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 s*plit* 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**

fission reaction

$$^{1}_{0}\text{n} + {}^{235}_{92}\text{U} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + 3\,{}^{1}_{0}\text{n}$$

neutrons can cause more rxns.--- chain reaction

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

1) **alpha (α)**

$$^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\text{He}$$

2) **beta (β)**

$$^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + {}^{0}_{-1}\text{e}$$

3) **gamma (γ)**

$$^{137}_{56}\text{Ba} \rightarrow {}^{137}_{56}\text{Ba} + \gamma$$

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) **<u>moderator</u>**—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) **<u>meltdown</u>**—actual melting of the core materials, causing explosions
   d) *LOCA – loss of coolant accident*

D. radioactive wastes ("**<u>radwaste</u>**")
   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 tsumani 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
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