Half-life

PowerPoint 7.2

Answer these questions in your group

1. For $^{131}_{53}I$,
   a. What is its name? Iodine-131
   b. How many protons and neutrons does it have? 53p, 78n ($131 – 53 = 78$)
   c. What is its mass? 131 a.m.u.
2. a. If $^{131}_{53}I$ underwent alpha decay, what would be produced? $^{127}_{51}Sb + ^{4}_{2}\alpha$
   b. Write the nuclear equation. $^{131}_{53}I \rightarrow ^{127}_{51}Sb + ^{4}_{2}\alpha$
3. a. If $^{131}_{53}I$ underwent beta decay, what would be produced? $^{131}_{54}Xe + ^{0}_{-1}\beta$
   b. Write the nuclear equation. $^{131}_{53}I \rightarrow ^{131}_{54}Xe + ^{0}_{-1}\beta$
4. a. If $^{131}_{53}I$ * underwent gamma decay, what would be produced? $^{131}_{53}I + ^{0}_{0}\gamma$
   b. Write the nuclear equation. $^{131}_{53}I^{*} \rightarrow ^{131}_{53}I + ^{0}_{0}\gamma$
5. What is the relative penetrating power of α, β, and γ decay?
   $\gamma > \beta > \alpha$

Review of PowerPoint 7.1

Parent isotope

Daughter isotope

$$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$$ Alpha decay

$$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}\beta$$ Beta decay

$$^{60}_{28}Ni \rightarrow {}^{60}_{28}Ni + {}^{0}_{0}\gamma$$ Gamma decay

Half-life

A ***half-life*** is the time needed for 50% of a particular isotope in a sample to decay.

Example, $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$ Beta decay

If we begin with 40 g of carbon-14, the time it takes for 20 g to decay to nitrogen-14 is the half-life of carbon-14.

For C-14, this timeframe happens to be 5730 years.

- Therefore, the half-life of $^{14}_{6}C$ is 5730 years.

- Different isotopes of different elements have different half-lives.

Half-Lives of Various Isotopes

Isotope	Half-life	Isotope	Half-life
Hydrogen-7	2.1 x 10^{-23} seconds	Carbon-14	5730 years
Lithium-11	0.00859 seconds	Plutonium-240	6563 years
Lithium-8	0.8399 seconds	Plutonium-239	24 110 years
Seaborgium-266	30 seconds	Lead-202	52 500 years
Nobelium-259	58 minutes	Iron-60	1 500 000 years
Iodine-131	8.02 days	Uranium-235	710 000 000 years
Chromium-51	27.7025 days	Potassium-40	1 300 000 000 years
Sulfur-35	87.32 days	Uranium-238	4 500 000 000 years
Californium-248	333.5 days	Thorium-235	14 000 000 000 years
Strontium-90	28.79 years	Robidium-87	47 000 000 000 years

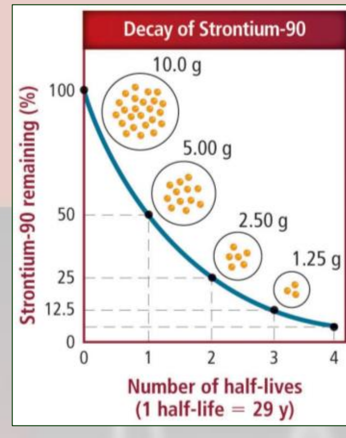
710 000 000 years = 710 Ma

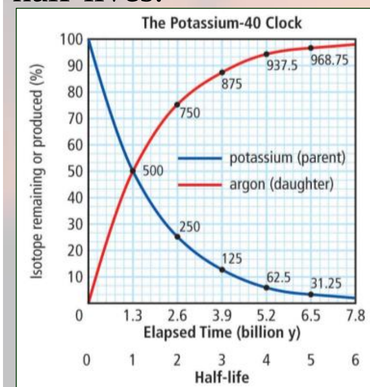
Radioactive decay of C-14
Half-life = 5730 years

Number of Half-lives	Time Elapsed (years)	Percent of Carbon-14 Remaining	Mass of Carbon-14 Remaining
0	0	100%	40 g
1	5730 (1 x 5730)	50%	$\left(\frac{1}{2}\ x\ 40\ g\right)$ = 20 g
2	11460 (2 x 5730)	25%	$\left(\frac{1}{2}\ \text{x}\ \frac{1}{2}\ x\ 40\ g\right)$ = 10 g
3	17190 (3 x 5730)	12.5%	$\left(\frac{1}{2}\ x\ \frac{1}{2}\ x\ \frac{1}{2}\ x\ 40\ g\right)$ = 5 g
4	22920 (4 x 5730)	6.25%	$\left(\frac{1}{2}\ x\ \frac{1}{2}\ x\ \frac{1}{2}\ \text{x}\ \frac{1}{2}\ x\ 40\ g\right)$ = 2.5 g

Decay Curve

A ***decay curve*** is a curved line on a graph that shows the rate at which radioisotopes decay.
The decay curve of ***each radioisotope parent will look the same***, with the exception of the length of their respective half-lives.





The plot of the presence of the daughter isotope shows how the abundance of the daughter isotope increases as that of the parent isotope decreases.

Radioisotope Dating

Radioisotope dating is utilized to determine the age of objects based on the relative abundance of parent and daughter isotopes.

- Different radioisotopes are useful in determining the age of objects of different ages.

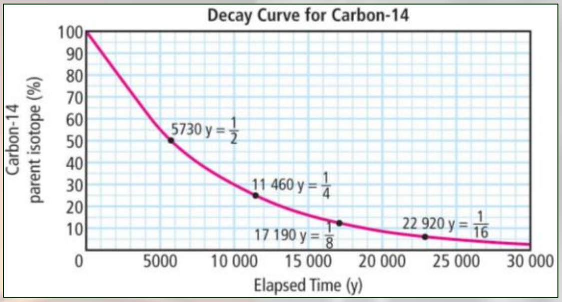
Isotope		**Half-Life of Parent (years)**	**Effective Dating Range (years)**
Parent	Daughter		
Carbon-14	Nitrogen-14	5730	Up to 50 000
Uranium-235	Lead-207	710 000 000	> 10 000 000
Potassium-40	Argon-40	1 300 000 000	10 000 to 3 000 000 000
Uranium-238	Lead-206	4 500 000 000	> 10 000 000
Thorium-235	Lead-208	14 000 000 000	> 10 000 000

Radiocarbon dating

Principles Behind Radioisotope Dating

Radiocarbon dating is typically utilized to date organisms.

- The abundance of C-14 in living organisms remains relatively constant while it is alive but decreases after it dies.



C-14's effective dating range is based on the fact that, after 50 000 years, very little C-14 will remain making its detection quite difficult.

Potassium-40 dating is typically utilized to date rocks and minerals.

- The abundance of K-40 decreases after molten rock solidifies after which it begins to form Ar-40 gas which becomes trapped in the rock.

Other Uses of Radioisotopes Based on Their Respective Half-Lives

- research, diagnose, and treat disease
- sterilize medical equipment
- trace processes in living organisms
- preserve food
- detect smoke
- analyze pollutants
- detect weakness in metal structures
- analyze minerals and fuels
- study the movement of water
- measure ages of rocks and remains of plants and animals

Provincial Exam Question

Question,
A rock sample originally contained 8 g of U-235 but now contains only 2 g of U-235. How old is the rock?

A. 710 Ma B. 1420 Ma C. 2130 Ma D. 2840 Ma

Answer,
The half-life of Uranium-235 is 710 000 000 years.
How many half-lives have past?

1 half-life, $\frac{8}{2} = 4$

2 half-lives, $\frac{4}{2} = 2$

2 half-lives having past mean that
2 x 710 000 000
1 420 000 000 years have past since this rock formed,
Therefore the answer is B.

Provincial Exam Question

Question,
A sealed container contains 200 g of radioactive iodine. After 24 days, the container has only 25 g of radioactive iodine. What is the half-life of this isotope of iodine?

A. 3 days B. 8 days C. 12 days D. 24 days.

Answer,
How many times has the original 200 g been divided in half to get to 25 g?

1 half-life, $\frac{200}{2} = 100\ g$ 2 half-lives, $\frac{100}{2} = 50\ g$ 3 half-lives, $\frac{50}{2} = 25\ g$

In 24 days, 3 half-lives have past, therefore each half-life is B,

$$\frac{24}{3} = 8\ days.$$

Summary

A ***half-life*** is the time needed for 50% of a particular isotope in a sample to decay from the parent isotope to the daughter isotope.

The reduction in the abundance of a particular radioisotope can be shown in a decay curve.

Utilizing known half-lives, one can determine the age of living and non-living materials.