RADIOACTIVITY

- The discovery of radioactivity can be attributed to several scientists. Wilhelm Roentgen discovered X-rays in 1895 and shortly after that Henri Becquerel observed radioactive behavior while experimenting with salts of uranium. However, the term radioactivity was first coined by Marie Curie in 1898.

- ***Radioactivity*** is the spontaneous emission of particles and/or rays from the nucleus of an atom. Nuclides are said to be either ***stable*** (non-radioactive) or ***unstable*** (radioactive).

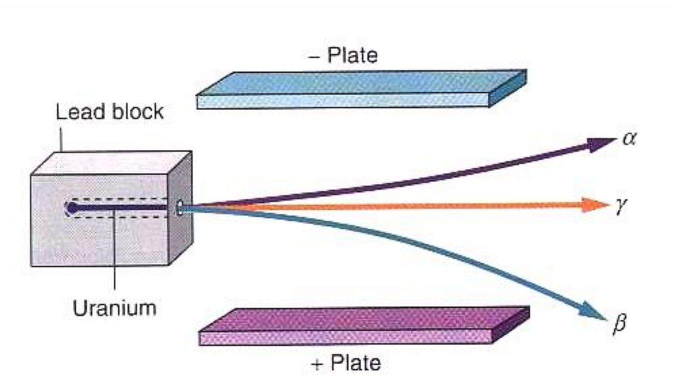
- All elements having an ***atomic number greater than 82*** (lead) have ***unstable nuclei***, which undergo ***spontaneous decay*** (disintegration), and are therefore ***radioactive***.

- These elements can undergo one of three different kinds of decay called ***α (alpha)***, ***β (beta)*** and ***γ (gamma)***. When decaying, the original nucleus (A) changes into another nucleus (B) and gives off radiation (b).

$$A \longrightarrow B + b$$

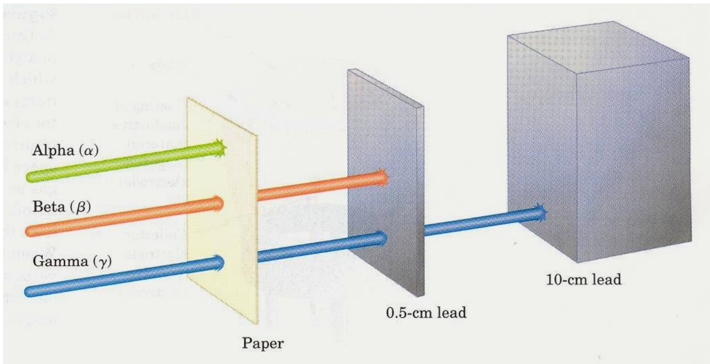
$$\text{Parent} \longrightarrow \text{daughter} + \text{radiation}$$

- The three different kinds of radiations can be distinguished by their ***interactions with an electric field***.
- ***α-Radiations*** carry a ***positive*** charge and are attracted to the negative plate.
- ***β-radiations*** carry a ***negative*** charge and are attracted to the positive plate.
- ***γ-radiations*** carry ***no charge*** and are attracted to neither plate.



- The three different kinds of radiation have different energies and penetration abilities.

- ***α-Rays*** have low energy and can be blocked by a thin sheet of paper.
- ***β-Rays*** have moderate energy and can be blocked by a thin sheet of metal.
- ***γ-Rays*** have high energy and can only be blocked by a thick sheet of lead.



ALPHA DECAY

- ***Alpha decay*** occurs when a nucleus changes into another nucleus and gives off an ***α-particle***, which is a ***helium nucleus*** $\left({}^{4}_{2}\text{He}\right)$.

$${}^{232}_{90}\text{Th} \longrightarrow {}^{228}_{88}\text{Ra} + {}^{4}_{2}\text{He}$$

- Note that the ***sum*** of the ***atomic numbers*** and the ***mass numbers*** on the ***left*** and the ***right*** side of the equation are ***equal***.

- As a result of alpha decay, the mass number (A) decreases by 4 and atomic number (Z) decreases by 2.

Examples:

1. ${}^{238}_{92}\text{U}$ undergoes alpha decay. Write the equation for the process.

$${}^{238}_{92}\text{U} \longrightarrow ???? + {}^{4}_{2}\text{He}$$

$${}^{238}_{92}\text{U} \longrightarrow \quad ??? + {}^{4}_{2}\text{He}$$

$${}^{238}_{92}\text{U} \longrightarrow \qquad + {}^{4}_{2}\text{He}$$

2. Write the equation for the decay of radium isotope ${}^{226}_{88}\text{Ra}$.

$${}^{226}_{88}\text{Ra} \longrightarrow \quad ??? + {}^{4}_{2}\text{He}$$

$${}^{226}_{88}\text{Ra} \longrightarrow \qquad + {}^{4}_{2}\text{He}$$

BETA & GAMMA DECAYS

- ***Beta decay*** occurs when a nucleus changes into another nucleus and gives off a ***ß-particle***, which is an ***electron*** $\left({}^{0}_{-1}e\right)$.

$$ {}^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e $$

- In ***beta decay***, a ***neutron*** is transformed into a ***proton*** and an ***electron***. The proton remains in the nucleus, while the ***electron is emitted as a beta particle***.

$$ {}^{1}_{0}n \longrightarrow {}^{1}_{1}p + {}^{0}_{-1}e $$

- ***Gamma decay*** occurs when a nucleus gives off ***γ-rays*** , and becomes a less energetic form of the same nucleus.

$$ {}^{204}_{82}Pb^{*} \longrightarrow {}^{204}_{82}Pb + \gamma $$

- Certain nuclear processes can also lead to a fourth form of radiation, called a ***positron*** $\left({}^{0}_{+1}e\right)$.

$$ {}^{17}_{9}F \longrightarrow {}^{17}_{8}O + {}^{0}_{+1}e $$

Examples:

1. Complete the following equations for nuclear decays:

$$ {}^{46}_{21}Sc^{*} \longrightarrow \qquad\qquad + \gamma $$

$$ {}^{47}_{21}Sc \longrightarrow \qquad\qquad + {}^{0}_{-1}e $$

2. Actinium-225 (${}^{225}_{89}Ac$) undergoes alpha decay followed by beta decay. Write reactions for these nuclear decays.

$$ {}^{225}_{89}Ac \xrightarrow{\alpha} \qquad\qquad\qquad \xrightarrow{\beta} $$

RADIONUCLIDES

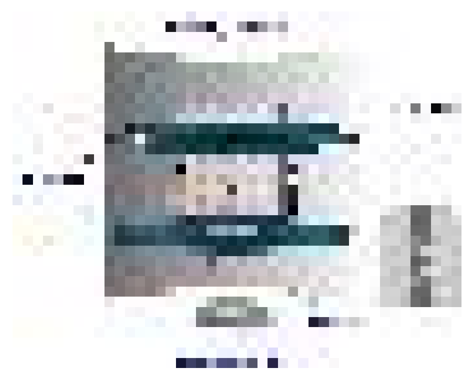
- A ***nuclide*** will be ***radioactive*** if it meets any of the following criteria:

  1. Its ***atomic number*** is greater than **83**.
  2. It has ***fewer n than p*** in the nucleus (except $^{1}_{1}H$, $^{3}_{2}He$).
  3. It has ***odd number of neutrons*** and odd number of ***protons*** (except for $^{2}_{1}H$, $^{6}_{3}Li$, $^{10}_{5}B$, $^{14}_{7}N$).

Examples:
Which is the radionuclide in each of the following pairs:

1. $^{208}_{82}Pb$ and $^{222}_{86}Rn$
2. $^{19}_{10}Ne$ and $^{20}_{10}Ne$
3. $^{63}_{29}Cu$ and $^{64}_{29}Cu$

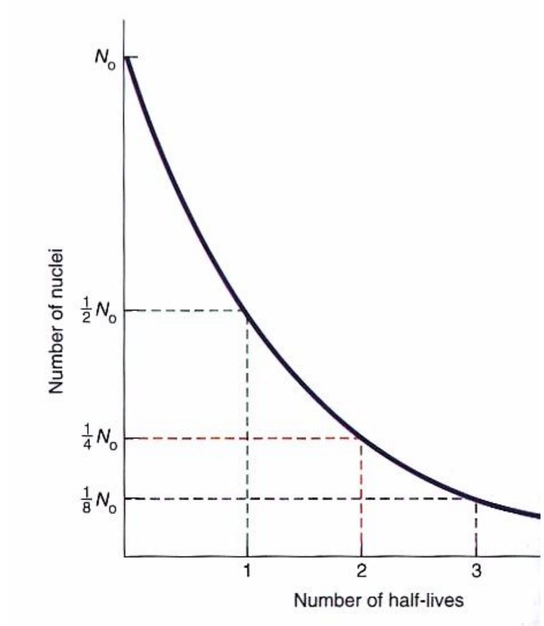
- One example of a practical use for radionuclides is their use in smoke detectors.
- In these detectors, the radioculide decays to form α-particles.
- The α-particles ionize (charge) the air particles and keep a current running through the circuit.
- When smoke particles interfere with the ions, current is reduced in the circuit, and an alarm goes off.



HALF-LIFE

- The ***time*** it takes for ***half*** of any ***radionuclide to decay*** is called ***half-life***. Some nuclides have half-lives of only seconds, while others have half-life of years.

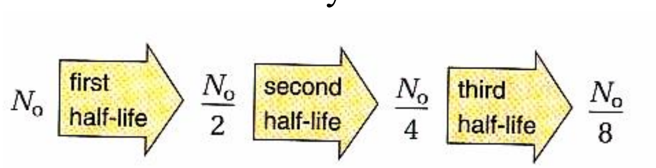
- The rate of decay of any radionuclide follows the graph to the right, with ***each half-life*** reducing the amount of radionuclide to ***half of the previous amount***.



Examples:

1. Iodine-131 has a half-life of 8 days. What mass of a 40 g sample of iodine-131 will remain after 24 days.

$$24 \text{ days} \times \frac{1 \text{ half-life}}{8 \text{ days}} = 3 \text{ half-lives}$$



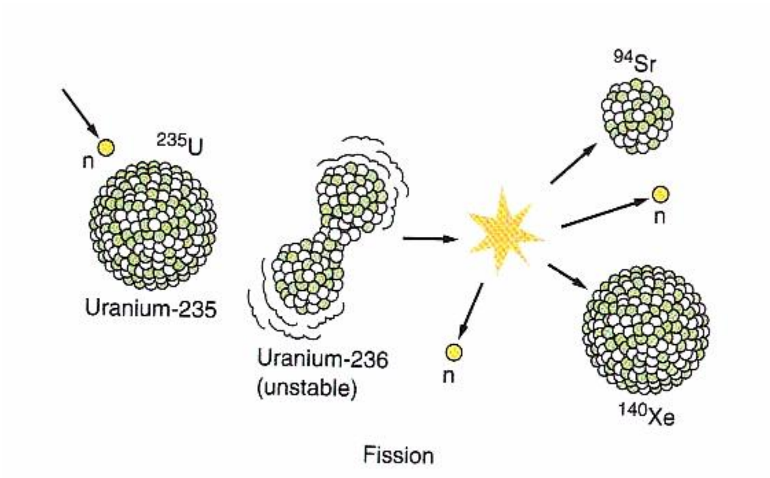
40 g $\xrightarrow{\text{1st half-life}}$ $\xrightarrow{\text{2nd half-life}}$ $\xrightarrow{\text{3rd half-life}}$

2. How long would it take for a sample of C-14 (½ Life=5730 y) to decay to ¼ of its original amount?

$$(2 \text{ half-lives}) \times \underline{\qquad\qquad} = \qquad \text{years}$$

NUCLEAR FISSION & FUSION

- ***Fission*** is the process by which a ***large nucleus is "split"*** into two smaller nuclei, with a ***large amount of energy released***.



$$ {}^{1}_{0}n + {}^{235}_{92}U \longrightarrow {}^{236}_{92}U \text{ (unstable)} $$

$$ {}^{236}_{92}U \longrightarrow {}^{140}_{54}Xe + {}^{94}_{38}Sr + 2\,{}^{1}_{0}n $$

- A ***nuclear bomb*** is an example of an ***uncontrolled fission***, while a ***nuclear reactor*** is an example of a ***controlled fission***.

- ***Fusion*** is the process by which ***smaller nuclei combine*** to ***form larger ones***, with the ***release of energy***.

- The ***sun*** uses ***fusion*** to produce a ***helium nucleus from 4 hydrogen nuclei***, giving off ***2 positrons*** and energy.

$$ 4\,{}^{1}_{1}H \longrightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}e + \text{energy} $$