11. Particle Physics

11.1 Atoms, nuclei and radiation

Paper 1

Question Paper

1 Hydrogen and deuterium can be represented by the nuclide symbols ${}^{1}_{1}\mathrm{H}$ and ${}^{2}_{1}\mathrm{H}$ respectively.

What is a difference between hydrogen and deuterium?

A The deuterium atom has twice the number of electrons as the hydrogen atom.

B The deuterium nucleus has a charge, but the hydrogen nucleus has no charge.

C The deuterium nucleus has less mass than the hydrogen nucleus.

D The deuterium nucleus has half the charge per unit mass of the hydrogen nucleus.

2 A radioactive sample decays by emitting β^- particles.

The energy released in the decay process is the same for each nucleus that decays, but the β^- particles emitted have a continuous range of kinetic energies.

Which statement explains why the β^- particles are emitted with a continuous range of kinetic energies?

A Some of the energy released is given to the remaining nucleons in the nucleus.

B Some of the energy released is taken by an emitted antineutrino.

C Some of the energy released is used to create the β^- particle.

D Some of the energy released is used to create a new nucleon.

3 Nuclide X with proton number Z undergoes β^+ decay to form nuclide Y.

The decay may be represented by the equation shown.

$$\mathrm{X} \rightarrow \mathrm{Y} + \beta^+ + \mathrm{W}$$

What is the proton number of Y and which particle is represented by the symbol W?

	proton number of Y	particle represented by W
A	Z – 1	antineutrino
B	Z – 1	neutrino
C	Z + 1	antineutrino
D	Z + 1	neutrino

4 The unstable nuclide $^{218}_{84}X$ decays through a sequence of emissions of α and β^- particles to form the stable nuclide $^{210}_{83}Y$.

How many α and β^- particles are emitted during this decay process?

	α-particles	β^- particles
A	1	1
B	2	1
C	2	3
D	3	2

5 Which statement about radioactive decay is correct?

A Neutrinos are always emitted during α-decay.

B The α-particles emitted from a radioactive sample have a continuous range of kinetic energies.

C The β^- particles emitted from a radioactive sample have a continuous range of kinetic energies.

D The proton number of a nucleus decreases by four when it undergoes α-decay.

6 The isotope fluorine-18, $^{18}_{9}F$, undergoes β^+ decay to form a stable isotope.

How many neutrons are there in a nucleus of the stable isotope?

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

7 An isotope of boron decays to beryllium by β^+ emission.

Which particle is emitted in addition to the β^+ particle?

A antineutrino

B electron

C neutrino

D neutron

8 A proton has mass m_p and charge $+e$.

What are the mass and charge of an antiproton?

	mass	charge
A	$-m_p$	$+e$
B	$-m_p$	$-e$
C	m_p	$+e$
D	m_p	$-e$

9 A uranium nucleus has 92 protons and 143 neutrons.

The nucleus emits a total of 3 α-particles and 4 β^- particles to form nucleus X.

How can nucleus X be represented?

A $^{131}_{90}X$ **B** $^{219}_{87}X$ **C** $^{223}_{82}X$ **D** $^{223}_{90}X$

10 What are isotopes?

A nuclei of different elements with the same number of neutrons

B nuclei of different elements with the same number of nucleons

C nuclei of the same element with different numbers of neutrons

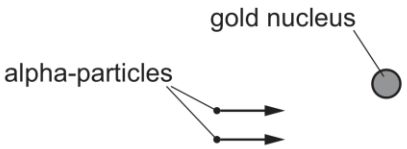
D nuclei of the same element with different numbers of protons

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

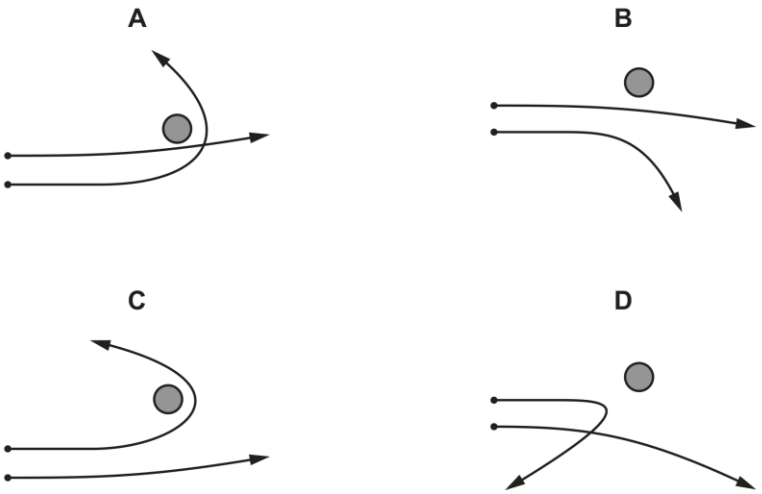
What is the number of free neutrons emitted when the $^{235}_{92}U$ nucleus splits?

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

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



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



13 Which nuclide is formed when $^{10}_{6}C$ undergoes β^+ decay?

A $^{11}_{6}C$ **B** $^{9}_{6}C$ **C** $^{10}_{5}B$ **D** $^{10}_{7}N$

14 Two nuclides are different isotopes of the same element.

Which statement about the nuclides is correct?

A Neutral atoms of the nuclides have the same number of electrons.

B Nuclei of the nuclides have different numbers of protons.

C Nuclei of the nuclides have the same number of nucleons.

D Nuclei of the nuclides have the same number of neutrons.

15 The charge-to-mass ratio *r* of a particle is given by the equation shown.

$$r = \frac{\text{charge on particle}}{\text{mass of particle}}$$

The value of *r* is determined for an α-particle, a β^+ particle and a proton p.

Which list shows the particles in order of increasing magnitude of *r* from left to right?

A $\alpha \rightarrow \beta^+ \rightarrow p$

B $\alpha \rightarrow p \rightarrow \beta^+$

C $p \rightarrow \alpha \rightarrow \beta^+$

D $p \rightarrow \beta^+ \rightarrow \alpha$

16 Carbon-14 decays into nitrogen-14 by emitting a β^- particle.

Which statement explains why the β^- particles are emitted with a range of different kinetic energies?

A The carbon-14 nuclei have slightly different masses.

B The emitted β^- particles have a range of different masses.

C The energy released in the decay process is different for each carbon-14 nucleus that decays.

D The energy released in the decay process is shared between the nitrogen-14 nucleus, a β^- particle and an antineutrino.

17 A nucleus of a radioactive element emits an α-particle, then a β^- particle and then another β^- particle.

Which statement describes the final element that is produced?

A It is a different element of higher proton number than the original element.

B It is a different element of lower nucleon number than the original element.

C It is an isotope of the original element.

D It is the same element as the original element but with a different proton number.

18 In an experiment on α-particle scattering, α-particles are directed at a thin gold foil. Most of the α-particles pass straight through the foil or are deflected by a small angle. A small number of α-particles are deflected by a large angle.

Which statement **cannot** be deduced from this experiment?

A Atoms are mostly empty space.

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

C The nucleus of an atom contains protons.

D The nucleus of an atom is small compared to the size of an atom.

19 Four nuclei are represented below.

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

Which statement about these nuclei is correct?

A An uncharged atom of element Q has 24 orbital electrons.

B Nuclei G and M are isotopes of the same element.

C When E absorbs a neutron and then emits an α-particle, E transforms into M.

D When M emits a β^- particle, M transforms into Q.

20 An α-particle passes close to a gold nucleus and is deflected through an angle greater than 90°.

Which property of the α-particle changes as a result of the deflection?

A charge

B momentum

C nucleon number

D proton number

21 A nucleus of $^{238}_{92}U$ decays in stages by emitting α-particles and β^- particles, eventually forming a nucleus of $^{206}_{82}Pb$.

How many α-particles and how many β^- particles are emitted during the decay chain?

	α-particles	β^- particles
A	8	6
B	8	10
C	16	6
D	16	22

22 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 by 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.

23 Which two particles have opposite charges?

A alpha-particle and helium nucleus

B antiproton and beta-plus particle

C beta-minus particle and electron

D positron and proton

24 A nucleus of uranium, $^{235}_{92}U$, undergoes a series of decays. During the series of decays, two α-particles and one β^- particle are emitted.

As a result, a nucleus of actinium, Ac, is formed.

What is the correct notation for the nuclide of actinium that is formed?

A $^{227}_{87}Ac$ **B** $^{227}_{89}Ac$ **C** $^{231}_{87}Ac$ **D** $^{231}_{89}Ac$

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

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

What are the values of P and Q?

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

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

Which series of decays could give this result?

A emission of four β^- particles

B emission of four γ-rays

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

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

27 An unstable nucleus decays by emitting a β^+ particle.

Which statement is correct?

A An antineutrino is also emitted.

B A neutron changes into a proton.

C Mass–energy is conserved.

D The nucleon number is not conserved.

28 An element has two isotopic forms.

What are the nuclear arrangements of these two isotopes?

A They have different nucleon numbers and different proton numbers.

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

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

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

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

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

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

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

30 Which statement about two nuclei that are isotopes of the same element is correct?

A The nuclei each have the same acceleration when in the same uniform electric field.

B The nuclei each have the same number of neutrons.

C The nuclei each have the same number of nucleons.

D Uncharged atoms containing the nuclei each have the same number of electrons.

31 In a nuclear physics experiment, a nucleus of $^{32}_{16}S$ collides with a nucleus of $^{94}_{42}Mo$. The nuclei combine together and immediately emit a single alpha-particle.

The nuclear reaction is shown.

$$^{32}_{16}S + ^{94}_{42}Mo \rightarrow X + \alpha$$

What is nucleus X?

A $^{122}_{56}X$ **B** $^{124}_{54}X$ **C** $^{126}_{58}X$ **D** $^{126}_{59}X$

32 What is a conclusion from the alpha-particle scattering experiment?

A Protons and electrons have equal but opposite charges.

B Protons have a much larger mass than electrons.

C The nucleus contains most of the mass of the atom.

D The nucleus of an atom contains protons and neutrons.

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

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

B Slower alpha-particles are deflected through larger angles.

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

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

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

Which particles could be emitted?

A 2 α-particles and 4 β^- particles

B 2 α-particles and 4 β^+ particles

C 3 α-particles and 2 β^- particles

D 3 α-particles and 2 β^+ particles

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

What is the minimum possible number of these particles emitted?

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

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

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

Two of the atoms are isotopes of the same element.

What is the proton number of this element?

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

37 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

38 Radon-211, $^{211}_{86}Rn$, francium-210, $^{210}_{87}Fr$, and radium-212, $^{212}_{88}Ra$, 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

39 A nucleus emits a β^- particle.

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

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

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

What are the other products?

A an electron and a neutrino

B an electron and an antineutrino

C a positron and a neutrino

D a positron and an antineutrino