Introduction to Physical Science

Nuclear Equations

Presented by Robert Wagner

Types of Particles in Nuclear Reactions

- Recall: Nuclear reactions involve changes in atomic numbers, mass numbers, or energy states of nuclei
- Particles:
  - Protons:
  - Neutrons:
  - Alpha Particles:
  - Beta Particles:
  - Positrons:

Types of Nuclear Reactions

Type	Nuclear equation	Representation	Change in mass/atomic numbers
Alpha decay	${}^{A}_{Z}X \rightarrow {}^{4}_{2}He + {}^{A-4}_{Z-2}Y$		A: decrease by 4 Z: decrease by 2
Beta decay	${}^{A}_{Z}X \rightarrow {}^{0}_{-1}e + {}^{A}_{Z+1}Y$		A: unchanged Z: increase by 1
Gamma decay	${}^{A}_{Z}X \rightarrow {}^{0}_{0}\gamma + {}^{A}_{Z}Y$	Excited nuclear state γ	A: unchanged Z: unchanged
Positron emission	${}^{A}_{Z}X \rightarrow {}^{0}_{+1}e + {}^{A}_{Z-1}Y$		A: unchanged Z: decrease by 1
Electron capture	${}^{A}_{Z}X + {}^{0}_{-1}e \rightarrow {}^{A}_{Z-1}Y$	X-ray	A: unchanged Z: decrease by 1

Image Credit: OpenStax Chemistry Figure 21.4 CC BY 4.0

Positrons

- Positron
  - Example of antimatter!
  - Like an electron but positively charged
- Matter and antimatter will annihilate each other
  - When an electron meets its antiparticle, they annihilate production gamma rays
  -
- Mass converted to energy
  - Can be calculated using:

Balancing Nuclear Reactions

- In chemical reactions, we had to make sure that the number of each atom remained the same
- In nuclear reactions, it is the number of nucleons that remains the same
- Two things to balance:
  - The sum of the mass numbers of the products is the same as the sum of the mass numbers of the reactants
  - The sum of the charges of the products is the same as the sum of the charges of the reactants

Example

- The reaction of an α-particle with magnesium-25 ( ) yields a proton and the nucleus of another element. What is the nucleus produced?

$^{25}_{12}Mg$ & $^{4}_{2}He$

$^{25}_{12}Mg + ^{4}_{2}He \longrightarrow ^{1}_{1}H + ^{A}_{Z}X$

Balance mass number:

25 + 4 = 1 + A ; 29 = 1+ A ; A = 28

Balance charges:

12 + 2 = 1 + Z ; 14 = 1 + Z ; Z = 13

Z = 13 is aluminum

$^{25}_{12}Mg + ^{4}_{2}He \longrightarrow ^{1}_{1}H + ^{28}_{13}Al$

Example Nuclear Reactions from History (2)

- 1898: Marie Curie - first naturally occurring unstable element
  -
- 1919: Ernest Rutherford - first nuclide created artificially
  -
- 1932: James Chadwick - discovery of the neutron
  -

Example Nuclear Reactions from History

- 1937: Emilio Segre & Carlo Perrier - Produced technetium which does not occur naturally on Earth
  -
- 1942: University of Chicago - controlled nuclear chain reaction
  -

Summary

- Particle in nuclear reactions include nucleons - protons & neutrons. In addition, alpha particles (helium nuclei) and electrons and positrons can be involved
- Nuclear reactions are balanced by balancing the mass number and the electrical charge of the reactants and products
- We looked at several nuclear reactions that have been important in the history of nuclear chemistry