

## Ch. 23 Overview Notes – NUCLEAR CHEMISTRY

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics*.

### I. How Nuclear Power Works

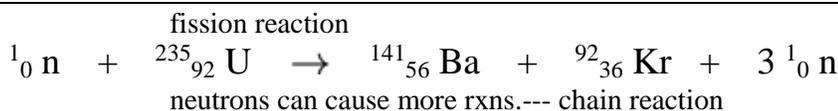
#### A. types of nuclear reactions

- 1) **fission**—one larger atom *split* into two smaller atoms
  - **fission products**—the lighter atoms resulting from the reaction (also called *daughter products*)
- 2) **fusion**—two smaller atoms are *joined* (fused) to form one larger atom (see section II G)
- 3) **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) **radioisotopes (radioactive isotopes)** are involved
- 6) *the identity of the original element changes = **transmutation***



### C. TYPES OF EMISSIONS (review from Ch. 3)

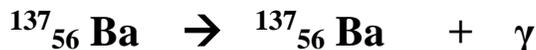
#### 1) **alpha** ( $\alpha$ )



#### 2) **beta** ( $\beta$ )



#### 3) **gamma** ( $\gamma$ )



### II. Nuclear Power Plants

#### A. fuel for nuclear power plants

- 1) uranium (U) ore is mined and refined, made into  $\text{UO}_2$  (*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 the first three 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
- 3) *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!*
- 2) ITER: International Thermonuclear Explosion Reactor [www.iter.org](http://www.iter.org)
  - 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) will produce 500 MW of fusion power
  - e) construction is underway and the first plasma operation is targeted for 2020, with full operation targeted for 2027