# Preamble

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# Instructions

Complete the problems below being sure to show your work. If you need to lookup nuclear data from an external source please reference the source in your solutions.

# Problems

**1. How many neutrons and protons are there in the nuclei of the following atoms:**

| Atom | Protons | Neutrons |
|---|---|---|
| $^{7}\mathrm{Li}$ | 3 | 4 |
| $^{24}\mathrm{Mg}$ | 12 | 12 |
| $^{135}\mathrm{Xe}$ | 54 | 81 |
| $^{209}\mathrm{Bi}$ | 83 | 126 |
| $^{222}\mathrm{Rn}$ | 86 | 136 |

**2. The atomic weight of $^{59}\mathrm{Co}$ is 58.93319. How many times heavier is $^{12}\mathrm{C}$?**

$$\frac{^{59}\mathrm{Co}}{^{12}\mathrm{C}} = \frac{58.93319}{12.00000} = 4.91110 \text{ times larger}$$

**3. How many atoms are there in 10g of $^{12}\mathrm{C}$?**

$$10\mathrm{g} \times \frac{1 \text{ mol } ^{12}\mathrm{C}}{12\mathrm{g}} \times \frac{0.6022045 \times 10^{24} \text{ atoms}}{1 \text{ mol } ^{12}\mathrm{C}} = 5.0184 \times 10^{23} \text{ atoms of } ^{12}\mathrm{C}$$

**4. A beaker contains 50 g of ordinary water.**

*a. How many moles of water are present?*

$50\text{g} \times \frac{1 \text{ mol } H_2O}{18.01528\text{g}} = 2.77542 \text{ moles of water}$

*b. How many hydrogen atoms?*

$2.77542 \text{ moles of water } \times \frac{2\text{mol}H}{1\text{mol}H_2O} \times \frac{0.6022045 \times 10^{24} \text{ atoms}}{1 \text{ mol } H} = 3.34274 \times 10^{24} \text{ H atoms}$

*c. How many deuterium atoms?*

$3.34274 \times 10^{24} \text{ H atoms} \times \frac{0.0156\,^2H}{1H} = 5.21468 \times 10^{22} \text{ deuterium atoms}$

**5. Find the mass of an atom of $^{235}\text{U}$**

*a. in amu;*

235.043928 amu

*b. in grams.*

$1 \text{ atom } ^{235}U \times \frac{1 \text{ mol } ^{235}U}{0.6022045 \times 10^{24} \text{ atoms}} \times \frac{235.043928 \text{ g}}{1 \text{ mol } ^{235}U} = 3.90306 \times 10^{-20} \text{ g}$

**6. The complete combustion of 1 kg of bituminous coal releases about $3 \times 10^7\text{J}$ in heat energy. The conversion of 1 g of mass into energy is equivalent to the burning of how much coal?**

The speed of light is 299,792,458 m/s.

$E = mc^2$

$E = 0.001 \text{ kg } (299792458 \text{ m/s })^2$

$E = 8.98755 \times 10^{13} \text{ J}$

$(8.98755 \times 10^{13} \text{ J }) \times \frac{1 \text{ kg}}{3 \times 10^7 \text{ J}} = 2995850 \text{ kg of coal}$

**7. Tritium ($^3\text{H}$) decays by negative beta decay with a half-life of 12.26 years. The atomic weight of $^3\text{H}$ is 3.016.**

*a. To what nucleus does $^3\text{H}$ decay?*

Helium-3

*b. What is the mass in grams of 1 mCi of tritium?*

First, we need to find the decay constant of tritium:

$\lambda = \frac{0.693 \text{ decay}}{12.26 \text{ years}} = 1.79241 \times 10^{-9} \frac{\text{decay}}{\text{s}}$

And we also know that one millicurie is:

$1 \text{ mCi} = 3.7 \times 10^{10} \frac{\text{decay}}{\text{s}}$

Therefore we find multiple of the decay constant we need:

$$\text{Ratio} = \frac{1 \text{ mCi}}{\lambda} = \frac{3.7 \times 10^{10} \frac{\text{decay}}{\text{s}}}{1.79241 \times 10^{-9} \frac{\text{decay}}{\text{s}}} = 2.06426 \times 10^{19}$$

Then we know we need this many atoms to decay (on average) at the mean activity. We now can convert to grams:

$$\left(2.06426 \times 10^{19}\right) \times \frac{1 \text{ mol } ^3H}{0.6022045 \times 10^{24} \text{atoms}} \times \frac{3.01605 \text{ g}}{1 \text{ mol } ^3H} = 1.03385 \times 10^{-4} \text{ g}$$

**8. Approximately what mass of $^{90}\text{Sr}$ (T-1/2 = 28.8 years) has the same activity as 1g of $^{60}\text{Co}$ (T-1/2 = 5.26 years)?**

First let's find the number of cobalt atoms:

$$1\text{g} \times \frac{1 \text{ mol } ^{60}\text{Co}}{59.934 \text{ g}} = 1.66850 \times 10^{-2} \text{ mol } ^{60}\text{Co}$$

Now we can find how much more strontium we need:

$$\frac{28.8 \text{ years}}{5.26 \text{ years}} = 5.47528$$

Finally we multiply this number by the moles of cobalt, and convert back to mass for strontium-90:

$$\left(1.66850 \times 10^{-2} \text{ mol } ^{60}\text{Co}\right) \times \frac{5.47528 \text{ mol } ^{90}\text{Sr}}{1 \text{ mol } ^{60}\text{Co}} \frac{89.90773 \text{ g}}{1 \text{ mol } ^{90}\text{Sr}} = 82.13525 \text{ g } ^{90}\text{Sr}$$

**9. Using the chart of the nuclides, complete the following reactions. If a daughter nucleus is radioactive, indicate the complete decay chain:**

$$^{18}\text{N} \rightarrow ^{18}\text{O}$$

$$^{83}\text{Y} \rightarrow ^{83}\text{Sr} \rightarrow ^{83}\text{Rb} \rightarrow ^{82}\text{Kr}$$

$$^{219}\text{Rn} \rightarrow ^{215}\text{Po} \rightarrow ^{211}\text{Pb} \rightarrow ^{211}\text{Bi} \rightarrow ^{207}\text{Ti} \rightarrow ^{207}\text{Pb} \rightarrow ^{203}\text{Hg} \rightarrow ^{203}\text{Tl}$$