11 **(a)** Fig. 11.1 shows data about nine elements.

proton number	element	symbol
2	helium	He
3	lithium	Li
4	beryllium	Be
5	boron	B
6	carbon	C
7	nitrogen	N
8	oxygen	O
9	fluorine	F
10	neon	Ne

Fig. 11.1

Carbon-14 is a radioactive isotope with a nucleon number of 14. It decays by emitting β-particles.

Use any data you need from Fig. 11.1 to write down the nuclide equation for this decay.

[4]

(b) A radioactive sample is placed close to a detector. The radioactive isotope in the sample has a long half-life. The detector records a count rate of 597 counts/s.

Fig. 11.2 shows the readings when different materials are placed between the radioactive sample and the detector.

material	$\frac{\text{count rate}}{\text{counts/s}}$
a sheet of paper	602
a piece of thin aluminium	598
a piece of thin lead	510

Fig. 11.2

Explain whether any α-particles, β-particles or γ-rays are emitted by the radioactive sample.

α-particles .....

.....

β-particles .....

.....

γ-rays .....

.....

[3]

[Total: 7]

12 **(a)** A detector of ionising radiation measures the background count rate in a classroom where there are no radioactive samples present.

The readings, in counts/minute, taken over a period of time are shown in Table 10.1.

Table 10.1

counts/minute	16	12	14	16	15	17

(i) State **two** possible sources of this background radiation.

.....

.....[2]

(ii) Explain why the readings are not the same.

.....

.....[1]

(b) With no radioactive sample present, a scientist records a background radiation count of 40 counts/minute.
He brings a radioactive sample close to the detector. The count rate increases to 200 counts/minute.
After 24 days the count rate is 50 counts/minute.

Calculate the half-life of the radioactive sample.

half-life = ...[4]

(c) Draw a line between each type of ionising radiation and its property and another line between the property and its use. One has been done for you.

Name of ionising radiation	Property	Use
X-ray	It is the most ionising radiation and is most easily absorbed by very small amounts of substance	Remotely detecting leaks in underground water pipes
α-particle	Penetration is affected by small changes in the amount of solid it is passing through	Detecting fractures in bones
β-particle	It is highly penetrating and is poorly ionising	Detecting smoke in a fire alarm system
γ-ray	Can pass easily through soft living tissue. Calcium absorbs more than soft tissue	Detecting a change in the thickness of aluminium foil during its manufacture

[3]

[Total: 10]

13 Thorium-234 ($^{234}_{90}$Th) is radioactive. It decays by β-emission to form an isotope of protactinium (Pa).

(a) Complete the nuclide equation for this decay.

$$^{234}_{90}\text{Th} \longrightarrow {}^{\cdots\cdots}_{\cdots\cdots}\text{Pa} + {}^{\cdots\cdots}_{\cdots\cdots}\beta$$

[2]

(b) A pure sample of thorium-234 emits β-particles at a count rate of 2480 counts / second. The half-life of thorium-234 is 24 days.

Calculate the count rate for the emission of β-particles from the thorium in the sample after 72 days have passed.

count rate .....[3]

(c) The isotope of protactinium in **(a)** is also radioactive. It decays by β-emission and has a half-life of 70 seconds.

State and explain how this would affect the **observed** count rate for the sample in **(b)** after 72 days.

.....

.....

.....

.....[3]

[Total: 8]

14 **(a)** A small quantity of radioactive material is taken from a nuclear reactor.

Describe how a scientist could prove that the material is releasing γ-rays but not α-particles or β-particles.

.....

.....

.....

.....

.....[3]

(b) The nuclear fuel used in a power station is plutonium-239.

$^{239}_{94}Pu$ decays by α-emission to produce an isotope of uranium.

Use the correct nuclide notation to write a symbol equation for this decay process.

$^{239}_{94}Pu \rightarrow$ ..... + ...

[2]

(c) The electricity produced in a nuclear power station is transferred from the power station to a nearby town using overhead power cables.

The resistance of a length of cable may be calculated using the equation shown.

$$\text{resistance} = \text{constant} \times \frac{\text{length}}{\text{cross-sectional area}}$$

One length of an overhead power cable has a resistance of 7.0 Ω.

Predict the resistance of a cable that has half the diameter but is the same length.

resistance = ... Ω [2]

[Total: 7]

15 Fig. 11.2 shows a geologist holding a radiation detector near a rock.

Fig. 11.2

She holds the detector in a fixed position and records the readings shown in Table 11.1.

Table 11.1

time / minutes	0	1	2	3	4	5
detector reading / counts / minute	16	14	17	13	17	15

Explain the changes in the detector readings.

.....

.....

.....

.....[2]

(c) A technician is handling a solid radioactive sample that emits α-particles and β-particles.

The technician wears thick rubber gloves.

Explain why this may provide some protection from the radiation, but it is not sufficient protection.

.....

.....

.....

.....[2]

[Total: 7]

16 Uranium-238 and uranium-234 are radioactive isotopes of the element uranium.

A uranium-238 nucleus is different from a uranium-234 nucleus but both decay by the emission of an α-particle.

(a) **(i)** In terms of the particles in each, state how a nucleus of uranium-238 differs from a nucleus of uranium-234.

.....

.....[2]

(ii) Although the two nuclei are different, they are both nuclei of uranium.

State a property that makes these isotopes the same element.

.....

.....[1]

(b) When α-particles pass through air, they are more strongly ionising than β-particles.

Suggest **two** reasons why this is so.

.....

.....[2]

(c) In an experiment, α-particles are allowed to strike a thin gold foil in a vacuum.

Almost all the α-particles pass straight through the gold undeflected. Only a very small number of α-particles are deflected from their original path.

This result reveals certain features of the atoms of the gold.

State what is shown about atoms by the fact that

(i) most α-particles pass straight through the gold undeflected,

.....

.....[1]

(ii) some α-particles are deflected back the way they came.

.....

.....[1]

[Total: 7]

17 **(a)** A radon-222 nucleus contains 86 protons and 136 neutrons. It decays by emitting an α-particle and becomes a nucleus of an isotope of polonium. The symbol for radon is Rn and the symbol for polonium is Po.

Write down the nuclide equation for this decay.

[3]

(b) Carbon-14 is radioactive with a half-life of 5700 years. An animal bone is dug up in an archaeological excavation. The quantity of carbon-14 in the bone is 25% of what it was when the bone was buried.

Calculate the time that has elapsed since it was buried.

time = ... years [2]

[Total: 5]

18 **(a)** The counter of a radiation detector placed close to a radioactive source gives a count rate of 1600 counts / s. The half-life of the source is 1 week.

Ignoring background radiation, calculate the count rate

(i) 1 week after the first measurement,

count rate = ...[1]

(ii) 3 weeks after the first measurement.

count rate = ...[1]

(b) Fig. 11.1 shows the arrangement for an experiment to investigate the shielding of radioactive sources.

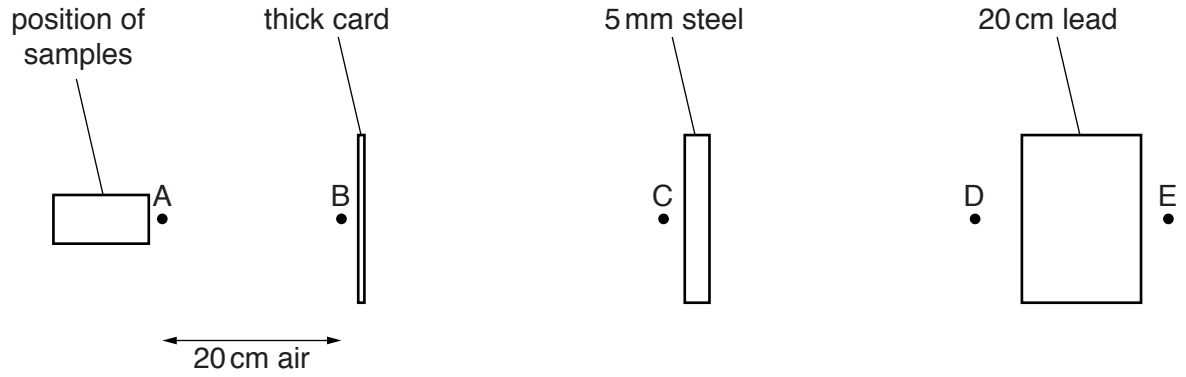

Fig. 11.1 (not to scale)

Samples containing three different radioactive sources are placed, one at a time, in the position shown.

The table shows the count rates when a radiation detector is placed at the positions A to E.

Complete the table to indicate whether α-particles, β-particles or γ-rays are emitted from each sample.

	A	B	C	D	E	type of radiation emitted
sample 1	high	high	high	high	low	
sample 2	high	high	low	0	0	
sample 3	high	0	0	0	0	

[3]

(c) State which type of radiation, α, β or γ, is the most strongly ionising.

.....[1]

[Total: 6]

B8 EXTENDED

19 **(a)** State, in terms of the particles in each nucleus, how the nuclei of two isotopes of the same element are different.

.....[1]

(b) Fig. 11.1 shows a graph of nucleon number against proton number. The nucleus $^{212}_{83}Bi$ is plotted on the graph at the cross marked P.

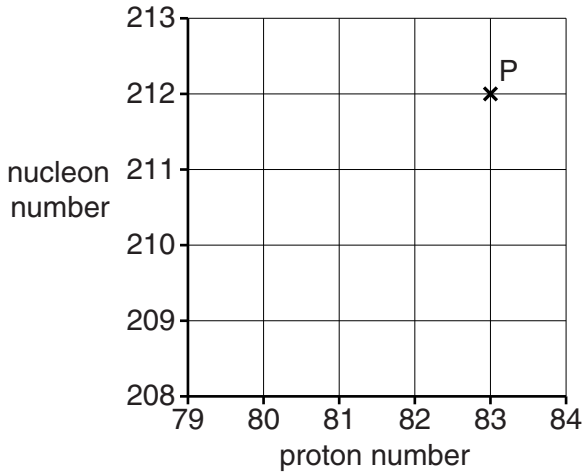

Fig. 11.1

(i) On Fig. 11.1,

1. plot a cross labelled Q for the nucleus formed when the $^{212}_{83}Bi$ nucleus emits an α-particle,

2. plot a cross labelled R for the nucleus formed when the $^{212}_{83}Bi$ nucleus emits a β-particle.

[4]

(ii) The half-life for the decay of $^{212}_{83}Bi$ is 60 minutes.

A sample of $^{212}_{83}Bi$ is placed at a fixed distance from a detector. The initial measurement of the count rate from the sample of $^{212}_{83}Bi$ is 2400 counts per minute.

Calculate the count rate from the sample 5.0 hours later.

count-rate = ...[2]

[Total: 7]

20 Bismuth-214 is radioactive. It has a half-life of 20 minutes.

(a) The nuclide notation for bismuth-214 is $^{214}_{83}Bi$.

State the composition of the nucleus of bismuth-214.

.....

..... [2]

(b) Bismuth-214 decays by β-decay to an isotope of polonium, Po.

Complete the equation for the decay of bismuth-214.

$$^{214}_{83}Bi \rightarrow \begin{matrix}\text{.....}\\ \text{.....}\end{matrix}\beta + \begin{matrix}\text{.....}\\ \text{.....}\end{matrix}Po$$

[3]

(c) The count rate from a sample of bismuth-214 is 360 counts / s.

Predict the count rate from the sample after 60 minutes.

count rate = ... [2]

(d) State **two** of the social, economic or environmental issues involved in the storage of radioactive materials with very long half-lives.

.....

.....

.....

..... [2]

[Total: 9]