Atomic and molecolar structure

Ing. G. Bertucelli - (file downloaded by http://www.extrabyte.info)

The **Atomic mass unit (amu)** is the 12^{th} part of the mass of C_6^{12} atom.
Thus the mass of C_6^{12} atom = 12 amu

- Neutron mass $= 1,00897$ amu
- Proton mass $= 1,00758$ amu
- Electron mass $= 0,00055$ amu
- Mass of hydrogen atom $= 1,00758\text{amu} + 0,00055$ amu $= 1.00813$ amu

One mole of atoms of every element is the quantity of substance containing exactly the same number of atoms of 12 g of pure C_6^{12}.

This number is the **Avogadro number** $N_A = 6,0221415 \cdot 10^{23}$ (according to CODATA of 2002). Thus:

$$\text{mass of 1 mole of atoms} = N_A \cdot \text{mass of 1 atom} = N_A \cdot 12 \text{ amu} = 12 \text{ g}$$

$1 \text{ g} = N_A$ amu

$$1 \text{ amu} = \frac{1}{N_A} \text{ g} = \frac{1}{6,022 \cdot 10^{23}} \text{ g}$$

The quantity of material containing $6,022 \cdot 10^{23}$ atoms is called gram-atom.
The quantity of material containing $6,022 \cdot 10^{23}$ molecules is called gram-moles.
The Avogadro's number $N_A = 6,0221415 \cdot 10^{23}$ is the number of molecules contained in equal volumes of ideal gases at the same temperature and pressure.

$$6,022 \cdot 10^{23} \frac{\text{number of molecules}}{\text{gram\_mol } (g_{mol})} \text{ or } \frac{\text{number of atoms}}{\text{gram\_atom } (g_{at})}$$

The molar volume is the volume of a gas containing "1 mole" i.e. a mass measured in gram numerically equal to its molecular mass. At the standard conditions:

$$1,013 \cdot 10^5 \text{ Pa and } 273\,\text{K} = 0\,°\text{C} - \text{this volume, for an ideal gas is } 22,4 \text{ dm}^3.$$

Example 1 *The natural proportions referring to the different isotopes of Silicon Si are:*

Isotopes	Proportions	Mass of Nucleus
Si^{28}	92,21/100	27,977
Si^{29}	4,70/100	28,976
Si^{30}	3,09/100	29,974

Find the atomic mass of Silicon.

$$A = \frac{9221 \cdot 27.977 + 4.70 \cdot 28.976 + 3.09 \cdot 29.974}{100} = 28.08566$$

Example 2 *The natural Carbon consists of 2 isotopes:* C^{12} *and* C^{13}*, whose masses are:* $12,00000$ *and* $13,0034$*. What is the percentage of the two isotopes in a sample of Carbon having atomic mass of* $12,01112$*?*

Let's be: $x =$ *the percentage of* C^{13} $100 - x =$ *the percentage of* C^{12}

$$1201112 = \frac{12.00000 \cdot (100 - x) + 13.0034 \cdot x}{100}$$

From the equation we find: $x = 1.109/100 \quad C^{13}$ $100 - x = 98.891/100 \;\; C^{12}$

Example 3 *Before 1961 a physical scale of the atomic masses was adopted, based on* $16,00000$ *for the* O^{16} *atom. In our actual scale the nucleus mass of* O^{16} *is* $15,9949$*.*

What would have been in the old scale (chemical scale) the physical atomic mass of C^{12} *?*

The mass ratios of whatever nuclei are constant with respect to any reference system; therefore we can write:

$$\left[\frac{mass\ of\ C^{12}}{mass\ of\ O^{16}}\right]_{old\ scale} = \left[\frac{mass\ of\ C^{12}}{mass\ of\ O^{16}}\right]_{new\ scale} = \frac{12.00000}{15.9949}$$

$$\left(M\ of\ C^{12}\right)_{old\ scale} = 12.0000 \cdot \frac{160000}{15.9949} = 12.0038 \tag{1}$$

Example 4 *From* $10\,\mathrm{g}$ *of we have obtained* $3.6111\,\mathrm{g}$ *of Calcium. Since the atomic mass of Chlorine is* $35.453\ \mathrm{g}\ /\ \mathrm{g}_{at}$ *what is the atomic mass of Calcium?*

We can write the proportion

$$\frac{Mass\ of\ C_aCl_2}{m_{C_a} + 2 \cdot m_{cl}} = \frac{Mass\ of\ C_a}{m_{C_a}} = \frac{Mass\ of\ Cl_2}{2 \cdot m_{cl}}$$

$Mass\ of\ C_aCl_2 = 10.0000\,\mathrm{g}$

$Mass\ of\ C_a\ in\ C_aCl_2 = 3.6111\,\mathrm{g}$

$Mass\ of\ Cl\ in\ C_aCl_2 = (10.0000 - 3.6111) = 6.388\,\mathrm{g}$

$$n_{Cl} = \frac{6.388\,\mathrm{g}}{35.453\,\mathrm{g}\,/\,\mathrm{g}_{at}} = 0.1802\,\mathrm{g}_{at}$$

From the formula C_aCl_2 *we note that:*

$$n_{C_a} = \frac{1}{2} n_{Cl} = \frac{1}{2} 0.1802 = 0.0901\,\mathrm{g}_{at}$$

The atomic mass of Calcium is:

$$M_{Ca} = \frac{3.6111}{0.0901} = 40.078\,\mathrm{g}\,/\,\mathrm{g}_{at}$$

Example 5

1. *How many gram-atoms are contained in: a)* $15\,\mathrm{g}$ *of Hydrogen, b)* $15\,\mathrm{g}$ *of Deuterium.*

2. *How many moles of Hydrogen are contained in* $10\,\mathrm{g}$ *of* H_2 *?*

3. *How many atoms are contained in* $1\,\mathrm{g}$ *of Deuterium?*
   atomic mass of $H^1 = 1.008142$ *amu. Therefore* $1\,\mathrm{g}_{at}$ *of* $H^1 = 1.008142\,\mathrm{g}$ *of* H^1
   atomic mass of $H^2 = 2.014735$ *amu. Therefore* $1\,\mathrm{g}_{at}$ *of* $H^2 = 2.014735\,\mathrm{g}$ *of* H^2

1.

$$\frac{mass\ of\ hydrogen}{atomic\ mass\ of\ hydrogen} = \frac{15\,\mathrm{g}}{1.008142\,\mathrm{g}\,/\,\mathrm{g}_{at}} = 14.8789\,\mathrm{g}_{at}\ \ of\ \ H^1$$

$$\frac{mass\ of\ deuterium}{atomic\ mass\ of\ deuterium} = \frac{15\,\mathrm{g}}{2.014735\,\mathrm{g}\,/\,\mathrm{g}_{at}} = 14.8789\,\mathrm{g}_{at}\ \ of\ \ H^1$$

2. $molecular\ mass\ of\ hydrogen\ H_2 = 2{\cdot}atomic\ mass\ of\ H{=}\ 2.016284\,\mathrm{g}\,/\,\mathrm{g}_{at}$

$$moles\ of\ H_2 = \frac{10\,\mathrm{g}\ \ of\ H}{molecular\ mass\ of\ H_2} = \frac{10\,\mathrm{g}}{2.01628\,\mathrm{g}\,/\,\mathrm{g}_{at}} = 0.49596\,\mathrm{g}_{at}$$

$$atoms\ of\ H^2 = 0.49596\,\mathrm{g}_{at}\cdot 6.022\cdot 10^{23}\,atoms/\mathrm{g}_{at} = 2.9867\cdot 10^{23}\,atoms\ of\ H^2$$