N5 Chemistry: Unit 3 – Chemistry in Society

Part B – Fertilisers, Nuclear and Chemical Analysis

Lesson 3 – Half-Life and Uses of Isotopes

Learning Outcomes

By the end of this lesson you should know:

1. How to calculate and identify the half-life for a radioisotope.
2. How to explain why a radioisotope has been chosen for its use based on its properties.

Success Criteria

You will have been successful in this lesson if you:

1. Watch the video lesson
2. Read and learn the notes given. Use these to fill in the blanks in your printed notes
3. Complete revision questions provided
4. Complete and submit homework assigned (HW 15)

There is also a further reading section to help you gain more depth of understanding for this section.

If you have any questions about the content of this lesson, you should ask your class teacher either through your class MS team or via email. MS Teams will be monitored throughout the week by a chemistry teacher. If you need help or clarification with either the task or the content of the lesson, just ask.

Links to Prior Knowledge

You may wish to revise the following to help you understand this lesson:

- N5 Unit 1: Nuclide notation and Isotopes

- N5 Unit 3: Nuclear Chemistry

Half-life and Uses of Radioisotopes	Unit 3 – Nuclear	https://youtu.be/cCR3yUTbIEg

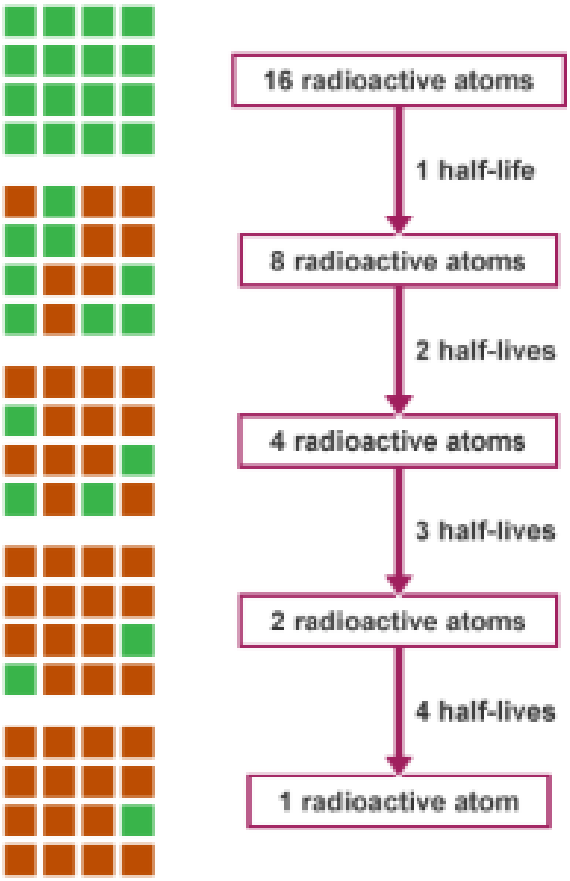
Words written in italics do not need to be copied and are there to provide instruction.

Half-Life

When a radioisotope emits radiation, its nuclear changes this is known as radioactive decay. Radioisotopes do not just decay once, they follow a path until they are stable. The time between the decays is known as the **half-life.**

The **half-life** is the time taken for the **mass or activity** of a radioisotope to decrease by half.

For a particular radioisotope, half-life is constant and **cannot** be changed by chemical or physical conditions.



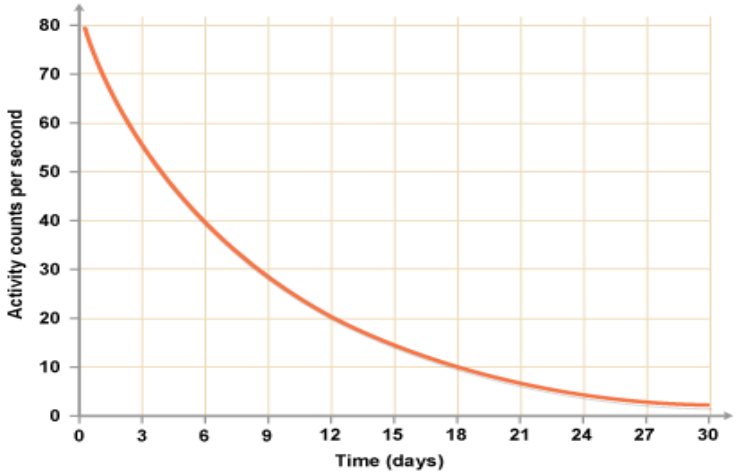
This diagram shows the green squares as the 'parent' unstable radioisotopes.

These unstable nuclei decay (we do not need to know which type of decay here) and form the red squares – the 'daughter' nuclei.

Calculating the Number of Half-Lives

There are two ways to look into half-life

1. **Using a decay curve**



You may wish to sketch a curve like this in your notes to show the activity of a radioisotope over a number of days and a worked example of how to use this graph.

- Take two values from the activity (one must be exactly half of the other e.g. 80 and 40).
- Draw a line from each value to the curve.
- Draw lines from the curve to the time values on the x-axis (e.g. 0 and 6)
- The half-life value will be the difference between the two time values (e.g. 6 days)

2. **Performing a calculation using the link between the number of half-lives, time and the proportion of a radioisotope remaining.**

Example 1: How many half-lives have occurred if after 5 days an Al-30 radioisotope's activity is only 1/8 of its original value?


= 1 half-life

Activity: 1 1/2 1/4 1/8

<u>= 3 half-lives</u>

Example 2: The activity of a radioisotope is found to be 1/16 of its original value after 32 days. What is its half-life?

Activity: 1 → 1/2 → 1/4 → 1/8 → 1/16

There has been 4 half-lives in 32 days.

So: half-life $= \frac{32}{4} =$ **<u>8 days</u>**

Uses of Radioisotopes

Radioisotopes are widely used in medicine and industry. Some common examples are:

Radioisotope	Use
Carbon-14	Used in 'carbon-dating' compounds
Iodine-131	Treatment for thyroid cancer
Amercium-214	Smoke detectors

You are not asked to know specific examples of radioisotopes but you should be able to explain the suitability of a radioisotope for its used based on the information about its half-life or the type of radiation emitted.

E.g. Technetium-99m is injected into the body to detect damage to heart tissue. It is a gamma-emitting radioisotope with a half-life of 6 hours.

Technetium-99m can be used safely in this way is gamma radiation would go right through the body and it has a short half-life so would not last long in the body.

Explanations of other isotopes and their uses:

https://scholar.hw.ac.uk/vle/scholar/session.controller?action=viewContent&back=topic&contentGUID=E2EA5A09-0E94-4D41-D0DA-46DB09AE69F1

Further Reading

To learn more about types of radiation, try the following online resources:

BBC Bitesize: https://www.bbc.co.uk/bitesize/guides/zxxrng8/revision/5

https://www.bbc.co.uk/bitesize/guides/zxxrng8/revision/6

Scholar: Log in through GLOW
National 5 Chemistry → Chemistry in Society → Nuclear Chemistry → read content 7.5 and 7.6

Evans2 chem web: https://www.evans2chemweb.co.uk/

Username: snhs password: giffnock
Select any teacher → revision → National 5 → Unit 3: Chemistry in Society → Nuclear Chemistry

Complete self-check exercises in your class work jotter and use the answers at the end of this document to mark.

Self Check 8

1. Technetium 99 is a beta emitting isotope used in medicine, it has a half-life of six hours.
Explain what is meant by a *half-life*.

2. The table below shows the half-life values for different radioisotopes:

Isotope	Half-life
Uranium-238	4.5×10^9 years
Uranium-235	0.7×10^9 years
Plutonium-239	24,000 years
Carbon-14	5730 years
Lead-210	22 years
Tritium (H-3)	12.5 years
Cobalt-60	5.27 years
Polonium-210	140 days
Iodine-125	60 days
Bismuth-210	5 days
Radon-222	3.8 days
Polonium-218	3 minutes

(a) Which isotope has the shortest half-life?
(b) Which isotope will take the longest time to become stable?
(c) Which will have the shortest half-life, a 1g lump of Co-60 or 1g of powder Co-60?

3. Using the above table calculate how long it will take for the following:

(a) C-14 to undergo 2 half-lives?
(b) H-3 to undergo 5 half-lives?
(c) Po-218 to undergo 10 half-lives?

4. How many half-lives have occurred?

(a) If a Pb-210 radioisotope's activity is only $^1/_4$ of its original value?
(b) If approximately 9.4g of I-125 remains from the original 150g sample?
(c) If 12.5% of Rn-222 remains?

5. The activity of a radioisotope is found to be $^{1}/_{8}$th of its original value after 27 days. What is the half-life value for this radioisotope?

6. The half-life of Bi-210 is 5 days.
What mass would remain after 10 days from an original sample of 80g?

7. A radioactive metal has an activity of **120** decays per minute. Its half-life is **10 minutes**.
What would the count rate be after?

(a) 20 minutes
(b) 40 minutes
(c) 1 hour

8. A radioactive source has an activity of **800** cpm. The half-life of the source is **5 years**. What would the activity of the source be after 20 years?

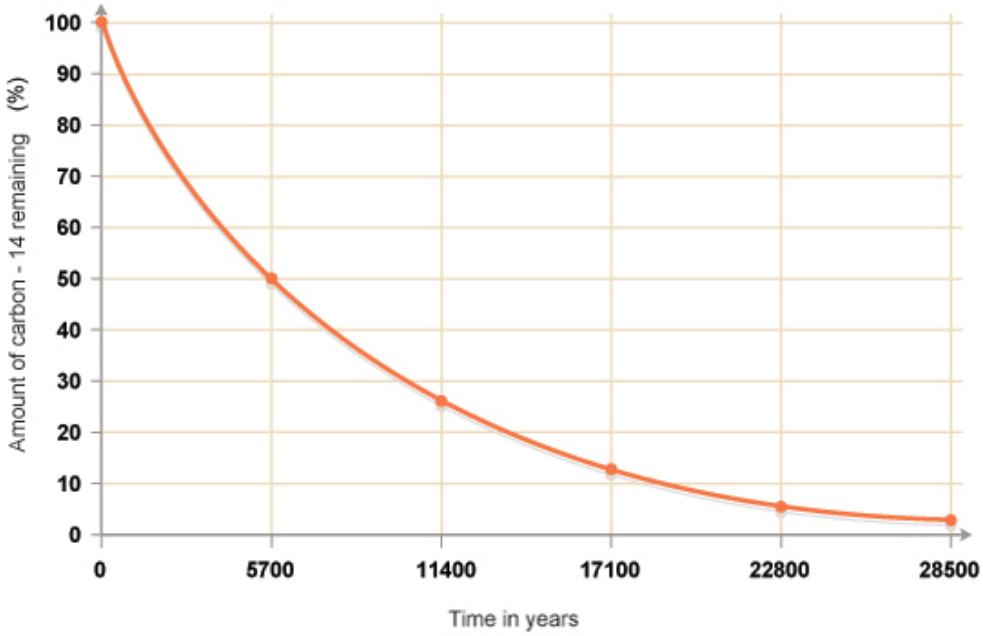
9. A radioactive isotope has an initial mass of 64g at time zero. After 3 hours the mass remaining is 16g.

(a) What is the half-life of the isotope?

(b) What will the mass be 9 hours after time zero?

Self Check 8(continued)

10. The graph below shows how the activity of an unknown radioactive source varies with time.



(a) Use the graph to estimate the half-life of the source.
(b) Using the **table from Q2**, determine the unknown radioisotope?

*Now complete **Homework 15: Nuclear Equations** and submit to your class teacher via Teams (or your usual channel). Your work should be submitted by **3pm on Friday 26th February.***

Nuclear Equations 15

1. Write nuclear equations for the following changes.

   (a) $^{14}_{6}C$ emits a β particle (b) $^{238}_{94}Pu$ emits an α particle

   (c) $^{61}_{28}Ni$ emits a β particle (d) $^{212}_{84}Po$ emits an α particle

2. What is formed when:

   (a) Cobalt-60 emits a proton particle
   (b) Uranium-230 emits a neutron particle
   (c) Thorium -232 emits a proton particle
   (d) Bismuth-210 emits a neutron particle

3. Americium-241, a radioisotope used in smoke detectors, has a half-life of 432 years.

   The equation for the decay of americium-241 is

$$^{241}_{95}\text{Am} \longrightarrow {}^{4}_{2}\text{He} + \text{X}$$

   Name element **X**.

4. P is a radioisotope which undergoes transitions as follows.

$$\mathbf{P} \xrightarrow{\beta\text{–emission}} \mathbf{Q} \xrightarrow{\beta\text{–emission}} \mathbf{R} \xrightarrow{\alpha\text{–emission}} \mathbf{S}$$

   If the atomic number of **P** is 88, and its mass number is 228, what is the atomic number and mass number for isotope **S**?

5. $^{27}_{13}Al$ can absorb an alpha particle with the emission of a neutron, forming a product Y.
   Write a nuclear equation to illustrate this reaction and identify Y.

Self Check 8 ANSWERS

1. The time for half of the nuclei of a particular isotope to decay.

2. (a) Po-218
(b) U-238
(c) Neither, both will still have the same half-life.

3. (a) 11,460 years
(b) 62.5 years
(c) 30 min

4. (a) 2
(b) 4
(c) 3

5. 9 days

6. 20g

7. (a) 30
(b) 7.5
(c) 1.88

8. 50 cpm

9. (a) 1.5 hours
(b) 1g

10. (a) 5,700 years
(b) Carbon-14