1 A scientist placed a radioactive source in front of a Geiger-Muller detector and measured the count rate every 20 minutes.

The table shows her data.

Time in minutes	Count rate in counts per minute	Corrected count rate in counts per minute
0	660	630
20	462	432
40	330	300
60	240	210
80	180	150
100	142	112

(a) The scientist corrects the count rate readings to allow for background radiation.

(i) State two sources of background radiation.

(2)

1 .....

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2 .....

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(ii) Describe how the scientist should measure the background radiation and correct the count rate readings.

(3)

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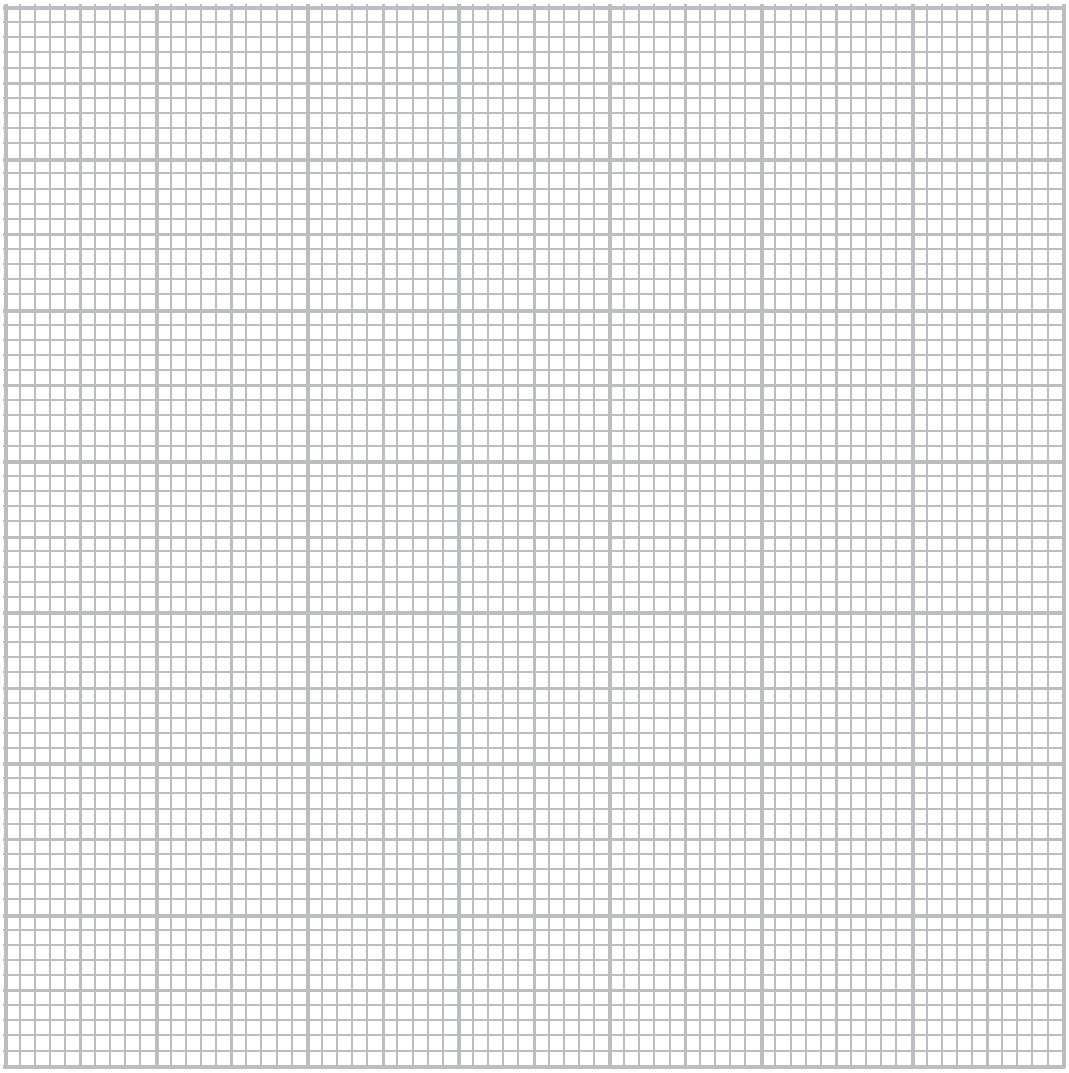
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(iii) Plot a graph of corrected count rate against time and draw the curve of best fit.

(5)



(iv) Use your graph to find the half-life of the radioactive source.

(2)

half-life = ... minutes

(b) The radioactive nuclei in the source emit beta radiation.

What effect does the emission of a beta particle have on a nucleus?

(2)

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(c) The scientist needs to reduce the risks when working with radioactive sources.

(i) Explain why radioactive sources can be dangerous.

(2)

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(ii) Describe how the risks of working with radioactive sources can be reduced.

(3)

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(Total for Question 1 = 19 marks)

2 Carbon-14 is a radioactive isotope of carbon.

It has the symbol

$$^{14}_{6}C$$

(a) (i) The number of **nucleons** in a carbon-14 nucleus is

(1)

☒ **A** 6

☒ **B** 8

☒ **C** 14

☒ **D** 20

(ii) The number of **neutrons** in a carbon-14 nucleus is

(1)

☒ **A** 6

☒ **B** 8

☒ **C** 14

☒ **D** 20

(iii) The number of **electrons** in a neutral carbon-14 atom is

(1)

☒ **A** 6

☒ **B** 8

☒ **C** 14

☒ **D** 20

(b) When carbon-14 decays it emits a beta particle.

What is a **beta particle**?

(1)

- ☒ **A** an electron
- ☒ **B** a neutron
- ☒ **C** a nucleus
- ☒ **D** a proton

(c) Carbon-14 has a half-life of 5700 years.

A sample of cloth contains 6.0 g of carbon-14.

What mass of carbon-14 will remain in the cloth after 11 400 years?

(1)

- ☒ **A** 1.5 g
- ☒ **B** 2.0 g
- ☒ **C** 2.5 g
- ☒ **D** 3.0 g

(d) The carbon atoms in the cloth are mainly atoms of carbon-12, a different isotope of carbon.

What are **isotopes**?

(2)

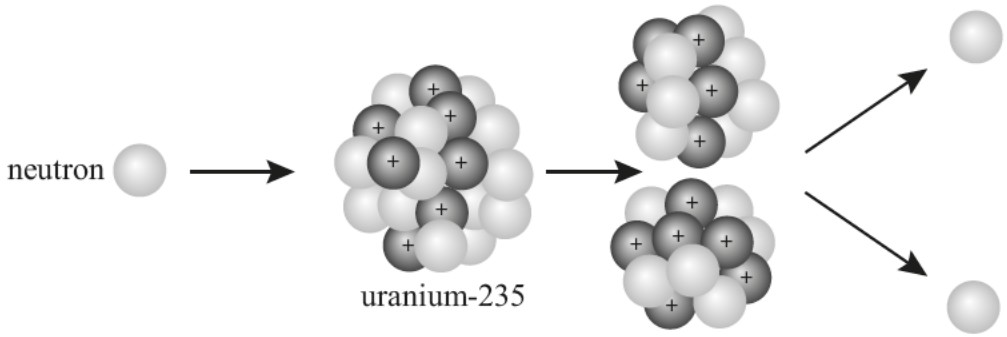
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(Total for Question 2 7 marks)

3 The diagram shows a neutron colliding with a nucleus of uranium-235, producing a number of products.



(a) Name the process shown in the diagram.

(1)

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(b) Explain how the process shown in the diagram can lead to a chain reaction.

(3)

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(c) This process releases energy.

Explain the form that this energy takes.

(2)

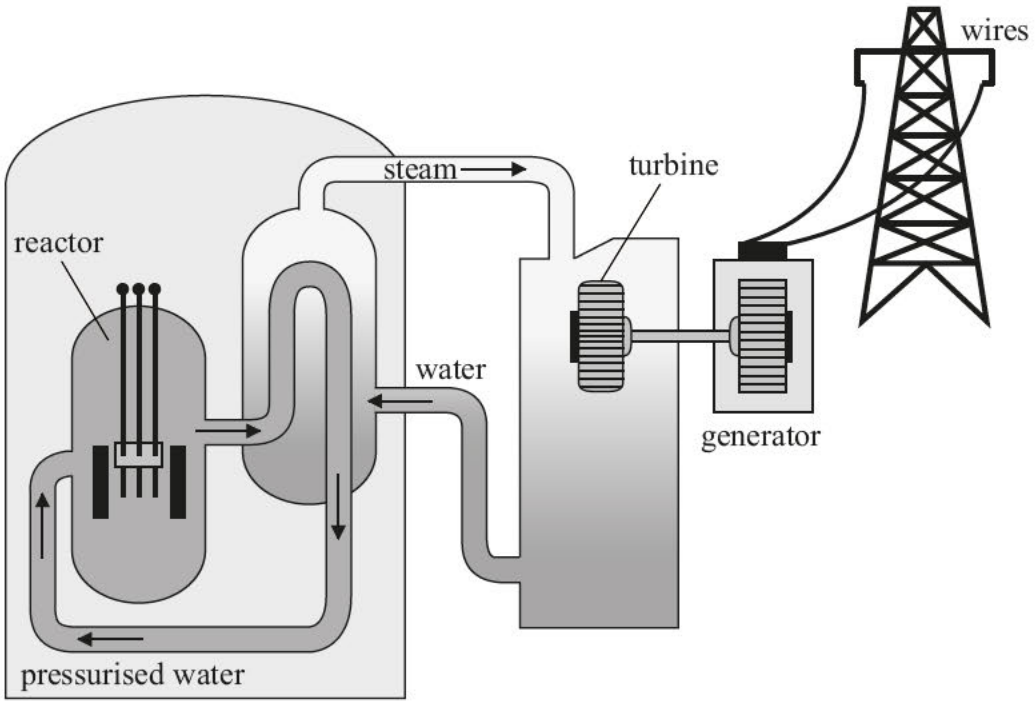
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(d) The energy released in this process can be used in a nuclear power station.



(i) The pressurised water acts as a coolant. It also acts as a moderator.

What is the purpose of a **moderator**?

(1)

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(ii) Complete the chart below to show the main useful energy transfers in a nuclear power station.

(4)

Heat energy released by reactor	..... energy in water/steam	..... energy in turbine	..... energy in generator	..... energy in wires

(Total for Question 3 11 marks)

4 A teacher shows his class how to investigate the half-life of a radioactive source.



(a) The readings from the counter need to be corrected for background radiation.

(i) State **one** source of background radiation.

(1)

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(ii) Describe the method the teacher should use to correct for background radiation.

(3)

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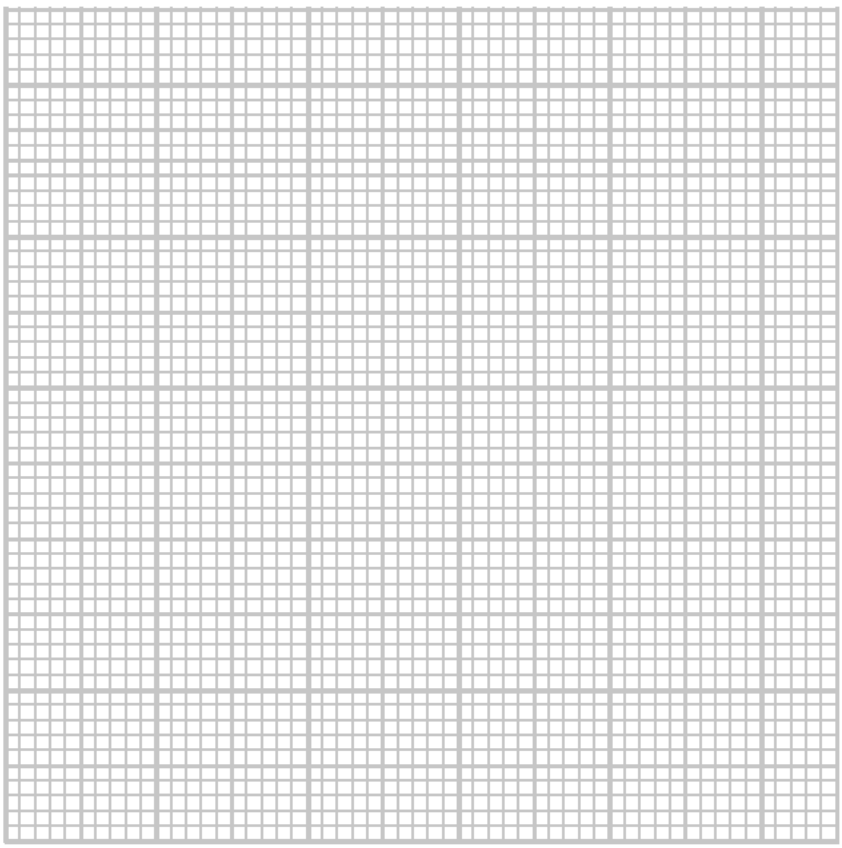
(b) Every half a minute, the teacher records the count rate.

He corrects for background radiation and produces this results table.

Time in minutes	Corrected count rate in Bq
0	49
0.5	30
1.0	24
1.5	18
2.0	15
2.5	11
3.0	10
3.5	9
4.0	5
4.5	6

(i) Draw a graph of corrected count rate against time for these results.

(5)



(ii) Use your graph to estimate the half-life for this material.

(1)

Half-life = ... minutes

(c) The isotope technetium-99 is a gamma emitter with a half-life of 6 hours. It is used as a radioactive tracer in medicine.

The technetium-99 is injected into a patient's bloodstream and carried around the body by the blood. The radiation it emits is detected outside the body.

Explain why technetium-99 is suitable for use as a tracer in this way.

(3)

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(Total for Question 4 = 13 marks)

5 John Leslie was a scientist who investigated heat and thermometers.

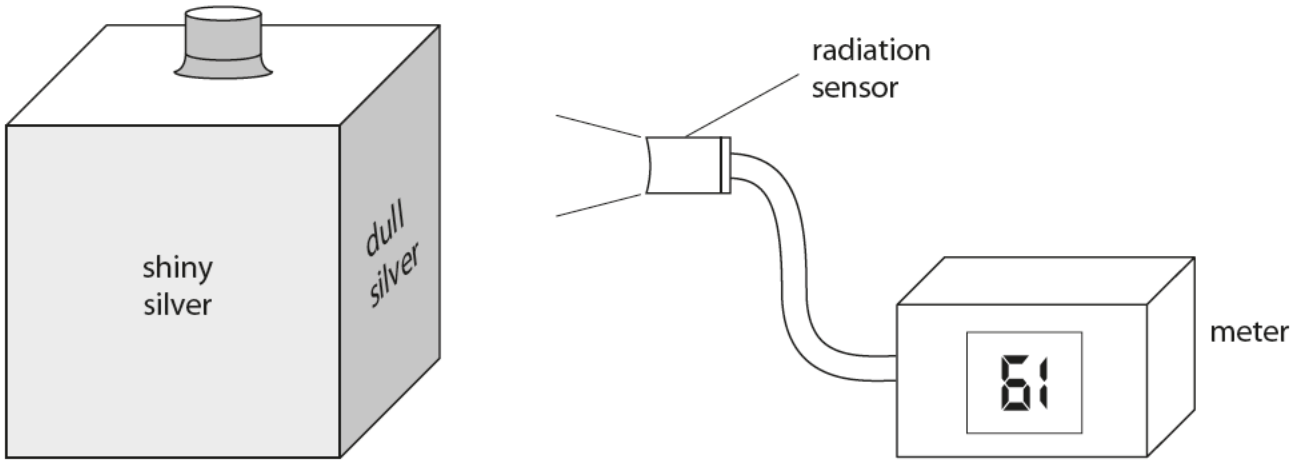
He experimented with a hollow metal cube. The cube had different surfaces on each side and was filled with boiling water.

(a) A student uses a modern version of Leslie's cube to investigate how the surface of a hot object affects the radiation emitted.

She uses a cube with four different vertical surfaces.

She fills the cube with boiling water so that the temperature of each surface is the same.

She uses the radiation sensor to measure the radiation emitted from each surface.



(i) The student's results are shown below.

Draw a line linking each surface colour with its correct meter reading.

One has been done for you.

(2)

surface colour	meter reading
shiny black	87
dull black	61
dull silver	70
shiny silver	47

(ii) The temperature of each surface is the same, but the radiation sensor gives a different reading for each surface.

What can you conclude from this?

(1)

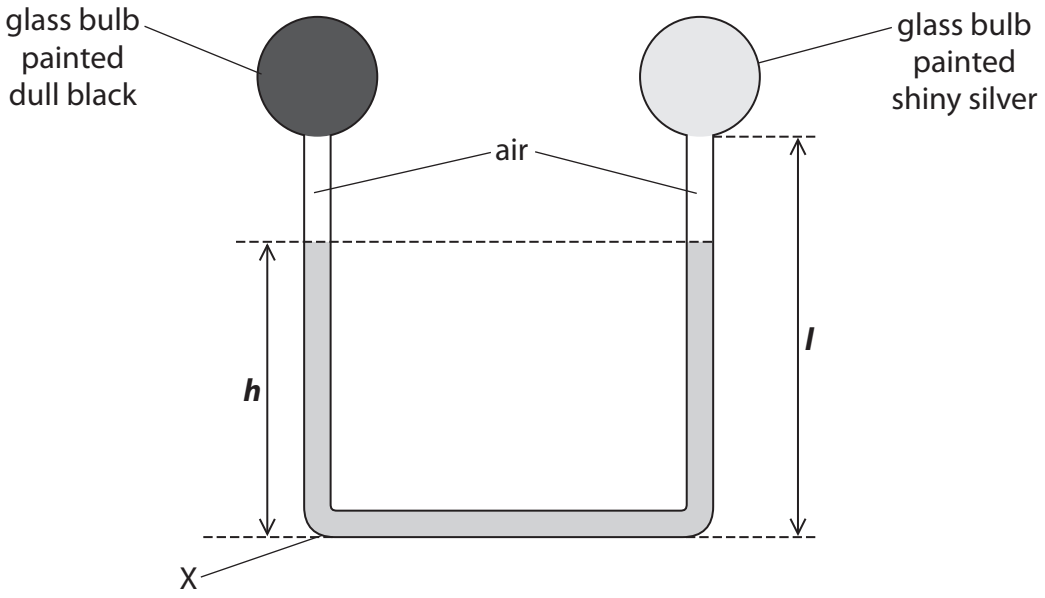
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(b) John Leslie also invented a differential thermometer.

The diagram shows this thermometer.

The bulbs are filled with air and are connected by a tube which contains liquid.



(i) State the equation linking pressure difference, height, density and *g*.

(1)

(ii) The density of the liquid is 1260 kg/m^3.

Calculate the pressure due to the liquid at X when the height, *h*, of the column of liquid is 0.25 m.

Give the unit.

(3)

pressure = ... unit .....

(iii) The student places the differential thermometer in bright sunlight for a few minutes.

She observes that the liquid level

- falls on the side of the dull black bulb making *h* lower
- rises on the side of the shiny silver bulb

Use ideas about heat transfer and particle theory to explain these observations.

(3)

(iv) Explain what would happen to the levels of the liquid if the student repeated the experiment with a denser liquid in the thermometer.

(2)

(v) Two students discuss the effect of changing the length, *l*, of the tube on both sides, while keeping the total volume of liquid constant.



If the length of the tube is increased, the thermometer can measure higher temperatures.



Changing the length of the tube will not make any difference to the range of temperatures that the thermometer can measure.

Explain which of these ideas is correct.

(2)

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(Total for Question 5 = 14 marks)