E. NATURAL MIXTURES OF ISOTOPES

The molar mass of chlorine is 35.5 g. Since there can't be 0.5 of a proton or neutron, then "35.5 g" ***must*** represent an ***AVERAGE*** value for a ***MIXTURE*** of isotopes. (Similarly, "the typical Canadian family has 2.5 children" is a statement referring to an average — how else do you get half a child?)

EXAMPLE: Experiments show that chlorine is a mixture which is 75.77% Cl–35 and 24.23% Cl–37. If the precise molar mass of Cl–35 is 34.968 852 g and of Cl–37 is 36.965 903 g, what is the average molar mass of the chlorine atoms in such a mixture?

Assume there are exactly 100 moles of the mixture.

Then # of moles of Cl–35 = 0.7577 x 100 mol = 75.77 mol

\# of moles of Cl–37 = 0.2423 x 100 mol = 24.23 mol

$$\text{mass of Cl–35} = 75.77\text{ mol} \times \frac{34.968\,852\text{ g}}{1\text{ mol}} = 2649.59\text{ g}$$

$$\text{mass of Cl–37} = 24.23\text{ mol} \times \frac{36.965\,903\text{ g}}{1\text{ mol}} = 895.68\text{ g}$$

total mass of mixture = 2649.59 + 895.68 = 3545.27 g

$$\text{average molar mass of mixture} = \frac{3545.27\text{ g}}{100\text{ mol}} = \mathbf{35.453}\ \frac{\mathbf{g}}{\mathbf{mol}}$$

Note: It is not necessary to take 100 mol of a mixture. You can assume that **one mole of *"average" atoms*** is used, having a composition which is 75.77 % Cl–35 and 24.23 % Cl–37. The above calculation is then simplified.

$$\text{mass of Cl–35 in mixture} = 0.7577\text{ mol} \times 34.968\,852\ \frac{\text{g}}{\text{mol}} = 26.4959\text{ g}$$

$$\text{mass of Cl–37 in mixture} = 0.2423\text{ mol} \times 36.965\,903\ \frac{\text{g}}{\text{mol}} = 8.9568\text{ g}$$

and total mass of mixture = 26.4959 + 8.9568 = **35.453 g**

This mass agrees with the value of 35.453 g found experimentally for naturally occurring chlorine because exact masses were used for Cl–35 and Cl–37. If you are NOT given the exact molar masses of the isotopes, but instead are told, for example, that

$$^{35}\text{Cl} = 75.77\%,\quad ^{37}\text{Cl} = 24.23\%$$

then use the atomic masses "35" and "37".

Average mass = 0.7577 x 35 + 0.2423 x 37 = 35.485 g

This average mass is less exact but still satisfactory for most purposes.

EXERCISES:

23. The following mixtures of isotopes are found in nature. Calculate the expected molar mass of a sample of each mixture.
    (a) ^{10}B = 18.8%, ^{11}B = 81.2%
    (b) ^{69}Ga = 60.0%, ^{71}Ga = 40.0%
    (c) ^{107}Ag = 51.8%, ^{109}Ag = 48.2%
    (d) ^{70}Ge = 20.5%, ^{72}Ge = 27.4%, ^{73}Ge = 7.8%, ^{74}Ge = 36.5%, ^{76}Ge = 7.8%
    (e) ^{64}Zn = 48.9%, ^{66}Zn = 27.8%, ^{67}Zn = 4.1%, ^{68}Zn = 18.6%, ^{70}Zn = 0.6%
    (f) ^{90}Zr = 51.5%, ^{91}Zr = 11.2%, ^{92}Zr = 17.1%, ^{94}Zr = 17.4%, ^{96}Zr = 2.8%
    (g) ^{92}Mo = 15.8%, ^{94}Mo = 9.0%, ^{95}Mo = 15.7%, ^{96}Mo = 16.5%, ^{97}Mo = 9.5%, ^{98}Mo = 23.8%, ^{100}Mo = 9.6%