Questions compiled by Leong Yee Pak

NUCLEAR PHYSICS

27.1 the nucleus
27.2 isotopes

****June 02 P1 Q39**

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

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

****Nov 02 P1 Q38**

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

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

***Nov 02 P1 Q39**

39 In an experiment to investigate the nature of the atom, a very thin gold film was bombarded with α-particles.

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.

Nov 02 P2 Q8

8 A nucleus of an atom of francium (Fr) contains 87 protons and 133 neutrons.

(a) Write down the notation for this nuclide.

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

(b) The nucleus decays by the emission of an α-particle to become a nucleus of astatine (At).

Write down a nuclear equation to represent this decay. [2]

***June 03 P1 Q38**

38 In what way do the atoms of the isotopes $^{12}_{6}C$, $^{13}_{6}C$ and $^{14}_{6}C$ differ?

A different charge

B different numbers of electrons

C different numbers of neutrons

D different numbers of protons

*****June 03 P1 Q40**

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

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

***Nov 03 P1 Q39**

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

Which 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

Nov 03 P2 Q6

6 One isotope of iron may be represented by the symbol

$$^{56}_{26}\text{Fe}.$$

(a) State, for one nucleus of this isotope,

(i) the number of protons,

number = ...

(ii) the number of neutrons.

number = ...

[2]

(b) The nucleus of this isotope of iron may be assumed to be a sphere of radius 5.7×10^{-15} m.

Calculate, for one such nucleus,

(i) the mass,

mass = ... kg

(ii) the density.

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

(c) An iron ball is found to have a density of 7900 kg m^{-3}. By reference to your answer in **(b)(ii)**, suggest what can be inferred about the structure of an atom of iron.

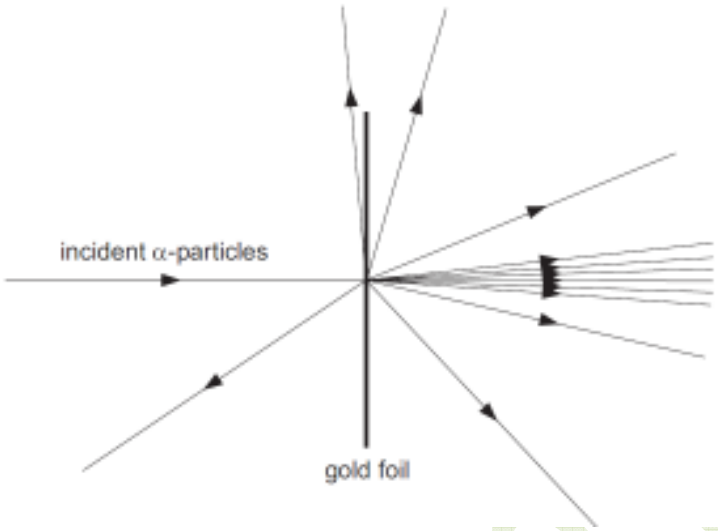
.....

.....

..... [2]

***June 04 P1Q39**

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



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.

***June 04 P1 Q40**

40 Isotopes of a given element all have the same

A charge / mass ratio

B neutron number

C nucleon number

D proton number

***Nov 04 P1 Q40**

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

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.

Nov 04 P2 Q7

7 The α-particle scattering experiment provided evidence for the existence of a nuclear atom.

(a) State what could be deduced from the fact that

(i) most α-particles were deviated through angles of less than 10°,

.....

.....

..... [2]

(ii) a very small proportion of the α-particles was deviated through angles greater than 90°.

.....

.....

..... [2]

(b) Fig. 7.1 shows the path AB of an α-particle as it approaches and passes by a stationary gold nucleus.

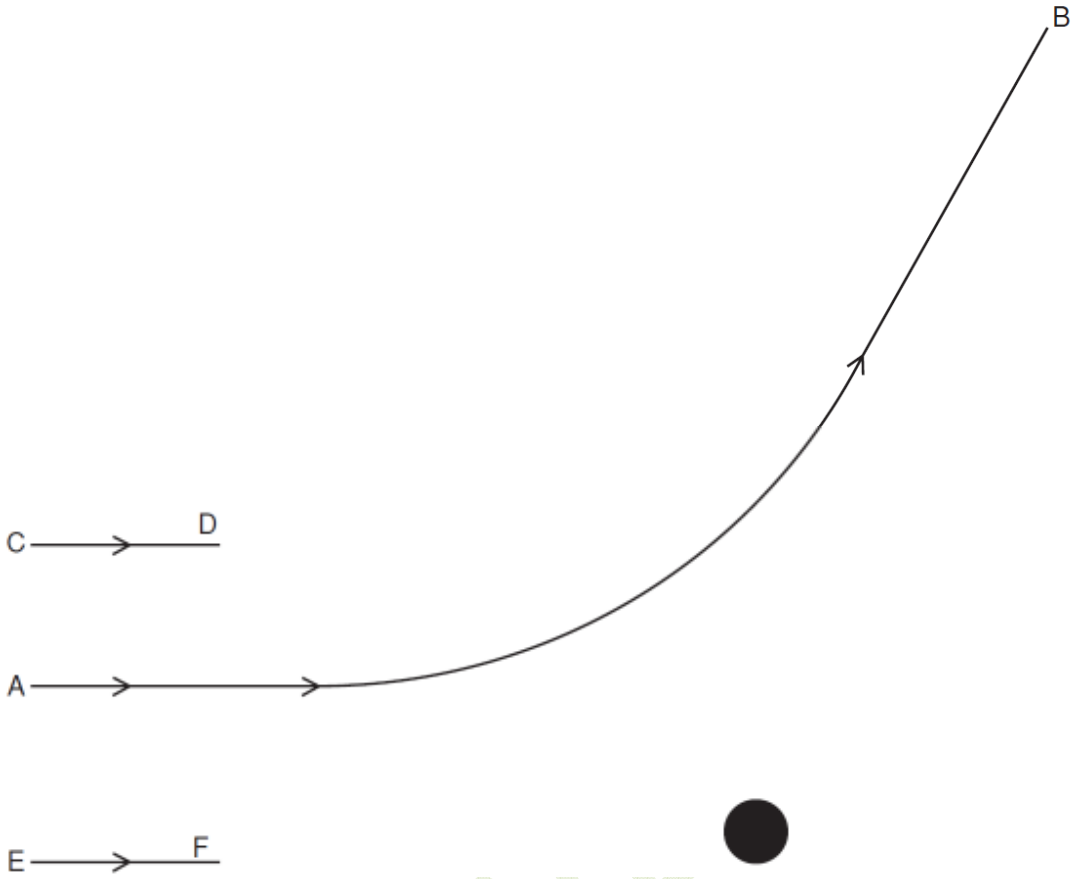


Fig. 7.1

On Fig. 7.1, draw lines (one in each case) to complete the paths of the α-particles passing by the gold nucleus when the initial direction of approach is

(i) along line CD,

(ii) along line EF.

[3]

****June 05 P1 Q38**

38 Which two nuclei contain the same number of neutrons?

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

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

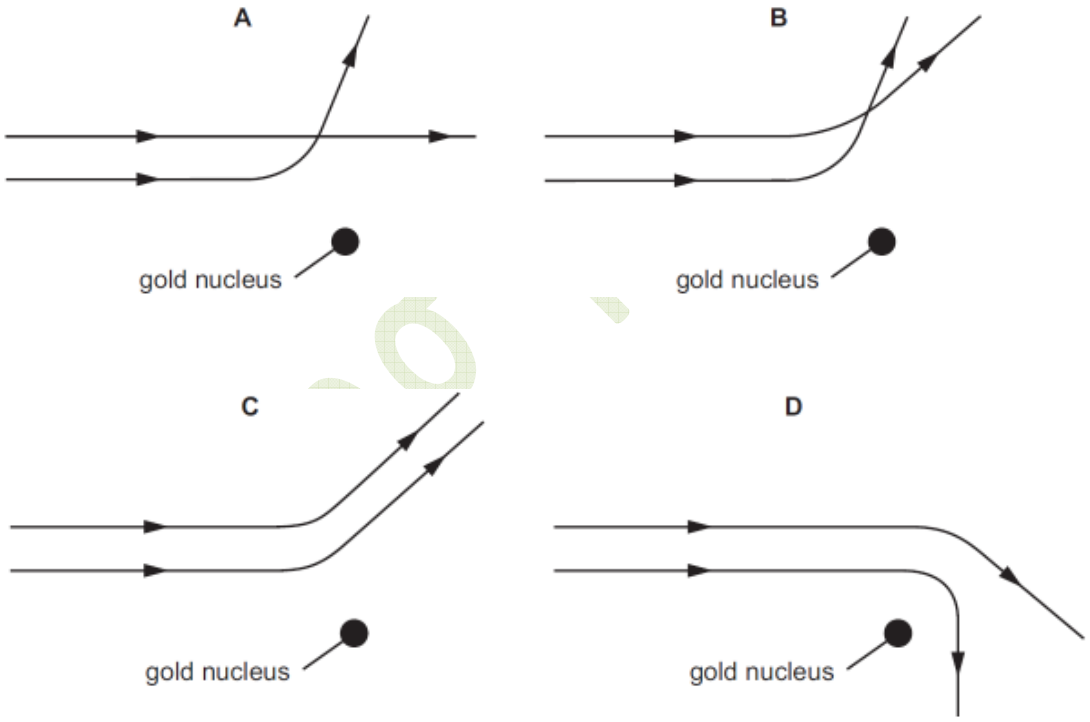
C $^{23}_{11}Na$ and $^{24}_{12}Mg$

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

***Nov 05 P1 Q39**

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

Which diagram best represents their paths?



***June 06 P1 Q38**

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

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

***Nov 06 P1 Q39**

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

	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

***Nov 07 P1 Q36**

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

A Their nuclei have different charge and different mass, and they emit different particles when they decay.

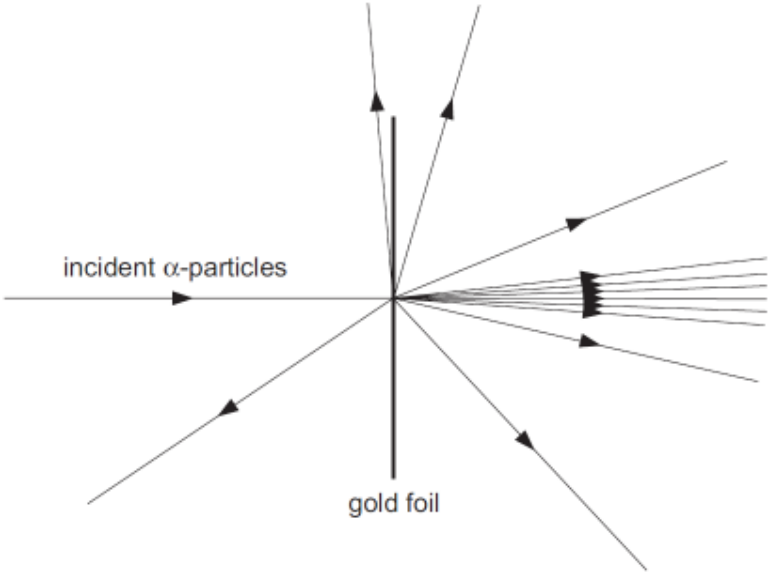
B Their nuclei have different charge but the same mass.

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.

***Nov 07 P1 Q38**

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



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

Nov 07 P2 Q7

7 **(a)** Evidence for the nuclear atom was provided by the α-particle scattering experiment. State the results of this experiment.

.....

.....

.....

..... [2]

(b) Give estimates for the diameter of

(i) an atom,

.....[1]

(ii) a nucleus.

.....[1]

****June 08 P1 Q39**

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

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

***Nov 08 P1 Q38**

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

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.

***Nov 08 P1 Q39**

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

Which of the following is an isotope of Q?

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

****June 09 P1 Q36**

36 How do the nucleon (mass) number and proton (atomic) number of two isotopes of an element compare?

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

****June 09 P1 Q38**

38 Which two nuclei contain the same number of neutrons?

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

27.3 Nuclear processes

***June 02 P1 Q38**

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

	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

****June 02 P1 Q40**

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

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

June 02 P2 Q9

9 The radiation from a radioactive source is detected using the apparatus illustrated in Fig. 9.1.

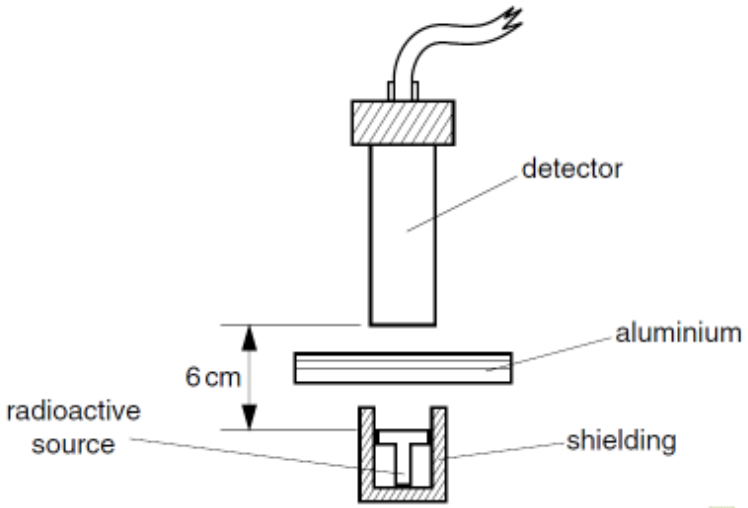


Fig. 9.1

Different thicknesses of aluminium are placed between the source and the detector. The count rate is obtained for each thickness. Fig. 9.2 shows the variation with thickness x of aluminium of the count rate.

Fig. 9.2

(a) Suggest why it is not possible to detect the presence of the emission of α-particles from the source.

.....

.....[1]

(b) State the evidence provided on Fig. 9.2 for the emission from the source of

(i) β-particles,

.....

.....

.....

(ii) γ-radiation.

.....

.....

.....

[4]

****Nov 02 P1 Q40**

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

What is the resulting nucleus?

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

****June 03 P1 Q39**

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

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

June 03 P2 Q6

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

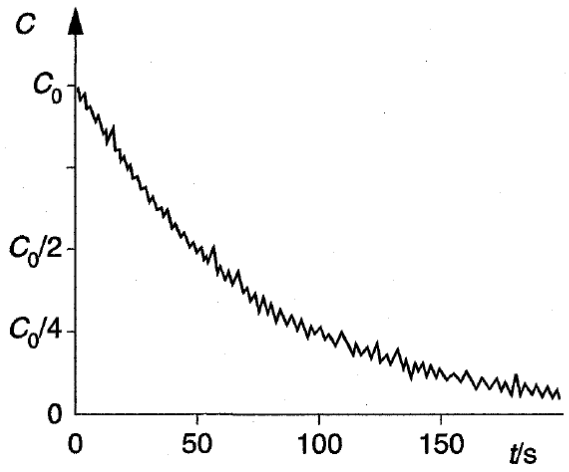


Fig. 6.1(a)

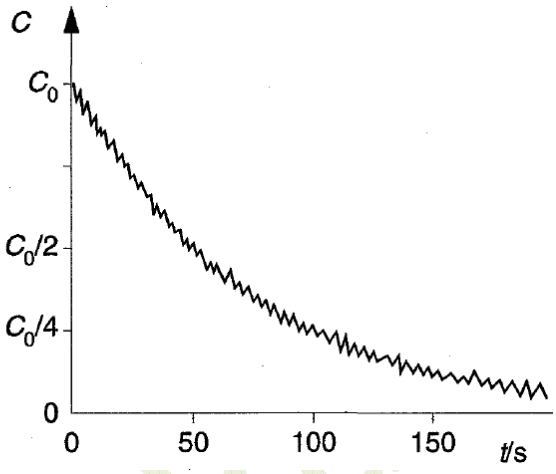


Fig. 6.1(b)

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

State the evidence that is provided by these two experiments for

(i) the random nature of radioactive decay,

.....

.....

(ii) the spontaneous nature of radioactive decay.

.....

.....

[2]

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

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

number = ... [1]

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

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

[3]

***Nov 03 P1 Q38**

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

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

****Nov 03 P1 Q40**

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.

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

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

****June 04 P1 Q38**

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

Which of the nuclides shown is formed?

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

**Nov 04 P1 Q38

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.

What is the symbol of this arsenic nuclide?

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

**Nov 04 P1 Q39

39 The table shows three properties of different types of ionising radiation.

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

**June 05 P1 Q39

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

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

**June 05 P1 Q40

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

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

What is the nuclide X?

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

June 05 P2 Q8

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

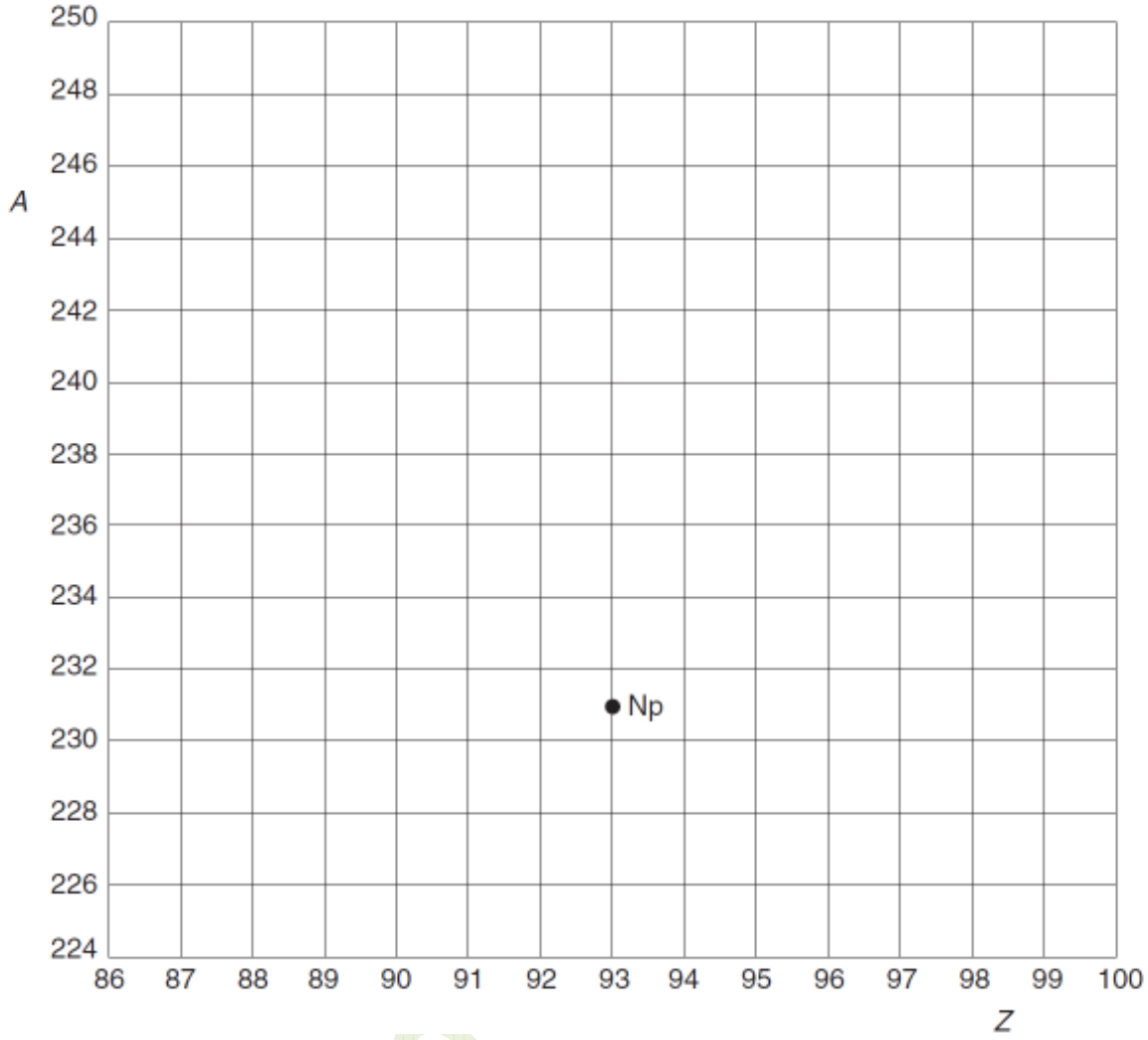


Fig. 8.1

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

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

***Nov 05 P1 Q38**

38 An atomic nucleus emits a β-particle.

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

****Nov 05 P1 Q 40**

40 A nuclear reaction is represented by the equation

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

What is particle X?

A an α-particle

B a β-particle

C a neutron

D a proton

***June 06 P1 Q39**

39 The decay of a nucleus of neptunium is accompanied by the emission of a β-particle and γ-radiation.

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

****June 06 P1 Q40**

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.

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

How many neutrons are in the radon and polonium nuclei?

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

June 06 P2 Q8

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

Explain what is meant by

(a) *radioactive decay* of a nucleus,

.....

.....

..... [2]

(b) *spontaneous* decay,

.....

.....

..... [2]

(c) *random* decay.

.....

.....

..... [2]

***Nov 06 P1 Q38**

38 Which statement concerning α-particles is correct?

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.

****Nov 06 P1 Q40**

40 Radon $^{222}_{86}Rn$ decays by α– and β–emission to bismuth $^{214}_{83}Bi$.

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

***June 07 P1 Q38**

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

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.

***June 07 P1 Q39**

39 The symbol $^{77}_{32}Ge$ represents a nucleus of germanium that decays to a nucleus of arsenic by emitting a β-particle.

What is the symbol of this arsenic nucleus?

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

*****June 07 P1 Q40**

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

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

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

June 07 P2 Q7

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

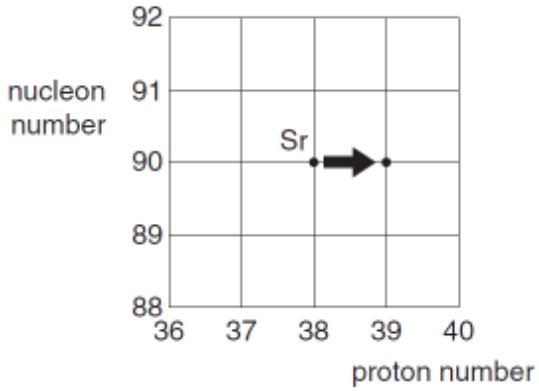


Fig. 7.1

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

.....[1]

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

.....

.....

.....[2]

***Nov 07 P1 Q37**

37 What is **not** conserved in nuclear processes?

A energy and mass together

B nucleon number

C neutron number

D charge

****Nov 07 P1 Q39**

39 A zirconium nucleus, $^{100}_{40}Zr$, is a β-emitter. The product nucleus is also a β-emitter.

What is the final resulting nucleus of these two decays?

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

*****Nov 07 P1 Q40**

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

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

A α-particle

B electron

C neutron

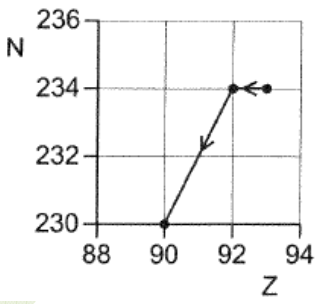
D proton

****June 08 P1 Q40**

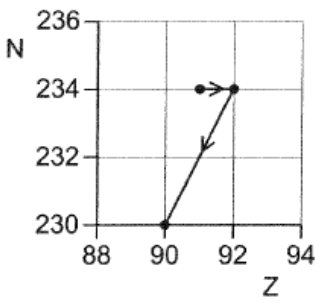
40 A radioactive nucleus is formed by β-decay. This nucleus then decays by α-emission.

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

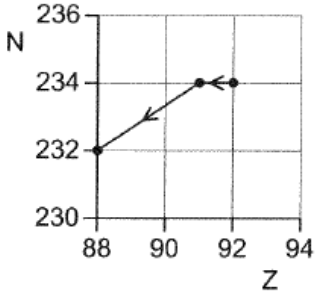
A



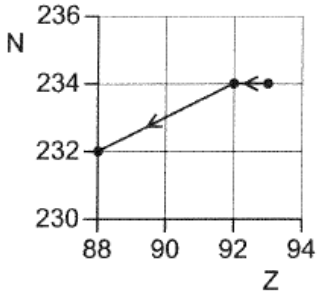
B



C



D



June 08 P2 Q7

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

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

.....

.....

.....

.....

.....

.....[4]

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

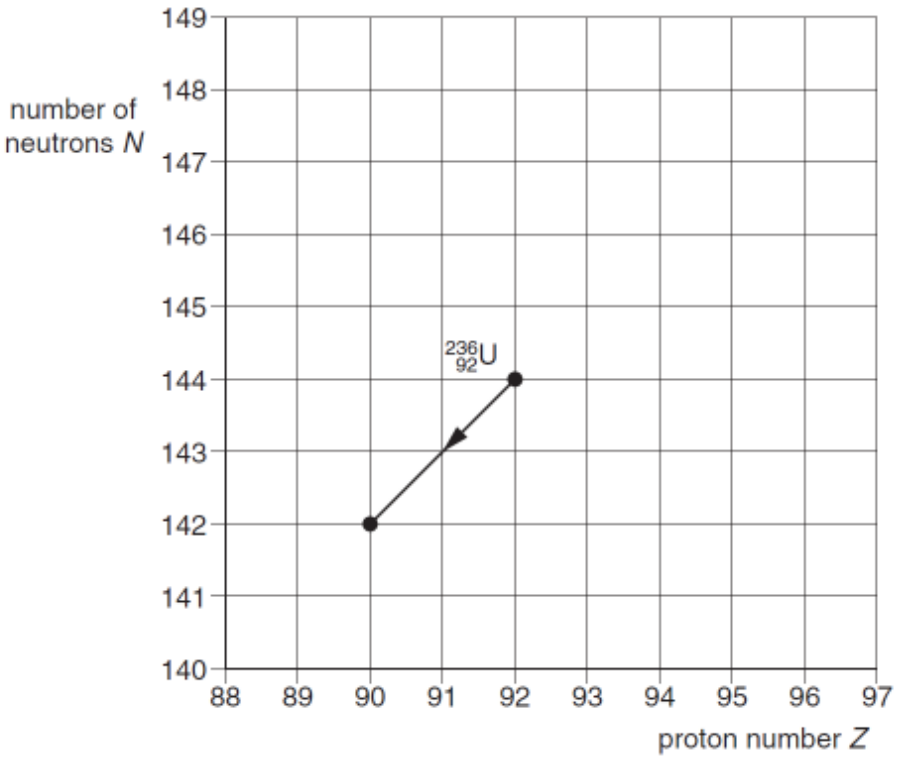


Fig. 7.1

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

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

.....[2]

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

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

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

****Nov 08 P1 Q40**

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

What was emitted in these two stages?

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

Nov 08 P2 Q8

8 Thoron is a radioactive gas. The variation with time *t* of the detected count rate *C* from a sample of the gas is shown in Fig. 8.1.

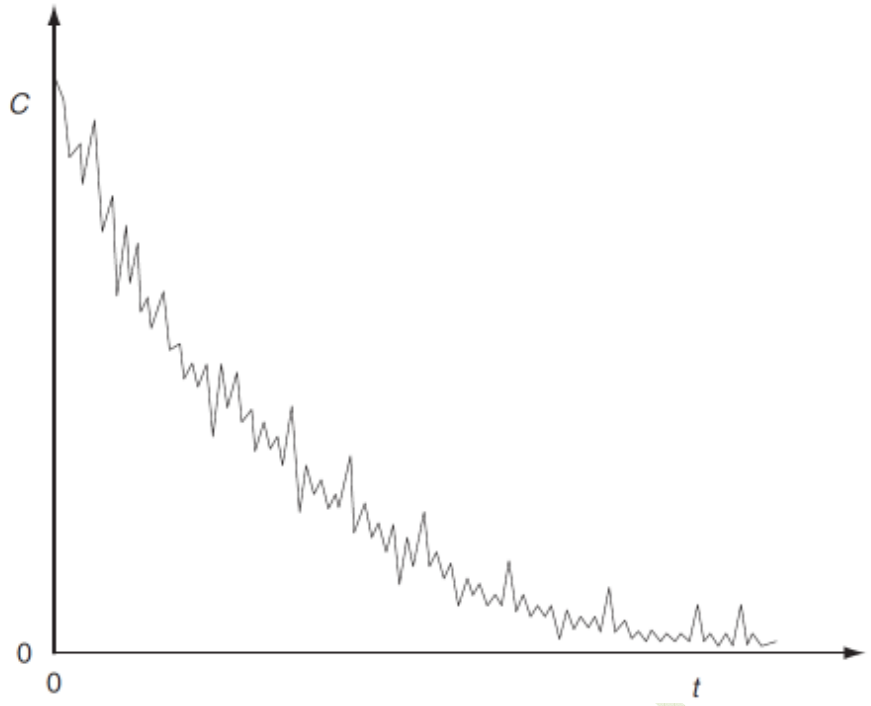


Fig. 8.1

Radioactive decay is said to be a random and spontaneous process.

(a) Explain, by reference to radioactive decay, what is meant by a *random* process.

.....

.....

..... [2]

(b) State the feature of Fig. 8.1 which indicates that the process is

(i) a decay process,

..... [1]

(ii) random.

..... [1]

(c) A second similar sample of thoron is prepared but it is at a much higher temperature. The variation with time of the count rate for this second sample is determined.
State the feature of the decay curves for the two samples that suggests that radioactive decay is a spontaneous process.

.....

..... [1]

****June 09 P1 Q37**

37 Nuclear decay is both spontaneous and random.

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

***June 09 P1 Q39**

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

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

**** June 09 P1 Q40**

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

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

June 09 P2 Q8

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

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

.....

.....

..... [2]

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

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

..... [1]

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

..... [1]

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

..... [1]

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

..... [1]