Name: _____

Class: _____

Date: _____

Atomic Structure part 1 AQA Triple Physics

Time: **83 minutes**

Marks: **78 marks**

Comments:

1. Different radioactive isotopes emit different types of radiation.

(a) One isotope of uranium (U) decays into thorium (Th) by emitting an alpha particle (He).

Which nuclear equation shows the decay of this isotope of uranium?

Tick (✓) **one** box.

$^{230}_{92}U \rightarrow {}^{226}_{90}Th + {}^{4}_{2}He$ ☐

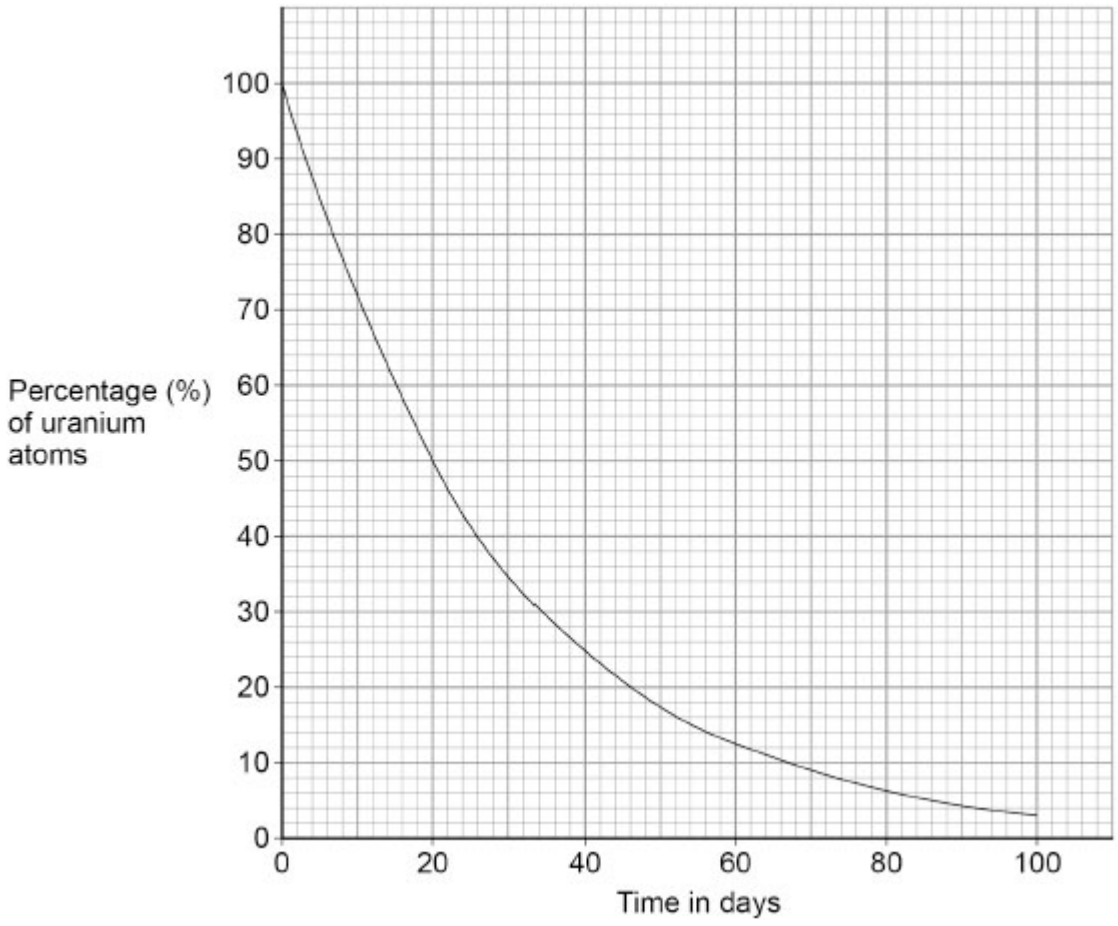
$^{226}_{90}Th \rightarrow {}^{230}_{92}U + {}^{4}_{2}He$ ☐

$^{230}_{92}U + {}^{226}_{90}Th \rightarrow {}^{4}_{2}He$ ☐

(1)

Figure 1 shows how the percentage of uranium atoms in a sample of one uranium isotope varies with time.

Figure 1



(b) What is the time taken for 50% of the atoms of this uranium isotope to decay?

Use **Figure 1**.

Time taken = _____ days

(1)

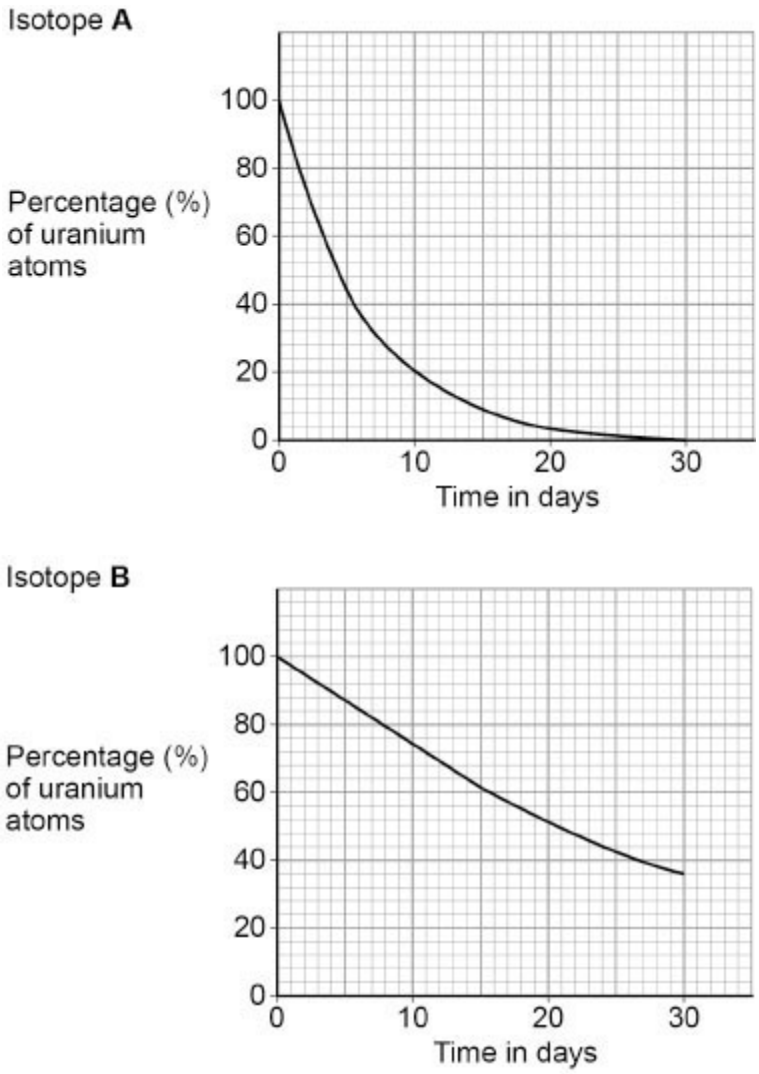
(c) What is the half-life of this uranium isotope?

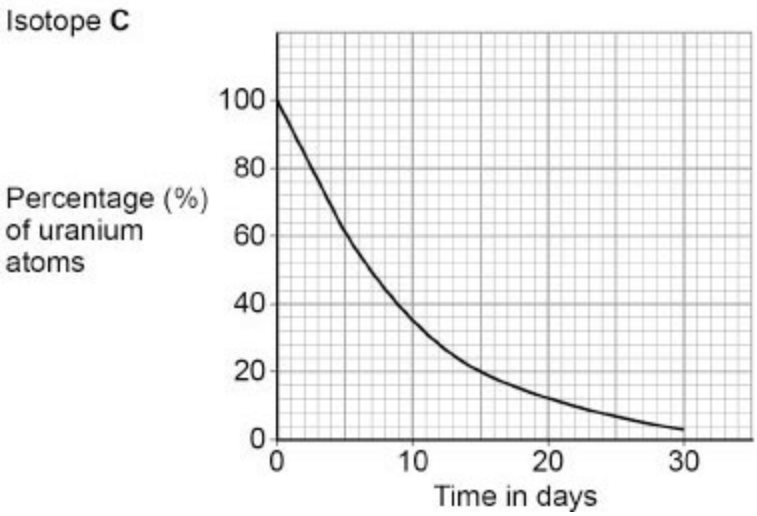
Half-life = _____ days

(1)

(d) **Figure 2** shows how the percentage of uranium atoms varies with time for three different isotopes of uranium, **A**, **B** and **C**.

Figure 2





Which isotope is the most unstable?

Give a reason for your answer.

Tick (✓) **one** box.

Isotope **A** ☐

Isotope **B** ☐

Isotope **C** ☐

Reason _____

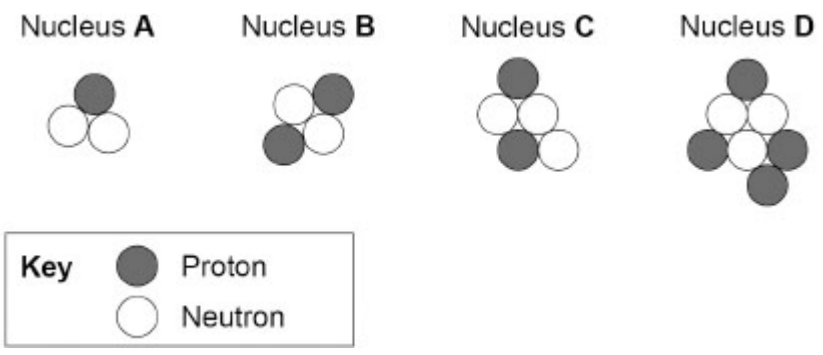
_____

_____

(2)

Figure 3 shows the nuclei of four different atoms.

Figure 3



(e) Which nucleus in **Figure 3** has the smallest **mass** number?

Tick (✓) **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)

(f) Which nucleus in **Figure 3** has an **atomic** number of 4?

Tick (✓) **one** box.

A ☐ **B** ☐ **C** ☐ **D** ☐

(1)

(g) Which **two** nuclei in **Figure 3** are isotopes of the same element?

Give a reason for your answer.

Nucleus ☐ and nucleus ☐

Reason _____

_____

(2)

Scientists have replaced old models of the atom with newer models.

The nuclear model of the atom has a nucleus at the centre.

(h) Which model of the atom was replaced by the nuclear model?

Tick (✓) **one** box.

Bohr model ☐

Plum pudding model ☐

Tiny spheres that cannot be divided ☐

(1)

(i) What does the nuclear model state about the mass of an atom?

Tick (✓) **one** box.

The mass of the atom is concentrated in the electrons. ☐

The mass of the atom is concentrated in the nucleus. ☐

The mass of the atom is spread throughout the atom. ☐

(1)

(Total 11 marks)

2. Scientists have used lasers to start a nuclear **fusion** reaction.

The scientists used the lasers to heat a small amount of an isotope of hydrogen.

(a) Describe what is meant by 'isotopes' of an element.

_____

_____

_____

_____

(2)

(b) Explain how nuclear **fusion** releases energy.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(c) The fusion reaction releases large amounts of energy.

The fusion reaction takes place in a reactor.

Explain why the walls of the reactor should be made from a material with a very high specific heat capacity.

_____

_____

_____

_____

(2)

(d) Nuclear fusion is safer than nuclear fission.

Nuclear **fission** can lead to an uncontrolled chain reaction.

Give **one** consequence of an uncontrolled chain reaction.

_____

_____

(1)

(Total 8 marks)

3. Some atoms emit radiation.

(a) Why do scientists sometimes change the model used to describe the structure of the atom?

Tick (✓) **one** box.

Existing models use ideas that are old fashioned.	☐
New evidence is discovered that existing models cannot explain.	☐
Scientists need to develop new models every 100 years.	☐
The public do not understand old models so new ones are created.	☐

(1)

(b) When radioactivity was discovered, the dangers of radiation were not known.

Some scientists were irradiated and contaminated while working with the radioactive materials.

Describe the difference between irradiation and radioactive contamination.

_____

_____

_____

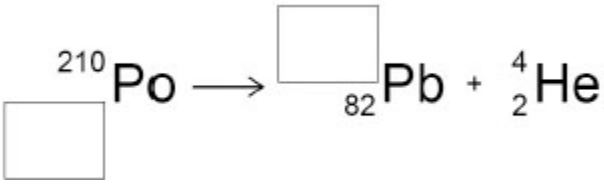
_____

(2)

(c) Polonium-210 was one of the first radioactive elements to be discovered.

Polonium-210 (Po) decays into lead (Pb).

Complete the nuclear equation for polonium-210.



(2)

(d) Polonium-210 has a half-life of 138 days.

A sample of polonium contains 256 000 atoms.

Calculate the time taken for the number of polonium-210 atoms to reach 16 000.

_____

_____

_____

_____

_____

Time taken = _____ days

(3)

(e) A sample of polonium contains equal numbers of polonium-209 atoms and polonium-210 atoms.

Polonium-209 has a half-life of 125 **years**.

Polonium-210 has a half-life of 138 **days**.

Explain how the activity of polonium-209 compares with the activity of polonium-210 in this sample.

_____

_____

_____

_____

(2)

(Total 10 marks)

4. A teacher measured the background radiation in a laboratory.

(a) Which sources of background radiation are natural and which are man-made?

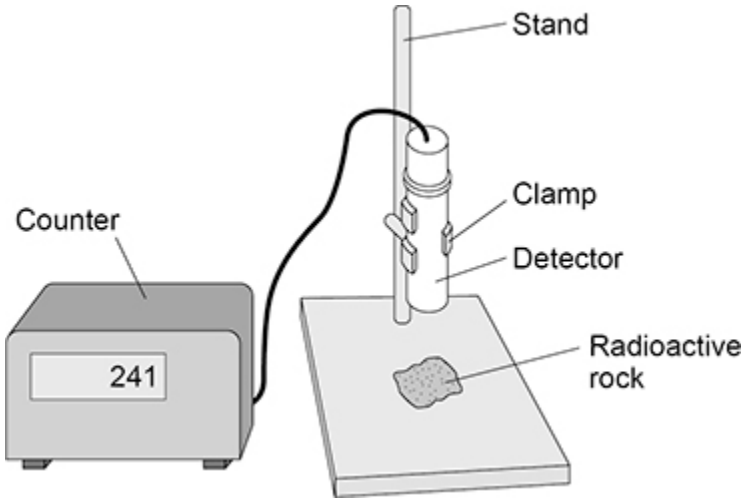
Tick (✓) **one** box in **each** row.

Source of background radiation	**Natural**	**Man-made**
Cosmic rays		
Medical X-rays		
Nuclear accidents		
Radon gas		

(2)

The teacher measured the radiation emitted by four different types of radioactive rock.

The figure below shows the equipment used.



Each radioactive rock was placed below the detector one at a time.

The radiation was recorded as the number of counts in 1 minute.

The experiment was repeated with different materials between each rock and the detector.

The table below shows the results.

	Number of counts in 1 minute		
	No material	One sheet of paper	Thick aluminium sheet
No rock	21	20	22
Rock **A**	450	448	18
Rock **B**	385	387	356
Rock **C**	870	21	20
Rock **D**	620	473	214

(b) Which radioactive rock emitted only alpha radiation?

Give a reason for your answer.

Tick (✓) **one** box.

Rock **A** ☐

Rock **B** ☐

Rock **C** ☐

Rock **D** ☐

Reason _____

_____

(2)

(c) Which radioactive rock emitted only beta radiation?

Give a reason for your answer.

Tick (✓) **one** box.

Rock **A** ☐

Rock **B** ☐

Rock **C** ☐

Rock **D** ☐

Reason _____

_____

(2)

(d) The teacher took safety precautions during the experiment.

Which precaution would prevent the teacher from becoming contaminated by the radioactive rocks?

Tick (✓) **one** box.

Displaying the radiation hazard symbol ☐

Handling the rocks with clean hands ☐

Wearing protective gloves ☐

(1)

(e) What is the activity of each rock after one half-life?

Tick (✓) **one** box.

The activity is a quarter of the original activity. ☐

The activity is half the original activity. ☐

The activity is double the original activity. ☐

The activity is zero. ☐

(1)

(f) How does the activity of a radioactive source affect the risk of harm from the source?

Tick (✓) **one** box.

The smaller the activity, the greater the risk of harm. ☐

The activity does not affect the risk of harm. ☐

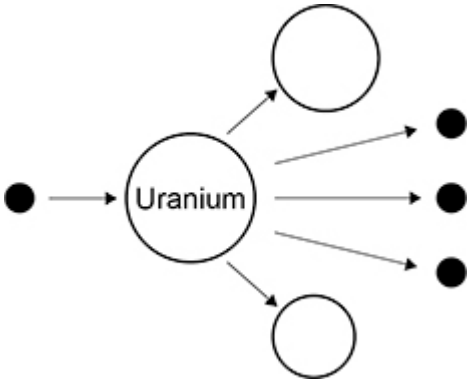
The greater the activity, the greater the risk of harm. ☐

(1)

(Total 9 marks)

5. The process of nuclear fission is used in nuclear power stations.

The figure below shows the process of nuclear fission.



(a) Complete the sentences.

Choose answers from the box.

electrons	**gamma rays**	**neutrons**	**nuclei**	**protons**

In nuclear power stations, energy is released from uranium

_____ .

The uranium in above figure splits into two parts and releases three

_____ .

The process of nuclear fission releases electromagnetic radiation in the form of

_____.

(3)

Use the Physics Equations Sheet to answer parts (a) and (b).

(b) Write down the equation which links energy (*E*), power (*P*) and time (*t*).

_____

(1)

(c) A nuclear power station has a power output of 500 MW.

Calculate the energy output in 3600 s.

Give your answer in J.

_____

_____

_____

_____

_____

Energy output = _____ J

(3)

(d) Radioactive waste produced by nuclear power stations has a long half-life.

Suggest **one** precaution taken to reduce the hazard caused by radioactive waste from power stations.

_____

_____

_____

(1)

(e) Nuclear power stations do **not** generate electricity every day of the year.

One nuclear power station generated electricity for 92% of a year.

one year = 365 days

Calculate the number of days during the year that the nuclear power station generated electricity.

_____

_____

_____

Number of days = _____

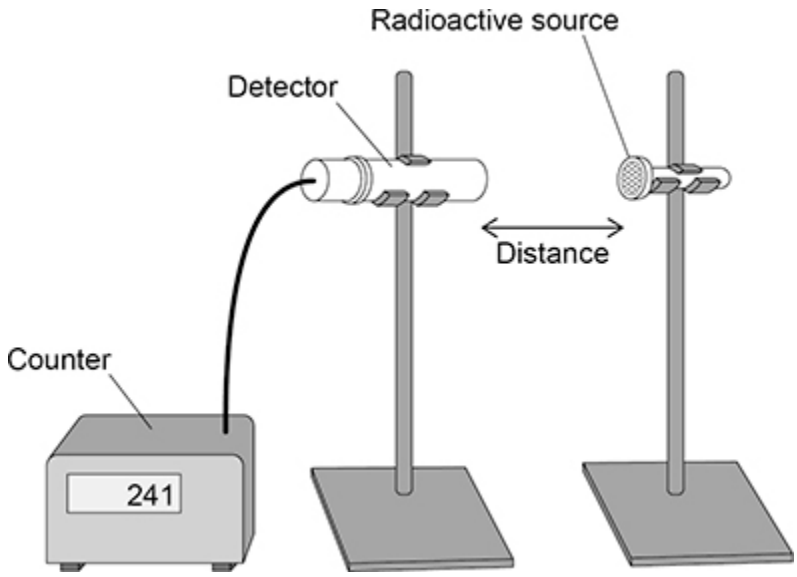
(2)

(Total 10 marks)

6. A teacher investigated the radiation emitted by two different radioactive sources, **A** and **B**.

Figure 1 shows a radiation detector positioned near one of the radioactive sources.

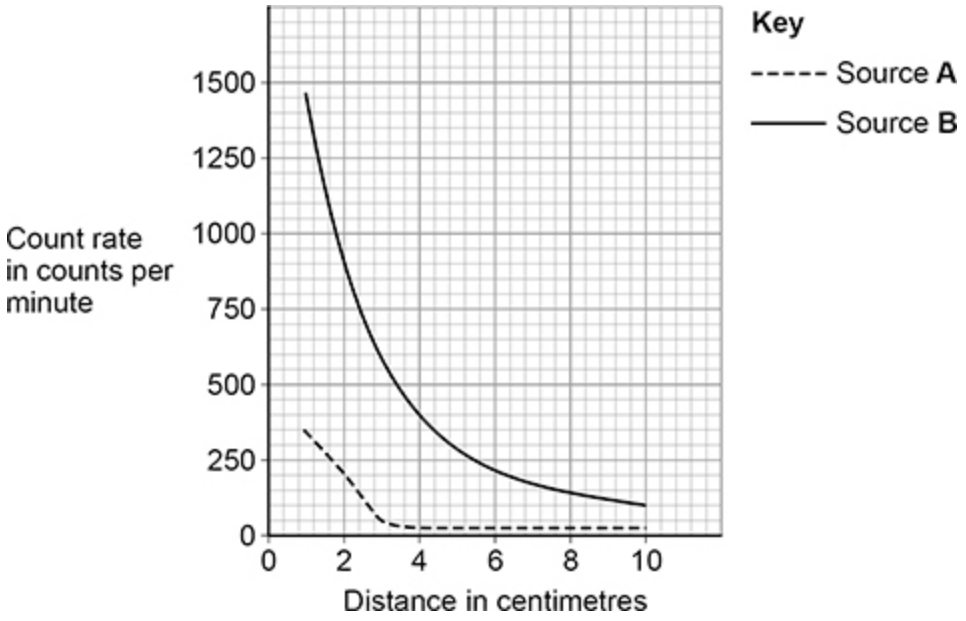
Figure 1



The teacher measured the count rate at different distances for each radioactive source.

Figure 2 shows the results.

Figure 2



(a) Explain how **Figure 2** shows that Source **A** only emits alpha radiation.

(3)

(b) **Figure 2** can **not** be used to determine if Source **B** emits beta radiation or gamma radiation.

Explain how an absorbing material could be used to show which type of radiation is emitted by Source **B**.

(2)

The teacher took safety precautions during the experiment.

(c) Suggest **one** safety precaution the teacher would have taken to reduce the radiation dose the teacher received.

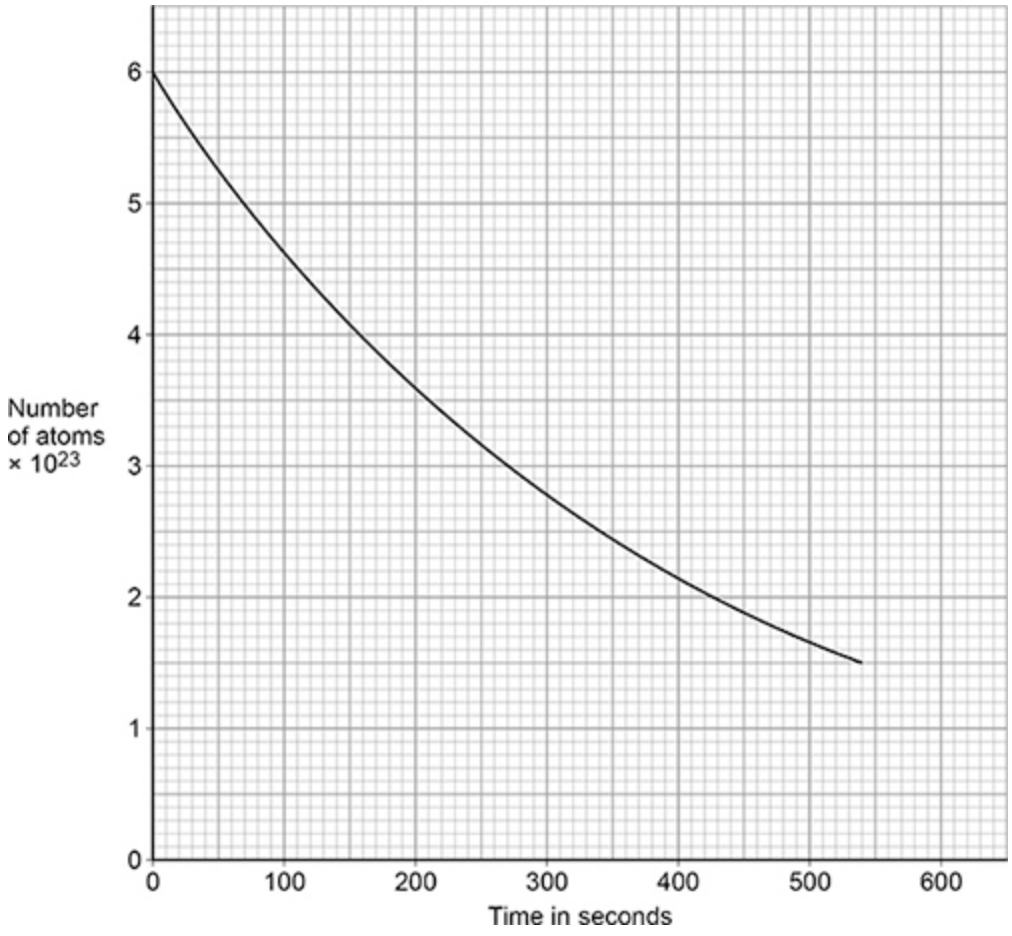
(1)

(d) Suggest **one** safety precaution that the teacher would have taken to avoid becoming contaminated.

(1)

(e) **Figure 3** shows how the number of atoms of a radioactive element in a sample varied with time.

Figure 3



Activity is the rate at which a source of unstable nuclei decays.

Determine the activity of the radioactive sample at 300 seconds.

Give the unit.

_____

_____

_____

_____

Activity = _____ Unit _____

(4)

(Total 11 marks)

7. Scientists developed different models of the atom as new discoveries were made.

(a) Which particle in the atom was discovered first?

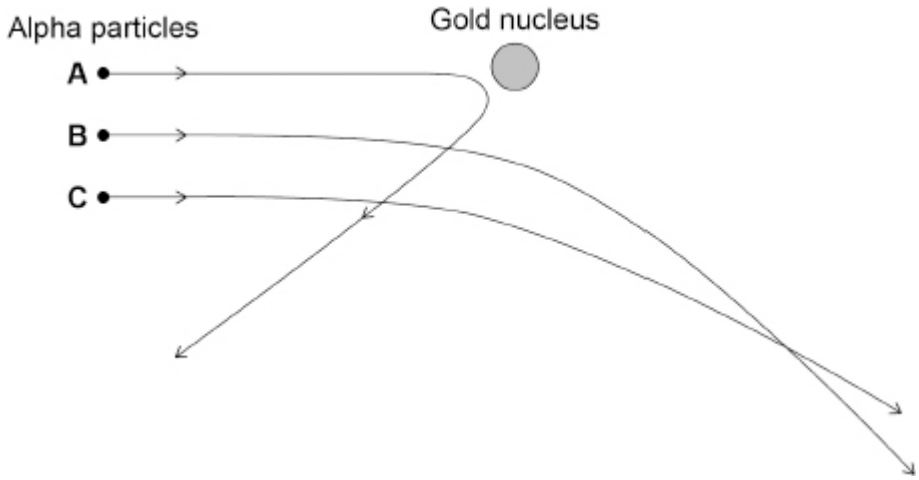
Tick (✓) **one** box.

Electron	☐
Neutron	☐
Proton	☐

(1)

In an experiment that led to the nuclear model of the atom, alpha particles were directed at a sheet of gold foil.

The figure below shows the path of three alpha particles passing close to a gold nucleus.



(b) An alpha particle has a radius of 1.7 femtometres.

The radius of a gold nucleus is 4.2 times larger than the radius of an alpha particle.

Calculate the radius of a gold nucleus in femtometres.

_____

_____

_____

Radius of a gold nucleus = _____ femtometres

(2)

(c) Alpha particles are deflected by the gold nucleus.

What are the charges on an alpha particle and a gold nucleus?

Tick (✓) **one** box.

An alpha particle and a gold nucleus are both neutral. ☐

An alpha particle and a gold nucleus are both positively charged. ☐

An alpha particle is positively charged and a gold nucleus is neutral. ☐

(1)

(d) Which statement describes the force between the alpha particle and the gold nucleus?

Tick (✓) **one** box.

A contact force ☐

A force of attraction ☐

A force of repulsion ☐

There is no force ☐

(1)

(e) Which alpha particle in the figure above experiences the largest force from the gold nucleus?

Tick (✓) **one** box.

A ☐ **B** ☐ **C** ☐

(1)

The table below lists different models of the atom in alphabetical order.

Model
Bohr
Nuclear
Plum pudding
Tiny spheres that cannot be divided

(f) Which model in the table above was developed first?

_____

(1)

(g) Which model in the table was developed last?

_____

(1)

(Total 8 marks)

8. Some isotopes emit nuclear radiation.

(a) Carbon-12 and carbon-14 are both isotopes of carbon.

Complete the sentences.

Choose answers from the box.

alpha particles	**electrons**	**neutrons**	**protons**

The nucleus of a carbon-12 atom and the nucleus of a carbon-14 atom have the **same** number of _____.

The nucleus of a carbon-12 atom and the nucleus of a carbon-14 atom have a **different** number of _____.

(2)

(b) Different radioactive isotopes have different half-lives.

What does ‘half-life’ mean?

Tick (✓) **one** box.

Half the time taken for all of the nuclei in a sample to decay. ☐

The time taken for half the nuclei in a sample to decay. ☐

The time taken for one nucleus to split in half. ☐

(1)

(c) **Table 1** shows the half-life of some different isotopes of carbon.

Table 1

Isotope	**Half-life in seconds**
Carbon-15	2.45
Carbon-16	0.75
Carbon-17	0.19
Carbon-18	0.09

Which isotope is the least stable?

Tick (✓) **one** box.

Carbon-15 ☐

Carbon-16 ☐

Carbon-17 ☐

Carbon-18 ☐

(1)

(d) Workers in nuclear power stations must be aware of nuclear irradiation and radioactive contamination.

Draw **one** line from each term to an example of the term.

Term	Example
Radioactive contamination	Exposure to a beam of gamma rays
	Exposure to ultraviolet radiation from the Sun
Nuclear irradiation	Accidental transfer of plutonium onto a human body
	Using a mobile phone

(2)

(e) Why are workers required to walk across a sticky floor before leaving the nuclear power station?

Tick (✓) **one** box.

To remove alpha particles from their shoes. ☐

To remove gamma radiation from their shoes. ☐

To remove radioactive dust from their shoes. ☐

(1)

(f) The places where people work and live contribute to the nuclear radiation they are exposed to.

Table 2 shows the mean daily dose of radiation caused by two different jobs.

Table 2

Job	**Mean daily dose in mSv**
Aeroplane pilot	0.072
Nuclear power station worker	0.00050

Calculate the number of days a nuclear power station worker must work before receiving the same dose that an aeroplane pilot receives in one day.

_____

_____

_____

Number of days = _____

(2)

(g) The process of nuclear fission takes place in nuclear power stations.

The process of nuclear fusion takes place in the Sun.

Draw **one** line from each process to its fuel.

Process	**Fuel**
Nuclear fission	Hydrogen
	Iron
	Lead
Nuclear fusion	Uranium

(2)

(Total 11 marks)

Mark schemes

1. (a) $^{230}_{92}U \rightarrow {}^{226}_{90}Th + {}^{4}_{2}He$

1

(b) 20 (days)

1

(c) 20 (days)

*allow ecf from question **(b)***

1

(c) isotope **A**

1

shortest half-life

or
decays quickest

or
graph is steepest (initially)

or
smallest percentage of atoms left (at any time after t = 0)

MP2 dependent on MP1 1

1

(e) **A**

1

(f) **D**

1

(g) **B** and **C**

1

same number of protons (and different number of neutrons)

MP2 dependent on MP1
allow same atomic number
ignore electrons

1

(h) plum pudding model

1

(i) the mass of the atom is concentrated in the nucleus

1

[11]

2. (a) (atoms of an element with) the same number of protons

ignore number of electrons

allow same atomic number

1

but a different number of neutrons

allow different mass number

1

(b) light(er) nuclei fuse

allow hydrogen nuclei fuse

ignore bonding / colliding

1

to form heavier nuclei / elements

allow to form helium nuclei

1

some of the mass (of the nuclei) is converted into energy (of radiation)

1

(c) (a large amount of energy transferred) causes a small temperature increase of the walls / material

1

(therefore) the walls of the reactor should not reach melting point

allow (therefore) the walls of the reactor should not melt

1

(d) any **one** from:

- a nuclear explosion
- a (nuclear) meltdown
- a nuclear bomb

allow atomic for nuclear

allow Chernobyl / Fukushima (disaster)

1

[8]

3. (a) new evidence is discovered that existing models cannot explain

1

(b) irradiation is the exposure to radiation

1

(radioactive) contamination is the (unwanted) presence of radioactive material on / inside a person

allow an object for a person

1

(c) (Po) 84

1

(Pb) 206

1

(d) number of half-lives = 4

1

time = 4 × 138

1

time = 552 (days)

1

(e) polonium-209 has a lower activity than polonium-210

ignore description of rate of decay

1

(because polonium-209) has a longer half-life

MP2 dependent on MP1

1

[10]

4. (a) 2 marks for 4 correct answers
1 mark for 2 or 3 correct answers

Source of background radiation	**Natural**	**Man-made**
Cosmic rays	✓	
Medical X-rays		✓
Nuclear accidents		✓
Radon gas	✓	

2

(b) rock **C**

1

(because) alpha is stopped by
(one sheet of) paper
or
(one sheet of) paper significantly decreased the radiation detected

MP2 dependent on scoring MP1

allow alpha is the least penetrating

1

(c) rock **A**

1

(because) beta radiation is stopped by (a thick) aluminium (sheet)

or

the (thick) aluminium (sheet) significantly decreased the radiation detected

MP2 dependent on scoring MP1

1

(d) wearing protective gloves

1

(e) the activity is half the original activity

1

(f) the greater the activity, the greater the risk of harm

1

[9]

5. (a) nuclei

1

neutrons

1

gamma rays

this order only

1

(b) energy = power × time
or
$E = P \times t$

1

(c) P = 500 000 000 (W)

1

E = 500 000 000 × 3600

allow a correct substitution of an incorrectly / not converted value of P

1

E = 1 800 000 000 000 (J)
or
$E = 1.8 \times 10^{12}$ (J)

allow an answer consistent with an incorrectly / not converted value of P

1

(d) any **one** from:

- bury the radioactive waste
- put the radioactive waste in cooling ponds

  allow store it for (at least) one half-life
- transport the radioactive waste in secure vessels
- store the radioactive waste in metal containers
- cover the radioactive waste in concrete

  ignore references to high / medium / low level waste

  ignore label the waste as hazardous

1

(e)

number of days = $\frac{92}{100} \times 365$

1

number of days = 335.8

allow answers of 335 and 336 days

allow an answer of 29.2 (days) for 1 mark

1

[10]

6. (a) radiation (from source **A**) travels (approximately) 3 cm (in air)

1

(after which) count rate decreases to background radiation

1

(because) alpha radiation has a short range (in air)

allow alpha radiation has (very) low penetrating ability

allow beta <u>and</u> gamma radiation have a (much) longer range in air

1

(b) use an aluminium sheet

allow other materials that beta would be stopped by e.g. brick, sheets of iron / lead, etc.

ignore sheet(s) of metal foil unless thickness is given

1

(which) beta radiation will not penetrate but gamma will
or
(which) only gamma will penetrate

MP2 dependent on scoring MP1

1

(c) any **one** from:

- increase distance between source and teacher
- limit exposure time
- use tongs / forceps
- wear a lead apron
- keep source in box unless in use
- stand behind safety screen
- point source away from teacher

allow any reasonable precaution that increases distance between the source and the teacher, or limits exposure time

ignore wear PPE unqualified ignore examples of additional clothing

1

(d) wear gloves / apron
or
wear a lab coat
or
handle source with tongs / forceps

allow no eating / drinking (while radioactive source is in the lab)

allow do not touch the source (with bare hands)

ignore wear a mask

ignore wear safety glasses

ignore protective clothing unqualified

ignore wear a hazmat suit

ignore wear PPE unqualified

1

(e) tangent drawn on line at 300 s

do not allow a line drawn that crosses the graph line

1

attempt to calculate gradient of the tangent

allow missing power for Δy

1

activity = 7.1×10^{20}

allow a value between 6.5 and 7.6 × 10^{20}

1

becquerel / Bq

ignore decays/second

1

[11]

7. (a) electron

1

(b) radius = 1.7 × 4.2

1

radius = 7.14 (femtometres)

allow 7.1 (femtometres)

1

(c) an alpha particle and a gold nucleus are both positively charged

1

(d) a force of repulsion

1

(e) A

1

(f) tiny spheres that can't be divided

1

(g) Bohr

1

[8]

8. (a) protons

this order only

1

neutrons

1

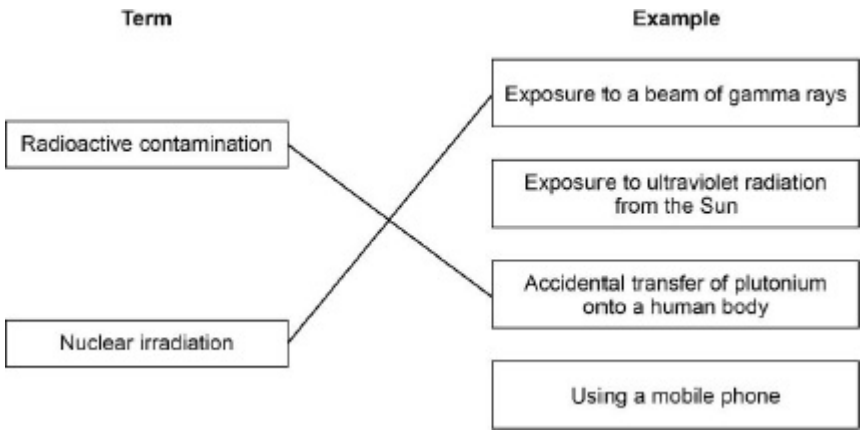
(b) the time taken for half the nuclei in a sample to decay

1

(c) carbon-18

1

(d)



1 mark for each correct line

additional line from a box on the left negates the mark for that box

2

(e) to remove radioactive dust from their shoes

1

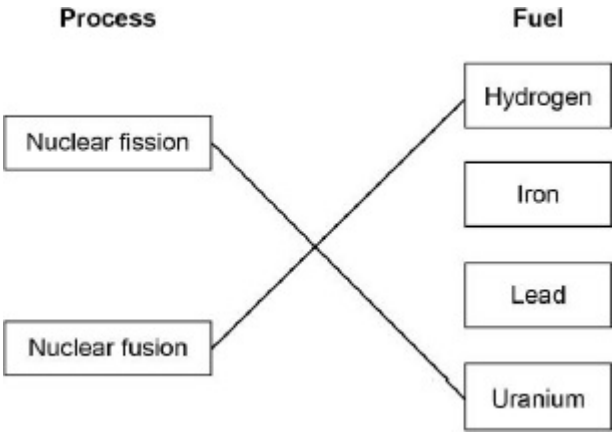
(f) $$\text{number of days} = \frac{0.072}{0.00050}$$

1

number of days = 144

1

(g)



1 mark for each correct line

additional line from a box on the left negates the mark for that box

2

[11]