

Chemistry 500: Chemistry in Modern Living

Topic 5: The Fires of Nuclear Fission

Atomic Structure, Nuclear Fission and Fusion, and Nuclear Weapons

Chemistry in Context, 2nd Edition: Chapter 8, Pages 245-280

Chemistry in Context, 3rd Edition: Chapter 7, Pages 265-304

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5A Atomic and Nuclear Structure

- Atomic Structure:
 - Nucleus
 - Electron Cloud

- Nuclear Structure:
 - Neutrons and Protons
 - Strong Nuclear Force vs. Electrostatic Force
 - Rubber Baggie Model

- Isotopes
 - Atomic Number
 - Determined by number of protons
 - Mass Number
 - Equals the total number of protons and neutrons

➤ Ask Students: Give the number of protons and the number of neutrons for each of the following isotopes or give the atomic symbol, as required

➤ Group Activity



➤ 32 protons and 37 neutrons ⇒

➤ 17 protons and 16 neutrons ⇒



5B Fission and Fusion

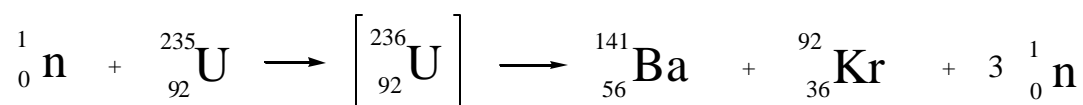
- **Fission Reactions** are nuclear reactions that split the nucleus into smaller fragments

- **Fusion Reactions** are nuclear reactions that join two units to form a larger nucleus

- These nuclear reactions can be extremely exothermic
 - They produce large amounts of heat
 - For example ^{235}U fission \Rightarrow energy equivalent to 33,000 tons of TNT from 1 kg of Uranium
 - This energy is produced via the conversion of mass to energy
 - Einstein $\Rightarrow E = m c^2$

5C Nuclear Reactions and Chain Reactions

- Involve the **splitting or combining of nuclei** and fragments
- They can be balanced much like chemical reactions



➤ Chain Reactions

- Graphics from Text: Figure 8.3 in 2nd Edition and 7.2 in 3rd

Edition, Chain Reaction Diagram

- Average of 2 to 3 **neutrons per fission**

➤ Induced nuclear fission

5D Nuclear Fission Reactors

- Graphics from Text: Figure 7.3 in 3rd Edition, Diagram of a nuclear power plant

- Roles of Major Components
 - Fuel Rods

 - Moderator (Thermal Neutrons)

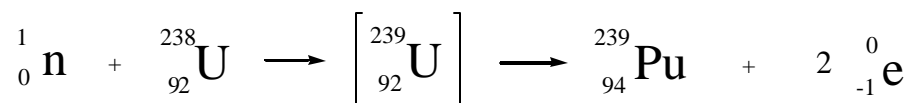
 - Control Rods

 - Steam system
 - Piping
 - Turbines
 - Cooling towers / heat exchangers

- Graphics from Text: Figure 7.4 in 3rd Edition, Diagram of fuel assembly in nuclear power plant

- Comparison of various reactor types
 - Key variables
 - Level of enrichment
 - Moderator type
 - Cooling fluid
 - Pressurized light water reactor
 - US Navy
 - Heavy water reactor, CANDU
 - Liquid metal cooled reactor
 - Graphite moderated / Helium Cooled reactor
 - Natural Reactors

- What prevents melt downs
 - Active control systems
 - Redundancy
 - Mechanical errors
 - Brittle piping (alloys), Welding, Pumps
 - Human errors
 - Homer Simpson
 - Passive control systems
 - Energy density
 - No-maintenance piles
- What happened at Chernobyl
- Breeder Reactors



5E Radiation and Radioactive Decay

- Graphics from Text: Table 8.1 in 2nd Edition and 7.1 in 3rd Edition, Radioactive emissions

- Types of Radiation
 - Alpha particles, Helium nuclei
 - Beta particles, electrons
 - Gamma rays, high energy photons
 - Neutrons

- Variations in penetrating power

- Doses
 - Lethal vs. typical
 - The controversy about low doses

- Graphics from Text: Table 8.4 in 2nd Edition and Figure 7.10 in 3rd Edition, US Background Radiation Sources

➤ Radioactive Decay

➤ Half life of an isotope for spontaneous decay

➤ Ranges of half lives in common isotopes

➤ Graphics from Text: Figure 8.9 in 2nd Edition and 7.12 in 3rd

Edition: Radioactive decay curve for ^{239}Pu

5F Nuclear Power and the World

- Graphics from Text: Table 8.5 from 2nd Edition and Table 7.4 from 3rd Edition, Nuclear Power Statistics for Selected Countries

- Graphics from Text: Figure 8.10 from 2nd Edition and Figure 7.19 from 3rd Edition, Percentage of Electrical Power Generated from Nuclear Reactors for Selected Countries

- Ask Students: Develop some reasons why the differences between different countries

- Group Activity

5G Nuclear Bomb Design

- Critical Mass
 - 15 to 18 kg of ^{235}U

- Crude Fission bomb design
 - Tube cannon
 - Collapsing shell

- Crude Fusion bomb design

- Miniaturization of bombs

Index of Vocabulary and Major Topics

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