

## Chem. I Notes - Ch. 24 topics

### I. How Nuclear Power Works

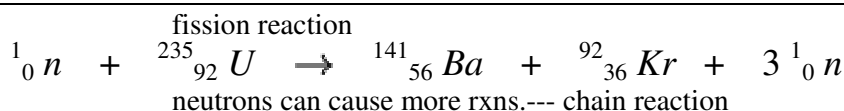
#### A. types of nuclear reactions

- 1) **fission**—one larger atom *split* into two smaller atoms
- 2) **fission products**—the lighter atoms resulting from the reaction (also called *daughter products*)
- 3) **fusion**—two smaller atoms are *joined* (fused) to form one larger atom (see section II G)
- 4) **chain reaction**—a domino effect; a repeating reaction cycle



#### B. characteristics of nuclear reactions

- 1) *mass of products* < *mass of reactants*
- 2) violates the Conservation Laws
- 3) massive energy is released (1 kg is enough to be a full-scale bomb)
- 4)  $E = mc^2$
- 5) **isotopes** are involved



### II. Nuclear Power Plants

#### A. fuel for nuclear power plants

- 1) uranium (U) ore is mined and refined, made into  $UO_2$  (*uranium dioxide*), also generically called *MOX (mined oxide fuel)*
- 2) **enrichment**—separating the isotopes (U-238 and U-235)

#### B. parts of nuclear reactors

- 1) *reactor core*, containing tubes called fuel elements or **fuel rods**
- 2) **control rods**, interspersed between the fuel rods, *contain neutron-absorbing material*
- 3) **moderator**—material that *slows down the neutrons* (such as water); can be referred to as the *coolant*  
“light water” = regular  $H_2O$  OR “heavy water,”  $D_2O$ , contains deuterium (H-2)
- 4) *reactor vessel* holds everything

#### C. nuclear power plant basics

- a) heat generated by the reactor boils water, creating steam
- b) steam powers turbogenerators
- c) **meltdown**—actual melting of the core materials, causing explosions
- d) *LOCA* – *loss of coolant accident*

#### D. radioactive wastes (“**radwaste**”)

- 1) *reprocessing*—recovery and recycling of isotope products of nuclear reactions to be used as fuel again (not done in U.S.)
- 2) types of radioactive waste: low-level and high-level

#### E. famous nuclear accidents

- 1) *Fukushima* 3/11/11
  - a) caused by tsunami and earthquake

- b) *LOCA – loss of coolant accident*
- c) released 10-20% of the radiation compared to Chernobyl

2) *Chernobyl* (former USSR; Ukraine, 4/26/86)

- a) summary: safety systems were disabled while running tests; reactor overheated; chain reaction went out of control; steam built up and blew the steel and concrete top off the reactor
- b) causes: design weaknesses, procedural violations, communication breakdown
- c) effects
  - 29 died within months
  - increased thyroid cancer and other types of cancer
  - increased cases of anxiety, depression, PTSD
  - power plant shut down
  - radiation poisoning of the area
  - lack of public trust

2) *Three Mile Island 2, “TMI-2”* (Pennsylvania, 3/28/79)

- a) summary: steam generator shut down due to lack of feedwater; valve opened to let out excess steam but did not close; equipment did not show that the valve was still open; partial meltdown of the core
- b) causes: design problems, equipment malfunction, miscommunication
- c) effects
  - lack of public trust
  - very low exposure to 2,000,000 people in the area
  - stricter standards of design, inspection, backup equipment, and human experience/ skill, troubleshooting
  - reactor shut down permanently

F. Economic problems with nuclear power

- 1) power plants lasting an average of only 17 years
  - a) *embrittlement*— the reactor parts themselves become brittle
  - b) *corrosion*—chemically eaten away; causes cracks in the pipes
- 2) *decommissioning* (closing down) a power plant is costly (hundreds of millions of dollars)
- 3) technical problems

G. fusion

- 1) **fusion**—*the joining of nuclei of two smaller atoms to form one larger atom*
- 2) hot fusion—deuterium (H-2) fusion, done in plasma
  - a) reaction results in equal quantities of tritium and neutrons
  - b) produces large amount of heat energy
  - c) “heavy hydrogen” isotopes *deuterium (D; H-2)* and *tritium (T; H-3)* are used in a *d-t reaction*
  - d) fusion requires 3,000,000 °C as well as high pressure—usually *ignited by a fission reaction!*
- 3) ITER: International Thermonuclear Explosion Reactor
  - a) international project; located in France
  - b) hydrogen plasma at 150 million °C – 10x higher than sun’s core!
  - c) uses magnetic fields to contain and control the hot plasma
  - d) first plasma operation is expected in 2016