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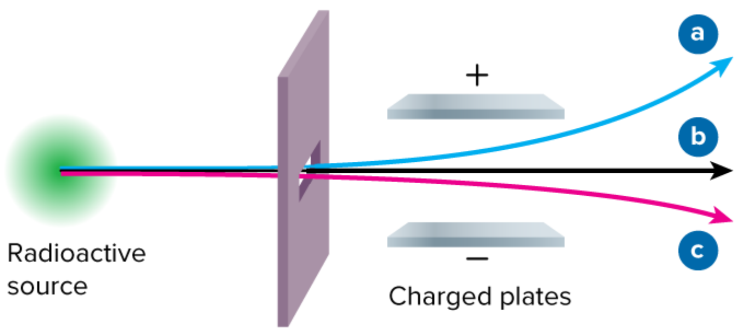
CHEMISTRY 2, LESSON 9

NUCLEAR RADIATION

1. What are isotopes of atoms with unstable nuclei called?
   a. **Radioisotopes**
   b. Radioactive decay
   c. Radiation
   d. Radioactivity
2. Match the different types of radiation with their charge.
   a. Alpha → 2+
   b. Beta → 1-
   c. Gamma → 0
3. What particle emitted during radioactive decay has a mass of 4 amu?
   a. Delta particle
   b. **Alpha particle**
   c. Gamma particle
4. Which type of radiation consists of high-energy electrons?
   a. **Gamma radiation**
   b. Beta radiation
   c. Delta radiation
   d. Alpha radiation
5. Alpha particles have low penetrating power because of their ___.
   a. Low mass and negative charge
   b. **High mass and positive charge**
   c. High mass and negative charge
   d. Low mass and positive charge



6. The diagram above shows alpha particles, beta particles, and gamma rays passing through a screen and between two charged plates. What can you infer about the identity of each radiation path (a, b, and c)? Explain your answer.

   I can infer that path *a* represents beta radiation, that path *b* represents gamma radiation, and that path *c* represents alpha radiation. The negative charge of beta radiation attracts it to a positively charged plate. The neutral charge of gamma radiation neither repels from nor attracts to any charge. The positive charge of alpha radiation attracts it to a negatively charged plate.

Table 2

	Alpha Radiation	*Beta Radiation*	*Gamma Radiation*
Symbol	α	β	γ
Composition	alpha particles	beta particles	high-energy electromagnetic radiation
Description of Radiation	helium nuclei; $4/2HE$	electrons	photons
Charge	2+	1-	0
Mass	$6.64 \times 10^{-27} kg$	$9.11 \times 10^{-31} kg$	0
Approximate Energy	5 MeV	0.05–1 MeV	1 MeV
Relative Penetrating Power	blocked by paper	blocked by metal foil	not completely blocked by lead or concrete

7. Table 2 gives approximate energy values in units of MeV. Convert each value into joules using the following conversion factor: $1MeV = 1.6 \times 10^{-13} J$

   a. Alpha

$$5MeV = 5 \times 1.6 \times 10^{-13} J = 8 \times 10^{-13} J$$

b. Beta

$$0.05 MeV = 0.05 \times 1.6 \times 10^{-13} J = 0.8 \times 10^{-13} J = 8 \times 10^{-14}$$
$$1 MeV = 1 \times 1.6 \times 10^{-13} J = 1.6 \times 10^{-13} J$$

c. Gamma

$$0 MeV = 0 \times 1.6 \times 10^{-13} J = 0$$

Radioactive Decay

1. Describe the forces acting on the particles within a nucleus and explain why neutrons are the glue holding the nucleus together.

   A nucleus is filled with protons and neutrons, those which are called nucleons in this context. Due to nuclear force between them, "all nucleons remain bound in the dense nucleus". This force overcomes the natural repulsion of similarly charged particles.

   See page 713 of the textbook.

2. Explain how you can predict whether or not an isotope is likely to be stable if you know its number of neutrons and protons.

   "For atoms with low atomic numbers($<$20), the most stable nuclei are those with neutron-to-proton ratios of 1:1. ... As atomic number increases, more and more neutrons are needed to balance the electrostatic repulsion force between protons. Therefore, the neutron-to-proton ratio for stable atoms gradually increases, reaching a maximum of approximately 1.5:1 for the largest atoms."

   See page 714 of the textbook.

3. Listed below are six radioisotopes and the isotopes into which they decay. Tell what kind of radioactive decay takes place in each case. The first one is done for you.

   See page 717 of the textbook.

   ${}^{66}_{28}Ni; {}^{65}_{29}Cu$

   Beta emission.

$^{199}_{82}Pb$; $^{199}_{81}Th$

Positron emission.

$^{190}_{78}Pt$; $^{186}_{76}Os$

Alpha decay.

$^{3}_{1}H$; $^{3}_{2}He$

Beta decay.

$^{115}_{51}Sb$; $^{115}_{50}Sn$

Beta decay.

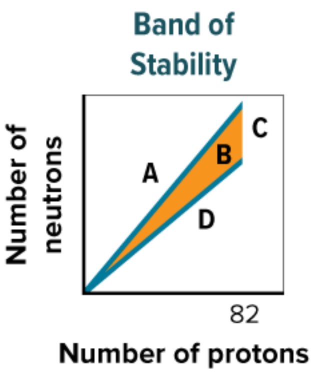
$^{58}_{27}Co$; $^{58}_{27}Co$

Gamma emission.

4. Calculate how much of a 10.0-g sample of americium-241 remains after four half-lives. Americium-241 is a radioisotope commonly used in smoke detectors and has a half-life of 430 years.

See page 719 of the textbook.

$$a = \frac{10}{2^4} = \frac{10}{16} = 6.25 \times 10^{-1}$$



5. In which region in the above graph are you likely to find:
   - Stable Nuclei?

     Region *B*.

   - Nuclei that undergo alpha decay?

     Region *C*.

   - Nuclei that undergo beta decay?

     Region *A*.

   - Nuclei that undergo positron emission?

     Region *D*.

See page 714 of the textbook.

6. Predict the nuclear equation for the alpha decay of radium-226, which was used on the tips of older lightning rods.

$$^{226}_{84}Ra \rightarrow \, ^{222}_{82}Ra + ^{4}_{2}He$$

See page 716 of the textbook.

Nuclear Reactions

1. Compare and contrast nuclear fission and nuclear fusion reactions. Describe the particles that are involved in each type of reaction and the changes they undergo.

   Nuclear fission consists of “the splitting of a nucleus into fragments.” A nuclear fission reaction is a specific sequence of chemical changes, that which involves nuclear fission. It is stated in the text: “The first nuclear fission reaction discovered involved uranium-235.”

See pages 727 and 728 of the textbook.

2. Describe the process that occurs during a nuclear chain reaction and explain how to control a chain reaction in a nuclear reactor.

   “If one fission reaction produces two neutrons, these two neutrons can cause two additional fissions. If those two fissions release four neutrons, those four neutrons could then produce four more fissions, and so on ... This self-sustaining process in which one reaction initiates the next is called a chain reaction.” So as to control a chain reaction, a given sample must be kept from reaching critical mass. “If much more mass than the critical mass is present, the chain reaction rapidly escalates.”

See pages 728 and 729 of the textbook.

3. The five equations below represent nuclear fission and nuclear fusion reactions. For each equation, tell whether fission or fusion has occurred and write the missing term in the equation.

$${}^{3}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}H + \_\_\_\_$$

See page 728 of the textbook.

Fusion. *H*.

$${}^{235}_{92}U + n \rightarrow {}^{95}_{38}Sr + \_\_\_\_ + 2n$$

Fission. ${}^{138}_{54}Xe$.

$${}^{2}_{1}H + \_\_\_\_ \rightarrow {}^{3}_{2}He + n$$

Fusion. $2n$.

$${}^{239}_{94}Pu + n \rightarrow {}^{88}_{37}Rb + \_\_\_\_ + 3n$$

Fission. ${}^{148}_{57}La$.

$$\_\_\_\_ + n \rightarrow {}^{92}_{39}Y + {}^{140}_{53}I + 2n$$

Fission. ${}^{230}_{92}U$.

4. What is the energy change (DE) associated with a change in mass (Dm) of 1.00mg?

$$\Delta E = \Delta mc^2 = \frac{1}{1000} kg \times 299792458 m/s^2 = \approx 9 \times 10^{10}$$

See page 726 of the textbook.

a. $9.00 \times 10^{9} J$
b. $\mathbf{9.00 \times 10^{10} J}$
c. $8.00 \times 10^{10} J$
d. $8.00 \times 10^{9} J$

5. ${}^{1}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + \gamma$ is one of the reactions in the Sun. The mass of ${}^{1}_{1}H$ is 1.007825 amu, the mass of ${}^{2}_{1}H$ is 2.014102 amu, and the mass of ${}^{3}_{2}He$ is 3.016029 amu.
   a. What is the mass defect of ${}^{3}_{2}He$?

$$\begin{aligned} MD &= m_{\text{nucleus}} - [N_p m_p + N_n m_n] \\ &= 3.016029 - [2.014102 + 1.007825] \\ &= 3.016029 - 3.021927 \\ &= -0.05898 amu \end{aligned}$$

See page 727 of the textbook.

   b. How much energy is released by the process?

$$\begin{aligned} -0.05898 amu &= -0.05898 \times 1.66054 \times 10^{-27} kg \\ &= 9.79386492 \times 10^{-30} kg \end{aligned}$$

$$\begin{aligned} 9.79386492 \times 10^{-30} kg &= 9.79386492 \times 10^{-30} \times 8.9876 \times 10^{16} J \\ &= 88.023340354992 \times 10^{-14} J \\ &= 8.8023340354992 \times 10^{-13} J \end{aligned}$$

The conversion rate from kilograms to joules was researched separately.

Applications and Effects of Nuclear Reactions

1. A Geiger counter works because radiation ___ the gas inside the tube.
   a. **Is absorbed by**
   b. Ionizes
   c. Reacts with
   d. Deflects off

See page 735 of the textbook.

2. Radiotracers are useful because replacing a stable atom of an element in a reaction with one of its ___ does not alter the reaction.
   a. Isomer
   b. **Isotope**
   c. Monomer
   d. Polymer

See page 737 of the textbook.

3. High energy ionizing radiation is dangerous because ___.
   a. It can prevent metabolism
   b. It can be transmitted from person to person
   c. It can be stored within the body for long periods of time
   d. **It can fragment and ionize molecules within biological tissue**

See page 739 of the textbook.

4. In a PET procedure, a radiotracer decays by ___ emission.
   a. **Positron**
   b. Neutron
   c. Alpha
   d. Gamma

See page 738 of the textbook.

5. Explain one way in which nuclear chemistry is used to diagnose or treat disease.

   "Radiation therapy is used to treat cancer by destroying the cancer cells ... radiation therapy has become one of the most effective treatment options in the fight against cancer."

See page 737 of the textbook.

6. A lab worker receives an average radiation dose of 21 mrem each month. Her allowed dose is 5,000 mrem/year. On average, what percentage of her yearly dose does she receive?

$$\frac{21 \times 12}{5000} \times 10 = \frac{252}{5000} \times 10 = 0.504 \times 10 = 5.04\%$$