.

energy = ... MeV [3]

(c) Suggest the forms of energy into which the energy calculated in **(b)(ii)** is transformed.

.....

.....

.....

.....[2]

[Total: 9]

409. 9702_s17_qp_42 Q: 12

One nuclear reaction that can take place in a nuclear reactor may be represented, in part, by the equation

$$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{95}_{42}\text{Mo} + {}^{139}_{57}\text{La} + 2{}^{1}_{0}\text{n} + \ldots\ldots\ldots\ldots + \text{energy}$$

Data for a nucleus and some particles are given in Fig. 12.1.

nucleus or particle	mass / u
$^{139}_{57}$La	138.955
$^{1}_{0}$n	1.00863
$^{1}_{1}$p	1.00728
$^{0}_{-1}$e	5.49×10^{-4}

Fig. 12.1

(a) Complete the nuclear reaction shown above. [1]

(b) **(i)** Show that the energy equivalent to 1.00 u is 934 MeV.

[3]

(ii) Calculate the binding energy per nucleon, in MeV, of lanthanum-139 ($^{139}_{57}$La).

binding energy per nucleon = ... MeV [3]

(c) State and explain whether the binding energy per nucleon of uranium-235 ($^{235}_{92}U$) will be greater, equal to or less than your answer in **(b)(ii)**.

.....

.....

.....

.....[3]

[Total: 10]

---

410. 9702_s17_qp_43 Q: 12

One possible nuclear reaction that takes place in a nuclear reactor is given by the equation

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{95}_{42}Mo + {}^{139}_{57}La + 2{}^{1}_{0}n + x\,{}^{0}_{-1}e$$

Data for the nuclei and particles are given in Fig. 12.1.

nucleus or particle	mass / u
$^{235}_{92}U$	235.123
$^{95}_{42}Mo$	94.945
$^{139}_{57}La$	138.955
$^{1}_{0}n$	1.00863
$^{0}_{-1}e$	5.49×10^{-4}

Fig. 12.1

(a) Determine, for this nuclear reaction, the value of x.

x = ...[1]

(b) **(i)** Show that the energy equivalent to 1.00 u is 934 MeV.

[3]

(ii) Calculate the energy, in MeV, released in this reaction. Give your answer to three significant figures.

energy = ... MeV [3]

(c) Suggest the forms of energy into which the energy calculated in **(b)(ii)** is transformed.

.....

.....

.....

.....[2]

[Total: 9]

---

411. 9702_m16_qp_42 Q: 9

A particle of charge $+q$ and mass m is travelling with a constant speed of $1.6\times10^{5}\,\text{m s}^{-1}$ in a vacuum. The particle enters a uniform magnetic field of flux density $9.7\times10^{-2}\,\text{T}$, as shown in Fig. 9.1.

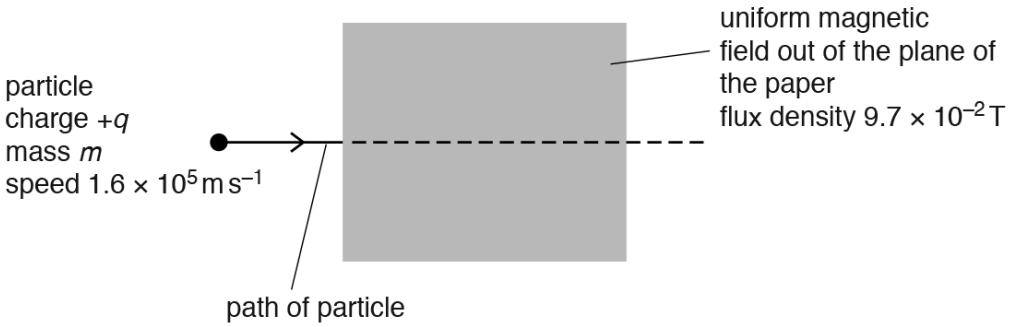


Fig. 9.1

The magnetic field direction is perpendicular to the initial velocity of the particle and perpendicular to, and out of, the plane of the paper.

A uniform electric field is applied in the same region as the magnetic field so that the particle passes undeviated through the fields.

(a) State and explain the direction of the electric field.

.....

.....

.....[2]

(b) Calculate the magnitude of the electric field strength.

Explain your working.

electric field strength = ... V m^{-1} [3]

(c) The electric field is now removed so that the positively-charged particle follows a curved path in the magnetic field. This path is an arc of a circle of radius 4.0 cm.

Calculate, for the particle, the ratio $\frac{q}{m}$.

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

(d) The particle has a charge of $3e$ where e is the elementary charge.

(i) Use your answer in **(c)** to determine the mass, in u, of the particle.

mass = ...u [2]

(ii) The particle is the nucleus of an atom. State the number of protons and the number of neutrons in this nucleus.

number of protons = ...

number of neutrons = ...
[1]

[Total: 11]

412. 9702_w16_qp_42 Q: 14

Phosphorus-30 ($^{30}_{15}$P) was the first artificial radioactive nuclide to be produced in a laboratory. This was achieved by bombarding aluminium-27 ($^{27}_{13}$A*l*) with α-particles.

A partial nuclear equation to represent this reaction is

$$^{27}_{13}\mathit{Al} + \alpha \rightarrow {}^{30}_{15}\mathrm{P} + \Phi$$

(a) State the full nuclear notation for

(i) the α-particle,

.....[1]

(ii) the particle represented by the symbol Φ.

.....[1]

(b) Data for the rest masses of the particles in the reaction are given in Fig. 14.1.

particle	mass/u
$^{27}_{13}Al$	26.98153
α	4.00260
$^{30}_{15}P$	29.97830
Φ	1.00867

Fig. 14.1

Calculate, for this reaction,

(i) the change in the total rest mass of the particles,

mass change = ... u [2]

(ii) the energy, in joule, equivalent to the mass change calculated in **(i)**.

energy = ... J [2]

(c) With reference to your answer in **(b)(i)**, comment on the energy of the α-particle such that the reaction can take place.

.....

.....

.....

.....[2]

[Total: 8]

413. 9702_m21_qp_42 Q: 12

(a) Radioactive decay is both spontaneous and random.

State what is meant by:

1. *spontaneous decay* .....

.....

2. *random decay.* .....

.....

[2]

(b) Strontium-90 ($^{90}_{38}$Sr) is an unstable nuclide.

The activity of a sample of 1.0×10^{-9} kg of strontium-90 is 5.2 MBq.

(i) Determine the decay constant λ of strontium-90.

λ = ... s^{-1} [3]

(ii) The activity of the sample after a time of 1.0 half lives is found to be greater than the expected 2.6 MBq.

Suggest a possible reason for this.

.....

..... [1]

[Total: 6]

414. 9702_s21_qp_41 Q: 6

(a) An isolated metal sphere of radius r is charged so that the electric field strength at its surface is E_0.

On Fig. 6.1, sketch the variation of the electric field strength E with distance x from the centre of the sphere. Your sketch should extend from $x = 0$ to $x = 3r$.

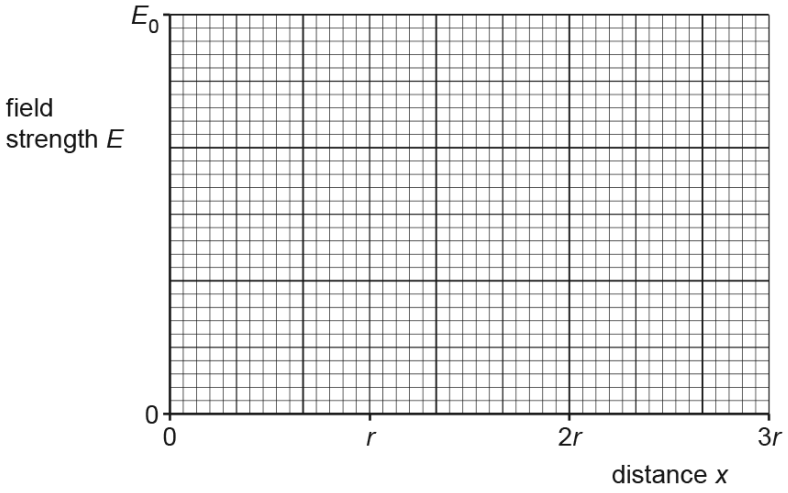


Fig. 6.1

[3]

(b) The de Broglie wavelength of a particle is λ_0 when its momentum is p_0.

On Fig. 6.2, sketch the variation with momentum p of the de Broglie wavelength λ of the particle for values of momentum from $\frac{p_0}{2}$ to p_0.

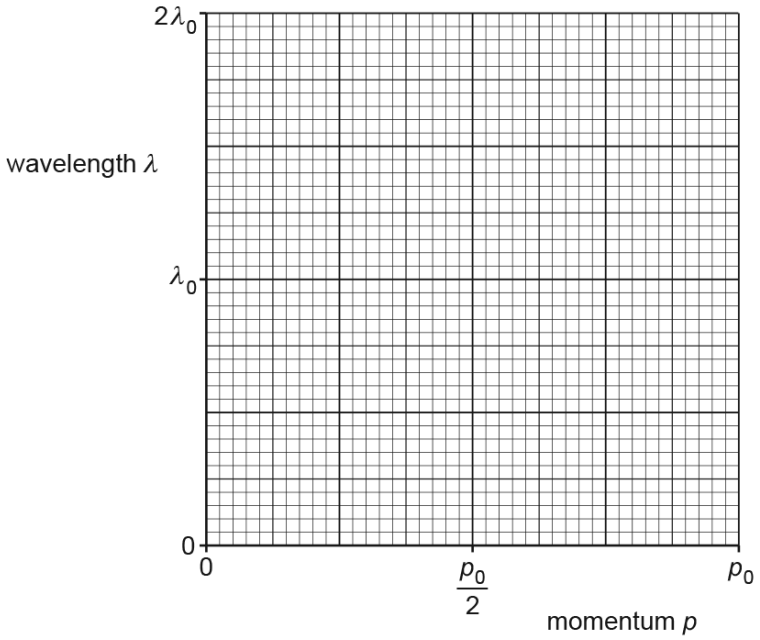


Fig. 6.2

[2]

(c) A radioactive isotope decays with a half-life of 15 s to form a stable product.

A fresh sample of the radioactive isotope at time $t = 0$ contains N_0 nuclei and no nuclei of the stable product.

On Fig. 6.3, sketch the variation with t of the number n of nuclei of the stable product for time $t = 0$ to time $t = 45$ s.

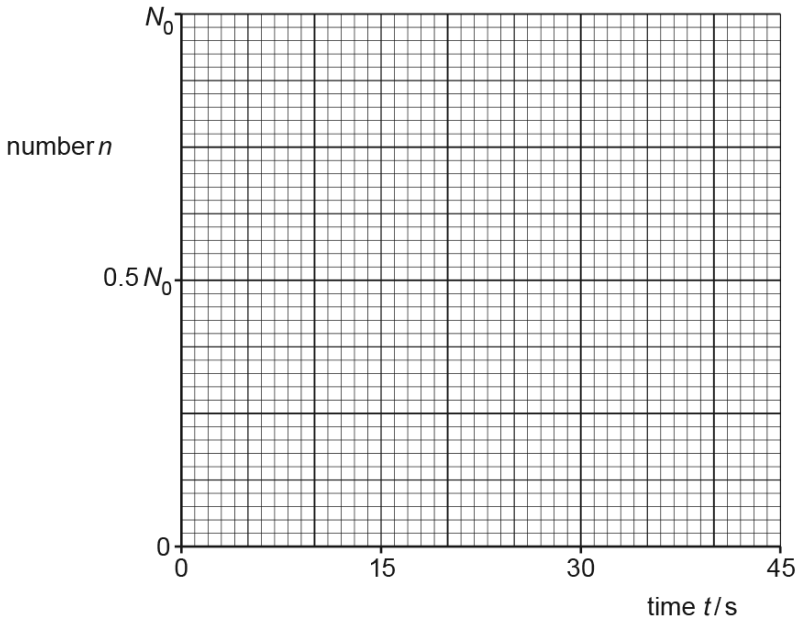


Fig. 6.3

[3]

[Total: 8]

415. 9702_s21_qp_42 Q: 5

(a) An isolated metal sphere of radius r is charged so that the electric potential at its surface is V_0.

On Fig. 5.1, sketch the variation with distance x from the centre of the sphere of the electric potential. Your graph should extend from $x = 0$ to $x = 3r$.

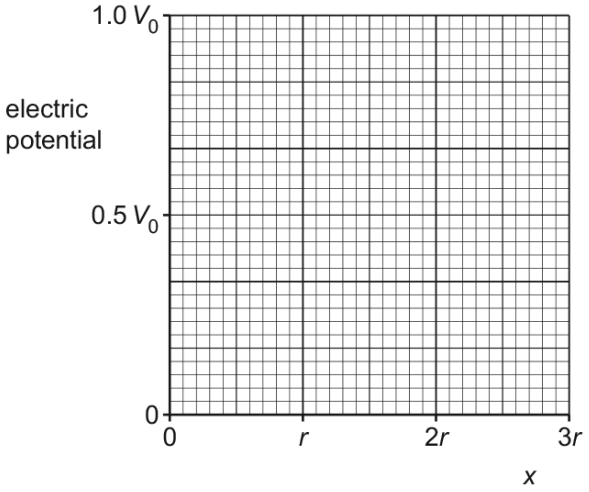


Fig. 5.1

[3]

(b) Photons having wavelength λ are incident on a metal surface.
The maximum wavelength for which there is emission of electrons is λ_0.
For photons of wavelength $\frac{\lambda_0}{2}$, the maximum kinetic energy of the emitted electrons is E_{MAX}.

On Fig. 5.2, sketch the variation with wavelength λ of the maximum kinetic energy for values of wavelength between $\lambda = \frac{\lambda_0}{3}$ and $\lambda = \lambda_0$.

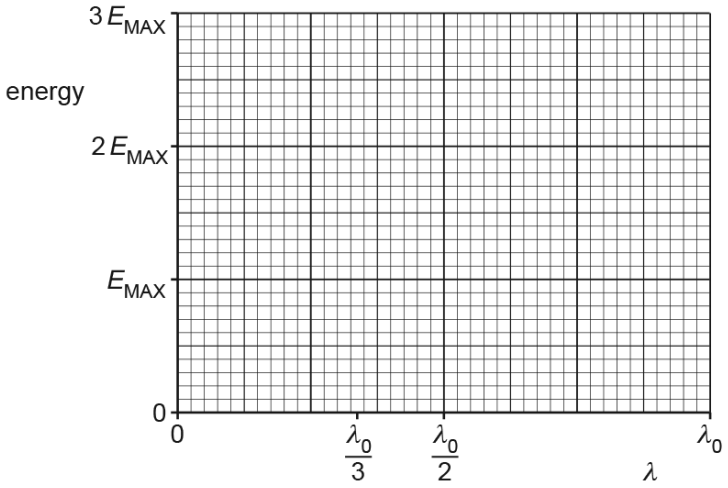


Fig. 5.2

[3]

(c) A pure sample of a radioactive isotope contains N_0 nuclei. The half-life of the isotope is $T_{\frac{1}{2}}$. The product of the radioactive decay is stable.

The variation with time t of the number N of nuclei of the radioactive isotope is shown in Fig. 5.3.

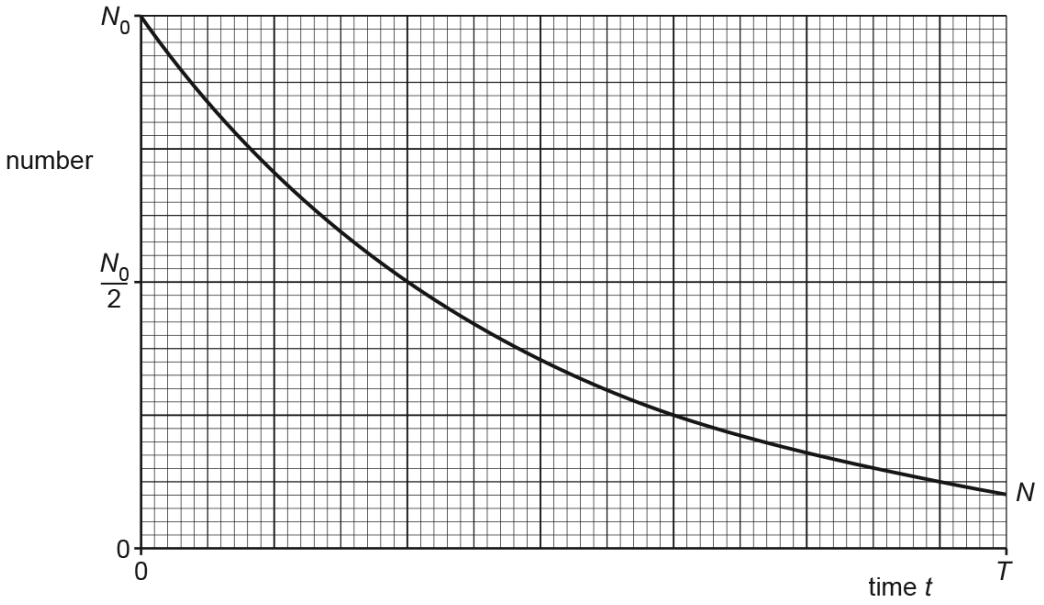


Fig. 5.3

On Fig. 5.3:

- label, on the time axis, the time $t = 1.0T_{\frac{1}{2}}$ and the time $t = 2.0T_{\frac{1}{2}}$
- sketch the variation with time t of the number of nuclei of the decay product for time $t = 0$ to time $t = T$.

[3]

[Total: 9]

416. 9702_s21_qp_43 Q: 6

(a) An isolated metal sphere of radius r is charged so that the electric field strength at its surface is E_0.

On Fig. 6.1, sketch the variation of the electric field strength E with distance x from the centre of the sphere. Your sketch should extend from $x = 0$ to $x = 3r$.

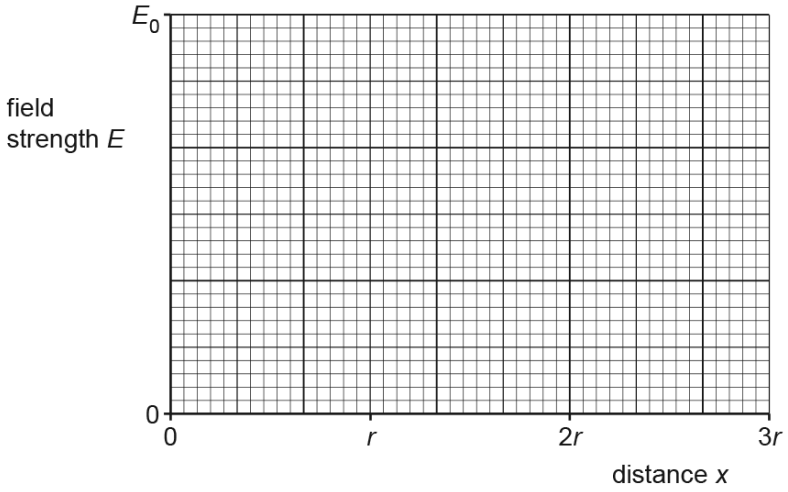


Fig. 6.1

[3]

(b) The de Broglie wavelength of a particle is λ_0 when its momentum is p_0.

On Fig. 6.2, sketch the variation with momentum p of the de Broglie wavelength λ of the particle for values of momentum from $\frac{p_0}{2}$ to p_0.

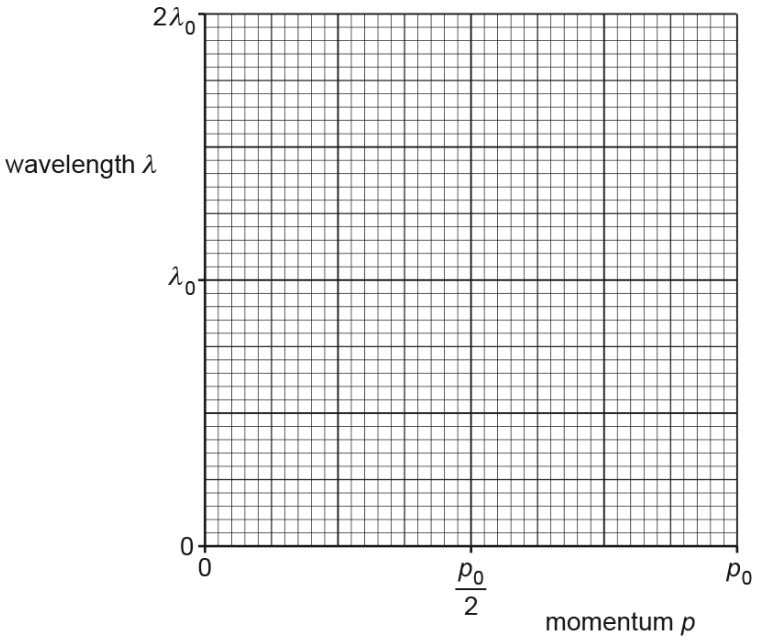


Fig. 6.2

[2]

(c) A radioactive isotope decays with a half-life of 15 s to form a stable product.

A fresh sample of the radioactive isotope at time $t = 0$ contains N_0 nuclei and no nuclei of the stable product.

On Fig. 6.3, sketch the variation with t of the number n of nuclei of the stable product for time $t = 0$ to time $t = 45$ s.

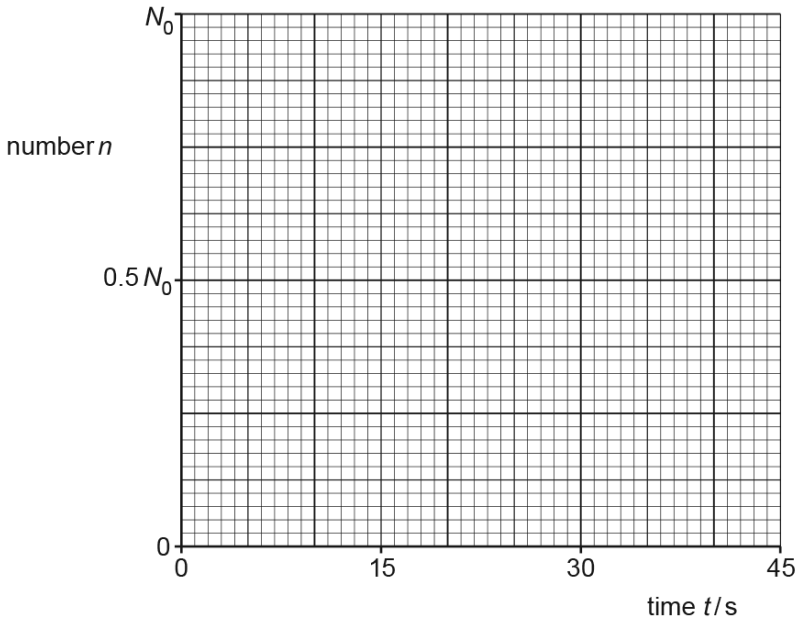


Fig. 6.3

[3]

[Total: 8]

417. 9702_w21_qp_41 Q: 12

(a) Define radioactive *decay constant*.

.....

.....

..... [2]

(b) A sample of radioactive iodine-131 ($^{131}_{53}\mathrm{I}$) of mass 5.87×10^{-10} kg has an activity of 2.92×10^{9} Bq.

Determine the decay constant of iodine-131.

decay constant = ... s^{-1} [3]

(c) Suggest **two** reasons why a detector placed near to the sample in **(b)** would record a count rate much less than 2.92×10^{9} counts per second.

1. .....

.....

2. .....

.....
[2]

[Total: 7]

---

418. 9702_w21_qp_42 Q: 12

(a) Radioactive decay is both random and spontaneous.

State what is meant by:

(i) *random*

.....

..... [1]

(ii) *spontaneous*.

.....

..... [1]

(b) A sample of radioactive material contains atoms of an unstable nuclide X. The activity of the sample due to the atoms of X is A. The variation with time t of ln A is shown in Fig. 12.1.

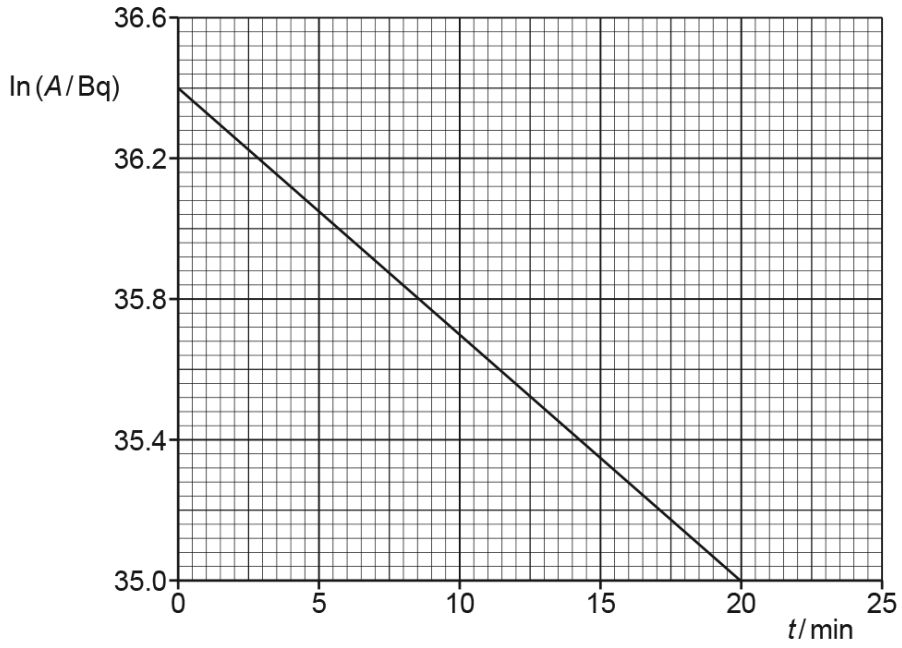


Fig. 12.1

(i) Use Fig. 12.1 to determine the half-life, in minutes, of nuclide X.

half-life = ... min [3]

(ii) At time $t = 0$, the mass of the atoms of X in the sample is 5.66×10^{-7} kg.

Determine the nucleon number of X.

nucleon number = ... [3]

[Total: 8]

---

419. 9702_w21_qp_43 Q: 12

(a) Define radioactive *decay constant*.

.....

.....

..... [2]

(b) A sample of radioactive iodine-131 ($^{131}_{53}\mathrm{I}$) of mass 5.87×10^{-10} kg has an activity of 2.92×10^{9} Bq.

Determine the decay constant of iodine-131.

decay constant = ... s^{-1} [3]

(c) Suggest **two** reasons why a detector placed near to the sample in **(b)** would record a count rate much less than 2.92×10^{9} counts per second.

1. .....

.....

2. .....

.....

[2]

[Total: 7]

420. 9702_m20_qp_42 Q: 12

(a) Explain what is meant by the *binding energy* of a nucleus.

.....

.....

..... [2]

(b) The following nuclear reaction takes place:

$$^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{144}_{55}Cs + {}^{90}_{x}Rb + y\,{}^{1}_{0}n$$

(i) Determine the values of x and y.

x = ...

y = ...
[1]

(ii) State the name of this type of nuclear reaction.

..... [1]

(iii) Compare the binding energy per nucleon of uranium-235 with the binding energy per nucleon of caesium-144.

.....

..... [1]

(c) Yttrium-90 decays into zirconium-90, a stable isotope.

A sample initially consists of pure yttrium-90.

Calculate the time, in days, when the ratio of the number of yttrium-90 nuclei to the number of zirconium-90 nuclei would be 2.0.

The half-life of yttrium-90 is 2.7 days.

time = ... days [3]

[Total: 8]

421. 9702_s20_qp_41 Q: 12

(a) The decay of a sample of a radioactive isotope is said to be random and spontaneous.

Explain what is meant by the decay being:

(i) *random*

.....

..... [1]

(ii) *spontaneous*.

.....

..... [1]

(b) A radioactive isotope X has a half-life of 1.4 hours.

Initially, a pure sample of this isotope X has an activity of 3.6×10^5 Bq.

Determine the activity of the isotope X in the sample after a time of 2.0 hours.

activity = ... Bq [3]

(c) The variation with time t of the actual activity A of the sample in **(b)** is shown in Fig. 12.1.

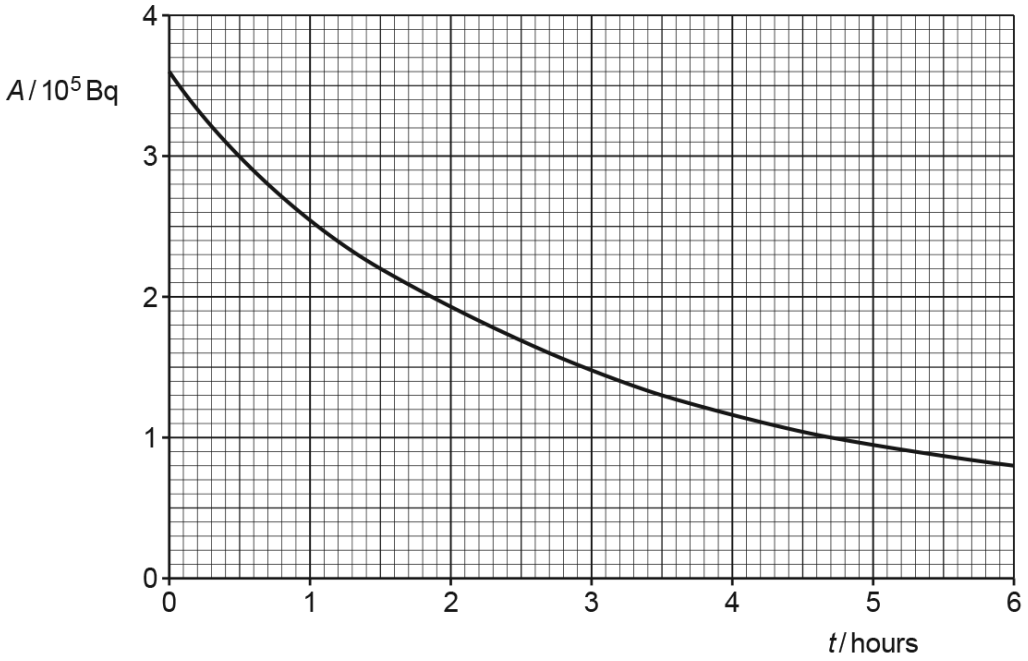


Fig. 12.1

(i) The initial activity of isotope X in the sample is 3.6×10^5 Bq.

Use information from **(b)** to sketch, on the axes of Fig. 12.1, the variation with time t of the activity of a pure sample of isotope X. [1]

(ii) Suggest an explanation for any difference between the actual activity of the sample shown in Fig. 12.1 and the curve you have drawn for the activity of isotope X.

.....

.....

..... [2]

[Total: 8]

422. 9702_s20_qp_43 Q: 12

(a) The decay of a sample of a radioactive isotope is said to be random and spontaneous.

Explain what is meant by the decay being:

(i) *random*

.....

..... [1]

(ii) *spontaneous*.

.....

..... [1]

(b) A radioactive isotope X has a half-life of 1.4 hours.

Initially, a pure sample of this isotope X has an activity of 3.6×10^5 Bq.

Determine the activity of the isotope X in the sample after a time of 2.0 hours.

activity = ... Bq [3]

(c) The variation with time t of the actual activity A of the sample in **(b)** is shown in Fig. 12.1.

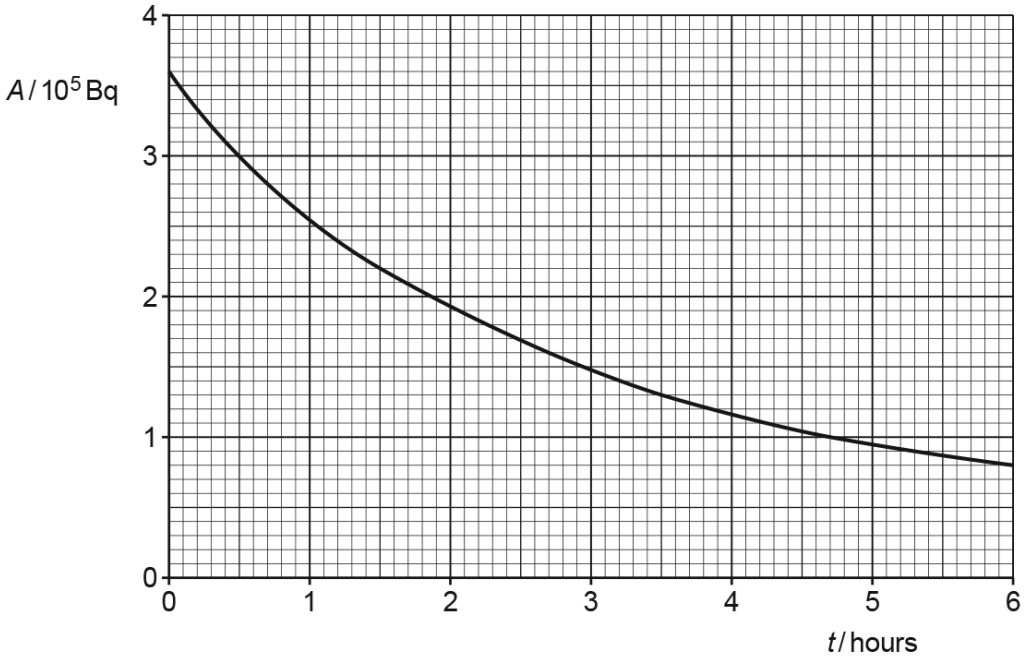


Fig. 12.1

(i) The initial activity of isotope X in the sample is 3.6×10^5 Bq.

Use information from **(b)** to sketch, on the axes of Fig. 12.1, the variation with time t of the activity of a pure sample of isotope X. [1]

(ii) Suggest an explanation for any difference between the actual activity of the sample shown in Fig. 12.1 and the curve you have drawn for the activity of isotope X.

.....

.....

..... [2]

[Total: 8]

423. 9702_s19_qp_41 Q: 12

(a) A sample of a radioactive isotope contains N nuclei of the isotope at time T.
At time $(T + \Delta T)$, the sample contains $(N - \Delta N)$ nuclei of the isotope. The time interval ΔT is short.

Use the symbols N, ΔN, T and ΔT to give expressions for:

(i) the average activity of the sample during the time ΔT

..... [1]

(ii) the probability of decay of a nucleus in the time ΔT

..... [1]

(iii) the decay constant λ of the isotope.

..... [1]

(b) The isotope polonium-208 ($^{208}_{84}$Po) is radioactive and decays to form lead-204 ($^{204}_{82}$Pb).
The nuclear equation for this decay is

$$^{208}_{84}\text{Po} \longrightarrow {}^{204}_{82}\text{Pb} + {}^{4}_{2}\text{He}.$$

Data for nuclear masses are given in Fig. 12.1.

	mass/u
$^{4}_{2}$He	4.002603
$^{204}_{82}$Pb	203.973043
$^{208}_{84}$Po	207.981245

Fig. 12.1

(i) Determine, for the decay of one nucleus of polonium-208:

1. the change, in u, of the mass

mass change = ... u [1]

2. the total energy, in pJ, released.

energy = ... pJ [3]

(ii) The polonium-208 nucleus is initially stationary. The initial kinetic energy of the $^{4}_{2}$He nucleus (α-particle) is found to be less than the energy calculated in **(i) part 2**.

Suggest **two** possible reasons for this difference.

1. .....

.....

2. .....

.....

[2]

[Total: 9]

424. 9702_s19_qp_42 Q: 12

(a) State what is meant by the *binding energy* of a nucleus.

.....

.....

.....[2]

(b) Some masses are shown in Fig. 12.1.

	mass/u
proton ($^{1}_{1}$p)	1.007
neutron ($^{1}_{0}$n)	1.009
lanthanum-141 ($^{141}_{57}$La) nucleus	140.911

Fig. 12.1

Calculate the binding energy of a nucleus of lanthanum-141.

binding energy = ... J [4]

(c) The nuclide lanthanum-141 ($^{141}_{57}$La) has a half-life of 3.9 hours.

Initially, a radioactive source contains only lanthanum-141. The initial activity of the source is A_0.

(i) Calculate the time for the activity of the lanthanum-141 to be reduced to $0.40A_0$.

time = ... hours [3]

(ii) Suggest why the total activity of the radioactive source measured at the time calculated in **(i)** may be greater than $0.40A_0$.

.....

.....[1]

[Total: 10]

---

425. 9702_s19_qp_43 Q: 12

(a) A sample of a radioactive isotope contains N nuclei of the isotope at time T.
At time $(T + \Delta T)$, the sample contains $(N - \Delta N)$ nuclei of the isotope. The time interval ΔT is short.

Use the symbols N, ΔN, T and ΔT to give expressions for:

(i) the average activity of the sample during the time ΔT

..... [1]

(ii) the probability of decay of a nucleus in the time ΔT

..... [1]

(iii) the decay constant λ of the isotope.

..... [1]

(b) The isotope polonium-208 ($^{208}_{84}$Po) is radioactive and decays to form lead-204 ($^{204}_{82}$Pb).
The nuclear equation for this decay is

$$^{208}_{84}\text{Po} \longrightarrow {}^{204}_{82}\text{Pb} + {}^{4}_{2}\text{He}.$$

Data for nuclear masses are given in Fig. 12.1.

	mass/u
$^{4}_{2}$He	4.002603
$^{204}_{82}$Pb	203.973043
$^{208}_{84}$Po	207.981245

Fig. 12.1

(i) Determine, for the decay of one nucleus of polonium-208:

1. the change, in u, of the mass

mass change = ... u [1]

2. the total energy, in pJ, released.

energy = ... pJ [3]

(ii) The polonium-208 nucleus is initially stationary. The initial kinetic energy of the $^{4}_{2}$He nucleus (α-particle) is found to be less than the energy calculated in **(i) part 2**.

Suggest **two** possible reasons for this difference.

1. .....

.....

2. .....

.....

[2]

[Total: 9]

426. 9702_w19_qp_42 Q: 12

Radon-222 ($^{222}_{86}$Ra) is a radioactive gas that decays randomly with a decay constant of 7.55×10^{-3} hour^{-1}.

(a) State what is meant by:

(i) *random* decay

.....

..... [1]

(ii) *decay constant*.

.....

.....

..... [2]

(b) The activity of radon gas in a sample of $4.80 \times 10^{-3}\,m^3$ of air taken from a building is 0.600 Bq.

There are 2.52×10^{25} air molecules in a volume of $1.00\,m^3$ of air.

Calculate, for $1.00\,m^3$ of the air, the ratio

$$\frac{\text{number of air molecules}}{\text{number of radon atoms}}.$$

ratio = ... [5]

[Total: 8]

427. 9702_m18_qp_42 Q: 13

(a) (i) Define radioactive *decay constant*.

.....

.....

.....[2]

(ii) Show that the decay constant λ is related to the half-life $t_{\frac{1}{2}}$ of a radioactive isotope by the expression

$$\lambda t_{\frac{1}{2}} = \ln 2$$

[2]

(b) A small volume of solution containing the radioactive isotope sodium-24 ($^{24}_{11}$Na) has an initial activity of 3.8×10^4 Bq. Sodium-24, of half-life 15 hours, decays to form a stable daughter isotope.

All of the solution is poured into a container of water. After 36 hours, a sample of water of volume 5.0 cm^3, taken from the container, is found to have an activity of 1.2 Bq.

Assuming that the solution of the radioactive isotope is distributed uniformly throughout the container of water, calculate the volume of water in the container.

volume = ... cm^3 [4]

[Total: 8]

428. 9702_s18_qp_41 Q: 13

(a) State what is meant by *radioactive decay*.

.....

.....

.....

.....[2]

(b) The variation with time t of the number N of technetium-101 nuclei in a sample of radioactive material is shown in Fig. 13.1.

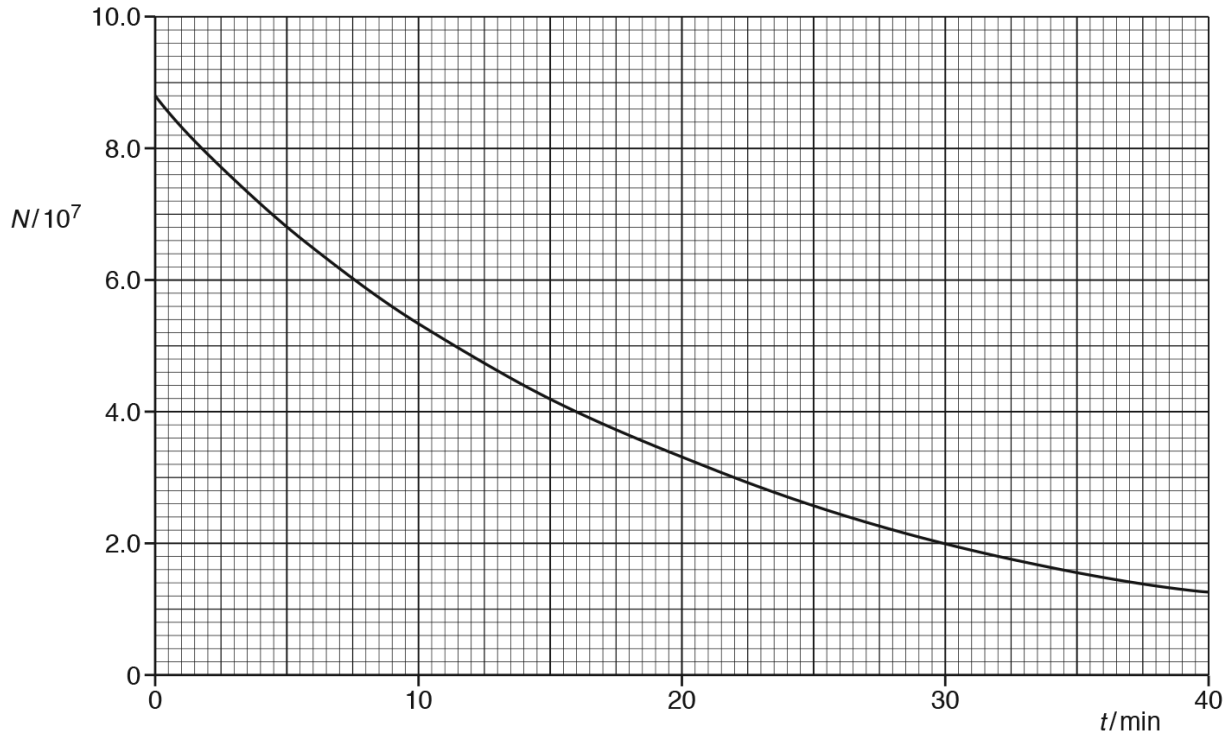


Fig. 13.1

(i) Use Fig. 13.1 to determine the activity, in Bq, of the sample of technetium-101 at time $t = 14.0$ minutes. Show your working.

activity = ... Bq [4]

(ii) Without calculating the half-life of technetium-101, use your answer in **(i)** to determine the decay constant λ of technetium-101.

λ = ... s^{-1} [2]

[Total: 8]

---

429. 9702_s18_qp_42 Q: 12

(a) State what is meant by *radioactive decay*.

.....

.....

.....

.....[2]

(b) An unstable nuclide P has decay constant λ_P and decays to form a nuclide D.
This nuclide D is unstable and decays with decay constant λ_D to form a stable nuclide S. The decay chain is illustrated in Fig. 12.1.

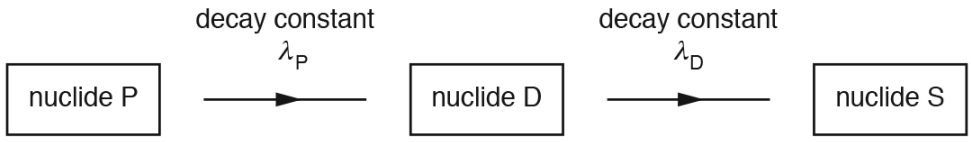


Fig. 12.1

The symbols P, D and S are not the nuclide symbols.

Initially, a radioactive sample contains only nuclide P.

The variation with time *t* of the number of nuclei of each of the three nuclides in the sample is shown in Fig. 12.2.

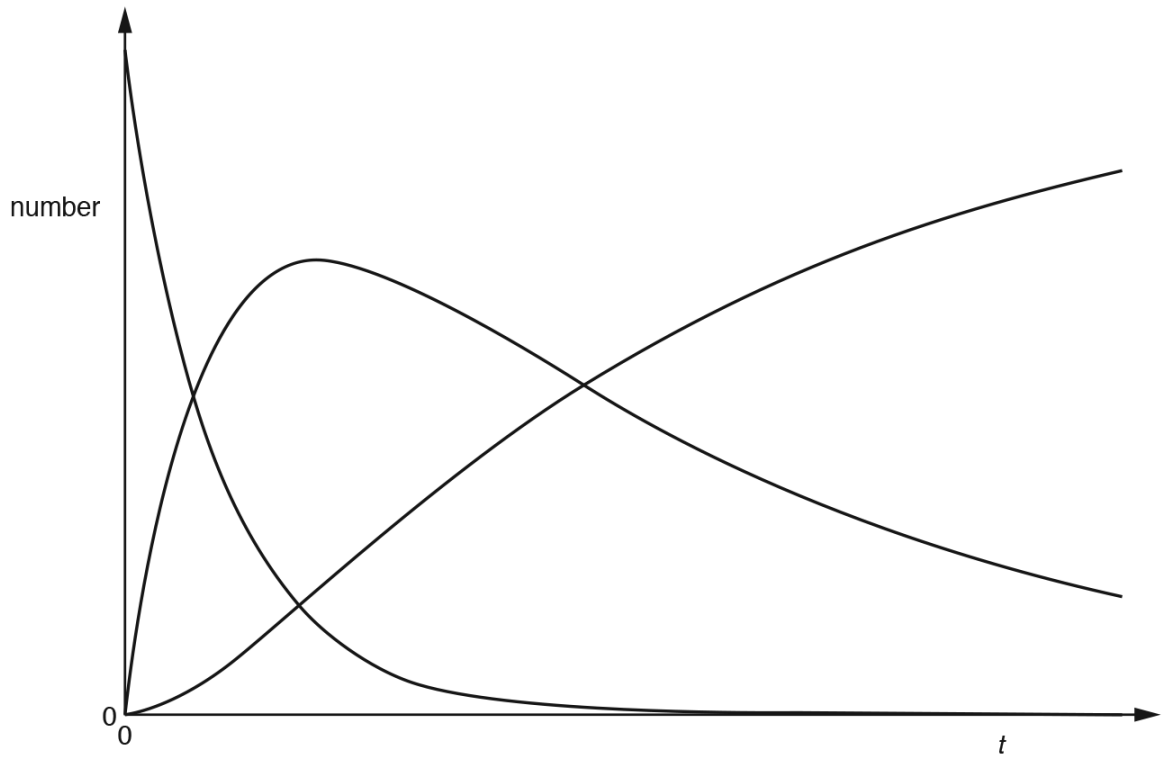


Fig. 12.2

(i) On Fig. 12.2, use the symbols P, D and S to identify the curve for each of the three nuclides. [2]

(ii) The half-life of nuclide P is 60.0 minutes.

Calculate the decay constant λ_P, in s^{-1}, of this nuclide.

λ_P = ... s^{-1} [2]

(c) In the decay chain shown in Fig. 12.1, λ_P is approximately equal to $5\lambda_D$.

The decay chain of a different nuclide E is illustrated in Fig. 12.3.

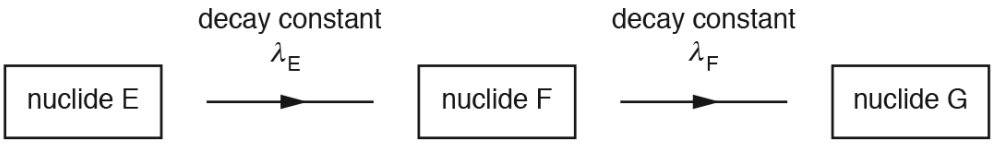


Fig. 12.3

The decay constant λ_F of nuclide F is very much larger than the decay constant λ_E of nuclide E.

By reference to the half-life of nuclide F, explain why the number of nuclei of nuclide F in the sample is always small.

.....

.....

.....[2]

[Total: 8]

430. 9702_s18_qp_43 Q: 13

(a) State what is meant by *radioactive decay*.

.....

.....

.....

.....[2]

(b) The variation with time t of the number N of technetium-101 nuclei in a sample of radioactive material is shown in Fig. 13.1.

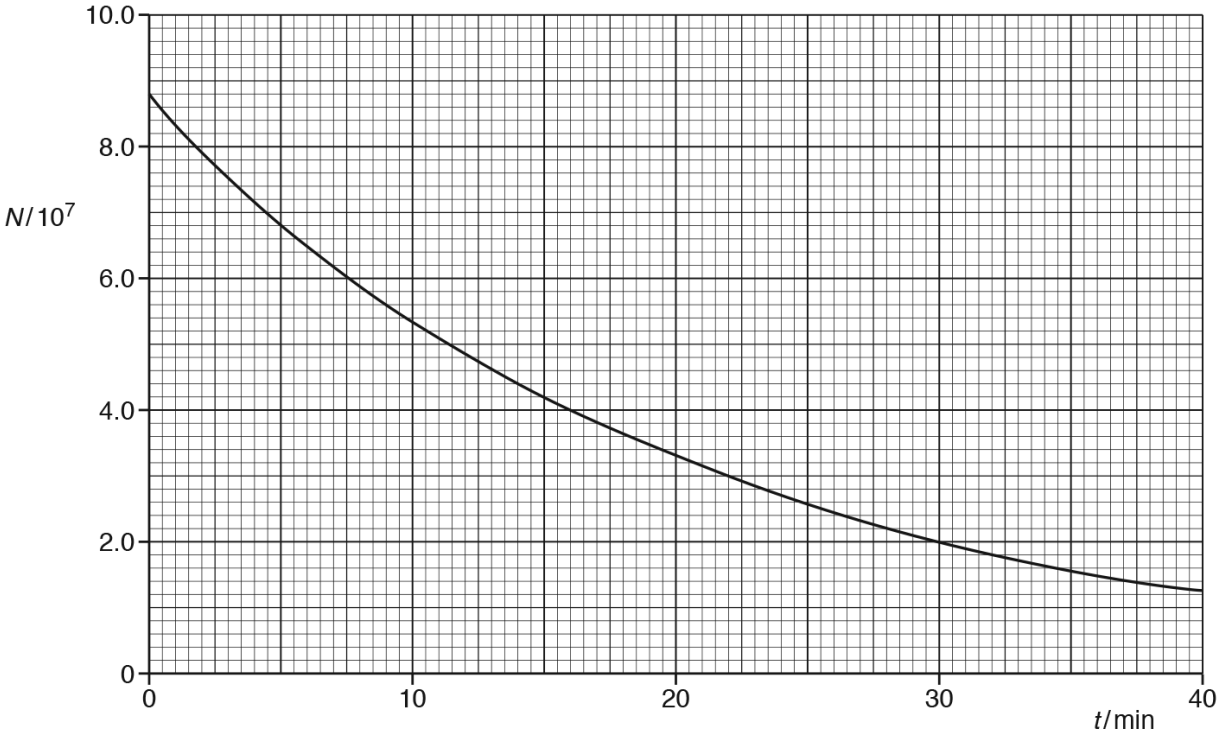


Fig. 13.1

(i) Use Fig. 13.1 to determine the activity, in Bq, of the sample of technetium-101 at time $t = 14.0$ minutes. Show your working.

activity = ... Bq [4]

(ii) Without calculating the half-life of technetium-101, use your answer in **(i)** to determine the decay constant λ of technetium-101.

λ = ... s^{-1} [2]

[Total: 8]

---

431. 9702_w18_qp_41 Q: 12

(a) State what is meant by *radioactive decay*.

.....

.....

.....

.....[3]

(b) The variation with time t of the number N of undecayed nuclei in a sample of a radioactive isotope is shown in Fig. 12.1.

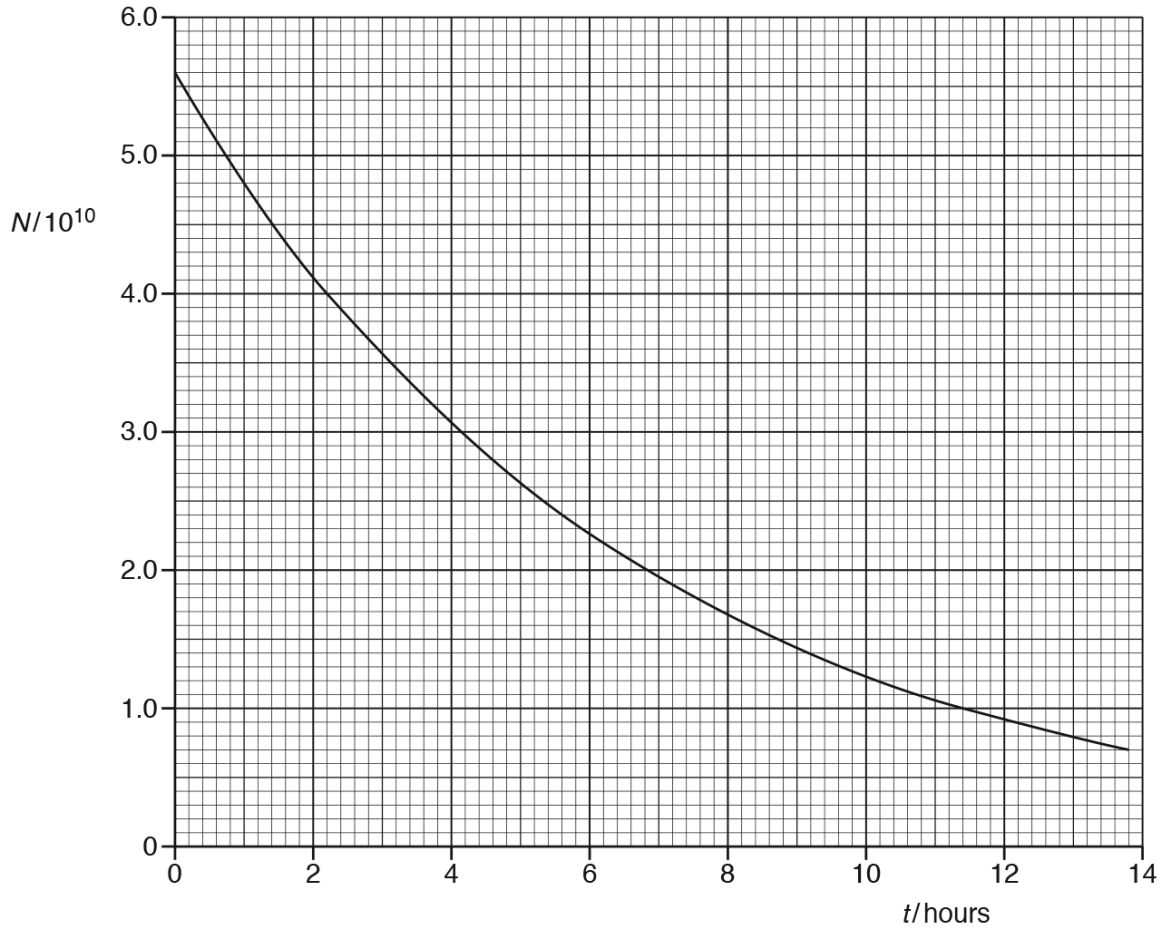


Fig. 12.1

(i) Use the gradient of the line in Fig. 12.1 to determine the activity, in Bq, of the sample at time $t = 4.0$ hours. Show your working.

activity = ... Bq [3]

(ii) Use your answer in **(i)** to show that the decay constant λ of the isotope is approximately $4 \times 10^{-5}\,s^{-1}$.

[2]

(c) A sample of a different radioactive isotope has an initial activity of 4.6×10^{3} Bq. The sample must be stored safely until its activity is reduced to 1.0×10^{3} Bq.

The decay constant of the isotope is $5.5 \times 10^{-7}\,s^{-1}$. The decay products are not radioactive.

Calculate the minimum time, in days, for which the sample must be stored.

time = ... days [3]

[Total: 11]

432. 9702_w18_qp_43 Q: 12

(a) State what is meant by *radioactive decay*.

.....

.....

.....

.....[3]

(b) The variation with time t of the number N of undecayed nuclei in a sample of a radioactive isotope is shown in Fig. 12.1.

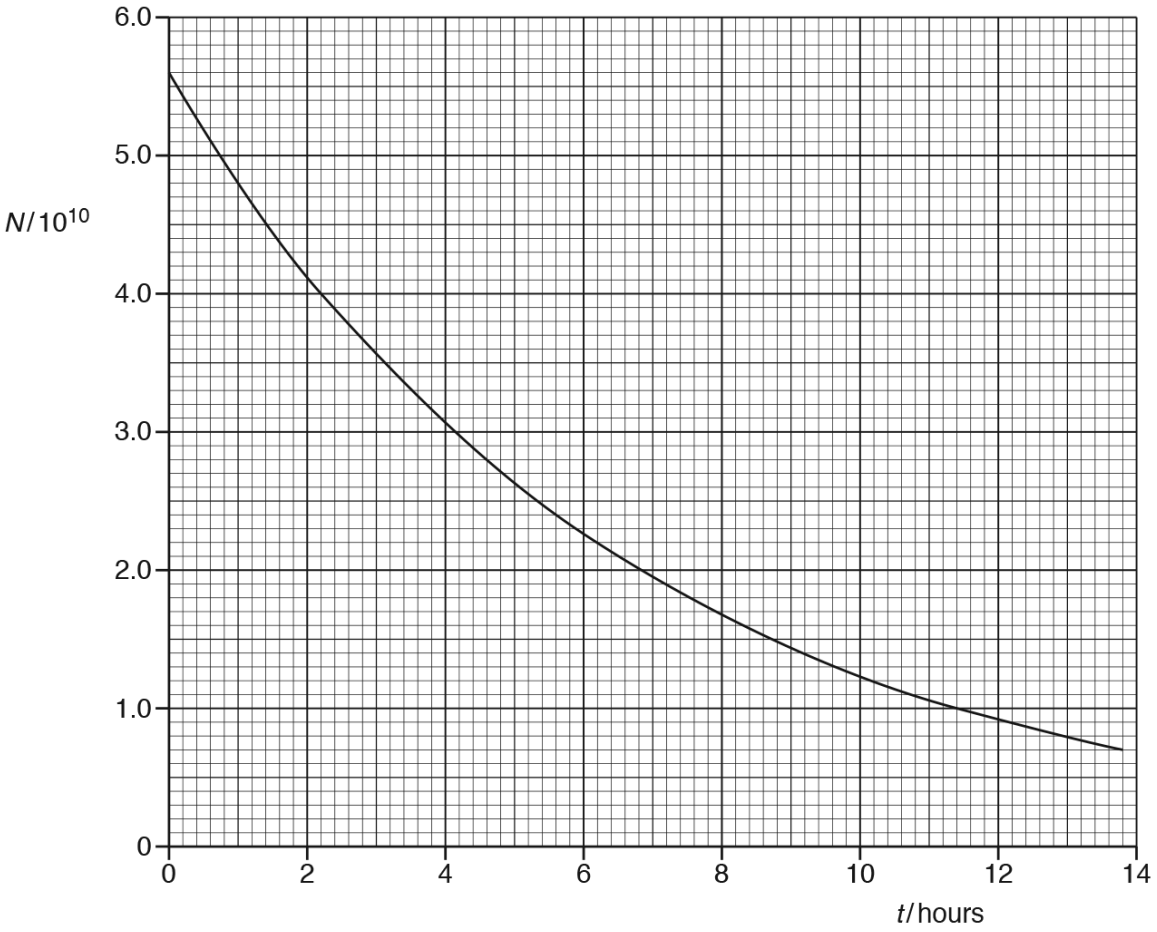


Fig. 12.1

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(i) Use the gradient of the line in Fig. 12.1 to determine the activity, in Bq, of the sample at time $t = 4.0$ hours. Show your working.

activity = ... Bq [3]

(ii) Use your answer in **(i)** to show that the decay constant λ of the isotope is approximately $4 \times 10^{-5}\,s^{-1}$.

[2]

(c) A sample of a different radioactive isotope has an initial activity of 4.6×10^{3} Bq. The sample must be stored safely until its activity is reduced to 1.0×10^{3} Bq.

The decay constant of the isotope is $5.5 \times 10^{-7}\,s^{-1}$. The decay products are not radioactive.

Calculate the minimum time, in days, for which the sample must be stored.

time = ... days [3]

[Total: 11]

(a) A radiation detector is placed close to a radioactive source. The detector does not surround the source.
Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different.

Suggest two other reasons why the activity and the measured count rate may be different.

1. .....

.....

2. .....

.....
[2]

(b) The variation with time t of the measured count rate in **(a)** is shown in Fig. 12.1.

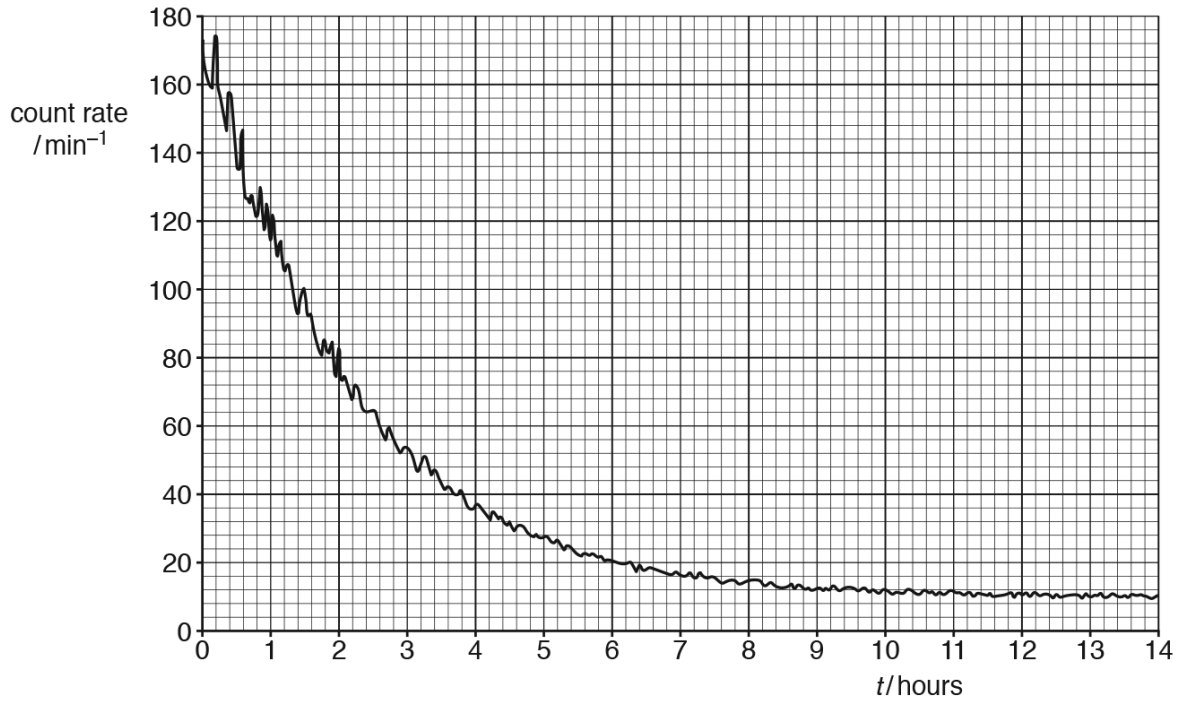


Fig. 12.1

(i) State the feature of Fig. 12.1 that indicates the random nature of radioactive decay.

.....

..... [1]

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(ii) Use Fig. 12.1 to determine the half-life of the radioactive isotope in the source.

half-life = ... hours [4]

(c) The readings in **(b)** were obtained at room temperature.
A second sample of this isotope is heated to a temperature of 500 °C.
The initial count rate at time $t = 0$ is the same as that in **(b)**.
The variation with time t of the measured count rate from the heated source is determined.

State, with a reason, the difference, if any, in

1. the half-life,

.....

.....

.....

2. the measured count rate for any specific time.

.....

.....

.....
[3]

[Total: 10]

434. 9702_w17_qp_42 Q: 12

The isotope iodine-131 ($^{131}_{53}I$) is radioactive with a decay constant of $8.6 \times 10^{-2}\,day^{-1}$.
β^- particles are emitted with a maximum energy of 0.61 MeV.

(a) State what is meant by

(i) *radioactive*,

.....

.....

.....[2]

(ii) *decay constant*.

.....

.....

.....[2]

(b) Explain why the emitted β^- particles have a range of energies.

.....

.....

.....[2]

(c) A sample of blood contains 1.2×10^{-9} g of iodine-131.

Determine, for this sample of blood,

(i) the activity of the iodine-131,

activity = ... Bq [3]

(ii) the time for the activity of the iodine-131 to be reduced to 1/50 of the activity calculated in **(i)**.

time = ... days [2]

[Total: 11]

---

435. 9702_w17_qp_43 Q: 12

(a) A radiation detector is placed close to a radioactive source. The detector does not surround the source.
Radiation is emitted in all directions and, as a result, the activity of the source and the measured count rate are different.

Suggest two other reasons why the activity and the measured count rate may be different.

1. .....

.....

2. .....

.....
[2]

(b) The variation with time t of the measured count rate in **(a)** is shown in Fig. 12.1.

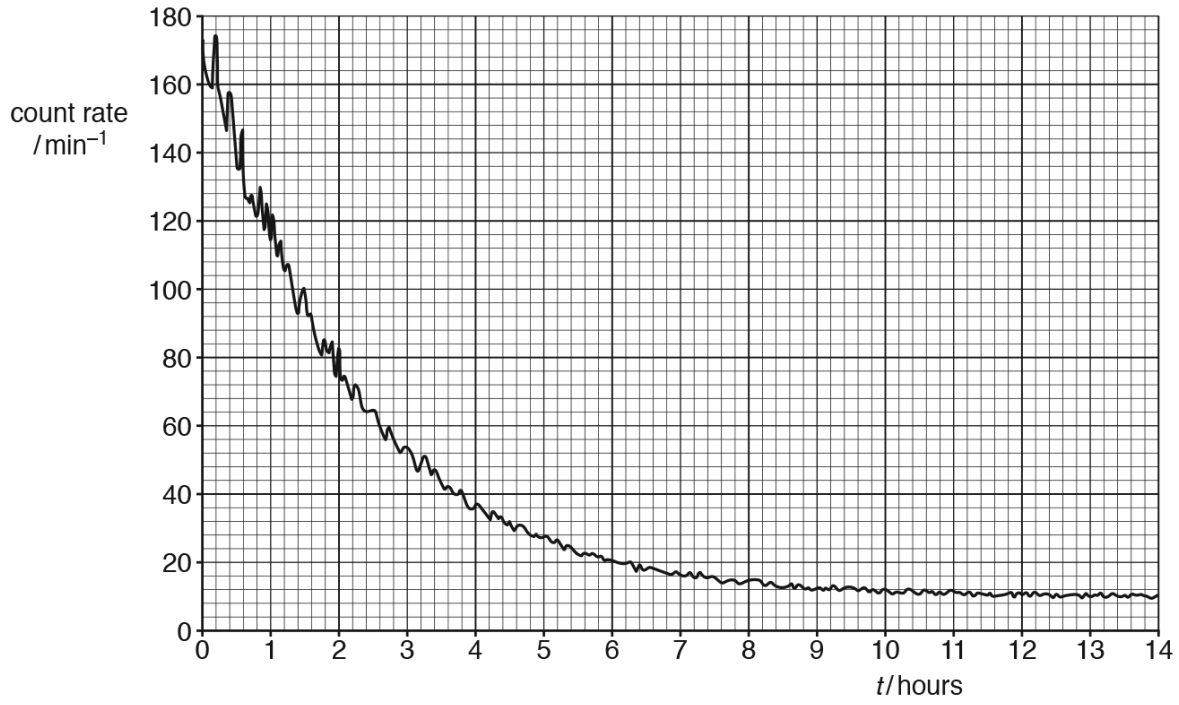


Fig. 12.1

(i) State the feature of Fig. 12.1 that indicates the random nature of radioactive decay.

.....

..... [1]

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(ii) Use Fig. 12.1 to determine the half-life of the radioactive isotope in the source.

half-life = ... hours [4]

(c) The readings in **(b)** were obtained at room temperature.
A second sample of this isotope is heated to a temperature of 500 °C.
The initial count rate at time $t = 0$ is the same as that in **(b)**.
The variation with time t of the measured count rate from the heated source is determined.

State, with a reason, the difference, if any, in

1. the half-life,

.....

.....

.....

2. the measured count rate for any specific time.

.....

.....

.....
[3]

[Total: 10]

436. 9702_m16_qp_42 Q: 13

Beryllium-7 ($^{7}_{4}$Be) is produced in the upper atmosphere and then sinks down onto the Earth's surface. Nuclei of beryllium-7 decay with a half-life of 53.3 days to form stable nuclei.

The activity of a sample of beryllium-7 on a tree leaf is 39 mBq.

(a) Show that the decay constant of beryllium-7 is $1.5 \times 10^{-7}\,s^{-1}$.

[1]

(b) Determine the mass of the beryllium-7 on the leaf.

mass = ... kg [3]

(c) The leaf is covered so that no further beryllium-7 is added to the existing sample from the atmosphere.

Calculate the time that must elapse before the activity of the sample is reduced to 2.0 mBq.

time = ... s [2]

[Total: 6]

437. 9702_w16_qp_41 Q: 12

Radon-222 ($^{222}_{86}$Rn) is a radioactive element found in atmospheric air.
The decay constant of radon-222 is $2.1 \times 10^{-6}\,s^{-1}$.

(a) (i) Define radioactive *half-life*.

.....

.....

..... [2]

(ii) Show that the half-life $t_{\frac{1}{2}}$ is related to the decay constant λ by the expression

$$\lambda t_{\frac{1}{2}} = 0.693.$$

[2]

(b) Radon-222 is considered to be an unacceptable health hazard when the activity of radon-222 is greater than 200 Bq in $1.0\,m^3$ of air.

Calculate the minimum mass of radon-222 in $1.0\,m^3$ of air above which the health hazard becomes unacceptable.

mass = ... kg [4]

[Total: 8]

438. 9702_w16_qp_43 Q: 12

Radon-222 ($^{222}_{86}$Rn) is a radioactive element found in atmospheric air.
The decay constant of radon-222 is $2.1 \times 10^{-6}\,s^{-1}$.

(a) (i) Define radioactive *half-life*.

.....

.....

..... [2]

(ii) Show that the half-life $t_{\frac{1}{2}}$ is related to the decay constant λ by the expression

$$\lambda t_{\frac{1}{2}} = 0.693.$$

[2]

(b) Radon-222 is considered to be an unacceptable health hazard when the activity of radon-222 is greater than 200 Bq in $1.0\,m^3$ of air.

Calculate the minimum mass of radon-222 in $1.0\,m^3$ of air above which the health hazard becomes unacceptable.

mass = ... kg [4]

[Total: 8]

Q1.

Use

6 (a) A student is provided with a freshly prepared sample of a radioactive material and the count rate C from the source is found to vary with time t as shown in Fig. 6.1(a).

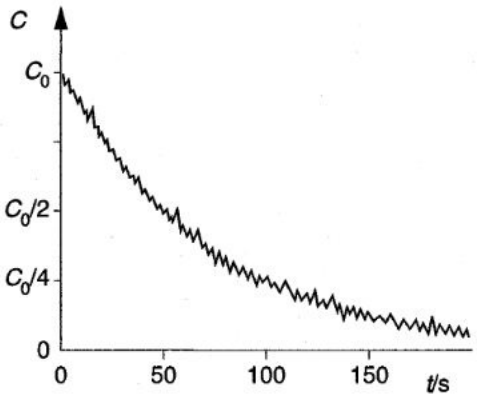


Fig. 6.1(a)

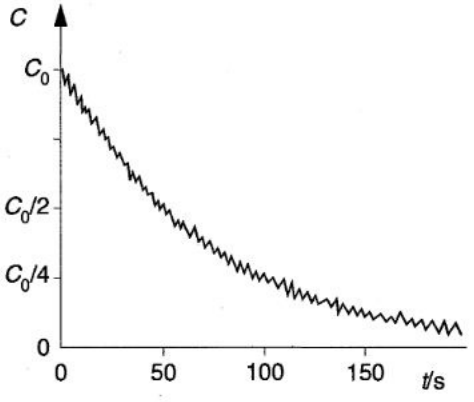


Fig. 6.1(b)

A second similar sample of the radioactive material is then prepared and the student repeats the experiment, but with the sample at a higher temperature. The variation with time of the count rate for the second sample is shown in Fig. 6.1(b).

State the evidence that is provided by these two experiments for

(i) the random nature of radioactive decay,

.....

.....

(ii) the spontaneous nature of radioactive decay.

.....

.....

[2]

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(b) The radioactive source in **(a)** is an isotope of radon ($^{220}_{86}$Rn) that emits α-radiation to become polonium (Po).

(i) State the number of neutrons in one nucleus of radon-220.

number = ... [1]

(ii) Write down a nuclear equation to represent the radioactive decay of a nucleus of radon.

$$^{220}_{86}\text{Rn} \rightarrow \underset{\ldots\ldots}{\ldots\ldots}\text{Po} + \underset{\ldots\ldots}{\ldots\ldots}$$

[3]

Q2.

8 Fig. 8.1 shows the position of Neptunium-231 ($^{231}_{93}$Np) on a diagram in which nucleon number (mass number) A is plotted against proton number (atomic number) Z.

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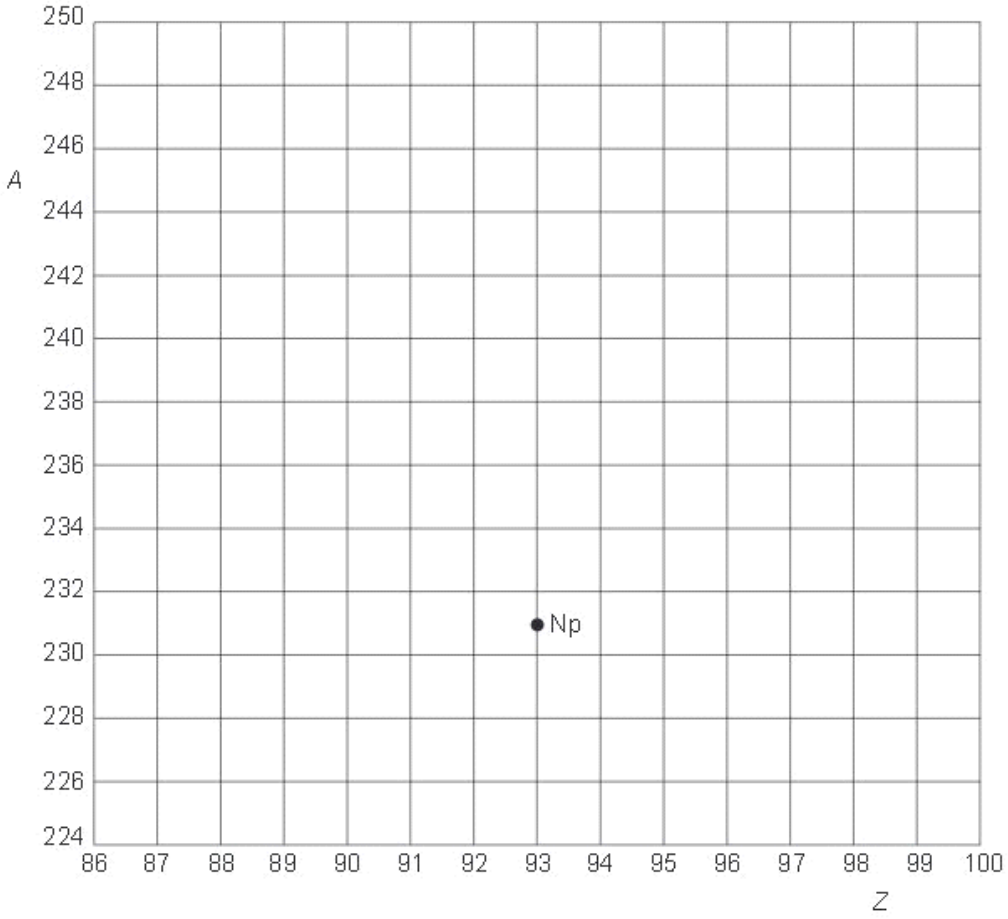


Fig. 8.1

(a) Neptunium-231 decays by the emission of an α-particle to form protactinium.
On Fig. 8.1, mark with the symbol Pa the position of the isotope of protactinium produced in this decay. [1]

(b) Plutonium-243 ($^{243}_{94}Pu$) decays by the emission of a β-particle (an electron).
On Fig. 8.1, show this decay by labelling the position of Plutonium-243 as Pu and the position of the daughter product as D. [2]

Q3.

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Use

8 The radioactive decay of nuclei is both spontaneous and random.

Explain what is meant by

(a) *radioactive decay* of a nucleus,

.....

.....

..... [2]

(b) *spontaneous* decay,

.....

.....

..... [2]

(c) *random* decay.

.....

.....

..... [2]

Q4.

7 The radioactive decay of a strontium (Sr) nucleus is represented in Fig. 7.1.

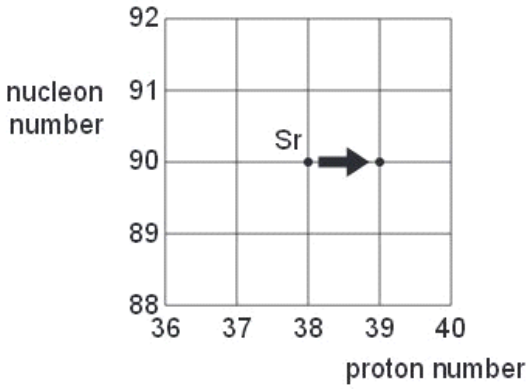


Fig. 7.1

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(a) State whether Fig. 7.1 represents α-decay, β-decay or γ-decay.

.....[1]

(b) One type of radioactive decay cannot be represented on Fig. 7.1.
Identify this decay and explain why it cannot be represented.

.....

.....

.....[2]

Q5.

7 Uranium-236 ($^{236}_{92}U$) and Uranium-237 ($^{237}_{92}U$) are both radioactive.
Uranium-236 is an α-emitter and Uranium-237 is a β-emitter.

(a) Distinguish between an α-particle and a β-particle.

.....

.....

.....

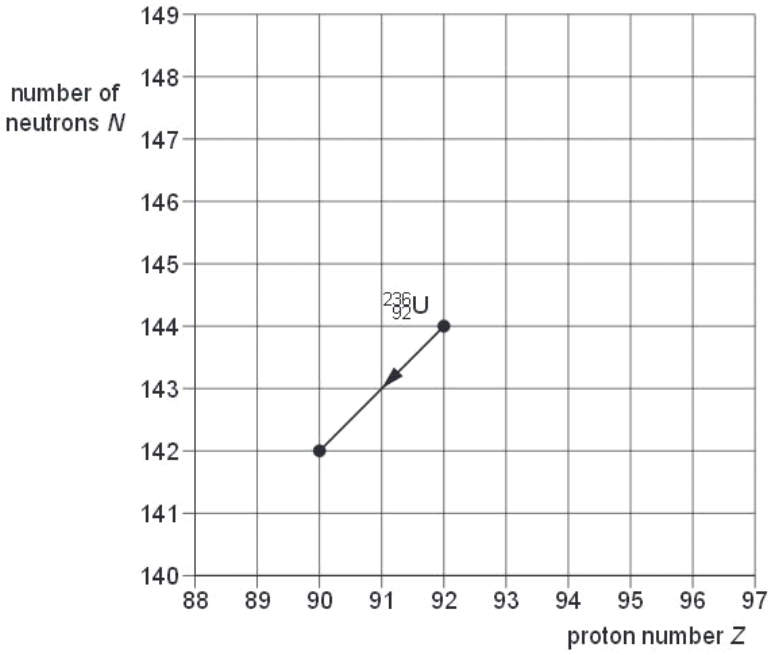
.....

.....

.....[4]

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(b) The grid of Fig. 7.1 shows some proton numbers Z on the x-axis and the number N of neutrons in the nucleus on the y-axis.



The α-decay of Uranium-236 ($^{236}_{92}U$) is represented on the grid. This decay produces a nucleus of thorium (Th).

For Examiner Use

(i) Write down the nuclear equation for this α-decay.

.....[2]

(ii) On Fig. 7.1, mark the position for a nucleus of

1. Uranium-237 (mark this position with the letter U),

2. Neptunium, the nucleus produced by the β-decay of Uranium-237 (mark this position with the letters Np). [2]

Q6.

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8 The spontaneous and random decay of a radioactive substance involves the emission of either α-radiation or β-radiation and/or γ-radiation.

(a) Explain what is meant by *spontaneous* decay.

.....

.....

..... [2]

(b) State the type of emission, one in each case, that

(i) is not affected by electric and magnetic fields,

..... [1]

(ii) produces the greatest density of ionisation in a medium,

..... [1]

(iii) does not directly result in a change in the proton number of the nucleus,

..... [1]

(iv) has a range of energies, rather than discrete values.

..... [1]

Q7.

7 One of the isotopes of uranium is uranium-238 ($^{238}_{92}U$).

(a) State what is meant by *isotopes*.

.....

.....

.....[2]

(b) For a nucleus of uranium-238, state

(i) the number of protons,

number = ... [1]

(ii) the number of neutrons.

number = ... [1]

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(c) A uranium-238 nucleus has a radius of 8.9×10^{-15} m.

Calculate, for a uranium-238 nucleus,

(i) its mass,

mass = ... kg [2]

(ii) its mean density.

density = ... kgm^{-3} [2]

(d) The density of a lump of uranium is $1.9 \times 10^{4}\,kgm^{-3}$.
Using your answer to **(c)(ii)**, suggest what can be inferred about the structure of the atom.

.....

.....

.....[2]

Q8.

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7 **(a)** The radioactive decay of some nuclei gives rise to the emission of α-particles. State

(i) what is meant by an α-particle,

.....[1]

(ii) two properties of α-particles.

1. .....

.....

2. .....

.....
[2]

(b) One possible nuclear reaction involves the bombardment of a stationary nitrogen-14 nucleus by an α-particle to form oxygen-17 and another particle.

(i) Complete the nuclear equation for this reaction.

$$^{14}_{7}\text{N} + ^{\cdots\cdots}_{\cdots\cdots}\alpha \rightarrow ^{17}_{8}\text{O} + \cdots\cdots\cdots\cdots \quad [2]$$

(ii) The total mass-energy of the nitrogen-14 nucleus and the α-particle is less than that of the particles resulting from the reaction. This mass-energy difference is 1.1 MeV.

1. Suggest how it is possible for mass-energy to be conserved in this reaction.

.....

.....[1]

2. Calculate the speed of an α-particle having kinetic energy of 1.1 MeV.

speed = ... m s^{-1} [4]

Q9.

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7 One property of α-particles is that they produce a high density of ionisation of air at atmospheric pressure. In this ionisation process, a neutral atom becomes an ion pair. The ion pair is a positively-charged particle and an electron.

Exa

(a) State

(i) what is meant by an α-particle,

.....

.....[1]

(ii) an approximate value for the range of α-particles in air at atmospheric pressure.

range = ... cm [1]

(b) The energy required to produce an ion pair in air at atmospheric pressure is 31 eV. An α-particle has an initial kinetic energy of 8.5×10^{-13} J.

(i) Show that 8.5×10^{-13} J is equivalent to 5.3 MeV.

[1]

(ii) Calculate, to two significant figures, the number of ion pairs produced as the α-particle is stopped in air at atmospheric pressure.

number = ...[2]

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(iii) Using your answer in **(a)(ii)**, estimate the average number of ion pairs produced per unit length of the track of the α-particle as it is brought to rest in air.

number per unit length = ...[2]

Q10.

7 **(a)** The spontaneous decay of polonium is shown by the nuclear equation

$$^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + \text{X}.$$

(i) State the composition of the nucleus of X.

.....

.....[1]

(ii) The nuclei X are emitted as radiation. State two properties of this radiation.

1. .....

.....

2. .....

.....

[2]

(b) The mass of the polonium (Po) nucleus is greater than the combined mass of the nuclei of lead (Pb) and X. Use a conservation law to explain qualitatively how this decay is possible.

.....

.....

.....[3]

Q11.

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7 **(a)** A nuclear reaction occurs when a uranium-235 nucleus absorbs a neutron. The reaction may be represented by the equation:

$$^{235}_{92}U + {}^{W}_{X}n \rightarrow {}^{93}_{37}Rb + {}^{141}_{Z}Cs + Y{}^{W}_{X}n$$

State the number represented by the letter

W .....

X .....

Y .....

Z .....

[3]

(b) The sum of the masses on the left-hand side of the equation in **(a)** is not the same as the sum of the masses on the right-hand side.

Explain why mass seems not to be conserved.

.....

.....

.....[2]

Q12.

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7 A radioactive source emits α-radiation and γ-radiation.

Explain how it may be shown that the source does not emit β-radiation using

(a) the absorption properties of the radiation,

.....

.....

.....

.....

.....[2]

(b) the effects of a magnetic field on the radiation.

.....

.....

.....

.....

.....[2]

Q13.

7 **(a)** Describe the two main results of the α-particle scattering experiment.

result 1: .....

.....

result 2: .....

.....

[3]

(b) Relate each of the results in **(a)** with the conclusions that were made about the nature of atoms.

result 1: .....

.....

result 2: .....

.....

[3]

Q14.

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7 A polonium nucleus $^{210}_{84}Po$ is radioactive and decays with the emission of an α-particle. The nuclear reaction for this decay is given by

$$^{210}_{84}Po \rightarrow {}^{W}_{X}Q + {}^{Y}_{Z}\alpha.$$

(a) (i) State the values of W .....

X .....

Y .....

Z .....

[2]

(ii) Explain why mass seems not to be conserved in the reaction.

.....

.....[2]

(b) The reaction is spontaneous. Explain the meaning of *spontaneous*.

.....

.....[1]

Q15.

7 **(a)** Two isotopes of uranium are uranium-235 ($^{235}_{92}U$) and uranium-238 ($^{238}_{92}U$).

(i) Describe in detail an atom of uranium-235.

.....

.....

.....

.....

.....[4]

(ii) With reference to the two forms of uranium, explain the term *isotopes*.

.....

.....

.....[2]

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(b) When a uranium-235 nucleus absorbs a neutron, the following reaction may occur:

$$^{235}_{92}\mathrm{U} + {}^{W}_{X}\mathrm{n} \rightarrow {}^{148}_{57}\mathrm{La} + {}^{Z}_{Y}\mathrm{Q} + 3{}^{W}_{X}\mathrm{n}$$

(i) Determine the values of Y and Z.

Y = ...

Z = ...

[2]

(ii) Explain why the sum of the masses of the uranium nucleus and of the neutron does not equal the total mass of the products of the reaction.

.....

.....

..... [2]

Q16.

8 A nucleus of an atom of francium (Fr) contains 87 protons and 133 neutrons.

(a) Write down the notation for this nuclide.

.....
Fr
..... [2]

(b) The nucleus decays by the emission of an α-particle to become a nucleus of astatine (At).

Write down a nuclear equation to represent this decay. [2]

Q17.

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Use

6 One isotope of iron may be represented by the symbol

$$^{56}_{26}\text{Fe}.$$

(a) State, for one nucleus of this isotope,

(i) the number of protons,

number = ...

(ii) the number of neutrons.

number = ...
[2]

(b) The nucleus of this isotope of iron may be assumed to be a sphere of radius 5.7×10^{-15} m.

Calculate, for one such nucleus,

(i) the mass,

mass = ... kg

(ii) the density.

density = ... kg m^{-3}
[4]

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(c) An iron ball is found to have a density of 7900 kgm^{-3}. By reference to your answer in **(b)(ii)**, suggest what can be inferred about the structure of an atom of iron.

.....

.....

..... [2]

Q18.

7 The α-particle scattering experiment provided evidence for the existence of a nuclear atom.

(a) State what could be deduced from the fact that

(i) most α-particles were deviated through angles of less than 10°,

.....

.....

..... [2]

(ii) a very small proportion of the α-particles was deviated through angles greater than 90°.

.....

.....

..... [2]

Q19.

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7 **(a)** Evidence for the nuclear atom was provided by the α-particle scattering experiment. State the results of this experiment.

.....

.....

.....

..... [2]

(b) Give estimates for the diameter of

(i) an atom,

.....[1]

(ii) a nucleus.

.....[1]

Q20.

8 Thoron is a radioactive gas. The variation with time t of the detected count rate C from a sample of the gas is shown in Fig. 8.1.

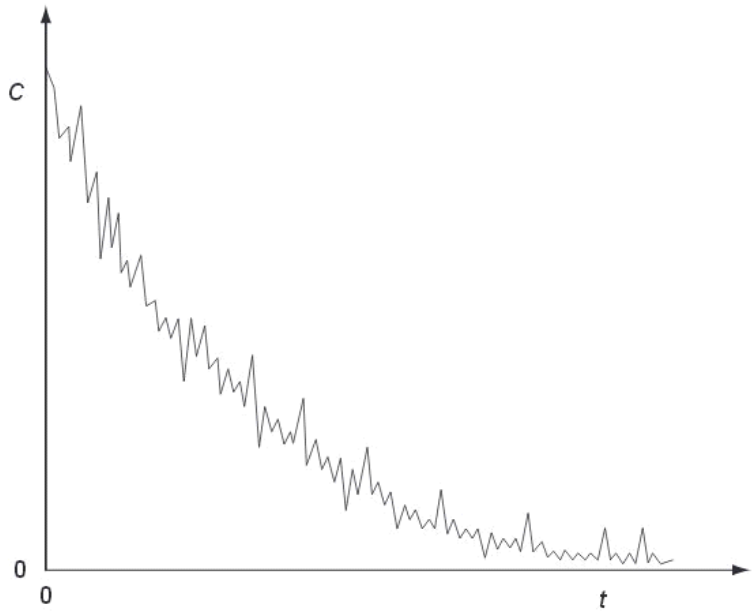


Fig. 8.1

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Radioactive decay is said to be a random and spontaneous process.

(a) Explain, by reference to radioactive decay, what is meant by a *random* process.

.....

.....

..... [2]

(b) State the feature of Fig. 8.1 which indicates that the process is

(i) a decay process,

..... [1]

(ii) random.

..... [1]

(c) A second similar sample of thoron is prepared but it is at a much higher temperature. The variation with time of the count rate for this second sample is determined. State the feature of the decay curves for the two samples that suggests that radioactive decay is a spontaneous process.

For Examiner Use

.....

..... [1]

Q21.

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7 An α-particle A approaches and passes by a stationary gold nucleus N. The path is illustrated in Fig. 7.1.

For Examiner Use

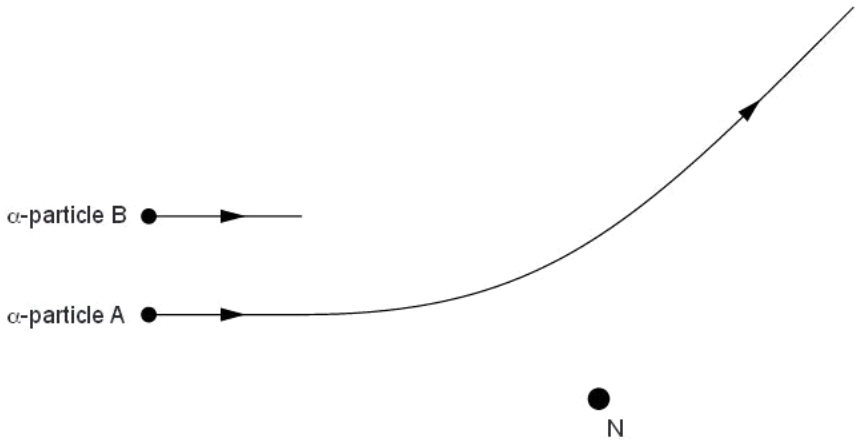


Fig. 7.1

(a) On Fig. 7.1, mark the angle of deviation *D* of this α-particle as a result of passing the nucleus N. [1]

(b) A second α-particle B has the same initial direction and energy as α-particle A.
On Fig. 7.1, complete the path of α-particle B as it approaches and passes by the nucleus N. [2]

(c) State what can be inferred about atoms from the observation that very few α-particles experience large deviations.

.....

.....

..... [2]

(d) The nucleus N could be one of several different isotopes of gold.

Suggest, with an explanation, whether different isotopes of gold would give rise to different deviations of a particular α-particle.

.....

.....

..... [2]

Q22.

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7 Tungsten-184 ($^{184}_{74}W$) and tungsten-185 ($^{185}_{74}W$) are two isotopes of tungsten.

Tungsten-184 is stable but tungsten-185 undergoes β-decay to form rhenium (Re).

(a) Explain what is meant by *isotopes*.

.....

.....

.....

..... [2]

(b) The β-decay of nuclei of tungsten-185 is spontaneous and random.

State what is meant by

(i) *spontaneous* decay,

.....

..... [1]

(ii) *random* decay.

.....

..... [1]

(c) Complete the nuclear equation for the β-decay of a tungsten-185 nucleus.

$^{185}_{74}W \rightarrow$ ..... + ... [2]

Q23.

STEMUP.CO.UK

7 **(a)** Uranium (U) has at least fourteen isotopes.
Explain what is meant by *isotopes*.

For Examiner Use

.....

.....

..... [2]

(b) One possible nuclear reaction involving uranium is

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

(i) State three quantities that are conserved in a nuclear reaction.

1. .....

.....

2. .....

.....

3. .....

.....
[3]

(ii) For this reaction, determine the value of

1. Z,

Z = ... [1]

2. x.

x = ... [1]

Q24.

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7 The results of the α-particle scattering experiment provided evidence for the existence and small size of the nucleus.

(a) State the result that provided evidence for

(i) the small size of the nucleus, compared with the atom,

.....

.....

.....[2]

(ii) the nucleus being charged and containing the majority of the mass of the atom.

.....

.....

.....[2]

(b) The α-particles in this experiment originated from the decay of a radioactive nuclide. Suggest two reasons why β-particles from a radioactive source would be inappropriate for this type of scattering experiment.

1. .....

.....

2. .....

.....

[2]

Q25.

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9 **(a)** Explain what is meant by *radioactive decay*.

.....

.....

..... [2]

(b) **(i)** State how the random nature of radioactive decay may be inferred from observations of the count rate.

.....

..... [1]

(ii) A radioactive source has a long half-life so that, over a period of several days, its rate of decay remains constant.
State the effect, if any, of a rise in temperature on this decay rate.

..... [1]

(iii) Suggest why some radioactive sources are found to contain traces of helium gas.

.....

.....

..... [2]

Q26.

7 **(a)** Two isotopes of the element uranium are $^{235}_{92}U$ and $^{238}_{92}U$.

Explain the term *isotope*.

.....

.....

..... [2]

(b) **(i)** In a nuclear reaction, proton number and neutron number are conserved. Other than proton number and neutron number, state a quantity that is conserved in a nuclear reaction.

..... [1]

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(ii) When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.

$$^{235}_{92}U + ^{a}_{b}n \longrightarrow ^{141}_{x}Ba + ^{y}_{36}Kr + 3\ ^{a}_{b}n$$

State the values of *a*, *b*, *x* and *y*.

a = ...

b = ...

x = ...

y = ...

[3]

(c) When the nucleus of $^{238}_{92}U$ absorbs a neutron, the nucleus decays, emitting an α-particle. State the proton number and nucleon number of the nucleus that is formed as a result of the emission of the α-particle.

proton number = ...

nucleon number = ...

[2]

Q27.

7 **(a)** State the experimental observations that show radioactive decay is

For Examiner's Use

(i) spontaneous,

.....

.....[1]

(ii) random.

.....

.....[1]

(b) On Fig. 7.1, complete the charge and mass of α-particles, β-particles and γ-radiation. Give example speeds of α-particles and γ-radiation emitted by a laboratory source.

	α-particle	β-particle	γ-radiation
charge			0
mass	4u		
speed		up to 0.99*c*	

Fig. 7.1

[3]

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(c) Explain the process by which α-particles lose energy when they pass through air.

.....

.....

.....[2]

Q28.

6 Two horizontal metal plates are separated by distance d in a vacuum. A potential difference V is applied across the plates, as shown in Fig. 6.1.

F Exam U

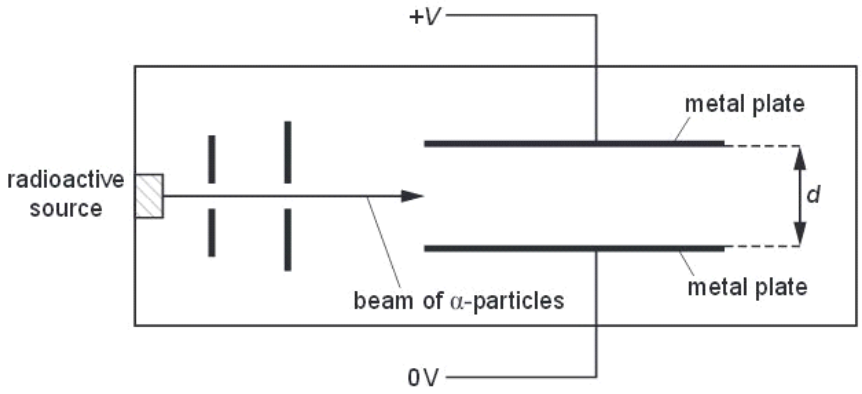


Fig. 6.1

A horizontal beam of α-particles from a radioactive source is made to pass between the plates.

A horizontal beam of α-particles from a radioactive source is made to pass between the plates.

(a) State and explain the effect on the deflection of the α-particles for each of the following changes:

(i) The magnitude of V is increased.

.....

.....[1]

(ii) The separation d of the plates is decreased.

.....

.....[1]

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(b) The source of α-particles is replaced with a source of β-particles.
Compare, with a reason in each case, the effect of each of the following properties on the deflections of α- and β-particles in a uniform electric field:

For Examiner Use

(i) charge

.....

.....

.....[2]

(ii) mass

.....

.....

.....[2]

(iii) speed

.....

.....

.....[1]

(c) The electric field gives rise to an acceleration of the α-particles and the β-particles. Determine the ratio

$$\frac{\text{acceleration of the } \alpha\text{-particles}}{\text{acceleration of the } \beta\text{-particles}}.$$

ratio = ...[3]

Q29.

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6 **(a)** Describe the structure of an atom of the nuclide $^{235}_{92}U$.

For Examiner Use

.....

.....

.....

..... [2]

(b) The deflection of α-particles by a thin metal foil is investigated with the arrangement shown in Fig. 6.1. All the apparatus is enclosed in a vacuum.

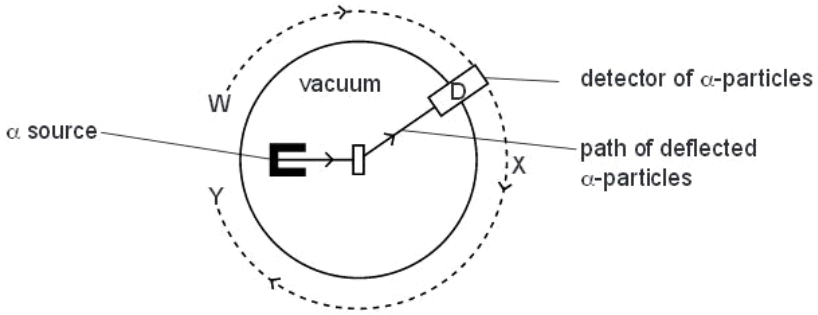


Fig. 6.1

The detector of α-particles, D, is moved around the path labelled WXY.

(i) Explain why the apparatus is enclosed in a vacuum.

.....

..... [1]

(ii) State and explain the readings detected by D when it is moved along WXY.

.....

.....

.....

.....

.....

..... [3]

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(c) A beam of α-particles produces a current of 1.5 pA. Calculate the number of α-particles per second passing a point in the beam.

number = ... s^{-1} [3]

Q30.

7 A nuclear reaction between two helium nuclei produces a second isotope of helium, two protons and 13.8 MeV of energy. The reaction is represented by the following equation.

$$^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{He} + 2\,{}^{\cdots\cdots}_{\cdots\cdots}\text{p} + 13.8\,\text{MeV}$$

(a) Complete the nuclear equation. [2]

(b) By reference to this reaction, explain the meaning of the term *isotope*.

.....

.....

.....[2]

(c) State the quantities that are conserved in this nuclear reaction.

.....

.....

.....

.....

.....[2]

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(d) Radiation is produced in this nuclear reaction.

State

(i) a possible type of radiation that may be produced,

.....[1]

(ii) why the energy of this radiation is less than the 13.8 MeV given in the equation.

.....[1]

(e) Calculate the minimum number of these reactions needed per second to produce power of 60 W.

number = ... s^{-1} [2]

Q31.

6 **(a)** β-radiation is emitted during the spontaneous radioactive decay of an unstable nucleus.

(i) State the nature of a β-particle.

..... [1]

(ii) State two properties of β-radiation.

1. .....

2. .....

[2]

(iii) Explain the meaning of *spontaneous radioactive decay*.

.....

..... [1]

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(b) The following equation represents the decay of a nucleus of hydrogen-3 by the emission of a β-particle.

Complete the equation.

$$^{3}_{1}\mathrm{H} \rightarrow \underset{\ldots\ldots}{\overset{\ldots\ldots}{\ldots\ldots}}\ \mathrm{He} + \underset{\ldots\ldots}{\overset{\ldots\ldots}{\ldots\ldots}}\ \beta$$ [2]

(c) The β-particle is emitted with an energy of 5.7×10^{3} eV.

Calculate the speed of the β-particle.

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

(d) A different isotope of hydrogen is hydrogen-2 (deuterium). Describe the similarities and differences between the atoms of hydrogen-2 and hydrogen-3.

.....

.....

..... [2]

Q32.

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7 **(a)** An electric field is set up between two parallel metal plates in a vacuum. The deflection of α-particles as they pass between the plates is shown in Fig. 7.1.

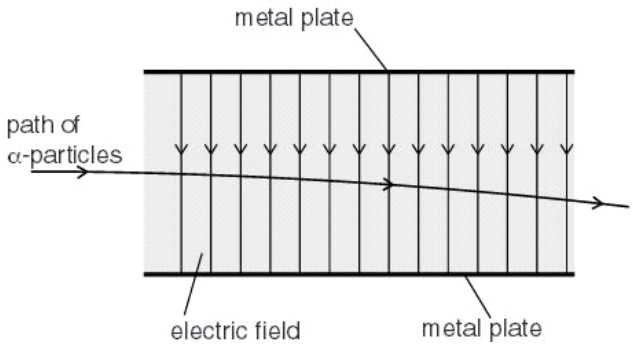


Fig. 7.1

The electric field strength between the plates is reduced. The α-particles are replaced by β-particles. The deflection of β-particles is shown in Fig. 7.2.

The electric field strength between the plates is reduced. The α-particles are replaced by β-particles. The deflection of β-particles is shown in Fig. 7.2.

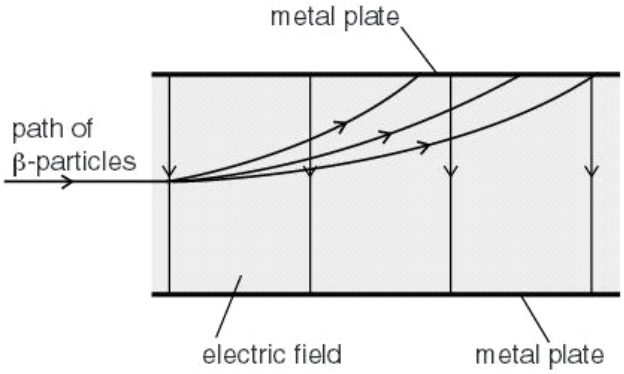


Fig. 7.2

(i) State one similarity of the electric fields shown in Fig. 7.1 and Fig. 7.2.

.....

.....[1]

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(ii) The electric field strength in Fig. 7.2 is less than that in Fig. 7.1. State two methods of reducing this electric field strength.

1. .....

2. .....

[2]

(iii) By reference to the properties of α-particles and β-particles, suggest three reasons for the differences in the deflections shown in Fig. 7.1 and Fig. 7.2.

For Examiner Use

1. .....

.....

2. .....

.....

3. .....

.....

[3]

(b) A source of α-particles is uranium-238. The nuclear reaction for the emission of α-particles is represented by

$$^{238}_{92}\mathrm{U} \rightarrow {}^{W}_{X}\mathrm{Q} + {}^{Y}_{Z}\alpha.$$

State the values of *W*.....

X .....

Y .....

Z .....

[2]

(c) A source of β-particles is phosphorus-32. The nuclear reaction for the emission of β-particles is represented by

$$^{32}_{15}\mathrm{P} \rightarrow {}^{A}_{B}\mathrm{R} + {}^{C}_{D}\beta.$$

State the values of *A* .....

B .....

C .....

D .....

[1]

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Particle Physics – 2021 AS

1. June/2021/Paper_11/No.39

A nucleus of uranium, $^{235}_{92}U$, undergoes a series of decays. During the series of decays, two α-particles and one β^- particle are emitted.

As a result, a nucleus of actinium, Ac, is formed.

What is the correct notation for the nuclide of actinium that is formed?

A $^{227}_{87}Ac$ **B** $^{227}_{89}Ac$ **C** $^{231}_{87}Ac$ **D** $^{231}_{89}Ac$

2. June/2021/Paper_11/No.40

Which particle is a fundamental particle?

A electron

B hadron

C neutron

D proton

3. June/2021/Paper_12/No.39

A nucleus of magnesium decays into a nucleus X by emitting a β^+ particle. The decay is represented by the equation shown.

$$^{23}_{12}Mg \rightarrow {}^{P}_{Q}X + {}^{0}_{1}\beta^+$$

What are the values of P and Q?

	P	Q
A	22	11
B	22	13
C	23	11
D	23	13

4. June/2021/Paper_12/No.40

In β^- decay, a neutron inside a nucleus changes to a proton.

Which statement describes the quark composition of the nucleus during the decay?

A The number of down quarks decreases by one.

B The number of down quarks increases by one.

C The number of down quarks stays the same.

D The number of up quarks stays the same.

5. Nov/2021/Paper_11/No.39

A uranium-238 nucleus, $^{238}_{92}U$, undergoes a series of nuclear decays to form uranium-234, $^{234}_{92}U$.

Which series of decays could give this result?

A emission of four β^- particles

B emission of four γ-rays

C emission of one α-particle and two β^- particles

D emission of two α-particles and eight β^- particles

6. Nov/2021/Paper_11/No.40

Which combination of up (u) and down (d) quarks forms a proton?

A u u u **B** u u d **C** u d d **D** d d d

7. Nov/2021/Paper_12/No.39

An unstable nucleus decays by emitting a β^+ particle.

Which statement is correct?

A An antineutrino is also emitted.

B A neutron changes into a proton.

C Mass–energy is conserved.

D The nucleon number is not conserved.

8. Nov/2021/Paper_12/No.40

Which statement is **not** correct?

A An antineutrino is a fundamental particle.

B An electron is made up of a quark and an antiquark.

C A neutrino is a lepton.

D A neutron is composed of three quarks.

9. Nov/2021/Paper_13/No.38

When α-particles are fired at a thin metal foil, most of the particles pass straight through but a few are deflected by a large angle.

Which change would increase the **proportion** of α-particles deflected by a large angle?

A using α-particles with greater kinetic energy

B using a double thickness foil

C using a foil made of a metal with fewer protons in its nuclei

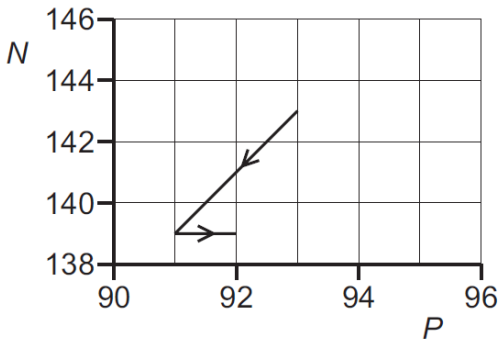
D using a source emitting more α-particles per unit time

10. Nov/2021/Paper_13/No.39

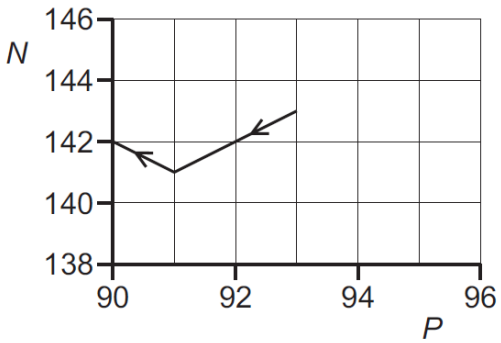
A nucleus of neptunium-236 contains 93 protons and 143 neutrons. This nucleus decays with the emission of an α-particle. The nucleus formed then emits a β^- particle.

Which diagram shows the changes in the number P of protons and the number N of neutrons in these nuclei?

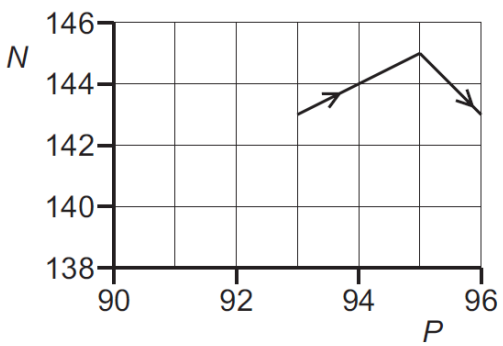
A



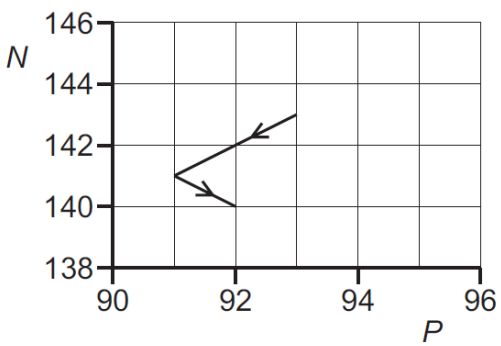
B



C



D



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11. Nov/2021/Paper_13/No.40

Which combination of quarks could **not** be the quark composition of the hadron shown?

p = proton

n = neutron

Σ^- = sigma particle of charge $-e$

Σ^+ = sigma particle of charge $+e$

u = up quark

d = down quark

s = strange quark

	hadron	quark composition
A	Σ^-	dds
B	Σ^+	uds
C	p	uud
D	n	udd

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1. Nov/2021/Paper_21/No.6

(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]

2. Nov/2021/Paper_22/No.7

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.

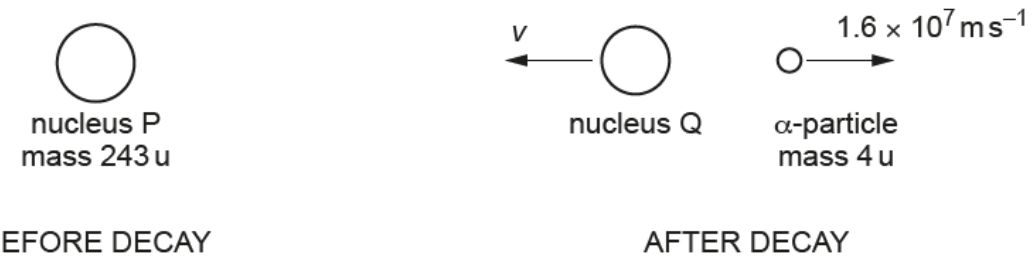


Fig. 7.1

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]

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

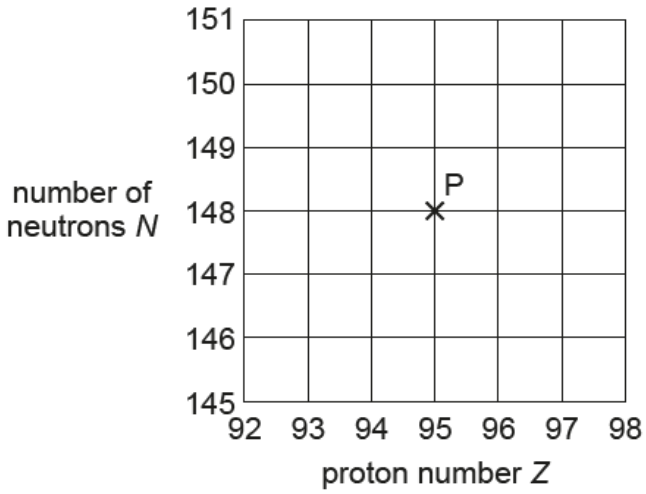


Fig. 7.2

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]

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3. June/2021/Paper_21/No.6

(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]

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(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.

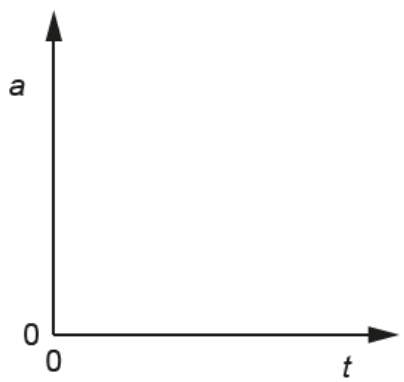


Fig. 6.1

[1]

[Total: 10]

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4. June/2021/Paper_22/No.6

(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]

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(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]

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5. June/2021/Paper_23/No.6

(a) State the quark composition of:

(i) a proton

..... [1]

(ii) a neutron

..... [1]

(iii) an alpha-particle.

.....

..... [2]

(b) In the alpha-particle scattering experiment, alpha-particles were directed at a thin gold foil.

State what may be inferred from:

(i) the observation that most alpha-particles pass through the foil

..... [1]

(ii) the observation that some alpha-particles are scattered through angles greater than 90°.

.....

.....

..... [2]

(c) A proton and an alpha-particle are moving in the same uniform electric field.

Determine the ratio

$$\frac{\text{acceleration of proton due to the electric field}}{\text{acceleration of alpha-particle due to the electric field}}.$$

ratio = ... [2]

[Total: 9]

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6. March/2021/Paper_22/No.7

(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]

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Particle Physics – 2023 June AS Physics 9702

1. June/2023/Paper_ 9702/11/No.38

A proton has mass m_p and charge $+e$.

What are the mass and charge of an antiproton?

	mass	charge
A	$-m_p$	$+e$
B	$-m_p$	$-e$
C	m_p	$+e$
D	m_p	$-e$

2. June/2023/Paper_ 9702/11/No.39

A uranium nucleus has 92 protons and 143 neutrons.

The nucleus emits a total of 3 α-particles and 4 β^- particles to form nucleus X.

How can nucleus X be represented?

A $^{131}_{90}X$ **B** $^{219}_{87}X$ **C** $^{223}_{82}X$ **D** $^{223}_{90}X$

3. June/2023/Paper_ 9702/11/No.40

Which statement about a proton is correct?

A A proton is a baryon but not a meson.

B A proton is a meson but not a hadron.

C A proton is both a hadron and a meson.

D A proton is both a meson and a baryon.

4. June/2023/Paper_ 9702/12/No.38

What are isotopes?

A nuclei of different elements with the same number of neutrons

B nuclei of different elements with the same number of nucleons

C nuclei of the same element with different numbers of neutrons

D nuclei of the same element with different numbers of protons

5. June/2023/Paper_ 9702/12/No.39

A neutron ${}^{1}_{0}n$ is fired at a ${}^{235}_{92}U$ nucleus. The neutron is absorbed by the nucleus which then splits to form nuclei of ${}^{141}_{56}Ba$ and ${}^{92}_{36}Kr$.

What is the number of free neutrons emitted when the ${}^{235}_{92}U$ nucleus splits?

A 0 **B** 1 **C** 2 **D** 3

6. June/2023/Paper_ 9702/12/No.40

A π^+ meson has a charge of $+e$, where e is the elementary charge. It consists of an up quark and one other quark.

What could be the other quark in the π^+ meson?

A anti-down

B anti-up

C bottom

D charm

7. June/2023/Paper_ 9702/13/No.38

The table contains data for four different nuclei P, Q, R and S.

nucleus	number of neutrons	nucleon number
P	5	10
Q	6	10
R	6	14
S	8	16

Which two nuclei are isotopes of the same element?

A P and Q **B** P and S **C** Q and R **D** R and S

8. June/2023/Paper_ 9702/13/No.39

Which statement about β^- decay is correct?

A A neutron changes to a proton in the nucleus and an electron and an antineutrino are emitted.

B A neutron changes to a proton in the nucleus and an electron and a neutrino are emitted.

C A proton changes to a neutron in the nucleus and an electron and an antineutrino are emitted.

D A proton changes to a neutron in the nucleus and an electron and a neutrino are emitted.

9. June/2023/Paper_ 9702/13/No.40

What is the quark composition of a hydrogen-3 nucleus, ${}^{3}_{1}H$?

	number of quarks	
	up	down
A	4	5
B	5	4
C	5	7
D	7	5

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10. June/2023/Paper_ 9702/21/No.8

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]

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11. June/2023/Paper_ 9702/22/No.8

(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]

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(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]

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13. March/2023/Paper_ 9702/12/No.38

What is a conclusion from the alpha-particle scattering experiment?

A Protons and electrons have equal but opposite charges.

B Protons have a much larger mass than electrons.

C The nucleus contains most of the mass of the atom.

D The nucleus of an atom contains protons and neutrons.

14. March/2023/Paper_ 9702/12/No.39

Americium-241 is a radioactive nuclide used in smoke detectors. It undergoes α-decay to form nuclide X. This decay may be represented by the equation shown.

$$^{241}_{95}\text{Am} \rightarrow {}^{A}_{Z}\text{X} + \alpha$$

What are the values of A and Z?

	A	Z
A	237	93
B	239	91
C	241	94
D	241	96

15. March/2023/Paper_ 9702/12/No.40

A top quark has a charge of $+\frac{2}{3}e$, where e is the elementary charge.

What is the charge of an anti top quark?

A $-\frac{2}{3}e$ **B** $-\frac{1}{3}e$ **C** $+\frac{1}{3}e$ **D** $+\frac{2}{3}e$

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16. March/2023/Paper_ 9702/22/No.7

(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]

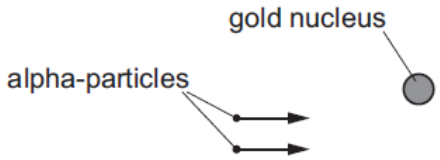
[Total: 5]

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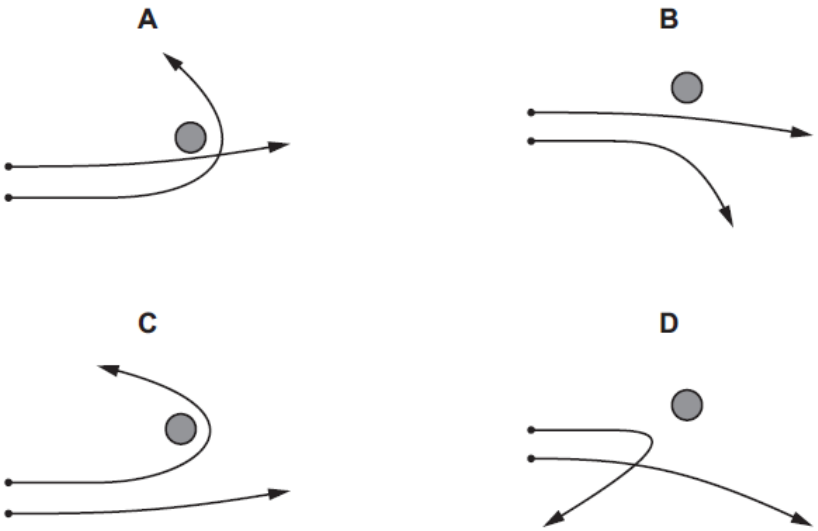
Particle Physics – 2023 Nov AS Physics 9702

1. Nov/2023/Paper_ 9702/11/No.38

Two alpha-particles with the same kinetic energy are moving towards, and are then deflected by, a gold nucleus.



Which diagram could show the paths of the two alpha-particles?



2. Nov/2023/Paper_ 9702/11/No.39

Which nuclide is formed when ${}^{10}_{6}C$ undergoes β^+ decay?

A ${}^{11}_{6}C$ **B** ${}^{9}_{6}C$ **C** ${}^{10}_{5}B$ **D** ${}^{10}_{7}N$

3. Nov/2023/Paper_ 9702/11/No.40

A particular hadron is composed of three quarks and has zero charge.

What is a possible quark composition of the hadron?

A down, down, strange

B up, down, strange

C up, up, down

D up, up, strange

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4. Nov/2023/Paper_ 9702/12/No.30

A fine mist of oil droplets is sprayed into air. As the oil droplets leave the nozzle of the spraying device they can become electrically charged.

What is **not** a possible value for the charge on an oil droplet?

A zero

B 1.0×10^{-19} C

C 4.8×10^{-19} C

D 8.0×10^{-19} C

5. Nov/2023/Paper_ 9702/12/No.38

Two nuclides are different isotopes of the same element.

Which statement about the nuclides is correct?

A Neutral atoms of the nuclides have the same number of electrons.

B Nuclei of the nuclides have different numbers of protons.

C Nuclei of the nuclides have the same number of nucleons.

D Nuclei of the nuclides have the same number of neutrons.

6. Nov/2023/Paper_ 9702/12/No.39

The charge-to-mass ratio r of a particle is given by the equation shown.

$$r = \frac{\text{charge on particle}}{\text{mass of particle}}$$

The value of r is determined for an α-particle, a β^+ particle and a proton p.

Which list shows the particles in order of increasing magnitude of r from left to right?

A $\alpha \rightarrow \beta^+ \rightarrow \text{p}$

B $\alpha \rightarrow \text{p} \rightarrow \beta^+$

C $\text{p} \rightarrow \alpha \rightarrow \beta^+$

D $\text{p} \rightarrow \beta^+ \rightarrow \alpha$

7. Nov/2023/Paper_ 9702/12/No.40

Which combination of up (u) and down (d) quarks forms a neutron?

A u u u **B** u u d **C** u d d **D** d d d

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8. Nov/2023/Paper_ 9702/13/No.38

The table shows the number of nucleons and the total number of particles (protons, neutrons and electrons) in neutral atoms of four nuclides W, X, Y and Z.

	number of nucleons	total number of particles
W	19	30
X	19	31
Y	21	32
Z	22	31

Which two nuclides are isotopes of each other?

A W and X **B** W and Y **C** X and Z **D** Y and Z

9. Nov/2023/Paper_ 9702/13/No.39

When a sample of a radioactive isotope decays by α-particle emission, the α-particles emitted have a single discrete energy.

When a sample of a radioactive isotope decays by β^- particle emission, the β^- particles emitted have a continuous range of energies.

What is the explanation for this?

A An antineutrino is emitted with a β^- particle but not with an α-particle.

B An antineutrino is emitted with an α-particle but not with a β^- particle.

C The α-particles have much more energy than the β^- particles.

D The β^- particles have much more energy than the α-particles.

10. Nov/2023/Paper_ 9702/13/No.40

Some particles are a combination of three quarks.

Which combination of quarks does **not** result in a particle with a charge of either $+1.6 \times 10^{-19}$ C or zero?

A up, down, down

B up, strange, strange

C up, up, down

D up, up, up

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11. Nov/2023/Paper_ 9702/21/No.7

(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]

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(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]

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12. Nov/2023/Paper_ 9702/21/No.7

(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]

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13. Nov/2023/Paper_ 9702/21/No.8

(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

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

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]

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(b) A radioactive source emits particles from its nuclei when it decays.
Fig. 8.1 shows, for the source, the variation with kinetic energy of the number of particles emitted.

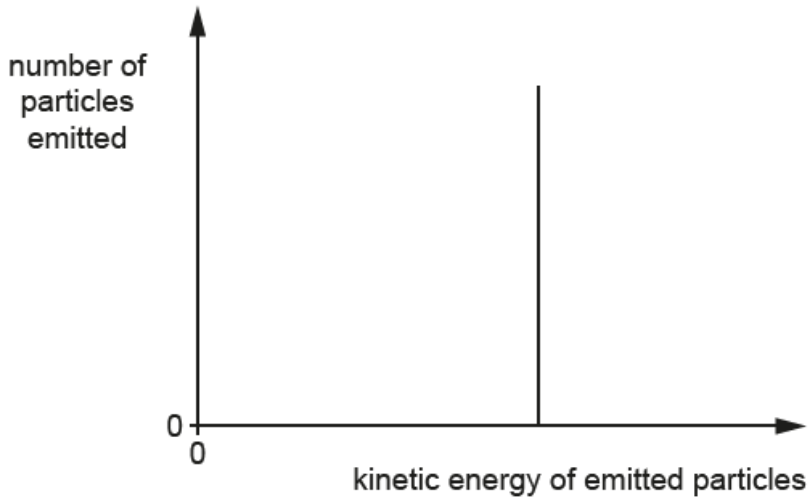


Fig. 8.1

State how Fig. 8.1 shows that these nuclei do **not** undergo beta-decay.

.....

..... [1]

[Total: 6]

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