Chemistry 20

Lesson 5 – The Mole

I. Mass, moles and molar mass

The **mass** of an object is a measure of the **amount of matter** that is present. In chemistry, mass is usually measure in grams (g). Mass is something that chemists can most easily measure. However, chemical equations are <u>not</u> mass equations. For example, when mercury and sulphur combine to form mercury (II) sulphide, the chemical equation is

$$8\,Hg_{(s)} \quad + \quad S_{8\,(s)} \quad \rightarrow \quad 8\,HgS_{(s)}$$

Eight mercury atoms combines with a group of eight sulphur atoms to form eight formula groups of mercury (II) sulphide. But in the real world of chemical reactions, gajillions (a technical term meaning “lots”) of mercury atoms are combining with gajillions of sulphur atoms. Therefore, we need a way to convert a measured mass into a number of atoms.

The **mole** (symbol mol) is the SI base unit of amount of substance. The name “mole” is an 1897 translation of the German Mol, coined by Wilhelm Ostwald in 1893, although the related concept of **equivalent mass** had been in use at least a century earlier. The name is assumed to be derived from the German word Molekül (molecule). The mole is defined as: the amount of substance that contains as many “elementary entities” (e.g. atoms, molecules, ions, electrons) as there are atoms in 12 g of carbon-12. A mole has 6.0221415×10^{23} (Avagadro’s number) atoms or molecules of the pure substance being measured. A mole will possess mass exactly equal to the substance's **atomic weight** or **molar mass** in grams. Because of this, one can measure the number of moles in a pure substance by weighing it and converting the result to its mass weight.

The **molar mass** number that you find on a periodic table is the average measured mass of one mole of the element. Note that this a measured value which is why some periodic tables differ slightly from others in their molar mass values.

It may be of interest to note that Avagadro’s number exists as a conversion from grams to moles. If we were converting from a different unit, say ounces to moles, Avagadro’s number would have a different value.

II. Converting mass to moles and moles to mass

The following equation can be used to convert mass into moles using the molar mass.

$$n = \frac{m}{M}$$

m – mass (g)
n – moles (mol)
M – molar mass (g/mol)

The molar mass can be calculated by adding up the atomic molar masses for an element or compound from the periodic table. For example, the molar mass of barium nitrate $Ba(NO_3)_2$ is:

1 Ba → 1 × 137.33 g/mol		137.33 g/mol
2 N → 2 × 14.01 g/mol	+	28.02 g/mol
6 O → 6 × 16.00 g/mol	+	96.00 g/mol
		261.35 g/mol

Example 1

How many moles are there in 2.00 g of sodium chloride?

$$n_{NaCl} = ?$$
$$m_{NaCl} = 2.00\text{g}$$
$$M_{NaCl} = 22.99 + 35.45$$
$$M_{NaCl} = 58.44\,{}^{g}\!/_{mol}$$

$$n_{NaCl} = \frac{m_{NaCl}}{M_{NaCl}} = \frac{2.00\text{g}}{58.44\,{}^{g}\!/_{mol}}$$
$$n_{NaCl} = \mathbf{0.0342\,mol}$$

Example 2

Determine the mass of 0.50 mol of water.

$$n_{H_2O} = 0.50\,\text{mol}$$
$$m_{H_2O} = ?$$
$$M_{H_2O} = 2 \times 1.01 + 16.00$$
$$M_{H_2O} = 18.02\,{}^{g}\!/_{mol}$$

$$m_{H_2O} = n_{H_2O}\,M_{H_2O} = 0.50\text{mol}(18.02\,{}^{g}\!/_{mol})$$
$$m_{H_2O} = \mathbf{9.0\,g}$$

Example 3

Determine the number of water molecules in 0.50 mol of water.

$$\#\text{of } H_2O\,\text{molecules} = 0.50\,\text{mol} \times \frac{6.0221415 \times 10^{23}\,\text{molecules}}{1\text{mol}} = 3.0 \times 10^{23}\,\text{molecules}$$

III. Assignment

A. Determine the <u>molar mass</u> of each of the following substances.

1. $FeSO_4$
2. magnesium sulfate
3. calcium carbonate
4. $MgSiO_3$
5. sodium hypochlorite
6. potassium dichromate
7. $Al(OH)_3$
8. sodium chloride
9. sodium carbonate decahydrate
10. dinitrogen oxide
11. $Na_2S_2O_3 \cdot 5H_2O$
12. $NH_4H_2PO_4$

B. Molar mass calculations. Show all of your work.

1. How many moles are found in 100 g of baking soda (sodium bicarbonate)?

2. What is the number of moles in 120 mL of water?

3. Certain cleaners contain sodium phosphate as their active ingredient. How many moles are found in 50 g of sodium phosphate?

4. 0.042 mol of potassium dichromate are required for a certain chemical reaction. What mass of this reactant should be measured out?

5. After a long day of walking, some people use Epsom salts (magnesium sulfate heptahydrate) in water to soak their aching toes. If 10 g of salt are used, how many moles are in the water solution?

6. How many grams is 0.025 mol of tin (II) fluoride?

7. What is the mass of 25.0 mol of quartz (silicon dioxide)?

8. The slaked lime used to grout bathroom tiles contains calcium hydroxide. If 1.50 kg of calcium hydroxide is used, how many moles are present?

9. Which contains the greater number of moles; 250 g of water or 70 g of helium gas?

10. Through an experiment it was found that 0.0125 moles of an unknown inert gas had a mass of 1.05 g. What gas is it?