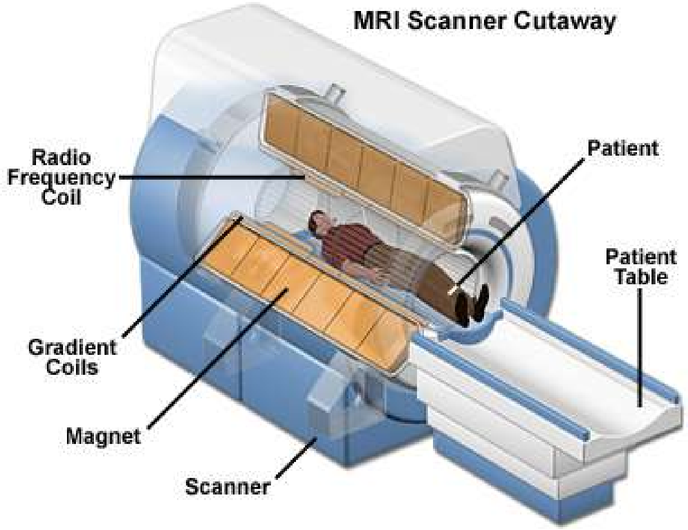
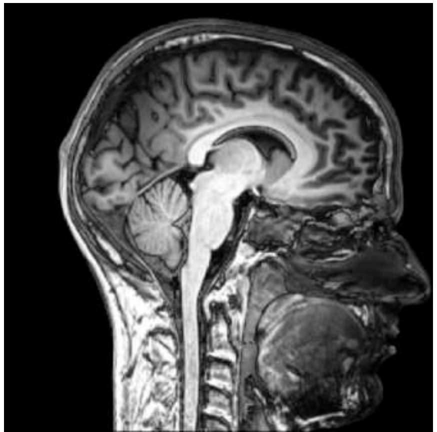
Nuclear Chemistry

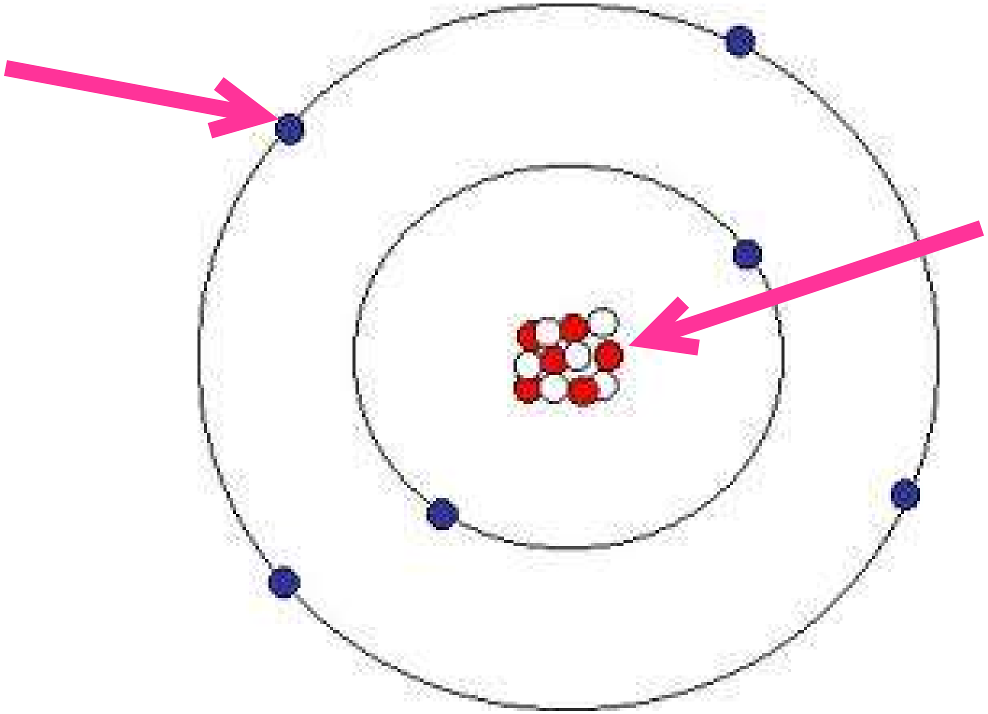
Radiation





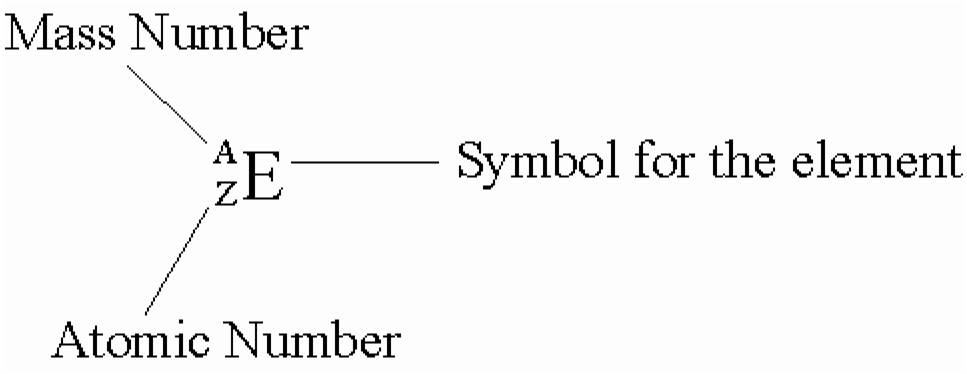
Background – Atomic Structure

Electrons

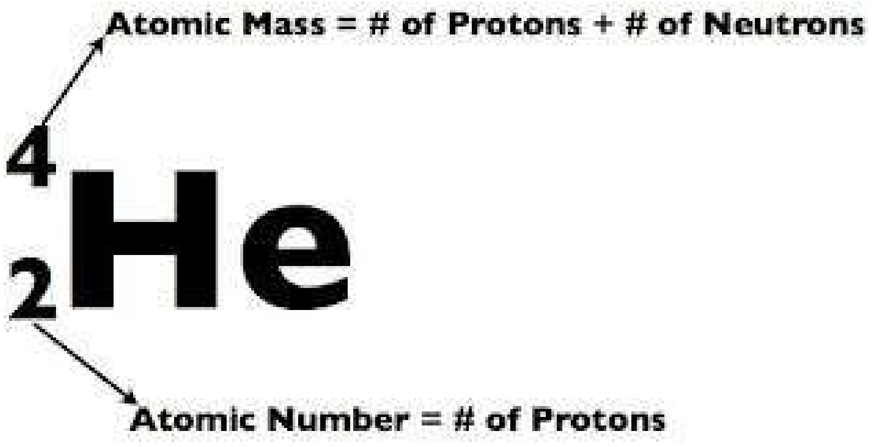


Nucleus
Protons + neutrons

Background



Examples:



Helium - 4

Chemical Equations

- Basic formula:

  $aA + bB \rightarrow cC + dD$

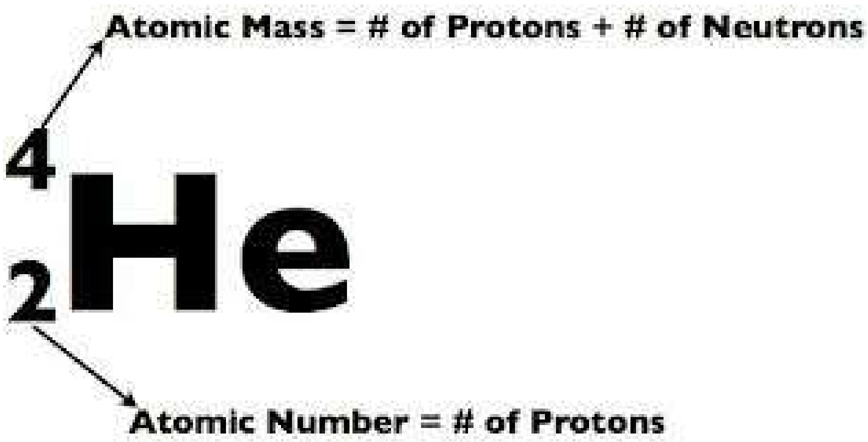
- Example:

  $Na + Cl_2 \rightarrow 2NaCl$

Nuclear Equations

In nuclear equations, we balance

- **atomic number**
- **mass number**



Nuclear Equations

- Example:

$$^{212}_{84}\text{Po} \rightarrow \, ^{4}_{2}\text{He} + \, ^{208}_{82}\text{Pb}$$

Nuclear Reactions

- Chemical Reactions = bonds forming and breaking
- **Nuclear reactions** = when the nuclei emit particles and/or rays

Power of Radiation

- **Alpha radiation** is least penetrating and can penetrate the outer layer of skin. Alpha radiation is stopped by a sheet of paper.

- **Beta radiation** can penetrate through a few cm of skin and tissue. Beta radiation is stopped by a sheet of aluminum foil.

- **Gamma radiation** will pass right through a body. Gamma radiation requires several cm of lead to stop.

Types of Radiation

I. Alpha = $^{4}_{2}\alpha$

- Example:
  - What is the equation when radon – 222 undergoes alpha decay?

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

Types of Radiation

II. Beta = $^{0}_{-1}\beta$ or $^{0}_{-1}e$

- Example:
  - ❖ Write the equation for hydrogen – 3 undergoing beta decay.

$$^{3}_{1}H \rightarrow \beta^{0}_{-1} + {}^{3}_{2}He$$

Types of Radiation

II. Beta (continued)

A. Positron: A positron is a particle equal in mass to an electron but with opposite charge.

- $^{0}_{+1}\beta$ or $^{0}_{+1}e$

Example:

- Fluorine – 18 emits a positron when it decays.

$$F \rightarrow {}^{18}_{9}\beta + {}^{0}_{+1}Ne \quad {}^{18}_{10}$$

Types of Radiation

III. Gamma = ${}^{0}_{0}\gamma$

- Example
  - ❖ Uranium - 238 emits an alpha particle and gamma rays when it decays.

$$U \xrightarrow[92]{238} \gamma + {}^{0}_{0}U \quad {}^{238}_{92}$$

TABLE 4.4 Nuclear Symbols for Subatomic Particles

Particles	Symbols	Nuclear Symbols
Proton	p	${}^{1}_{1}p$ or ${}^{1}_{1}H$
Neutron	n	${}^{1}_{0}n$
Electron	e^- or β	${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$
Positron	e^+ or β^+	${}^{0}_{+1}e$ or ${}^{0}_{+1}\beta$
Alpha particle	α	${}^{4}_{2}He$ or ${}^{4}_{2}\alpha$
Beta particle	β or β^-	${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$
Gamma ray	γ	${}^{0}_{0}\gamma$

Practice

1) Plutonium-239 emits an alpha particle when it decays.

$$^{239}_{94}Pu \rightarrow \, ^{4}_{2}\alpha + \, ^{235}_{92}U$$

2) Protactinium-234 undergoes beta decay.

$$^{234}_{91}Pa \rightarrow \, ^{0}_{-1}\beta + \, ^{234}_{92}U$$

3) Carbon-11 emits a positron when it decays.

$$^{11}_{6}C \rightarrow {}^{0}_{+1}\beta + {}^{11}_{5}B$$

4) Carbon-11 undergoes electron capture.

$$^{11}_{6}C + {}^{0}_{-1}e \rightarrow {}^{11}_{5}B$$

5) Radium-226 decays by alpha emission.

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

6) Sodium-24 undergoes beta decay.

$$^{24}_{11}Na \rightarrow ^{0}_{-1}\beta + ^{24}_{12}Mg$$

8) Gold-188 decays by positron emission.

$$^{188}_{79}Au \rightarrow ^{0}_{+1}\beta + ^{188}_{78}Pt$$

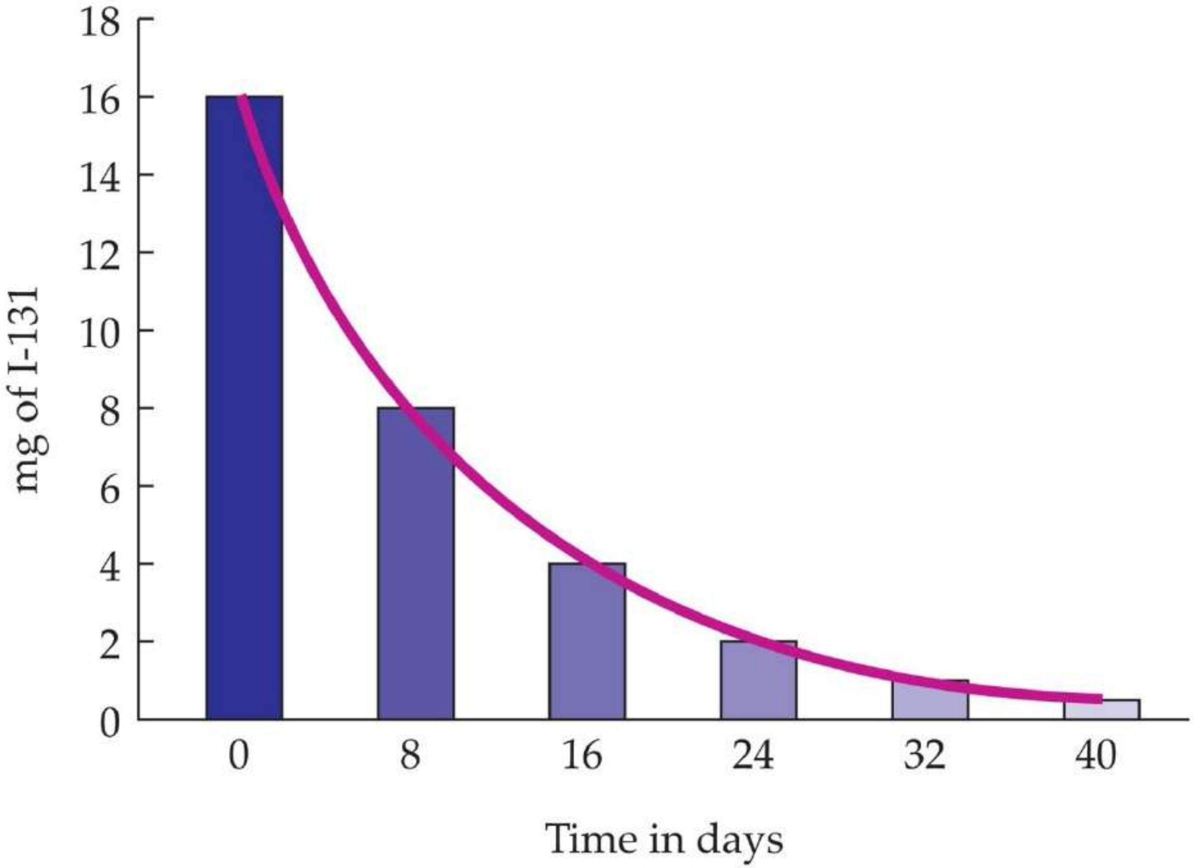
9) Argon-37 undergoes electron capture.

$$^{37}_{18}Ar + ^{0}_{-1}e \rightarrow ^{37}_{17}Cl$$

Half-Life

Half-life of a radioactive sample is the time required for ½ of the material to undergo radioactive decay.

Half-Life



Half-Life

$$\text{Final mass} = \text{Initial mass} \times (0.5^{n})$$

Final mass: Mass after the amount of half-lives “n” have past

Initial mass: Mass before radioactive decay

n: Number of half lives

$$n = \frac{\text{time elapsed}}{\text{Length of half life}}$$

$M_F = M_I \times 0.5^n$

n = # of half lives

Practice

1. If gallium – 68 has a half-life of 68.3 minutes, how much of a 160.0 mg sample is left after 1 half life?

$160.0\,mg \times 0.5^1 = \boxed{80.00\,mg}$

2 half lives?

$160.0\,mg \times 0.5^2 = \boxed{40.00\,mg}$

3 half lives?

$160.0\,mg \times 0.5^3 = \boxed{20.00\,mg}$

2. The half life of I-123 is 13 hr. How much of a 64 mg sample of I-123 is left after 39 hours?

$n = 39/13 = 3$

$64\,mg \times 0.5^3 = \boxed{8.0\,mg}$

3. Cobalt – 60, with a half-life of 5 years, is used in cancer radiation treatments. If a hospital purchases a supply of 30.0 g, how much would be left after 15 years?

$n = 15/5 = 3$ half lives

$30.0g \times 0.5^3 = \boxed{3.75g}$

4. Iron-59 is used in medicine to diagnose blood circulation disorders. The half-life of iron-59 is 44.5 days. How much of a 2.000 mg sample will remain after 133.5 days?

$n = 133.5/44.5 = 3$ half lives

$2.000\,\text{mg} \times 0.5^3 = \boxed{0.2500\,\text{mg}}$

5. The half-life of polonium-218 is 3.0 minutes. If you start with 20.0 g, how long will it take before only 1.25 g remains?

half lives

1 [20.0 g / 2 = 10.0 g

2 [5.0 g

3 [2.5 g

4 [1.25 g

n = 4 half lives

4 half lives x 3.0 min =

12 minutes

6. A sample initially contains 150.0 mg of radon-222. After 11.4 days, the sample contains 18.75 mg of radon-222. Calculate the half-life.

1 [150.0 mg/2 =
75.0 mg

2 [37.5 mg

3 [18.75 mg

$n = 3$ half lives

$$3 \text{ half lives} = \frac{11.4 \text{ days}}{\text{Length of half life}}$$

half life = 3.8 days