

CHEM 2
Problem Set Ch.20

Key Begins on Page 3.

1. Write the complete nuclear equation for the following processes:

a) tritium, ${}^3_1\text{H}$, undergoes β decay.

b) Plutonium-242 (${}^{242}\text{Pu}$) undergoes α particle emission.

2. Why is it impossible for the isotope ${}^2_2\text{He}$ to exist?

3. For each pair of isotopes listed, indicate the nuclide that is radioactive:

a) ${}^{95}_{42}\text{Mo}$ or ${}^{92}_{43}\text{Tc}$

b) ${}^{22}_{11}\text{Na}$ or ${}^{25}_{11}\text{Na}$

c) ${}^{40}_{20}\text{Ca}$ or ${}^{45}_{20}\text{Ca}$

4. The radioactive decay of Tl-206 to Pb-206 has a half-life of 4.20 min. Starting with 5.00×10^{22} atoms of Tl-206, calculate the number of such atoms left after 42.0 min.

5. The radioactive potassium-40 isotope decays to argon-40 with a half-life of 1.2×10^9 yr.

a) Write a balanced equation for the reaction

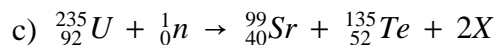
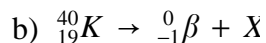
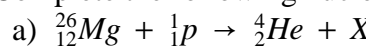
b) A sample of moon rock is found to contain 18 percent potassium-40 and 82 percent argon by mass. Calculate the age of the rock in years

6. Write balanced nuclear equations for the following reactions

a) ${}^{14}_7\text{N}(p, a) {}^{12}_6\text{C}$

b) ${}^9_4\text{Be}(d, 2p) {}^9_3\text{Li}$

7. Complete the following nuclear equations and identify X in each case.



8. Define a tracer and describe three applications of isotopes in chemistry and medicine.

9. A laboratory rat weighs 265 g and receives 1.77×10^{10} β particles, each with an energy of 2.20×10^{-13} J.

a) How many rads does the animal receive?

b) If the RBE is 0.75, how many mrem is this?

10. The ${}^{80}\text{Br}$ nuclide decays by either β decay or electron capture.

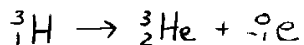
a) What is the product of each process?

b) Which process releases more energy? (Masses of atoms: ${}^{80}\text{Br} = 79.918528$ amu; ${}^{80}\text{Kr} = 79.916380$ amu; ${}^{80}\text{Se} = 79.961520$ amu; neglect the mass of the electron involved.)

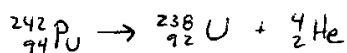
11. Nuclear disarmament could be accomplished if weapons were not "replenished." The tritium in nuclear warhead decays with a half-life of 12.26 yr to helium, and must be periodically replaced or the weapon is useless. What fraction of the tritium is lost in 5 years?

1. Write the complete nuclear equation for the following processes:

a) tritium, ${}^3_1\text{H}$, undergoes β decay.



b) Plutonium-242 (${}^{242}\text{Pu}$) undergoes α particle emission.



2. Why is it impossible for the isotope ${}^2_2\text{He}$ to exist?

Two opposing forces help stabilize the nucleus: (1) repulsive force between protons and (2) strong force - the attractive force between proton and neutron nucleons. If one of these forces is missing, the isotope will not exist.

${}^2_2\text{He}$ nucleus consists of 2 protons and 0 neutrons. This nucleus is unstable because the repulsive force between 2 protons is not countered by the strong force.

3. For each pair of isotopes listed, indicate the nuclide that is radioactive:

a) ${}^{95}_{42}\text{Mo}$ or ${}^{92}_{43}\text{Tc}$

Contains odd number of protons + neutrons, which is very unstable

b) ${}^{22}_{11}\text{Na}$ or ${}^{23}_{11}\text{Na}$

Contains an odd number of protons + neutrons, which is unstable.

c) ${}^{40}_{20}\text{Ca}$ or ${}^{45}_{20}\text{Ca}$

↑ contains a magic number of protons + neutrons, very stable

↑ has a odd number of neutrons + ~~protons~~ a magic number of protons, less stable than ${}^{40}_{20}\text{Ca}$

4. The radioactive decay of Tl-206 to Pb-206 has a half-life of 4.20 min. Starting with 5.00×10^{22} atoms of Tl-206, calculate the number of such atoms left after 42.0 min.

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{4.20 \text{ min}} = 0.165/\text{min} \quad \ln \frac{N_t}{N_0} = -kt$$

$$\frac{N_t}{N_0} = e^{-kt}$$

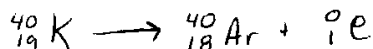
$$\frac{N_t}{N_0} = e^{-(0.165/\text{min})(42.0 \text{ min})} = 9.78 \times 10^{-4}$$

$$N_t = (9.78 \times 10^{-4}) N_0 = (9.78 \times 10^{-4})(5.00 \times 10^{22} \text{ atoms})$$

$$N_t = 4.89 \times 10^{19} \text{ nuclides remain}$$

5. The radioactive potassium-40 isotope decays to argon-40 with a half-life of 1.2×10^9 yr.

a) Write a balanced equation for the reaction



b) A sample of moon rock is found to contain 18 percent potassium-40 and 82 percent argon by mass.

Calculate the age of the rock in years

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{1.2 \times 10^9 \text{ yr}}$$

$$k = 5.78 \times 10^{-10} \text{ yr}^{-1}$$

$$\ln \frac{N_t}{N_0} = -kt$$

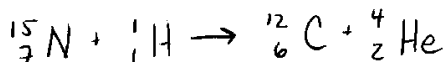
$$t = -\frac{1}{k} \ln \frac{N_t}{N_0}$$

$$t = -\frac{1}{5.78 \times 10^{-10} \text{ yr}^{-1}} \ln \left(\frac{18}{100} \right)$$

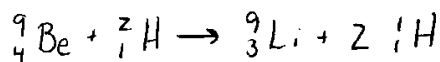
$$t = 3.0 \times 10^9 \text{ yr}$$

6. Write balanced nuclear equations for the following reactions

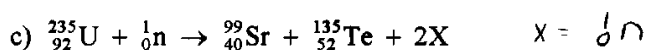
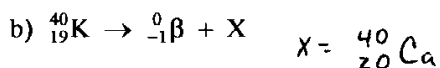
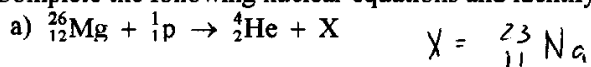
a) ${}^{15}_7\text{N}(\alpha, \alpha){}^{12}_6\text{C}$



b) ${}^9_4\text{Be}(d, 2p){}^7_3\text{Li}$



7. Complete the following nuclear equations and identify X in each case.



8. Define a tracer and describe three applications of isotopes in chemistry and medicine.

A tracer is a very small amount of radioactive isotope added to a chemical, biological, or physical system to study the system.

3 applications out of several

- ① follow a reaction mechanism
- ② verify dynamic equilibrium
- ③ trace a metabolic pathway

9. A laboratory rat weighs 265 g and receives 1.77×10^{10} β particles, each with an energy of 2.20×10^{-13} J.

a) How many rads does the animal receive?

$$\frac{(1.77 \times 10^{10} \beta \text{ particles})(2.20 \times 10^{-13} \text{ J/particle})}{0.265 \text{ kg}} = 1.47 \times 10^{-2} \frac{\text{J}}{\text{kg}} = 1.47 \times 10^{-2} \text{ rad}$$

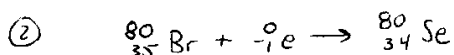
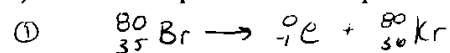
b) If the RBE is 0.75, how many mrem is this?

$$\text{rem} = \text{RBE} \times \text{rad}$$

$$0.75 \times (1.47 \times 10^{-2} \text{ rad}) = 1.10 \times 10^{-2} \text{ rem} \left(\frac{1 \text{ mrem}}{10^{-3} \text{ rem}} \right) = \boxed{11.0 \text{ mrem}}$$

10. The ${}^{80}\text{Br}$ nuclide decays by either β decay or electron capture.

a) What is the product of each process?



b) Which process releases more energy? (Masses of atoms: ${}^{80}\text{Br} = 79.918528$ amu; ${}^{80}\text{Kr} = 79.916380$ amu; ${}^{80}\text{Se} = 79.961520$ amu; neglect the mass of the electron involved.)

$$\Delta m = \text{mass of products} - \text{mass of reactants}$$

$$\Delta E = (\Delta m)c^2$$

① $\Delta m = 79.916380 - 79.918528 = -0.002148 \text{ amu}$

$$\Delta E = (2.148 \times 10^{-6} \text{ kg})(2.998 \times 10^8 \text{ m/s})^2$$

$$\Delta E = -1.93 \times 10^{11} \text{ J}$$

energy is released

② $\Delta m = 79.961520 - 79.918528 = 0.042992 \text{ amu}$

$$\Delta E = (4.292 \times 10^{-5} \text{ kg})(2.998 \times 10^8 \text{ m/s})^2$$

$$\Delta E = 3.86 \times 10^{12} \text{ J}$$

energy is absorbed

11. Nuclear disarmament could be accomplished if weapons were not "replenished." The tritium in nuclear warhead decays with a half-life of 12.26 yr to helium, and must be periodically replaced or the weapon is useless. What fraction of the tritium is lost in 5 years?

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{12.26 \text{ yr}}$$

$$k = 5.65 \times 10^{-2} \text{ yr}^{-1}$$

$$\ln \frac{N_t}{N_0} = -kt$$

$$\frac{N_t}{N_0} = e^{-kt} = e^{-(5.65 \times 10^{-2} \text{ yr}^{-1})(5 \text{ yr})}$$

$$\frac{N_t}{N_0} = 0.753$$

75.3% tritium remains after 5 years

and
24.6% of tritium is lost in 5 years