

PHYSICS



EXAM QUESTION PACK

23 NUCLEAR PHYSICS

SCORE

/

PERCENTAGE

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- 1 Which set of radioactive emissions corresponds to the descriptions given in the table headings?

9702/1/M/J/02/Q38

	high-speed electrons	high-speed helium nuclei	high-frequency photons
A	α	β	γ
B	α	γ	β
C	β	α	γ
D	β	γ	α

- 2 The nucleus of one of the isotopes of nickel is represented by ${}^{60}_{28}\text{Ni}$.

9702/1/M/J/02/Q39

Which line in the table correctly describes a neutral atom of this isotope?

	number of protons	number of neutrons	number of orbital electrons
A	28	32	28
B	28	60	28
C	60	28	28
D	60	32	32

- 3 A nucleus of bohrium ${}^x_y\text{Bh}$ decays to mendelevium ${}^{255}_{101}\text{Md}$ by a sequence of three α -particle emissions.

9702/1/M/J/02/Q40

bohrium ${}^x_y\text{Bh} \longrightarrow \text{dubnium} + \alpha$

$\quad \quad \quad \longrightarrow \text{lawrencium} + \alpha$

$\quad \quad \quad \longrightarrow \text{mendelevium } {}^{255}_{101}\text{Md} + \alpha$

How many neutrons are there in a nucleus of ${}^x_y\text{Bh}$?

- A** 267
B 261
C 160
D 154

- 4 The numbers of protons, neutrons and nucleons in three nuclei are shown.

9702/1/O/N/02/Q38

nucleus	number of protons	number of neutrons	number of nucleons
X	15	16	31
Y	15	17	32
Z	16	16	32

Which nuclei are isotopes of the same element?

- A** X and Y **B** X and Z **C** Y and Z **D** none of them
- 5 In an experiment to investigate the nature of the atom, a very thin gold film was bombarded with α -particles.

9702/1/O/N/02/Q39

What pattern of deflection of the α -particles was observed?

- A** A few α -particles were deflected through angles greater than a right angle.
B All α -particles were deflected from their original path.
C Most α -particles were deflected through angles greater than a right angle.
D No α -particle was deflected through an angle greater than a right angle.
- 6 When a nucleus of $^{238}_{92}\text{U}$ absorbs a slow neutron it subsequently emits two β -particles.

9702/1/O/N/02/Q40

What is the resulting nucleus?

- A** $^{240}_{93}\text{Np}$ **B** $^{240}_{91}\text{Pa}$ **C** $^{239}_{94}\text{Pu}$ **D** $^{239}_{90}\text{Th}$
- 7 In what way do the atoms of the isotopes $^{12}_6\text{C}$, $^{13}_6\text{C}$ and $^{14}_6\text{C}$ differ?
- A** different charge
B different numbers of electrons
C different numbers of neutrons
D different numbers of protons

9702/01/M/J/03/Q38

- 8 A nickel nucleus $^{59}_{28}\text{Ni}$ can be transformed by a process termed K-capture. In this process the nucleus absorbs an orbital electron.

9702/01/O/N/03/Q40

If no other process is involved, what is the resulting nucleus?

- A** $^{58}_{28}\text{Ni}$ **B** $^{58}_{27}\text{Co}$ **C** $^{59}_{27}\text{Co}$ **D** $^{59}_{29}\text{Cu}$

- 9 Strontium- 90 ($^{90}_{38}\text{Sr}$) is radioactive and emits β -particles.

9702/01/M/J/03/Q39

Which equation could represent this nuclear decay?

- A** $^{90}_{38}\text{Sr} \rightarrow ^{90}_{39}\text{Sr} + ^0_{-1}\beta$
B $^{90}_{38}\text{Sr} \rightarrow ^{90}_{39}\text{Y} + ^0_{-1}\beta$
C $^{90}_{38}\text{Sr} \rightarrow ^{90}_{37}\text{Rb} + ^0_{+1}\beta$
D $^{90}_{38}\text{Sr} \rightarrow ^{90}_{37}\text{Sr} + ^0_{+1}\beta$

- 10 Protons and neutrons are thought to consist of smaller particles called quarks.

9702/01/M/J/03/Q40

The 'up' quark has a charge of $\frac{2}{3}e$: a 'down' quark has a charge of $-\frac{1}{3}e$, where e is the elementary charge ($+1.6 \times 10^{-19}\text{C}$).

How many up quarks and down quarks must a proton contain?

	up quarks	down quarks
A	0	3
B	1	1
C	1	2
D	2	1

- 11 Which are the correct descriptions of a γ -ray and a β -particle?

9702/01/O/N/03/Q38

	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

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

9702/01/O/N/03/Q39

Which is an isotope of Uranium-235?

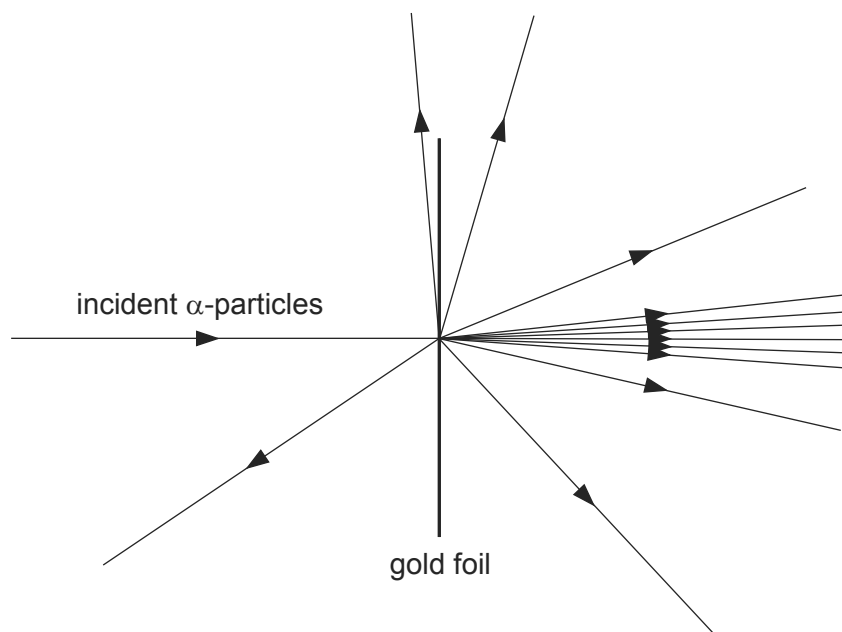
	nucleon number	proton number	neutron number
A	235	91	144
B	236	92	144
C	237	94	143
D	238	95	143

- 13 A nucleus of the nuclide $^{241}_{94}\text{Pu}$ decays by emission of a β -particle followed by the emission of an α -particle. 9702/01/M/J/04/Q38

Which of the nuclides shown is formed?

- A** $^{239}_{93}\text{Np}$ **B** $^{239}_{91}\text{Pa}$ **C** $^{237}_{93}\text{Np}$ **D** $^{237}_{92}\text{U}$

- 14 A thin gold foil is bombarded with α -particles as shown. 9702/01/M/J/04/Q39



The results of this experiment provide information about the

- A** binding energy of a gold nucleus.
B energy levels of electrons in gold atoms.
C size of a gold nucleus.
D structure of a gold nucleus.
- 15 Isotopes of a given element all have the same 9702/01/M/J/04/Q40
- A** charge/mass ratio.
B neutron number.
C nucleon number.
D proton number.
- 16 What is a correct order of magnitude estimate for the diameter of a typical atomic nucleus? 9702/01/M/J/06/Q38
- A** 10^{-14} m **B** 10^{-18} m **C** 10^{-22} m **D** 10^{-26} m

- 17 The symbol ${}^{77}_{32}\text{Ge}$ represents a nuclide of germanium that decays to a nuclide of arsenic (As) by emitting a β -particle.

9702/01/O/N/04/Q38

What is the symbol of this arsenic nuclide?

- A** ${}^{76}_{32}\text{As}$ **B** ${}^{78}_{32}\text{As}$ **C** ${}^{78}_{31}\text{As}$ **D** ${}^{77}_{33}\text{As}$

- 18 The table shows three properties of different types of ionising radiation.

9702/01/O/N/04/Q39

	X	Y	Z
charge	0	$-1e$	$+2e$
mass	0	$\frac{1}{1840}u$	$4u$
speed	c	$\sim 0.9c$	$\sim 0.1c$

What are the radiations **X**, **Y** and **Z**?

	X	Y	Z
A	alpha	beta	X-rays
B	gamma	alpha	beta
C	gamma	beta	alpha
D	X-rays	alpha	beta

- 19 Which conclusion can be drawn from the results of the experiment showing the scattering of α -particles by gold foil?

9702/01/O/N/04/Q40

- A** Electrons orbit the atomic nucleus in well-defined paths.
B Nuclei of different isotopes contain different numbers of neutrons.
C The atomic nucleus contains protons and neutrons.
D The nucleus is very small compared with the size of the atom.

- 20 Which two nuclei contain the same number of neutrons?

9702/01/M/J/05/Q38

- A** ${}^{12}_6\text{C}$ and ${}^{14}_6\text{C}$
B ${}^{16}_7\text{N}$ and ${}^{15}_8\text{O}$
C ${}^{23}_{11}\text{Na}$ and ${}^{24}_{12}\text{Mg}$
D ${}^{32}_{14}\text{Si}$ and ${}^{32}_{15}\text{P}$

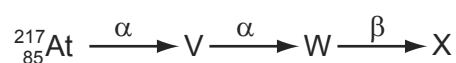
- 21 A student conducts an experiment using an α -particle source.

9702/01/M/J/05/Q39

When considering safety precautions, what can be assumed to be the maximum range of α -particles in air?

- A** between 0 and 5 mm
B between 5 mm and 200 mm
C between 200 mm and 500 mm
D between 500 mm and 1000 mm
- 22 The following represents a sequence of radioactive decays involving two α -particles and one β -particle.

9702/01/M/J/05/Q40



What is the nuclide X?

- A** ${}_{85}^{213}\text{At}$ **B** ${}_{77}^{215}\text{Ir}$ **C** ${}_{82}^{209}\text{Pb}$ **D** ${}_{81}^{217}\text{Tl}$
- 23 An atomic nucleus emits a β -particle.

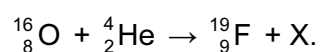
9702/01/O/N/05/Q38

What change does this cause to the proton and nucleon numbers of the nucleus?

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

- 24 A nuclear reaction is represented by the equation

9702/01/O/N/05/Q40

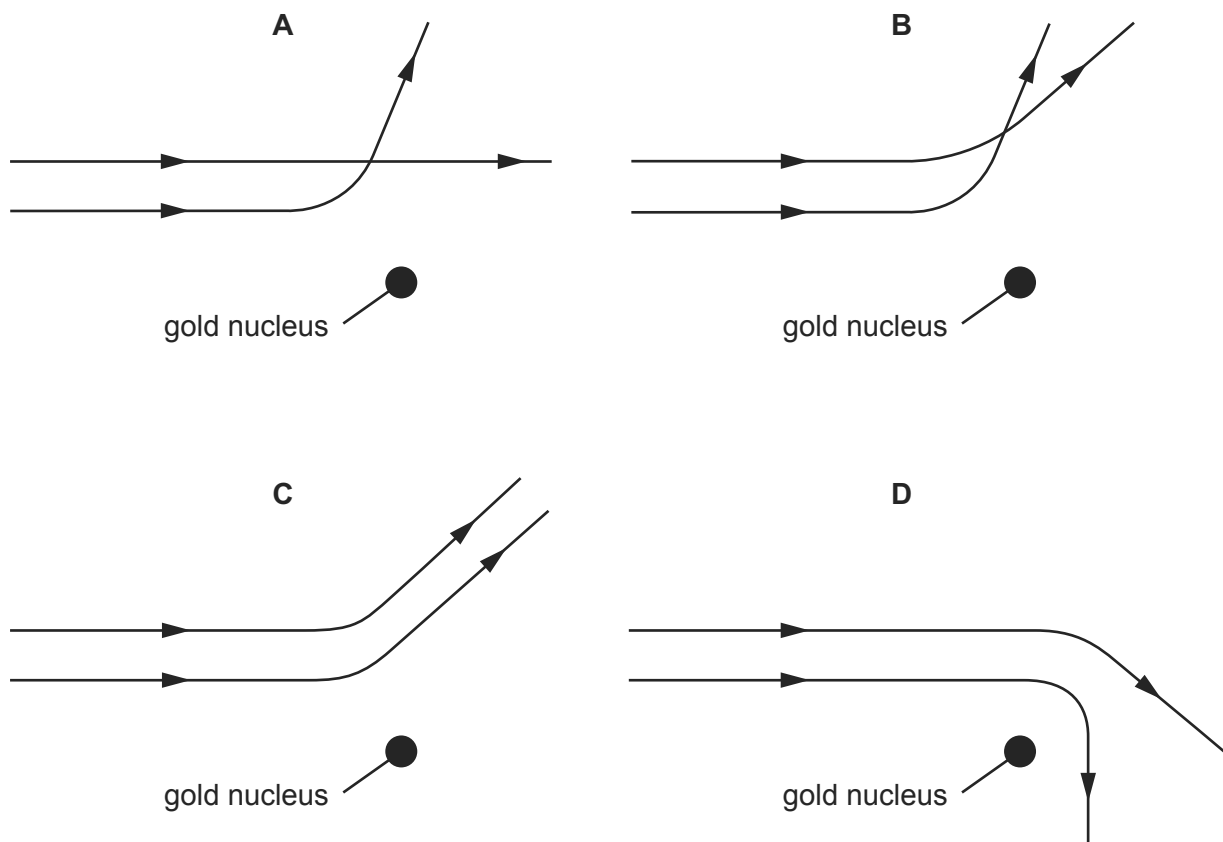


What is particle X?

- A** an α -particle
B a β -particle
C a neutron
D a proton

- 25 Two α -particles with equal energies are fired towards the nucleus of a gold atom. 9702/01/O/N/05/Q39

Which diagram best represents their paths?



- 26 The decay of a nucleus of neptunium is accompanied by the emission of a β -particle and γ -radiation. 9702/01/M/J/06/Q39

What effect (if any) does this decay have on the proton number and the nucleon number of the nucleus?

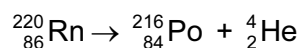
	proton number	nucleon number
A	increases	decreases
B	decreases	increases
C	unchanged	decreases
D	increases	unchanged

- 27 The symbol ${}^{77}_{32}\text{Ge}$ represents a nucleus of germanium that decays to a nucleus of arsenic by emitting a β -particle. 9702/01/M/J/07/Q39

What is the symbol of this arsenic nucleus?

- A** ${}^{76}_{32}\text{As}$ **B** ${}^{78}_{32}\text{As}$ **C** ${}^{78}_{31}\text{As}$ **D** ${}^{77}_{33}\text{As}$

- 28 Radon-220 is radioactive and decays to Polonium-216 with the emission of an α -particle. The equation for the radioactive decay is shown. 9702/01/M/J/06/Q40



How many neutrons are in the radon and polonium nuclei?

	Rn	Po
A	86	84
B	134	132
C	220	212
D	220	216

- 29 Which statement concerning α -particles is correct?

9702/01/O/N/06/Q38

- A** An α -particle has charge $+4e$.
- B** An α -particle is a helium atom.
- C** When α -particles travel through air, they cause ionisation.
- D** When α -particles travel through a sheet of gold foil, they make the gold radioactive.

- 30 Where are electrons, neutrons and protons found in an atom?

9702/01/O/N/06/Q39

	electrons	neutrons	protons
A	in the nucleus	in the nucleus	orbiting the nucleus
B	in the nucleus	orbiting the nucleus	in the nucleus
C	orbiting the nucleus	in the nucleus	orbiting the nucleus
D	orbiting the nucleus	in the nucleus	in the nucleus

- 31 Radon ${}_{86}^{222}\text{Rn}$ decays by α - and β -emission to bismuth ${}_{83}^{214}\text{Bi}$.

9702/01/O/N/06/Q40

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

	α -particles	β -particles
A	1	1
B	2	1
C	1	2
D	2	2

- 32 A detector is exposed to a radioactive source. Fluctuations in the count-rate are observed.

9702/01/M/J/07/Q38

What do these fluctuations indicate about radioactive decay?

- A It is random.
- B It is spontaneous.
- C It is exponential.
- D It is non-linear.

- 33 Each of the nuclei below is accelerated from rest through the same potential difference.

9702/01/M/J/07/Q40

Which one completes the acceleration with the **lowest** speed?

- A ${}^1_1\text{H}$ B ${}^4_2\text{He}$ C ${}^7_3\text{Li}$ D ${}^9_4\text{Be}$

- 34 How is it possible to distinguish between the isotopes of uranium?

9702/01/O/N/07/Q36

- A Their nuclei have different charge and different mass, and they emit different particles when they decay.
- B Their nuclei have different charge but the same mass.
- C Their nuclei have the same charge but different mass.
- D Their nuclei have the same charge and mass, but they emit different particles when they decay.

- 35 What is **not** conserved in nuclear processes?

9702/01/O/N/07/Q37

- A energy and mass together
- B nucleon number
- C neutron number
- D charge

- 36 The following particles are each accelerated from rest through the same potential difference.

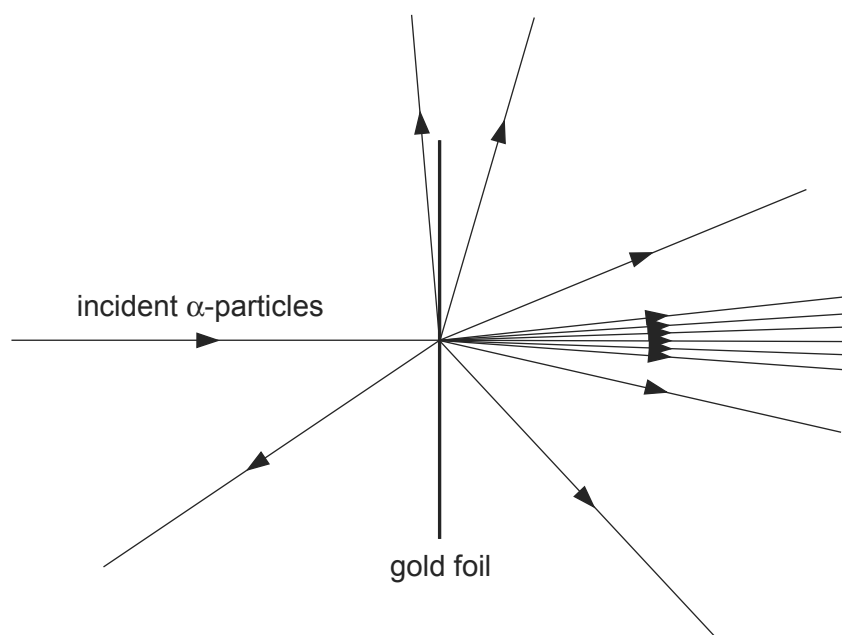
9702/01/O/N/07/Q40

Which one completes the acceleration with the **greatest** momentum?

- A α -particle
- B electron
- C neutron
- D proton

37 A thin gold foil is bombarded with α -particles as shown.

9702/01/O/N/07/Q38

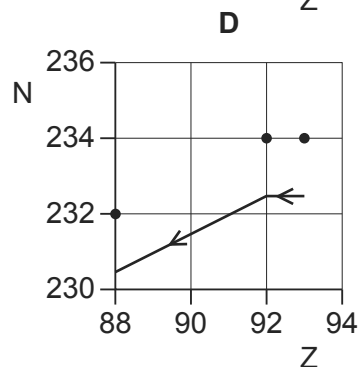
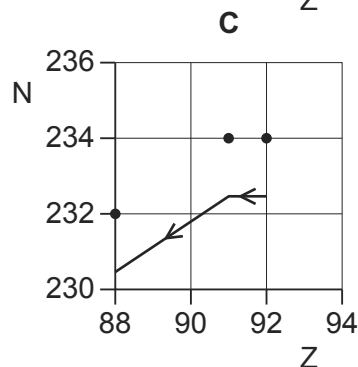
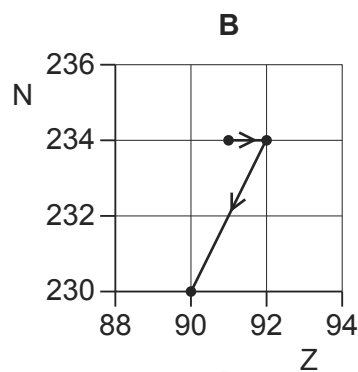
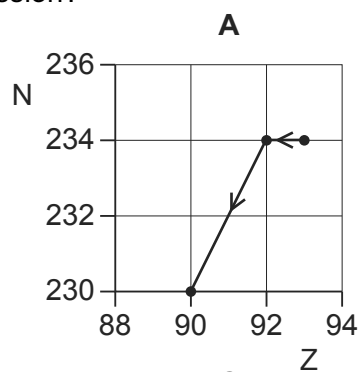


What can be deduced from this experiment?

- A** the binding energy of a gold nucleus
- B** the energy levels of electrons in gold atoms
- C** the small size of a gold nucleus
- D** the structure of a gold nucleus

38 A radioactive nucleus is formed by β -decay. This nucleus then decays by α -emission. 9702/01/M/J/08/Q40

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



39 What is the approximate mass of a nucleus of uranium?

9702/01/M/J/08/Q39

- A** 10^{-15} kg **B** 10^{-20} kg **C** 10^{-25} kg **D** 10^{-30} kg

40 A zirconium nucleus, $^{100}_{40}\text{Zr}$, is a β -emitter. The product nucleus is also a β -emitter. 9702/01/O/N/07/Q39

What is the final resulting nucleus of these two decays?

- A** $^{100}_{38}\text{Sr}$ **B** $^{100}_{42}\text{Mo}$ **C** $^{98}_{40}\text{Zr}$ **D** $^{102}_{40}\text{Zr}$

41 Which conclusion can be drawn from the results of the experiment showing the scattering of α -particles by gold foil? 9702/01/O/N/08/Q38

- A** Electrons orbit the atomic nucleus in well-defined paths.
B Nuclei of different isotopes contain different numbers of neutrons.
C The atomic nucleus contains protons and neutrons.
D The nucleus is very small compared with the size of the atom.

42 A nucleus Q has the notation ^y_xQ .

9702/01/O/N/08/Q39

Which of the following is an isotope of Q?

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

43 A $^{238}_{92}\text{U}$ nucleus decays in two stages to a $^{234}_{91}\text{Pa}$ nucleus.

9702/01/O/N/08/Q40

What was emitted in these two stages?

- A** $\alpha + \beta$ **B** $\alpha + \gamma$ **C** $\beta + \beta$ **D** $\beta + \gamma$

44 How do the nucleon (mass) number and proton (atomic) number of two isotopes of an element compare? 9702/01/M/J/09/Q36

	nucleon number	proton number
A	different	different
B	different	same
C	same	different
D	same	same

- 45 Nuclear decay is both spontaneous and random.

9702/01/M/J/09/Q37

When the count rate of a radioactive isotope is measured, the readings fluctuate.

Which row describes what the fluctuations demonstrate?

	spontaneous nature	random nature
A	no	no
B	no	yes
C	yes	no
D	yes	yes

- 46 Which two nuclei contain the same number of neutrons?

9702/01/M/J/09/Q38

- A** $^{12}_6\text{C}$ and $^{14}_6\text{C}$
- B** $^{16}_7\text{N}$ and $^{15}_8\text{O}$
- C** $^{23}_{11}\text{Na}$ and $^{24}_{12}\text{Mg}$
- D** $^{32}_{14}\text{Si}$ and $^{32}_{15}\text{P}$

- 47 The calcium nuclide $^{42}_{20}\text{Ca}$ is formed by beta decay.

9702/01/M/J/09/Q39

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

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

- 48 When boron-11 ($^{11}_5\text{B}$) is bombarded with α -particles, a new nucleus is formed and a neutron is released.

9702/01/M/J/09/Q40

Which nuclear equation could represent this reaction?

- A** $^{11}_5\text{B} + ^1_1\text{He} \rightarrow ^{11}_6\text{C} + ^1_0\text{n}$
- B** $^{11}_5\text{B} + ^2_2\text{He} \rightarrow ^{12}_7\text{N} + ^1_0\text{n}$
- C** $^{11}_5\text{B} + ^4_2\text{He} \rightarrow ^{14}_6\text{C} + ^1_1\text{n}$
- D** $^{11}_5\text{B} + ^4_2\text{He} \rightarrow ^{14}_7\text{N} + ^1_0\text{n}$

- 49 The gold nucleus $^{185}_{79}\text{Au}$ undergoes alpha decay.

9702/11/O/N/09/Q37

What are the nucleon (mass) number and proton (atomic) number of the nucleus formed by this decay?

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

- 50 The nuclei of the isotopes of an element all contain the same number of a certain particle.

9702/11/O/N/09/Q38

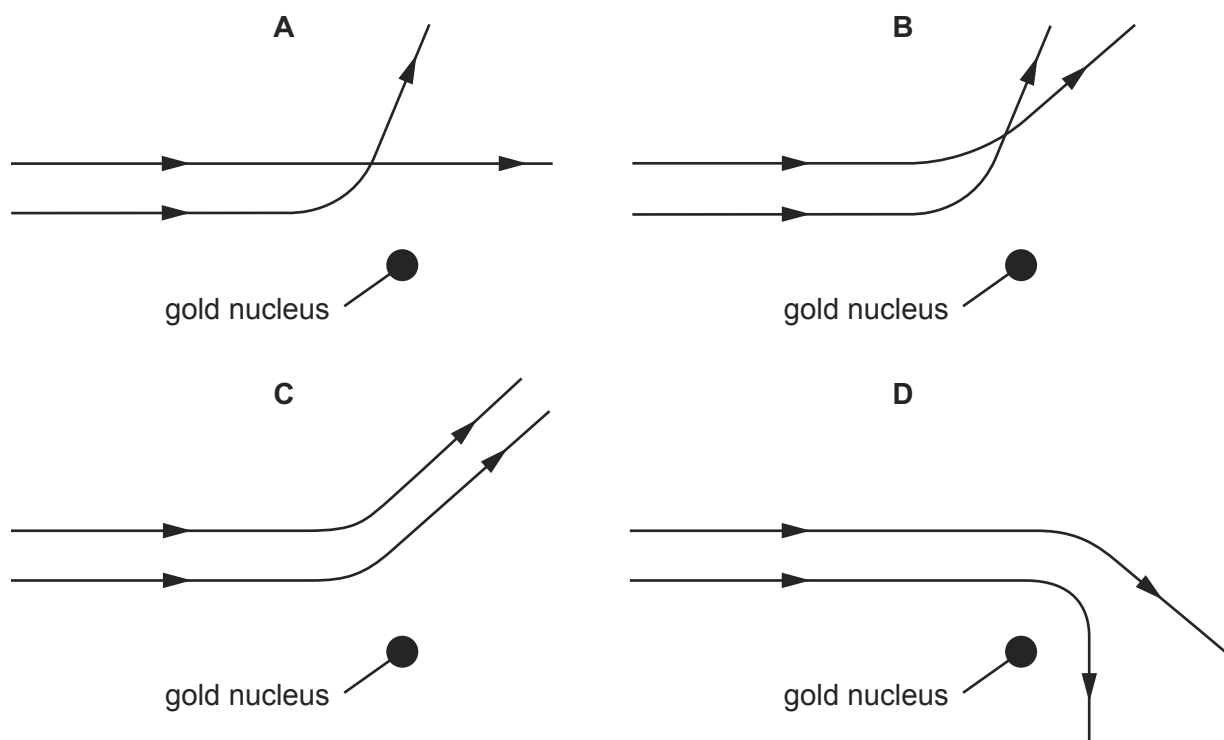
What is this particle?

- A** electron
- B** neutron
- C** nucleon
- D** proton

- 51 Two α -particles with equal energies are fired towards the nucleus of a gold atom.

9702/11/O/N/09/Q40

Which diagram best represents their paths?

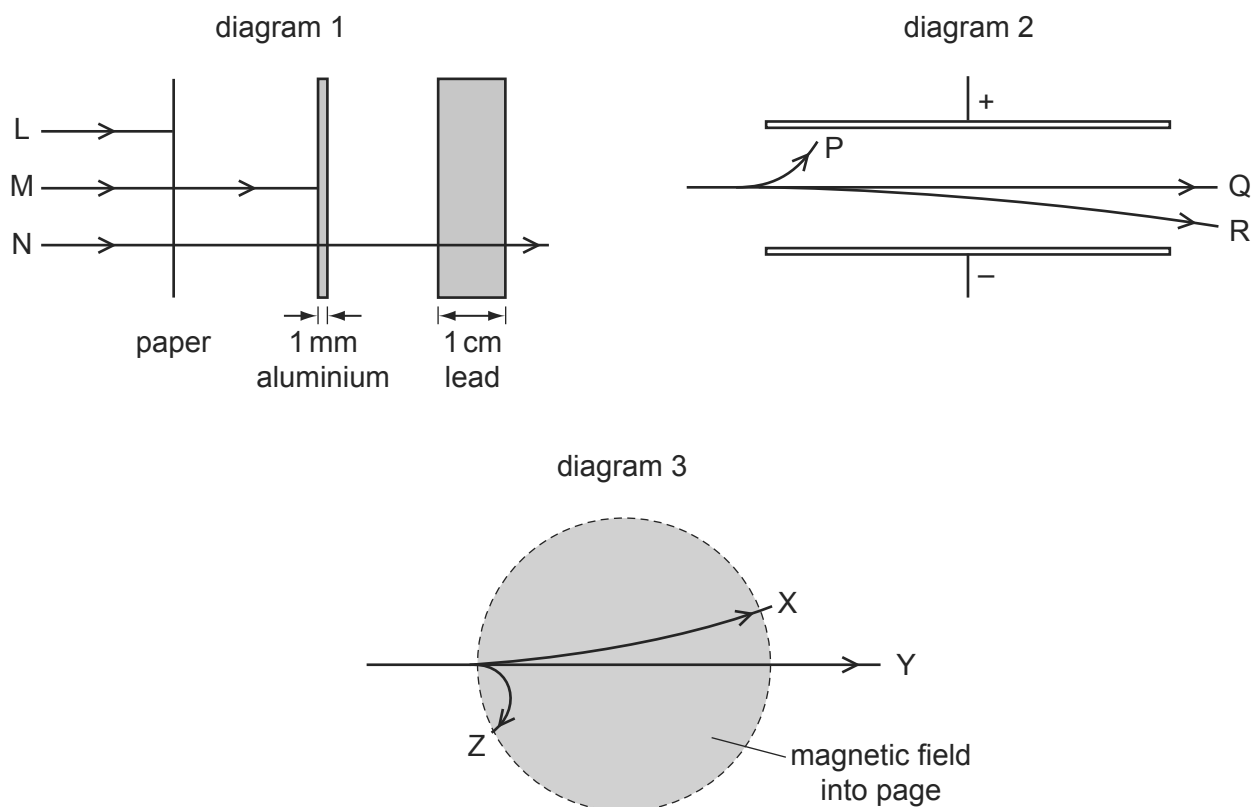


52 Alpha, beta and gamma radiations

9702/11/O/N/09/Q39

- 1 are absorbed to different extents in solids,
- 2 behave differently in an electric field,
- 3 behave differently in a magnetic field.

The diagrams illustrate these behaviours.



Which three labels on these diagrams refer to the **same** kind of radiation?

- A** L, P, X **B** L, P, Z **C** M, P, Z **D** N, Q, X

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

9702/12/O/N/09/Q36

What are the nucleon (mass) number and proton (atomic) number of the nucleus formed by this decay?

	nucleon number	proton number
A	183	79
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9702/12/O/N/09/Q37

What is this particle?

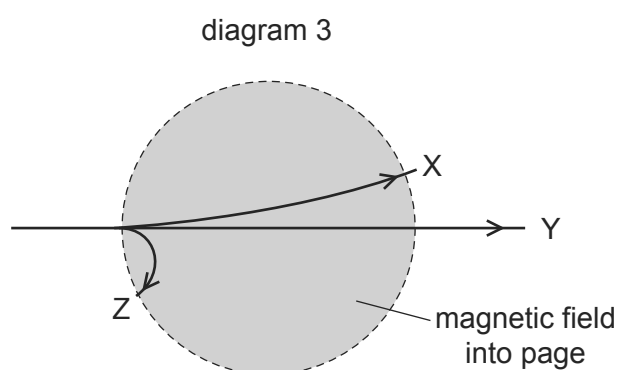
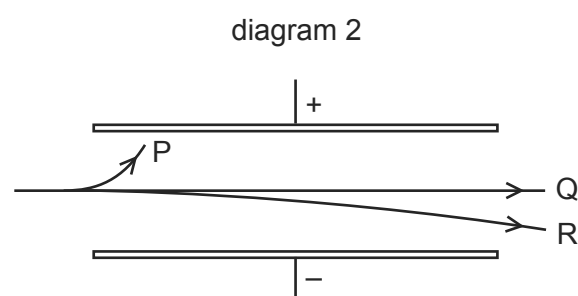
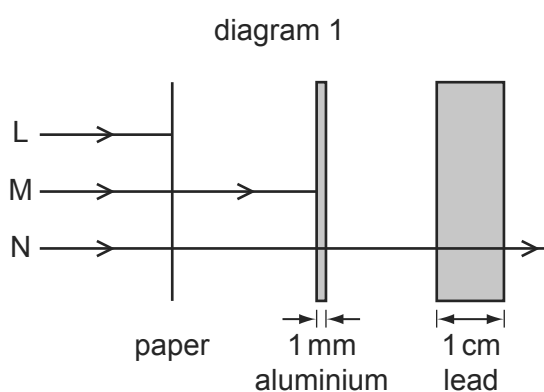
- A electron
- B neutron
- C nucleon
- D proton

- 55 Alpha, beta and gamma radiations

9702/12/O/N/09/Q38

- 1 are absorbed to different extents in solids,
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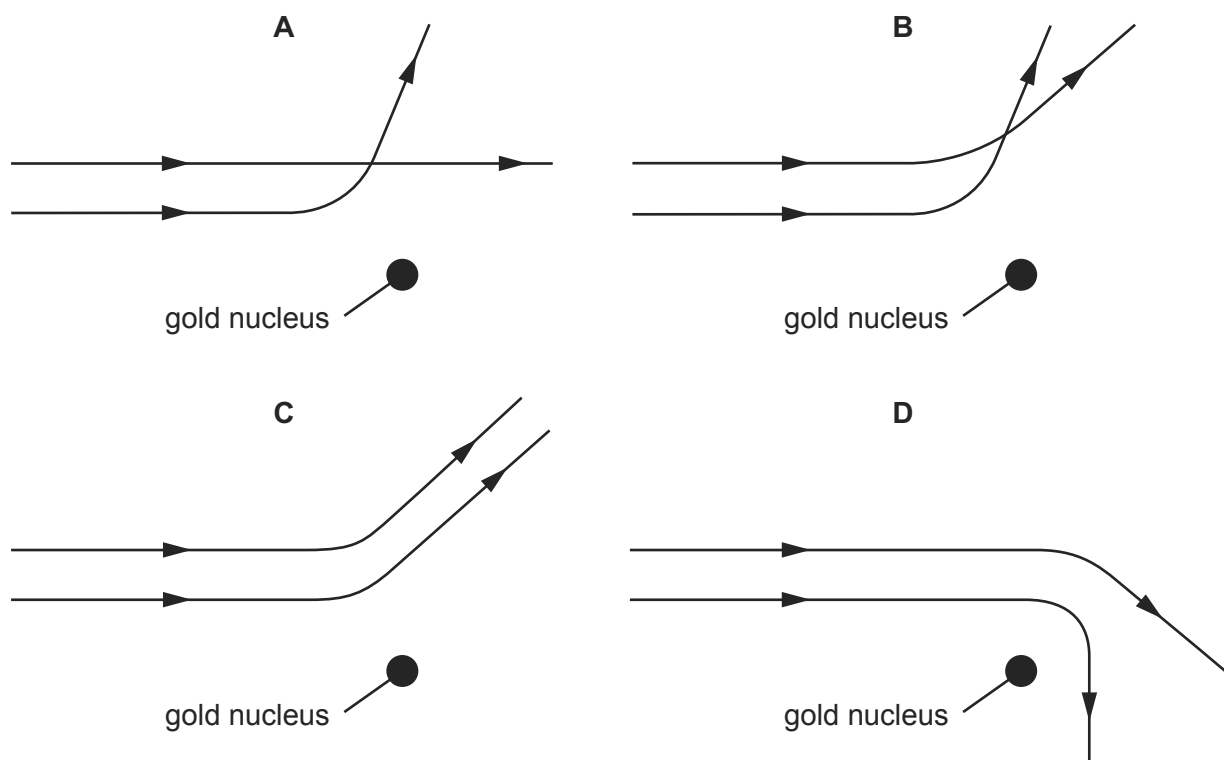


Which three labels on these diagrams refer to the **same** kind of radiation?

- A L, P, X
- B L, P, Z
- C M, P, Z
- D N, Q, X

56 Two α -particles with equal energies are fired towards the nucleus of a gold atom. 9702/12/O/N/09/Q39

Which diagram best represents their paths?



57 What are the correct descriptions of a γ -ray and a β -particle? 9702/11/M/J/10/Q37

	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

58 What is **not** conserved in nuclear processes? 9702/11/M/J/10/Q39

- A** charge
- B** momentum
- C** the total number of neutrons
- D** the total number of nucleons

- 59 The grid shows a number of nuclides arranged according to the number of protons and the number of neutrons in each.

9702/11/M/J/10/Q38

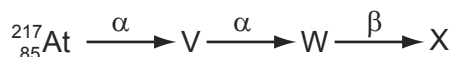
A nucleus of the nuclide ${}^8_3\text{Li}$ decays by emitting a β -particle.

What is the resulting nuclide?

number of protons							
4					A	B	
3				${}^6_3\text{Li}$	${}^7_3\text{Li}$	${}^8_3\text{Li}$	
2		${}^3_2\text{He}$	${}^4_2\text{He}$			C	D
1	${}^1_1\text{H}$	${}^2_1\text{H}$					
	0	1	2	3	4	5	6
	number of neutrons						

- 60 The following represents a sequence of radioactive decays involving two α -particles and one β -particle.

9702/11/M/J/10/Q40



What is the nuclide X?

A ${}^{213}_{85}\text{At}$ **B** ${}^{215}_{77}\text{Ir}$ **C** ${}^{209}_{82}\text{Pb}$ **D** ${}^{217}_{81}\text{Tl}$

- 61 The grid shows a number of nuclides arranged according to the number of protons and the number of neutrons in each.

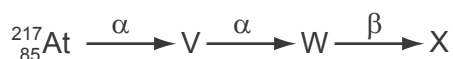
9702/12/M/J/10/Q37

A nucleus of the nuclide ${}^8_3\text{Li}$ decays by emitting a β -particle.

What is the resulting nuclide?

number of protons							
4					A	B	
3				${}^6_3\text{Li}$	${}^7_3\text{Li}$	${}^8_3\text{Li}$	
2		${}^3_2\text{He}$	${}^4_2\text{He}$			C	D
1	${}^1_1\text{H}$	${}^2_1\text{H}$					
	0	1	2	3	4	5	6
	number of neutrons						

- 62 The following represents a sequence of radioactive decays involving two α -particles and one β -particle. 9702/12/M/J/10/Q38



What is the nuclide X?

- A** ${}_{85}^{213}\text{At}$ **B** ${}_{77}^{215}\text{Ir}$ **C** ${}_{82}^{209}\text{Pb}$ **D** ${}_{81}^{217}\text{Tl}$

- 63 What are the correct descriptions of a γ -ray and a β -particle? 9702/12/M/J/10/Q39

	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

- 64 What is **not** conserved in nuclear processes? 9702/12/M/J/10/Q40

- A** charge
B momentum
C the total number of neutrons
D the total number of nucleons

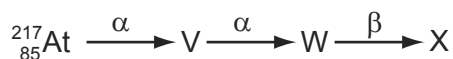
- 65 The grid shows a number of nuclides arranged according to the number of protons and the number of neutrons in each. 9702/13/M/J/10/Q40

A nucleus of the nuclide ${}^8_3\text{Li}$ decays by emitting a β -particle.

What is the resulting nuclide?

number of protons	4					A	B	
3				${}^6_3\text{Li}$	${}^7_3\text{Li}$	${}^8_3\text{Li}$		
2		${}^3_2\text{He}$	${}^4_2\text{He}$			C	D	
1	${}^1_1\text{H}$	${}^2_1\text{H}$						
	0	1	2	3	4	5	6	
	number of neutrons							

- 66 The following represents a sequence of radioactive decays involving two α -particles and one β -particle. 9702/13/M/J/10/Q39



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- A** ${}_{85}^{213}\text{At}$ **B** ${}_{77}^{215}\text{Ir}$ **C** ${}_{82}^{209}\text{Pb}$ **D** ${}_{81}^{217}\text{Tl}$

- 67 What is **not** conserved in nuclear processes? 9702/13/M/J/10/Q37

- A** charge
B momentum
C the total number of neutrons
D the total number of nucleons

- 68 What are the correct descriptions of a γ -ray and a β -particle? 9702/13/M/J/10/Q38

	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

- 69 When a magnesium nucleus ${}_{12}^{25}\text{Mg}$ is hit by a gamma ray, a sodium nucleus ${}_{11}^{24}\text{Na}$ is formed and another particle is emitted.

What are the nucleon number (mass number) and proton number (atomic number) of the other particle produced in this nuclear reaction? 9702/11/O/N/10/Q39

	nucleon number	proton number
A	0	-1
B	0	1
C	1	-1
D	1	1

- 70 Uranium-238, ${}_{92}^{238}\text{U}$, decays by α -emission into a daughter product which in turn decays by β -emission into a grand-daughter product. 9702/13/M/J/11/Q40

What is the grand-daughter product?

- A** ${}_{90}^{234}\text{Th}$ **B** ${}_{91}^{234}\text{Pa}$ **C** ${}_{92}^{234}\text{U}$ **D** ${}_{90}^{230}\text{Th}$

71 Uranium-235 may be represented by the symbol ${}_{92}^{235}\text{U}$.

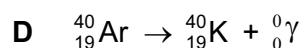
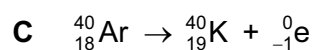
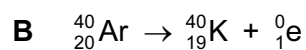
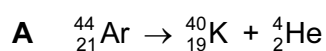
9702/11/O/N/10/Q38

Which row shows the numbers of nucleons, protons and neutrons in a ${}_{92}^{235}\text{U}$ nucleus?

	nucleons	protons	neutrons
A	92	235	143
B	143	92	235
C	235	92	143
D	235	143	92

72 Which nuclear equation shows the beta decay of a nucleus of argon (Ar) into potassium (K)?

9702/11/O/N/10/Q40



73 A counter recording radioactive decays from a radioactive source gives the following counts in equal intervals of time.

9702/12/O/N/10/Q40

time / min	counts
0–10	424
10–20	395
20–30	413
30–40	363
40–50	366
50–60	294
60–70	301
70–80	253
80–90	212

What can be deduced from these readings?

- A** that radioactivity is random and that the half-life is 90 minutes
- B** that radioactivity is random and that the half-life is uncertain
- C** that radioactivity is spontaneous and that the half-life is 90 minutes
- D** that radioactivity is spontaneous and that the half-life is uncertain

- 74 In the Rutherford scattering experiment, α -particles were fired at a thin gold foil. A small proportion of the α -particles were deflected through large angles. 9702/12/O/N/10/Q38

Which statement gives the correct conclusion that could be drawn directly from these results?

- A The atom is made up of electrons, protons and neutrons.
- B The nucleus is at the centre of the atom.
- C The nucleus is made up of protons and neutrons.
- D The atom contains a very small, charged nucleus.

- 75 Which statement about the nuclei of the atoms of an element is correct? 9702/12/O/N/10/Q39

- A Every nucleus of an element contains an equal number of neutrons and protons.
- B Every nucleus of an element contains the same number of neutrons as all others of that element, but the number of protons may differ.
- C Every nucleus of an element contains the same number of protons as all others of that element, but the number of neutrons may differ.
- D The number of protons in a nucleus differs from isotope to isotope of an element, as do the number of neutrons.

- 76 When a magnesium nucleus $^{25}_{12}\text{Mg}$ is hit by a gamma ray, a sodium nucleus $^{24}_{11}\text{Na}$ is formed and another particle is emitted. 9702/13/O/N/10/Q40

What are the nucleon number (mass number) and proton number (atomic number) of the other particle produced in this nuclear reaction?

	nucleon number	proton number
A	0	-1
B	0	1
C	1	-1
D	1	1

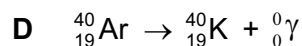
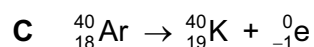
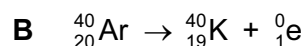
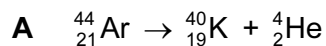
- 77 The first artificial radioactive substance was made by bombarding aluminium, $^{27}_{13}\text{Al}$, with α -particles. This produced an unstable isotope of phosphorus, $^{30}_{15}\text{P}$. 9702/11/M/J/11/Q38

What was the by-product of this reaction?

- A an α -particle
- B a β -particle
- C a γ -ray
- D a neutron

- 78 Which nuclear equation shows the beta decay of a nucleus of argon (Ar) into potassium (K)?

9702/13/O/N/10/Q38



- 79 Uranium-235 may be represented by the symbol ${}_{92}^{235}\text{U}$.

9702/13/O/N/10/Q39

Which row shows the numbers of nucleons, protons and neutrons in a ${}_{92}^{235}\text{U}$ nucleus?

	nucleons	protons	neutrons
A	92	235	143
B	143	92	235
C	235	92	143
D	235	143	92

- 80 The uranium nucleus ${}_{92}^{238}\text{U}$ undergoes α -decay, producing nucleus X.

9702/12/M/J/11/Q39

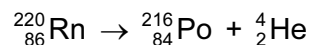
Nucleus X undergoes β -decay, producing nucleus Y.

For nucleus Y, what are the values of the proton number and nucleon number?

	proton number	nucleon number
A	89	234
B	89	236
C	91	234
D	91	236

- 81 Radon-220 is radioactive and decays to polonium-216 with the emission of an α -particle. The equation for the radioactive decay is shown.

9702/12/M/J/11/Q40



How many neutrons are in the radon and polonium nuclei?

	Rn	Po
A	86	84
B	134	132
C	220	212
D	220	216

- 82 Uranium-238, $^{238}_{92}\text{U}$, decays by α -emission into a daughter product which in turn decays by β -emission into a grand-daughter product. 9702/11/M/J/11/Q39

What is the grand-daughter product?

- A** $^{234}_{90}\text{Th}$ **B** $^{234}_{91}\text{Pa}$ **C** $^{234}_{92}\text{U}$ **D** $^{230}_{90}\text{Th}$

- 83 Which statement about nuclei is correct? 9702/11/M/J/11/Q40

- A** Different isotopic nuclei have different proton numbers.
B For some nuclei, the nucleon number can be less than the proton number.
C In some nuclear processes, mass-energy is not conserved.
D Nucleon numbers of nuclei are unchanged by the emission of β -particles.

- 84 Which statement about nuclei is correct? 9702/13/M/J/11/Q38

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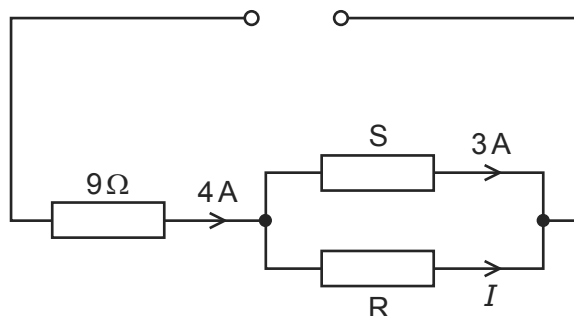
- A** an α -particle
B a β -particle
C a γ -ray
D a neutron

- 86 An experiment in which α -particles were deflected by a gold foil produced new insights into the structure of the atom. 9702/11/M/J/12/Q39

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.

- 87 The circuit below has a current I in the resistor R .



What must be known in order to determine the value of I ?

- A** e.m.f. of the power supply
B resistance of resistor S
C Kirchhoff's first law
D Kirchhoff's second law
- 88 Which statement concerning α -particles is correct? 9702/12/O/N/11/Q39
- A** An α -particle has charge $+4e$.
B An α -particle is a helium atom.
C When α -particles travel through air, they cause ionisation.
D When α -particles travel through a sheet of gold foil, they make the gold radioactive.
- 89 A nucleus of the nuclide $^{241}_{94}\text{Pu}$ decays by emission of a β -particle followed by the emission of an α -particle. 9702/12/O/N/11/Q40

Which nucleus is formed?

- A** $^{239}_{93}\text{Np}$ **B** $^{239}_{91}\text{Pa}$ **C** $^{237}_{93}\text{Np}$ **D** $^{237}_{92}\text{U}$
- 90 Radon $^{222}_{86}\text{Rn}$ is the start of a decay chain that forms bismuth $^{214}_{83}\text{Bi}$ by alpha and beta emission. 9702/12/M/J/12/Q40
- 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

- 91 Nuclear decay is both spontaneous and random in nature.

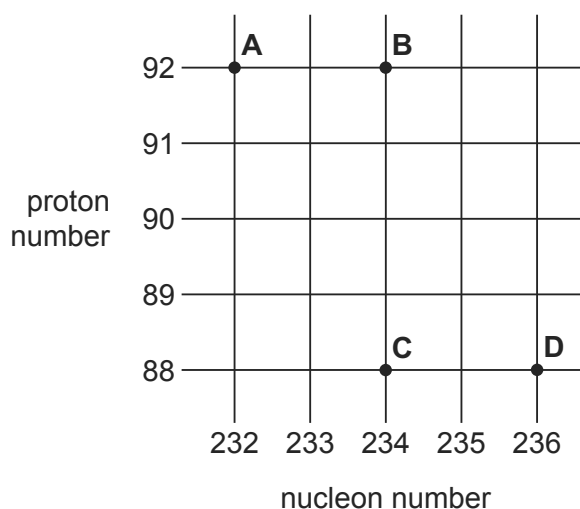
Which row gives the correct experimental evidence for these properties?

	spontaneous nature of decay	random nature of decay
A	the decay rate is not affected by pressure	the decay rate is not affected by temperature
B	the decay rate is not affected by pressure	the rate at which radiation is received at a counter fluctuates
C	the decay rate is not affected by temperature	the decay rate is not affected by pressure
D	the rate at which radiation is received at a counter fluctuates	the decay rate is not affected by pressure

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

9702/11/M/J/12/Q40

Which letter in the diagram represents the granddaughter product?



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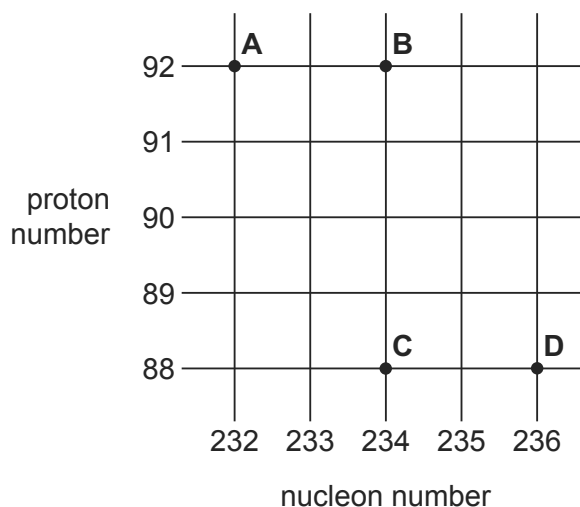
9702/13/M/J/12/Q40

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- 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.

- 94 Thorium-234 ($^{234}_{90}\text{Th}$) decays by β -emission into a daughter product which in turn decays by further β -emission into a granddaughter product. 9702/13/M/J/12/Q39

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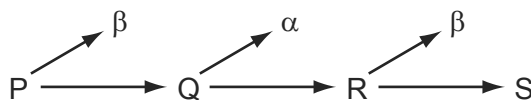


- 95 A material contains a radioactive isotope that disintegrates solely by the emission of α -particles at a rate of 100 s^{-1} . 9702/12/O/N/12/Q39

Which statement about this material is correct?

- A** The number of atoms in the material diminishes at a rate of 100 s^{-1} .
 - B** The number of neutrons in the material diminishes at a rate of 100 s^{-1} .
 - C** The number of nucleons in the material diminishes at a rate of 400 s^{-1} .
 - D** The number of protons in the material diminishes at a rate of 100 s^{-1} .
- 96 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. 9702/11/O/N/12/Q40



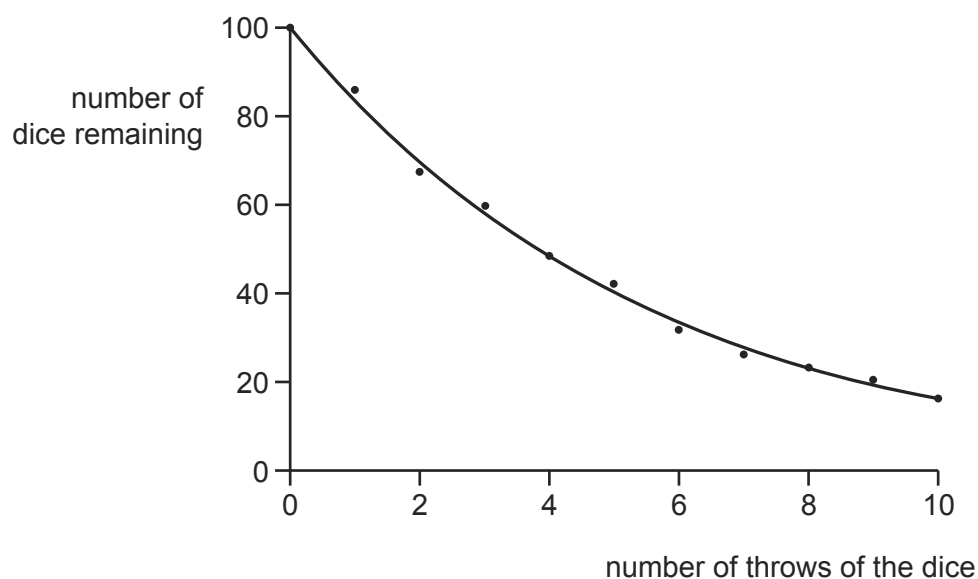
Nuclides P and S are compared.

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.

- 97 A class of students used dice to simulate radioactive decay. After each throw, those dice showing a '6' were removed. The graph shows the results.

9702/11/O/N/12/Q38



What could the scatter of points about the best-fit curve represent for actual radioactive decay?

- A** background count not being taken into account
 - B** more than one type of radiation being present
 - C** the random nature of radioactive decay
 - D** the spontaneous nature of radioactive decay
- 98 Which statement about alpha, beta and gamma radiation is correct?
- A** Alpha radiation has the greatest ionising power.
 - B** Beta radiation has the greatest ionising power.
 - C** Gamma radiation has the greatest ionising power.
 - D** Alpha, beta and gamma radiation have nearly equal ionising powers.

9702/11/O/N/12/Q39

- 99 A different nucleus can be formed by bombarding a stable nucleus with an energetic α -particle.

9702/12/O/N/12/Q40

${}_{11}^{23}\text{Na}$ is bombarded with an energetic α -particle.

What could be the products of this nuclear reaction?

- A** ${}_{10}^{25}\text{Ne}$ + neutron
- B** ${}_{11}^{25}\text{Na}$ + proton
- C** ${}_{12}^{26}\text{Mg}$ + β
- D** ${}_{13}^{27}\text{Al}$ + γ

- 100 A nuclear isotope emits radiation which is detected by a Geiger-Müller tube held at a distance of about 10 cm from the radioactive source. The radiation is stopped completely by a 2 mm thick sheet of lead.

9702/13/O/N/12/Q38

What can be deduced from this information about the emission from the isotope?

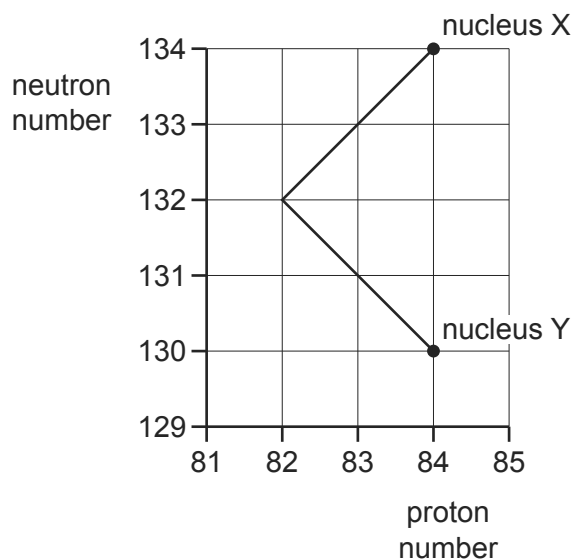
- A** It could be alpha and beta radiation, but not gamma radiation.
B It could be alpha and gamma radiation, but not beta radiation.
C It could be beta and gamma radiation, but not alpha radiation.
D It could be alpha, beta and gamma radiation.
- 101 What remains constant during β -emission from a number of identical nuclei in a substance?

9702/13/O/N/12/Q39

- A** energy of the β -particles
B neutron number of the nuclei
C nucleon number of the nuclei
D proton number of the nuclei

- 102 The graph of neutron number against proton number represents a sequence of radioactive decays.

9702/13/O/N/12/Q40



Nucleus X is at the start of the sequence and, after the decays have occurred, nucleus Y is formed.

What is emitted during the sequence of decays?

- A** one α -particle followed by one β -particle
B one α -particle followed by two β -particles
C two α -particles followed by two β -particles
D two β -particles followed by one α -particle

- 103 A nickel nucleus $^{59}_{28}\text{Ni}$ can be transformed by a process termed K-capture. In this process the nucleus absorbs an orbital electron. 9702/11/M/J/13/Q38

If no other process is involved, what is the resulting nucleus?

- A** $^{58}_{28}\text{Ni}$ **B** $^{58}_{27}\text{Co}$ **C** $^{59}_{27}\text{Co}$ **D** $^{59}_{29}\text{Cu}$

- 104 It was once thought that the mass of an atom is spread uniformly through the volume of the atom. When α -particles are directed at a piece of gold foil, the results led scientists to believe instead that nearly all the mass of the gold atom is concentrated at a point inside the atom. 9702/11/M/J/13/Q39

Which effect is possible **only** if nearly all the mass of the gold atom is concentrated at a point?

- A** a few α -particles bounce back
B most α -particles are only slightly deflected
C some α -particles pass through without any deflection
D some α -particles are absorbed

- 105 Which pair of nuclei are isotopes of one another? 9702/11/M/J/13/Q40

	nucleon number	number of neutrons
A	186	112
	180	118
B	186	112
	182	108
C	184	110
	187	110
D	186	110
	186	112

- 106 An actinium nucleus has a nucleon number of 227 and a proton number of 89. It decays to form a radium nucleus, emitting a beta particle and an alpha particle in the process. 9702/12/M/J/13/Q40

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

	nucleon number	proton number
A	223	87
B	223	88
C	224	87
D	225	86

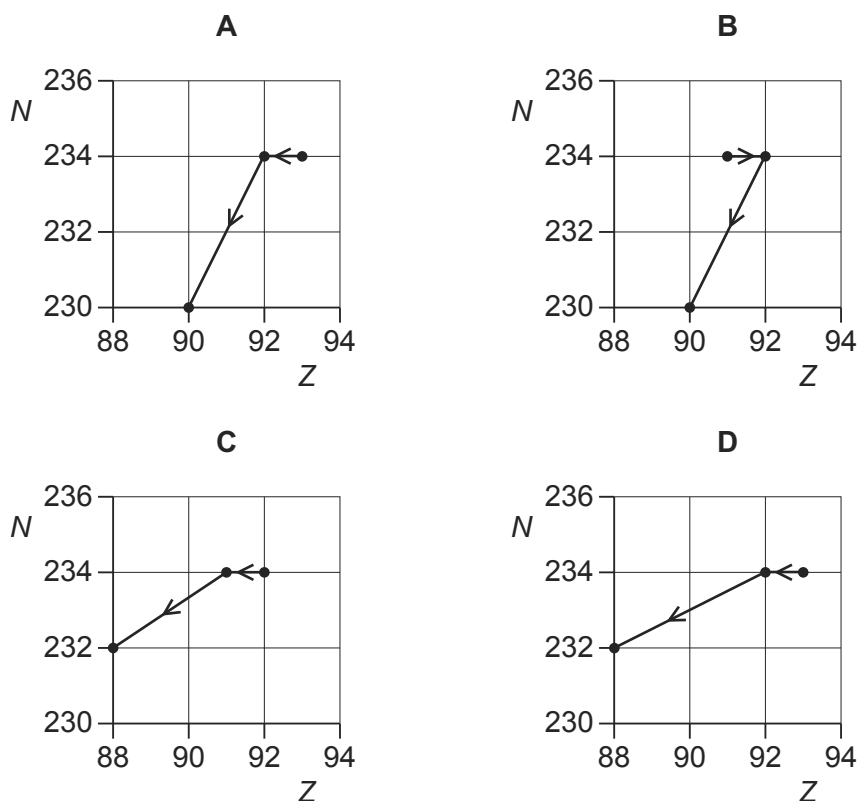
107 What is the approximate mass of an alpha particle?

9702/12/M/J/13/Q39

- A 10^{-28} kg
- B 10^{-26} kg
- C 10^{-24} kg
- D 10^{-22} kg

108 A radioactive nucleus is formed by β -decay. This nucleus then decays by α -emission. 9702/13/M/J/13/Q40

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



109 The decay of a nucleus of neptunium is accompanied by the emission of a β -particle and γ -radiation. 9702/13/M/J/13/Q39

What effect (if any) does this decay have on the proton number and on the nucleon number of the nucleus?

	proton number	nucleon number
A	increases	decreases
B	decreases	increases
C	unchanged	decreases
D	increases	unchanged

- 110 Scientists investigating the count rate from a radioactive source observed that the count rate fluctuates. 9702/13/M/J/13/Q38

What do these fluctuations imply about the nature of radioactive decay?

- A It involves atomic nuclei.
 - B It is predictable.
 - C It is random.
 - D It is spontaneous.
- 111 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. 9702/11/O/N/13/Q39

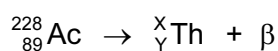
Which change would increase the **proportion** of α -particles deflected by a large angle?

- A using α -particles with greater kinetic energy
 - B using a foil made of a metal with fewer protons in its nuclei
 - C using a double thickness foil
 - D using an alpha source with a higher activity
- 112 Plutonium-239 ($^{239}_{94}\text{Pu}$) decays by emitting α -radiation. 9702/11/O/N/13/Q40

Which nuclide is formed from one of these decay reactions? (The product nuclides are represented by X.)

- A $^{235}_{92}\text{X}$ B $^{237}_{92}\text{X}$ C $^{239}_{93}\text{X}$ D $^{239}_{95}\text{X}$

- 113 A nucleus of the nuclide $^{228}_{89}\text{Ac}$ decays by emitting a beta particle. The nuclear equation below represents this decay. 9702/13/O/N/13/Q39



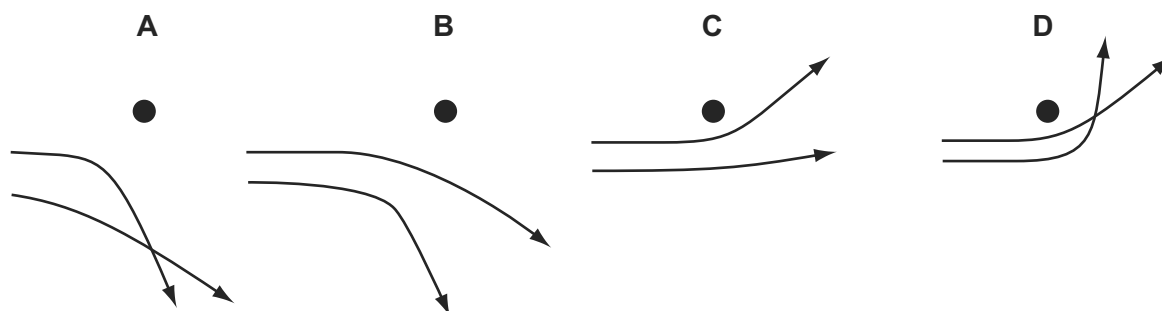
Which pair of values of X and Y is correct?

	X	Y
A	224	87
B	224	89
C	228	88
D	228	90

- 114 Two α -particles with equal energies are deflected by a large nucleus.

9702/13/O/N/13/Q40

Which diagram best represents their paths?



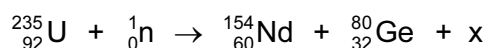
- 115 A nucleus X decays into a nucleus Y by emitting an alpha particle followed by two beta particles.

9702/12/M/J/14/Q38

Which statement about this nuclear decay is correct?

- A** Beta particle decay occurs when a proton changes into a neutron.
 - B** Nucleus Y has the same nucleon number as nucleus X.
 - C** Nucleus Y is an isotope of nucleus X.
 - D** The total mass of the products is equal to the mass of the initial nucleus X.
- 116 A slow-moving neutron collides with a nucleus of uranium-235. This results in a nuclear reaction that is represented by the following nuclear equation

9702/12/M/J/14/Q39



where x represents one or more particles.

What does x represent?

- A** one neutron
 - B** two electrons
 - C** two neutrons
 - D** two protons
- 117 The first artificial radioactive substance was made by bombarding aluminium, ${}_{13}^{27}\text{Al}$, with α -particles. This produced an unstable isotope of phosphorus, ${}_{15}^{30}\text{P}$.

9702/12/M/J/14/Q40

What was the by-product of this reaction?

- A** an α -particle
- B** a β -particle
- C** a neutron
- D** a proton

- 118 An isotope of thorium has a nucleon number of 232 and a proton number of 90. It decays to form another isotope of thorium with a nucleon number of 228.

9702/12/M/J/14/Q39

How many alpha particles and beta particles are emitted by a nucleus of thorium during this decay?

	alpha particles	beta particles
A	0	4
B	1	0
C	1	2
D	2	1

- 119 Four nuclei are represented below.

9702/12/M/J/14/Q40



Which statement about these nuclei is correct?

- A** An uncharged atom of element Q has 24 orbital electrons.
- B** Nucleus M could transform into Q by emitting a beta particle.
- C** Nuclei G and M are isotopes of the same element.
- D** When E absorbs a neutron and then emits an alpha particle, nucleus E transforms into M.
- 120 The grid shows a number of nuclides arranged according to the number of protons and the number of neutrons in each.

9702/11/M/J/14/Q40

A nucleus of the nuclide ${}^8_3\text{Li}$ decays by emitting a β -particle.

What is the resulting nuclide?

					A	B	
4							
3				${}^6_3\text{Li}$	${}^7_3\text{Li}$	${}^8_3\text{Li}$	
2		${}^3_2\text{He}$	${}^4_2\text{He}$			C	D
1	${}^1_1\text{H}$	${}^2_1\text{H}$					
	0	1	2	3	4	5	6
	number of neutrons						

- 121 In 2002, two-proton radioactive decay of an isotope of iron, ${}^{45}_{26}\text{Fe}$, was observed. 9702/11/M/J/14/Q38

What could be the resulting product?

- A** ${}^{43}_{26}\text{Fe}$ **B** ${}^{43}_{24}\text{Cr}$ **C** ${}^{45}_{24}\text{Cr}$ **D** ${}^{47}_{28}\text{Ni}$

- 122 U^{++} is a doubly-ionised uranium atom. The uranium atom has a nucleon number of 235 and a proton number of 92. 9702/11/M/J/14/Q39

In a simple model of the atom, how many particles are in this ionised atom?

- A** 235 **B** 325 **C** 327 **D** 329

- 123 Alpha, beta and gamma radiations have various depths of penetration in matter and different charges. 9702/11/M/J/14/Q37

Which row best summarises the penetration and charge of each radiation?

	alpha	beta	gamma
A	absorbed by a sheet of card negative charge	absorbed by several mm of aluminium no charge	not fully absorbed by several cm of lead no charge
B	absorbed by a sheet of card negative charge	absorbed by several mm of aluminium positive charge	not fully absorbed by several cm of lead no charge
C	absorbed by a sheet of card positive charge	absorbed by several mm of aluminium negative charge	not fully absorbed by several cm of lead no charge
D	absorbed by several mm of aluminium positive charge	not fully absorbed by several cm of lead negative charge	absorbed by a sheet of card no charge

- 124 Which statement about α -particles is correct? 9702/11/O/N/14/Q38

- 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 $1.5 \times 10^7 \text{ ms}^{-1}$.

- 125 The isotope $^{222}_{86}\text{Rn}$ decays in a sequence of emissions to form the isotope $^{206}_{82}\text{Pb}$. At each stage of the decay sequence, it emits either an α -particle or a β -particle. 9702/11/O/N/14/Q39

What is the number of stages in the decay sequence?

- A** 4 **B** 8 **C** 16 **D** 20

- 126 What is the approximate mass of a nucleus of uranium? 9702/11/O/N/14/Q40

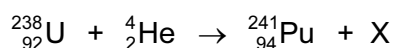
- A** 10^{-15} kg **B** 10^{-20} kg **C** 10^{-25} kg **D** 10^{-30} kg

- 127 The nucleus of a radioactive isotope of an element emits an alpha particle. The daughter nucleus then emits a beta particle and then the daughter nucleus of that reaction emits another beta particle. 9702/13/O/N/14/Q38

Which statement describes the final nuclide that is formed?

- A** It is a different isotope of the original element.
B It is a nuclide of a different element of higher proton number.
C It is a nuclide of the same element but with different proton number.
D It is identical to the original nuclide.

- 128 A nuclear reaction is shown. 9702/13/O/N/14/Q39



What is product X?

- A** an alpha particle
B an electron
C a neutron
D a proton

- 129 The nuclide $^{222}_{86}\text{Rn}$ decays in a sequence of stages to form the nuclide $^{206}_{82}\text{Pb}$. 9702/11/M/J/15/Q40

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

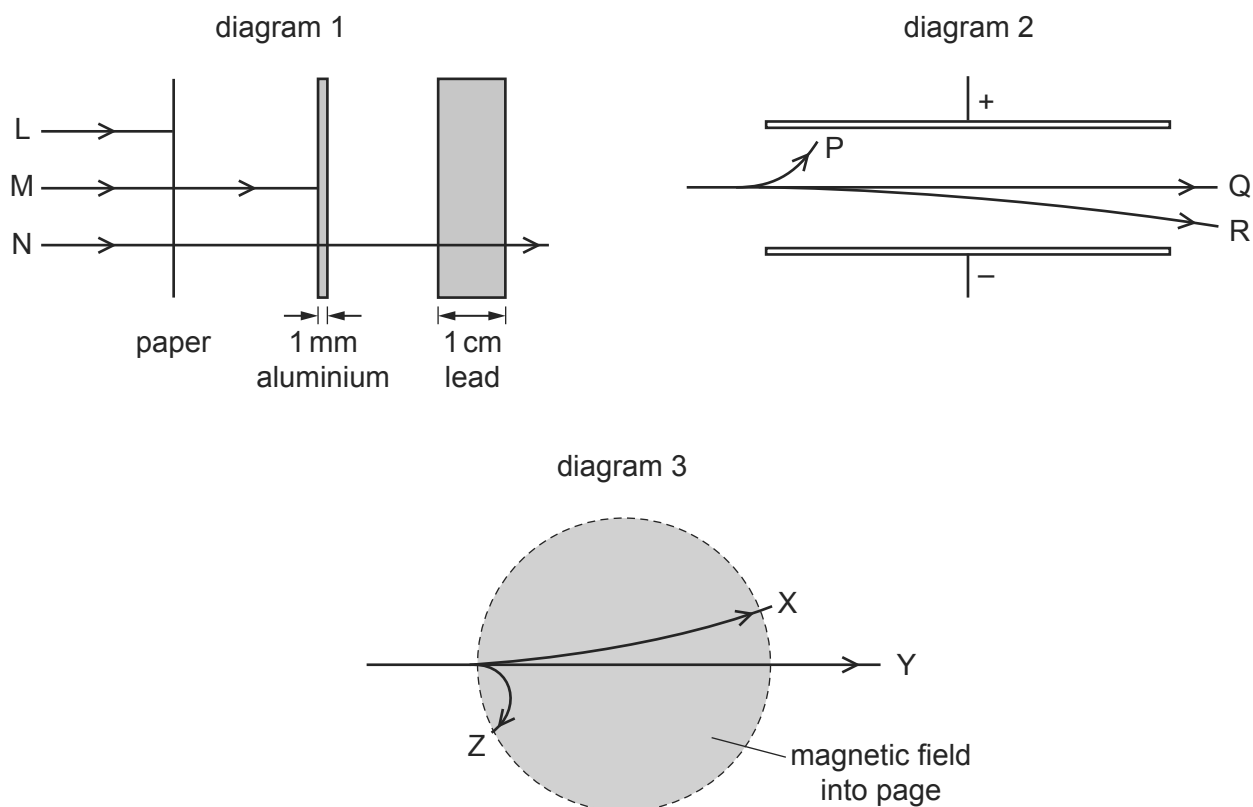
How many nuclides formed in the decay sequence are β -particle emitters?

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

130 Alpha, beta and gamma radiations

- 1 are absorbed to different extents in solids,
- 2 behave differently in an electric field,
- 3 behave differently in a magnetic field.

The diagrams illustrate these behaviours.

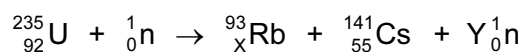


Which three labels on these diagrams refer to the **same** kind of radiation?

- A** L, P, X **B** L, P, Z **C** M, P, Z **D** N, Q, X

131 The nuclear equation for a fission reaction is shown below.

9702/13/M/J/15/Q40



What are the values of X and Y?

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

- 132 A radioactive substance contains a number of identical nuclei that emit β -particles. 9702/12/M/J/15/Q39

Which property of these nuclei remains unaltered by the emission?

- A** charge
- B** neutron number
- C** nucleon number
- D** proton number

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

9702/12/M/J/15/Q40

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

- 134 When α -particles are directed at gold leaf

9702/11/M/J/15/Q39

- 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

1. Nov/2020/Paper_41/No.12

Iodine-131 ($^{131}_{53}\text{I}$) is a radioactive isotope with a decay constant of $9.9 \times 10^{-7} \text{ s}^{-1}$.

(a) State what is meant by:

(i) *radioactive*

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

(ii) *decay constant.*

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

(b) Some water becomes contaminated with iodine-131.
The activity of the iodine-131 in 1.0 kg of water is 560 Bq.

Determine the number of iodine-131 atoms in 1.0 kg of water.

number = ... [2]

(c) Regulations require that the activity of iodine-131 in 1.0 kg of water is to be less than 170 Bq.

Calculate the time, in days, for the activity of the contaminated water in **(b)** to be reduced to 170 Bq.

time = ... days [3]

[Total: 9]

(a) (i) Define nuclear *binding energy*.

.....

.....

..... [2]

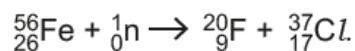
(ii) Explain what is meant by a *nuclear fission* reaction.

.....

.....

..... [2]

(b) A student suggests that one possible nuclear reaction is



The binding energy per nucleon of a nucleus varies with the nucleon number.

Use this variation to explain why the reaction would **not** result in an overall release of energy.

.....

.....

.....

.....

..... [3]

[Total: 7]

(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.

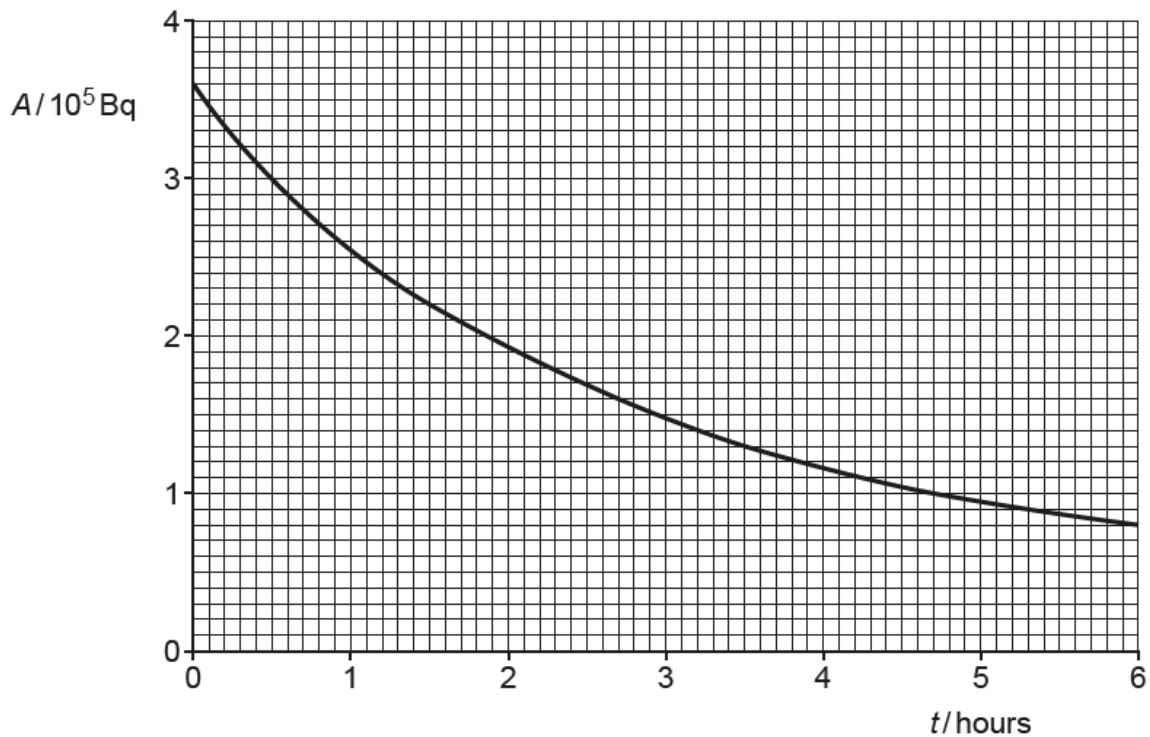


Fig. 12.1

- (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]

4. [June/2020/Paper_42/No.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]

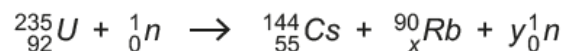
(a) Explain what is meant by the *binding energy* of a nucleus.

.....

.....

..... [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]

1. Nov/2021/Paper_41/No.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]

(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.

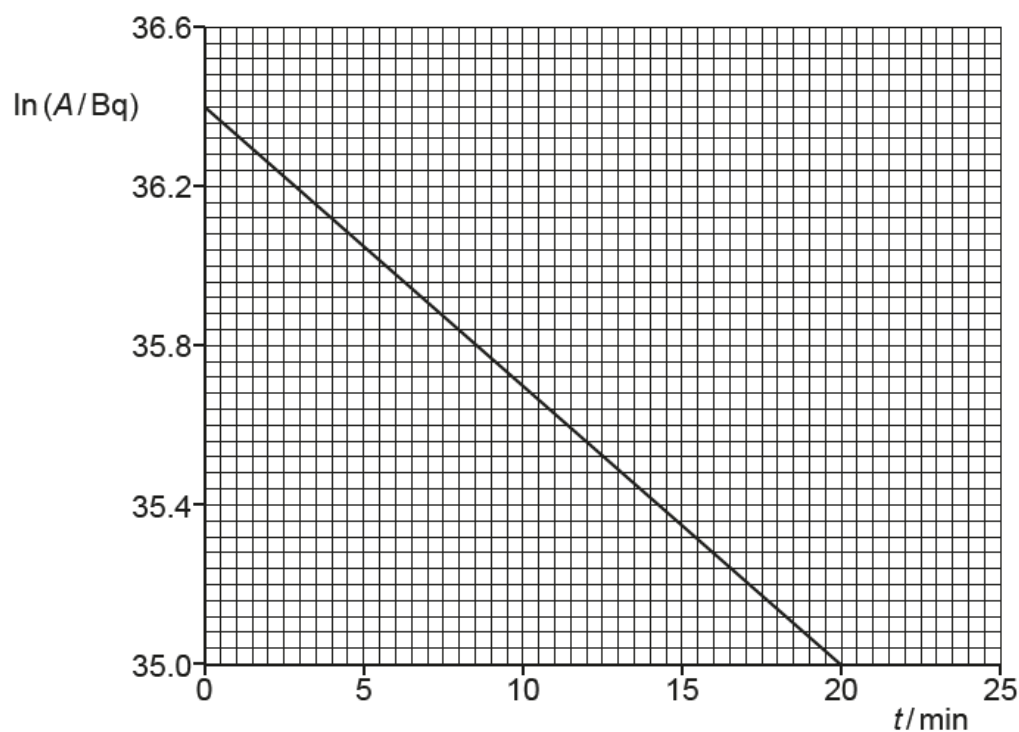


Fig. 12.1

(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]

(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.

$$\lambda = \dots\dots\dots \text{ s}^{-1} \quad [3]$$

(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]

1. Nov/2023/Paper_9702/41/No.9

(a) State what is meant by nuclear fusion.

.....

.....

..... [2]

(b) On Fig. 9.1, sketch the variation of binding energy per nucleon with nucleon number A for values of A between 1 and 250.

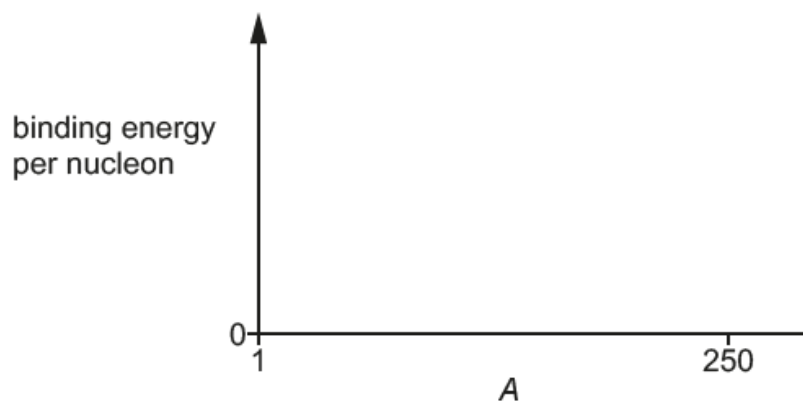


Fig. 9.1

[2]

(c) On your line in Fig. 9.1, label:

(i) a point X that could represent a nucleus that undergoes alpha-decay [1]

(ii) a point Y that could represent a nucleus that undergoes nuclear fusion. [1]

- (d) A nucleus Z undergoes nuclear fission to form strontium-93 ($^{93}_{38}\text{Sr}$) and xenon-139 ($^{139}_{54}\text{Xe}$) according to

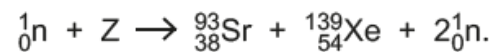


Table 9.1 shows the binding energies of the strontium-93 and xenon-139 nuclei.

Table 9.1

nucleus	binding energy / J
$^{93}_{38}\text{Sr}$	1.25×10^{-10}
$^{139}_{54}\text{Xe}$	1.81×10^{-10}

The fission of 1.00 mol of Z releases 1.77×10^{13} J of energy.

Determine the binding energy per nucleon, in MeV, of Z.

binding energy per nucleon = ... MeV [4]

[Total: 10]

Carbon-11 is radioactive and decays by β^+ emission to form boron-11. Carbon-11 has a half-life of 20 minutes. Boron-11 is stable.

(a) Define half-life.

.....
 [1]

(b) A sample contains N_0 nuclei of carbon-11 and no other nuclei at time $t = 0$.

On Fig. 9.1, sketch the variation with t of the number of nuclei of **boron-11** in the sample.

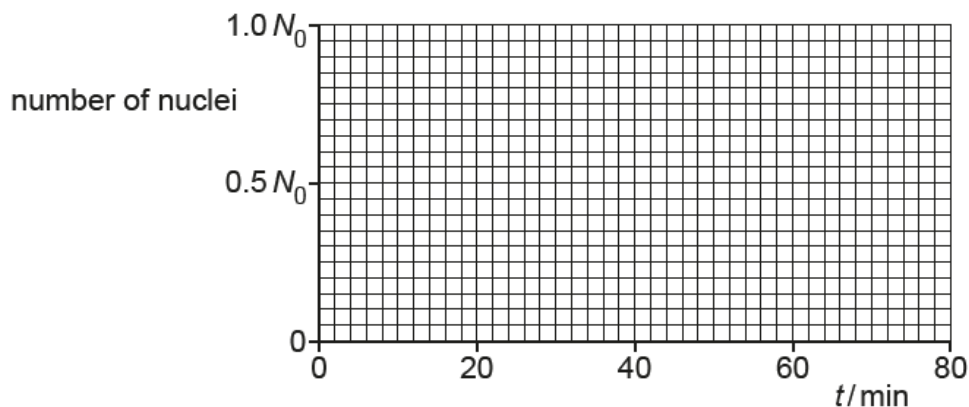


Fig. 9.1

[3]

(c) (i) Explain, with reference to the random nature of radioactive decay, why the activity of the carbon-11 sample in (b) decreases with time.

.....

 [2]

- (ii) State, with reasons, whether a radiation detector placed near to the sample of carbon-11 indicates a measured count rate from the sample that is less than, the same as or greater than the activity of the sample.

.....

.....

.....

.....

..... [3]

[Total: 9]

(a) Define mass defect.

.....

.....

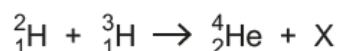
..... [2]

(b) Table 9.1 shows the mass defects of three nuclei.

Table 9.1

nucleus	mass defect/u
${}^2_1\text{H}$	0.002 388
${}^3_1\text{H}$	0.009 105
${}^4_2\text{He}$	0.030 377

The nuclear fusion process in a particular star is described by



where X is a particle that has no mass defect.

(i) State the name of particle X.

..... [1]

(ii) Show that the energy released when one nucleus of ${}^4_2\text{He}$ is formed in this fusion reaction is $2.8 \times 10^{-12} \text{ J}$.

[3]

- (c) The star in (b) has a radius of $2.3 \times 10^9 \text{ m}$ and a luminosity of $1.4 \times 10^{28} \text{ W}$.
All the energy released from the formation of ${}^4_2\text{He}$ is radiated away from the star.
All the energy that is radiated from the star has been released in the formation of ${}^4_2\text{He}$.

Determine:

- (i) the mass of ${}^4_2\text{He}$ produced per unit time by the fusion process

mass per unit time = ... kg s^{-1} [3]

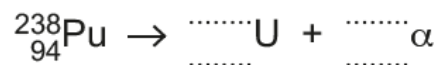
- (ii) the surface temperature of the star.

temperature = ... K [2]

[Total: 11]

Plutonium-238 ($^{238}_{94}\text{Pu}$) is unstable and undergoes alpha decay.

- (a) Complete the equation to show the decay of plutonium-238.



[2]

- (b) The power source in a space probe contains 0.874 kg of plutonium-238. Each nucleus of plutonium-238 that decays emits 5.59 MeV of energy. The half-life of plutonium-238 is 87.7 years.

- (i) Calculate the initial number N_0 of nuclei of plutonium-238 in the power source.

$$N_0 = \dots\dots\dots [1]$$

- (ii) Determine the initial activity of the source. Give a unit with your answer.

$$\text{activity} = \dots\dots\dots \text{unit} \dots\dots\dots [2]$$

- (iii) Use your answer in (b)(ii) to determine the initial power output from the source due to the decay of plutonium-238.

$$\text{power output} = \dots\dots\dots \text{W} [2]$$

- (iv) The space probe will continue to function until the power output from the plutonium in the source decreases to 65.3% of its initial value.

Calculate the time, in years, for which the space probe will function.

time = ... years [2]

- (c) An alternative power source uses energy generated from the radioactive decay of polonium-210. This isotope has a half-life of 0.378 years. The mass of the isotope needed for the same initial power output as in (b) is 3.37 g.

Suggest **one** advantage and **one** disadvantage of using polonium-210 as the source of energy.

advantage

.....

disadvantage

.....

[2]

[Total: 11]

Nuclear Physics - 2018

1. 9702/11/M/J/18/No.38

Which elementary particle is a lepton?

- A proton
- B neutron
- ☒ C electron
- D quark

2. 9702/11/M/J/18/No.39

How many down quarks are in a nucleus of hydrogen-3, ${}^3_1\text{H}$?

A 2

B 3

C 4

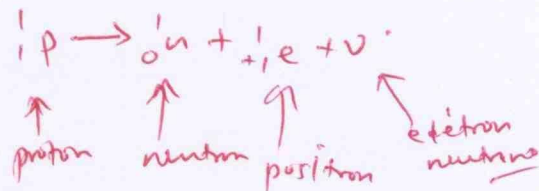
☒ D 5

${}^3_1\text{H}$ - 1 proton - uud
2 neutrons - udd + udd

3. 9702/11/M/J/18/No.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



4. 9702/12/M/J/18/No.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.

5. 9702/12/M/J/18/No.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

$$\begin{aligned} \text{Rn}, n &= 211 - 86 = 125 \\ \text{Fr}, n &= 210 - 87 = 123 \\ \text{Ra}, n &= 212 - 88 = 124 \end{aligned}$$

6. 9702/12/M/J/18/No.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 $d \rightarrow u + \beta^- + \bar{\nu}_e$

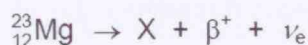
C $u \rightarrow d + \beta^+ + \nu_e$

D $u \rightarrow d + \beta^+ + \bar{\nu}_e$

$$\begin{aligned} n &\rightarrow p + e^- + \bar{\nu}_e \\ udd &\rightarrow uud \\ d &\rightarrow u + e^- + \bar{\nu}_e \\ d &\rightarrow u + \beta^- + \bar{\nu}_e \end{aligned}$$

7. 9702/13/M/J/18/No.39

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



What is nucleus X?

A $^{22}_{11}\text{Na}$

B $^{22}_{13}\text{Al}$

C $^{23}_{11}\text{Na}$

D $^{23}_{13}\text{Al}$

8. 9702/13/M/J/18/No.40

Which list contains only leptons?

☒ A electron, neutrino, positron

B electron, neutrino, proton

C electron, proton, neutron

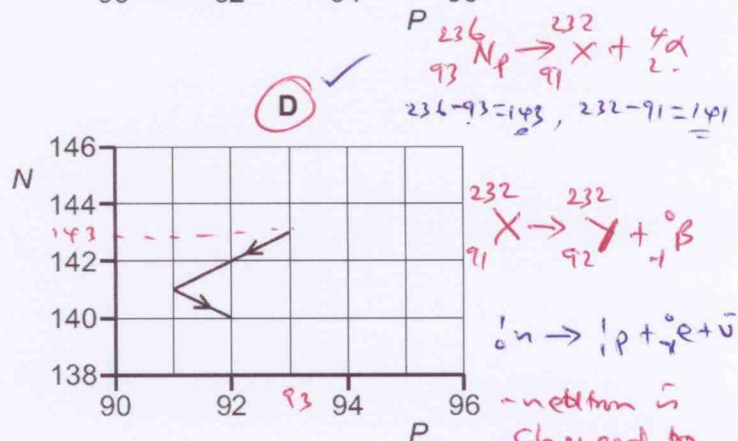
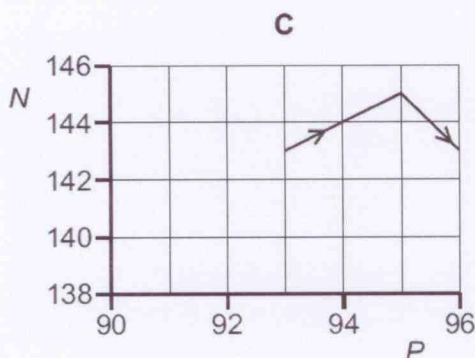
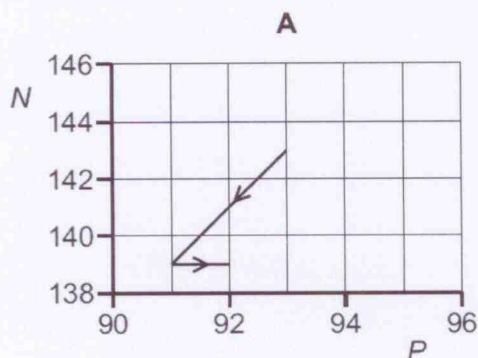
D neutrino, neutron, positron

Two subatomic particles types
hadrons - protons, neutrons, π^+ , π^-
leptons - electrons, neutrino, positron

9. 9702/12/F/M/18/No.39

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

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



10. 9702/12/F/M/18/No.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

Handwritten notes for Q10:

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

$$udd \rightarrow uud$$

$$d \rightarrow u$$

- β decay is due to weak interaction force.