Grade 12 Physics, Explained

Unit 24 · Radioactivity and Nuclear Reactions

ANSWER KEY · FOR TEACHERS

Full marks 34

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

i. ✓ **True** K · 4

ii. ✗ **False**: Nothing done to the sample (heat, pressure, chemical change) changes its rate of decay.

iii. ✓ **True**

iv. ✗ **False**: Gamma rays carry no charge, so a field doesn't bend them at all.

v. ✓ **True**

vi. ✗ **False**: The mean life, $1/\lambda$, is about 1.44 times the half-life.

vii. ✓ **True**

viii. ✗ **False**: They are the least penetrating (a sheet of paper stops them) and the most ionizing.

Each carries 0.5 mark.

2 Label the diagram

1. window, W′
2. metal cylinder, C (−)
3. wire, W (+)
4. gas at low pressure

K · 2

Each carries 0.5 mark.

3 Multiple choice

i. **b.** mass number 228 and atomic number 88 A · 1

An alpha particle takes 4 from the mass number and 2 from the atomic number: $232 - 4 = 228$, $90 - 2 = 88$ (radium).

ii. **c.** 1/8 A · 1

$11.4 \div 3.8 = 3$ half-lives: $(1/2)^3 = 1/8$.

iii. **c.** 11.5 days A · 1

$$\tau = \frac{1}{\lambda} = \frac{T_{1/2}}{0.693} = \frac{8.0}{0.693} = 11.5 \text{ days.}$$

iv. **c.** 7.4×10^{10} Bq A · 1

1 Ci $= 3.7 \times 10^{10}$ Bq, so 2.0 Ci $= 7.4 \times 10^{10}$ Bq.

v. **b.** a wooden beam from an old temple U · 1

Only things that were once alive took in carbon-14 from the air in a known proportion: the wood. Rock, iron and clay never did.

4 Short answers

a. MARKING SCHEME U · 2

✓ Large charge and mass, slow: it ionizes many molecules on its way.

✓ Each ion costs energy, so its energy is soon spent: a short range.

b. MARKING SCHEME U · 2

✓ Opposite charges, so opposite forces.

✓ The beta particle is much lighter, so it is bent much more.

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c. MARKING SCHEME U · 2

✓ Each nucleus decays at random, with a fixed chance per second.

✓ With huge numbers, the fraction decaying is predictable, so the half-life is fixed.

5 Long answer

ANSWER U · 4

The rate of decay of a sample at any instant is in proportion to the number of undecayed atoms: $\frac{dN}{dt} = -\lambda N$, λ the decay constant. So $\frac{dN}{N} = -\lambda\, dt$; integrating from N_0 at t = 0, $\ln \frac{N}{N_0} = -\lambda t$, and $N = N_0 e^{-\lambda t}$.

At the half-life $N = N_0/2$: $e^{-\lambda T_{1/2}} = \frac{1}{2}$, so $\lambda T_{1/2} = \ln 2$ and $T_{1/2} = \frac{0.693}{\lambda}$.

MARKING SCHEME

✓ The law: $dN/dt = -\lambda N$.

✓ Separating and integrating.

✓ $N = N_0 e^{-\lambda t}$.

✓ $T_{1/2} = 0.693/\lambda$.

6 Numerical problems

a. ANSWER A · 4

i. $N = \frac{1.0 \times 10^{-6}}{131} \times 6.02 \times 10^{23} = \mathbf{4.6 \times 10^{15}\ atoms}$.

ii. $\lambda = \frac{0.693}{8.0 \times 86\,400} = \mathbf{1.0 \times 10^{-6}\ s^{-1}}$.

iii. $A = \lambda N = 1.0 \times 10^{-6} \times 4.6 \times 10^{15} = \mathbf{4.6 \times 10^{9}\ Bq}$.

iv. $4.6 \times 10^{9} \div 3.7 \times 10^{10} = \mathbf{0.12\ Ci}$.

MARKING SCHEME

✓ $N = 4.6 \times 10^{15}$.

✓ $\lambda = 1.0 \times 10^{-6}\ s^{-1}$.

✓ $A = 4.6 \times 10^{9}$ Bq.

✓ 0.12 Ci.

b. ANSWER A · 3

$A = A_0 e^{-\lambda t}$, so $t = \frac{T_{1/2}}{0.693} \ln \frac{A_0}{A} = \frac{5730}{0.693} \times \ln \frac{0.23}{0.16} = 8270 \times 0.363 = \mathbf{3000\ years}$.

MARKING SCHEME

✓ $t = (1/\lambda)\ln(A_0/A)$.

✓ $\lambda = 0.693/5730$ per year.

✓ About 3000 years.

c. ANSWER A · 3

$\lambda = 0.693 \div 3.8 = 0.182$ per day. After 10 days: $e^{-1.82} = 0.16$: **16 %**.

For 10 %: $t = \frac{\ln 10}{\lambda} = \frac{2.303}{0.182} = \mathbf{12.6\ days}$.

MARKING SCHEME

✓ $\lambda = 0.182$ per day.

✓ 16 % after 10 days.

✓ 12.6 days to 10 %.

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7 Think

ANSWER HA · 3

Only alpha decays change the mass number, by 4 each: $(232 - 208) \div 4 = $ **6 alpha particles**. They alone would take the atomic number down by 12, to 78; it ends at 82, so 4 must have been added back, one by each beta decay: **4 beta particles**.

MARKING SCHEME

- ✓ Alpha count from the mass number: $24 \div 4 = 6$.
- ✓ Six alphas take Z from 90 to 78.
- ✓ Betas: $82 - 78 = 4$.

8 Activity: The radioactive dating game (Activity 24.1)

(not marked)

WHAT STUDENTS SHOULD FIND

Each object's percentage read on the decay curve gives its age. Carbon-14 works for things that were alive (wood, bones) and younger than about 50,000 years; the rock was never alive, so it is dated with uranium-238, whose half-life is billions of years.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Tree Ring Cross-Section** (exhibit): Each ring is one year's wood, made from carbon in that year's air: rings counted in very old wood are how radiocarbon ages are corrected.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	6	11	14	3	**34**

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