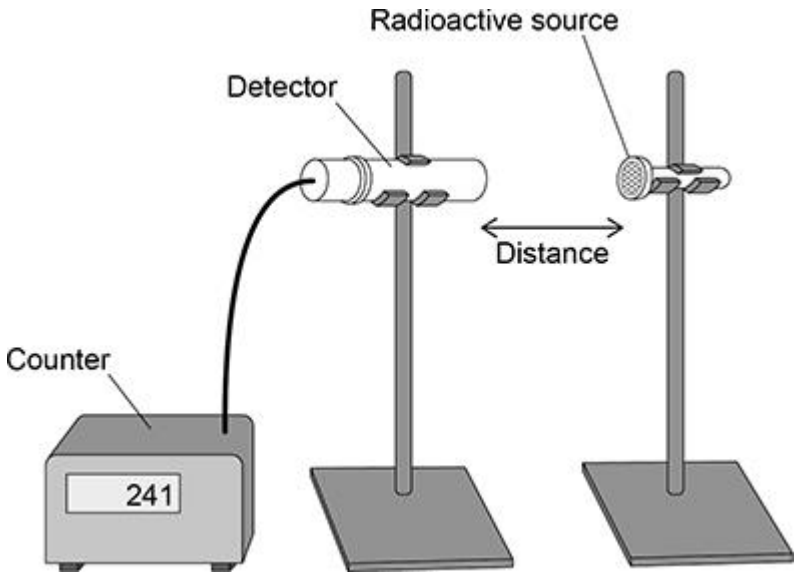
Questions are for both separate science and combined science students unless indicated in the question

Q1.

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.

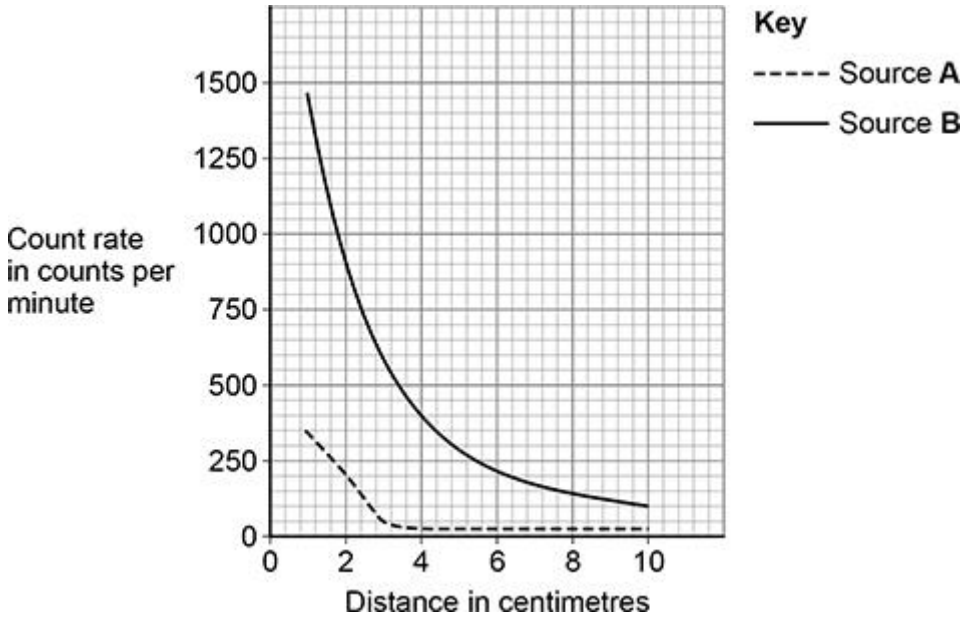
Figure 1



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.

Radiation from Source A travels ~ 3 cm in air, after which the count rate decreases to background radiation, because Alpha (α) radiation has a short range in air

(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**.

Use an aluminium sheet, which beta (β) radiation will not penetrate, but gamma (γ) will.

(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.

Increase distance between source and teacher.

(1)

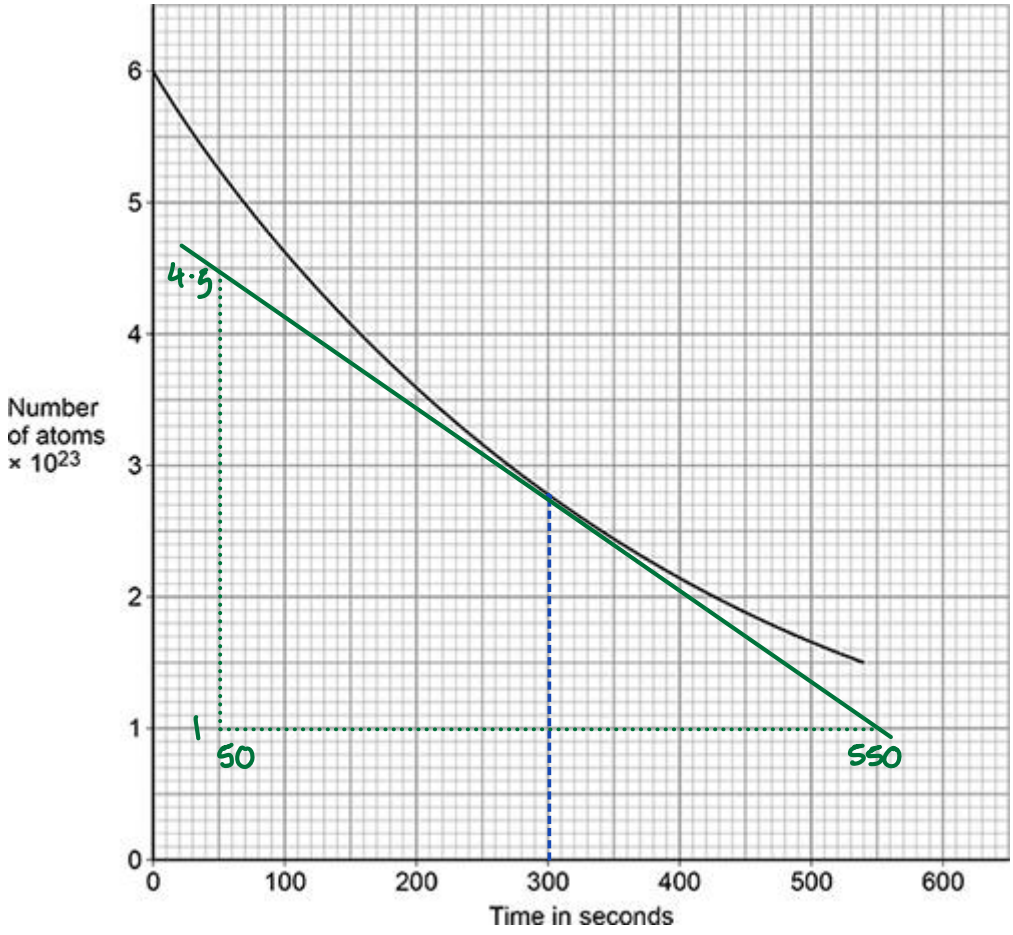
(d) Suggest **one** safety precaution that the teacher would have taken to avoid becoming contaminated.

Wear a lab coat and gloves.

(1)

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

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.

Rate = Gradient of tangent at 300 s:

Gradient = $\frac{\text{change in } y}{\text{change in } x} = \frac{(1 - 4{\cdot}5) \times 10^{23}}{550 - 50}$

$= -7 \times 10^{20}$ rate $= 7 \times 10^{20}$ atoms per sec.

Activity = 7×10^{20} Unit Bq

(4)

(Total 11 marks)

Activity measured in: decays per second or Becquerel (Bq)

N.B. Even though the gradient slopes down and is negative, the rate at which the nuclei are decaying is positive.

Q2.

Some isotopes emit nuclear radiation.

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

Compare the structure of an atom of carbon-14 with the structure of an atom of carbon-12.

Similarities:

C-12 and C-14 have same number of protons thus, same number of electrons and same Atomic Number

Differences:

C-12 and C-14 have different number of neutrons and hence masses

(3)

(b) Carbon-14 is a radioactive isotope.

Carbon-14 has a half-life of 5700 years.

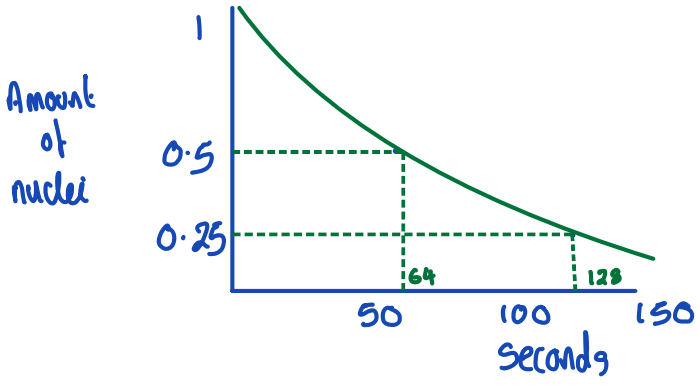
What does 'a half-life of 5700 years' mean?

The time it takes for the number of nuclei in a radioactive sample to halve (5700 years for C-14)

(1)

The table below gives the half-life of some other radioactive isotopes.

Isotope	Half-life in seconds
Nitrogen-18	0.62
Nitrogen-17	4.17
Fluorine-17	64.37
Fluorine-18	6584.34



(c) A sample of fluorine-17 has an activity that is one quarter of its original activity.

Calculate the age of the sample of fluorine-17.

1 $\xrightarrow{t_{1/2}}$ ½ $\xrightarrow{t_{1/2}}$ ¼ = 2 halflives.

$t_{1/2}$ for F-17 = 64.37 s

time to decay to ¼ original = 64.37 × 2 = 128.74

Age = 128.74 s

(2)

(d) All of the isotopes in the table above emit beta radiation.

Explain which isotope would cause the biggest risk to a person's health based only on the half-life of each isotope. **(Physics only)**

The shorter the half-life, the greater the activity. The greater the activity, the more radiation emitted per second.

So greatest dose of radiation absorbed, per second and greatest risk.

Nitrogen-18 has the shortest half-life of 0.62 s

(3)

(e) People who work in the nuclear power industry need to be aware of irradiation and contamination.

Describe the difference between irradiation and contamination.

Irradiation: Exposure of a person or object to radiation.

Contamination: Unwanted presence of radioactive material on a person or object.

(2)

(f) Give **one** health risk to a person working close to a source of nuclear radiation.

Cancer (radiation poisoning etc.)

(1)

(g) Workers in nuclear power stations are monitored to check the radiation they emit.

A worker stands 1 cm away from a radiation detector.

The amount of radiation the worker emits is recorded. **(HT only) (Physics only)**

Explain why the worker needs to stand close to the radiation detector.

Some radioactive materials emit alpha (α) radiation which has a very short range in air. Needs to stand close so any α is recorded.

(2)

(h) Workers in the nuclear power industry are exposed to nuclear radiation.

Pilots on aircraft are exposed to cosmic radiation from space.

daily dose caused by working in a nuclear power station = 0.00050 mSv

hourly dose from cosmic rays to a pilot while flying = 0.0030 mSv

Calculate the number of days it takes for a nuclear power station worker to receive the same dose as a pilot flying for 24 hours. **(HT only) (Physics only)**

Pilot's dose = 0·003 mSv per hour

= 0·003 mSv × 24

= 0·072 mSv.

Worker's dose = 0·0005 mSv per day

No. equivalent days = $\frac{0·072}{0·0005}$ = 144 days

Number of days = 144

(3)

(Total 17 marks)

Q3.

Alpha particles, beta particles and gamma rays are types of nuclear radiation.

(a) What does an alpha particle consist of?

2 protons and 2 neutrons.

(1)

(b) A krypton (Kr) nucleus decays into a rubidium (Rb) nucleus by emitting a beta particle.

Complete the nuclear equation for this decay by writing the missing number in each box.

85+0 = 85

$$\boxed{85}_{36}\mathrm{Kr} \longrightarrow {}^{85}_{\boxed{37}}\mathrm{Rb} + {}^{0}_{-1}\mathrm{e}$$

37-1 = 36

(2)

(c) Internal contamination of the human body means radioactive material is inside the human body.

Explain how the risk from internal contamination is different to the risk from external irradiation by a source of alpha radiation. **(HT only)**

Alpha radiation has a low penetrating ability, so is stopped by skin, and so is low risk

Internally, Alpha radiation is absorbed by living tissue/organs.
As Alpha radiation is highly ionising, internal contamination will cause greater risk of harm to cells.

(5)

(Total 8 marks)