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

9702/1/M/J/02

	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

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

9702/1/M/J/02

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

40 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

bohrium $^{x}_{y}\text{Bh} \longrightarrow$ dubnium + α

$\longrightarrow$ lawrencium + α

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

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

A 267

B 261

C 160

D 154

38 The numbers of protons, neutrons and nucleons in three nuclei are shown. 9702/1/O/N/02

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

39 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

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.

40 When a nucleus of $^{238}_{92}U$ absorbs a slow neutron it subsequently emits two β-particles. 9702/1/O/N/02

What is the resulting nucleus?

A $^{240}_{93}Np$ **B** $^{240}_{91}Pa$ **C** $^{239}_{94}Pu$ **D** $^{239}_{90}Th$

38 In what way do the atoms of the isotopes $^{12}_{6}C$, $^{13}_{6}C$ and $^{14}_{6}C$ differ? 9702/01/M/J/03

A different charge

B different numbers of electrons

C different numbers of neutrons

D different numbers of protons

40 A nickel nucleus $^{59}_{28}Ni$ can be transformed by a process termed K-capture. In this process the nucleus absorbs an orbital electron. 9702/01/O/N/03

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

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

39 Strontium- 90 ($^{90}_{38}Sr$) is radioactive and emits β-particles. 9702/01/M/J/03

Which equation could represent this nuclear decay?

A $^{90}_{38}Sr \rightarrow {}^{90}_{39}Sr + {}^{0}_{-1}\beta$

B $^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}\beta$

C $^{90}_{38}Sr \rightarrow {}^{90}_{37}Rb + {}^{0}_{1}\beta$

D $^{90}_{38}Sr \rightarrow {}^{90}_{37}Sr + {}^{0}_{1}\beta$

40 Protons and neutrons are thought to consist of smaller particles called quarks. 9702/01/M/J/03

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 ($+1.6 \times 10^{-19}$ 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

38 Which are the correct descriptions of a γ-ray and a β-particle? 9702/01/O/N/03

	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

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. 9702/01/O/N/03

Which is an isotope of Uranium-235?

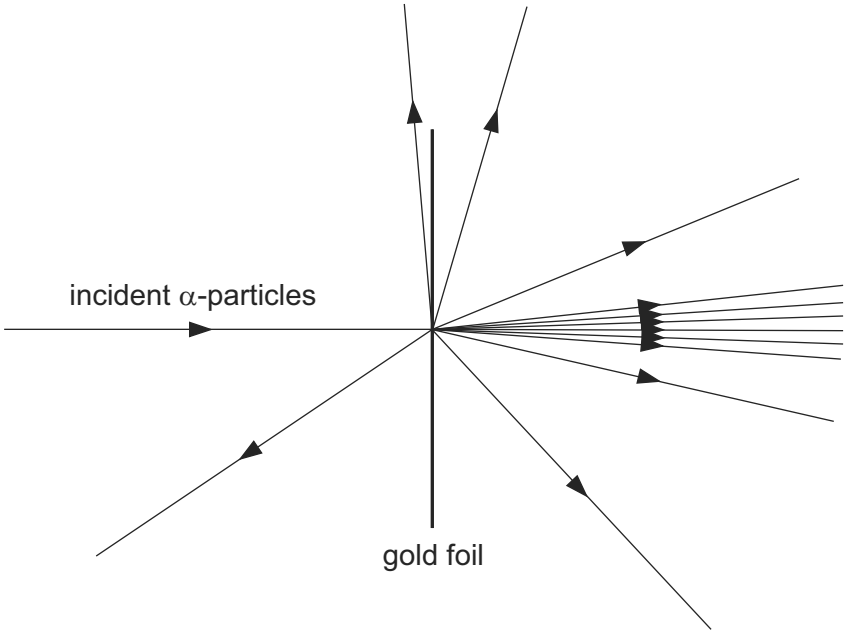
	nucleon number	proton number	neutron number
A	235	91	144
B	236	92	144
C	237	94	143
D	238	95	143

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

Which of the nuclides shown is formed?

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

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



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.

40 Isotopes of a given element all have the same 9702/01/M/J/04

A charge / mass ratio.

B neutron number.

C nucleon number.

D proton number.

38 What is a correct order of magnitude estimate for the diameter of a typical atomic nucleus? 9702/01/M/J/06

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

38 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

What is the symbol of this arsenic nuclide?

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

39 The table shows three properties of different types of ionising radiation. 9702/01/O/N/04

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

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

40 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

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.

38 Which two nuclei contain the same number of neutrons? 9702/01/M/J/05

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 $^{32}_{15}\text{P}$

39 A student conducts an experiment using an α-particle source. 9702/01/M/J/05

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

40 The following represents a sequence of radioactive decays involving two α-particles and one β-particle. 9702/01/M/J/05

$$^{217}_{85}\text{At} \xrightarrow{\alpha} \text{V} \xrightarrow{\alpha} \text{W} \xrightarrow{\beta} \text{X}$$

What is the nuclide X?

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

38 An atomic nucleus emits a β-particle. 9702/01/O/N/05

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

40 A nuclear reaction is represented by the equation 9702/01/O/N/05

$$^{16}_{8}\text{O} + ^{4}_{2}\text{He} \rightarrow ^{19}_{9}\text{F} + \text{X}.$$

What is particle X?

A an α-particle

B a β-particle

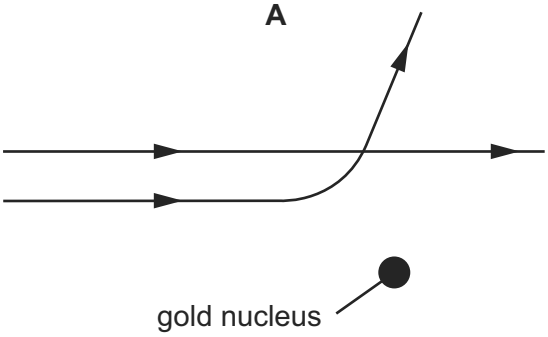
C a neutron

D a proton

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

Which diagram best represents their paths?

A



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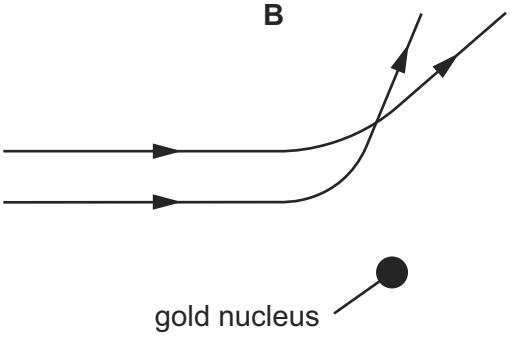

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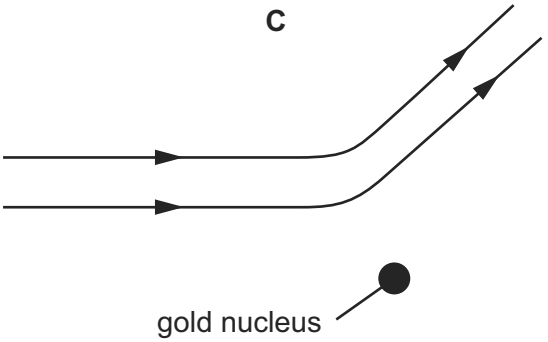

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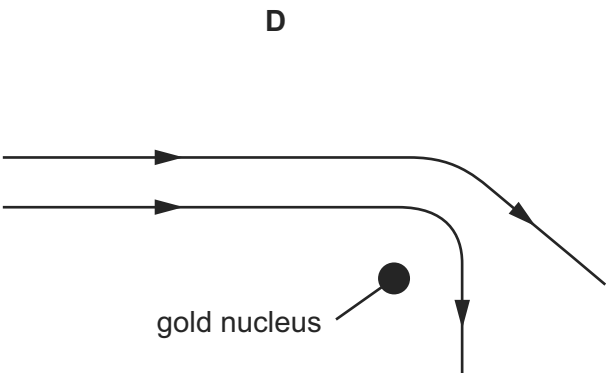


39 The decay of a nucleus of neptunium is accompanied by the emission of a β-particle and γ-radiation. 9702/01/M/J/06

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

39 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

What is the symbol of this arsenic nucleus?

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

40 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

$$^{220}_{86}\text{Rn} \rightarrow {}^{216}_{84}\text{Po} + {}^{4}_{2}\text{He}$$

How many neutrons are in the radon and polonium nuclei?

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

38 Which statement concerning α-particles is correct? 9702/01/O/N/06

A An α-particle has charge +4*e*.

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.

39 Where are electrons, neutrons and protons found in an atom? 9702/01/O/N/06

	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

40 Radon $^{222}_{86}\text{Rn}$ decays by α and β emission to bismuth $^{214}_{83}\text{Bi}$. 9702/01/O/N/06

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

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

9702/01/M/J/07

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.

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

9702/01/M/J/07

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

A $^{1}_{1}H$ **B** $^{4}_{2}He$ **C** $^{7}_{3}Li$ **D** $^{9}_{4}Be$

36 How is it possible to distinguish between the isotopes of uranium? 9702/01/O/N/07

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.

37 What is **not** conserved in nuclear processes? 9702/01/O/N/07

A energy and mass together

B nucleon number

C neutron number

D charge

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

9702/01/O/N/07

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

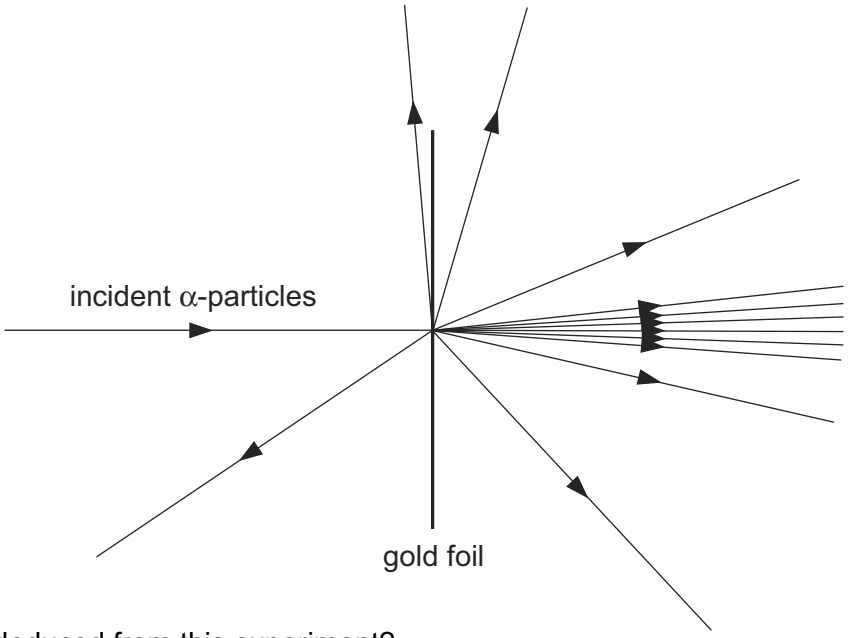
A α-particle

B electron

C neutron

D proton

38 A thin gold foil is bombarded with α-particles as shown. 9702/01/O/N/07



What can be deduced from this experiment?

A the binding energy of a gold nucleus

B the energy levels of electrons in gold atoms

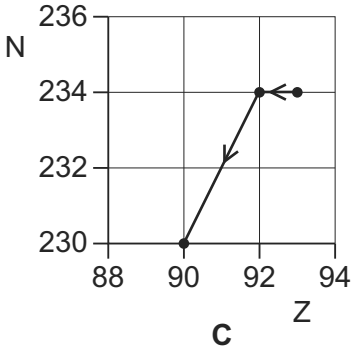
C the small size of a gold nucleus

D the structure of a gold nucleus

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

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

A



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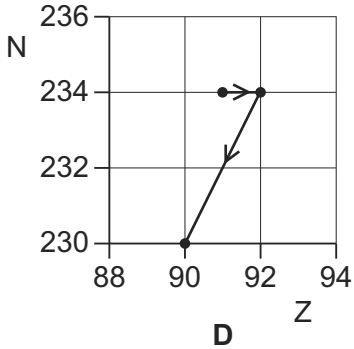

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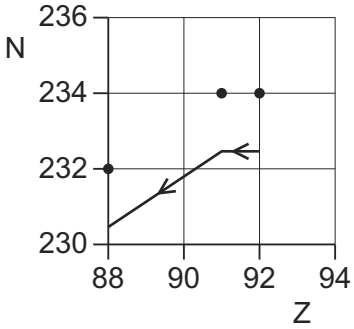

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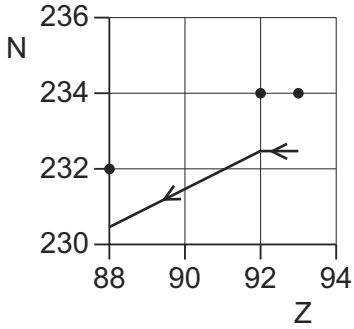


39 What is the approximate mass of a nucleus of uranium? 9702/01/M/J/08

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

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

What is the final resulting nucleus of these two decays?

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

38 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

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.

39 A nucleus Q has the notation $^{y}_{x}Q$. 9702/01/O/N/08

Which of the following is an isotope of Q?

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

40 A $^{238}_{92}U$ nucleus decays in two stages to a $^{234}_{91}Pa$ nucleus. 9702/01/O/N/08

What was emitted in these two stages?

A α + β **B** α + γ **C** β + β **D** β + γ

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

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

37 Nuclear decay is both spontaneous and random. 9702/01/M/J/09

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

38 Which two nuclei contain the same number of neutrons? 9702/01/M/J/09

A $^{12}_{6}C$ and $^{14}_{6}C$

B $^{16}_{7}N$ and $^{15}_{8}O$

C $^{23}_{11}Na$ and $^{24}_{12}Mg$

D $^{32}_{14}Si$ and $^{32}_{15}P$

39 The calcium nuclide $^{42}_{20}Ca$ is formed by beta decay. 9702/01/M/J/09

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

40 When boron-11 ($^{11}_{5}B$) is bombarded with α-particles, a new nucleus is formed and a neutron is released. 9702/01/M/J/09

Which nuclear equation could represent this reaction?

A $^{11}_{5}B + {}^{1}_{1}He \rightarrow {}^{11}_{6}C + {}^{1}_{0}n$

B $^{11}_{5}B + {}^{2}_{2}He \rightarrow {}^{12}_{7}N + {}^{1}_{0}n$

C $^{11}_{5}B + {}^{4}_{2}He \rightarrow {}^{14}_{6}C + {}^{1}_{1}n$

D $^{11}_{5}B + {}^{4}_{2}He \rightarrow {}^{14}_{7}N + {}^{1}_{0}n$

37 The gold nucleus $^{185}_{79}Au$ undergoes alpha decay. 9702/11/O/N/09

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

38 The nuclei of the isotopes of an element all contain the same number of a certain particle. 9702/11/O/N/09

What is this particle?

A electron

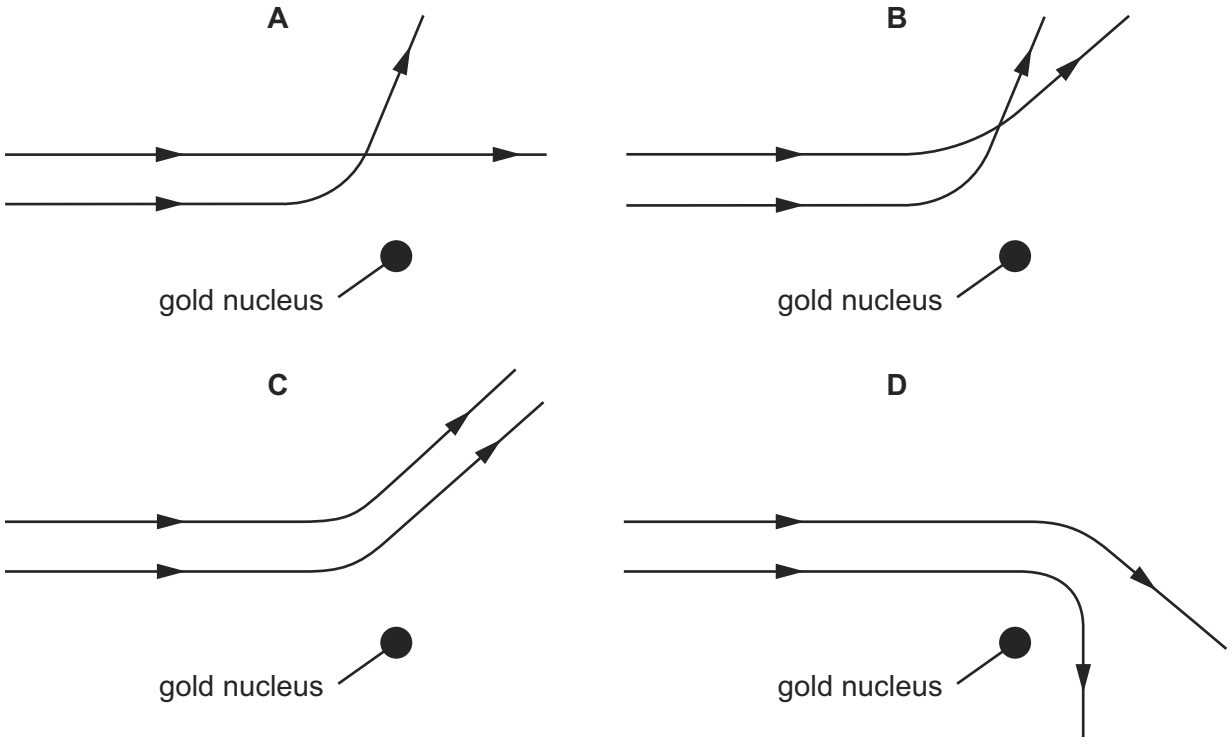
B neutron

C nucleon

D proton

40 Two α-particles with equal energies are fired towards the nucleus of a gold atom. 9702/11/O/N/09

Which diagram best represents their paths?



39 Alpha, beta and gamma radiations 9702/11/O/N/09

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.

diagram 1

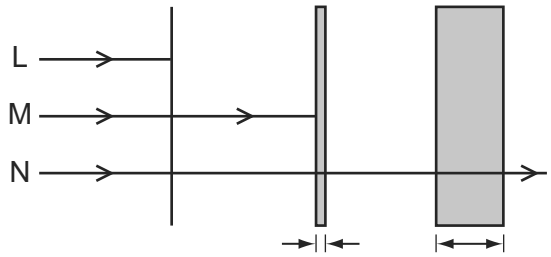


diagram 2

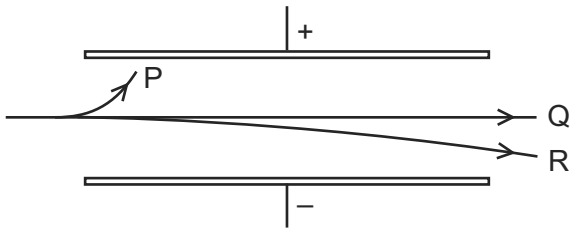
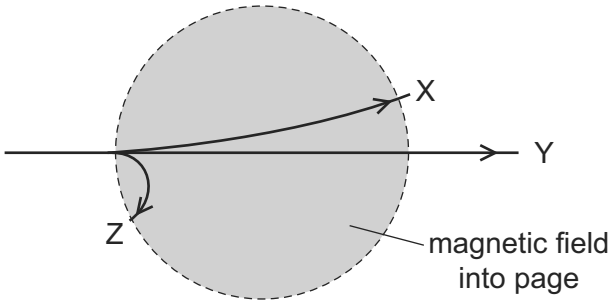


diagram 3



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

36 The gold nucleus $^{185}_{79}Au$ undergoes alpha decay. 9702/12/O/N/09

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

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9702/12/O/N/09

What is this particle?

A electron

B neutron

C nucleon

D proton

38 Alpha, beta and gamma radiations

9702/12/O/N/09

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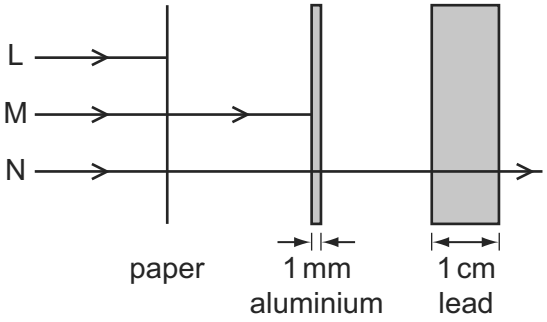


diagram 2

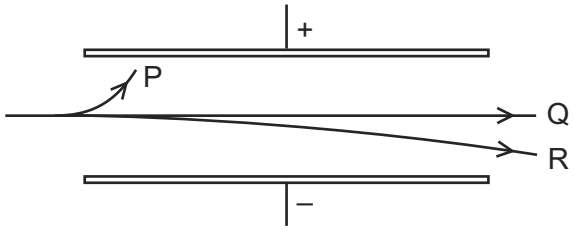
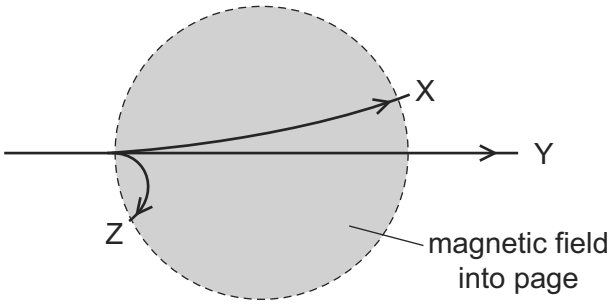


diagram 3



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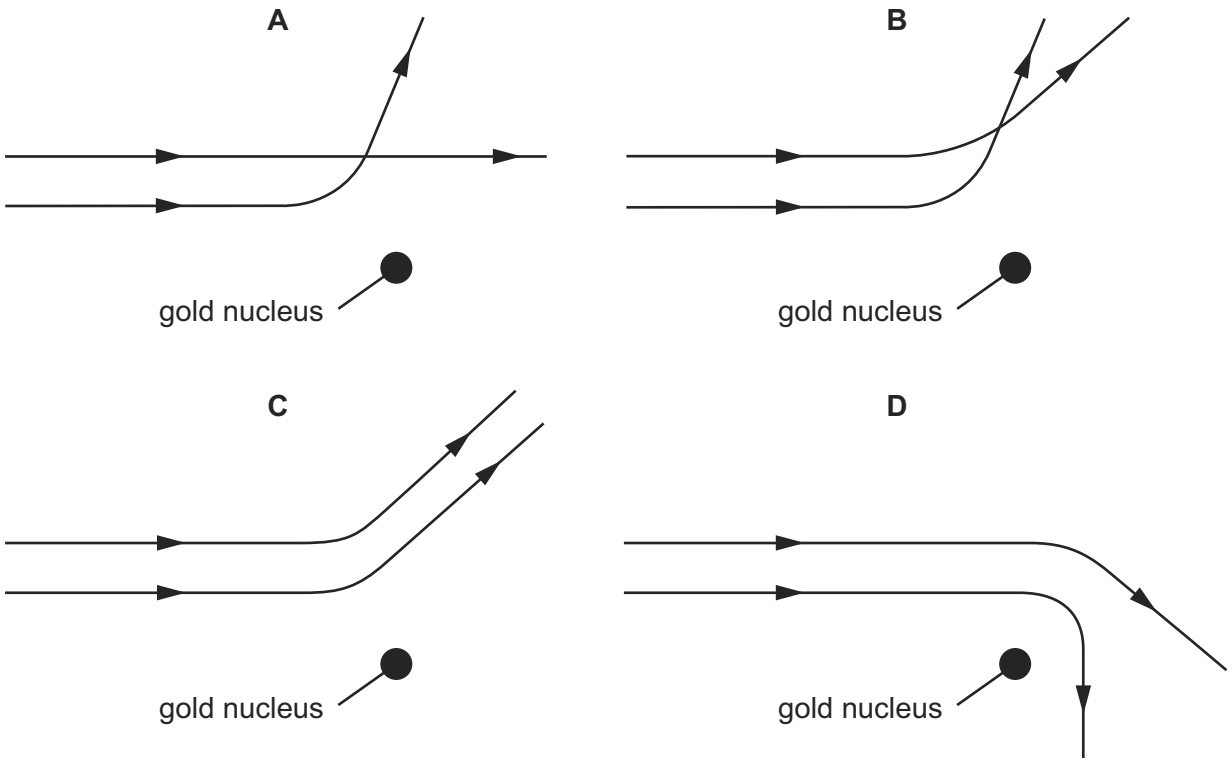
Which diagram best represents their paths?



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

	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

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

A charge

B momentum

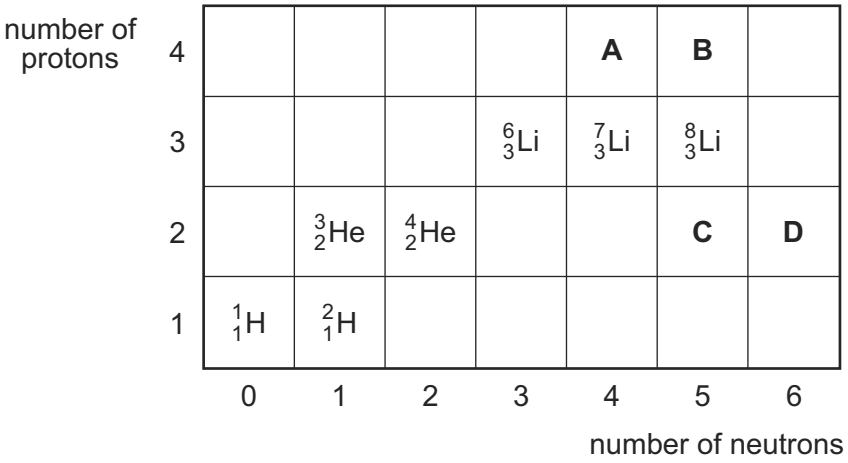
C the total number of neutrons

D the total number of nucleons

38 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

A nucleus of the nuclide $^{8}_{3}\text{Li}$ decays by emitting a β-particle.

What is the resulting nuclide?



40 The following represents a sequence of radioactive decays involving two α-particles and one β-particle. 9702/11/M/J/10

$$^{217}_{85}\text{At} \xrightarrow{\alpha} \text{V} \xrightarrow{\alpha} \text{W} \xrightarrow{\beta} \text{X}$$

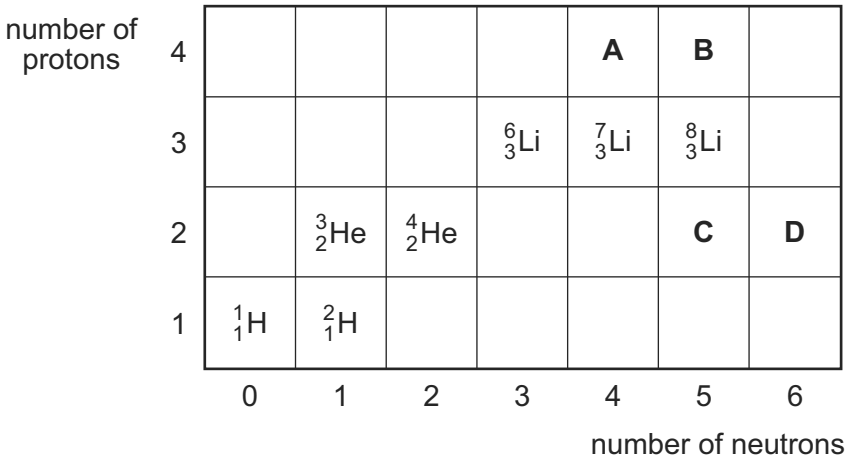
What is the nuclide X?

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

37 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

A nucleus of the nuclide $^{8}_{3}\text{Li}$ decays by emitting a β-particle.

What is the resulting nuclide?



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

$$^{217}_{85}\text{At} \xrightarrow{\alpha} \text{V} \xrightarrow{\alpha} \text{W} \xrightarrow{\beta} \text{X}$$

What is the nuclide X?

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

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

	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

40 What is **not** conserved in nuclear processes? 9702/12/M/J/10

A charge

B momentum

C the total number of neutrons

D the total number of nucleons

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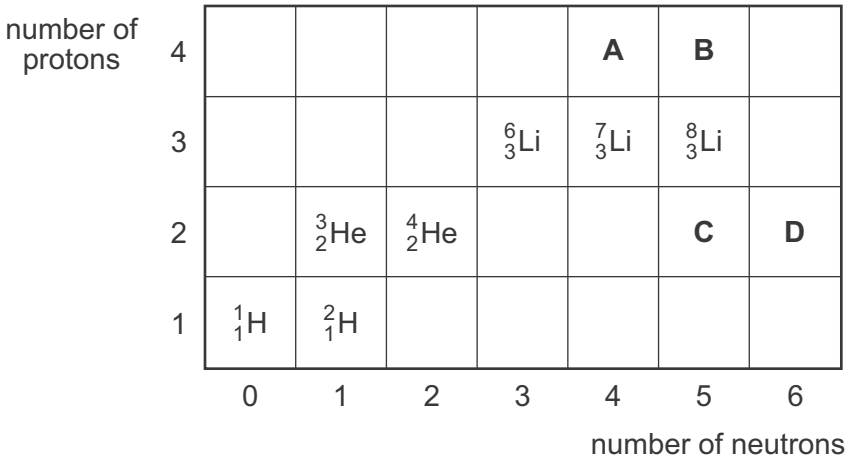

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C	electromagnetic radiation	high-speed electron
D	high-speed electron	helium-4 nucleus

39 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.

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

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

40 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. 9702/13/M/J/11

What is the grand-daughter product?

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

38 Uranium-235 may be represented by the symbol $^{235}_{92}U$. 9702/11/O/N/10

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

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

40 Which nuclear equation shows the beta decay of a nucleus of argon (Ar) into potassium (K)? 9702/11/O/N/10

A $^{44}_{21}Ar \rightarrow {}^{40}_{19}K + {}^{4}_{2}He$

B $^{40}_{20}Ar \rightarrow {}^{40}_{19}K + {}^{0}_{1}e$

C $^{40}_{18}Ar \rightarrow {}^{40}_{19}K + {}^{0}_{1}e$

D $^{40}_{19}Ar \rightarrow {}^{40}_{19}K + {}^{0}_{0}\gamma$

40 A counter recording radioactive decays from a radioactive source gives the following counts in equal intervals of time. 9702/12/O/N/10

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

38 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

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.

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

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.

40 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

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

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

What was the by-product of this reaction?

A an α-particle

B a β-particle

C a γ-ray

D a neutron

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

39 The uranium nucleus $^{238}_{92}\text{U}$ undergoes α-decay, producing nucleus X. 9702/12/M/J/11

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

40 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

$$^{220}_{86}\text{Rn} \rightarrow {}^{216}_{84}\text{Po} + {}^{4}_{2}\text{He}$$

How many neutrons are in the radon and polonium nuclei?

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

39 Uranium-238, $^{238}_{92}U$, 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

What is the grand-daughter product?

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

40 Which statement about nuclei is correct? 9702/11/M/J/11

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.

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What was the by-product of this reaction?

A an α-particle

B a β-particle

C a γ-ray

D a neutron

39 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

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

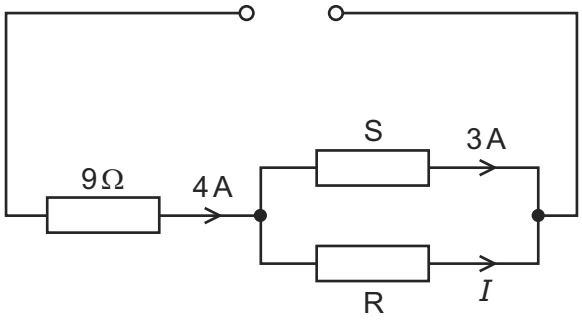
A Atomic nuclei occupy a very small fraction of the volume of an atom.

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.

38 The circuit below has a current I in the resistor R. 9702/11/M/J/12



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

39 Which statement concerning α-particles is correct? 9702/12/O/N/11

A An α-particle has charge +4*e*.

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.

40 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

Which nucleus is formed?

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

40 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

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

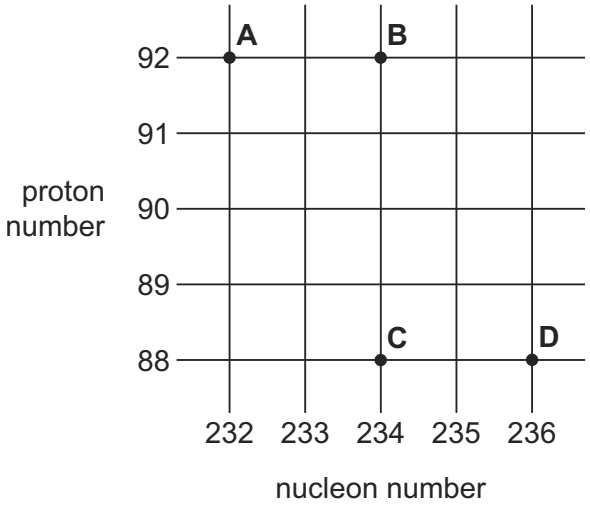
39 Nuclear decay is both spontaneous and random in nature. 9702/12/M/J/12

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

40 Thorium-234 ($^{234}_{90}$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

Which letter in the diagram represents the granddaughter product?



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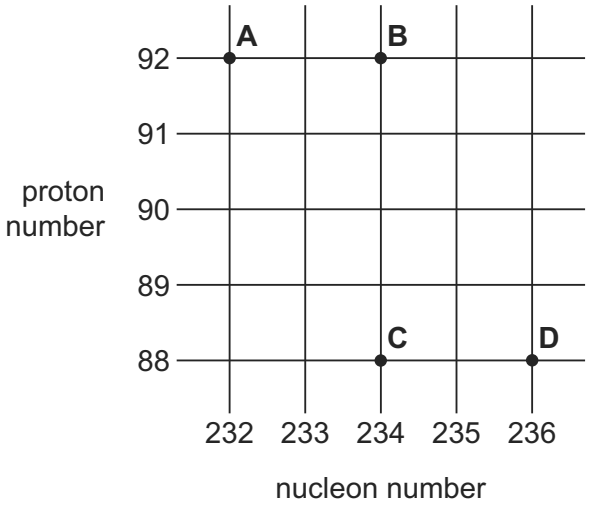


39 A material contains a radioactive isotope that disintegrates solely by the emission of α-particles at a rate of 100 s $^{-1}$. 9702/12/O/N/12

Which statement about this material is correct?

A The number of atoms in the material diminishes at a rate of 100 s $^{-1}$.

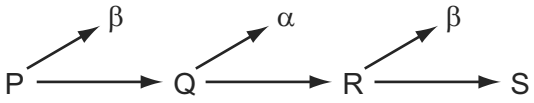
B The number of neutrons in the material diminishes at a rate of 100 s $^{-1}$.

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 $^{-1}$.

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. 9702/11/O/N/12



Nuclides P and S are compared.

Which statement is correct?

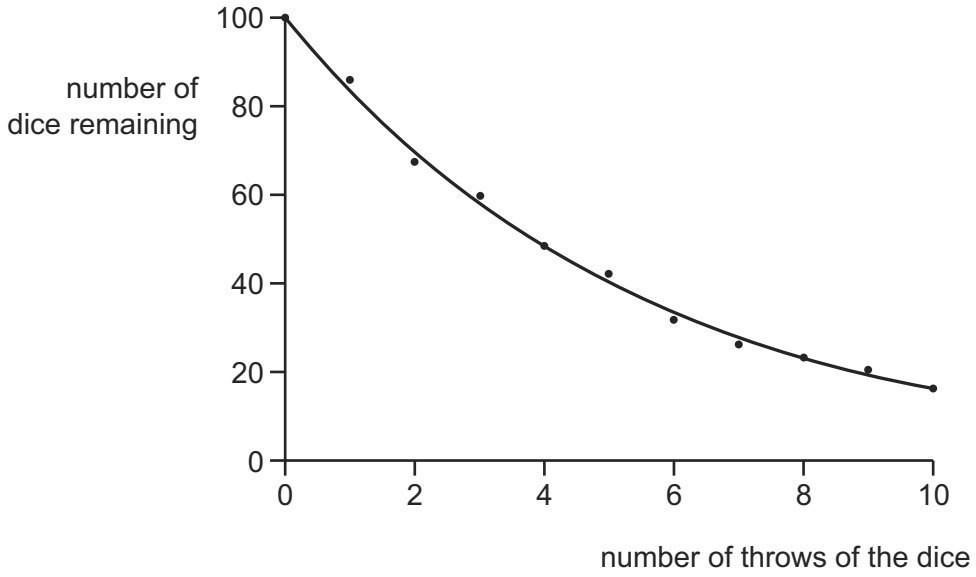
A P and S are identical in all respects.

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.

38 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



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

39 Which statement about alpha, beta and gamma radiation is correct? 9702/11/O/N/12

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.

40 A different nucleus can be formed by bombarding a stable nucleus with an energetic α-particle. 9702/12/O/N/12

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

What could be the products of this nuclear reaction?

A $^{25}_{10}$Ne + neutron

B $^{25}_{11}$Na + proton

C $^{26}_{12}$Mg + β

D $^{27}_{13}$Al + γ

38 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

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.

39 What remains constant during β-emission from a number of identical nuclei in a substance?

9702/13/O/N/12

A energy of the β-particles

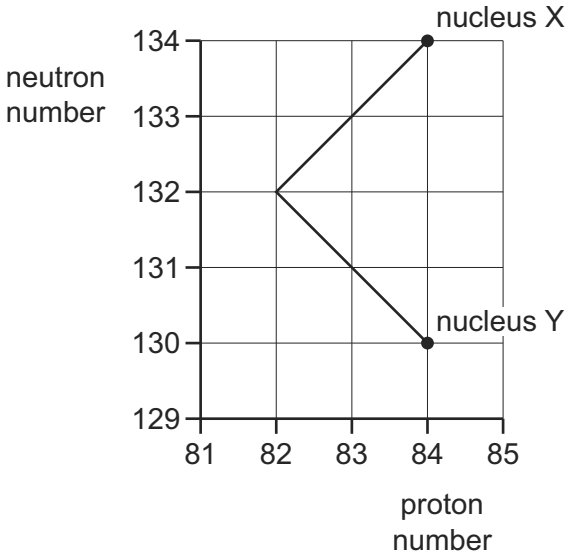
B neutron number of the nuclei

C nucleon number of the nuclei

D proton number of the nuclei

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

9702/13/O/N/12



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

9702/12/O/N/12

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

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

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

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

39 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

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

40 Which pair of nuclei are isotopes of one another? 9702/11/M/J/13

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

40 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

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

39 What is the approximate mass of an alpha particle? 9702/12/M/J/13

A 10^{-28} kg

B 10^{-26} kg

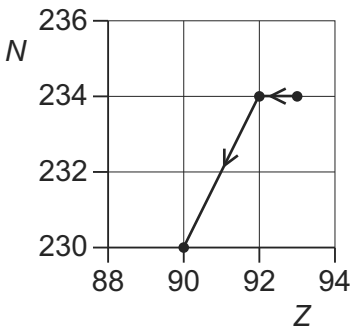
C 10^{-24} kg

D 10^{-22} kg

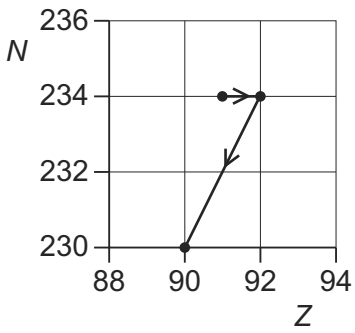
40 A radioactive nucleus is formed by β-decay. This nucleus then decays by α-emission. 9702/13/M/J/13

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

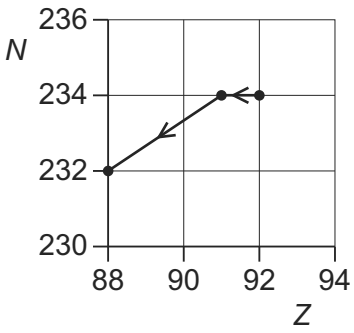
A



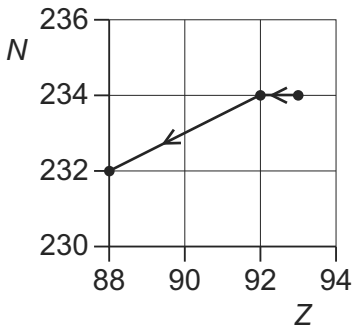
B



C



D



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

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

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

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.

39 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

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

40 Plutonium-239 ($^{239}_{94}\text{Pu}$) decays by emitting α-radiation. 9702/11/O/N/13

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** $^{239}_{95}\text{X}$

39 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

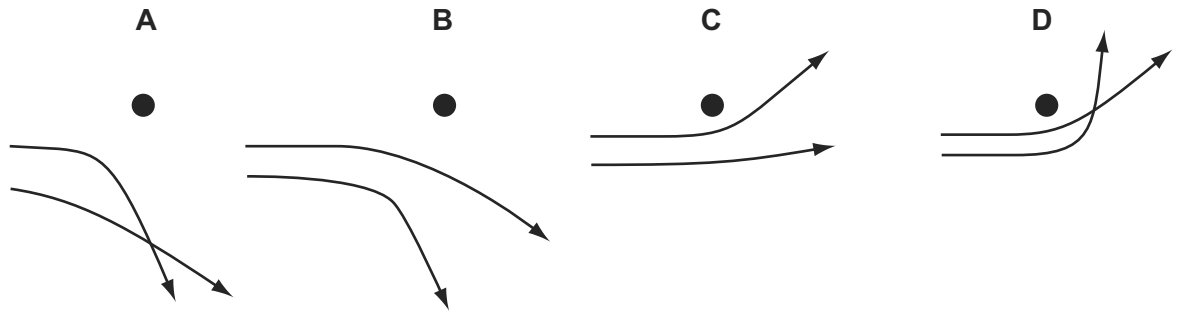
$$^{228}_{89}\text{Ac} \rightarrow {}^{X}_{Y}\text{Th} + \beta$$

Which pair of values of X and Y is correct?

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

40 Two α-particles with equal energies are deflected by a large nucleus. 9702/13/O/N/13

Which diagram best represents their paths?



38 A nucleus X decays into a nucleus Y by emitting an alpha particle followed by two beta particles. 9702/12/M/J/14

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.

39 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

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

where x represents one or more particles.

What does x represent?

A one neutron

B two electrons

C two neutrons

D two protons

40 The first artificial radioactive substance was made by bombarding aluminium, $^{27}_{13}\text{A}l$, with α-particles. This produced an unstable isotope of phosphorus, $^{30}_{15}\text{P}$. 9702/12/M/J/14

What was the by-product of this reaction?

A an α-particle

B a β-particle

C a neutron

D a proton

39 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

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

40 Four nuclei are represented below.

9702/12/M/J/14

$^{28}_{14}E$ $^{25}_{15}G$ $^{25}_{12}M$ $^{24}_{13}Q$

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.

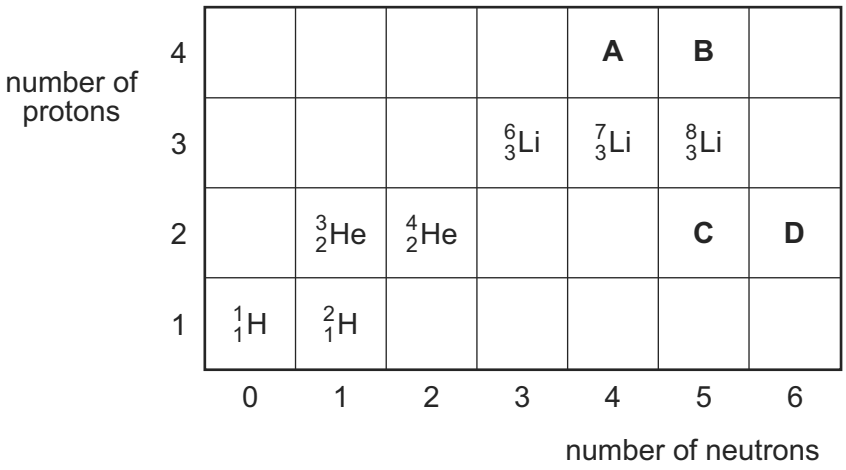
D When E absorbs a neutron and then emits an alpha particle, nucleus E transforms into M.

40 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

A nucleus of the nuclide $^{8}_{3}Li$ decays by emitting a β-particle.

What is the resulting nuclide?



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

What could be the resulting product?

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

39 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

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

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

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

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

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

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 $+1.60 \times 10^{-19}$ C.

D The speeds of α-particles can be as high as 1.5×10^{7} m s^{-1}.

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

What is the number of stages in the decay sequence?

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

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

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

38 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

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.

39 A nuclear reaction is shown. 9702/13/O/N/14

$$^{238}_{92}U + ^{4}_{2}He \rightarrow ^{241}_{94}Pu + X$$

What is product X?

A an alpha particle

B an electron

C a neutron

D a proton

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

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

40 Alpha, beta and gamma radiations

9702/13/O/N/14

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.

diagram 1

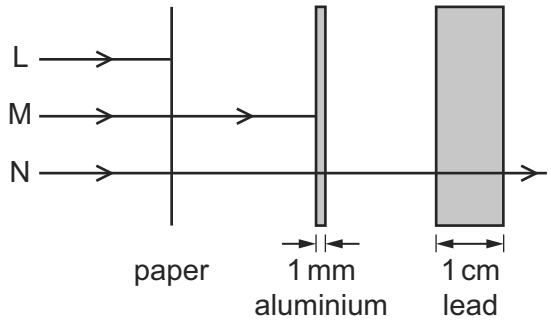


diagram 2

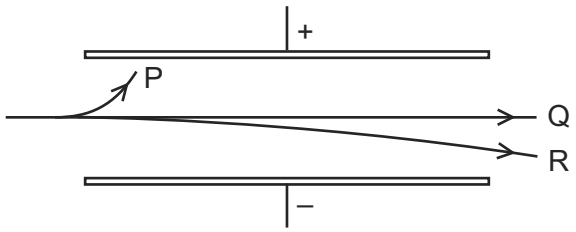
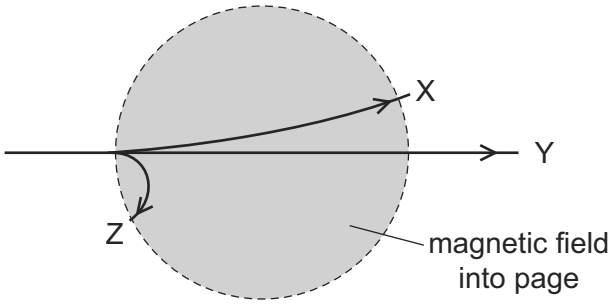


diagram 3



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

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

9702/13/M/J/15

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

What are the values of X and Y?

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

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

Which property of these nuclei remains unaltered by the emission?

A charge

B neutron number

C nucleon number

D proton number

40 A uranium-238 nucleus, $^{238}_{92}U$, undergoes nuclear decays to form uranium-234, $^{234}_{92}U$.
9702/12/M/J/15

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

39 When α-particles are directed at gold leaf 9702/11/M/J/15

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