Ch 11 Nuclear (Radioactivity)

1) Nucleons - protons and neutrons that collectively make up the atomic nuclei.

2) Nuclide - a specific isotope of an atom given as atomic number and mass number.

Example: $^{228}_{88}Ra$ ← mass number: Protons + Neutrons; ← atomic number: Protons

Radium-228

3) Mass defect - difference between the mass of an atom and the sum of the masses of its protons, neutrons, and electrons. It is caused by the conversion of mass to energy upon formation of the nucleus.

4) Nuclear binding energy - energy released when a nucleus is formed from nucleons.

Note: binding energy/nucleon used to compare stability of different nuclides.

Higher binding energy the more tightly the nucleons are held together.

5) Characteristics of stable nuclides -

1) Low atomic numbers - neutron-proton ratio 1:1
2) Increased atomic number - neutron-proton ratio 1.5:1
3) Beyond atomic number 83 - repulsive forces of the protons are too great for stable nuclides.

6) Nuclear shell model - Nucleons exist in different energy levels, or shells in the nucleus.

7) Magic numbers - Number of nucleons that represent complete nuclear energy levels
2, 8, 20, 28, 50, 82, and 126.

8) Nuclear reaction - reaction that affects the nucleus of an atom.

9) Transmutation - change in the identity of a nucleus as a result of a change in the number of it's protons.

example: ${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n$

10) Radioactive decay - the spontaneous disintegration of a nucleus into a slightly lighter nucleus, accompanied by emission of particles, electromagnetic radiation, or both.

11) Nuclear radiation - particles or electromagnetic radiation emitted from the nucleus during radioactive decay.

12) Alpha particle - is 2 protons and 2 neutrons bound together and is emitted from the nucleus during some kinds of radioactive decay.

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

↑ alpha particle

13) Beta particle - is an electron emitted from the nucleus during some kinds of radioactive decay.

Example:

$$_{0}^{1}n \rightarrow {}_{1}^{1}p + {}_{-1}^{0}\beta$$

neutron — proton — Beta particle

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

6 Protons, 8 Neutrons — 7 Protons, 7 Neutron — Beta particle

14) Positron - a particle that has the same mass as an electron, but has a positive charge, and is emitted from the nucleus during some kinds of radioactive decay.

Example:

$$_{1}^{1}p \rightarrow {}_{0}^{1}n + {}_{+1}^{0}\beta$$

proton — neutron — Positron

$$_{19}^{38}K \rightarrow {}_{18}^{38}Ar + {}_{+1}^{0}\beta$$

Positron

proton changed to a neutron

15) Electron Capture - an inner orbital electron is captured by the nucleus of its own atom and combines with a proton to form a neutron.

Example:

$$_{1}^{1}p + {}_{-1}^{0}e \rightarrow {}_{0}^{1}n$$

$$_{47}^{106}Ag + {}_{-1}^{0}e \rightarrow {}_{46}^{106}Pd$$

proton + electron → neutron

16) Gamma ray – are high-energy electromagnetic waves emitted from a nucleus as it changes from an excited state to a ground energy state.

17) Half-life – is the time required for half the atoms of a radioactive nuclide to decay.

Note: 1) Each radioactive nuclide has its own half-life.
2) More stable nuclide decay slowly and have long half-lifes.
3) Less stable nuclide decay fast with short half-lifes.

18) Calculation for half-life:

Example #1: Phosphorus-32 has a half-life of 14.3 days. How many milligrams of phosphorus-32 remain after 57.2 days if you start with 4.0 mg of the isotope?

$$\#\text{ half-lifes} = \left(\text{time elapsed}\right) \times \frac{1 \text{ half-life}}{\text{time}} =$$

$$\left(57.2\text{ da}\right)\left(\frac{1 \text{ half-life}}{14.3\text{ da}}\right) = 4 \text{ half-lifes}$$

$$\left(4.0\text{mg}\right)\left(\frac{1}{2}\right) = 2.0\text{mg}\left(\frac{1}{2}\right) = \left(1.0\text{mg}\right)\left(\frac{1}{2}\right) = \left(.50\text{mg}\right)\left(\frac{1}{2}\right) = \boxed{.25\text{mg}}$$

remaining Isotope

Example #2: Half-life Po-210 is 138.4 days. Give number milligrams remaining after 415.2 days when starting with 2.0 mg.

$$\left(415.2\text{ days}\right)\left(\frac{\text{half-life}}{138.4\text{da}}\right) = 3 \text{ half-life}$$

$$\left(2.0\text{mg}\right)\left(\frac{1}{2}\right) = \left(1.0\text{mg}\right)\left(\frac{1}{2}\right) = \left(.5\text{mg}\right)\left(\frac{1}{2}\right) = .25\text{mg}$$

19) Decay Series - a series of radioactive nuclides produced by successive radioactive decay until a stable nuclide is reached.

20) Daughter nuclides - nuclides produced by the decay of parent nuclides.

Example: $^{238}_{92}U \rightarrow ^{234}_{90}Th + ^{4}_{2}He$ (Alpha particle)

$^{234}_{90}Th \rightarrow ^{234}_{91}Pa + ^{0}_{-1}\beta$ (Beta particle)

$^{234}_{91}Pa \rightarrow ^{234}_{92}U + ^{0}_{-1}\beta$

$^{234}_{92}U \rightarrow ^{230}_{90}Th + ^{4}_{2}He$

$^{230}_{90}Th \rightarrow ^{226}_{88}Ra + ^{4}_{2}He$

$^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + ^{4}_{2}He$

ect.

↓

21) Artificial transmutations - radioactive nuclide not found naturally but are produced by bombarding the nucleus of the atom with charged and uncharged particles. using a particle accelerator.

Example: $^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}U$

$^{239}_{92}U \rightarrow ^{239}_{93}Np + ^{0}_{-1}\beta$

(5)

22) Transuranium elements – elements with more than 92 protons in their nuclei.

23) Roentgen (R) – unit used to measure nuclear radiation exposure.

24) Rem – unit used to measure the dose of any type of ionizing radiation that factors in the effect that the radiation has on human tissue.

25) Detection devices
1) Film badges
2) Geiger counter
3) Scintillation counter
4) Cloud chamber
5) Bubble chamber

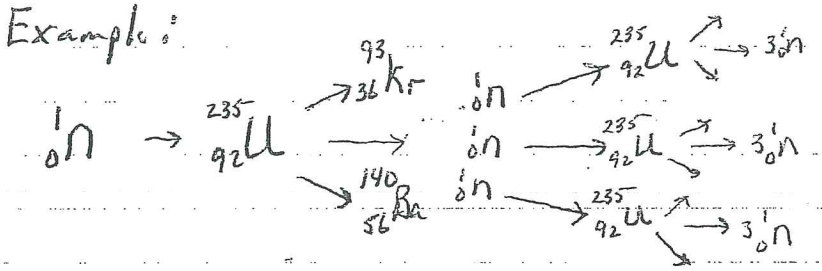
26) Radioactive dating – process by which the approximate age of an object is determined based on the amount of certain radioactive nuclides present.

27) Radioactive tracers – radioactive atoms that are incorporated into substances so that movement of the substance can be followed by doctors.

28) Nuclear Fission – process in which a very heavy nucleus splits into more stable nuclei of intermediate mass. A slow neutron is bombarded on a uranium nucleus make it unstable and causing it to split.

29) Chain reaction - a reaction in which the material that starts the reaction is also one of the products and can start another reaction.

Example:



30) Critical mass - Minimum amount of nuclide that provides the number of neutrons needed to sustain a chain reaction

31) Nuclear reactor - device that controlled-fission chain reaction to produce energy and radioactive nuclides.

32) Nuclear power plant - use energy as heat from nuclear reactors to produce electrical energy.

33) Nuclear Fusion - low-mass nuclei combine to form a heavier, more stable nucleus. It combines hydrogen nuclei at extremely high temperatures and pressure to form a helium nucleus. More energy per gram of fuel is produced in fusion compared to fission.

Example:

$$4\,{}^{1}_{1}H \longrightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}\beta + \text{energy}$$