COLLATED QUESTIONS: RADIOACTIVE DECAY

2011(1): CARBON DATING

$^{14}_{6}$C has a half-life of 5 730 years. It decays by **beta** decay to nitrogen.

$^{14}_{6}$C dating is accurate to approximately 50 000 years.

A sample of dead organic tissue from an archaeology site has an activity of 0.014 counts per minute per gram carbon. Living organic tissue has an activity of 14 counts per minute per gram carbon. Complete the decay equation for $^{14}_{6}$C.

$$^{14}_{6}C \rightarrow \square + \square$$

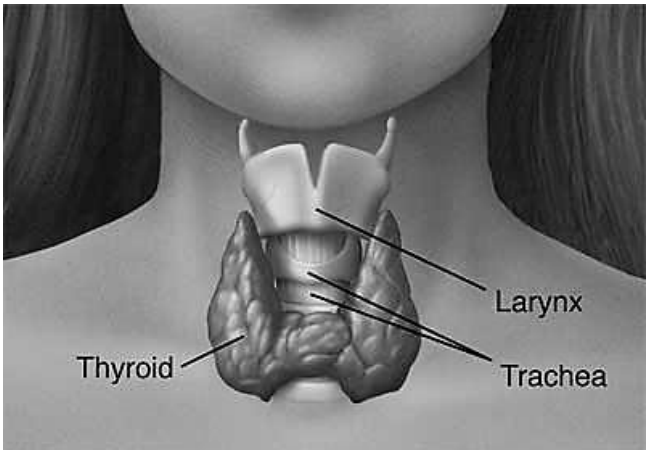
Calculate the age of the sample, and discuss the validity of the answer.

Your answer should include:

- The number of half lives
- The calculated age of the tissue sample
- How $^{14}_{6}$C enters organic tissue
- A discussion of why the calculated age of the tissue may be inaccurate.

2010(1): RADIOACTIVITY IN MEDICINE

Nearly all of the iodine (I) that humans consume in their diets goes to the thyroid gland. There the iodine is used to produce hormones.



^{123}I and ^{131}I are isotopes of iodine. Both are used in nuclear medicine. One is used as a tracer to determine how well the thyroid is functioning. The other is used in radiation therapy to destroy cancerous cells.

Isotope	½ life	Radiation emitted
^{123}I	13.2 hours	γ
^{131}I	8 days	β + γ

Discuss which isotope is used as a tracer and which is used in radiation therapy. Your answer should include:

- completing the equation below for the decay of iodine-131
- a comparison of the radiation emitted by each isotope
- a comparison of the half-life of each isotope.

$$^{131}_{53}\mathrm{I} \rightarrow \square^{\square}\mathrm{Xe} + \square^{\square}\square$$

2009(1): NUCLEAR DECAY

(a) The element americium (Am) is used in smoke detectors. It decays by emitting alpha radiation. Use the equation below to complete the table.

$$^{241}_{95}\mathrm{Am} \rightarrow {}^{a}_{b}\mathrm{Np} + {}^{c}_{d}\mathrm{X}$$

a =	c =
b =	d =
	X =

(b) A smoke alarm works by the alpha radiation ionising the air, which allows a steady small electric current to flow between two electrodes. When smoke enters the alarm, the radiation is absorbed by smoke particles, causing the electric current to fail, which sets off the alarm. Discuss why americium is used, rather than an element that emits β or γ radiation. In your discussion refer to each form of radiation in relation to: penetrating power ionising potential.

2008(1): Nuclear Decay

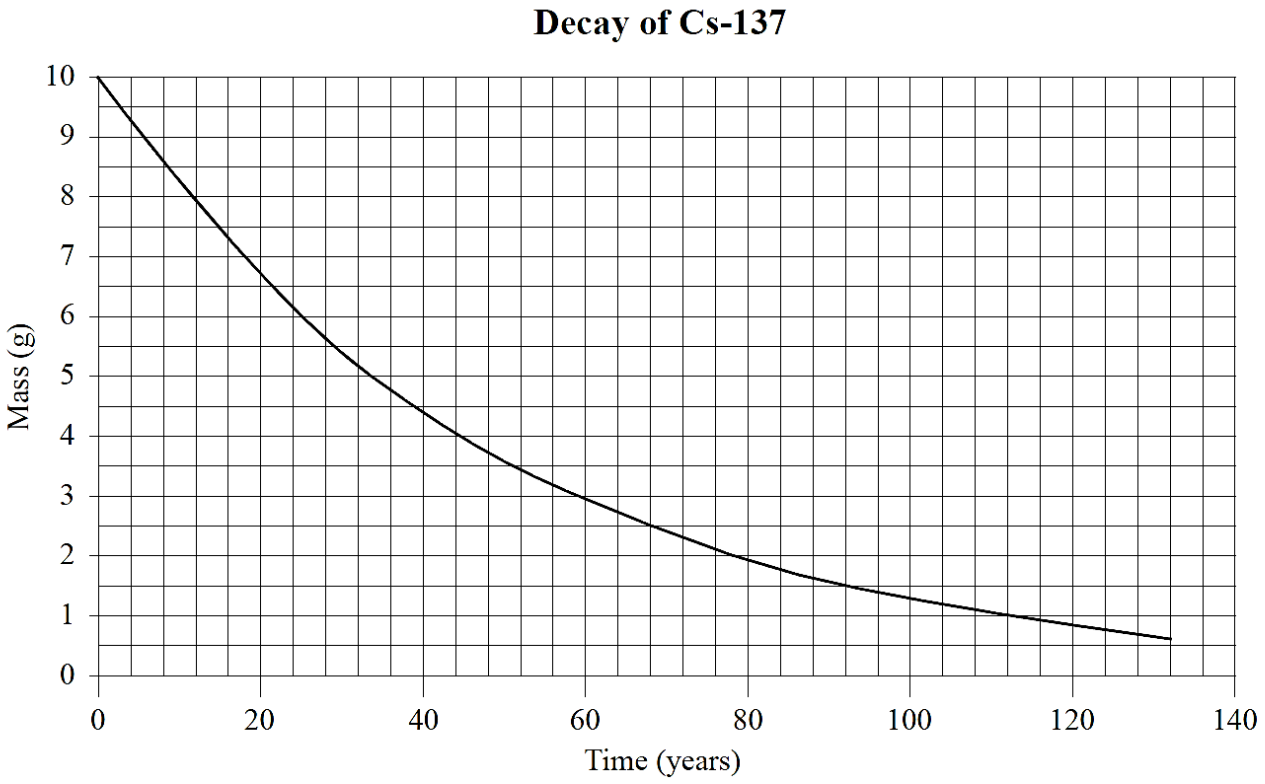
(a) Complete this decay equation for the radioactive decay of caesium-137 (Cs-137) to barium-137 (Ba-137)

$$^{137}_{55}Cs \rightarrow {}^{137}_{56}Ba + {}^{\quad}_{\quad}\_\_\_ + \gamma$$

(b) Caesium exists in a number of different isotopes. Give the number of protons and neutrons in these two common caesium isotopes:

$$^{137}_{55}Cs \text{ and } {}^{112}_{55}Cs$$

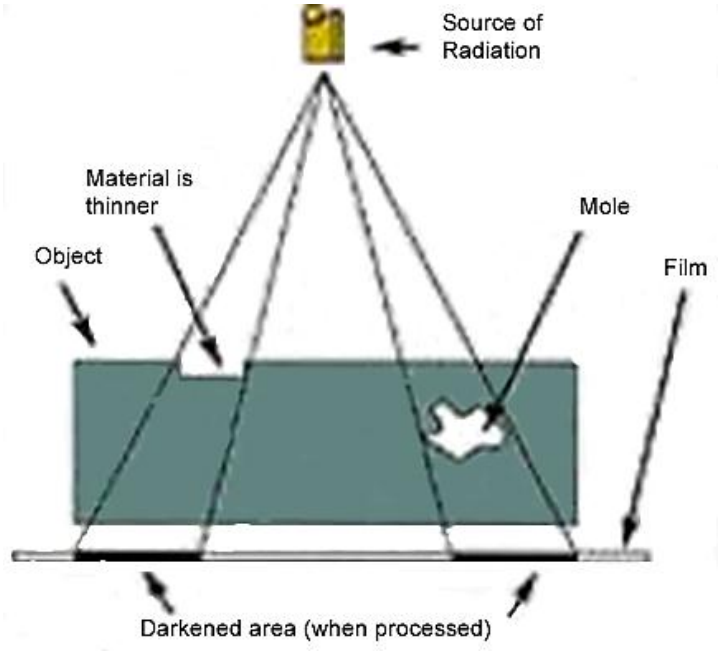
Using the graph below, show that the half-life of Cs-137 is 34 years.



(c) A sample of cs-137 has an initial activity of 12 000 mbq (mbq = mega becquerel). How long would it take for the activity of this sample to drop to 1500 mbq? Show your working.

(d) Alpha particles are a form of ionising radiation. Explain how alpha particles cause the formation of ions in the material they are moving through.

(e) One method of inspecting welded joints involves the use of radioactive decay. Welding is the process of attaching two pieces of metal together. A welder uses heat to melt the areas that are to be joined and then uses a molten filler material to help bond the metal pieces together. The radiation source is placed above the joint to be inspected and a film is placed below. The film when developed shows darker areas where it has been exposed to more radiation, as shown below.



One radiation source used is the radioisotope caesium-137 (cs-137). By referring to the above diagram, discuss why gamma rays are more suitable for inspecting welds than alpha or beta particles.

2007(2): RADIOACTIVE DECAY

Carbon-14 emits beta particles when it decays.

(a) Describe the changes in the **nucleus** of a radioactive atom when **beta** decay occurs.

(b) Complete the equation for the beta decay of carbon-14, using the information in the boxes below. Show all atomic and mass numbers.

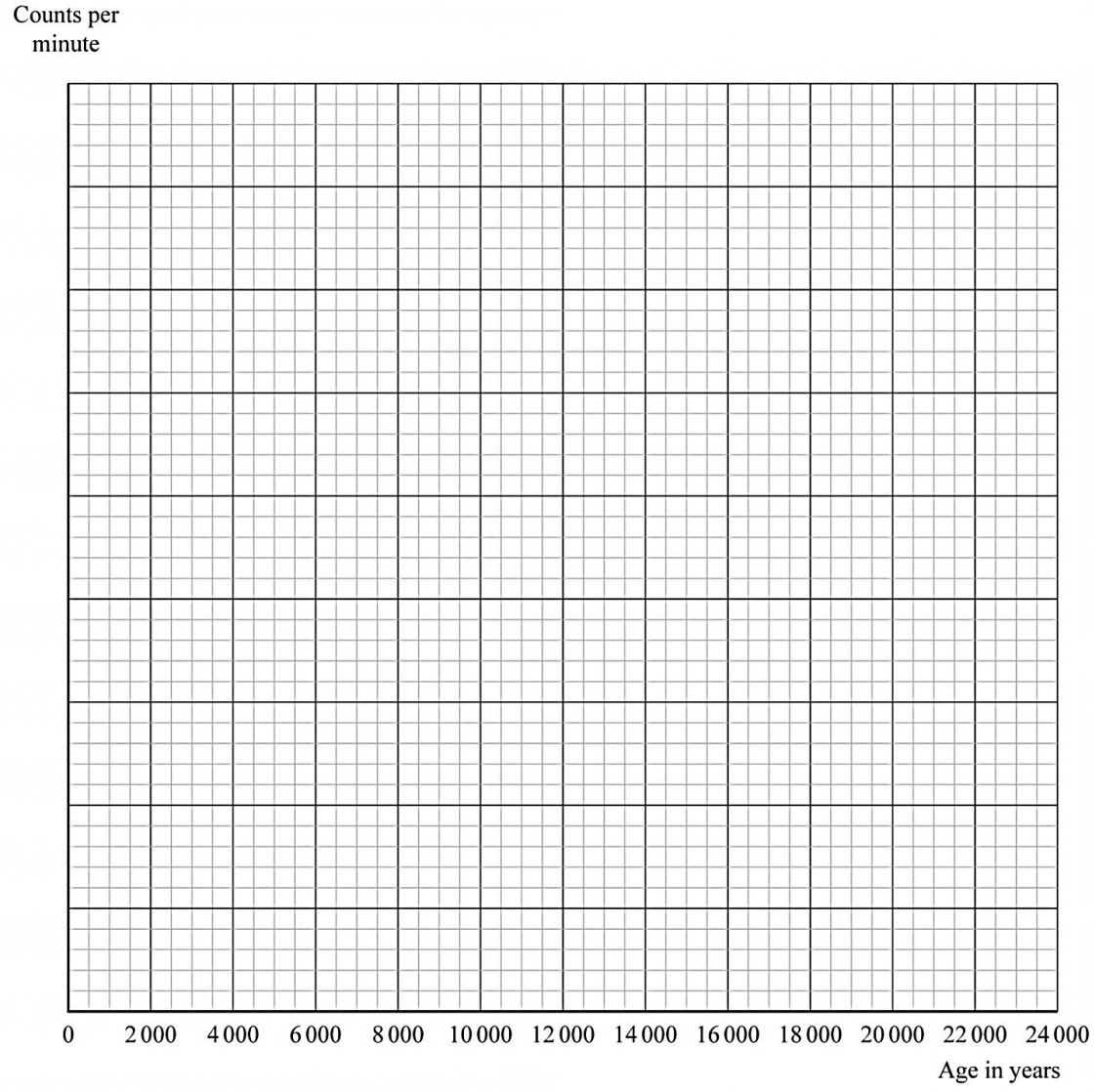
Beryllium Be 4	Boron B 5	Carbon C 6	Nitrogen N 7	Oxygen O 8	Fluorine F 9

$$^{14}_{6}C \rightarrow \square + \square$$

The half-life of carbon-14 is 5750 years.

(c) Describe what is meant by the term **half-life**.

Draw a decay graph on the grid below by plotting the change in count rate for carbon-14 over **three** half-lives. The initial sample has a count rate of 16 counts per minute.



The age of wood can be calculated by radiocarbon dating. When a dead kauri tree is dug up from a swamp, its age can be calculated by analysing the proportion of radioactive carbon-14 in a sample of the wood.

(d) A piece of kauri wood has a carbon-14 reading exactly one-sixteenth of that of a live tree. Calculate the age of the sample of kauri. Show your working.

(e) Only tiny amounts of carbon-14 are absorbed by a tree within its lifetime. Using radiocarbon dating, the age of some kauri trees that have been dug up has been found to be as old as 30 000 years. Explain why this may not be an accurate date.

2006(1): Radioactive decay

Radioactive isotopes that emit gamma rays are regularly used in medical diagnosis. One of the common radioactive isotopes used in medical imaging is technetium-99m.
Technetium-99m (Tc-99m) is an unstable form of technetium-99 (Tc-99). Tc-99m is generated by hospitals from molybdenum-99 (Mo-99) as it is needed.

(a) Complete the equation below for the decay of molybdenum-99 to form technetium-99m

$$^{99}_{42}\text{Mo} \longrightarrow \square + {}^{99\text{m}}_{43}\text{Tc}$$

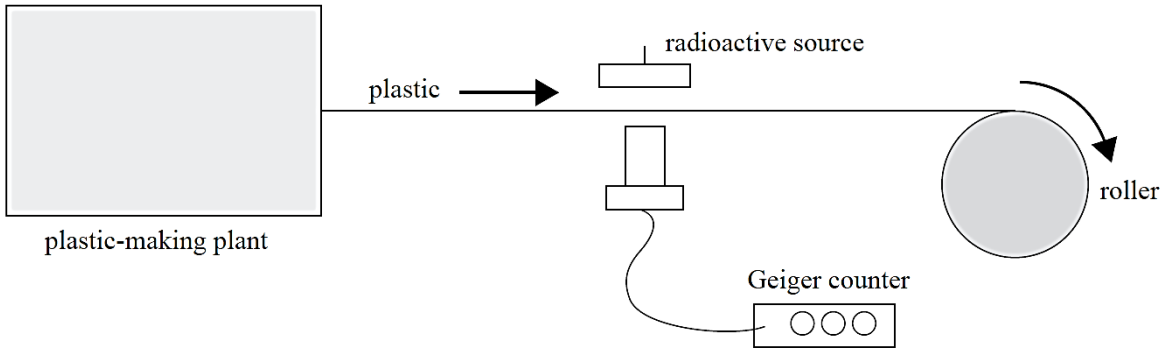
(b) How many protons and neutrons are contained in the nucleus of one Tc-99m atom?

Tc-99m forms Tc-99 by emission of gamma radiation. Tc-99m emits gamma radiation with a half-life of **6 hours**.

(c) After a patient is injected with a sample of Tc-99m, a Geiger counter initially records **12400 counts per second**. Calculate the expected count rate from the patient 24 hours later.
(d) Technetium exists in a number of isotopes other than Tc-99. Describe what is meant by the term **isotope**.
(e) Discuss why radioisotopes with **short half-lives** (like Tc-99m at 6 hours) are used for medical diagnosis. Include both **advantages** and **disadvantages** in your answer.

2005(2): RADIOACTIVE DECAY

In a plastic manufacturing factory a beta radiation source is used to measure the thickness of the plastic sheets produced. The setup is shown in the diagram.



(a) (i) Explain what happens to the **nucleus** of a radioactive atom when beta decay occurs.
(ii) Discuss why **beta particles** are more suitable than **alpha particles** or **gamma rays** for determining the thickness of plastic sheets.

(b) Strontium-90 can be used as a beta particle source. Use the table below to complete the equation for the decay of strontium-90.

Krypton **Kr** 36	Rubidium **Rb** 37	Strontium **Sr** 38	Yttrium **Y** 39	Zirconium **Zr** 40	Niobium **Nb** 41

$$^{90}_{38}\mathrm{Sr} \rightarrow \square + \square$$

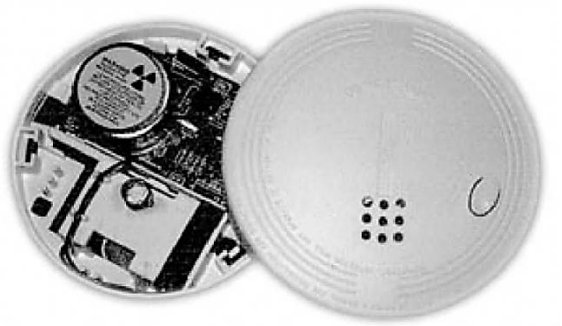
(c) The half-life of strontium-90 is 28 years. The radioactive source contains two grams of strontium-90. Draw a decay graph on the grid to show how the mass of strontium-90 changes over three half-lives.

(d) Gamma rays, another form of radioactive decay, have several uses. Describe one use of gamma rays.

(e) A commonly used gamma ray has a wavelength of 3.0 x10^{-12} m. Calculate its **frequency**. Show all working. The speed of light is 3.0 x10^{8} ms^{-1}.

2004(3): RADIOACTIVE DECAY

(a) A common smoke detector used in homes contains a radioactive material called americium-241.



The radioactive material decays, releasing radiation that ionises the air inside the smoke detector. The following equation shows the decay of americium-241.

$$^{241}_{95}\mathrm{Am} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{x}_{y}\mathrm{Np} + \mathrm{energy}$$

(i) State the values of *x* and *y* in the above equation.

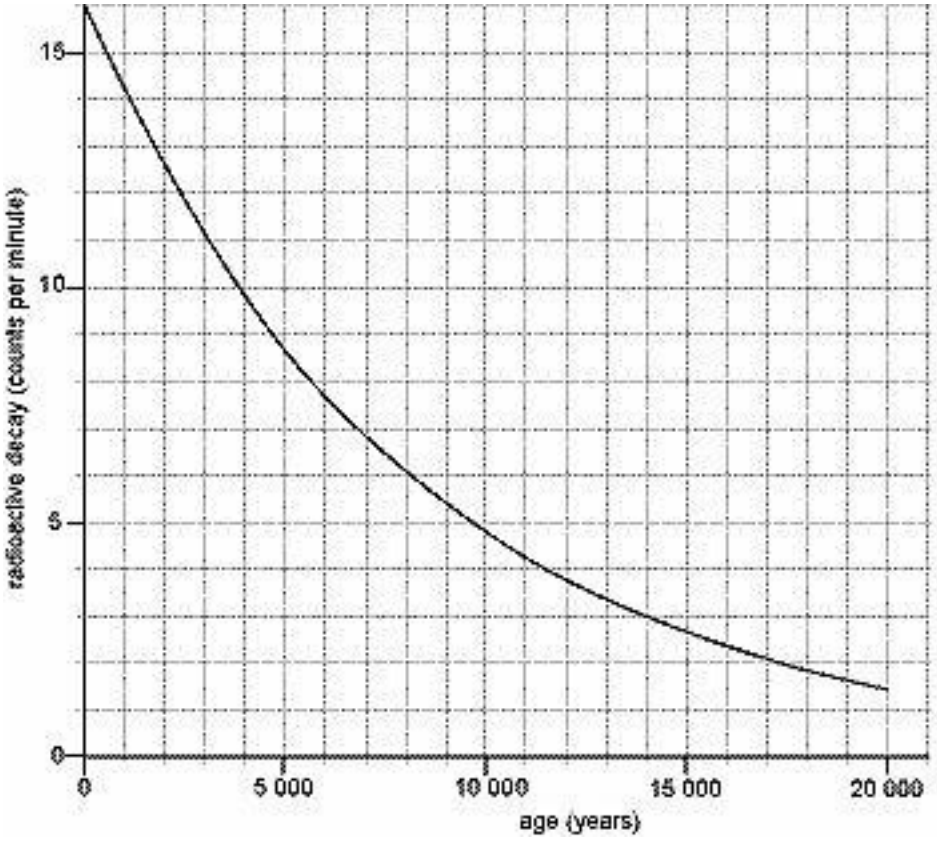
(ii) Explain why the charged particles used in the smoke detector are not harmful to humans unless ingested, ie taken internally.

(iii) Discuss how $^{4}_{2}\mathrm{He}$ ionises the air inside the smoke detector.

(b) Carbon Dating: Fossils are dated using the radioactive decay of carbon-14. Carbon-14 decays with a half-life of 5 730 years.

(i) Describe what is meant by the term **half-life**.

The following graph shows how the radioactivity of 1.0 g of processed carbon decreases.



(ii) 1.0 g of a similarly processed sample of carbon obtained from a fossil had an activity of 5.0 counts per minute. Use the graph to estimate the age of the fossil. Give the appropriate unit.

The half-life of an unknown material was investigated using a Geiger counter. The initial count rate was 156 per second. After 7 minutes the count rate fell to 39 per second.

(iii) Calculate the half-life of the material.

(iv) Explain why it is not possible to predict when a particular atom in a radioactive sample will decay.