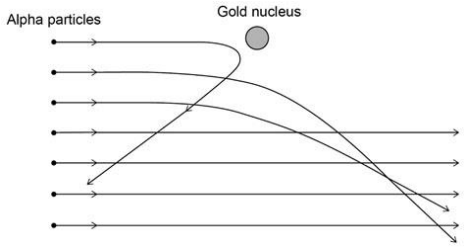
Q1. Higher

In the early 20th century, scientists developed an alpha particle scattering experiment using gold foil.

The diagram shows the paths of some of the alpha particles in the alpha particle scattering experiment.



(a) Explain how the paths of the alpha particles were used to develop the nuclear model of the atom.

_____

_____

_____

_____

_____

_____

(4)

(b) Niels Bohr adapted the nuclear model by suggesting electrons orbited the nucleus at specific distances.

Explain how the distance at which an electron orbits the nucleus may be changed.

_____

_____

_____

_____ **(3)**

(Total 7 marks)

Q2.

Polonium-210 $(^{210}_{84}Po)$ is a radioactive isotope that decays by emitting alpha radiation.

(a) Complete the decay equation for polonium-210

$$^{210}_{84}Po \longrightarrow \square Pb + {}^{4}_{2}He$$

(2)

(b) Explain why contamination of the inside of the human body by a radioactive material that emits alpha radiation is highly dangerous. **(3)**

_____

_____

_____

_____

_____

_____

(c) A sample of polonium-210 was left for 414 days.

After this time it had a mass of 1.45×10^{-4} g

The half-life of polonium-210 is 138 days.

Calculate the initial mass of the sample.

_____

_____

_____

_____

Initial mass = _____ g **(3)**

(Total 8 marks)

Q3.

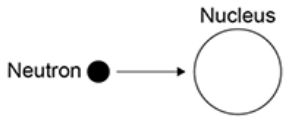
Electricity is generated in a nuclear power station.

Fission is the process by which energy is released in the nuclear reactor.

(a) **Figure 1** shows the first part of the nuclear fission reaction.

Complete **Figure 1** to show how the fission process starts a chain reaction.

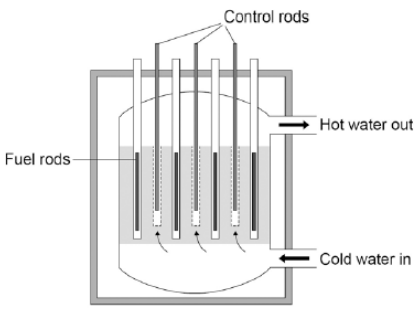
Figure 1



(3)

(b) **Figure 2** shows the inside of a nuclear reactor in a nuclear power station.

Figure 2



In a nuclear reactor a chain reaction occurs, which causes neutrons to be released.

The control rods absorb neutrons.

The control rods can be moved up and down.

Explain how the energy released by the chain reaction is affected by moving the control rods.

_____

_____

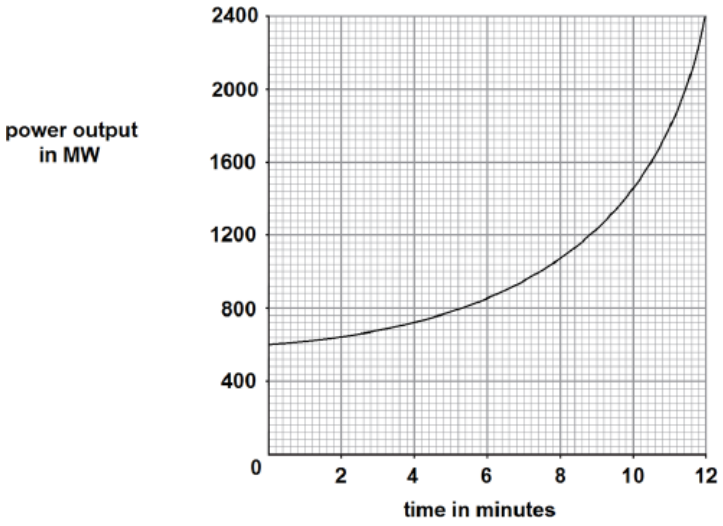
_____

_____

(2)

(c) **Figure 3** shows how the power output of the nuclear reactor would change if the control rods were removed.

Figure 3



Calculate the rate of increase of power output at 10 minutes.

_____

_____

_____

_____

Rate of increase of power output = _____ MW / minute **(2)**

(Total 7 marks)

Q4.

Many countries use nuclear power stations to generate electricity.
Nuclear power stations use the process of nuclear fission to release energy.

(a) (i) What is nuclear fission?

_____

_____

(1)

(ii) Plutonium-239 is one substance used as a fuel in a nuclear reactor. For nuclear fission to happen, the nucleus must absorb a particle.

What type of particle must be absorbed?

_____

(1)

(b) Nuclear **fusion** also releases energy.
Nuclear fusion happens at very high temperatures. A high temperature is needed to overcome the repulsion force between the nuclei.

(i) Why is there a repulsion force between the nuclei of atoms?

_____

_____

(1)

(ii) Where does nuclear fusion happen naturally?

_____

(1)

(c) In 1991, scientists produced the first controlled release of energy from an experimental nuclear **fusion** reactor. This was achieved by fusing the hydrogen isotopes, deuterium and tritium.

Deuterium is naturally occurring and can easily be extracted from seawater. Tritium can be produced from lithium. Lithium is also found in seawater.

The table gives the energy released from 1 kg of fusion fuel and from 1 kg of fission fuel.

Type of fuel	**Energy released from 1 kg of fuel in joules**
Fusion fuel	3.4×10^{14}
Fission fuel	8.8×10^{13}

(i) Suggest **two** advantages of the fuel used in a fusion reactor compared with plutonium and the other substances used as fuel in a fission reactor.

1. _____

_____

_____

2. _____

_____

_____

(2)

(ii) Some scientists think that by the year 2050 a nuclear fusion power station capable of generating electricity on a large scale will have been developed.

Suggest **one** important consequence of developing nuclear fusion power stations to generate electricity.

_____

_____

_____

(1)

(d) Tritium is radioactive.

After 36 years, only 10 g of tritium remains from an original sample of 80 g.

Calculate the half-life of tritium.

Show clearly how you work out your answer.

_____

_____

Half-life = _____ years **(2)**

(Total 9 marks)

Q5. Foundation

(a) Nuclear fission is used in nuclear power stations to generate electricity. Nuclear fusion happens naturally in stars.

(i) Explain briefly the difference between *nuclear fission* and *nuclear fusion*.

_____

_____

_____

_____**(2)**

(ii) What is released during both nuclear fission and nuclear fusion?

_____**(1)**

(b) Plutonium-239 is used as a fuel in some nuclear reactors.

(i) Name another substance used as a fuel in some nuclear reactors.

_____**(1)**

(ii) There are many isotopes of plutonium.

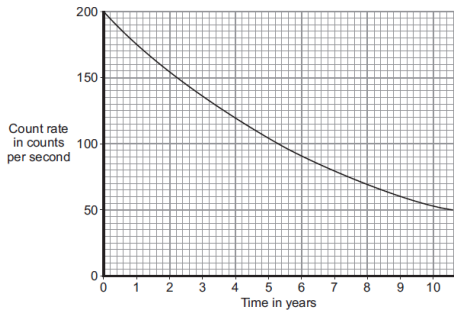
What do the nuclei of different plutonium isotopes have in common?

_____**(1)**

(Total 5 marks)

Q6

(a) The graph shows how the count rate from a sample containing the radioactive substance cobalt-60 changes with time.



(i) What is the range of the count rate shown on the graph?

From _____ counts per second to _____ counts per second.

(1)

(ii) How many years does it take for the count rate to fall from 200 counts per second to 100 counts per second?

Time = _____ years

(1)

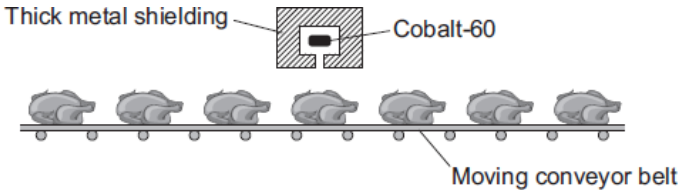
(iii) What is the half-life of cobalt-60?

Half-life = _____ years

(1)

(b) The gamma radiation emitted from a source of cobalt-60 can be used to kill the bacteria on fresh, cooked and frozen foods. Killing the bacteria reduces the risk of food poisoning.

The diagram shows how a conveyor belt can be used to move food past a cobalt-60 source.



(i) Which **one** of the following gives a way of increasing the amount of gamma radiation the food receives?

Increase the temperature of the cobalt-60 source. ☐

Make the conveyor belt move more slowly. ☐

Move the cobalt-60 source away from the conveyor belt. ☐

(1)

(ii) To protect people from the harmful effects of the gamma radiation, the cobalt-60 source has thick metal shielding.

Which **one** of the following metals should be used?

Draw a ring around your answer.

aluminium **copper** **lead**

(1)

(c) A scientist has compared the vitamin content of food exposed to gamma radiation with food that has not been exposed.

The table gives the data the scientist obtained when she tested 1 kg of cooked chicken.

Vitamin	Food not exposed to gamma radiation	Food exposed to gamma radiation
	Mass in milligrams	Mass in milligrams
B6	1.22	1.35
B12	21.00	28.00
E	3.30	2.15
Niacin	58.00	55.50
Riboflavin	2.10	2.25

Considering only this data, which **one** of the following is a correct conclusion?

Vitamin content is not affected by gamma radiation. ☐

Gamma radiation completely destroys some types of vitamin. ☐

Exposure increased the content of some types of vitamin. ☐

(1)

(Total 6 marks)

Q7.

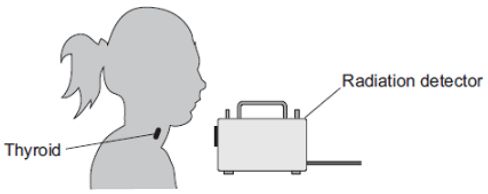
(a) The names of three types of radiation are given in **List A**. Some properties of these three types of radiation are given in **List B**.

Draw **one** line from each type of radiation in **List A** to its correct property in **List B**.

List A **Type of radiation**	**List B** **Property of radiation**
	will pass through paper but is stopped by thin metal
alpha	
	has the shortest range in air
beta	
	will not harm human cells
gamma	
	is very weakly ionising

(3)

(b) The radioactive isotope iodine-123 can be used by a doctor to examine the thyroid gland of a patient. The iodine, taken as a tablet, is absorbed by the thyroid gland. The gamma radiation emitted as the iodine atoms decay is detected outside the body.



The doctor uses an isotope emitting gamma radiation to examine the thyroid gland rather than an isotope emitting alpha or beta radiation.

Which **one** of the following gives a reason why gamma radiation is used?

Gamma radiation will pass through the body. ☐

Gamma radiation is not deflected by a magnet. ☐

Gamma radiation has a long range in air. ☐

(1)

(c) Iodine-123 has a half-life of 13 hours.

Use a word from the box to complete the sentence.

all	half	most

After 13 hours _____ of the iodine-123 atoms the thyroid absorbed have decayed.

(1)

(d) Iodine-123 and iodine-131 are two of the isotopes of iodine.

Draw a ring around the correct answer to complete the sentence.

The nucleus of an iodine-123 atom has the same number of

electrons
neutrons
protons

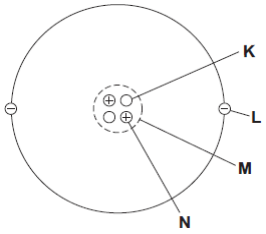
as the nucleus of an iodine-131 atom.

(1)

(Total 6 marks)

Q8.

(a) The diagram represents a helium atom.



(i) Which part of the atom, **K**, **L**, **M** or **N**, is an electron?

Part ☐

(1)

(ii) Which part of the atom, **K**, **L**, **M** or **N**, is the same as an alpha particle?

Part ☐

(1)

(b) A radioactive source emits alpha particles.

What might this source be used for?

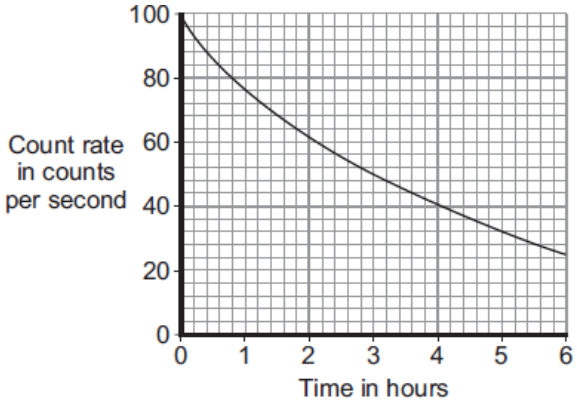
to monitor the thickness of aluminium foil as it is made in a factory ☐

to make a smoke detector work ☐

to inject into a person as a medical tracer ☐

(1)

(c) The graph shows how the count rate from a source of alpha radiation changes with time.



What is the count rate after 4 hours?

_____ counts per second

(1)

(Total 4 marks)

Q1.

(a) most alpha particles pass straight through the atom

1

which shows that the atom is mostly empty space

1

very few alpha particles are deflected through a large angle

1

which shows the atom contains a nucleus where the mass / charge of the atom is concentrated

1

(b) electron may absorb electromagnetic radiation

full credit may be scored for a description of an electron emitting electromagnetic radiation

1

(and) move further from the nucleus

1

to a higher energy level

1

[7]

Q2.

(a) $^{206}_{82}Pb$

2

(b) alpha radiation is highly ionising

1

causing an increased risk of cancer
or
organ failure
or
radiation sickness / poisoning
or
mutation of genes / DNA
or
damage to cells / tissues / organs

allow kill cells

1

until the radioactive material is removed / excreted

allow all the alpha radiation is absorbed by the body

or

activity of radioactive material reaches / approaches background radiation levels

ignore references to half-life

1

(c)

*an answer of 1.16 × 10^{-3} (g) scores **3** marks*

$\frac{414}{138} = 3$ (half-lives)

1

$1.45 \times 10^{-4} \times 2 \times 2 \times 2$

1

$= 1.16 \times 10^{-3}$ (g)
or
= 0.00116 (g)

1

[8]

Q3.

(a) Nucleus splitting into two fragments and releasing two or three neutrons

1

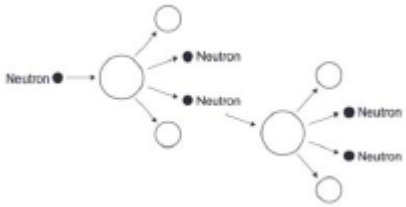
(at least one) fission neutron shown to be absorbed by additional large nucleus and causing fission

1

two or three additional neutrons released from fission reaction

1

*This diagram would gain all **3** marks:*



(b) lowering the control rods increases the number of neutrons absorbed
accept converse description

1

(so) energy released decreases

1

*allow changing the position of the control rods affects the number of neutrons absorbed for **1** mark*

(c) rate of increase between 240 and 276 (MW / min)

2

*allow **1** mark for attempt to calculate gradient of line at 10 minutes*

[7]

Q4.

(a) (i) splitting of a(n atomic) nucleus
do not accept splitting an atom

1

(ii) Neutron

1

(b) (i) nuclei have the same charge
or
nuclei are positive

accept protons have the same charge

1

(ii) (main sequence) star

accept Sun or any correctly named star

accept red (super) giant

1

(c) (i) any **two** from:

- easy to obtain / extract
- available in (very) large amounts
- releases more energy (per kg)

*do **not** accept figures only*

- produces little / no radioactive waste.

naturally occurring is insufficient

seawater is renewable is insufficient

less cost is insufficient

2

(ii) any **one** from:

- makes another source of energy available
- increases supply of electricity
- able to meet global demand
- less environmental damage
- reduces amount of other fuels used.

accept any sensible suggestion

accept a specific example

accept a specific example

1

(d) 12

*allow **1** mark for obtaining 3 half-lives*

2

[9]

Q5.

(a) (i) (nuclear) fission is the splitting of a (large atomic) nucleus

*do **not** accept particle/atom for nucleus*

1

(nuclear) fusion is the joining of (two atomic) nuclei (to form a larger one)

do not accept particles/atoms for nuclei

1

(ii) energy

accept heat/radiation/nuclear energy

accept gamma (radiation)

do not accept neutrons/neutrinos

1

(b) (i) uranium (–235)

accept U (–235)

ignore any numbers given with uranium

accept thorium

accept MOX (mixed oxide)

*do **not** accept hydrogen*

1

(ii) (same) number of protons

accept (same) atomic number

accept (same) positive charge

ignore reference to number of electrons

1

[5]

Q6.

(a) (i) 200 to 50

accept either order

1

(ii) 5.3

accept values between 5.2 and 5.4 inclusive

1

(iii) 5.3

accept values between 5.2 and 5.4 inclusive

or

their (a)(ii)

1

(b) (i) Make the conveyor belt move more slowly

1

(ii) lead

1

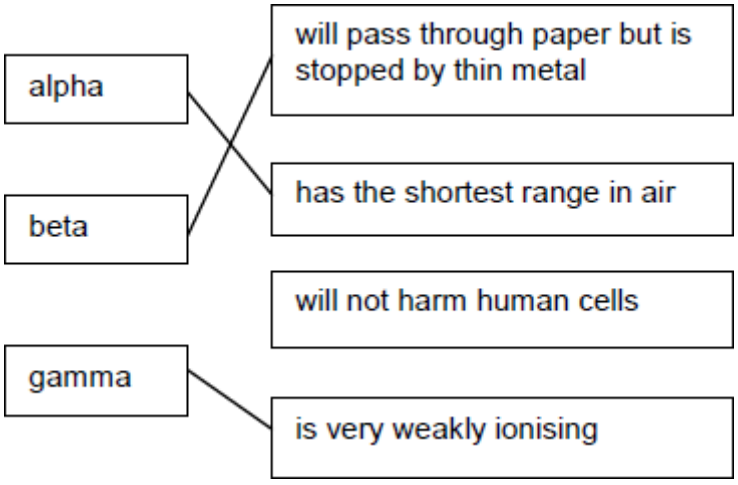
(c) Exposure increased the content of some types of vitamin.

1

[6]

Q7.

(a) 3 lines correct



*allow **1** mark for each correct line*

if more than one line is drawn from any type of radiation box then all of those lines are wrong

3

(b) Gamma radiation will pass through the body

1

(c) half

1

(d) protons

1

[6]

Q8.

(a) (i) **L**

1

(ii) **M**

1

(b) To make a smoke detector work.

1

(c) **40**

no tolerance

1

[4]