

PHYSICS



EXAM QUESTION PACK

11 PARTICLE PHYSICS

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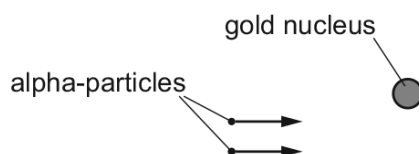
Chapter 13

Particle and nuclear physics

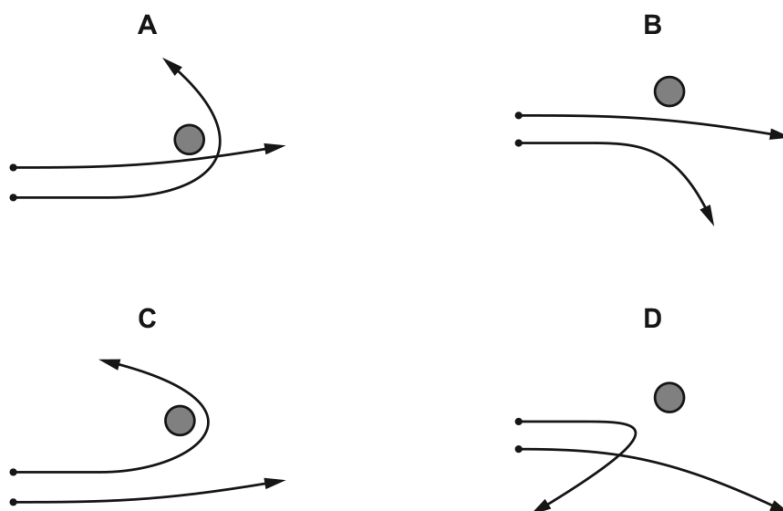
13.1 Atoms, nuclei and radiation

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?



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 ${}_0^1\text{n}$ is fired at a ${}_{92}^{235}\text{U}$ nucleus. The neutron is absorbed by the nucleus which then splits to form nuclei of ${}_{56}^{141}\text{Ba}$ and ${}_{36}^{92}\text{Kr}$.

What is the number of neutrons emitted when the ${}_{92}^{235}\text{U}$ 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 $\rightarrow$ neutron + electron + electron antineutrino
B proton $\rightarrow$ neutron + electron + electron neutrino
C proton $\rightarrow$ neutron + positron + electron antineutrino
D proton $\rightarrow$ 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 (${}_{87}^{221}\text{Fr}$) decays into a nucleus of bismuth-209 (${}_{83}^{209}\text{Bi}$) 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
-

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.

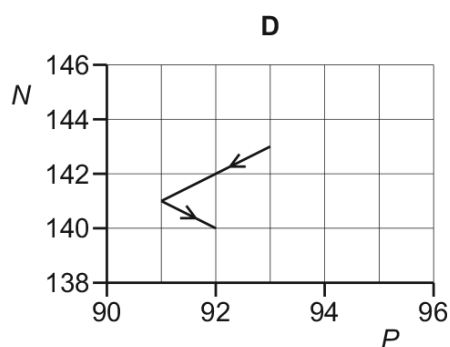
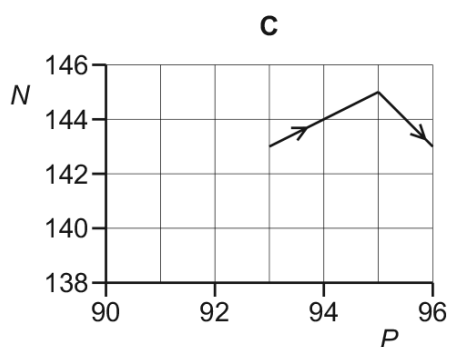
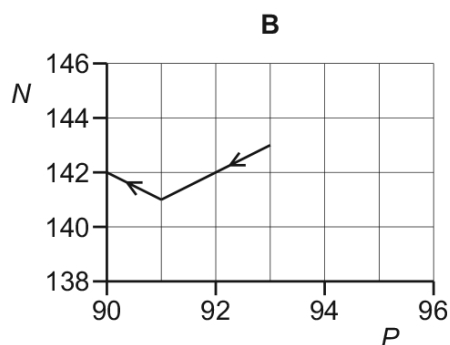
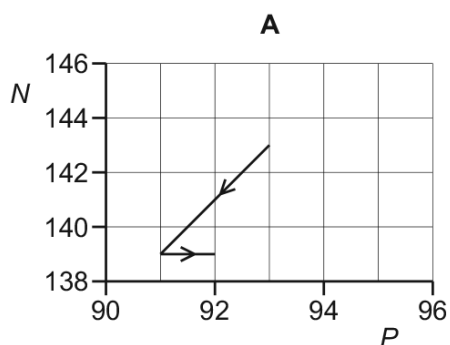
Which decay could create the product nucleus stated?

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

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?



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

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

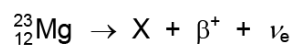
Radon-211, $^{211}_{86}\text{Rn}$, francium-210, $^{210}_{87}\text{Fr}$, and radium-212, $^{212}_{88}\text{Ra}$, are three nuclides.

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.



What is nucleus X?

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

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

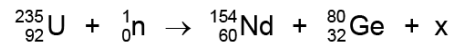
A proton in a nucleus undergoes β^+ decay. One of the products is a neutron.

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



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 ${}_x^yQ$.

Which of the following is an isotope of Q ?

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

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

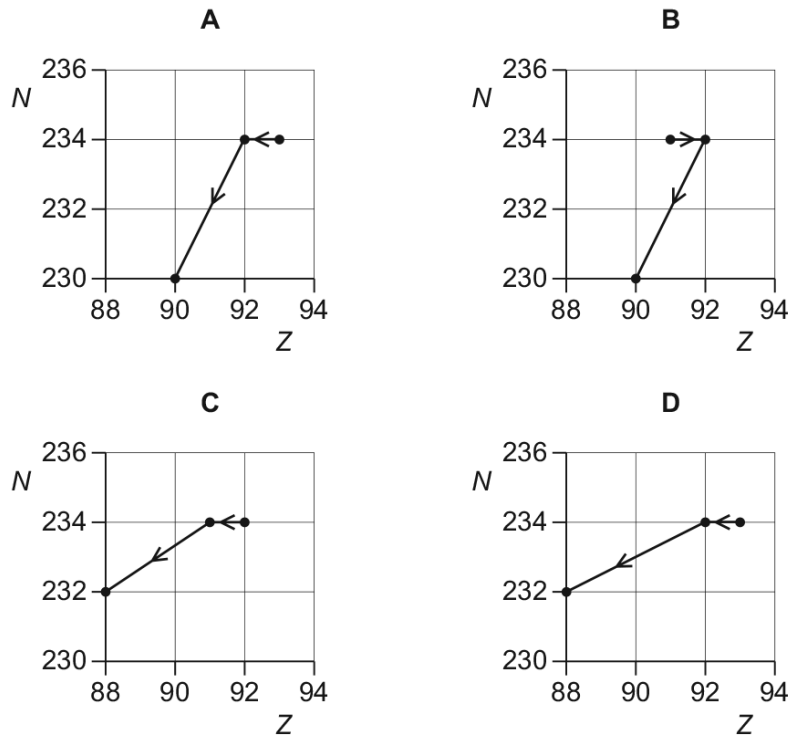
Which row in the following table correctly shows three nuclei of the same element, and three nuclei that have the same number of neutrons?

	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 $2\text{ m} \times 2\text{ m} \times 2\text{ m}$ 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

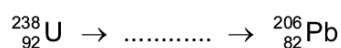
A certain nuclide, uranium-235, has nucleon number 235, proton number 92 and neutron number 143. Data on four other nuclides are given below.

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



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

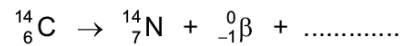
1337. 9702_s17_qp_13 Q: 38

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 $+1.60 \times 10^{-19}\text{C}$.
- D** The speeds of α -particles can be as high as $1.5 \times 10^7\text{ms}^{-1}$.

1338. 9702_s17_qp_13 Q: 39

The nuclear equation shown has a term missing.



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

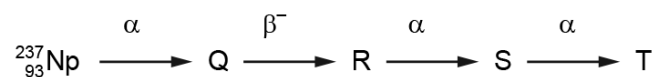
An astatine nucleus has a nucleon number of 218 and a proton number of 85. It decays to form a polonium nucleus, emitting a β^- particle and an α -particle in the process.

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.



What is nuclide T?

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

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.

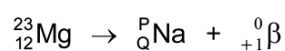
The emitted β^- particles have a range of energies.

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.



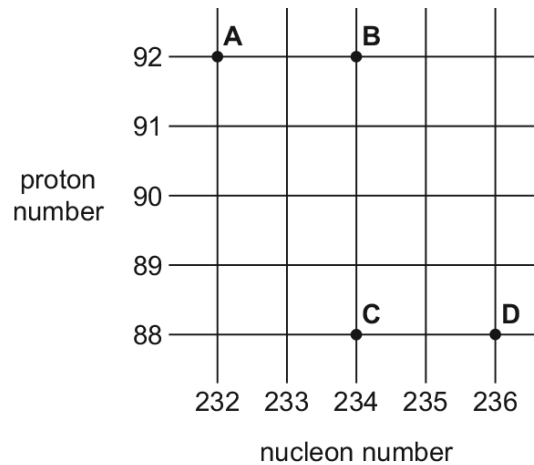
What are the values of P and Q?

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

1344. 9702_m16_qp_12 Q: 40

Thorium-234 (${}^{234}_{90}\text{Th}$) 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 $\rightarrow$ neutron + electron + electron antineutrino
- B** proton $\rightarrow$ neutron + electron + electron neutrino
- C** proton $\rightarrow$ neutron + positron + electron antineutrino
- D** proton $\rightarrow$ 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 $^{185}_{79}\text{Au}$ 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 $^{13}_7\text{N}$ 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** $^{13}_7\text{N} \rightarrow ^{13}_6\text{C} + \beta^- + \bar{\nu} + \gamma$
- B** $^{13}_7\text{N} \rightarrow ^{13}_6\text{C} + \beta^- + \nu + \gamma$
- C** $^{13}_7\text{N} \rightarrow ^{13}_6\text{C} + \beta^+ + \bar{\nu} + \gamma$
- D** $^{13}_7\text{N} \rightarrow ^{13}_6\text{C} + \beta^+ + \nu + \gamma$

1349. 9702_s16_qp_13 Q: 39

Radon $^{222}_{86}\text{Rn}$ is the start of a decay chain that forms bismuth $^{214}_{83}\text{Bi}$ 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

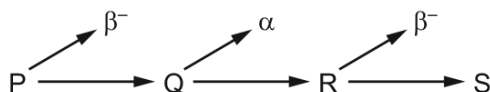
What are the correct descriptions of a γ -ray and a β^- particle?

	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 $^{42}_{20}\text{Ca}$ 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

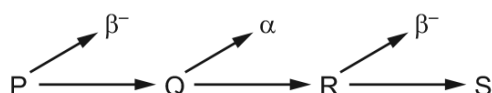
What are the correct descriptions of a γ -ray and a β^- particle?

	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

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

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

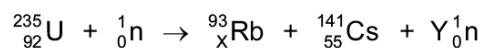
A neutral atom has a nucleus given by the symbol ${}^{133}_{55}\text{Cs}$.

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.



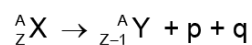
What are the values of X and Y?

	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.



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?

A

B

C

D

key

u = up quark
s = strange quark

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 $+1.6 \times 10^{-19} \text{ C}$ 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

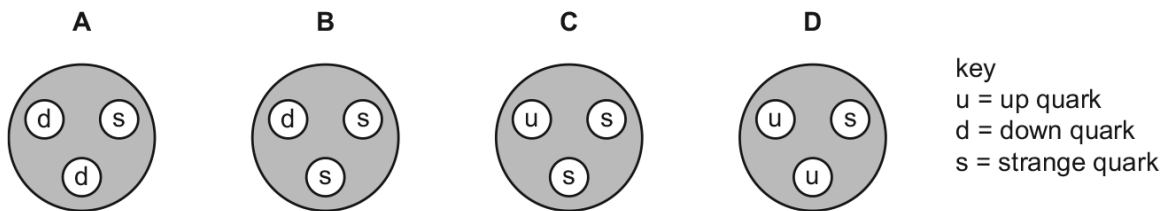
Which statement describes β^- decay in terms of a simple quark model?

- 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, ${}^3_1\text{H}$?

- 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 $\bar{\nu}_e$.)

- A** $d \rightarrow u + \beta^- + \nu_e$
- B** $d \rightarrow u + \beta^- + \bar{\nu}_e$
- C** $u \rightarrow d + \beta^+ + \nu_e$
- D** $u \rightarrow d + \beta^+ + \bar{\nu}_e$

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 ${}^{37}_{17}\text{Cl}$?

	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, ${}_{11}^{21}\text{Na}$, 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, ${}^3_1\text{H}$?

	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

C

D

key

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

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

Paper 1 Multiple Choice Answers: Particle Physics

Question	Paper	Q. No.	Answer
1309	9702_m20_qp_12	38	D
1310	9702_s20_qp_11	39	B
1311	9702_s20_qp_12	39	B
1312	9702_s20_qp_13	39	A
1313	9702_m19_qp_12	39	D
1314	9702_m19_qp_12	40	D
1315	9702_s19_qp_11	39	A
1316	9702_s19_qp_12	38	C
1317	9702_s19_qp_13	39	A
1318	9702_w19_qp_11	39	B
1319	9702_w19_qp_12	38	B
1320	9702_w19_qp_12	39	C
1321	9702_w19_qp_13	39	D
1322	9702_m18_qp_12	39	D
1323	9702_s18_qp_11	40	D
1324	9702_s18_qp_12	38	C
1325	9702_s18_qp_12	39	B
1326	9702_s18_qp_13	39	C
1327	9702_w18_qp_11	39	D
1328	9702_w18_qp_12	39	C
1329	9702_w18_qp_13	38	C
1330	9702_w18_qp_13	39	A
1331	9702_m17_qp_12	38	C
1332	9702_s17_qp_11	38	A
1333	9702_s17_qp_11	39	B
1334	9702_s17_qp_12	38	A
1335	9702_s17_qp_12	39	B
1336	9702_s17_qp_13	37	A
1337	9702_s17_qp_13	38	D
1338	9702_s17_qp_13	39	A
1339	9702_w17_qp_11	39	B
1340	9702_w17_qp_12	39	A
1341	9702_w17_qp_13	39	C
1342	9702_m16_qp_12	38	A
1343	9702_m16_qp_12	39	C
1344	9702_m16_qp_12	40	B
1345	9702_s16_qp_11	39	D
1346	9702_s16_qp_11	40	A
1347	9702_s16_qp_12	38	C
1348	9702_s16_qp_13	38	D
1349	9702_s16_qp_13	39	B
1350	9702_w16_qp_11	39	C
1351	9702_w16_qp_11	40	B
1352	9702_w16_qp_12	39	C
1353	9702_w16_qp_13	39	C
1354	9702_w16_qp_13	40	B

Paper 1 Multiple Choice Answers: Particle Physics (continued)

Question	Paper	Q. No.	Answer
1355	9702_sl5_qp_11	39	C
1356	9702_sl5_qp_11	40	B
1357	9702_sl5_qp_12	38	A
1358	9702_sl5_qp_12	39	C
1359	9702_sl5_qp_12	40	C
1360	9702_sl5_qp_13	38	D
1361	9702_sl5_qp_13	39	A
1362	9702_sl5_qp_13	40	C
1363	9702_m20_qp_12	39	D
1364	9702_m20_qp_12	40	C
1365	9702_s20_qp_11	40	C
1366	9702_s20_qp_12	40	A
1367	9702_s20_qp_13	40	C
1368	9702_sl9_qp_11	40	D
1369	9702_sl9_qp_12	39	C
1370	9702_sl9_qp_12	40	D
1371	9702_sl9_qp_13	40	A
1372	9702_w19_qp_11	40	D
1373	9702_w19_qp_12	40	B
1374	9702_w19_qp_13	40	A
1375	9702_m18_qp_12	40	B
1376	9702_sl8_qp_11	38	C
1377	9702_sl8_qp_11	39	D
1378	9702_sl8_qp_12	40	B
1379	9702_sl8_qp_13	40	A
1380	9702_w18_qp_11	40	B
1381	9702_w18_qp_12	40	A
1382	9702_w18_qp_13	40	A
1383	9702_m17_qp_12	39	B
1384	9702_m17_qp_12	40	C
1385	9702_sl7_qp_11	40	C
1386	9702_sl7_qp_12	40	A
1387	9702_sl7_qp_13	40	A
1388	9702_w17_qp_11	40	A
1389	9702_w17_qp_12	40	C
1390	9702_w17_qp_13	40	B
1391	9702_sl6_qp_11	38	A
1392	9702_sl6_qp_12	39	B
1393	9702_sl6_qp_12	40	D
1394	9702_sl6_qp_13	40	C
1395	9702_w16_qp_11	38	A
1396	9702_w16_qp_12	40	A
1397	9702_w16_qp_13	38	A

Chapter 13

Particle and nuclear physics

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.

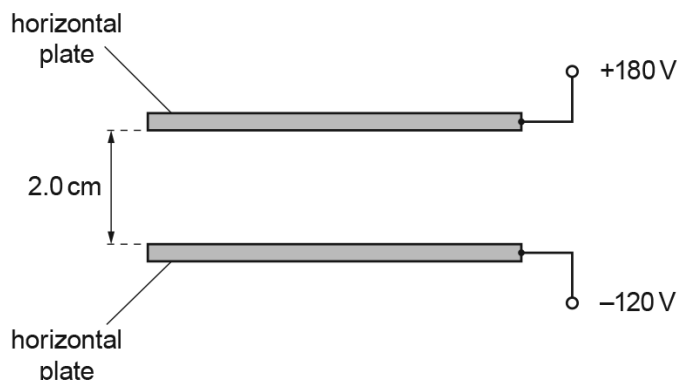


Fig. 6.1

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 ($^{238}_{92}\text{U}$) 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 $+2e$, 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 ($^{238}_{92}\text{U}$) decays in stages, by emitting α -particles and β^- particles, to form a nucleus of thorium-230 ($^{230}_{90}\text{Th}$).

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.

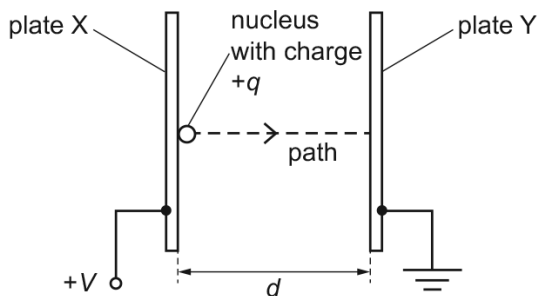


Fig. 7.1 (not to scale)

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 ($^{14}_6\text{C}$). 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]

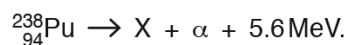
- (ii) State the name of the particle of negligible mass.

..... [1]

[Total: 7]

252. 9702_w19_qp_22 Q: 7

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



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

number of protons = ...

number of neutrons = ...

[2]

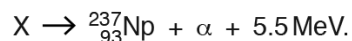
- (b) Calculate the number of plutonium-238 nuclei that must decay in a time of 1.0 s to produce a power of 0.15 W.

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



- (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]

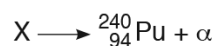
- (b) A particle of mass m and charge q is in a uniform electric field of strength E . The particle has acceleration a due to the field.

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.



- (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 ($^{212}_{83}\text{Bi}$) 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 $9.3 \times 10^{-13} \text{ J}$. 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, ${}_{11}^{23}\text{Na}$.

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.

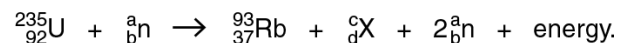
similarity:

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



(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.

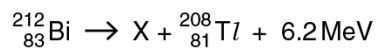
.....

.....

..... [2]

260. 9702_s15_qp_23 Q: 7

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



- (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.

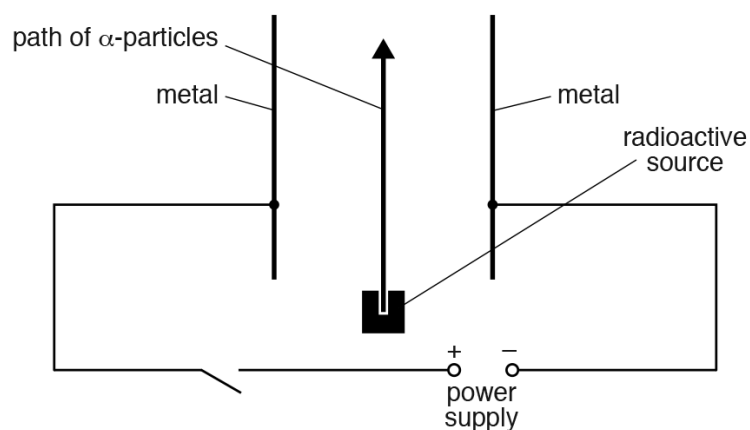
.....
.....
.....[2]

- (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 $^{63}_{29}\text{Cu}$, the atom and its nucleus are assumed to be spherical.

The diameter of the nucleus is $2.8 \times 10^{-14}\text{m}$. The diameter of the atom is $2.3 \times 10^{-10}\text{m}$.

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 $6.69 \times 10^{-13} \text{ J}$.

- (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.

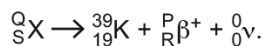
State **two** possible forms of the remainder of the released energy.

.....
..... [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 (${}^{39}_{19}\text{K}$) and a neutrino. The decay is represented by



- (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 $+2e$, 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.

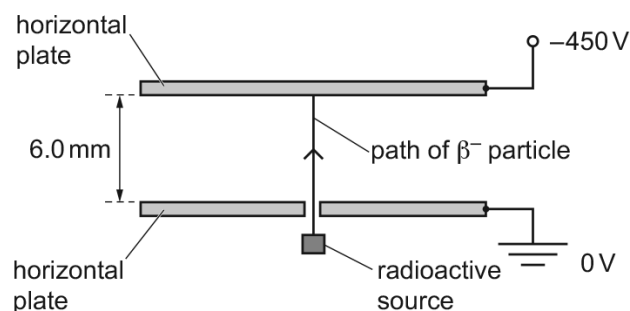


Fig. 7.1

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]

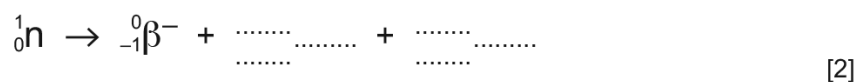
- (b) The β^- particle is emitted from the source with a kinetic energy of $3.4 \times 10^{-16} \text{ J}$.

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

speed = ... ms^{-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.



- (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 (${}^{25}_{13}\text{Al}$):

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

number of protons = ...

number of neutrons = ...

[1]

(ii) show that the charge is $2.1 \times 10^{-18} \text{ C}$.

[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.

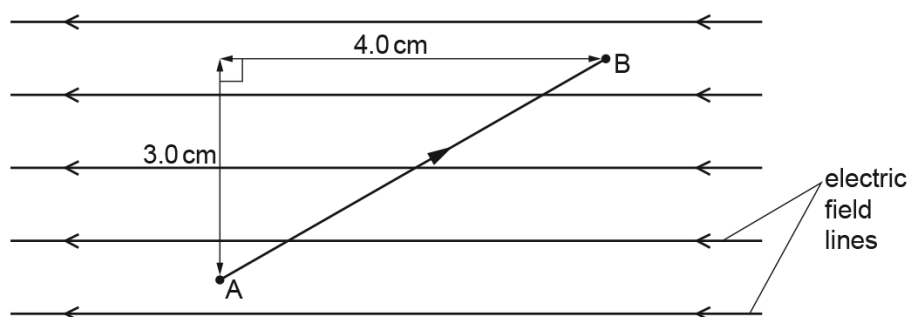


Fig. 8.1

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.

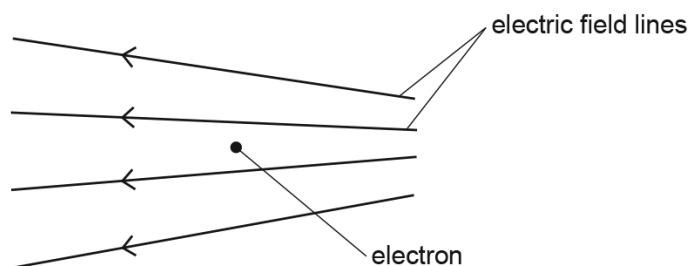


Fig. 7.1

- (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 0.15u 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]

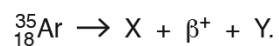
(d) has a continuous range of energies, rather than discrete values of energy.

.....[1]

[Total: 4]

273. 9702_w19_qp_21 Q: 7

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



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.

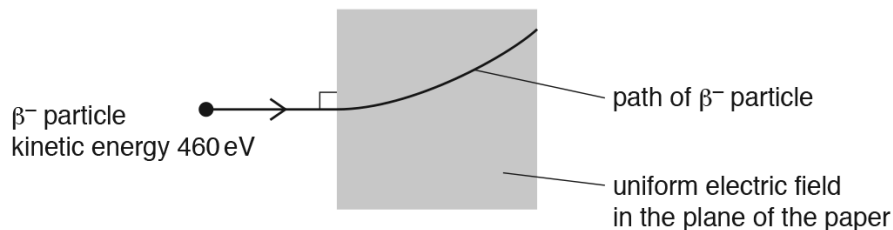


Fig. 7.1

- (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 = ... ms^{-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.

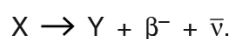
.....

[2]

[Total: 6]

275. 9702_s18_qp_22 Q: 7

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



(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.

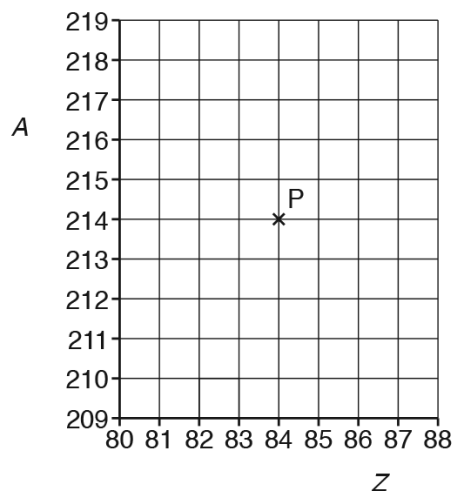


Fig. 7.1

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, ${}^{27}_{12}\text{Mg}$, decays by emitting a β^- particle and γ radiation. An incomplete equation to represent this decay is



- (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 $^{90}_{38}\text{Sr}$ decays by the emission of a β^- particle. A nucleus of $^{64}_{29}\text{Cu}$ 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 ${}^{60}_{27}\text{Co}$ to form nucleus Q by β^- emission.



- (i) Complete Fig. 7.1.

	value
A	
B	

Fig. 7.1

[1]

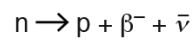
- (ii) State the name of the particle x.

.....[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.



(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			

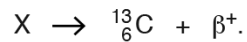
Fig. 8.1

[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 (${}^{13}_6\text{C}$). An incomplete equation to represent this decay is



- (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 $2.2 \times 10^{-26}\text{kg}$. Its kinetic energy as a result of the decay process is 0.80MeV .

Calculate the speed of this nucleus.

speed = ... ms^{-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.

$${}_0^1\text{n} \rightarrow \begin{array}{c} \text{.....} \\ \text{.....} \end{array} + \begin{array}{c} \text{.....} \\ \text{.....} \end{array} \beta^- + \begin{array}{c} \text{.....} \\ \text{.....} \end{array} \bar{\nu} \quad [2]$$

(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 $\rightarrow$ + ... + ... [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.

$${}^1_1\text{p} \rightarrow \dots\dots\dots \text{n} + \dots\dots\dots + \dots\dots\dots$$

[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]

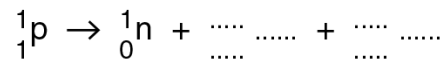
[Total: 7]

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



- (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]

249. 9702_w15_qp_22 Q: 5

- (a) (i) $I = V/R$ C1
 $(= 240/1500 =) 0.16\text{ A}$ A1 [2]
- (ii) $I_2 = 0.40 - 0.16 (= 0.24)$ C1
 $0.24(350 + R) = 240$
 $R = 650\Omega$ A1 [2]
- (iii) power = IV or I^2R or V^2/R C1
ratio = $(84 \times 0.24)/(88 \times 0.16)$
or $[(0.24)^2 \times 350]/[(0.16)^2 \times 550]$
or $(84^2/350)/(88^2/550)$
or $20.16/14.08$
 $= 1.4(3)$ A1 [2]
- (b) (i) p.d. across 350Ω resistor = 0.24×350
or p.d. across 550Ω resistor = 0.16×550 C1
 $V_{350} = 84\text{ (V)}$ and $V_{550} = 88\text{ (V)}$ gives $V_{AB} = 4.0\text{ V}$
or $V_{950} = 152\text{ (V)}$ and $V_R = 156\text{ V}$ gives $V_{AB} = 4.0\text{ V}$ A1 [2]
- (ii) p.d. across R increases or potential at B increases or V_{350} decreases hence V_{AB} increases B1 [1]

250. 9702_s20_qp_21 Q: 6

	Answer	Mark
(a)(i)	$E = \Delta V / \Delta d$	C1
	$E = (180 + 120) / (2.0 \times 10^{-2})$	A1
	$= 1.5 \times 10^4 \text{ N C}^{-1}$	
(a)(ii)	vertically downwards	B1
(b)(i)	number of protons = 92	A1
	number of neutrons = 146	A1
	number of electrons = 90	A1
(b)(ii)	$F = EQ$	C1
	$= 1.5 \times 10^4 \times 2 \times 1.60 \times 10^{-19}$	A1
	$= 4.8 \times 10^{-15} \text{ N}$	
(b)(iii)	number of α -particles = 2	A1
	number of β^- particles = 2	A1

251. 9702_w20_qp_23 Q: 7

	Answer	Mark
(a)(i)	electric field strength = V/d	B1
(a)(ii)	force = Vq/d	B1
(a)(iii)	kinetic energy = Vq	B1
(b)(i)	no change	B1
(b)(ii)	no change	B1
(c)(i)	nucleon number = 14 and proton number = 7	A1
(c)(ii)	(electron) antineutrino	B1

252. 9702_w19_qp_22 Q: 7

	Answer	Mark
(a)	number of protons = 92	A1
	number of neutrons = 142	A1
(b)	$5.6 \text{ MeV} = 5.6 \times 1.60 \times 10^{-19} \times 10^6$ (= $8.96 \times 10^{-13} \text{ J}$)	C1
	number = $0.15 / (5.6 \times 1.60 \times 10^{-13})$ = 1.7×10^{11}	A1
	or	
	$0.15 \text{ W} = 0.15 / (1.60 \times 10^{-19} \times 10^6)$ (= $9.38 \times 10^{11} \text{ MeV s}^{-1}$)	(C1)
	number = $9.38 \times 10^{11} / 5.6$ = 1.7×10^{11}	(A1)

253. 9702_w19_qp_23 Q: 7

	Answer	Mark
(a)	number of protons = 95	A1
	number of neutrons = 146	A1
(b)	Np/neptunium (nucleus) has <u>kinetic</u> energy or gamma/ γ -radiation produced	B1
(c)(i)	$I = NQ/t$	C1
	$I = (6.9 \times 10^{11} \times 2 \times 1.60 \times 10^{-19}) / 30$ = $7.4 \times 10^{-9} \text{ A}$	A1
(c)(ii)	$P = (6.9 \times 10^{11} \times 5.5 \times 10^6 \times 1.60 \times 10^{-19}) / 30$	C1
	= 0.020 W	A1

254. 9702_m18_qp_22 Q: 6

	Answer	Mark
(a)	-1 / decreases by 1	A1
(b)	$I = Q/t$ or Ne/t	C1
	$= (9.8 \times 10^{10} \times 1.6 \times 10^{-19}) / (2.0 \times 60)$ $= 1.3 \times 10^{-10}$ (A)	C1
	$= 130$ pA	A1
(c)	antineutrino(s) (emitted) / other particle(s) (emitted)	C1
	energy / momentum shared with antineutrino(s)	A1

255. 9702_w18_qp_21 Q: 5

	Answer	Mark
(a)	region (of space) where a force acts on a (stationary) charge	B1
(b)	$E = F/Q$	B1
	$F = ma$ and (so) $a = \frac{Eq}{m}$	A1
(c)(i)	protons = 96	A1
	neutrons = 148	A1
(c)(ii)	mass-energy is conserved/mass change is 'seen' as energy	B1
	energy released as gamma (radiation)/KE of α /KE of Pu	B1
(c)(iii)	ratio = $\frac{2}{4} \times \frac{240}{94}$ or ratio = $\frac{2 \times 1.60 \times 10^{-19}}{4 \times 1.66 \times 10^{-27}} \times \frac{240 \times 1.66 \times 10^{-27}}{94 \times 1.60 \times 10^{-19}}$	C1
	ratio = 1.3	A1

256. 9702_w18_qp_23 Q: 5

	Answer	Mark
(a)	$E = F/Q$	M1
	$F = ma$ and (so) $q/m = a/E$	A1
(b)	$m = (4 \times 1.60 \times 10^{-19} \times 3.5 \times 10^4) / 1.5 \times 10^{12}$ ($= 1.49 \times 10^{-26}$ kg)	B1
	$= 1.49 \times 10^{-26} / 1.66 \times 10^{-27} = 9.0$ (u)	A1
(c)	protons: 4 and neutrons: 5	A1
(d)(i)	nuclei have the same charge and so same (magnitudes of) force	B1
(d)(ii)	nuclei have different masses and same force and so different (magnitudes of) acceleration	B1

257. 9702_m17_qp_22 Q: 7

	Answer	Mark
(a)	number of protons = 83 and number of neutrons = 129	A1
(b)	$\lambda = 3.8 \times 10^{-12}$	C1
	$f = 3.0 \times 10^8 / 3.8 \times 10^{-12}$	C1
	$f = 7.9 \times 10^{19} (7.89 \times 10^{19}) \text{ Hz}$	A1
(c)	use an electric field (at an angle to the beam)	M1
	α is deflected <u>and</u> γ is undeflected	A1
(d)	<i>either</i>	
	energy = $9.3 \times 10^{-13} / 1.8 \times 10^5 (= 5.17 \times 10^{-18} \text{ J})$	C1
	$= 5.17 \times 10^{-18} / 1.6 \times 10^{-19}$ $= 32 (32.3) \text{ eV}$	A1
	<i>or</i>	
	energy = $9.3 \times 10^{-13} / 1.6 \times 10^{-19} (= 5.81 \times 10^6 \text{ eV})$	(C1)
	$= 5.81 \times 10^6 / 1.8 \times 10^5$ $= 32 (32.3) \text{ eV}$	(A1)

258. 9702_w17_qp_23 Q: 7

	Answer	Mark
(a)	nucleons = 23	B1
	neutrons = 11	B1
(b)	similarity: same (rest) mass <i>or</i> equal (magnitude of) charge	B1
	difference: opposite (sign of) charge <i>or</i> one is matter and one is antimatter <i>or</i> one is an electron and one is an antielectron	B1

259. 9702_s15_qp_22 Q: 7

(a) 92 protons and 143 neutrons B1 [1]

(b)

	value
a	1
b	0
c	141
d	55

(a and b both required)

B1
B1
B1 [3](c) kinetic energy (of products) or gamma/ γ (radiation or photon) B1 [1](d) (total) mass on left-hand side/reactants is greater than (total) mass on right-hand side/products

M1

difference in mass is (converted to) energy

A1 [2]

260. 9702_s15_qp_23 Q: 7

- (a) (i) (rate of decay) not affected by any external factors **or** changes in temperature and pressure etc. B1 [1]
- (ii) two protons and two neutrons B1 [1]
- (b) (i) (total) mass before decay/on left-hand side is greater than (total) mass on right-hand side/after the decay M1
- the difference in mass is released as kinetic energy of the products A1 [2]
- (may also be some γ radiation) (to conserve mass-energy)
- (ii) $(6.2 \times 10^6 \times 1.6 \times 10^{-19} =) 9.9(2) \times 10^{-13} \text{ J}$ A1 [1]

261. 9702_w15_qp_21 Q: 7

- (a) (i) curved path towards negative (–) plate (right-hand side) B1 [1]
- (ii) range of α -particle is only few cm in air/loss of energy of the α -particles due to collision with air molecules/ionisation of the air molecules B1 [1]
- (iii) $V = E \times d$ C1
- $= 140 \times 10^6 \times 12 \times 10^{-3} = 1.7 (1.68) \text{ MV}$ A1 [2]
- (b) β have opposite charge to α therefore deflection in opposite direction B1
- β has a range of velocities/energies hence number of different deflections B1
- β have less mass or q/m is larger hence deflection is greater
or
 β with (very) high speed (may) have less deflection B1 [3]

(c)

emitted particle	change in Z	change in A
α -particle	–2	–4
β -particle	+1	0

A1 [1]

262. 9702_w15_qp_22 Q: 8

- (a) result: majority/most (of the α -particles) went straight through/were deviated by small angles M1
- conclusion: most of the atom is (empty) space **or** size/volume of nucleus very small compared with atom A1
- result: a small proportion were deflected through large angles or $>90^\circ$ or came straight back M1
- conclusion: the mass or majority of mass is in a (very) small charged volume/region/nucleus A1 [4]
- (b) $\rho = m/V$ C1
- mass of atom and mass of nucleus (approx.) equal stated **or** cancelled **or** values given e.g. 63u or $63 \times 1.66 \times 10^{-27}$ C1
- ratio = $(r_A)^3/(r_N)^3 = (1.15 \times 10^{-10})^3/(1.4 \times 10^{-14})^3$
or
 ratio = $(d_A)^3/(d_N)^3 = (2.3 \times 10^{-10})^3/(2.8 \times 10^{-14})^3$
 $= 5.5 \times 10^{11}$ A1 [3]

263. 9702_w15_qp_23 Q: 8

- (a) mass-energy
 proton number or charge
 nucleon number B2 [2]
- (b) (i) $E_k = \frac{1}{2}mv^2$ and $p = mv$ with working leading to
 [via $E_k = \frac{1}{2}m^2v^2/m$ or $\frac{1}{2}m(p/m)^2$]
 to $E_k = \frac{p^2}{2m}$ B1 [1]
- (ii) $p = (2E_k m)^{1/2}$ hence $(2[E_k]_\alpha)^{1/2} = (2[E_k]_{Th})^{1/2}$ C1
- $2 \times [E_k]_{Th} \times 234 = 2 \times 6.69 \times 10^{-13} \times 4$ C1
- $[E_k]_{Th} = 1.14 \times 10^{-14} \text{ J}$
 $= 71(.5) \text{ keV}$ A1
- or**
- calculation of speed of α -particle = $1.42 \times 10^7 \text{ m s}^{-1}$
 calculation of momentum of α -particle/nucleus = $9.43 \times 10^{-20} \text{ N s}$ (C1)
- $[E_k]_{Th} = 1.14 \times 10^{-14} \text{ J}$ (C1)
 $= 71(.5) \text{ keV}$ (A1) [3]

264. 9702_m20_qp_22 Q: 7

	Answer	Mark
(a)	made up of quarks (so) not a fundamental particle	B1
(b)(i)	beta plus / β^+ (particle)	B1
	(electron) neutrino / $\nu_{(e)}$	B1
(b)(ii)	kinetic energy of nucleus	B1
	gamma / γ radiation	B1

265. 9702_s20_qp_22 Q: 7

	Answer	Mark
(a)(i)	P = 0 and Q = 39	A1
	R = (+)1 and S = 20	A1
(a)(ii)	weak (nuclear force/interaction)	B1
(b)	charge of quark(s) = (+) $2e/3$	B1
	up/u (quarks)	B1

266. 9702_s20_qp_23 Q: 7

	Answer	Mark
(a)(i)	$E = V/d$ or $E = F/Q$	C1
	$F = (450 \times 1.60 \times 10^{-19}) / 6.0 \times 10^{-3}$	C1
	$= 1.2 \times 10^{-14} \text{ N}$	A1
	direction: vertically downwards	B1

	Answer	Mark
(a)(ii)	work done = Fs or Fd or EQd	C1
	$= (-)1.2 \times 10^{-14} \times 6.0 \times 10^{-3}$	A1
	$= (-)7.2 \times 10^{-17} \text{ J}$	
	or	
	work done = VQ	(C1)
(b)	$E = \frac{1}{2}mv^2$	C1
	$3.4 \times 10^{-16} = \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$	A1
	$v = 2.7 \times 10^7 \text{ m s}^{-1}$	
(c)(i)	${}^1_1\text{p}$	A1
	${}^0_{-1}\text{e}$ or $\nu_{(e)}$	A1
(c)(ii)	1. hadrons	B1
	2. leptons	B1

267. 9702_w20_qp_21 Q: 8

	Answer	Mark
(a)	similarity: same/equal mass or same/equal (magnitude of) charge or both fundamental (particles)	B1
	difference: opposite (sign of) charge or one is matter and the other is antimatter	B1
(b)(i)	number of protons = 13 and number of neutrons = 12	A1
(b)(ii)	(charge =) $13 \times 1.60 \times 10^{-19} \text{ (C)} = 2.1 \times 10^{-18} \text{ (C)}$	A1
(c)	force = $11 \times 10^3 \times 2.1 \times 10^{-18}$	C1
	work done = $11 \times 10^3 \times 2.1 \times 10^{-18} \times 0.04$	C1
	= $9.2 \times 10^{-16} \text{ J}$	A1

268. 9702_w20_qp_22 Q: 7

	Answer	Mark
(a)	similarity: same/equal mass or same/equal (magnitude of) charge or both fundamental (particles)	B1
	difference: opposite (sign of) charge or one is matter and the other is antimatter	B1
(b)(i)	arrow points to the right	B1
(b)(ii)	(electric) field strength increases or (electric) force increases	B1
	acceleration increases	B1
(b)(iii)	force (on α -particle) has twice the magnitude (of force on electron)	B1
	force (on α -particle) is in opposite direction (to force on electron)	B1

269. 9702_m19_qp_22 Q: 7

	Answer	Mark
(a)(i)	alpha, neutron and proton	B1
(a)(ii)	neutron	B1
(a)(iii)	beta plus or β^+	B1
(b)	$\bar{d}$ has charge $(+)\frac{1}{3}e$	C1
	(so) other quark has charge $= e - \frac{1}{3}e$ $= (+)\frac{2}{3}e$	M1
	other quark is an up / u	A1

270. 9702_s19_qp_21 Q: 7

	Answer	Mark
(a)	nucleus is charged	B1
	the mass is <u>concentrated</u> in (very small) nucleus or the <u>majority</u> of the mass is in (very small) nucleus	B1
(b)(i)	$-(1/3)e$	B1
(b)(ii)	$2q - (1/3)e = e$ so $q = (2/3)e$	M1
	up / u (quarks) (allow charm or top quarks)	A1

271. 9702_s19_qp_22 Q: 6

	Answer	Mark
(a)	path/direction in which a (free) <u>positive</u> charge will move	B1
(b)	(lines) closer together in Y/further apart in X	B1
(c)(i)	$a = Eq / m$	C1
	or $F = Eq$ and $F = ma$	
	ratio = $(1e / 0.15 \text{ u}) \times (4 \text{ u} / 2e)$ or $1 / 0.15 \times 4 / 2$	C1
	ratio = 13	A1
(c)(ii)	down quark charge is $-(1/3)e$	C1
	$-(1/3)e + q = -1e$ so $q = -(2/3)e$	A1
	$-(2/3)e$ is anti-up / $\bar{u}$ (quark) (allow charm or top antiquark)	B1

272. 9702_s19_qp_23 Q: 7

	Answer	Mark
(a)	beta/ β	B1
(b)	alpha/ α	B1
(c)	gamma/ γ	B1
(d)	beta/ β	B1

273. 9702_w19_qp_21 Q: 7

	Answer	Mark
(a)(i)	proton number = 17 and nucleon number = 35	A1
(a)(ii)	(electron) neutrino	B1
(b)	d/down (quark charge) is $-1/3(e)$ or two d/down (quark charges) is $-2/3(e)$ or s/strange (quark charge) is $-1/3(e)$	C1
	charge = $-1/3(e) - 1/3(e) - 1/3(e)$ $= -1(e)$	A1

274. 9702_s18_qp_21 Q: 7

	Answer	Mark
(a)	arrow pointing vertically down the page	B1
(b)	$E = \frac{1}{2}mv^2$	C1
	$E = 460 \times 1.60 \times 10^{-19} (= 7.36 \times 10^{-17} \text{ (J)})$	C1
	$v = [(2 \times 460 \times 1.60 \times 10^{-19}) / (9.11 \times 10^{-31})]^{1/2}$ $= 1.3 \times 10^7 \text{ ms}^{-1}$	A1
(c)	β^- particles have range of/different/various speeds/velocities/momenta/energies	M1
	so they follow different paths	A1

275. 9702_s18_qp_22 Q: 7

	Answer	Mark
(a)	circle(s) drawn only around β^- and $\bar{\nu}$ symbols	B1
(b)	(electron) <u>antineutrino</u>	B1
(c)	kinetic (energy)	B1
(d)	Y has one more proton (and one less neutron)/X has one less proton (and one more neutron) or Y has more protons (and fewer neutrons)/X has fewer protons (and more neutrons) or a neutron changes to a proton or the number of protons increases	M1
	(so) not isotopes	A1
(e)	up down down changes to up up down or udd $\rightarrow$ uud or down changes to up or d $\rightarrow$ u	B1

276. 9702_s18_qp_23 Q: 7

	Answer	Mark
(a)(i)	Q plotted at (82, 210)	A1
(a)(ii)	R plotted at (83, 210)	A1
(b)	lepton(s)	B1
(c)	up down down changes to up up down or udd $\rightarrow$ uud or down changes to up or d $\rightarrow$ u	B1

277. 9702_w18_qp_22 Q: 8

	Answer	Mark
(a)	<u>antineutrino</u> and <u>positron</u> both underlined (and no other particles)	B1
(b)(i)	nucleon number = 27	A1
	proton number = 13	A1
(b)(ii)	weak (nuclear force/interaction)	B1
(b)(iii)	an (electron) antineutrino / $\bar{\nu}_{(e)}$ is produced (and this has energy)	B1
	X has kinetic energy	B1

278. 9702_s17_qp_21 Q: 7

	Answer	Mark									
(a)(i)	(proton is uud so) $(2/3)e + (2/3)e - (1/3)e = e$	B1									
(a)(ii)	(neutron is udd so) $(2/3)e - (1/3)e - (1/3)e = 0$	B1									
(b)(i)	<table border="1"> <tr> <td></td><td>β^-</td><td>β^+</td></tr> <tr> <td>nucleon number</td><td>90</td><td>64</td></tr> <tr> <td>proton number</td><td>39</td><td>28</td></tr> </table> <i>all correct</i>		β^-	β^+	nucleon number	90	64	proton number	39	28	B1
	β^-	β^+									
nucleon number	90	64									
proton number	39	28									
(b)(ii)	weak (nuclear force/interaction)	B1									
(b)(iii)	β^- decay: electron and (electron) antineutrino β^+ decay: positron and (electron) neutrino <i>all correct</i>	B1									

279. 9702_s17_qp_22 Q: 8

	Answer	Mark
(a)	β^- emission: neutron changes to proton (+ beta ⁻ /electron) and β^+ emission: proton changes to neutron (+ beta ⁺ /positron)	B1
	β^- emission: (electron) antineutrino also emitted and β^+ emission: (electron) neutrino also emitted	B1
(b)	proton: up up down (and zero strange) neutron: up down down (and zero strange)	B1

280. 9702_s17_qp_23 Q: 7

	Answer	Mark						
(a)	electron and quark both underlined/clearly indicated and no others	B1						
(b)(i)	<table><tr><td></td><td>value</td></tr><tr><td>A</td><td>60</td></tr><tr><td>B</td><td>28</td></tr></table> <i>both correct</i>		value	A	60	B	28	B1
	value							
A	60							
B	28							
(b)(ii)	(electron) antineutrino	B1						

281. 9702_w17_qp_21 Q: 8

	Answer	Mark
(a)	(quark structure is) up, down, down/udd	B1
	up/u has charge $+\frac{2}{3}(e)$, down/d has charge $-\frac{1}{3}(e)$	C1
	$+\frac{2}{3}e - \frac{1}{3}e - \frac{1}{3}e = 0$	A1
(b)	charge: p $+1.6(0) \times 10^{-19}$ (C) or $+e$ β^- $-1.6(0) \times 10^{-19}$ (C) or $-e$ $\bar{\nu}$ zero/0	B1
	mass: p 1.67×10^{-27} (kg)/ 1.7×10^{-27} (kg) β^- $9.1(1) \times 10^{-31}$ (kg) $\bar{\nu}$ very small/zero/0	B1

282. 9702_w17_qp_22 Q: 7

	Answer	Mark
(a)	lepton(s)	B1
(b)	protons: 7 and neutrons: 6	A1
(c)	$E = \frac{1}{2}mv^2$	C1
	$= 0.80 \times 10^6 \times 1.60 \times 10^{-19}$	C1
	$= 1.28 \times 10^{-13} \text{ (J)}$	A1
	$v^2 = 2 \times 1.28 \times 10^{-13} / 2.2 \times 10^{-26}$ $v = 3.4 \times 10^6 \text{ m s}^{-1}$	
(d)	an (electron) neutrino/ $\nu_{(e)}$ is also produced (and this has energy)	B1

283. 9702_m16_qp_22 Q: 6

- (a) ${}^1_1\text{p}$ B1
 ${}^0_{-1}\beta^-$ and ${}^0_0\bar{\nu}$ B1
- (b) an (electron) antineutrino B1
- (c) lepton(s) B1
- (d) (i) down, down, up/ddu B1
(ii) a down/d (quark) changes to an up/u (quark) or $\text{ddu} \rightarrow \text{uud}$ B1

284. 9702_s16_qp_21 Q: 7

- (a) hadron: neutron/proton
and
lepton: electron/(electron) neutrino B1 [1]
(allow other correct particles)
- (b) (i) proton: up up down or uud B1 [1]
(ii) neutron: up down down or udd B1 [1]
- (c) (i) neutron $\rightarrow$ proton + electron + (electron) antineutrino B1 [1]
(ii) up down down (quarks) change to up up down (quarks)
or
down (quark) changes to up (quark) B1 [1]

285. 9702_s16_qp_22 Q: 8

- (a) both electron and neutrino: lepton(s) B1
 both neutron and proton: hadron(s)/baryon(s) B1 [2]
- (b) (i) ${}_1^1\text{p} \rightarrow {}_0^1\text{n} + {}_1^0\beta + {}_0^0\nu$
 correct symbols for particles M1
 correct numerical values (allow no values on neutrino) A1 [2]
- (ii) up up down or uud $\rightarrow$ up down down or udd B1 [1]
- (iii) weak (nuclear) B1 [1]

286. 9702_s16_qp_23 Q: 8

- (a) α -particle is 2 protons and 2 neutrons; β^+ -particle is positive electron/positron
 α -particle has charge +2e; β^+ -particle has +e charge
 α -particle has mass 4u; β -particle has mass (1/2000)u
 α -particle made up of hadrons; β^+ -particle a lepton
 any three B3 [3]
- (b) ${}_1^1\text{p} \rightarrow {}_0^1\text{n} + {}_1^0\beta + {}_0^0\nu$
 all terms correct M1
 all numerical values correct (ignore missing values on ν) A1 [2]
- (c) (i) 1. proton: up, up, down / uud B1
 2. neutron: up, down, down / udd B1 [2]
- (ii) up quark has charge +2/3 (e) and down quark has charge -1/3 (e)
 total is +1(e) B1 [1]

287. 9702_w16_qp_21 Q: 7

- (a) hadron not a fundamental particle/lepton is fundamental particle
or
 hadron made of quarks/lepton not made of quarks
or
 strong force/interaction acts on hadrons/does not act on leptons B1 [1]
- (b) (i) proton: up, up, down/uud B1
 neutron: up, down, down/udd B1 [2]
- (ii) composition: $2(\text{uud}) + 2(\text{udd})$
 $= 6 \text{ up, } 6 \text{ down/} 6\text{u, } 6\text{d}$ B1 [1]
- (c) (i) most of the atom is empty space
or
 the nucleus (volume) is (very) small compared to the atom B1 [1]
- (ii) nucleus is (positively) charged B1
- the mass is concentrated in (very small) nucleus/small region/small volume/small core
or
 the majority of mass in (very small) nucleus/small region/small volume/small core B1 [2]
-

288. 9702_w16_qp_22 Q: 6

- (a) hadron not a fundamental particle/lepton is fundamental particle
 or
 hadron made of quarks/lepton not made of quarks
 or
 strong force/interaction acts on hadrons/does not act on leptons B1 [1]
- (b) (i) ${}^0_1\text{e}^{(+)}$ or ${}^0_1\text{p}^{(+)}$ B1
- ${}^0_0\nu_{(\text{e})}$ B1 [2]
- (ii) weak (nuclear force/interaction) B1 [1]
- (iii) • mass-energy
 • momentum
 • proton number
 • nucleon number
 • charge
- Any three of the above quantities, 1 mark each* B3 [3]
- (c) (quark structure of proton is) up, up, down or uud B1
- up/u (quark charge) is $(+) \frac{2}{3}(e)$, down/d (quark charge) is $-\frac{1}{3}(e)$ C1
- $\frac{2}{3}e + \frac{2}{3}e - \frac{1}{3}e = (+)e$ A1 [3]

289. 9702_w16_qp_23 Q: 7

- (a) hadron not a fundamental particle/lepton is fundamental particle
 or
 hadron made of quarks/lepton not made of quarks
 or
 strong force/interaction acts on hadrons/does not act on leptons B1 [1]
- (b) (i) proton: up, up, down / uud B1
 neutron: up, down, down / udd B1 [2]
- (ii) composition: $2(\text{uud}) + 2(\text{udd})$
 $= 6 \text{ up, } 6 \text{ down} / 6\text{u, } 6\text{d}$ B1 [1]
- (c) (i) most of the atom is empty space
 or
 the nucleus (volume) is (very) small compared to the atom B1 [1]
- (ii) nucleus is (positively) charged B1
- the mass is concentrated in (very small) nucleus/small region/small volume/small core
 or
 the majority of mass in (very small) nucleus/small region/small volume/small core B1 [2]

Chapter 16

Particle and nuclear physics

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 ${}^1_1\text{p}$	1.007 276
neutron ${}^1_0\text{n}$	1.008 665
helium-4 (${}^4_2\text{He}$) 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 = ... Ns [2]

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

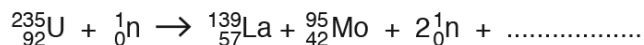
.....

 [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



- (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.

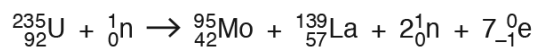
1.

2.
 [2]

[Total: 7]

401. 9702_w19_qp_41 Q: 12

One possible nuclear reaction that takes place is



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
${}_{42}^{95}\text{Mo}$	94.906	95.765	0.859	8.443
${}_{57}^{139}\text{La}$	138.906	140.125	1.219	8.189
${}_{92}^{235}\text{U}$	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 (${}_{92}^{235}\text{U}$). 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.

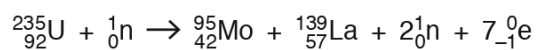
Calculate the average power release during the time of 25 ms.

power = ... W [3]

[Total: 10]

402. 9702_w19_qp_43 Q: 12

One possible nuclear reaction that takes place is



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
${}_{42}^{95}\text{Mo}$	94.906	95.765	0.859	8.443
${}_{57}^{139}\text{La}$	138.906	140.125	1.219	8.189
${}_{92}^{235}\text{U}$	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 (${}_{92}^{235}\text{U}$). 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.

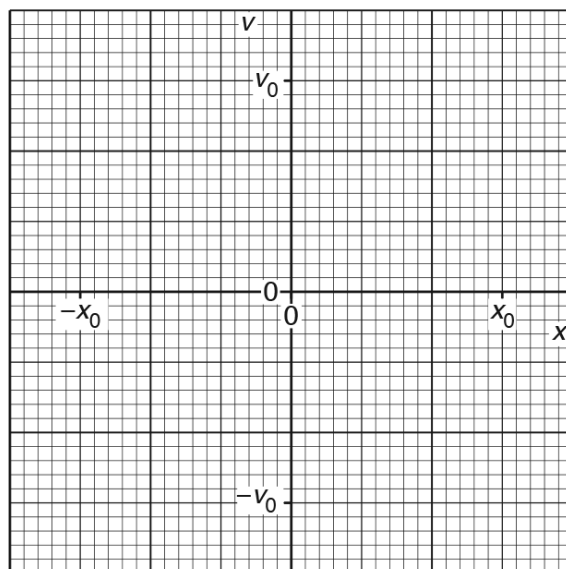


Fig. 3.1

[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° .

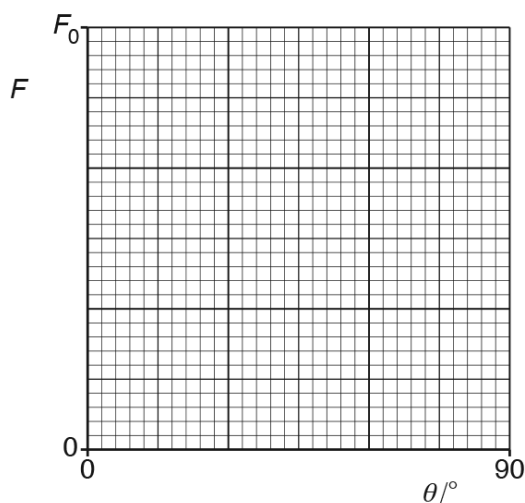


Fig. 3.2

[2]

- (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.

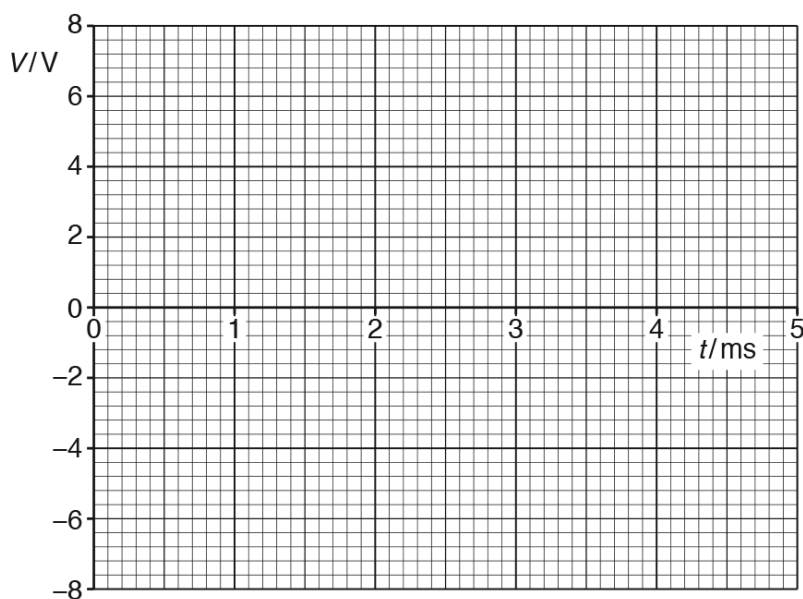
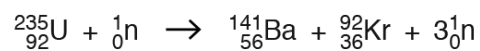


Fig. 3.3

[2]

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



The variation with nucleon number A of the binding energy per nucleon B_{E} is shown in Fig. 3.4.

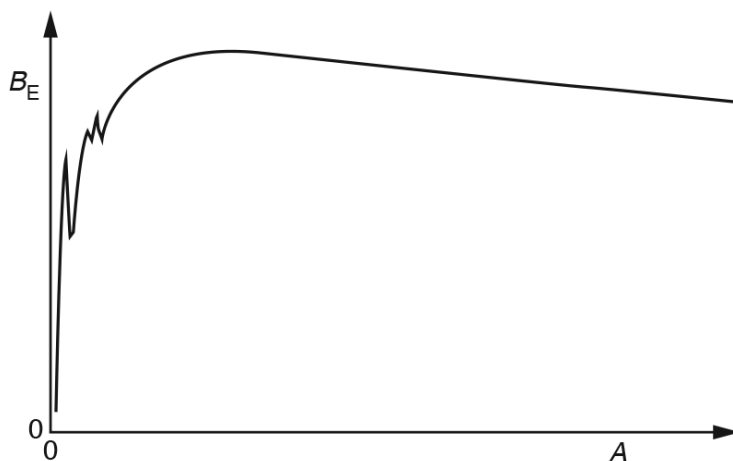


Fig. 3.4

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

- (i) the nucleus ${}_{92}^{235}\text{U}$ (label this point U),
- (ii) the nucleus ${}_{56}^{141}\text{Ba}$ (label this point Ba),
- (iii) the nucleus ${}_{36}^{92}\text{Kr}$ (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 0.51 MeV.

(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.

$\Delta m =$ kg [2]

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

.....

[1]

[Total: 9]

405. 9702_w18_qp_42 Q: 12

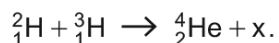
- (a) State what is meant by *nuclear fusion* and *nuclear fission*.

nuclear fusion:

 nuclear fission:

 [3]

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



- (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 $E_B / 10^{-13} \text{ J}$
deuterium	${}^2_1\text{H}$	1.7813
tritium	${}^3_1\text{H}$	4.5285
helium	${}^4_2\text{He}$	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 2.0g of deuterium (${}^2_1\text{H}$) reacts with 3.0g of tritium (${}^3_1\text{H}$).

energy = ... J [1]

[Total: 8]

406. 9702_w18_qp_43 Q: 11

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

(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.

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

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

.....
.....
.....[1]

[Total: 9]

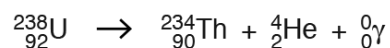
407. 9702_m17_qp_42 Q: 12

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

.....

[2]

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



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.

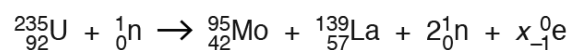
.....

[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



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

nucleus or particle	mass/u
${}_{92}^{235}\text{U}$	235.123
${}_{42}^{95}\text{Mo}$	94.945
${}_{57}^{139}\text{La}$	138.955
${}_0^1\text{n}$	1.00863
${}_{}^0\text{e}$	5.49×10^{-4}

Fig. 12.1

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

$x = \dots\dots\dots$ [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]

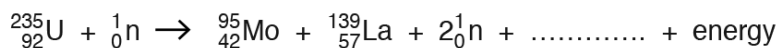
(c) Suggest the forms of energy into which the energy calculated in **(b)(ii)** is transformed.

.....
.....
.....
.....[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



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

nucleus or particle	mass/u
${}_{57}^{139}\text{La}$	138.955
${}_0^1\text{n}$	1.00863
${}_1^1\text{p}$	1.00728
${}_{-1}^0\text{e}$	5.49×10^{-4}

Fig. 12.1

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

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

[3]

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

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

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

.....

.....

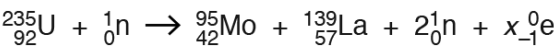
.....

.....[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



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

nucleus or particle	mass/u
$^{235}_{92}\text{U}$	235.123
$^{95}_{42}\text{Mo}$	94.945
$^{139}_{57}\text{La}$	138.955
${}^1_0\text{n}$	1.00863
${}^0_{-1}\text{e}$	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 $1.6 \times 10^5 \text{ m s}^{-1}$ in a vacuum. The particle enters a uniform magnetic field of flux density $9.7 \times 10^{-2} \text{ T}$, as shown in Fig. 9.1.

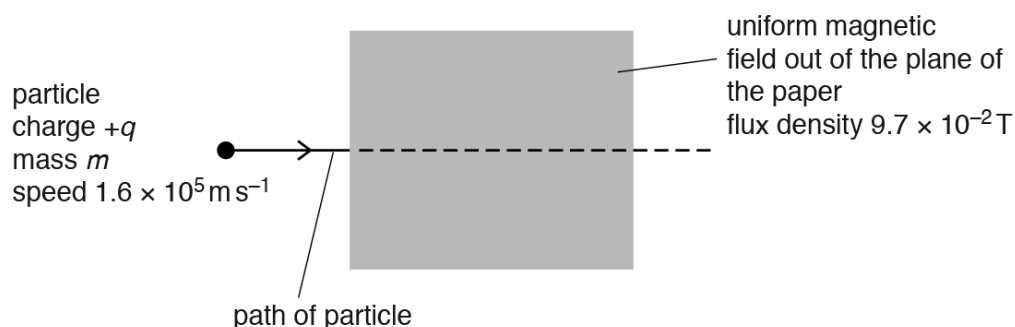


Fig. 9.1

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 = ...

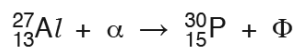
number of neutrons = ... [1]

[Total: 11]

412. 9702_w16_qp_42 Q: 14

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

A partial nuclear equation to represent this reaction is



(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
${}^{27}_{13}\text{Al}$	26.98153
α	4.00260
${}^{30}_{15}\text{P}$	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 ($^{90}_{38}\text{Sr}$) 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.

$\lambda = \dots\dots\dots \text{s}^{-1}$ [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 $x = 3r$.

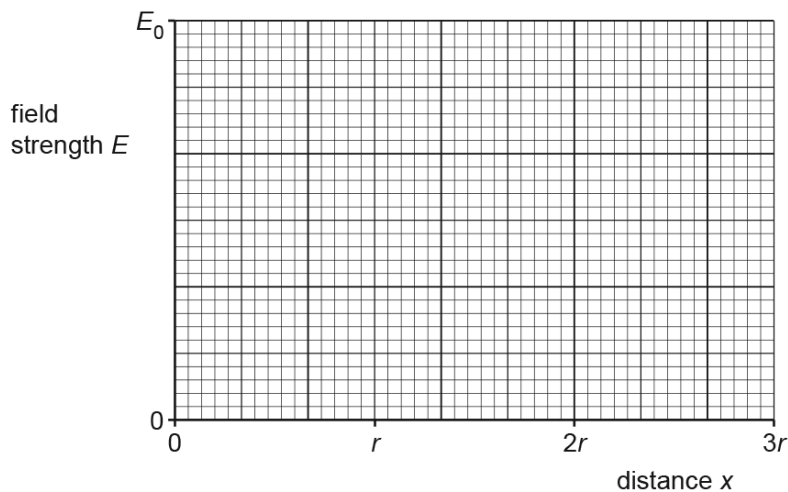


Fig. 6.1

[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 .

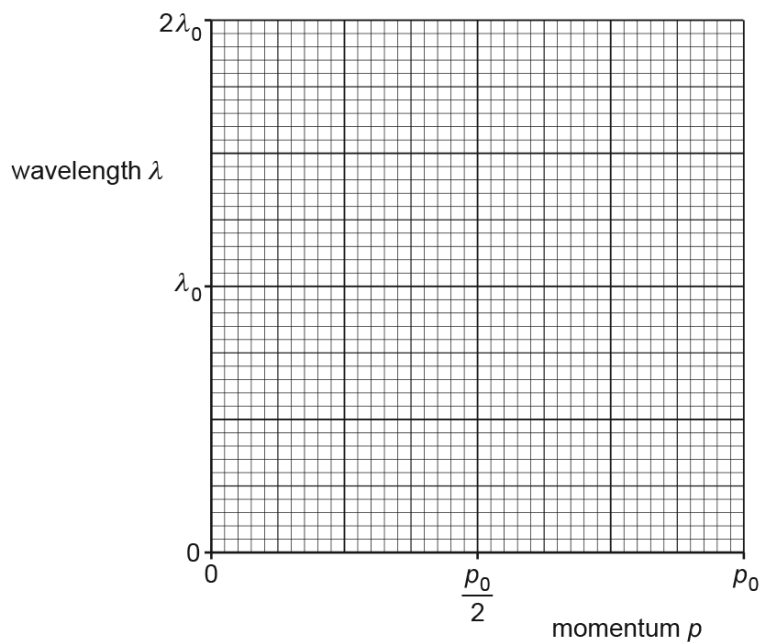


Fig. 6.2

[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.

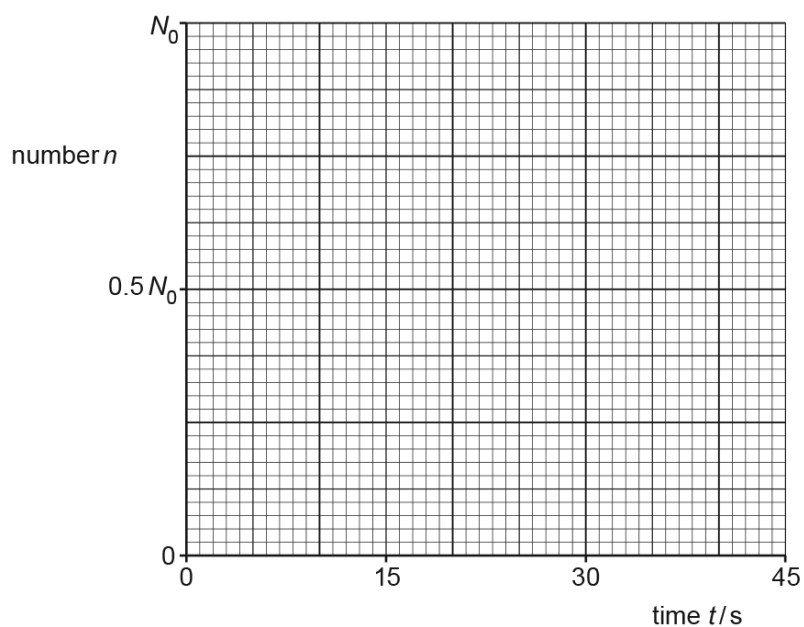


Fig. 6.3

[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 $x = 3r$.

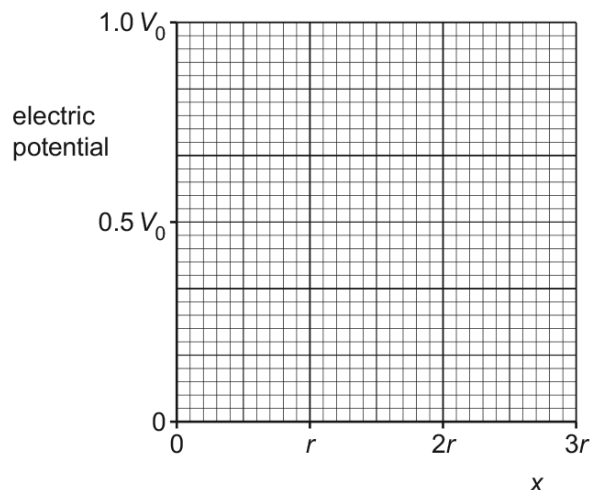


Fig. 5.1

[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 $\lambda = \lambda_0$.

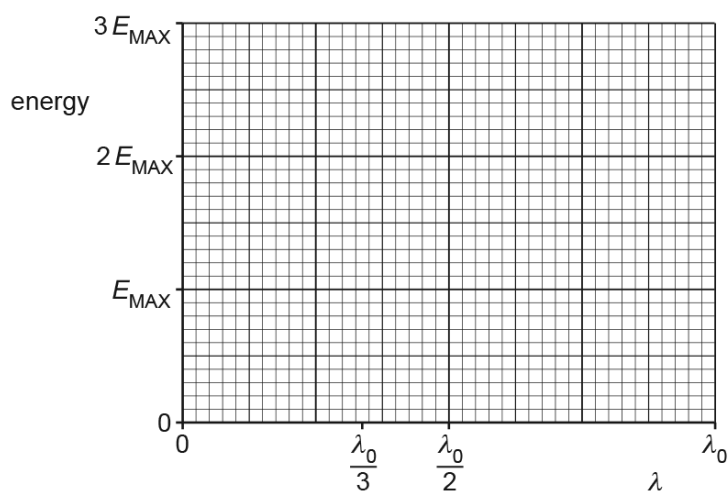


Fig. 5.2

[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.

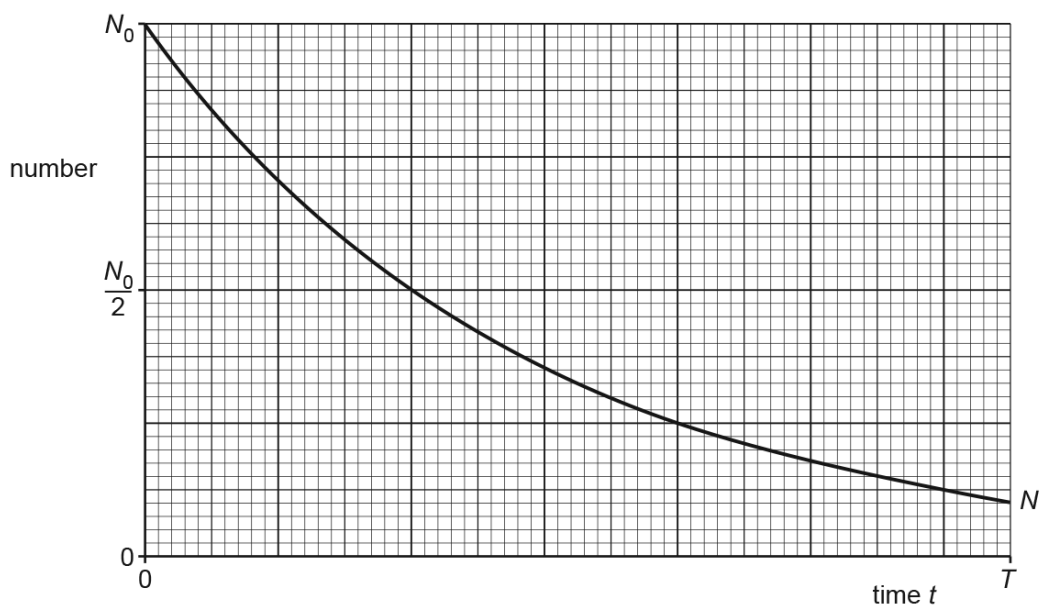


Fig. 5.3

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 $x = 3r$.

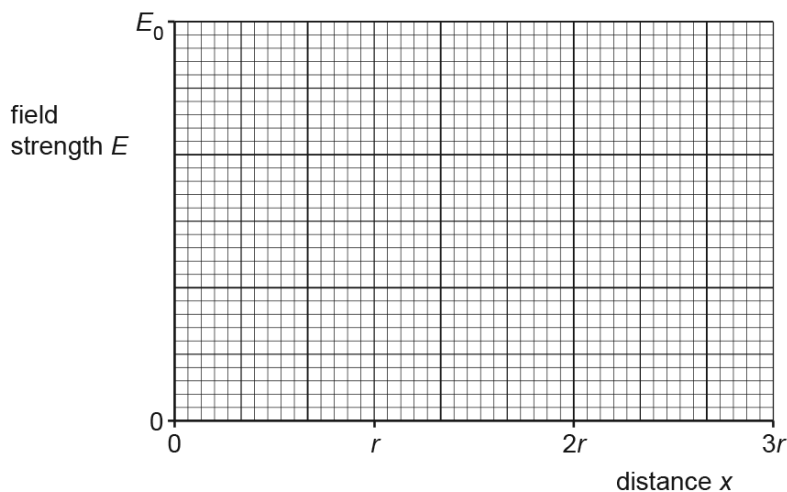


Fig. 6.1

[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 .

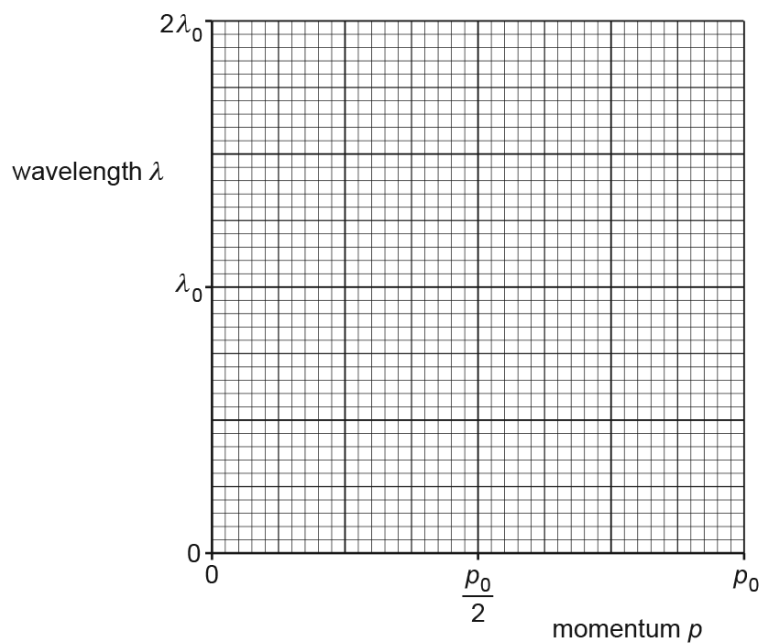


Fig. 6.2

[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.

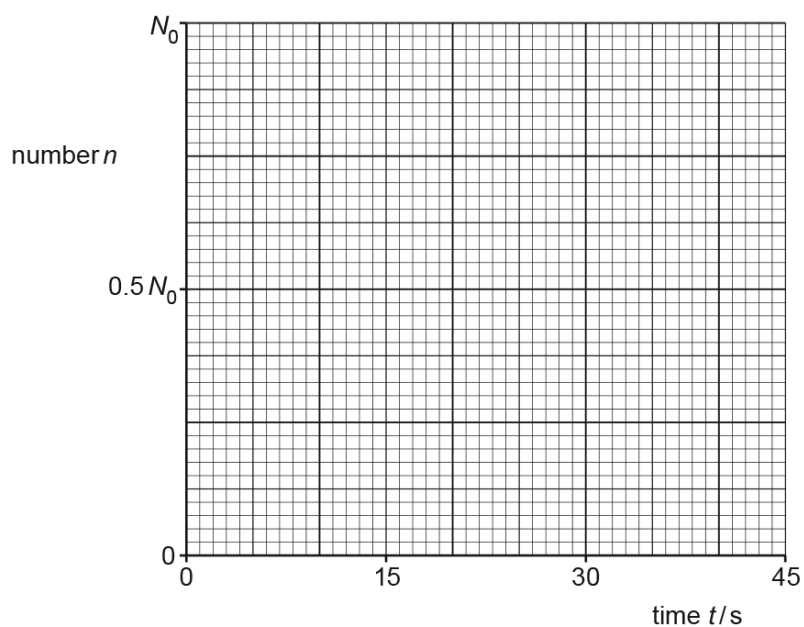


Fig. 6.3

[3]

[Total: 8]

417. 9702_w21_qp_41 Q: 12

(a) Define radioactive *decay constant*.

.....
.....
..... [2]

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

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.

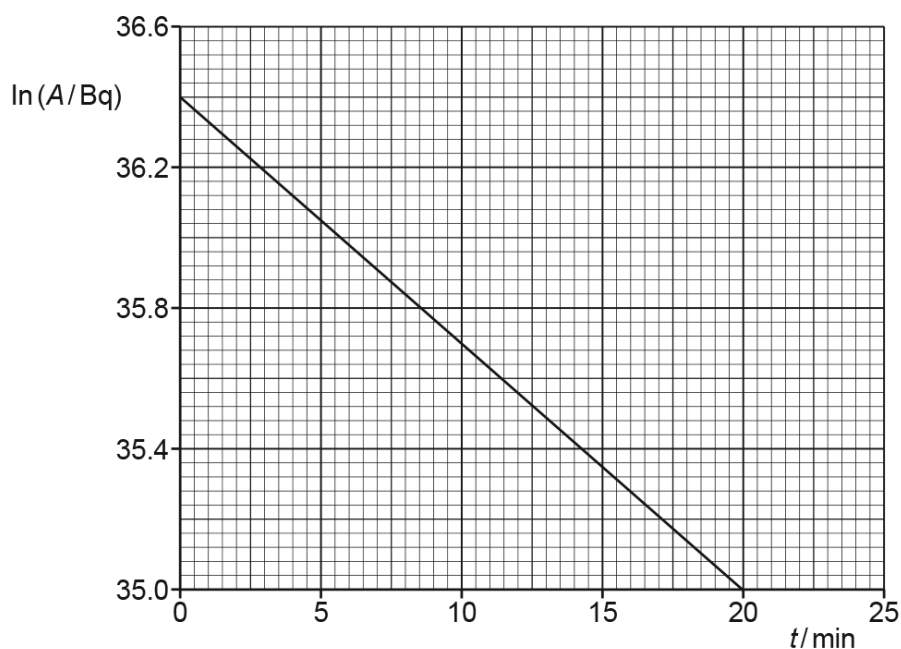


Fig. 12.1

- (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 ($^{131}_{53}\text{I}$) of mass $5.87 \times 10^{-10} \text{ kg}$ has an activity of $2.92 \times 10^9 \text{ Bq}$.

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]

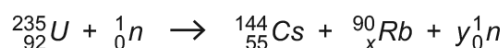
420. 9702_m20_qp_42 Q: 12

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

.....

 [2]

- (b) The following nuclear reaction takes place:



- (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 $3.6 \times 10^5 \text{ Bq}$.

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.

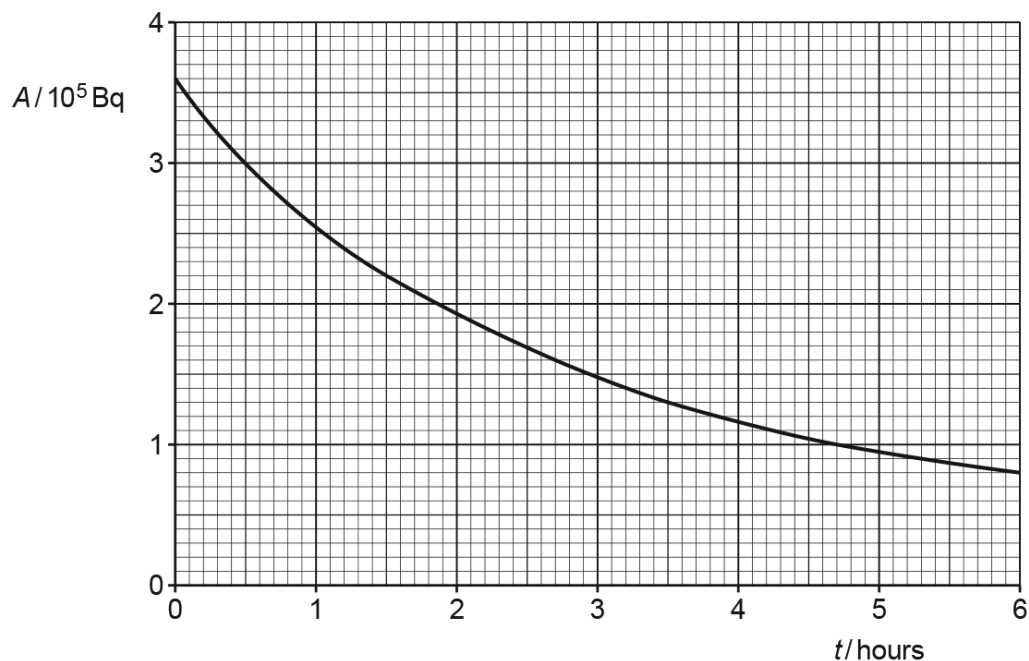


Fig. 12.1

- (i) The initial activity of isotope X in the sample is $3.6 \times 10^5 \text{ Bq}$.

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 $3.6 \times 10^5 \text{ Bq}$.

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.

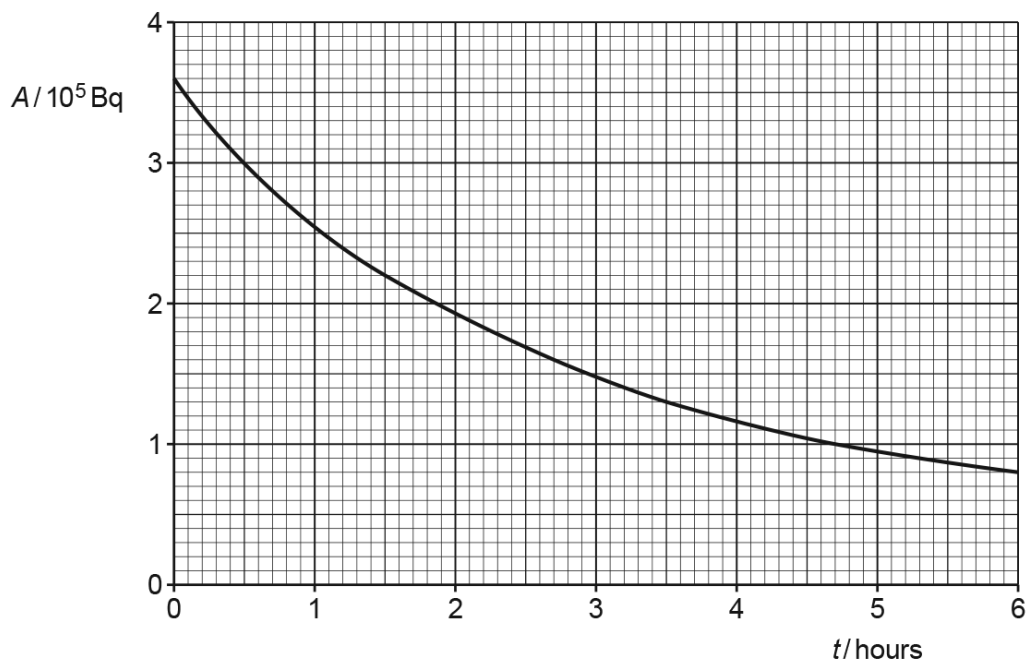


Fig. 12.1

- (i) The initial activity of isotope X in the sample is $3.6 \times 10^5 \text{ Bq}$.

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



Data for nuclear masses are given in Fig. 12.1.

	mass/u
^4_2He	4.002 603
$^{204}_{82}\text{Pb}$	203.973 043
$^{208}_{84}\text{Po}$	207.981 245

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 ${}^4_2\text{He}$ 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 (${}^1_1\text{p}$)	1.007
neutron (${}^1_0\text{n}$)	1.009
lanthanum-141 (${}^{141}_{57}\text{La}$) 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 (${}^{141}_{57}\text{La}$) 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]

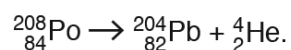
- (ii) the probability of decay of a nucleus in the time ΔT

..... [1]

- (iii) the decay constant λ of the isotope.

..... [1]

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



Data for nuclear masses are given in Fig. 12.1.

	mass/u
^4_2He	4.002 603
$^{204}_{82}\text{Pb}$	203.973 043
$^{208}_{84}\text{Po}$	207.981 245

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 ${}^4_2\text{He}$ 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 ($^{222}_{86}\text{Ra}$) is a radioactive gas that decays randomly with a decay constant of $7.55 \times 10^{-3} \text{ hour}^{-1}$.

(a) State what is meant by:

(i) *random decay*

.....
 [1]

(ii) *decay constant*.

.....

 [2]

(b) The activity of radon gas in a sample of $4.80 \times 10^{-3} \text{ m}^3$ 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 (${}^{24}_{11}\text{Na}$) has an initial activity of $3.8 \times 10^4 \text{ Bq}$. 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.

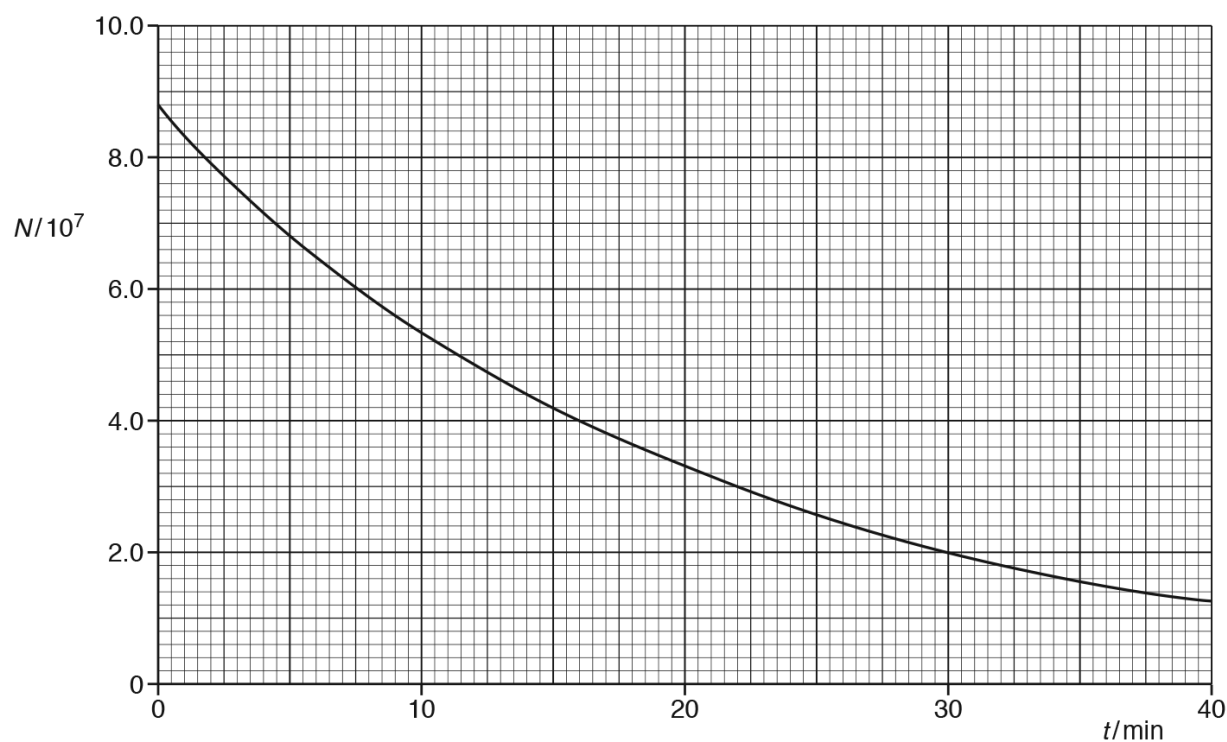


Fig. 13.1

- (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.

$\lambda =$ 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.

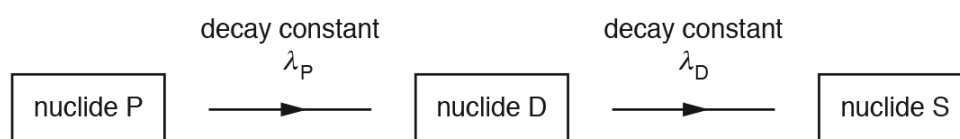


Fig. 12.1

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.

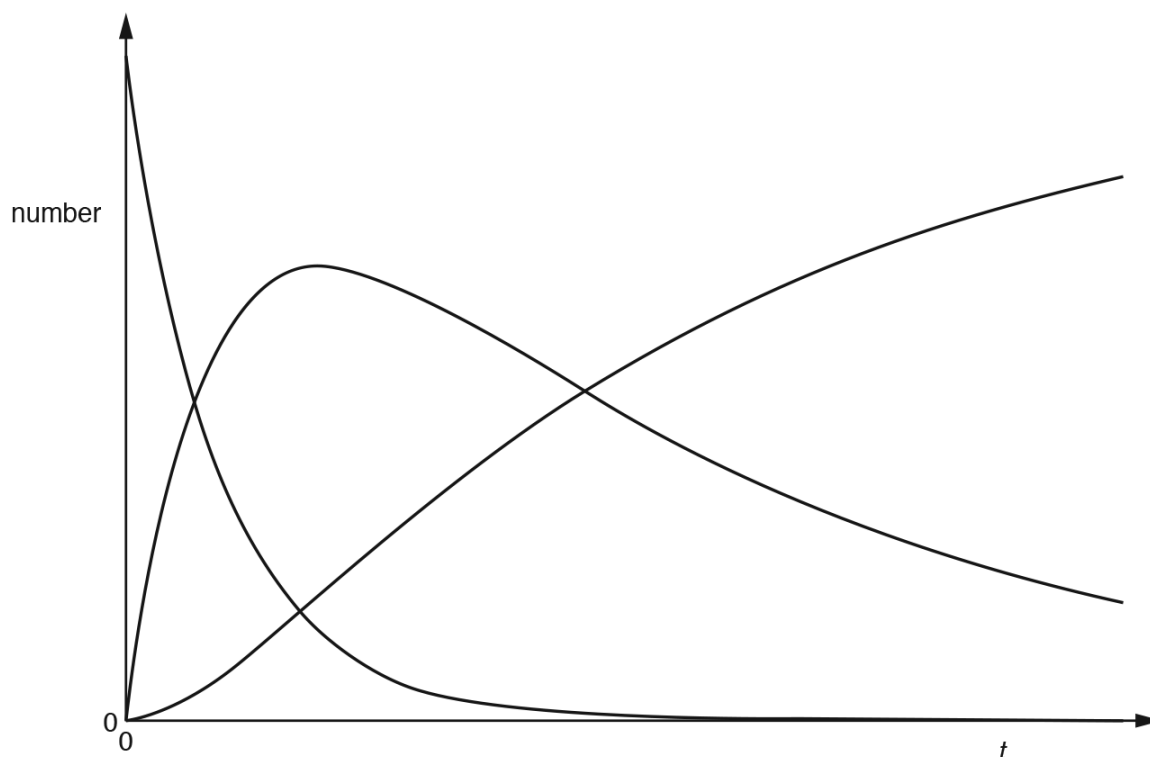


Fig. 12.2

(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.

$$\lambda_P = \dots\dots\dots \text{s}^{-1} \quad [2]$$

(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.

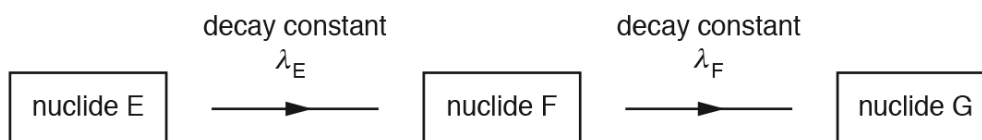


Fig. 12.3

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.

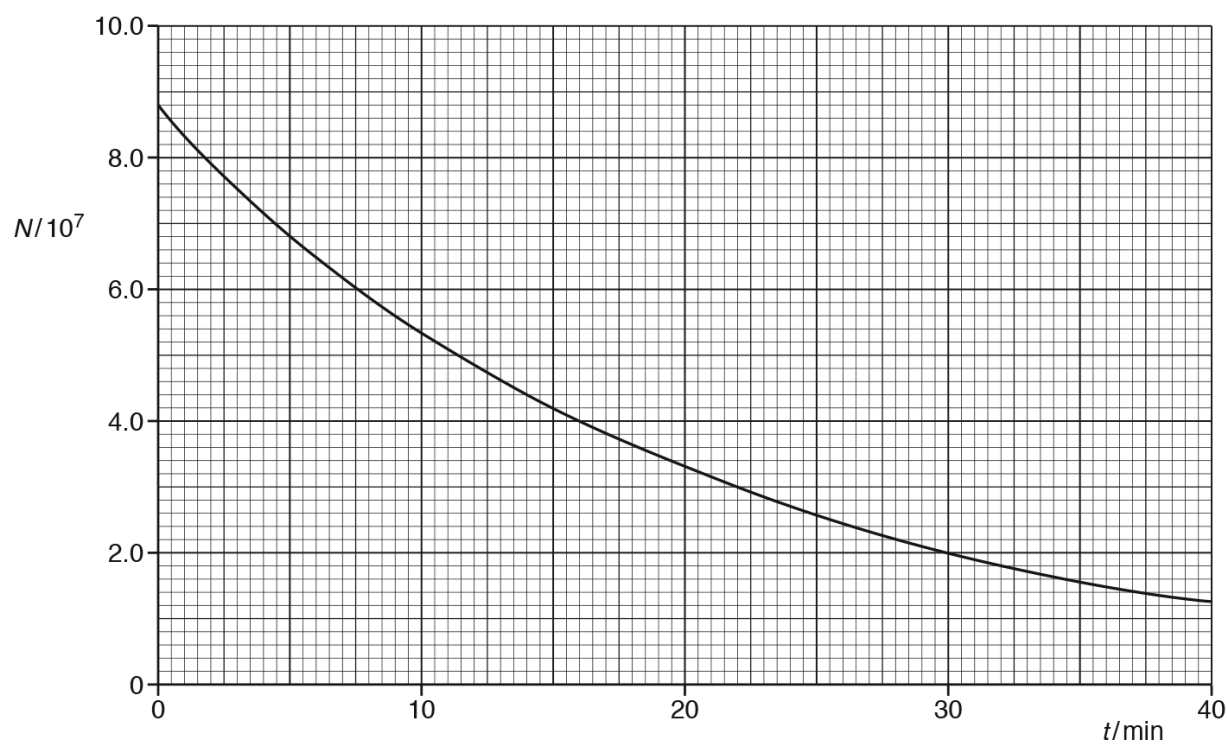


Fig. 13.1

- (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.

$\lambda = \dots\dots\dots \text{s}^{-1}$ [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.

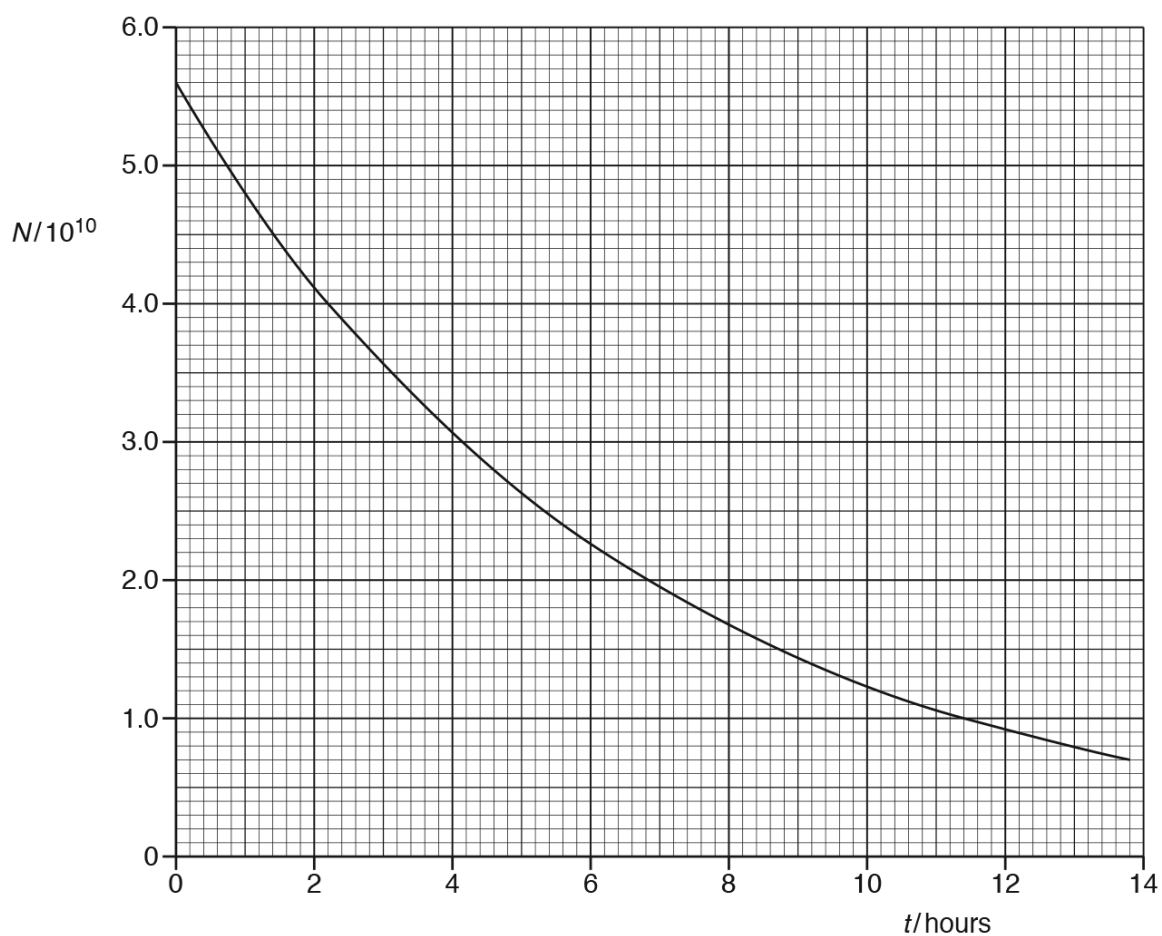


Fig. 12.1

- (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 $4 \times 10^{-5} \text{ s}^{-1}$.

[2]

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

The decay constant of the isotope is $5.5 \times 10^{-7} \text{ s}^{-1}$. 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.

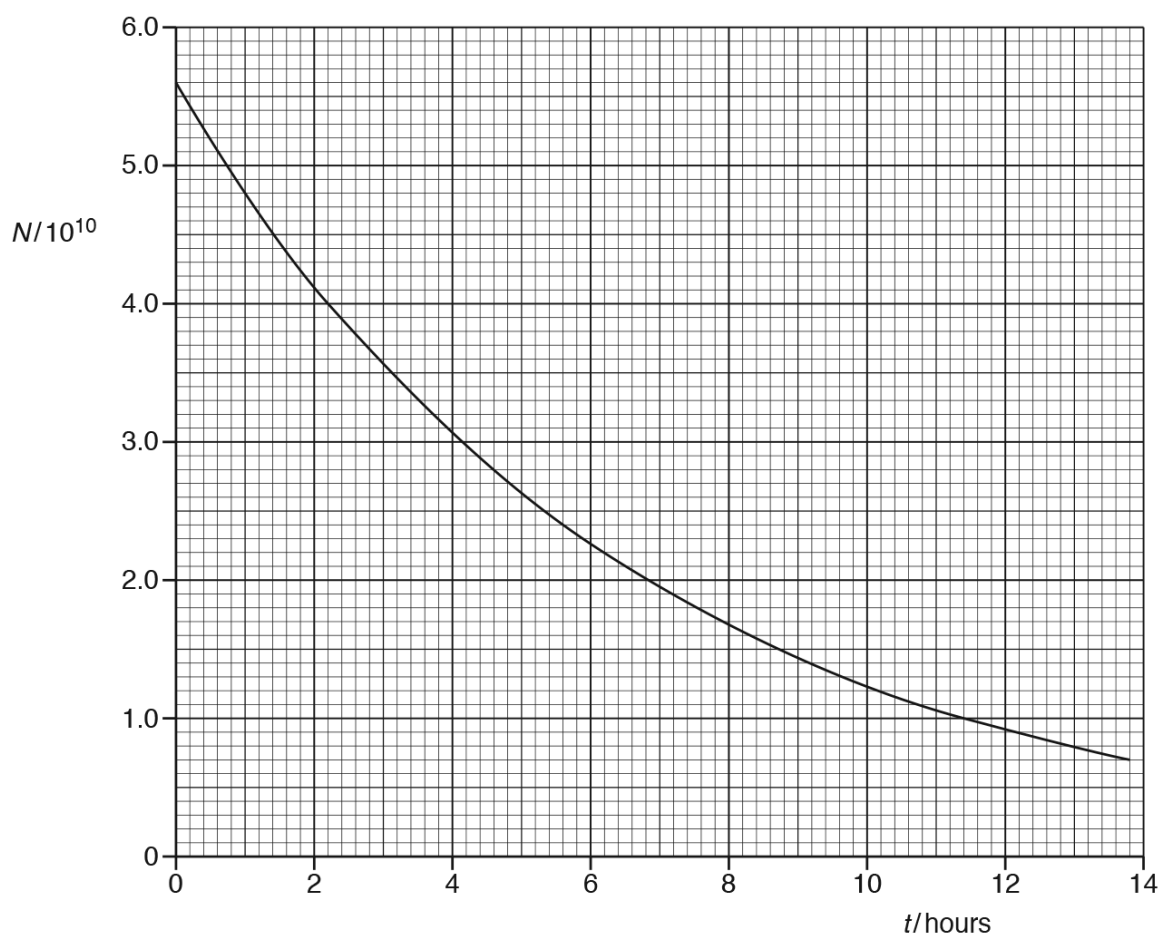


Fig. 12.1

- (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 $4 \times 10^{-5} \text{ s}^{-1}$.

[2]

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

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

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

time = ... days [3]

[Total: 11]

433. 9702_w17_qp_41 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.

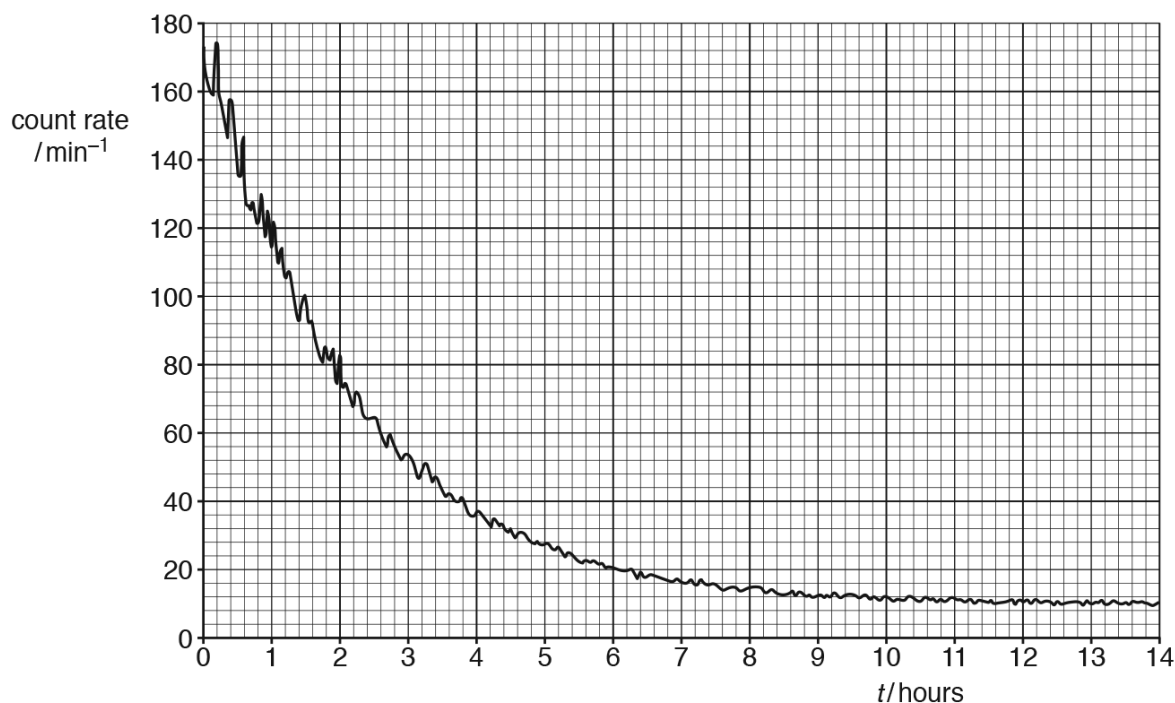


Fig. 12.1

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

.....

..... [1]

- (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 ($^{131}_{53}\text{I}$) is radioactive with a decay constant of $8.6 \times 10^{-2} \text{ day}^{-1}$.
 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 $1.2 \times 10^{-9} \text{ g}$ 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.

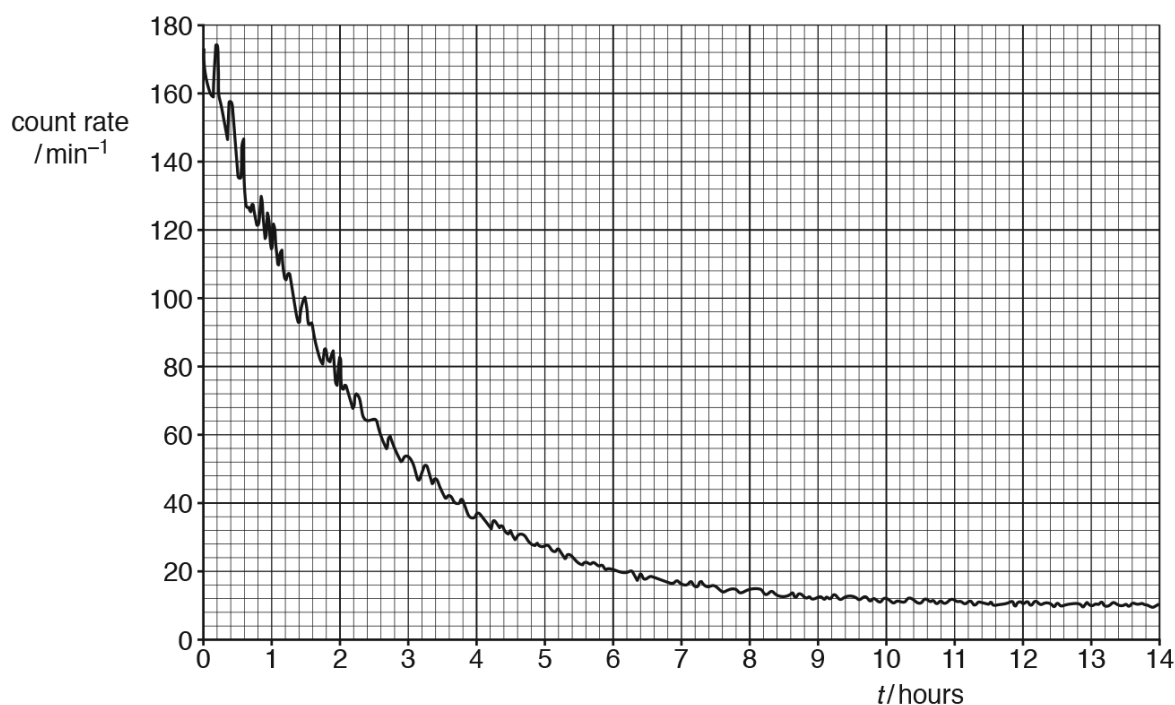


Fig. 12.1

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

.....

..... [1]

- (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 (${}^7_4\text{Be}$) 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 $1.5 \times 10^{-7} \text{ s}^{-1}$.

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

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

(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]

397. 9702_s20_MS_41 Q: 11

	Answer	Marks
(a)(i)	$E = mc^2$	C1
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$	A1
	$= 8.2 \times 10^{-14} \text{ J}$	
(a)(ii)	$p = h / \lambda$ and $E = hc / \lambda$ or $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$	A1
	$= 2.7 \times 10^{-22} \text{ N s}$	
(b)	total momentum (before and after interaction) is zero or momentum must be conserved (in the interaction) or momentum of the photons must be equal and opposite	B1
	(photons emitted in) opposite directions	B1

398. 9702_s20_MS_42 Q: 12

	Answer	Marks
(a)	difference between mass of nucleus and mass of (constituent) nucleons	M1
	where nucleons are separated to infinity	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 / (1.60 \times 10^{-13}) = 934 \text{ MeV}$	A1
(b)(ii)	mass defect = $2 \times (1.007276 + 1.008665) - 4.001506$ (= 0.030376)	B1
	binding energy per nucleon = $(0.030376 \times 934) / 4 = 7.09 \text{ MeV}$	A1
(c)	binding energy per nucleon is much greater	M1
	so would require a large amount of energy to separate the nucleons in helium	A1
	or	
	amount of energy released in forming hydrogen isotopes	(M1)
	is less than energy required to break apart helium nucleus	(A1)

399. 9702_s20_MS_43 Q: 11

	Answer	Marks
(a)(i)	$E = mc^2$	C1
	$= 9.11 \times 10^{-31} \times (3.0 \times 10^8)^2$	A1
	$= 8.2 \times 10^{-14} \text{ J}$	
(a)(ii)	$p = h / \lambda$ and $E = hc / \lambda$ or $E = pc$	C1
	$p = (8.2 \times 10^{-14}) / (3.0 \times 10^8)$	A1
	$= 2.7 \times 10^{-22} \text{ N s}$	
(b)	total momentum (before and after interaction) is zero or momentum must be conserved (in the interaction) or momentum of the photons must be equal and opposite	B1
	(photons emitted in) opposite directions	B1

400. 9702_m19_MS_42 Q: 12

	Answer	Marks
(a)(i)	fission	B1
(a)(ii)	either ${}^0_{-1}\text{e}$ or ${}^0_{-1}\beta$	M1
	7	A1
(b)(i)	energy $= c^2 \Delta m$ $= 0.223 \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	C1
	$= 3.33 \times 10^{-11} \text{ J}$	A1

	Answer	Marks
(b)(ii)	Any 2 from: kinetic energy of products gamma photons neutrinos	B2

401. 9702_w19_MS_41 Q: 12

	Answer	Marks
(a)	$E = (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27} (= 1.49 \times 10^{-10} \text{ J})$	M1
	$= (1.49 \times 10^{-10}) / (1.60 \times 10^{-19}) = 9.34 \times 10^8 = 934 \text{ MeV}$	A1
	or	
	binding energy = 8.443×95 [or equivalent using La-139 nucleus]	(M1)
	binding energy / mass defect = $(8.443 \times 95) / 0.859 = 934 \text{ MeV}$	(A1)
(b)(i)	binding energy = $1.865 \times 934 (= 1741.91 \text{ MeV})$	C1
	binding energy per nucleon = $1741.91 / 235$ $= 7.41 \text{ (MeV)}$	A1
(b)(ii)	less (than)	B1
(c)	energy = $\{(1.219 + 0.859) - 1.865\} \times 934$ or energy = $(95 \times 8.443) + (139 \times 8.189) - (235 \times 7.412)$	C1
	$= 199 \text{ MeV}$	A1
(d)	number of reactions = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$ $= 7.22 \times 10^{16}$	C1
	energy release (for one reaction) = $199 \times 1.60 \times 10^{-13} (= 3.18 \times 10^{-11} \text{ J})$	C1
	power = $(7.22 \times 10^{16} \times 3.18 \times 10^{-11}) / (25 \times 10^{-3})$ $= 9.2 \times 10^7 \text{ W}$	A1

402. 9702_w19_MS_43 Q: 12

	Answer	Marks
(a)	$E = (3.0 \times 10^8)^2 \times 1.66 \times 10^{-27} (= 1.49 \times 10^{-10} \text{ J})$	M1
	$= (1.49 \times 10^{-10}) / (1.60 \times 10^{-19}) = 9.34 \times 10^8 = 934 \text{ MeV}$	A1
	or	
	binding energy = 8.443×95 [or equivalent using La-139 nucleus]	(M1)
	binding energy / mass defect = $(8.443 \times 95) / 0.859 = 934 \text{ MeV}$	(A1)
(b)(i)	binding energy = $1.865 \times 934 (= 1741.91 \text{ MeV})$	C1
	binding energy per nucleon = $1741.91 / 235$ $= 7.41 \text{ (MeV)}$	A1
(b)(ii)	less (than)	B1
(c)	energy = $\{(1.219 + 0.859) - 1.865\} \times 934$ or energy = $(95 \times 8.443) + (139 \times 8.189) - (235 \times 7.412)$	C1
	$= 199 \text{ MeV}$	A1
(d)	number of reactions = $1.2 \times 10^{-7} \times 6.02 \times 10^{23}$ $= 7.22 \times 10^{16}$	C1
	energy release (for one reaction) = $199 \times 1.60 \times 10^{-13} (= 3.18 \times 10^{-11} \text{ J})$	C1
	power = $(7.22 \times 10^{16} \times 3.18 \times 10^{-11}) / (25 \times 10^{-3})$ $= 9.2 \times 10^7 \text{ W}$	A1

403. 9702_m18_MS_42 Q: 3

	Answer	Marks
(a)	reasonably shaped circle or oval surrounding the origin	B1
	closed loop passing through $(0, \pm v_0)$ and $(\pm x_0, 0)$	B1
(b)	line from $(0,0)$ to $(90, F_0)$	B1
	curve with decreasing positive gradient, zero gradient at $\theta = 90$	B1
(c)	reasonable sinusoidal wave, one cycle, period 4.0 ms	B1
	amplitude at 4.0 V	B1
(d)	U near right-hand end of line with Ba between U and peak of graph	B1
	Ba on right hand side of peak and Kr between Ba and peak of graph	B1

404. 9702_w18_MS_41 Q: 11

	Answer	Marks
(a)	discrete amount/quantum/packet of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(i)	energy = hc/λ	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8)/(0.51 \times 10^6 \times 1.60 \times 10^{-19})$ $= 2.4 \times 10^{-12} \text{ m}$	A1
(b)(ii)	$p = h/\lambda$ $= (6.63 \times 10^{-34})/(2.44 \times 10^{-12})$ or $p = E/c$ $= (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^8)$	C1
	$p = 2.7 \times 10^{-22} \text{ N s}$	A1
(c)(i)	$E = c^2 \Delta m$	C1
	$\Delta m = (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^8)^2$ $= 9.1 \times 10^{-31} \text{ kg}$	A1
(c)(ii)	(momentum is conserved so) nucleus must have momentum in opposite direction to photon	B1

405. 9702_w18_MS_42 Q: 12

	Answer	Marks
(a)	fusion: two nuclei <u>combine</u> to form a (single) nucleus	B1
	fission: a (single) large nucleus <u>divides</u> to form (smaller) nuclei	B1
	Any one from: - fusion is initiated by (very) high temperatures - fission is initiated by neutron bombardment - resulting nuclei in fission are of similar size (both processes) release energy - binding energy per nucleon increases - total binding energy increases - fission involves release of neutrons	B1
12(b)(i)	neutron	B1
12(b)(ii)	1. zero	A1
	2. $(4 \times 11.3290 \times 10^{-13}) - (2 \times 1.7813 \times 10^{-13}) - (3 \times 4.5285 \times 10^{-13})$	C1
	energy change = $45.316 \times 10^{-13} - 17.148 \times 10^{-13}$ $= 2.82 \times 10^{-12} \text{ J}$	A1
(b)(iii)	1.0 mol or N_A nuclei of each energy = $2.817 \times 10^{-12} \times 6.02 \times 10^{23}$ $= 1.7 \times 10^{12} \text{ J}$	A1

406. 9702_w18_MS_43 Q: 11

	Answer	Marks
(a)	discrete amount/quantum/packet of <u>energy</u>	M1
	of electromagnetic radiation	A1
(b)(i)	energy = hc/λ	C1
	$\lambda = (6.63 \times 10^{-34} \times 3.00 \times 10^8)/(0.51 \times 10^6 \times 1.60 \times 10^{-19})$ $= 2.4 \times 10^{-12} \text{ m}$	A1
(b)(ii)	$p = h/\lambda$ $= (6.63 \times 10^{-34})/(2.44 \times 10^{-12})$ or $p = E/c$ $= (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^8)$	C1
	$p = 2.7 \times 10^{-22} \text{ N s}$	A1
(c)(i)	$E = c^2 \Delta m$	C1
	$\Delta m = (0.51 \times 1.60 \times 10^{-13})/(3.00 \times 10^8)^2$ $= 9.1 \times 10^{-31} \text{ kg}$	A1
(c)(ii)	(momentum is conserved so) nucleus must have momentum in opposite direction to photon	B1

407. 9702_m17_MS_42 Q: 12

	Answer	Marks
(a)	<i>either</i>	
	(minimum) energy required / work done to separate the nucleons (in a nucleus)	M1
	to infinity	A1
	<i>or</i>	
	energy released when nucleons come together (to form a nucleus)	(M1)
	from infinity	(A1)
(b)(i)	(total) binding energy of thorium and helium (nuclei) greater than binding energy of uranium (nucleus)	B1
(b)(ii)1	change in mass = $238.05076 - (234.04357 + 4.00260)$ $= 4.59 \times 10^{-3} \text{ u}$	A1
(b)(ii)2	<i>either</i>	
	$E = mc^2$ $= 4.59 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	C1
	$= 6.9 \times 10^{-13} \text{ J}$	A1
	<i>or</i>	
	$1 \text{ u} = 931 \text{ MeV}$ $E = 4.59 \times 10^{-3} \times 931 \times 10^6 \times 1.6 \times 10^{-19}$	(C1)
	$= 6.8 \times 10^{-13} \text{ J}$	(A1)
(b)(iii)	Th nucleus / He nucleus / product nucleus has kinetic energy	M1
	energy of gamma photon must be less than energy released	A1

408. 9702_s17_MS_41 Q: 12

	Answer	Marks
(a)	$x = 7$	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$	C1
	$= 1.494 \times 10^{-10} \text{ J}$	
	division by 1.6×10^{-13} clear to give 934 MeV	A1
(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ or $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	C1
	$= 0.21053 \text{ u}$	C1
	energy $= 0.21053 \times 934$	A1
	$= 197 \text{ MeV}$	
(c)	kinetic energy of nuclei/particles/products/fragments	B1
	γ -ray photon energy	B1

409. 9702_s17_MS_42 Q: 12

	Answer	Marks
(a)	7^0_{-1}e	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	M1
	$= 1.494 \times 10^{-10} \text{ J}$	A1
	division by 1.60×10^{-13} clear to give 934 MeV	
(b)(ii)	$\Delta m = (82 \times 1.00863\text{u}) + (57 \times 1.00728\text{u}) - 138.955\text{u}$ $= (-) 1.16762 \text{ (u)}$	C1
	energy $= 1.16762 \times 934$	C1
	energy per nucleon $= (1.16762 \times 934) / 139$	A1
	$= 7.85 \text{ MeV}$	
(c)	above $A = 56$, binding energy per nucleon decreases as A increases	B1
	U-235 has larger nucleon number	M1
	so less (binding energy per nucleon)	A1
	or	
	fission takes place with uranium	(B1)
	fission reaction releases energy	(M1)
	binding energy per nucleon less (for uranium than for products)	(A1)

410. 9702_s17_MS_43 Q: 12

	Answer	Marks
(a)	$x = 7$	A1
(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$	C1
	$= 1.494 \times 10^{-10} \text{ J}$	
	division by 1.6×10^{-13} clear to give 934 MeV	A1
(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ or $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	C1
	$= 0.21053 \text{ u}$	C1
	energy $= 0.21053 \times 934$	A1
	$= 197 \text{ MeV}$	
(c)	kinetic energy of nuclei/particles/products/fragments	B1
	γ -ray photon energy	B1

411. 9702_m16_MS_42 Q: 9

- (a) direction of force due to electric field opposite to force due to magnetic field
 electric field is up the page
 B1
 B1 [2]
- (b) force due to electric field = force due to magnetic field or $Eq = Bqv$
 $E = Bv$
 $= 9.7 \times 10^{-2} \times 1.6 \times 10^5$
 $= 1.6 (1.55) \times 10^4 \text{ V m}^{-1}$
 B1
 C1
 A1 [3]
- (c) $q/m = v/Br$
 $= 1.6 \times 10^5 / (9.7 \times 10^{-2} \times 4.0 \times 10^{-2})$
 $= 4.1 (4.12) \times 10^7 \text{ C kg}^{-1}$
 C1
 C1
 A1 [3]
- (d) (i) $m = (3 \times 1.60 \times 10^{-19}) / (4.12 \times 10^7)$
 $m = 1.16 \times 10^{-26} / 1.66 \times 10^{-27}$
 $= 7(.0) \text{ u (allow 7.1 u)}$
 C1
 A1 [2]
- (ii) 3 protons, 4 neutrons
 A1 [1]

412. 9702_w16_MS_42 Q: 14

(a) (i) ${}^4_2\text{He}$ or ${}^4_2\alpha$ B1 [1](ii) ${}^1_0\text{n}$ B1 [1](b) (i) $\Delta m = (29.97830 + 1.00867) - (26.98153 + 4.00260)$ C1

$$= 30.98697 - 30.98413$$

$$= 2.84 \times 10^{-3} \text{ u}$$
 C1 [2]

(ii) $E = c^2\Delta m$ or mc^2 C1

$$= (3.0 \times 10^8)^2 \times 2.84 \times 10^{-3} \times 1.66 \times 10^{-27}$$

$$= 4.2 \times 10^{-13} \text{ J}$$
 A1 [2]

(c) mass of products is greater than mass of Al plus α
 or
 reaction causes (net) increase in (rest) mass (of the system)

B1

α -particle must have at least this amount of kinetic energy

B1 [2]

413. 9702_m21_MS_42 Q: 12

	Answer	Marks
(a)	1 not affected by external factors	B1
	2 cannot predict when a (particular) nucleus will decay or cannot predict which nucleus will decay (next)	B1
(b)(i)	Number of atoms = $\frac{1.0 \times 10^{-9}}{90 \times 1.66 \times 10^{-27}}$ or $\frac{1.0 \times 10^{-9} \times 6.02 \times 10^{23}}{90 \times 10^{-3}}$	C1
	$= 6.693 \times 10^{15}$	
	$A = \lambda N$	C1
	$\lambda = \frac{5.2 \times 10^6}{6.693 \times 10^{15}}$	
	$\lambda = 7.8 \times 10^{-10} \text{ s}^{-1}$	A1
(b)(ii)	daughter nucleus is unstable	B1

414. 9702_s21_MS_41 Q: 6

	Answer	Marks
(a)	from $x = 0$ to $x = r$: $E = 0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	B1
	line passing through $(2r, E_0/4)$ and $(3r, E_0/9)$	B1
(b)	from $p = p_0/2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	B1
	line passing through $(\frac{1}{2}p_0, 2\lambda_0)$	B1
(c)	from $t = 0$ to $t = 45$ s: curve with positive gradient of decreasing magnitude starting at $(0, 0)$	B1
	line passing through $(15, \frac{1}{2}N_0)$	B1
	line passing through $(30, 0.75N_0)$ and $(45, 0.88N_0)$	B1

415. 9702_s21_MS_42 Q: 5

	Answer	Marks
(a)	from $x = 0$ to $x = r$: horizontal line at $V = 1.0V_0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude starting at $(r, 1.0V_0)$	B1
	line passing through $(2r, \frac{1}{2}V_0)$ and $(3r, \frac{1}{3}V_0)$	B1
(b)	line with negative gradient from $\lambda = \frac{1}{3}\lambda_0$ to $\lambda = \lambda_0$	B1
	line passing through $(\lambda_0, 0)$	B1
	curve with negative gradient of decreasing magnitude passing through $(\frac{1}{2}\lambda_0, E_{\text{MAX}})$ and $(\frac{1}{3}\lambda_0, 2E_{\text{MAX}})$	B1
(c)	$1.0T_{\frac{1}{2}}$ shown at $\frac{1}{2}N_0$ and $2.0T_{\frac{1}{2}}$ shown at $\frac{1}{4}N_0$	B1
	line starting at $(0, 0)$ and reaching $(T, N_0 - N)$	B1
	line starting at $(0, 0)$ and reaching original curve at $(1.0T_{\frac{1}{2}}, \frac{1}{2}N_0)$	B1

416. 9702_s21_MS_43 Q: 6

	Answer	Marks
(a)	from $x = 0$ to $x = r$: $E = 0$	B1
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	B1
	line passing through $(2r, E_0/4)$ and $(3r, E_0/9)$	B1
(b)	from $p = p_0/2$ to $p = p_0$: curve with negative gradient of decreasing magnitude passing through (p_0, λ_0)	B1
	line passing through $(\frac{1}{2}p_0, 2\lambda_0)$	B1
(c)	from $t = 0$ to $t = 45$ s: curve with positive gradient of decreasing magnitude starting at $(0, 0)$	B1
	line passing through $(15, \frac{1}{2}N_0)$	B1
	line passing through $(30, 0.75N_0)$ and $(45, 0.88N_0)$	B1

417. 9702_w21_MS_41 Q: 12

	Answer	Marks
(a)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	$N = \text{mass} / (\text{nucleon number} \times u)$	C1
	$2.92 \times 10^9 = (\lambda \times 5.87 \times 10^{-10}) / (131 \times 1.66 \times 10^{-27})$	A1
	$\lambda = 1.08 \times 10^{-6} \text{ s}^{-1}$	
(c)	- sample emits radiation in all directions - some radiation is absorbed by air/detector window - self-absorption within the source - dead time/inefficiency of detector <i>Any two points, 1 mark each</i>	B2

418. 9702_w21_MS_42 Q: 12

	Answer	Marks
(a)(i)	cannot predict when a particular nucleus will decay or cannot predict which nucleus will decay next	B1
(a)(ii)	(decay is) not affected by external (environmental) factors	B1
(b)(i)	$A = A_0 \exp(-\lambda t)$ and so $\ln A = \ln A_0 - \lambda t$	C1
	gradient of line = $(-\lambda)$	
	$\lambda = (36.4 - 35.0) / (20 - 0)$	C1
	$(= 0.07(0) \text{ min}^{-1})$	
	half-life = $\ln 2 / \lambda$	A1
	$= \ln 2 / 0.070$	
	$= 10 \text{ min}$	
	or	
	$A_0 = \exp(-36.4) = 6.43 \times 10^{15} \text{ (Bq)}$	(C1)
	$A_0 / 2 = 3.21 \times 10^{15} \text{ (Bq)}, \text{ so } \ln(A_0 / 2) = 35.7$	(C1)
	read off half-life = 10 min	(A1)
	or	
	(at one half-life,) $\ln A = 36.4 - \ln 2$	(C1)
	$= 35.7$	(C1)
	read off half-life = 10 min	(A1)

	Answer	Marks
(b)(ii)	$A = \lambda N$	C1
	$N = \text{mass} / (\text{nucleon number} \times u)$ or $N = (\text{mass} / \text{nucleon number}) \times N_A$	C1
	$\exp(36.4) = (1.17 \times 10^{-3} \times 5.66 \times 10^{-7}) / (\text{nucleon number} \times 1.66 \times 10^{-27})$ or $\exp(36.4) = (1.17 \times 10^{-3} \times 5.66 \times 10^{-4} \times 6.02 \times 10^{23}) / \text{nucleon number}$	A1
	nucleon number = 62	

419. 9702_w21_MS_43 Q: 12

	Answer	Marks
(a)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	$N = \text{mass} / (\text{nucleon number} \times u)$	C1
	$2.92 \times 10^9 = (\lambda \times 5.87 \times 10^{-10}) / (131 \times 1.66 \times 10^{-27})$	A1
	$\lambda = 1.08 \times 10^{-6} \text{ s}^{-1}$	
(c)	- sample emits radiation in all directions - some radiation is absorbed by air/detector window - self-absorption within the source - dead time/inefficiency of detector <i>Any two points, 1 mark each</i>	B2

420. 9702_m20_MS_42 Q: 12

	Answer	Marks
(a)	(minimum) energy required to separate the nucleons	M1
	to infinity	A1
(b)(i)	37 2	B1
(b)(ii)	fission	B1
(b)(iii)	binding energy per nucleon smaller for U than for Cs	B1
(c)	Current ratio 2 Y to 1 Zr, so initially 3 Y	C1
	$2 = 3 e^{-\lambda t}$	
	$\lambda = 0.693 / 2.7$	
	$\ln(2/3) = -(\ln 2 / 2.7)t$	C1
	t = 1.6 days	A1
	or	
	$(\frac{1}{2})^n = 2/3$	(C1)
	n = 0.585	(C1)
	time = 0.585×2.7 = 1.6 days	(A1)

421. 9702_s20_MS_41 Q: 12

	Answer	Marks
(a)(i)	time at which a nucleus will decay cannot be predicted or constant probability of decay of a nucleus	B1
(a)(ii)	decay (of a nucleus) not affected by environmental factors	B1
(b)	$A = A_0 e^{-\lambda t}$ and $\lambda = \ln 2 / t_{1/2}$	C1
	$= 3.6 \times 10^5 \times \exp [-(2 \times \ln 2) / 1.4]$	C1
	or	
	$A = A_0 \times 0.5^N$	(C1)
	$= 3.6 \times 10^5 \times 0.5^N$ where $N = 2 / 1.4$	(C1)
	$A = 1.3 \times 10^5 \text{ Bq}$	A1
(c)(i)	smooth curve, starting at $(0, 3.6 \times 10^5)$ and passing through $(1.4, 1.8 \times 10^5)$ and $(2.0, 1.3 \times 10^5)$	B1
(c)(ii)	(activity of sample is greater than activity of X so) there must be an additional source of activity	C1
	the decay product (of isotope X) is radioactive	A1

422. 9702_s20_MS_43 Q: 12

	Answer	Marks
(a)(i)	time at which a nucleus will decay cannot be predicted or constant probability of decay of a nucleus	B1
(a)(ii)	decay (of a nucleus) not affected by environmental factors	B1
(b)	$A = A_0 e^{-\lambda t}$ and $\lambda = \ln 2 / t_{1/2}$	C1
	$= 3.6 \times 10^5 \times \exp [-(2 \times \ln 2) / 1.4]$	C1
	or	
	$A = A_0 \times 0.5^N$	(C1)
	$= 3.6 \times 10^5 \times 0.5^N$ where $N = 2 / 1.4$	(C1)
	$A = 1.3 \times 10^5 \text{ Bq}$	A1
12(c)(i)	smooth curve, starting at $(0, 3.6 \times 10^5)$ and passing through $(1.4, 1.8 \times 10^5)$ and $(2.0, 1.3 \times 10^5)$	B1
(c)(ii)	(activity of sample is greater than activity of X so) there must be an additional source of activity	C1
	the decay product (of isotope X) is radioactive	A1

423. 9702_s19_MS_41 Q: 12

	Answer	Marks
(a)(i)	$\Delta N / \Delta T$	B1
(a)(ii)	$\Delta N / N$	B1
(a)(iii)	$\Delta N / (N \Delta T)$	B1
(b)(i)	1. mass change $= 5.60 \times 10^{-3} \text{ u}$	A1
	2. energy $= (\Delta)mc^2$	C1
	$= 5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $(= 8.36 \times 10^{-13} \text{ J})$	C1
	$= 0.84 \text{ pJ}$	A1
(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	B1
	energy of γ -ray photon	B1

424. 9702_s19_MS_42 Q: 12

	Answer	Marks
(a)	energy required to separate the nucleons (in a nucleus)	M1
	to infinity	A1
	or	
	energy released when nucleons come together (to form nucleus)	(M1)
	from infinity	(A1)
(b)	mass defect = $140.911 - (57 \times 1.007) - (84 \times 1.009)$	C1
	= $140.911 - 142.155$	C1
	= (-1.244 (u))	
	energy = $c^2(\Delta)m$	C1
	= $(3.00 \times 10^8)^2 \times 1.244 \times 1.66 \times 10^{-27}$ = $1.9 \times 10^{-10} \text{ J}$	A1
(c)(i)	$A = A_0 e^{-\lambda t}$ and $\ln 2 = \lambda t_{1/2}$	C1
	$0.40 = \exp(-\ln 2 \times t / 3.9)$	C1
	or	
	$(0.5)^n = 0.40$	(C1)
	$n = 1.32$ and $t = 1.32 \times 3.9$	(C1)
	$t = 5.2 \text{ hours}$	A1
(c)(ii)	daughter product may be radioactive or random nature of decay	B1

425. 9702_s19_MS_43 Q: 12

	Answer	Marks
(a)(i)	$\Delta N / \Delta T$	B1
(a)(ii)	$\Delta N / N$	B1
(a)(iii)	$\Delta N / (N \Delta T)$	B1
(b)(i)	1. mass change = $5.60 \times 10^{-3} \text{ u}$	A1
	2. energy = $(\Delta)mc^2$	C1
	= $5.6 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ (= $8.36 \times 10^{-13} \text{ J}$)	C1
	= 0.84 pJ	A1
(b)(ii)	kinetic energy (of recoil) of lead (nucleus)	B1
	energy of γ -ray photon	B1

426. 9702_w19_MS_42 Q: 12

	Answer	Marks
(a)(i)	(decay is) unpredictable/cannot be predicted	B1
(a)(ii)	probability of decay (of a nucleus)	M1
	per unit time	A1
(b)	$A = \lambda N$	C1
	(for 1.00 m^3) $A = 0.600 / 4.80 \times 10^{-3}$ (= 125 Bq)	C1
	$N = 125 / ([7.55 \times 10^{-3}] / 3600)$ (= 5.96×10^7)	C1
	so ratio = $(2.52 \times 10^{25}) / (5.96 \times 10^7)$	C1
	or	
	(for $4.80 \times 10^{-3} \text{ m}^3$) N for air = $2.52 \times 10^{25} \times 4.80 \times 10^{-3}$ (= 1.21×10^{23})	(C1)
	N for radon = $0.600 / ([7.55 \times 10^{-3}] / 3600)$ (= 2.86×10^5)	(C1)
	so ratio = $(1.21 \times 10^{23}) / (2.86 \times 10^5)$	(C1)
	ratio = 4.2×10^{17}	A1

427. 9702_m18_MS_42 Q: 13

	Answer	Marks
(a)(i)	probability of decay (of a nucleus)	M1
	per unit time	A1
(a)(ii)	$A = A_0 e^{-\lambda t}$	M1
	after one half-life, $\frac{1}{2}A_0 = A_0 e^{-\lambda t_{1/2}}$	
	$\frac{1}{2} = \exp(-\lambda t_{1/2})$ and hence taking logs, $\ln 2 = \lambda t_{1/2}$	A1
(b)	activity = $3.8 \times 10^4 \exp(-\ln 2 \times 36 / 15)$	C1
	= 7200 Bq	C1
	or activity = $3.8 \times 10^4 / 2^{2.4}$	(C1)
	= 7200 Bq	(C1)
	volume = $(7200 / 1.2) \times 5.0$	C1
	= $3.0 \times 10^4 \text{ cm}^3$	A1
	OR activity of 5.0 cm^3 = $1.2 \times 2^{2.4}$	(C1)
	= 6.3336 Bq	(C1)
	volume = $(3.8 \times 10^4 / 6.3336) \times 5.0$	(C1)
	= $3.0 \times 10^4 \text{ cm}^3$	(A1)

428. 9702_s18_MS_41 Q: 13

	Answer	Marks
(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
(b)(i)	use of graph to determine half-life = 14 minutes	B1
	hence $\lambda = \ln 2 / (14 \times 60) \text{ (s}^{-1}\text{)}$	C1
	N at 14 minutes = 4.4×10^7 and $A = \lambda N$	C1
	activity = $4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ = $3.6 \times 10^4 \text{ Bq}$	A1
	or	
	correct tangent drawn at time $t = 14$ minutes	(B1)
	magnitude of gradient of tangent identified as activity	(C1)
	correct working for gradient leading to activity	(C1)
	activity = $3.6 \times 10^4 \text{ Bq}$	(A1)
(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ or $\lambda = \ln 2 / (14.0 \times 60)$	C1
	$\lambda = 8.2 \times 10^{-4} \text{ s}^{-1}$	A1

429. 9702_s18_MS_42 Q: 12

	Answer	Marks
(a)	emission of particles/radiation by <u>unstable nucleus</u>	B1
	spontaneous emission	B1
(b)(i)	P – the curve that starts with a high number D – the curve with the peak S – the curve that increases from zero throughout <i>(one correct 1 mark, all three correct 2 marks)</i>	B2
(b)(ii)	$\lambda t_{1/2} = 0.693$ $\lambda = 0.693 / (60.0 \times 60)$ = $1.93 \times 10^{-4} \text{ s}^{-1}$	C1
		A1
(c)	half-life of F is much shorter than half-life of E	B1
	<u>nuclei</u> of F decay (almost) as soon as they are produced	B1

430. 9702_s18_MS_43 Q: 13

	Answer	Marks
(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
(b)(i)	use of graph to determine half-life = 14 minutes	B1
	hence $\lambda = \ln 2 / (14 \times 60) \text{ (s}^{-1}\text{)}$	C1
	N at 14 minutes = 4.4×10^7 and $A = \lambda N$	C1
	activity = $4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ = $3.6 \times 10^4 \text{ Bq}$	A1
	or	
	correct tangent drawn at time $t = 14$ minutes	(B1)
	magnitude of gradient of tangent identified as activity	(C1)
	correct working for gradient leading to activity	(C1)
	activity = $3.6 \times 10^4 \text{ Bq}$	(A1)
(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ or $\lambda = \ln 2 / (14.0 \times 60)$	C1
	$\lambda = 8.2 \times 10^{-4} \text{ s}^{-1}$	A1

431. 9702_w18_MS_41 Q: 12

	Answer	Marks
(a)	unstable nucleus	B1
	emission of particles/photons	B1
	emission is spontaneous or (particles/radiation) are ionising	B1
(b)(i)	tangent drawn and gradient calculation attempted	B1
	activity = $1.3 \times 10^6 \text{ Bq}$ (1 mark for answer within $\pm 0.2 \times 10^6 \text{ Bq}$, 2 marks for answer within $\pm 0.1 \times 10^6 \text{ Bq}$)	A2
(b)(ii)	$A = \lambda N$	C1
	$\lambda = (1.3 \times 10^6) / (3.05 \times 10^{10}) = 4.3 \times 10^{-5} \text{ s}^{-1} (\approx 4 \times 10^{-5} \text{ s}^{-1})$	A1
(c)	$A = A_0 e^{-\lambda t}$	C1
	$1.0 \times 10^3 = 4.6 \times 10^3 \exp(-5.5 \times 10^{-7} \times t)$	
	$\ln(4.6) = 5.5 \times 10^{-7} \times t$	C1
	$t = 2.78 \times 10^6 \text{ s}$ = 32 days	A1

432. 9702_w18_MS_43 Q: 12

	Answer	Marks
(a)	unstable nucleus	B1
	emission of particles/photons	B1
	emission is spontaneous or (particles/radiation) are ionising	B1
(b)(i)	tangent drawn and gradient calculation attempted	B1
	activity = 1.3×10^6 Bq (1 mark for answer within $\pm 0.2 \times 10^6$ Bq, 2 marks for answer within $\pm 0.1 \times 10^6$ Bq)	A2
(b)(ii)	$A = \lambda N$	C1
	$\lambda = (1.3 \times 10^6)/(3.05 \times 10^{10}) = 4.3 \times 10^{-5} \text{ s}^{-1}$ ($\approx 4 \times 10^{-5} \text{ s}^{-1}$)	A1
(c)	$A = A_0 e^{-\lambda t}$	C1
	$1.0 \times 10^3 = 4.6 \times 10^3 \exp(-5.5 \times 10^{-7} \times t)$	
	$\ln(4.6) = 5.5 \times 10^{-7} \times t$	C1
	$t = 2.78 \times 10^6 \text{ s}$ $= 32 \text{ days}$	A1

433. 9702_w17_MS_41 Q: 12

	Answer	Marks
(a)	• emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • dead-time of counter • background radiation Any two points.	B2
(b)(i)	curve is not smooth or curve fluctuates/curve is jagged	B1
(b)(ii)	clear evidence of allowance for background	B1
	half-life determined at least twice	B1
	half-life = 1.5 hours (1 mark if in range 1.7–2.0; 2 marks if in range 1.4–1.6)	A2
(c)	1. half-life: no change	M1
	because decay is spontaneous/independent of environment	A1
	2. count rate (likely to be or could be) different/is random/cannot be predicted	B1

434. 9702_w17_MS_42 Q: 12

	Answer	Marks
(a)(i)	<u>nucleus</u> emits particles/EM radiation/ionising radiation	B1
	emission/release from unstable <u>nucleus</u> or emission from <u>nucleus</u> is random and/or spontaneous	B1
(a)(ii)	probability of decay (of a nucleus) or fraction of (number of undecayed) nuclei that will decay	M1
	per unit time	A1
(b)	energy is shared with another particle	B1
	mention of antineutrino	B1
(c)(i)	number = $[(1.2 \times 10^{-9}) / 131] \times 6.02 \times 10^{23}$ or number = $(1.2 \times 10^{-3} \times 10^{-9}) / (131 \times 1.66 \times 10^{-27})$ (= 5.51×10^{12})	C1
	$A = \lambda N$	C1
	= $[0.086 / (24 \times 3600)] \times 5.51 \times 10^{12}$ = 5.5×10^6 Bq	A1
(c)(ii)	$1/50 = \exp(-0.086t)$ or $1/50 = 0.5^n$	C1
	$t = 45$ days	A1

435. 9702_w17_MS_43 Q: 12

	Answer	Marks
(a)	• emission from radioactive daughter products • self-absorption in source • absorption in air before reaching detector • detector not sensitive to all radiations • window of detector may absorb some radiation • dead-time of counter • background radiation Any two points.	B2
(b)(i)	curve is not smooth or curve fluctuates/curve is jagged	B1
(b)(ii)	clear evidence of allowance for background	B1
	half-life determined at least twice	B1
	half-life = 1.5 hours (1 mark if in range 1.7–2.0; 2 marks if in range 1.4–1.6)	A2
(c)	1. half-life: no change	M1
	because decay is spontaneous/independent of environment	A1
	2. count rate (likely to be or could be) different/is random/cannot be predicted	B1

436. 9702_m16_MS_42 Q: 13

- (a) $\lambda = \ln 2 / T_{1/2}$
 $= \ln 2 / (53.3 \times 24 \times 60 \times 60) = 1.5 \times 10^{-7} \text{ s}^{-1}$ A1 [1]
- (b) $A = \lambda N$ C1
 $N = 39 \times 10^{-3} / 1.5 \times 10^{-7} = 2.6 \times 10^5$
 $m = (2.6 \times 10^5 / 6.0 \times 10^{23}) \times 7 \times 10^{-3}$ or $2.6 \times 10^5 \times 1.66 \times 10^{-27} \times 7$ C1
 $= 3.0 \times 10^{-21} \text{ kg}$ A1 [3]
- (c) $2/39 = \exp(-1.5 \times 10^{-7} \times t)$ or $2/39 = (1/2)^{[t/(53.3 \times 24 \times 3600)]}$ C1
 $t = 2.0 \times 10^7 \text{ s}$ A1 [2]

437. 9702_w16_MS_41 Q: 12

- (a) (i) time for number of atoms/nuclei or activity to be reduced to one half M1
 reference to (number of...) original nuclide/single isotope
 or
 reference to half of original value/initial activity A1 [2]
- (ii) $A = A_0 \exp(-\lambda t)$ and either $t = t_{1/2}$, $A = \frac{1}{2}A_0$ or $\frac{1}{2}A_0 = A_0 \exp(-\lambda t_{1/2})$ M1
 so $\ln 2 = \lambda t_{1/2}$ (and $\ln 2 = 0.693$), hence $0.693 = \lambda t_{1/2}$ A1 [2]
- (b) $A = \lambda N$
 $N = 200 / (2.1 \times 10^{-6})$ C1
 $= 9.52 \times 10^7$ C1
 mass = $(9.52 \times 10^7 \times 222 \times 10^{-3}) / (6.02 \times 10^{23})$
 or
 mass = $9.52 \times 10^7 \times 222 \times 1.66 \times 10^{-27}$ C1
 $= 3.5 \times 10^{-17} \text{ kg}$ A1 [4]

438. 9702_w16_MS_43 Q: 12

- (a) (i) time for number of atoms/nuclei or activity to be reduced to one half M1
 reference to (number of...) original nuclide/single isotope
 or
 reference to half of original value/initial activity A1 [2]
- (ii) $A = A_0 \exp(-\lambda t)$ and either $t = t_{1/2}$, $A = \frac{1}{2}A_0$ or $\frac{1}{2}A_0 = A_0 \exp(-\lambda t_{1/2})$ M1
 so $\ln 2 = \lambda t_{1/2}$ (and $\ln 2 = 0.693$), hence $0.693 = \lambda t_{1/2}$ A1 [2]
- (b) $A = \lambda N$
 $N = 200 / (2.1 \times 10^{-6})$ C1
 $= 9.52 \times 10^7$ C1
 $\text{mass} = (9.52 \times 10^7 \times 222 \times 10^{-3}) / (6.02 \times 10^{23})$
 or
 $\text{mass} = 9.52 \times 10^7 \times 222 \times 1.66 \times 10^{-27}$ C1
 $= 3.5 \times 10^{-17} \text{ kg}$ A1 [4]

Q1.

- 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).

Use

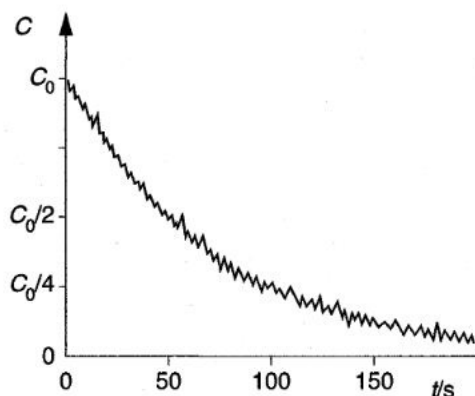


Fig. 6.1(a)

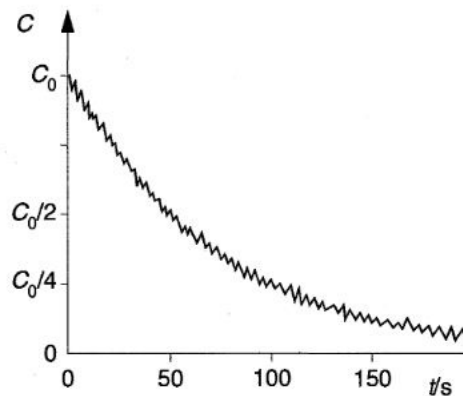


Fig. 6.1(b)

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.

.....
.....

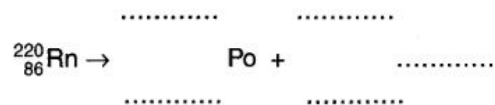
[2]

(b) The radioactive source in (a) is an isotope of radon ($^{220}_{86}\text{Rn}$) 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.



[3]

Q2.

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

5

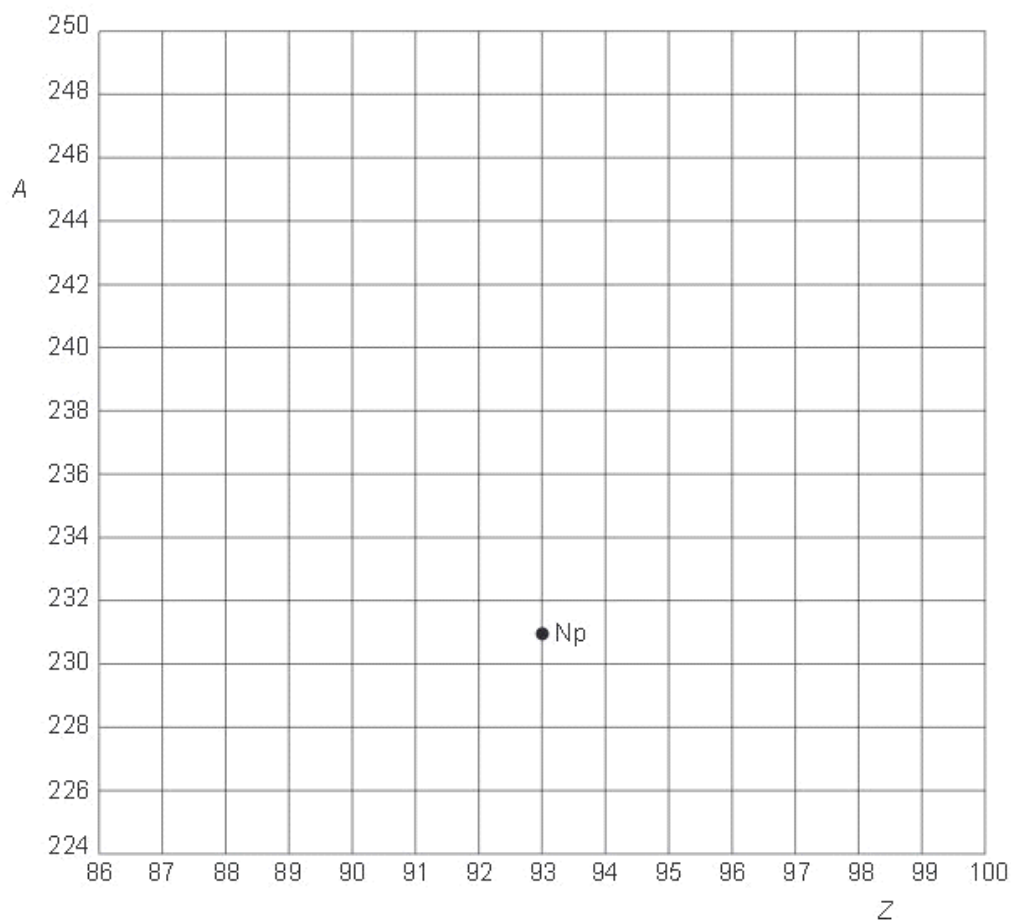


Fig. 8.1

- (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 ($^{243}_{94}\text{Pu}$) 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.

- 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.

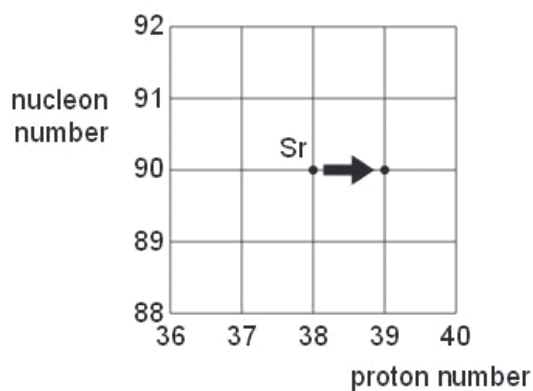


Fig. 7.1

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

Ex

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

.....

.....

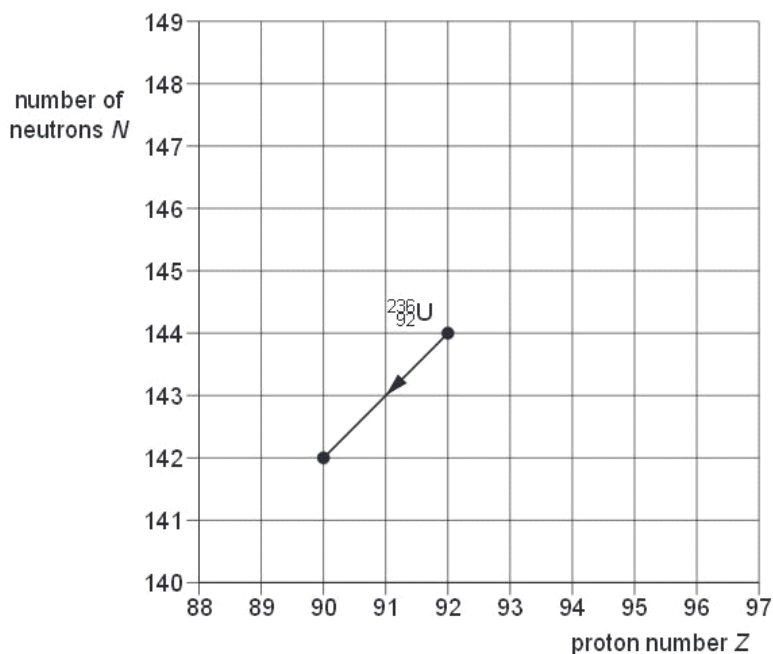
.....

.....

.....

.....[4]

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

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- (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.

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

F0
Exam
Us

- (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 ($^{238}_{92}\text{U}$).

F
Exam
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]

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

Calculate, for a uranium-238 nucleus,

(i) its mass,

mass = ... kg [2]

(ii) its mean density.

density = ... kg m^{-3} [2]

(d) The density of a lump of uranium is $1.9 \times 10^4 \text{ kg m}^{-3}$.

Using your answer to (c)(ii), suggest what can be inferred about the structure of the atom. Ex.

.....
.....
..... [2]

Q8.

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

Expt

- (i) what is meant by an α -particle,

.....[1]

- (ii) two properties of α -particles.

1.

.....

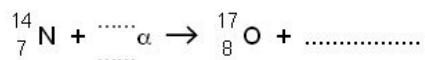
2.

.....

[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.



[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.

- 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. Ex6

(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]

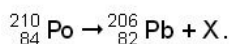
- (iii) Using your answer in (a)(ii), estimate the average number of ion pairs produced per unit length of the track of the α -particle as it is brought to rest in air.

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U:

number per unit length = ...[2]

Q10.

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



Ex

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

.....
.....[1]

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

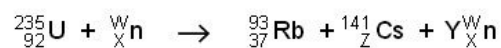
1.
.....
2.
.....
.....[2]

- (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.

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



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.

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

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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.

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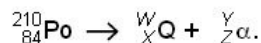
result 1:
.....
result 2:
..... [3]

- (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.

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



- (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 (${}^{235}_{92}\text{U}$) and uranium-238 (${}^{238}_{92}\text{U}$).

- (i) Describe in detail an atom of uranium-235.

.....

 [4]

- (ii) With reference to the two forms of uranium, explain the term *isotopes*.

.....

 [2]

Exa

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(b) When a uranium-235 nucleus absorbs a neutron, the following reaction may occur:



(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.

6 One isotope of iron may be represented by the symbol

Use



(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 $5.7 \times 10^{-15} \text{ m}$.

Calculate, for one such nucleus,

(i) the mass,

mass = ... kg

(ii) the density.

density = ... kg m^{-3}
[4]

- (c) An iron ball is found to have a density of 7900 kg m^{-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.

- 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.

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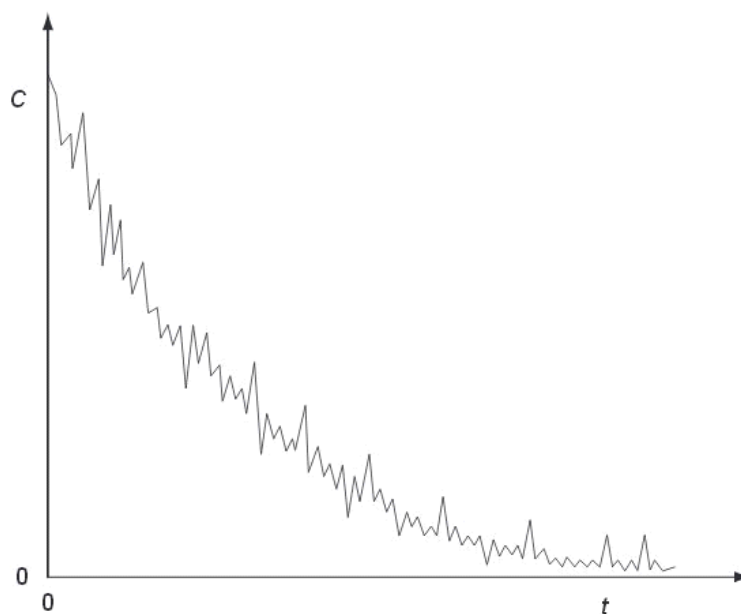


Fig. 8.1

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.

.....
..... [1]

For
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Use

Q21.

- 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

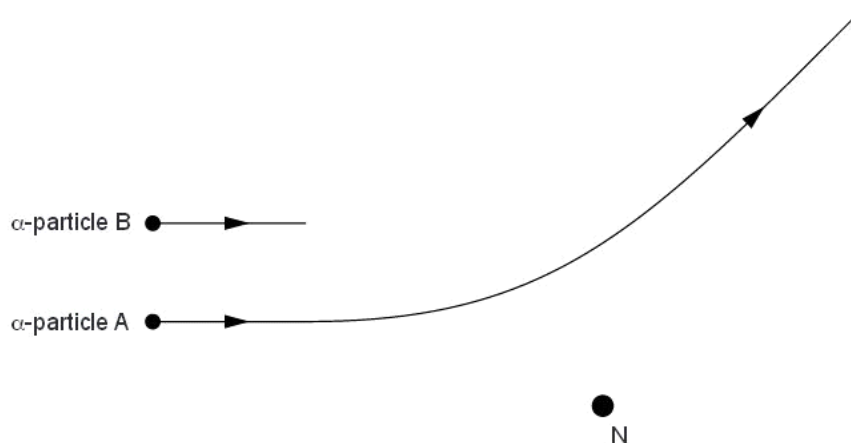


Fig. 7.1

- (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.

Q22.

- 7 Tungsten-184 ($^{184}_{74}\text{W}$) and tungsten-185 ($^{185}_{74}\text{W}$) 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

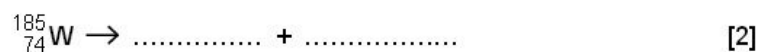
- (i) *spontaneous* decay,

.....
..... [1]

- (ii) *random* decay.

.....
..... [1]

- (c) Complete the nuclear equation for the β -decay of a tungsten-185 nucleus.

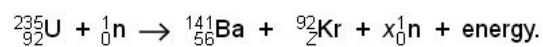


Q23.

- 7 (a) Uranium (U) has at least fourteen isotopes.
Explain what is meant by *isotopes*.

.....
.....
..... [2]

- (b) One possible nuclear reaction involving uranium is



- (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.

- 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.

- 9 (a) Explain what is meant by *radioactive decay*.

Ex

.....
.....
..... [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 $^{235}_{92}\text{U}$ and $^{238}_{92}\text{U}$.

Explain the term *isotope*.

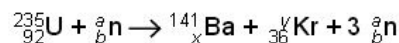
For
Examine
Use

.....
.....
..... [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]

- (ii) When a nucleus of uranium-235 absorbs a neutron, the following reaction may take place.



State the values of a , b , x and y .

$a = \dots\dots\dots$

$b = \dots\dots\dots$

$x = \dots\dots\dots$

$y = \dots\dots\dots$

[3]

- (c) When the nucleus of ${}_{92}^{238}\text{U}$ 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 = $\dots\dots\dots$

nucleon number = $\dots\dots\dots$

[2]

Q27.

- 7 (a) State the experimental observations that show radioactive decay is

- (i) spontaneous,

$\dots\dots\dots$
 $\dots\dots\dots$ [1]

- (ii) random.

$\dots\dots\dots$
 $\dots\dots\dots$ [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 0.99c	

Fig. 7.1

[3]

For
Examiner's
Use

(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
Ex
U

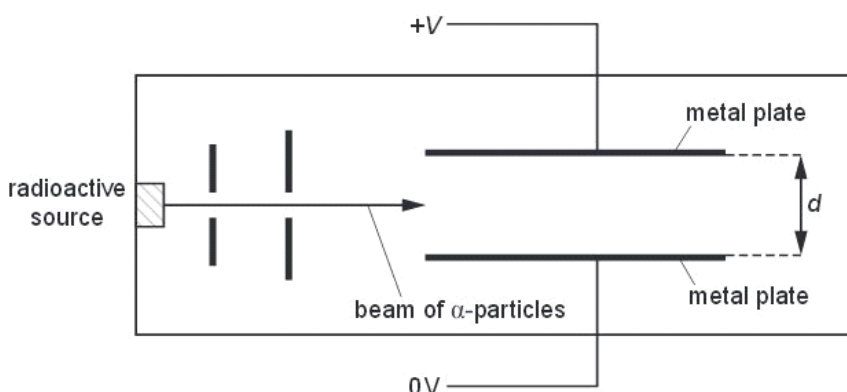


Fig. 6.1

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]

- (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:

(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.

- 6 (a) Describe the structure of an atom of the nuclide $^{235}_{92}\text{U}$.

.....

 [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.

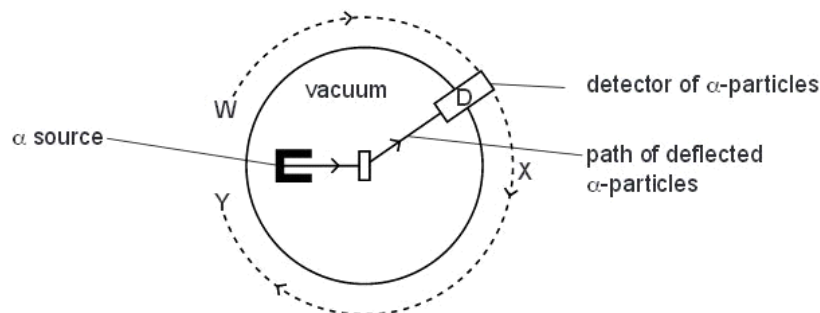


Fig. 6.1

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]

- (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.

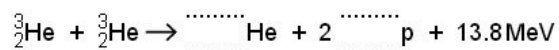
For
Examiners
Use

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.

For
Examiners
Use



- (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]

(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]

- (b) The following equation represents the decay of a nucleus of hydrogen-3 by the emission of a β -particle.

Complete the equation.



- (c) The β -particle is emitted with an energy of $5.7 \times 10^3 \text{ eV}$.

Calculate the speed of the β -particle.

speed = ... ms^{-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.

- 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.

Ex

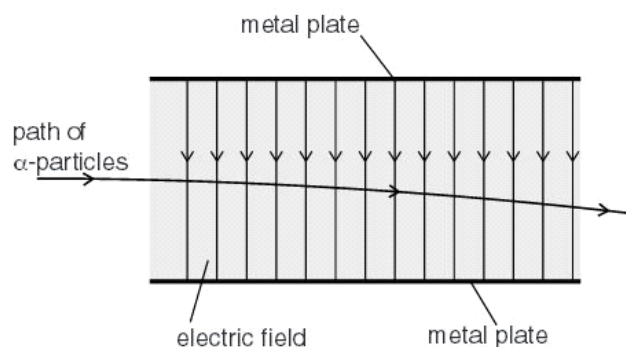


Fig. 7.1

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.

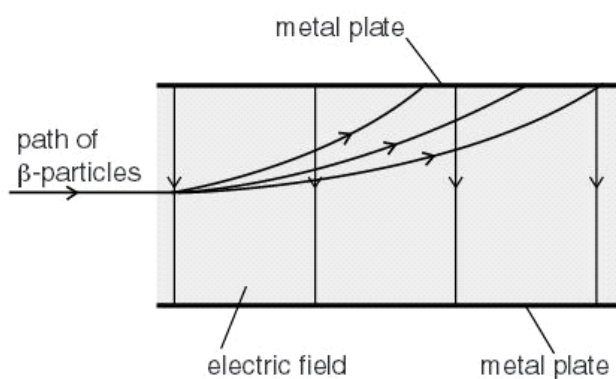


Fig. 7.2

- (i) State one similarity of the electric fields shown in Fig. 7.1 and Fig. 7.2.

.....
[1]

- (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.

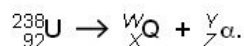
.....

3.

.....

[3]

- (b) A source of α -particles is uranium-238. The nuclear reaction for the emission of α -particles is represented by



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



State the values of A

B

C

D

[1]

Q1.

- 6 (a) (i) curve is not smooth, fluctuations, etc B1
- (ii) curve is same shape or same half-life, not affected by temperature, etc..... B1 [2]
- (b) (i) 134..... B1 [1]
- (ii) α -particle shown as ${}^4_2\text{He}$ or as ${}^4_2\alpha$ B1
- nucleon number of Po shown as 216 B1
- proton number of Po shown as 84..... B1
- [3]

Q2.

- 8 (a) position shown as $A = 227, Z = 91$ B1 [1]
- (b) Pu shown as $A = 243, Z = 94$ B1
- D shown with $A = A_{\text{Pu}}$ and with $Z = (Z_{\text{Pu}} + 1)$ B1 [2]

Q3.

- 8 (a) nucleus emits M1
- α - or β - particles and/or γ -rays A1 [2]
- (b) decay unaffected by environmental changes M1
- such as temperature, pressure etc. (*one e.g. is sufficient*) A1 [2]
- (c) constant probability of decay (per unit time) of a nucleus B1
- cannot predict which particular nucleus will decay next B1 [2]

Q4.

- 7 (a) β (-decay) B1 [1]
- (b) γ (-decay) B1
- either* any two of Z, N and A do not change
- or* it is loss of energy only
- or* it is an electromagnetic wave B1 [2]
- Allow ' α (-decay) as change of 4 in the nucleon number cannot be shown on the diagram' (B2)
- Do not give credit for a 'bald' α (-decay)

Q5.

- 7 (a) α -particle: *either* helium nucleus *or* contains 2 protons + 2 neutrons
or ${}^4_2\text{He}$ B1
- β -particle: *either* electron *or* ${}^0_{-1}\text{e}$ B1
- α speed < β speed (1)
- α discrete values of speed/energy, β continuous spectrum (1)
- either* α ionising power >> β ionising power (1)
- or* α range << β range (1)
- α positive, β negative (*only if first two B marks not scored*) (1)
- α mass > β mass (*only if first two B marks not scored*) (1)
- (*any two sensible pairs of statements relevant to differences,*
– do not allow statements relevant to only α or β , 1 each, max 2) B2 [4]
- (b) (i) ${}^{236}_{92}\text{U} \rightarrow {}^{232}_{90}\text{Th} + {}^4_2\text{He}$ M1
- A1 [2]
- (ii) 1. correct position for U at $Z = 92$, $N = 145$ B1
2. correct position for Np relative to U i.e. $Z + 1$ and $N - 1$ B1 [2]

Q6.

- 8 (a) rate of decay / activity / decay (of nucleus) is not affected by external factors / environment / surroundings B2 [2]
(*If states specific factor(s), rather than giving general statement above, then give 2 marks for two stated factors, but 1 mark only if one factor stated*)
- (b) (i) gamma / γ B1 [1]
- (ii) alpha / α B1 [1]
- (iii) gamma / γ B1 [1]
- (iv) beta / β B1 [1]

Q7.

- 7 (a) nuclei/atoms with same proton number/atomic number B1
 nuclei/atoms contain different numbers of neutrons/different atomic mass B1 [2]
- (b) (i) 92 A1 [1]
 (ii) 146 A1 [1]
- (c) (i) mass = $238 \times 1.66 \times 10^{-27}$ C1
 $= 3.95 \times 10^{-25}$ kg A1 [2]
- (ii) volume = $\frac{4}{3} \pi \times (8.9 \times 10^{-15})^3$ ($= 2.95 \times 10^{-42}$) C1
 density = $(3.95 \times 10^{-25}) / (2.95 \times 10^{-42})$
 $= 1.3 \times 10^{17}$ kg m⁻³ A1 [2]
- (d) nucleus contains most of mass of atom B1
 either nuclear diameter/volume very much less than that of atom
 or atom is mostly (empty) space B1 [2]

Q8.

- 7 (a) (i) either helium nucleus
 or contains 2 protons and 2 neutrons B1 [1]
- (ii) e.g. range is a few cm in air/sheet of thin paper
 speed up to 0.1 c
 causes dense ionisation in air
 positively charged or deflected in magnetic or electric fields
 (any two, 1 each to max 2) B2 [2]
- (b) (i) ${}^4_2\alpha$ B1
 either ${}^1_1p$ or ${}^1_1H$ B1 [2]
- (ii) 1 initially, α -particle must have some kinetic energy B1 [1]
- (ii) 2 $1.1 \text{ MeV} = 1.1 \times 1.6 \times 10^{-13} = 1.76 \times 10^{-13} \text{ J}$ C1
 $E_K = \frac{1}{2}mv^2$ C1
 $1.76 \times 10^{-13} = \frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2$ C1
 $v = 7.3 \times 10^6 \text{ m s}^{-1}$ A1 [4]
 use of 1.67×10^{-27} kg for mass is a maximum of 3/4

Q9.

7	(a)	(i) <i>either</i> helium nucleus or particle containing two protons and two neutrons	B1	[1]
		(ii) allow any value between 1 cm and 10 cm	B1	[1]
	(b)	(i) energy = $(8.5 \times 10^{-13}) / (1.6 \times 10^{-13})$ = 5.3 MeV	M1 A0	[1]
		(ii) number = $(5.3 \times 10^6) / 31$ = 1.7×10^5 (<i>allow 2 s.f. only</i>)	C1 A1	[2]
		(iii) number per unit length = $(1.7 \times 10^5) / (a)(ii)$ correct numerical value correct unit	A1 B1	[2]

Q10.

7	(a)	(i) 2 protons and 2 neutrons	B1	[1]
		(ii) e.g. positively charged 2e mass 4u constant energy absorbed by thin paper or few cm of air (3 cm → 8 cm) (<i>not low penetration</i>) highly ionizing deflected in electric/magnetic fields (<i>One mark for each property, max 2</i>)	B2	[2]
	(b)	<u>mass-energy</u> is conserved difference in mass 'changed' into a form of energy energy in the form of kinetic energy of the products / γ -radiation photons / e.m. radiation	B1 B1 B1	[3]

Q11.

7	(a)	W = 1 and X = 0 Y = 2 Z = 55	A1 A1 A1	[1] [1] [1]
	(b)	explanation in terms of mass – energy conservation energy released as gamma or photons or kinetic energy of products or em radiation	B1 B1	[2]

Q12.

- 7 (a) thin paper reduces count rate hence α B1
 addition of 1 cm of aluminium causes little more count rate reduction hence only B1 [2]
 other radiation is γ
- (b) magnetic field perpendicular to direction of radiation B1
 look for a count rate in expected direction / area if there were negatively B1 [2]
 charged radiation present. If no count rate recorded then β not present.

Q13.

- 7 (a) the majority/most went straight through B1
 or were deviated by small angles
- a very small proportion/a few were deviated by large angles B1
 small angles described as $< 10^\circ$ and large angles described as $>90^\circ$ B1 [3]
- (b) most of the atom is empty space/nucleus very small compared with atom B1
 mass and charge concentrated in (very small) nucleus B1
 correct links made with statements in (a) B1 [3]

Q14.

-
- 7 (a) (i) $W = 206$ and $X = 82$ A1
 $Y = 4$ and $Z = 2$ A1 [2]
- (ii) mass-energy is conserved B1
 mass on rhs is less because energy is released B1 [2]
- (b) not affected by external conditions/factors/environment B1 [1]
 or two examples temperature and pressure

Q15.

- 7 (a) (i) nucleus contains 92 protons B1
 nucleus contains 143 neutrons (missing 'nucleus' 1/2) B1
 outside / around nucleus 92 electrons (B1)
 most of atom is empty space / mass concentrated in nucleus (B1)
 total charge is zero (B1)
 diameter of atom $\sim 10^{-10}$ m or size of nucleus $\sim 10^{-15}$ m (B1)
 any two of (B1) marks [4]
- (ii) nucleus has same number / 92 protons B1
 nuclei have 143 and 146 neutrons (missing 'nucleus' 1/2) B1 [2]
- (b) (i) $Y = 35$ A1
 $Z = 85$ A1 [2]
- (ii) mass-energy is conserved in the reaction B1
 mass on rhs of reaction is less so energy is released
 explained in terms of $E = mc^2$ B1 [2]

Q16.

- 8 (a) shows nucleon number as 220 B1
 shows proton number as 87 B1 [2]
- (b) shows products as ${}^4_2\text{He}$ OR ${}^4_2\alpha$ B1
 and ${}^{216}_{85}\text{At}$ (allow e.c.f. from (a)) B1 [2]

Q17.

- 6 (a) (i) 26 protons..... B1
 (ii) 30 neutrons..... B1 [2]
- (b) (i) mass = $56 \times 1.66 \times 10^{-27}$ C1
 (allow $\times 1.67 \times 10^{-27}$ but 0/2 for use of 26 or 30)
 = 9.3×10^{-26} kg..... A1
- (ii) density = mass/volume where volume = $\frac{4}{3} \times \pi \times r^3$ C1
 = $(9.3 \times 10^{-26}) / (\frac{4}{3} \times \pi \times \{5.7 \times 10^{-15}\}^3)$
 = 1.2×10^{17} kg m⁻³ A1 [4]
- (c) nucleus occupies only very small fraction of volume of atom
 or 'lot of empty space inside atom' B1
 (do not allow spacing between atoms)
 any further good physics e.g. nuclear material is very dense B1 [2]

Q18.

7 (a) (i) nucleus is small	M1	
in comparison to size of atom	A1	[2]
(ii) nucleus is massive/heavy/dense	B1	
and charged (allow to be scored in (i) or (ii))	B1	[2]
(b) (i) symmetrical path and deviation correct w.r.t. position of nucleus	B1	
deviation less than in path AB	B1	
(ii) deviation > 90° and in correct direction	B1	[3]

Q19.

7 (a) most α -particles deviated through small angles (accept 'undeviated')	B1	
few α -particles deviated through angles greater than 90°	B1	[2]
(b) (i) allow 10^{-9} m $\rightarrow$ 10^{-11} m	B1	[1]
(ii) allow 10^{-13} m $\rightarrow$ 10^{-15} m (if (i) and (ii) out of range but (ii) = 10^{-4} (i), then allow 1 mark) (if no units or wrong units but (ii) = 10^{-4} (i), then allow 1 mark)	B1	[1]

Q20.

8 (a) <u>nucleus</u> has constant probability of decay per unit time / in a given time (allow 1 mark for 'cannot predict which <u>nucleus</u> will decay next')	M1 A1	[2]
(b) (i) count rate / activity decreases	B1	[1]
(ii) count rate fluctuates / is not smooth	B1	[1]
(c) either the (decay) curves are similar / same or curves indicate same half-life	B1	[1]

Q21.

- 7 (a) deviation shown correctly B1 [1]
- (b) smaller deviation (not zero deviation) M1
 acceptable path wrt position of N A1 [2]
- (c) the nucleus is (very) small M1
 in comparison to the atom A1 [2]
 (special case: 'atom is mostly empty space' scores 1 mark)
- (d) deviation depends on charge on the nucleus / N / electrostatic repulsion B1
 same charge so no change in deviation B1 [2]

[Total: 7]

Q22.

- 7 (a) either forms of same element
 or atoms / nuclei with same number of protons M1
 atoms / nuclei contain different numbers of neutrons A1 [2]
 (use of 'element' rather than atoms / nuclei scores max 1 mark)
- (b) (i) decay is not affected by environmental factors B1 [1]
 (allow two named factors)
- (ii) either time of decay (of a nucleus) cannot be predicted
 or nucleus has constant probability in a given time B1 [1]
- (c) $^{185}_{75}\text{Re}$ B1
 either $^0_{-1}\text{e}$ or $^0_{-1}\beta$ B1 [2]

[Total: 6]

Q23.

- 7 (a) either different forms of same element
 or nuclei have same number of protons M1
 different numbers of neutrons (in the nucleus) A1 [2]
- (b) (i) proton number conserved B1
 nucleon number conserved B1
 mass-energy conserved B1 [3]
- (ii) 1. $Z = 36$ A1 [1]
 2. $x = 3$ A1 [1]

Q24.

- 7 (a) (i) most α -particles were deviated through small angles
(allow 1 mark for 'straight through' / undeviated) B2 [2]
- (ii) small fraction of α -particles deviated through large angles
greater than 90° (allow rebound back) M1
A1 [2]
- (b) e.g. β -particles have a range of energies
 β -particles deviated by (orbital) electrons
 β -particle has (very) small mass
(any two sensible suggestions, 1 each, max 2) B2 [2]

Do not allow β -particles have negative charge or β -particles have high speed

Q25.

- 9 (a) nucleus emits α -particles or β -particles and/or γ -radiation
to form a different / more stable nucleus B1
B1 [2]
- (b) (i) fluctuations in count rate (not 'count rate is not constant') B1 [1]
- (ii) no effect B1 [1]
- (iii) if the source is an α -emitter B1
either α -particles stopped within source (and gain electrons)
or α -particles are helium nuclei B1 [2]
- allow 1/2 for 'parent nucleus gives off radiation to form daughter nucleus'

Q26.

- 7 (a) nuclei with the same number of protons
and a different number of neutrons B1
B1 [2]
- (b) (i) (mass + energy) (taken together) is conserved (B1)
momentum is conserved (B1)
one point required max. 1 B1 [1]
- (ii) $a = 1$ and $b = 0$ B1
 $x = 56$ B1
 $y = 92$ B1 [3]
- (c) proton number = 90 B1
nucleon number = 235 B1 [2]

Q27.

- 7 (a) (i) the half life / count rate / rate of decay / activity is the same no matter what external factors / environmental factors **or** two named factors such as temperature and pressure changes are applied B1 [1]

- (ii) the observations of the count rate / count rate / rate of decay / activity / radioactivity during decay shows variations / fluctuations B1 [1]

(b)

property	α -particle	β -particle	γ -radiation
charge	(+)2e	-e	0
mass	4u	$9.11 \times 10^{-31} \text{ kg}$	0
speed	0.01 to 0.1 c	up to 0.99 c	c

one mark for each correct line B3 [3]

- (c) collision with molecules B1
causes ionisation (of the molecule) / electron is removed B1 [2]

Q28.

- 6 (a) (i) greater deflection M0
greater electric field / force on α -particle A1 [1]

- (ii) greater deflection M0
greater electric field / force on α -particle A1 [1]

- (b) (i) *either* deflections in opposite directions M1
because oppositely charged A1
or β less deflection (M1)
 β has smaller charge (A1) [2]

- (ii) α smaller deflection M1
because larger mass A1 [2]

- (iii) β less deflection because higher speed B1 [1]

- (c) *either* $F = ma$ and $F = Eq$ *or* $a = Eq / m$ C1
ratio = *either* $\frac{(2 \times 1.6 \times 10^{-19}) \times (9.11 \times 10^{-31})}{(1.6 \times 10^{-19}) \times 4 \times (1.67 \times 10^{-27})}$
or $[2e \times 1 / 2000 u] / [e \times 4u]$ C1
ratio = 1 / 4000 *or* 2.5×10^{-4} *or* 2.7×10^{-4} A1 [3]

Q29.

- 6 (a) 92 protons in the nucleus and 92 electrons around nucleus
143 neutrons (in the nucleus) B1
B1 [2]
- (b) (i) α -particle travels short distance in air B1 [1]
- (ii) very small proportion in backwards direction / large angles B1
majority pass through with no /small deflections B1
either most of mass is in very small volume (nucleus) and is charged or most of atom is empty space B1 [3]
- (c) $I = Q / t$ C1
 $n/t = (1.5 \times 10^{-12}) / (2 \times 1.6 \times 10^{-19})$ C1
 $n/t = 4.7 \times 10^6 \text{ s}^{-1}$ A1 [3]

Q30.

- 7 (a) ${}^3_2\text{He} + {}^3_2\text{He} \rightarrow {}^4_2\text{He} + 2 {}^1_1\text{p} + Q$
A numbers correct (4 and 1) B1
Z numbers correct (2 and 1) B1 [2]
- (b) both nuclei have 2 protons B1
the two isotopes have 1 neutron and two neutrons B1 [2]
[allow 1 for 'same number of protons but different number of neutrons']
- (c) proton number and neutron number B1
energy – mass B1
momentum B1 [2]
- (d) (i) γ radiation B1 [1]
- (ii) product(s) must have kinetic energy B1 [1]
- (e) $13.8 \text{ MeV} = 13.8 \times 1.6 \times 10^{-19} \times 10^6 (= 2.208 \times 10^{-12})$ C1
 $60 = n \times 13.8 \times 1.6 \times 10^{-13}$
 $n = 2.7(2) \times 10^{13} \text{ s}^{-1}$ A1 [2]

Q31.

6	(a) (i) electron	B1	[1]
	(ii) any two : can be deflected by electric and magnetic fields or negatively charged / absorbed by few (1 – 4) mm of aluminum / 0.5 to 2 m or metres for range in air / speed up to 0.99c / range of speeds / energies	B2	[2]
	(iii) decay occurs and cannot be affected by external / environmental factors or two stated factors such as chemical / pressure / temperature / humidity	B1	[1]
	(b) 3 and 0 for superscript numbers 2 and –1 for subscript numbers	B1 B1	[2]
	(c) energy = $5.7 \times 10^3 \times 1.6 \times 10^{-19}$ (= 9.12×10^{-16} J)	C1	
	$v^2 = \frac{2 \times 9.12 \times 10^{-16}}{9.11 \times 10^{-31}}$	C1	
	$v = 4.5 \times 10^7 \text{ m s}^{-1}$	A1	[3]
	(d) both have 1 proton and 1 electron 1 neutron in hydrogen-2 and 2 neutrons in hydrogen-3 (special case: for one mark 'same number of protons / atomic number different number of neutrons')	B1 B1	[2]

Q32.

7	(a) (i) the direction of the fields is the same OR fields are uniform OR constant electric field strength OR $E = V / d$ with symbols explained	B1	[1]
	(ii) reduce p.d. across plates increase separation <u>of plates</u>	B1 B1	[2]
	(iii) α opposite charge to β (as deflection in opposite direction) β has a range of velocities OR energies (as different deflections) and α all have same velocity OR energy (as constant deflection) α are more massive (as deflection is less for greater field strength)	B1 B1 B1	[3]
	(b) $W = 234$ and $X = 90$ $Y = 4$ and $Z = 2$	B1 B1	[2]
	(c) $A = 32$ and $B = 16$ and $C = 0$ and $D = -1$	B1	[1]

1. June/2021/Paper_11/No.39

A nucleus of uranium, ${}^{235}_{92}\text{U}$, 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 ${}^{227}_{87}\text{Ac}$

B ${}^{227}_{89}\text{Ac}$

C ${}^{231}_{87}\text{Ac}$

D ${}^{231}_{89}\text{Ac}$

2. June/2021/Paper_11/No.40

Which particle is a fundamental particle?

A electron

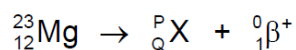
B hadron

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.



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, $^{238}_{92}\text{U}$, undergoes a series of nuclear decays to form uranium-234, $^{234}_{92}\text{U}$.

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

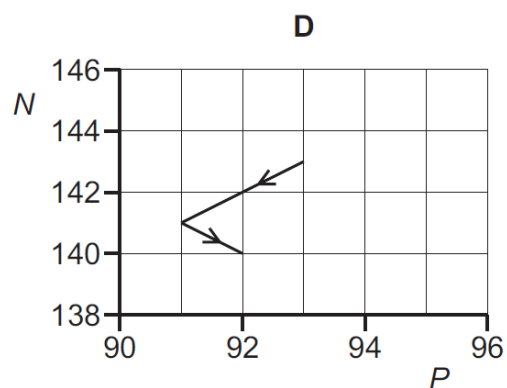
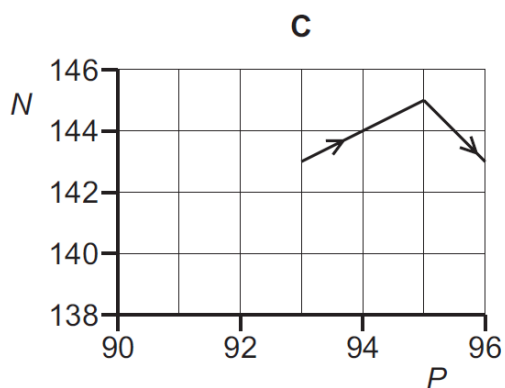
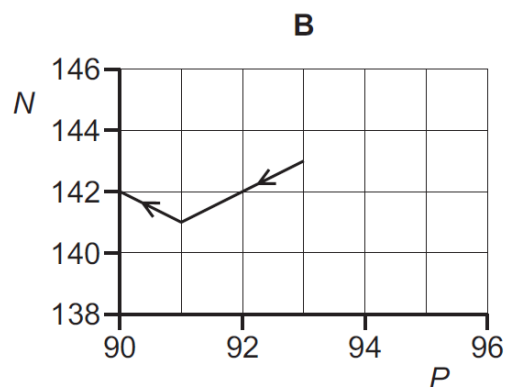
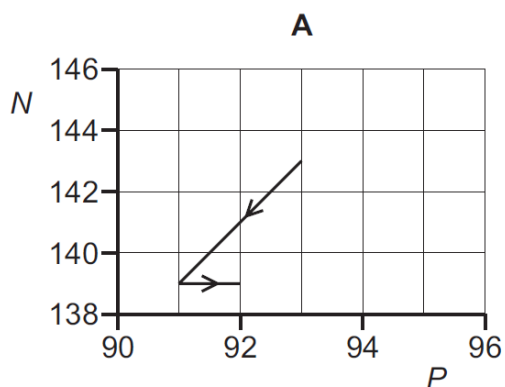
When α -particles are fired at a thin metal foil, most of the particles pass straight through but a few are deflected by a large angle.

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

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?



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

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]

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

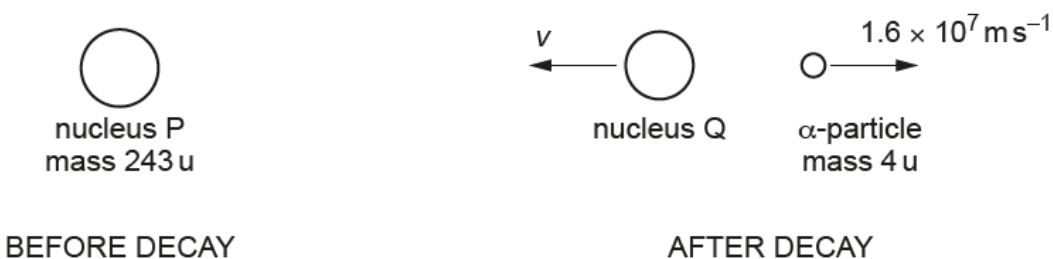


Fig. 7.1

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

- (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.

$v = \dots\dots\dots \text{ ms}^{-1}$ [2]

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

kinetic energy = $\dots\dots\dots \text{ MeV}$ [3]

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

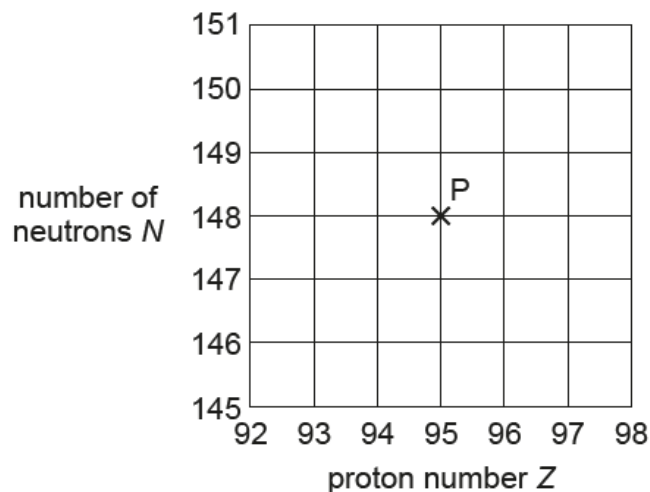


Fig. 7.2

The graph shows a cross that represents nucleus P.

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

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

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

1. nucleus R (label this cross R)

2. nucleus S (label this cross S).

[2]

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

..... [1]

[Total: 10]

(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 ($^{12}_6\text{X}$) and a nucleus Y ($^{16}_8\text{Y}$) are accelerated by the same uniform electric field.

(i) Determine the ratio

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

ratio = ... [2]

(ii) Determine the ratio

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

ratio = ... [1]

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

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

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

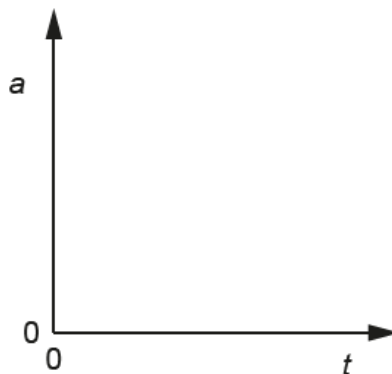


Fig. 6.1

[1]

[Total: 10]

- (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 $6.9 \times 10^{-9} \text{ A}$.

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

number = ... [3]

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

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

.....

.....

..... [2]

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

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

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

.....

.....

..... [2]

[Total: 10]

(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]

- (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

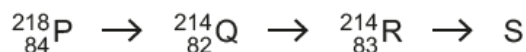
.....
 [1]

- (ii) result 2.

.....

 [2]

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



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]

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 ${}^{131}_{90}\text{X}$

B ${}^{219}_{87}\text{X}$

C ${}^{223}_{82}\text{X}$

D ${}^{223}_{90}\text{X}$

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 ${}_0^1\text{n}$ is fired at a ${}_{92}^{235}\text{U}$ nucleus. The neutron is absorbed by the nucleus which then splits to form nuclei of ${}_{56}^{141}\text{Ba}$ and ${}_{36}^{92}\text{Kr}$.

What is the number of free neutrons emitted when the ${}_{92}^{235}\text{U}$ 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, ${}^3_1\text{H}$?

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

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]

(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]

- (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]

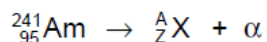
13. March/2023/Paper_9702/12/No.38

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.



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 $+\frac{2}{3}e$

- (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]

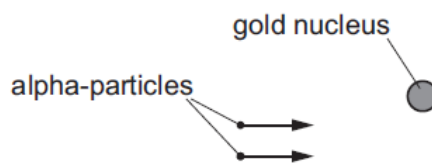
- (ii) Describe, in general terms, the quark structure of hadrons that belong to group Q.

.....
 [1]

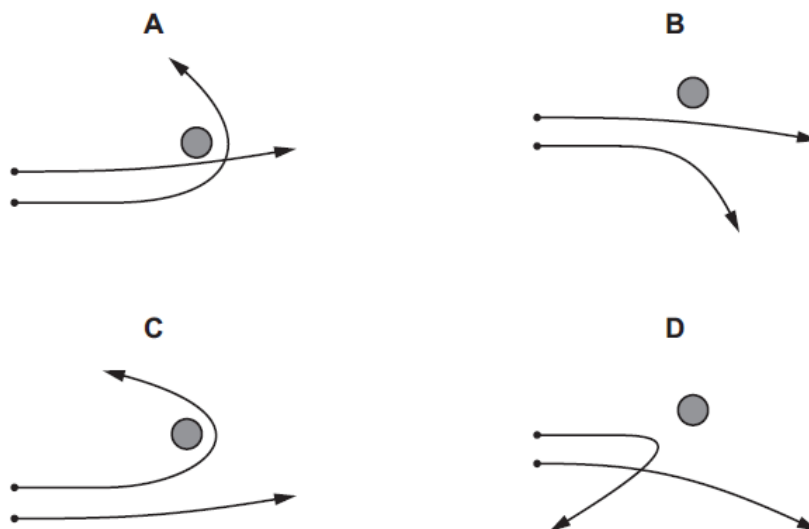
[Total: 5]

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.

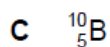


Which diagram could show the paths of the two alpha-particles?



2. Nov/2023/Paper_ 9702/11/No.39

Which nuclide is formed when $^{10}_6\text{C}$ undergoes β^+ decay?



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

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 $1.0 \times 10^{-19} \text{ C}$
- C $4.8 \times 10^{-19} \text{ C}$
- D $8.0 \times 10^{-19} \text{ C}$

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

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 $+1.6 \times 10^{-19} \text{ C}$ or zero?

- A up, down, down
 B up, strange, strange
 C up, up, down
 D up, up, up

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

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

.....

.....

.....

..... [2]

- (b) State the composition of γ -radiation.

..... [1]

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

Table 7.1

particle name	classification		
	baryon	hadron	lepton
neutrino			
neutron			
positron			

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

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

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

mass = ... u [1]

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

[2]

[Total: 8]

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

antineutrino baryon nucleon positron [1]

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

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]

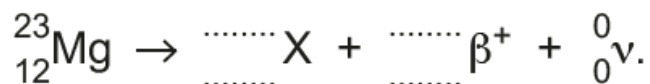
(c) A meson has a charge of $-1e$, where e is the elementary charge. The quark composition of the meson includes a charm antiquark.

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

.....
 [2]

[Total: 5]

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



Four numbers are missing from the equation.

- (i) For the nuclide $^{23}_{12}\text{Mg}$, 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]

- (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.

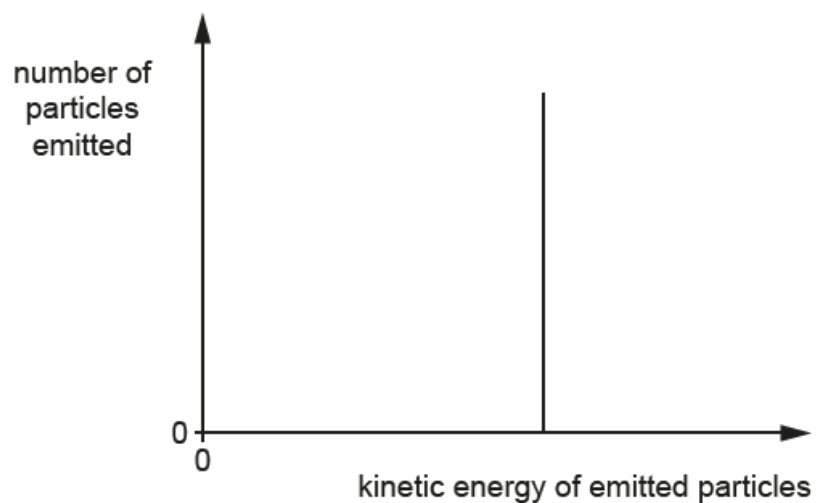


Fig. 8.1

State how Fig. 8.1 shows that these nuclei do **not** undergo beta-decay.

.....

..... [1]

[Total: 6]