# Nuclear Radiation and Half Life

Questions

Name: _____

Class: _____

Date: _____

Time: **101 minutes**

Marks: **101 marks**

Comments:

**1** (a) (i) Describe the structure of alpha particles.

_____

_____

_____

_____

**(2)**

(ii) What are beta particles?

_____

_____

_____

**(1)**

(b) Describe how beta radiation is produced by a radioactive isotope.

_____

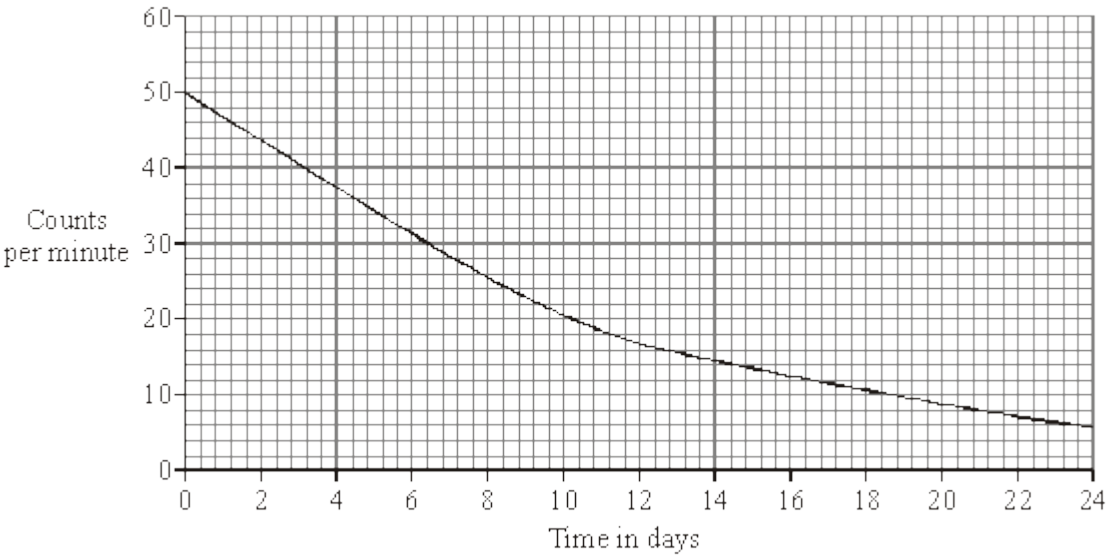
_____

**(1)**

**(Total 4 marks)**

**2** Iodine-131 ($^{131}I$) is a radioactive isotope used in medicine.

The graph shows how the count rate of a sample of iodine-131 changed over 24 days.



(i) Use the graph to calculate the half-life of iodine-131. To obtain full marks you should show clearly how you work out your answer.

Half-life _____ days

**(2)**

(ii) Iodine-131 is used to destroy cancer cells in the human thyroid gland.

Explain why the length of the half-life of iodine-131 is important in this use.

**(2)**

**(Total 4 marks)**

**3** In 2011 an earthquake caused severe damage to a nuclear power station in Japan.

The damage led to the release of large amounts of radioactive iodine-131 ($^{131}_{53}\mathrm{I}$) into the atmosphere.

(a) The table gives some information about an atom of iodine-131 ($^{131}_{53}\mathrm{I}$).

Complete the table.

| | |
|---|---|
| mass number | 131 |
| number of protons | 53 |
| number of neutrons | |

**(1)**

(b) Complete the sentence.

The number of protons in an atom is called the proton number or

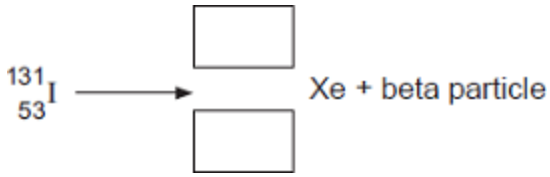
the _____ number.

**(1)**

(c) An atom of iodine-131 decays into an atom of xenon (Xe) by emitting a beta particle.

(i) The decay of iodine-131 can be represented by the equation below.

Complete the equation by writing the correct number in each of the **two** boxes.




**(2)**

(ii) A sample of rainwater contaminated with iodine-131 gives a count rate of 1200 counts per second.

Calculate how many days it will take for the count rate from the sample of rainwater to fall to 75 counts per second.

Half-life of iodine-131 = 8 days

Show clearly how you work out your answer.

_____

_____

_____ days

**(2)**

(iii) If people drink water contaminated with iodine-131, the iodine-131 builds up in the thyroid gland. This continues until the thyroid is saturated with iodine-131 and cannot absorb any more. The radiation emitted from the iodine-131 could cause cancer of the thyroid.

In Japan, people likely to be drinking water contaminated with iodine-131 were advised to take tablets containing a non-radioactive isotope of iodine.

Suggest why this advice was given.

_____

_____

_____

_____

**(2)**

**(Total 8 marks)**

**4** (a) Carbon has three naturally occurring isotopes. The isotope, carbon-14, is radioactive. An atom of carbon-14 decays by emitting a beta particle.

(i) Complete the following sentences.

The atoms of the three carbon isotopes are the same as each other because

_____

The atoms of the three carbon isotopes are different from each other because

_____

**(2)**

(ii) What is a beta particle and from what part of an atom is it emitted?

_____

_____

**(1)**

(b) Carbon-14 is constantly being made in the atmosphere, yet for most of the last million years, the amount of carbon-14 in the atmosphere has not changed.

How is this possible?

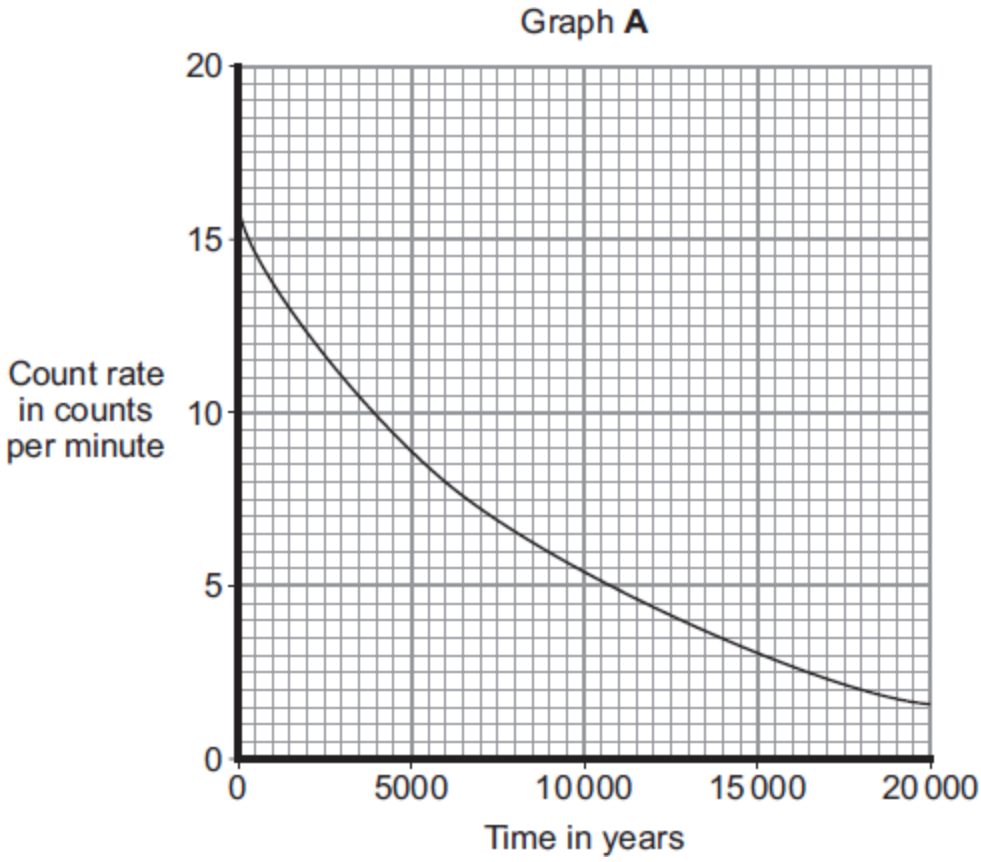
_____

_____

**(1)**

(c) Trees take in carbon-12 and carbon-14 from the atmosphere. After the tree dies, the proportion of carbon-14 that the tree contains decreases.

Graph **A** shows the decay curve for carbon-14.



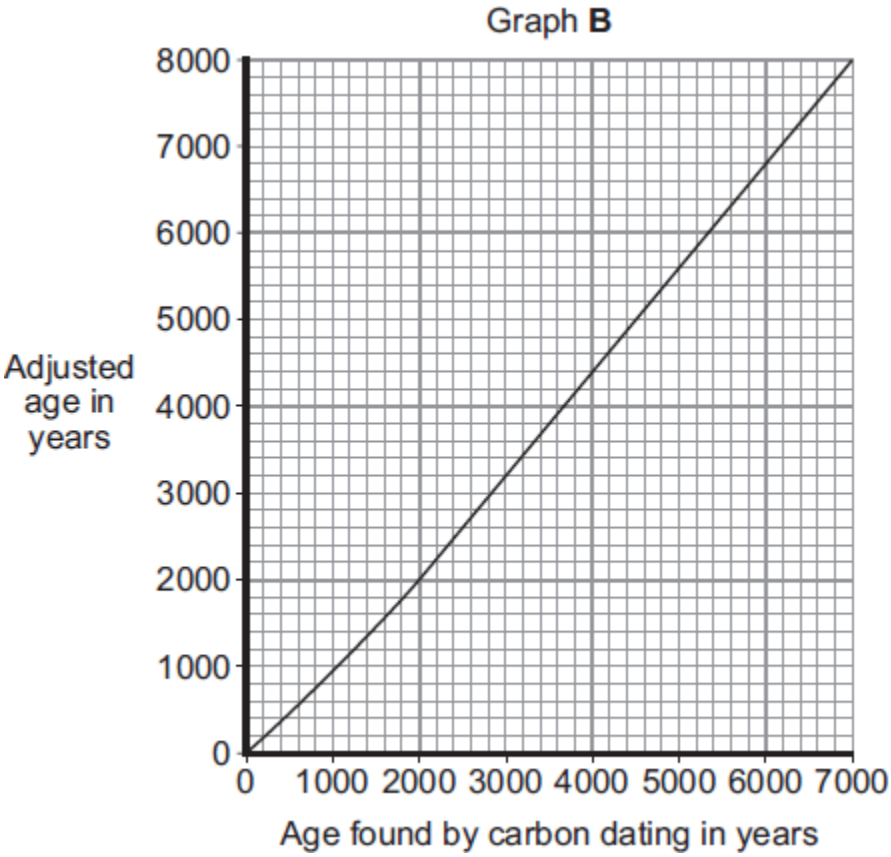

(i) Lake Cuicocha in Ecuador was formed after a volcanic eruption.
Carbon taken from a tree killed by the eruption was found to have a count rate of 10.5 counts per minute.
At the time of the eruption, the count rate would have been 16 counts per minute.

Use graph **A** to find the age of Lake Cuicocha.

Age of Lake Cuicocha = _____ years

**(1)**

(ii) Finding the age of organic matter by measuring the proportion of carbon-14 that it contains is called carbon dating. This technique relies on the ratio of carbon-14 to carbon-12 in the atmosphere remaining constant. However, this ratio is not constant so the age found by carbon dating needs to be adjusted.




Graph **B** is used to adjust the age of an object found by carbon dating.
The value obtained from graph **B** will be no more than 50 years different to the true age of the object.

Use graph **B** and the information above to find the maximum age that Lake Cuicocha could be.

Show clearly how you obtain your answer.

_____

_____

Maximum age of Lake Cuicocha = _____ years

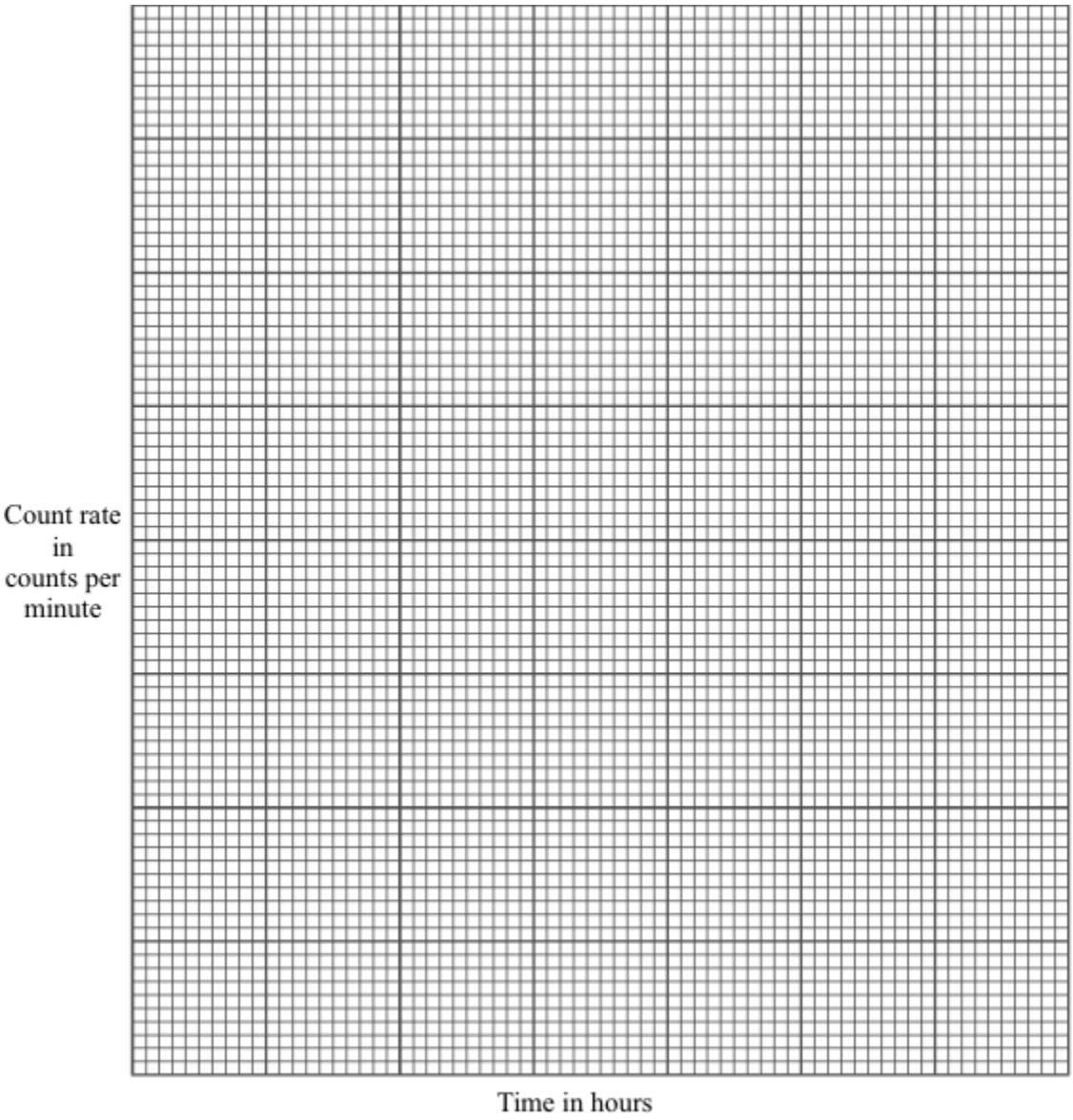
**(2)**

**(Total 7 marks)**

**5** The isotope of sodium with a mass number of 24 is radioactive. The following data were obtained in an experiment to find the half-life of sodium-24.

| Time in hours | Count rate in counts per minute |
|---|---|
| 0 | 1600 |
| 10 | 1000 |
| 20 | 600 |
| 30 | 400 |
| 40 | 300 |
| 50 | 150 |
| 60 | 100 |

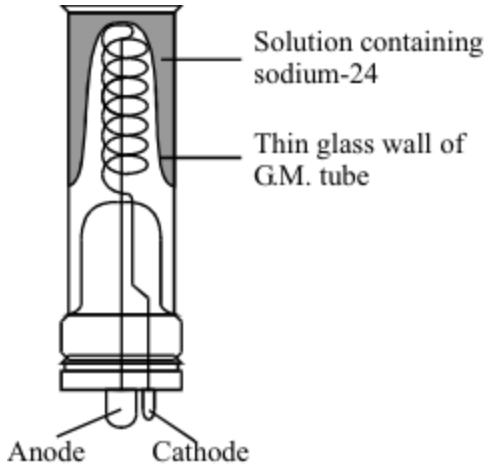
(a) Draw a graph of the results and find the half-life for the isotope. On the graph show how you obtain the half-life.




Half-life = _____ hours

**(4)**

(b) Sodium-24 decays by beta emission. The G.M. tube used in the experiment is shown in the diagram. Each beta particle which gets through the glass causes a tiny electric current to pass in the circuit connected to the counter.




(i) Why must the glass wall of the G.M. tube be very thin?

_____

_____

**(1)**

(ii) Why is this type of arrangement of no use if the radioactive decay is by alpha emission?

_____

_____

**(1)**

(c) Sodium chloride solution is known as saline. It is the liquid used in 'drips' for seriously-ill patients. Radioactive sodium chloride, containing the isotope sodium-24, can be used as a tracer to follow the movement of sodium ions through living organisms.

Give **one** advantage of using a sodium isotope with a half-life of a few hours compared to using an isotope with a half-life of:

(i) five years; _____

_____

**(1)**

(ii) five seconds. _____

_____

**(1)**

**(Total 8 marks)**

**6** (a) A radioactive source emits alpha (α), beta (β) and gamma (γ) radiation.

(i) Which **two** types of radiation will pass through a sheet of card?

_____

**(1)**

(ii) Which **two** types of radiation would be deflected by an electric field?

_____

**(1)**

(iii) Which type of radiation has the greatest range in air?

_____

**(1)**

(b) A student suggests that the radioactive source should be stored in a freezer at –20 °C. The student thinks that this would reduce the radiation emitted from the source.

Suggest why the student is wrong.

_____

_____

**(1)**

(c) Phosphorus-32 is a radioactive isotope that emits beta radiation.

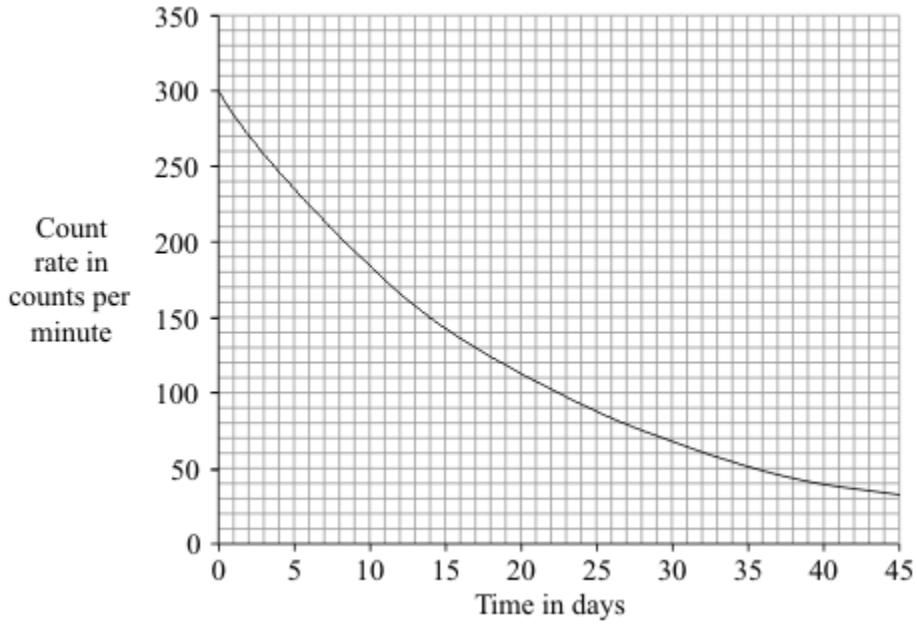
(i) How is an atom of phosphorus-32 different from an atom of the stable isotope phosphorus-31?

_____

_____

**(1)**

(ii) The graph shows how the count rate of a sample of phosphorus-32 changes with time.




Use the graph to calculate the half-life of phosphorus-32.

Show clearly how you used the graph to obtain your answer.

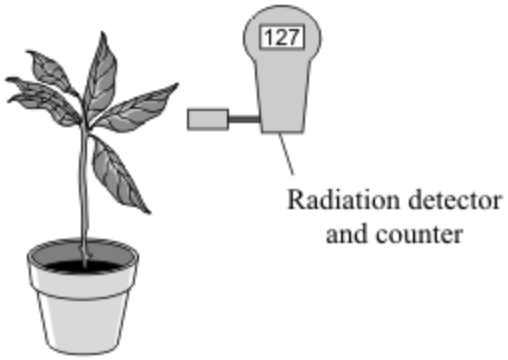
_____

_____

Half-life = _____ days

**(2)**

(iii) Plants use phosphorus compounds to grow. Watering the root system of a plant with a solution containing a phosphorus-32 compound can help scientists to understand the growth process.




Explain why phosphorus-32 is suitable for use as a tracer in this situation.

_____

_____

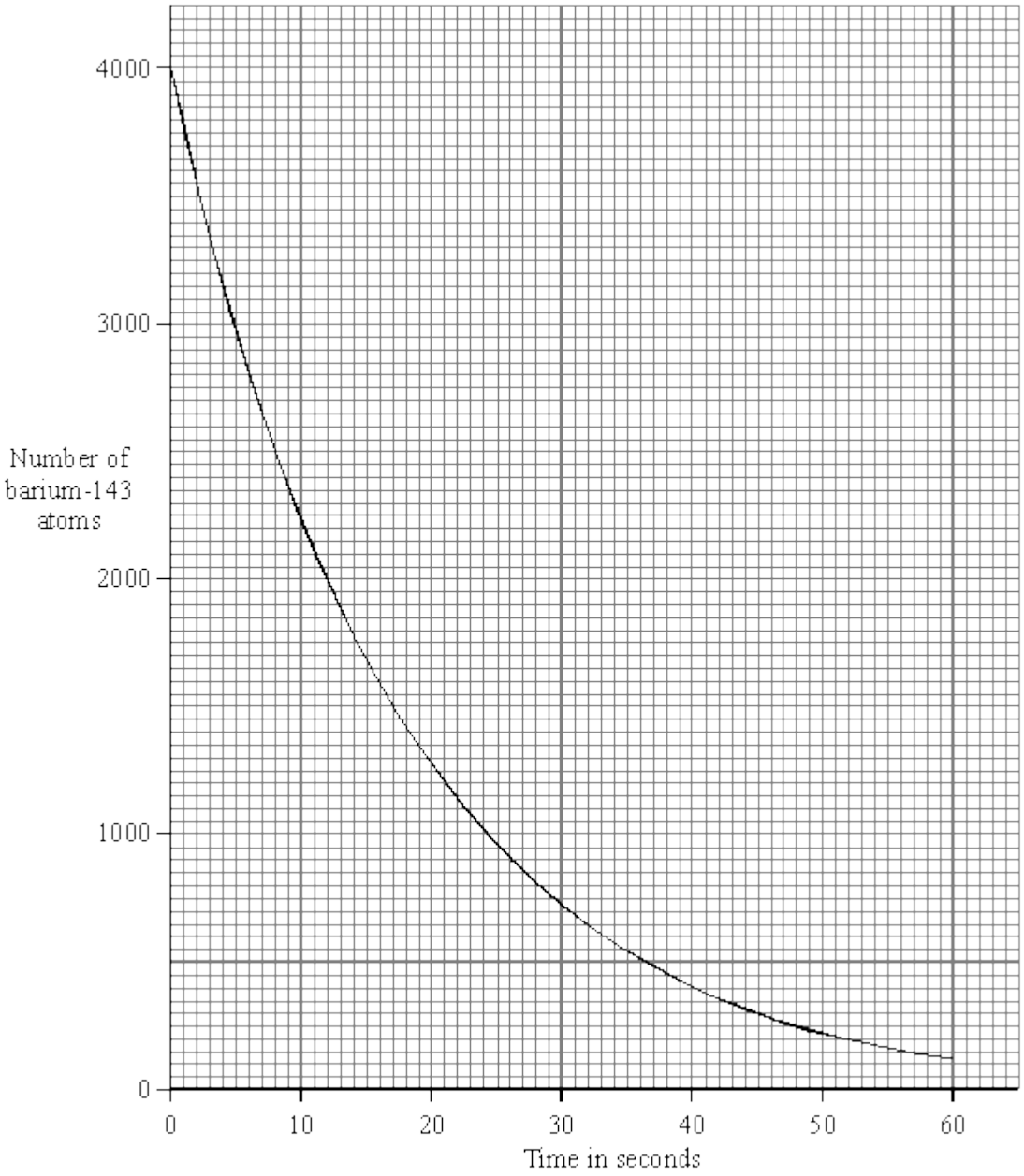
_____

_____

**(2)**

**(Total 9 marks)**

**7** (a) The graph shows how a sample of barium-143, a radioactive *isotope* with a short *half-life,* decays with time.




(i) What is meant by the term *isotope?*

_____

_____

**(1)**

(ii) What is meant by the term *half-life*?

_____

_____

**(1)**

(iii) Use the graph to find the half-life of barium-143.

Half-life = _____ seconds

**(1)**

(b) Humans take in the radioactive isotope carbon-14 from their food. After their death, the proportion of carbon-14 in their bones can be used to tell how long it is since they died. Carbon-14 has a half-life of 5700 years.

(i) A bone in a living human contains 80 units of carbon-14. An identical bone taken from a skeleton found in an ancient burial ground contains 5 units of carbon-14. Calculate the age of the skeleton. Show clearly how you work out your answer.

_____

_____

_____

Age of skeleton = _____ years

**(2)**

(ii) Why is carbon-14 unsuitable for dating a skeleton believed to be about 150 years old?

_____

_____

**(1)**

(c) The increased industrial use of radioactive materials is leading to increased amounts of radioactive waste. Some people suggest that radioactive liquid waste can be mixed with water and then safely dumped at sea. Do you agree with this suggestion? Explain the reason for your answer.

_____

_____

_____

_____

_____

_____

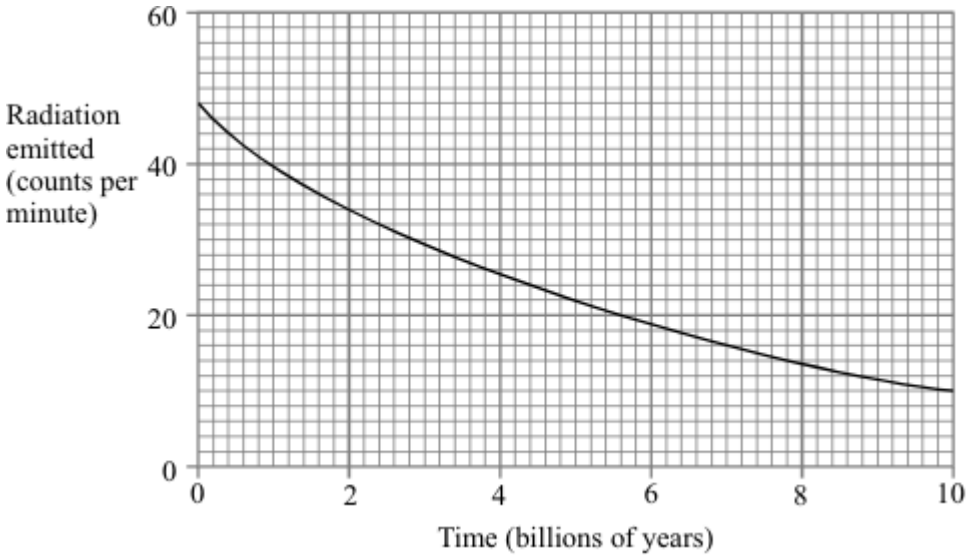
_____

_____

**(3)**

**(Total 9 marks)**

**8** The graph shows how the amount of radiation emitted by a sample of the radionuclide uranium 238 ($U^{238}$) changes as time passes.




(a) What is the half-life of uranium 238 ($U^{238}$)?
(You should show how you obtained your answer. You may do this on the graph if you wish.)

_____

_____

Answer _____

**(3)**

(b) What fraction (or percentage) of the uranium 238 ($U^{238}$) atoms will have decayed after 9 billion years?

_____

**(1)**

(c) Uranium 238 ($U^{238}$) decays through a long series of intermediate radionuclides to stable atoms of the isotope lead 206 (Pb).

A sample of igneous rock contains 3 atoms of uranium 238 ($U^{238}$) for every atom of lead 206 ($Pb^{206}$).

(i) The intermediate radionuclides are not important when estimating the age of the rock. Explain why.

_____

_____

**(1)**

(ii) Estimate the age of the rock.
(You should explain how you obtained your answer.)

_____

_____

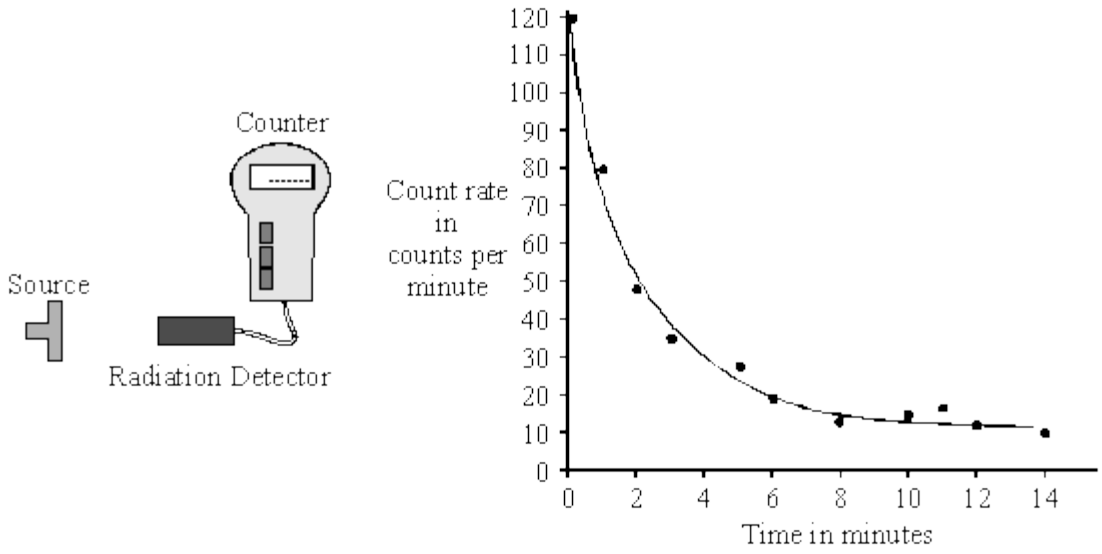
_____

Answer _____ billion years

**(3)**

**(Total 8 marks)**

**9** (a) A radiation detector and counter were used to detect and measure the radiation emitted from a weak source. The graph shows how the number of counts recorded in one minute changed with time.




(i) Even though the readings from the counter were accurately recorded, not all the points fit the smooth curve. What does this tell us about the process of radioactive decay?

_____

**(1)**

(ii) After ten minutes the number of counts recorded each minute is almost constant. Explain why.

_____

_____

_____

**(2)**

(b) The radioactive isotope sodium-24 injected into the bloodstream can be used to trace blood flow to the heart. Sodium-24 emits both *beta particles* and *gamma rays*.

(i) What is a *beta particle*?

_____

**(1)**

(ii) What is a *gamma ray*?

_____

_____

**(1)**

(iii) The count rate from a solution containing sodium-24 decreases from 584 counts per minute to 73 counts per minute in 45 hours. Calculate the half-life of sodium-2.2. Show clearly how you work out your answer.

_____

_____

_____

Half-life = _____ hours

**(3)**

(iv) Give **one** advantage of using sodium-24 to trace blood flow compared to using an isotope with a half-life of:

[A] ten years; _____

_____

**(1)**

[B] ten seconds. _____

_____

**(1)**

**(Total 10 marks)**

**10** Most elements have some *isotopes* which are *radioactive*.

(a) What is meant by the terms:

(i) *isotopes*

_____

_____

**(1)**

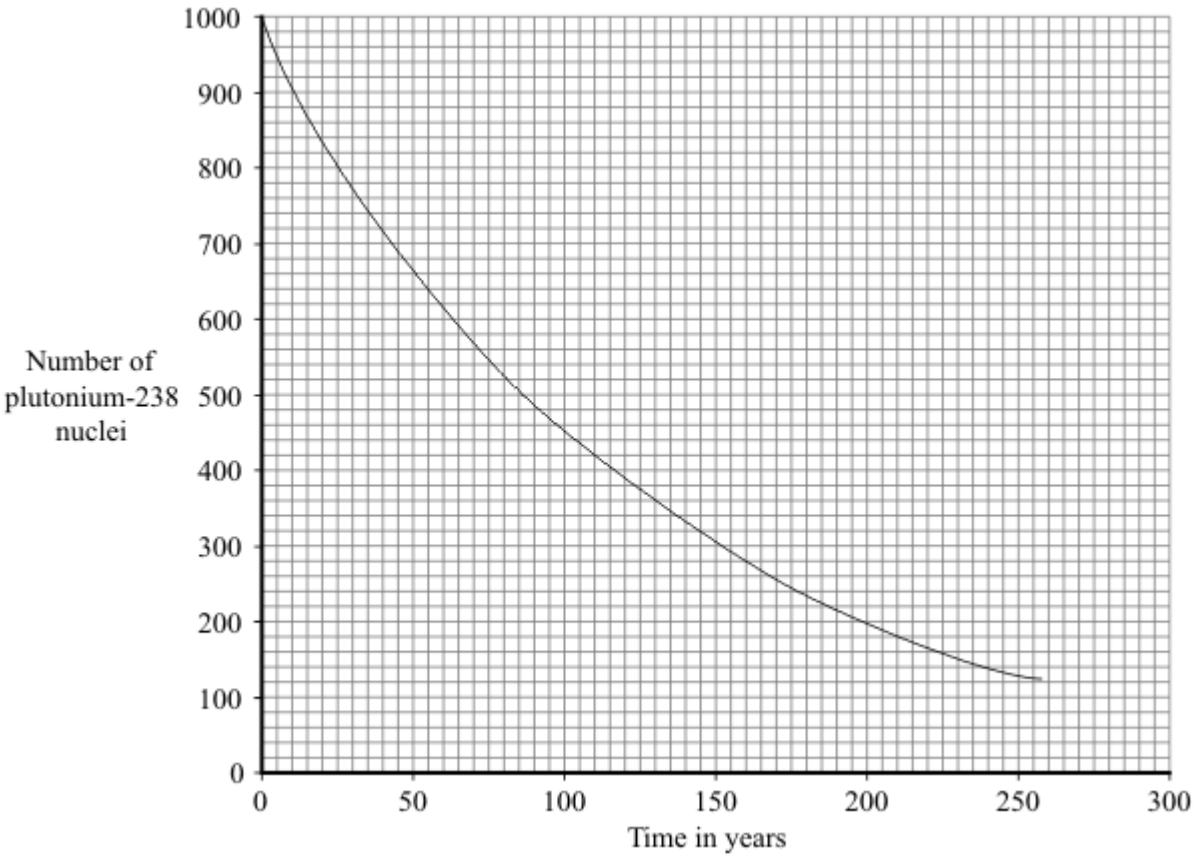
(ii) *radioactive*?

_____

_____

**(1)**

(b) The graph shows how the number of nuclei in a sample of the radioactive isotope plutonium-238 changes with time.




Use the graph to find the half-life of plutonium-238.

Show clearly on the graph how you obtain your answer.

Half-life = _____ years

**(2)**

(c) The Cassini spacecraft launched in 1997 took seven years to reach Saturn.

The electricity to power the instruments on board the spacecraft is generated using the heat produced from the decay of plutonium-238.

(i) Plutonium-238 decays by emitting alpha particles.

What is an alpha particle?

_____

**(1)**

(ii) During the 11 years that Cassini will orbit Saturn, the output from the generators will decrease.

Explain why.

_____

_____

_____

_____

**(2)**

(d) Plutonium-238 is highly dangerous. A tiny amount taken into the body is enough to kill a human.

(i) Plutonium-238 is unlikely to cause any harm if it is outside the body but is likely to kill if it is inside the body.

Explain why.

_____

_____

_____

_____

**(2)**

(ii) In 1964, a satellite powered by plutonium-238 was destroyed, causing the release of radioactive material into the atmosphere.

Suggest why some environmental groups protested about the launch of Cassini.

_____

_____

**(1)**

**(Total 10 marks)**

**11** Food irradiation is a process that exposes food to radiation. Irradiation can be used to kill the bacteria that cause food poisoning or to slow down the ripening of fresh fruit and vegetables. Frozen foods and food inside packaging can also be irradiated.

(a) The table gives information about five radioactive isotopes.

| Isotope | Half-life | Radiation emitted |
|---|---|---|
| Caesium-134 | 2.1 years | beta |
| Cobalt-60 | 5.3 years | gamma |
| Curium-242 | 160 days | alpha |
| Strontium-90 | 28 years | beta |
| Technetium-99 | 6 hours | gamma |

Which of these radioactive isotopes would be most suitable for irradiating food?

_____

Explain the reasons for your choice.

_____

_____

_____

_____

_____

**(3)**

(b) Many people think that food should not be irradiated. Consumer groups have said that they are worried about the nutritional value and safety of eating irradiated foods.

(i) Suggest **one** reason why some people may be concerned about the safety of eating irradiated food.

_____

_____

**(1)**

(ii) Independent scientific committees in several countries, including Sweden, Canada and the UK, have concluded that it is safe to eat irradiated food.

These scientific committees need to be independent from government influence.

Suggest why.

_____

_____

**(1)**

(iii) One group of scientists has compared the vitamin content of non-irradiated foods with irradiated foods.

The table below gives the data obtained for 1 kg of cooked chicken.

| Vitamin | Non-irradiated food in milligrams | Irradiated food 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 the data in the table, is it valid to conclude that irradiated food is less nutritional than non-irradiated food?

Explain your answer.

_____

_____

_____

_____

_____

**(2)**

(iv) In a restaurant, meals with ingredients that have been irradiated must be clearly identified on the menu.

It is important that people eating in a restaurant are given this information.

Suggest why.

_____

_____

**(1)**

(c) The isotope caesium-137 decays by emitting beta radiation.
Caesium-137 has a half-life of 30 years.

(i) What is a beta particle, and from which part of an atom is a beta particle emitted?

_____

_____

**(1)**

(ii) A sample containing caesium-137 has a count rate of 600 counts per minute.

Calculate how long it would take for the count rate from the sample to fall to 75 counts per minute.

Show clearly how you work out your answer.

_____

_____

_____

Time taken = _____ years

**(2)**

**(Total 11 marks)**

**12** (a) When an atom of thorium-232 decays, an alpha (α) particle is emitted from the nucleus.
An atom of radium is left behind.

An alpha particle consists of two protons and two neutrons.

We can represent this radioactive decay in a special kind of equation:

$$^{232}_{90}\text{Th} \longrightarrow {}^{4}_{2}\text{a} + {}^{228}_{88}\text{Ra}$$

228 ◄- - - number of nucleons (protons + neutrons)

88 ◄- - - number of protons

Thorium-228 is also radioactive.

Atoms of this isotope also decay by emitting an alpha particle and producing an isotope of radium.

Complete the equation for this decay.

$$^{228}_{90}\text{Th} \longrightarrow$$

**(4)**

(b) An atom of radium-228 decays by emitting a beta (β) particle from the nucleus.

A beta particle is in fact an electron (symbol $^{0}_{-1}\text{e}$).

The effect of this is to change a neutron into a proton.

An atom of actinium remains.

This type of decay can also be represented by an equation:

$$^{228}_{88}\text{Ra} \longrightarrow {}^{0}_{-1}\text{e} + {}^{228}_{89}\text{Ac}$$

228 ◄- - - number of nucleons (protons + neutrons)

89 ◄- - - number of protons

This isotope of actinium is radioactive.

An atom of actinium-228 also decays by emitting a beta particle.

An isotope of thorium is left behind.

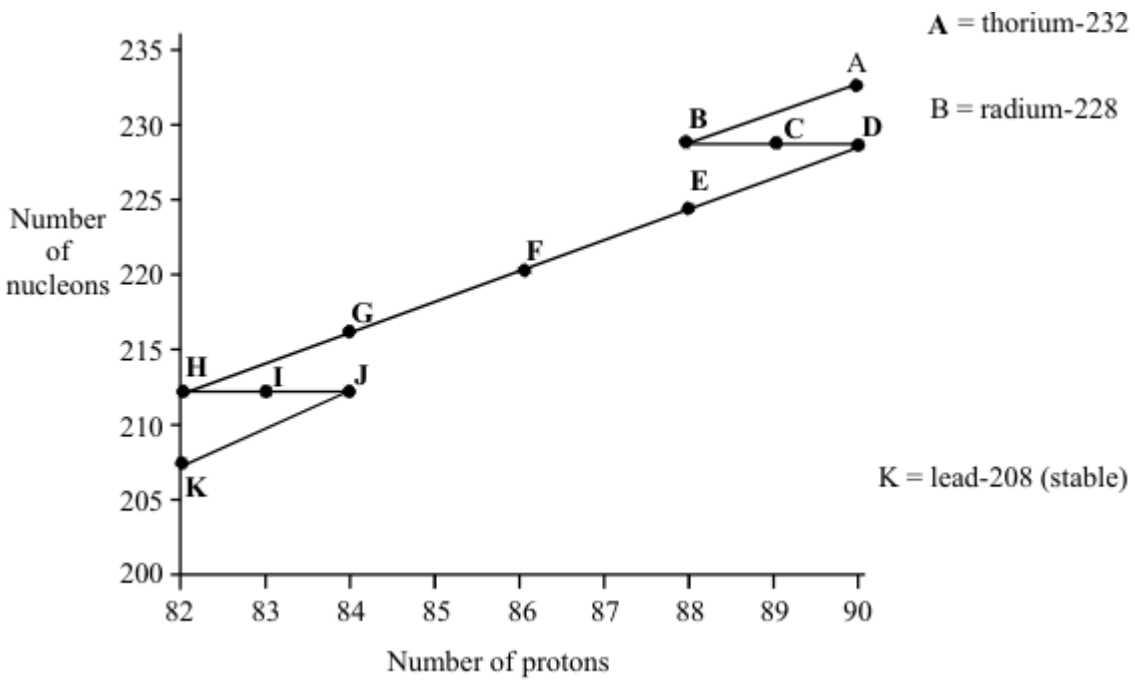
Complete the equation for this decay.

$$^{228}_{89}\text{Ac} \longrightarrow$$

**(4)**

(c) Thorium-232 eventually decays to the stable isotope lead-208.

All the steps in this process can be shown on a diagram.




(i) Complete the sentences:

During the decay from (A) to (B) a _____ particle is emitted.

During the decay from (B) to (C) a _____ particle is emitted.

During the decay from (E) to (F) a _____ particle is emitted.

During the decay from (I) to (J) a _____ particle is emitted.

**(2)**

(ii) The table shows how long it takes for half of the atoms of each isotope to decay.

| ISOTOPE | TIME FOR HALF TO DECAY |
|---|---|
| A | billions of years |
| B | 7 years |
| C | 6 years |
| D | 2 years |
| E | 4 days |
| F | 1 minute |
| G | 0.4 seconds |
| H | 10 hours |
| I | 1 hour |
| J | 0.3 microseconds |

A rock sample contains:

- many atoms of thorium-232
- even more atoms of lead-208
- hardly any atoms of any of the other isotopes shown on the diagram

Explain this as fully as you can.

_____

_____

_____

_____

_____

**(3)**

**(Total 13 marks)**