**Marks**
**7**

- Technetium-99m is an important radionuclide for medical imaging. It is produced from molybdenum-99. Fill in the box below to give a balanced nuclear equation for the production of Tc-99m from Mo-99.

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

The half-life of Tc-99m is 6.0 hours. Calculate the decay constant, λ, in $s^{-1}$.

Answer:

Calculate the molar activity in Bq $mol^{-1}$.

Answer:

Calculate the time in hours for 90% of the activity of a sample of Tc-99m to decay.

Answer:

Why is Tc-99m suitable for medical imaging? Give two reasons.

Marks 6

- The isotope $^{60}_{27}Co$ undergoes radioactive decay to produce a stable isotope of nickel. Give the balanced equation for this decay process.

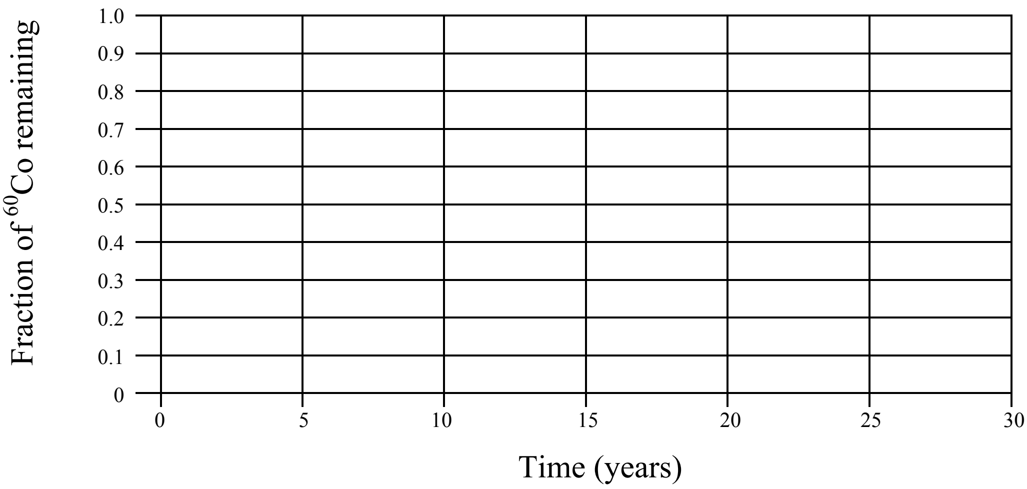
The half-life of $^{60}Co$ is 5 years. Calculate the value of the decay constant, λ, (in $s^{-1}$).

Answer:

What is the molar activity of $^{60}Co$ (in Bq $mol^{-1}$)?

Answer:

Complete the graph below.




Estimate from the graph the fraction of $^{60}Co$ remaining after 12 years.

**Marks**
**4**

- Radioactivity may have damaging effects on humans but can also be used for medical imaging to potentially save lives. Which of alpha and gamma radiation is better suited for medical imaging? Give reasons.

Given nuclides with half-lives of minutes, hours or years, which would be best used for medical imaging? Explain.

- Complete the blanks in the following nuclear equations.

**Marks**
**2**

| | |
|---|---|
| $^{54}_{27}Co \rightarrow ^{54}_{26}Fe$ + | [ ] |
| [ ] | $\rightarrow ^{234}_{90}Th + \alpha$ |

Marks
5

- The generation of energy in a nuclear reactor is largely based on the fission of either $^{235}U$ or $^{239}Pu$. The fission products include every element from zinc through to the *f*-block. Explain why most of the radioactive fission products are β-emitters.

The radioactivity of spent fuel rods can be modelled by the exponential decay of $^{137}Cs$, which has a half-life of 30.23 years. What is the specific activity of $^{137}Cs$, in Bq $g^{-1}$?

Answer:

**Marks**
**6**

- On the 6th of April 2011, after the earthquake and tsunami in Japan, levels of $^{131}I$ in seawater were recorded at $7.5 \times 10^6$ times the legal limit. The half-life of $^{131}I$ is 8.02 days. How long will it take for the radioactivity of the initially sampled seawater to fall back to the legal limit?

Answer:

Why is the $^{131}I$ nucleus unstable?

Write a balanced equation for a likely decay mechanism of $^{131}I$.

Another significant seawater contaminant detected after the tsunami was $^{137}Cs$, which has a half-life of 30 years. If you were exposed to equal concentrations of both isotopes for 1 hour, which isotope, $^{137}Cs$ or $^{131}I$, would do more damage? Explain your reasoning.

Marks 5

- How does the ratio of the number of neutrons to the number of protons in a stable or long-lived radionuclide change as the atomic number increases?

The generation of energy in a nuclear reactor is largely based on the fission of certain long-lived radionuclides (usually $^{235}U$ or $^{239}Pu$). The fission products include every element from zinc through to the *f*-block. Explain why most of the radioactive fission products are β-emitters.

Two of the more common isotopes produced in nuclear reactors are $^{131}I$ (half-life of 8.02 days) and $^{137}Cs$ (half-life of 30 years). Both are β-emitters. If you were exposed to equal concentrations of both isotopes for 1 hour, which isotope, $^{137}Cs$ or $^{131}I$, would do more damage? Explain your reasoning.

- Radon gas decays into polonium with a half-life of 3.82 days via the following mechanism: 3

$$^{222}_{86}\text{Rn} \rightarrow \, ^{218}_{84}\text{Po} + \, ^{4}_{2}\text{He}$$

Give three reasons why $^{222}_{86}\text{Rn}$ is biologically a very harmful nuclide.

**Marks**
**3**

- Consider the process of electron capture by the manganese-54 isotope.

  Write a balanced nuclear formula.

**Marks**
**8**

- Sixteen unstable isotopes of strontium are known to exist. Of greatest importance are $^{90}$Sr with a half-life of 28.78 years and $^{89}$Sr with a half-life of 50.5 days. $^{90}$Sr is found in nuclear fallout as it is a by-product of nuclear fission.

  Calculate the activity (in Bq) of 20.0 g of $^{90}$Sr.

Answer:

Calculate the age (to the nearest year) of a sample of $^{90}$Sr that has an activity one-eighth of a freshly prepared sample.

Answer:

Determine the specific activity of $^{90}$Sr in Ci g$^{-1}$.

Answer:

$^{90}$Sr presents a long-term health problem as it substitutes for calcium in bones. Comment on why Sr can substitute for Ca so readily.

Marks

- Scholars think that a parchment scroll recently found in the Middle East could have originated from the same group responsible for the Dead Sea Scrolls. If a modern piece of parchment has an activity of $4.0 \times 10^{-4}$ Ci $g^{-1}$, calculate the expected activity of the recently discovered scroll if it originated 2100 years ago. **2**

Answer:

- $^{11}C$ is an unstable isotope of carbon. Which force within the $^{11}C$ nucleus is responsible for its instability? Explain. **2**

Which force is responsible for the greater stability of the $^{12}C$ isotope compared to the $^{11}C$ isotope? Explain.

**Marks**
**5**

- Write two possible mechanisms for the radioactive decay of $^{83}$Rb to $^{83}$Kr.

The half-life of $^{83}$Rb is 86.2 days. Calculate the activity (in Bq) of an isotopically pure 1.000 g sample of $^{83}$Rb. (The molar mass of $^{83}$Rb is 82.915110 g mol$^{-1}$.)

Answer:

How many days will it take for this sample to diminish to 1 % of its initial activity?

Answer:

**Marks**
**5**

- Write two possible mechanisms for the radioactive decay of $^{55}Fe$ to $^{55}Mn$.

The activity of an isotopically pure 1.000 g sample of $^{55}Fe$ is measured as $8.750 \times 10^{13}$ Bq. Calculate the half-life (in days) of $^{55}Fe$.
(The molar mass of $^{55}Fe$ is 54.94 g mol$^{-1}$.)

Answer:

How many years will it take for the activity of this pure 1.000 g sample of $^{55}Fe$ to drop to $1.000 \times 10^{9}$ Bq?

Answer:

**Marks**
**6**

- Write down an equation representing the decay mechanism of $^{14}C$.

The half-life of $^{14}C$ is 5730 years. What is the activity of precisely 1 g of this isotope, given that each atom weighs 14.00 amu? Give your answer in Bq.

Answer:

Carbon-14 is used as a radioactive tracer in the urea breath test, a diagnostic test for *Helicobacter pylori*. Name an instrument which can be used to detect radioactive carbon dioxide in the breath of a patient.

A patient ingests 1.00 g of urea with a total activity of 1.00 μCi. What is the percentage, by weight, of carbon-14 in this sample?

Answer:

**Marks**

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **3**

$$^{55}_{26}\text{Fe} + {}^{0}_{-1}\text{e} \rightarrow \boxed{\quad}$$

$$^{3}_{2}\text{He} + {}^{3}_{2}\text{He} \rightarrow 2\,{}^{1}_{1}\text{p} + \boxed{\quad}$$

$$^{15}_{7}\text{N} + {}^{1}_{1}\text{p} \rightarrow {}^{15}_{8}\text{O} + \boxed{\quad}$$

- Calculate the atomic mass of lead from the isotope information provided. **2**

| Isotope | Mass of isotope (a.m.u.) | Relative abundance |
|---|---|---|
| $^{204}$Pb | 203.97304 | 1.40% |
| $^{206}$Pb | 205.97446 | 24.10% |
| $^{207}$Pb | 206.97589 | 22.10% |
| $^{208}$Pb | 207.97664 | 52.40% |

Answer:

- Calculate the molar activity of $^{11}$C (in curie), given its half-life of 20.3 minutes. **3**

Answer:

**Marks**

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **3**

$$^{60}_{29}\text{Cu} \rightarrow \boxed{\phantom{XX}} + {}^{0}_{+1}\text{e}$$

$$\boxed{\phantom{XX}} + {}^{0}_{-1}\text{e} \rightarrow {}^{55}_{25}\text{Mn}$$

$$^{28}_{14}\text{Si} + {}^{2}_{1}\text{H} \rightarrow {}^{29}_{15}\text{P} + \boxed{\phantom{XX}}$$

- Calculate the following properties of the $^{13}$N nuclide, given that its half-life is 9.96 minutes. **3**

(a) the decay constant in $s^{-1}$

Answer:

(b) the molar activity in Ci $mol^{-1}$

Answer:

Marks

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **3**

$$^{63}_{28}\text{Ni} \rightarrow \, ^{63}_{29}\text{Cu} + \boxed{\phantom{X}}$$

$$^{53}_{26}\text{Fe} + \, ^{0}_{-1}\text{e} \rightarrow \boxed{\phantom{X}}$$

$$^{28}_{14}\text{Si} + \, ^{2}_{1}\text{H} \rightarrow \, ^{1}_{0}\text{n} + \boxed{\phantom{X}}$$

- Calculate the energy (in J) and the wavelength (in nm) of the photon of radiation emitted when the electron in $Be^{3+}$ drops from an *n* = 3 state to an *n* = 2 state. **3**

| Energy: | Wavelength: |
| --- | --- |

Marks 4

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide.

$$^{212}_{83}\text{Bi} \rightarrow {}^{208}_{81}\text{Tl} + \square$$

$$^{8}_{4}\text{Be} + \square \rightarrow {}^{12}_{6}\text{C}$$

$$^{14}_{7}\text{N} + {}^{1}_{0}\text{n} \rightarrow {}^{1}_{1}\text{p} + \square$$

What is a common source of the neutrons in the previous reaction?

2

- Explain why solid α emitters are generally considered as low risk radioisotopes while gaseous α emitters are high risk.

Marks

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **3**

$$^{55}_{26}\text{Fe} + ^{0}_{-1}\text{e} \rightarrow \square$$

$$^{2}_{1}\text{H} + ^{1}_{1}\text{H} \rightarrow ^{3}_{2}\text{He} + \square$$

$$^{15}_{7}\text{N} + ^{1}_{1}\text{p} \rightarrow ^{15}_{8}\text{O} + \square$$

- Calculate the atomic mass of silicon from the isotope information provided. **2**

| Isotope | Mass of isotope (a.m.u.) | Relative abundance |
|---|---|---|
| $^{28}$Si | 27.97693 | 92.21% |
| $^{29}$Si | 28.97649 | 4.70% |
| $^{30}$Si | 29.97376 | 3.09% |

Answer:

- Calculate the molar activity of $^{3}$H (in Curie), given its half-life of 12.26 years. **3**

Answer:

| | Marks |
|---|---|
| • Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide.<br><br>$^{1}_{1}H + ^{1}_{1}H \rightarrow ^{2}_{1}H + \square$<br><br>$^{2}_{1}H + \square \rightarrow ^{3}_{2}He$<br><br>$^{3}_{2}He + ^{3}_{2}He \rightarrow \square + ^{1}_{1}H + ^{1}_{1}H$<br><br>Where might these reactions occur naturally? | **4** |
| | |
| • The half life of $^{131}I$ is 8.06 days. Calculate the activity, in Bq, of 12.0 g of pure $^{131}I$. Calculate the activity of $^{131}I$ in Ci $mol^{-1}$. | **3** |
| | |

| | |
|---|---|
| Answer: Bq | Answer: Ci $mol^{-1}$ |