This is a Class 1 exam

Lebanon Evangelical School
for Boys and Girls
Loueizeh - Baabda

Stage Exam 04

27MAR2023

Do NOT write in this box. Your MARK will be placed here.

Subject :	A Level : Physics 2 : RB
Class :	12A
Teacher :	Dr Ruth Brett
Duration :	1 hour

You should have a physics formula booklet

Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

- Do not open this paper until the teacher in charge instructs you to do so.
- The most important thing to remember in taking an exam is NEVER PANIC.
- If you are caught cheating in this exam, you will be awarded zero for ALL exams that are taken on this day.

Q1. A radiation detector is placed near a radioactive source and measures the count rate from the source. Different absorbers are placed between the detector and the source. The results are shown in the table.

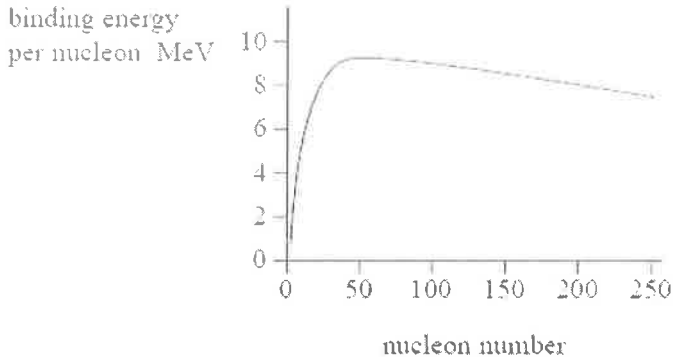
Absorber	Corrected count rate / s^{-1}
None	850
Paper	850
Aluminium foil	150
Lead sheet	20

Which of the following is emitted by the source?

- ☐ **A** α-radiation only
- ☐ **B** β-radiation only
- ☐ **C** α-radiation and β-radiation
- ☐ **D** β-radiation and γ-radiation

(Total for question = 1 mark)

Q2. The graph shows how the binding energy per nucleon varies with nucleon number.

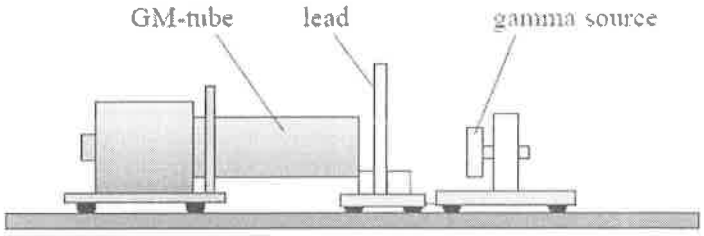


Which of the following conclusions is supported by this graph?

- ☐ **A** The total energy released is greatest when two low mass nuclei fuse.
- ☐ **B** The total energy absorbed is greatest when two low mass nuclei fuse.
- ☐ **C** The total energy released is greatest when a massive nucleus undergoes fission.
- ☐ **D** The total energy absorbed is greatest when a massive nucleus undergoes fission.

(Total for question = 1 mark)

Q3. A student used a GM-tube to measure the background count for 10 minutes. She then used the apparatus below to measure the count for 2 minutes for different thicknesses of lead.



To correct the readings for the effect of background radiation she should

- ☐ **A** add the background count to each count.
- ☐ **B** add the background count rate to each count rate.
- ☐ **C** subtract the background count from each count.
- ☐ **D** subtract the background count rate from each count rate.

(Total for question = 1 mark)

Q4. The student in Q3 discovered that a thickness of 1.0 cm of lead reduced the corrected count rate to 50% of its initial value with no lead.

Which of the following statements is correct?

- ☐ **A** A thickness of 0.5 cm would reduce the corrected count rate to 75% of its initial value.
- ☐ **B** A thickness of 0.5 cm would reduce the corrected count rate to 25% of its initial value.
- ☐ **C** A thickness of 2.0 cm would reduce the corrected count rate to 25% of its initial value.
- ☐ **D** A thickness of 2.0 cm would reduce the corrected count rate to zero.

(Total for question = 1 mark)

Q5. A different student used a Geiger-Müller (GM) tube to determine a value for the background count. He recorded the count for 2 minutes, every 15 minutes, as shown in the table.

Time / min	Count for 2 min
0	34
15	39
30	28

The counts are not the same.

Which of the following is the reason for this?

- ☐ **A** The background count rate is random.
- ☐ **B** The counter is incorrectly calibrated.
- ☐ **C** The temperature has not stayed constant.
- ☐ **D** There is a systematic error in the measurement.

(Total for question = 1 mark)

Q6.
A radioactive source is placed a few cm away from a detector. There is no change in the count rate when a thin aluminium foil is placed between the source and the detector, but the count rate is reduced to the background rate when a 0.5 cm aluminium plate is introduced.

These observations show that the source must be emitting

- ☐ **A** alpha and beta radiation.
- ☐ **B** beta and gamma radiation.
- ☐ **C** beta radiation only.
- ☐ **D** gamma radiation only.

(Total for Question = 1 mark)

Q7. When a photographic film that is not exposed to light is placed near to a source of ionising radiation the film darkens.

(a) (i) State what is meant by ionising radiation.

(1)

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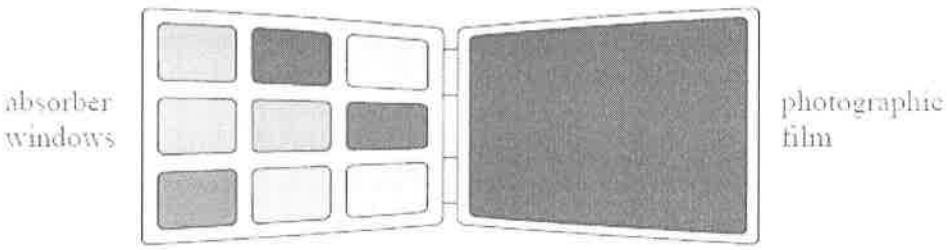
(ii) Complete the table to show α, β, and γ radiations in order of increasing ionising power.

(1)

Least ionising →		Most ionising

(b) In a physics lesson some students are learning about the use of a film badge to monitor exposure to ionising radiation.

Each absorber window is made from a different material and the type of radiation can be determined from the extent to which the film is darkened.



film badge

The students are asked to predict what would happen if α, β, and γ radiations were incident upon absorber windows made from paper, aluminium and lead.

(i) Complete the table to show the penetration of α, β, and γ radiations through each material. Use the words "passes through" or "stopped".

(3)

	Paper	**0.5 cm aluminium**	**0.5 cm lead**
α radiation		stopped	
β radiation			stopped
γ radiation	passes through		

(ii) In a nuclear power plant there may be other radiation present which would **not** be detected by a film badge.

Suggest what type of radiation this is and why it would not be detected by a film badge.

(2)

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(Total for question = 7 marks)

Q8.

The uranium isotope $^{238}_{92}U$ becomes the lead isotope $^{206}_{82}Pb$ through a series of radioactive decays.

Calculate the number of α particles and the number of β particles emitted for one nucleus of $^{238}_{92}U$ to decay to become a nucleus of $^{206}_{82}Pb$.

(2)

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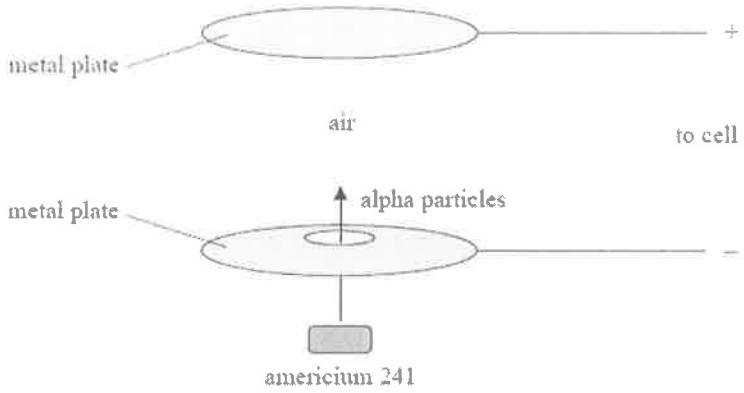
Number of α particles = ...

Number of β particles = ...

(Total for question = 5 marks)

Q9. Some types of smoke detector contain a radioactive isotope of americium, ^{241}Am. The nuclei of ^{241}Am decay by emitting an alpha particle.

The diagram shows part of a smoke detector.
The detectors use a small amount of ^{241}Am to make the air between two metal plates conduct charge.



(a) (i) Explain why a stream of alpha particles will cause charge to flow between the metal plates.

(2)

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(ii) Suggest how smoke particles entering the space between the plates will cause the current to decrease.

(1)

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(b) (i) The decay of ^{241}Am is said to be random and spontaneous.
State what is meant by random and spontaneous.

(2)

Random

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Spontaneous

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(ii) Complete the equation for the decay of ^{241}Am.

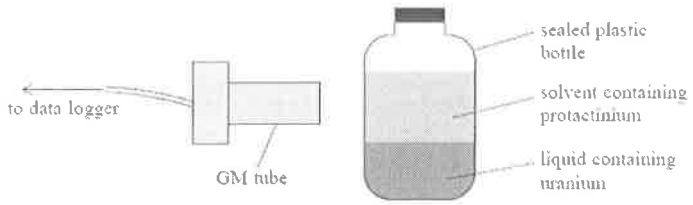
(2)

$$^{241}Am \rightarrow \ \ _{93}Np + \ \ \alpha$$

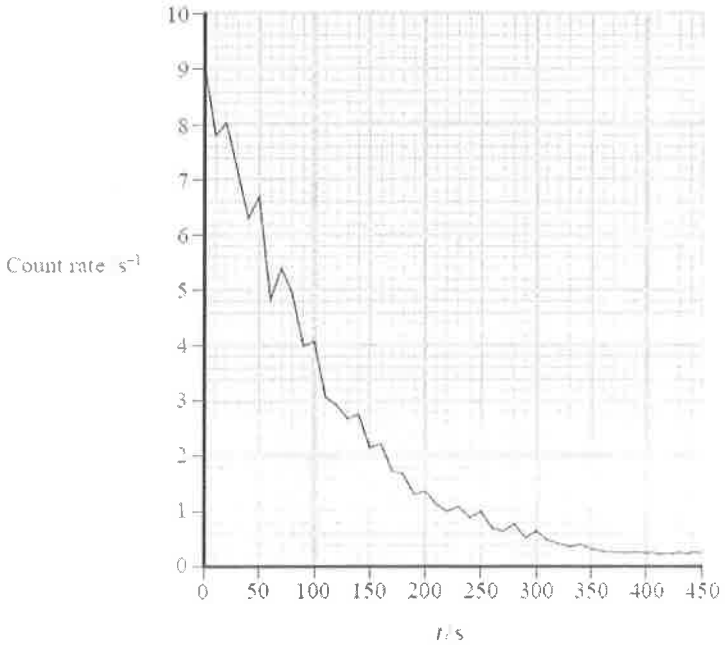
(Total for question = 7 marks)

Q10. A teacher demonstrated the decay of protactinium using a Geiger-Müller (GM) tube connected to a data logger.

A sealed plastic bottle contains a solvent floating above a liquid containing a uranium salt. Protactinium is produced from the decay of uranium and is present in the solvent as shown.



The data logger output is shown below.



(i) Determine the half-life of the protactinium.

[4]

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(ii) Explain why the count rate doesn't reach zero.

(2)

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(Total for question = 6 marks)

Q11. Potassium chloride may be used to flavour food. Potassium chloride contains trace amounts of a radioactive isotope of potassium (K). This decays into an isotope of calcium (Ca) by beta decay.

(a) (i) Complete the nuclear equation for this decay:

$$___\ {}^{40}\mathrm{K} \rightarrow ___\ {}_{20}\mathrm{Ca} + ___\ \beta^{-} + {}^{0}_{0}\overline{\nu}_{e}$$

(2)

(ii) Calculate the energy, in MeV, released when a nucleus of potassium-40 decays into a nucleus of calcium.

	Mass / u
Potassium nucleus	39.963998
Calcium nucleus	39.962591
Electron	0.00054858
Electron neutrino ($\overline{\nu}_e$)	negligible

(5)

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Energy released = ... MeV

(iii) Explain why there is a range of energies for the beta particles emitted in the decay of a sample of potassium-40.

(2)

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(b) A sample of potassium chloride initially contains 1.10×10^{22} atoms of potassium-40.

half-life of potassium-40 = 1.25×10^{9} years
1 year = 3.15×10^{7} s
(i) Show that the activity of this sample is about 1.9×10^{5} Bq.

(3)

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(ii) It is claimed that after a period of 50 years, the activity of the sample would be less than the activity of a typical
school source.
Assess the validity of this claim. Your answer should include a calculation.
activity of a school source = 1.85×10^{5} Bq

(2)

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(Total for question = 14 marks)

Q12. Actinium-225 and bismuth-210 are radioactive isotopes. A sample of each isotope is prepared so that each sample has the same number of nuclei initially.

Explain why the activity of each sample would be the same after 10 days.

half-life of actinium-225 = 10 days
half-life of bismuth-210 = 5 days

(4)

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(Total for question = 4 marks)

Q13. Scientists have been working to achieve a practical nuclear fusion reactor for more than 70 years. So far, this has been with only limited success.

Explain the difficulties involved with fusion as a viable source of power on Earth.

You should include reference to the conditions necessary for fusion to occur.

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(Total for question = 4 marks)

Q1. A radiation detector is placed near a radioactive source and measures the count rate from the source. Different absorbers are placed between the detector and the source. The results are shown in the table.

Absorber	Corrected count rate / s^{-1}
None	850
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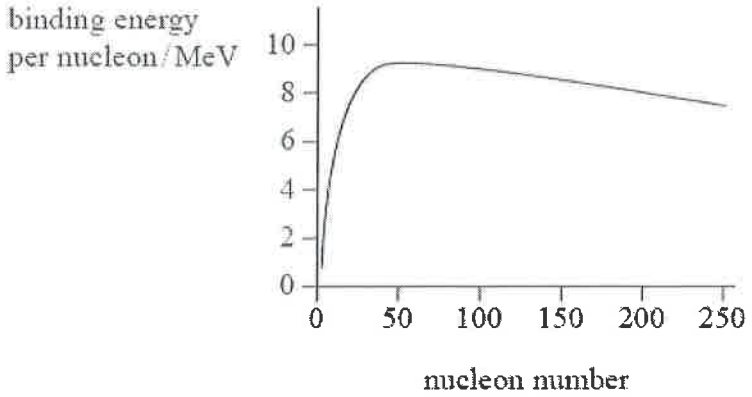
Which of the following is emitted by the source?

- ☐ **A** α-radiation only
- ☐ **B** β-radiation only
- ☐ **C** α-radiation and β-radiation
- ☒ **D** β-radiation and γ-radiation

(1)

(Total for question = 1 mark)

Q2. The graph shows how the binding energy per nucleon varies with nucleon number.



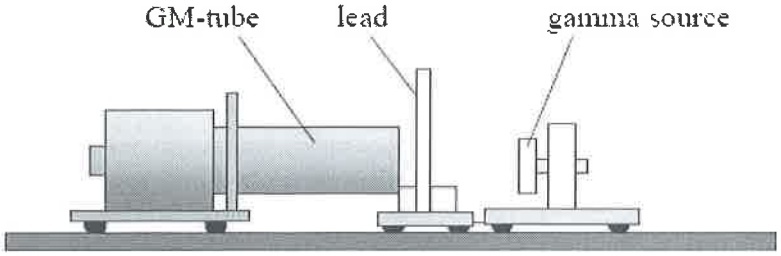
Which of the following conclusions is supported by this graph?

- ☐ **A** The total energy released is greatest when two low mass nuclei fuse.
- ☐ **B** The total energy absorbed is greatest when two low mass nuclei fuse.
- ☒ **C** The total energy released is greatest when a massive nucleus undergoes fission.
- ☐ **D** The total energy absorbed is greatest when a massive nucleus undergoes fission.

(1)

(Total for question = 1 mark)

Q3. A student used a GM-tube to measure the background count for 10 minutes. She then used the apparatus below to measure the count for 2 minutes for different thicknesses of lead.



To correct the readings for the effect of background radiation she should

- ☐ **A** add the background count to each count.
- ☐ **B** add the background count rate to each count rate.
- ☐ **C** subtract the background count from each count.
- ☒ **D** subtract the background count rate from each count rate.

(1)

(Total for question = 1 mark)

Q4. The student in Q3 discovered that a thickness of 1.0 cm of lead reduced the corrected count rate to 50% of its initial value with no lead.

Which of the following statements is correct?

- ☐ **A** A thickness of 0.5 cm would reduce the corrected count rate to 75% of its initial value.
- ☐ **B** A thickness of 0.5 cm would reduce the corrected count rate to 25% of its initial value.
- ☒ **C** A thickness of 2.0 cm would reduce the corrected count rate to 25% of its initial value.
- ☐ **D** A thickness of 2.0 cm would reduce the corrected count rate to zero.

(1)

(Total for question = 1 mark)

Q5. A different student used a Geiger-Müller (GM) tube to determine a value for the background count. He recorded the count for 2 minutes, every 15 minutes, as shown in the table.

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(1)

☒ **A** The background count rate is random.

☐ **B** The counter is incorrectly calibrated.

☐ **C** The temperature has not stayed constant.

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(Total for question = 1 mark)

Q6.
A radioactive source is placed a few cm away from a detector. There is no change in the count rate when a thin aluminium foil is placed between the source and the detector, but the count rate is reduced to the background rate when a 0.5 cm aluminium plate is introduced.

These observations show that the source must be emitting

☐ **A** alpha and beta radiation.

☐ **B** beta and gamma radiation.

(1)

☒ **C** beta radiation only.

☐ **D** gamma radiation only.

(Total for Question = 1 mark)

Q7. When a photographic film that is not exposed to light is placed near to a source of ionising radiation the film darkens.

(a) (i) State what is meant by ionising radiation.

(1)

Ionising radiation removes electrons from atoms (1)

(ii) Complete the table to show α, β, and γ radiations in order of increasing ionising power.

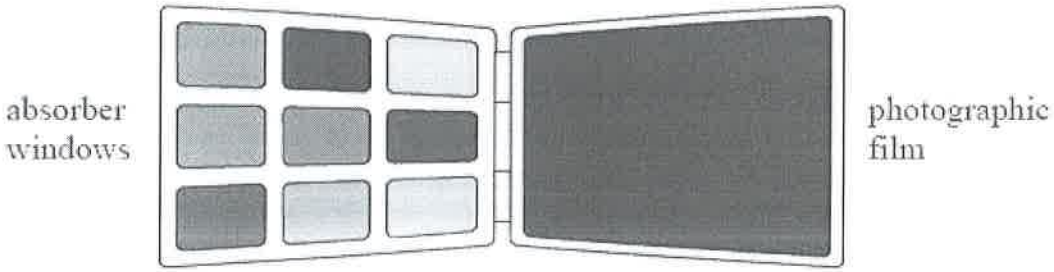
(1)

Least ionising →		Most ionising
γ	β	α

(1)

(b) In a physics lesson some students are learning about the use of a film badge to monitor exposure to ionising radiation.

Each absorber window is made from a different material and the type of radiation can be determined from the extent to which the film is darkened.



film badge

The students are asked to predict what would happen if α, β, and γ radiations were incident upon absorber windows made from paper, aluminium and lead.

(i) Complete the table to show the penetration of α, β, and γ radiations through each material. Use the words "passes through" or "stopped".

(3)

	Paper	**0.5 cm aluminium**	**0.5 cm lead**
α radiation	stopped	stopped	stopped
β radiation	passes through	stopped	stopped
γ radiation	passes through	passes through	passes through

(1) (1) (1)

1 mark for each correct line

(ii) In a nuclear power plant there may be other radiation present which would **not** be detected by a film badge.

Suggest what type of radiation this is and why it would not be detected by a film badge.

(2)

Neutrons (1) would not be detected by a film badge because they are not ionising, (1) as they are not charged.

(Total for question = 7 marks)

Q8.

The uranium isotope $^{238}_{92}U$ becomes the lead isotope $^{206}_{82}Pb$ through a series of radioactive decays.

Calculate the number of α particles and the number of β particles emitted for one nucleus of $^{238}_{92}U$ to decay to become a nucleus of $^{206}_{82}Pb$.

(2)

238 - 206 = 32 so 8 α particles as they each reduce the mass number by 4

Leaving $^{206}_{(92-16)} \rightarrow {}^{206}_{76}$

82 - 76 = 6 so there must be 6 β to increase the atomic number by 6.

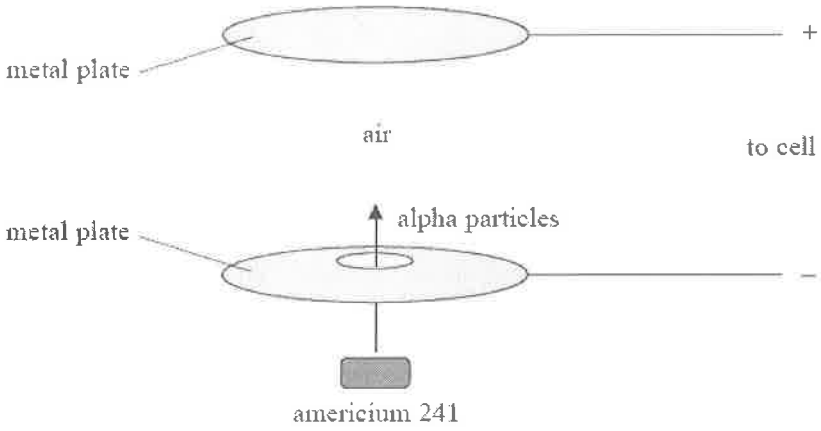
Number of α particles = 8 (1)

Number of β particles = 6 (1)

(Total for question = 5 marks)

Q9. Some types of smoke detector contain a radioactive isotope of americium, ^{241}Am. The nuclei of ^{241}Am decay by emitting an alpha particle.

The diagram shows part of a smoke detector.
The detectors use a small amount of ^{241}Am to make the air between two metal plates conduct charge.



(a) (i) Explain why a stream of alpha particles will cause charge to flow between the metal plates.

(2)

α particles ionise the air (1) and the ions then move (1) between the charged plates

(ii) Suggest how smoke particles entering the space between the plates will cause the current to decrease.

(1)

α particles collide with the smoke particles, reducing the ionisation of the air. (1)

(b) (i) The decay of ^{241}Am is said to be random and spontaneous.
State what is meant by random and spontaneous.

(2)

Random

We cannot identify which nucleus will decay next. (1)

Spontaneous

The decay is not influenced by external factors. (1)

(ii) Complete the equation for the decay of ^{241}Am.

(2)

$$^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\alpha$$

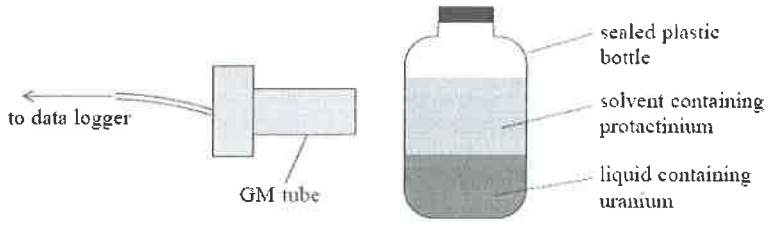
(1) TOP LINE
(1) BOTTOM LINE

(Total for question = 7 marks)

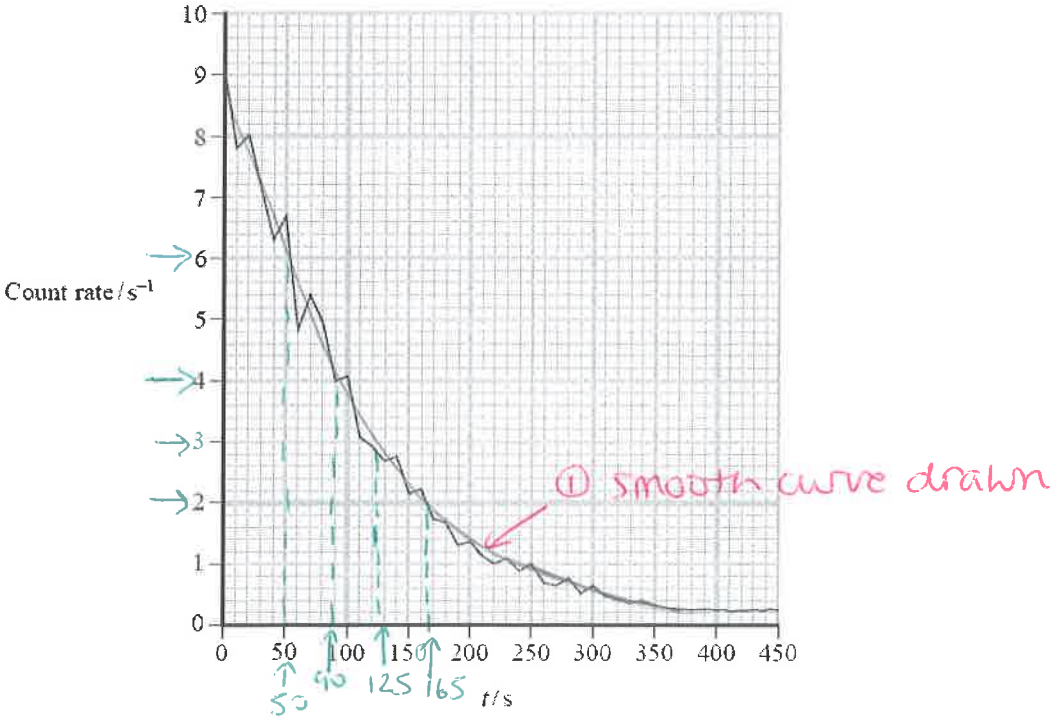
10

Q16. A teacher demonstrated the decay of protactinium using a Geiger-Müller (GM) tube connected to a data logger.

A sealed plastic bottle contains a solvent floating above a liquid containing a uranium salt. Protactinium is produced from the decay of uranium and is present in the solvent as shown.



The data logger output is shown below.



(i) Determine the half-life of the protactinium.

(4)

Count rate 6 s^{-1} → 3 s^{-1} $t = 125 - 50 = 75s$ ①

Count rate 4 s^{-1} → 2 s^{-1} $t = 165 - 90 = 75s$ ① 2nd reading

average half-life $= \frac{75 + 75}{2} = 75\,s$ ① average

Range 60s → 80s

(ii) Explain why the count rate doesn't reach zero.

(2)

There is background radiation (1) which has not been subtracted from the count rate (1) and will always be recorded/measured.

(Total for question = 6 marks)

Q11. Potassium chloride may be used to flavour food. Potassium chloride contains trace amounts of a radioactive isotope of potassium (K). This decays into an isotope of calcium (Ca) by beta decay.

(a) (i) Complete the nuclear equation for this decay:

$$^{40}_{19}\mathrm{K} \rightarrow {}^{40}_{20}\mathrm{Ca} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_{e}$$

(2)

(ii) Calculate the energy, in MeV, released when a nucleus of potassium-40 decays into a nucleus of calcium.

	Mass/u
Potassium nucleus	39.963998
Calcium nucleus	39.962591
Electron	0.00054858
Electron neutrino ($\bar{\nu}_e$)	negligible

(5)

LHS $m = 39.963998u$

RHS $m = 39.962591u + 0.00054858u = 39.96313958u$

$\Delta m = 8.5842 \times 10^{-4}u$ (1)

In kg this is $8.5842 \times 10^{-4} \times 1.66 \times 10^{-27} = 1.42498 \times 10^{-30}$ kg (1)

$\Delta E = \Delta mc^2 = 1.42498 \times 10^{-30} \times (3 \times 10^8)^2 = 1.282 \times 10^{-13}$ J (1)

In MeV this is $\dfrac{1.282 \times 10^{-13}\ (1)}{1.6 \times 10^{-19} \times 10^6} = 0.8015$ MeV

Energy released = 0.802 (1) MeV

(iii) Explain why there is a range of energies for the beta particles emitted in the decay of a sample of potassium-40.

(2)

KE / momentum is shared between the calcium nucleus, beta particle and the neutrino (1). The way the energy is split between the neutrino and the beta particle varies (1), so the KE of the beta particle ~~also~~ varies

(b) A sample of potassium chloride initially contains 1.10×10^{22} atoms of potassium-40.

half-life of potassium-40 = 1.25×10^{9} years
1 year = 3.15×10^{7} s

(i) Show that the activity of this sample is about 1.9×10^{5} Bq.

(3)

$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{(1.25 \times 10^{9} \times 3.15 \times 10^{7})} = 1.76 \times 10^{-17}\ s^{-1}$ (1)

$A = -\lambda N$ (1) $A = 1.76 \times 10^{-17} \times 1.10 \times 10^{22} = 1.94 \times 10^{5}$ Bq (1)

(ii) It is claimed that after a period of 50 years, the activity of the sample would be less than the activity of a typical school source.

Assess the validity of this claim. Your answer should include a calculation.

activity of a school source = 1.85×10^{5} Bq

(2)

$A = A_0 e^{-\lambda t} = 1.94 \times 10^{5}\, e^{-(1.76 \times 10^{-17} \times 50 \times 3.15 \times 10^{7})}$ (1)

$A = 1.94 \times 10^{5}\, e^{-2.772 \times 10^{-8}} = 1.93997 \times 10^{5} = 1.94 \times 10^{5}$ Bq

The claim is false since 1.94×10^{5} Bq $> 1.85 \times 10^{5}$ Bq (1)

(Total for question = 14 marks)

Q12. Actinium-225 and bismuth-210 are radioactive isotopes. A sample of each isotope is prepared so that each sample has the same number of nuclei initially.

Explain why the activity of each sample would be the same after 10 days.

half-life of actinium-225 = 10 days
half-life of bismuth-210 = 5 days

(4)

$\lambda_{Ac} = \frac{\ln(2)}{10}$ (1) Initial $A_{Ac} = \lambda_{Ac} N = \frac{\ln(2) N}{10}$ (1) FOR BOTH

for Ac, 10 days is $t_{1/2}$ so new $A_{Ac} = \frac{\ln(2) N}{10}\left(\frac{1}{2}\right) = \frac{\ln(2) N}{20}$ (1)

$\lambda_{Bi} = \frac{\ln(2)}{5}$ Initial $A_{Bi} = \lambda_{Bi} N = \frac{\ln(2) N}{5}$

for Bi, 10 days is $2t_{1/2}$ so new $A_{Bi} = \left(\frac{1}{2}\right)\left(\frac{1}{2}\right)\frac{\ln(2) N}{5} = \frac{\ln(2) N}{20}$ (1)

The activity will therefore be the same after 10 days

(Total for question = 4 marks)

Q13. Scientists have been working to achieve a practical nuclear fusion reactor for more than 70 years. So far, this has been with only limited success.

Explain the difficulties involved with fusion as a viable source of power on Earth.

You should include reference to the conditions necessary for fusion to occur.

Very high temperatures (1) are needed to give the nuclei enough kinetic energy to overcome the electrostatic repulsion between the nuclei.
A high density (1) is needed to have a high enough collision rate for the fusion reaction to be sustained.
Very strong magnetic fields (1) are needed to contain the plasma because if the plasma touches the container, the temperature would decrease (1) and fusion would stop.

(Total for question = 4 marks)