**Chem. I Notes - Ch. 24 topics**

I. How Nuclear Power Works

A. types of nuclear reactions

1) **fission**—one larger atom s*plit* 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

fission reaction

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

neutrons can cause more rxns.--- chain reaction

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 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 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