The Mole: A Measurement of Matter

We live in a quantitative world. We often measure the amount of something by one of three different ways - by count, mass, and volume.

As an example, when apples are purchased, they can be measured in 3 different ways.

- by count (3 for $2.40)
- by weight ($1.29/pound) or mass ($2.79/kg)
- by volume ($12.00/buschel)

Example:

What is the mass of 90 average-sized apples if 1 dozen of the apples have a mass of 2.0 kg?

mass of 90 apples (kg) =

$$\frac{2.0\ \text{kg}}{1\ \text{dozen apples}} \times \frac{1\ \text{dozen apples}}{12\ \text{apples}} \times 90\ \text{apples}$$

What is a Mole?

Similar to how specific numbers of things like apples can be grouped and quantified, chemists use a unit that is a specified number of particles.

The **mole** (mol) of a substance is 6.02×10^{23} representative particles (rep. part.) of a substance and is the SI unit for measuring the amount of a substance.

This number is called **Avagadro's number** and was named after the Italian scientist who helped clarify the difference between atoms and molecules.

A **representative particle** refers to the atoms, molecules, or formula units present.

Most representative particles are just the atoms themselves; ie- iron is composed of iron atoms.

The diatomic molecules (I_2, H_2, N_2, Br_2, O_2, Cl_2, F_2) and other molecular compounds have representative elements that are the molecule itself.

For ionic compounds, the representative element is the formula unit of the compound (ie - $CaCl_2$)

A mole of any substance contains Avagadro's number of representative particles, or 6.02×10^{23} representative particles.

Converting particles to moles...

$$\text{moles} = \text{rep. part.} \times \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ rep. part.}}$$

Example:

How many moles of magnesium is 1.25×10^{23} atoms of magnesium?

Converting Moles to Number of Particles...

A mole of a molecule contains Avagadro's number. But each molecule contains the number of atoms within that molecule.

$$\text{rep. part.} = \text{moles} \times \frac{6.02 \times 10^{23} \text{ rep. part.}}{1 \text{ mole}}$$

Example:

How many atoms are in 2.12 moles of propane (C_3H_8)

atoms of C_3H_8 =

$$2.12 \text{ moles} \times \frac{6.02 \times 10^{23} \text{ molecules of } C_3H_8}{1 \text{ mole}} \times \frac{11 \text{ atoms of } C_3H_8}{1 \text{ molecule of } C_3H_8}$$

The Mass of A Mole

Remember that the mass of an atom is measured in amu's (atomic mass units). For example, carbon has 12.0 amu's and is 12 times heavier than hydrogen at 1.0 amu.

Therefor, carbons number of moles would also be 12 times that of hydrogen.

In the lab, quantities are expressed in grams for convenience.

The atomic mass of an element expressed in grams is the mass of a mole of the element. The mass of a mole of that element is its **molar mass**.

For carbon, the molar mass is 12.0 grams. For hydrogen, its 1.0 gram.

The molar mass of any element contains 1 mol or 6.02×10^{23} atoms of that element. The mole can now be further defined as *the amount of substance that contains as many representative particles as the number of atoms in 12.0 grams of carbon-12.*

Carbon-12 has a molar mass of 12.0 grams, so 12.0 g is 1 mol of carbon. The same relationship applies to hydrogen. 1.0 grams of hydrogen is 1 mol of hydrogen.

The molar mass is the mass of 1 mol of atoms of any element.

To find the mass of a compound, you need to know the formula of the compound.

For example, the formula of sulfur trioxide is SO_3. It is composed of 3 oxygen atoms and 1 sulfur atom. By adding their masses we get that the molecular mass of SO_3 is 80.1 amu. This also means that 1 mol of SO_3 has a mass of 80.1 g.

To calculate the molar mass of a compound, find the number of grams of each element in one mole of the compound. Then add the masses of the elements in the compound.

Example

The decomposition of hydrogen peroxide (H_2O_2) provides sufficient energy to launch a rocket. What is the molar mass of hydrogen peroxide?

molar mass of H_2O_2 =

mass units of hydrogen

$$2 \text{ mol H} \times \frac{1.0 \text{ g H}}{1 \text{ mol H}} = 2.0 \text{ g H}$$

mass units of oxygen

$$2 \text{ mol O} \times \frac{16.0 \text{ g O}}{1 \text{ mol O}} = 32.0 \text{ g O}$$

Therefor hydrogen peroxide has a molar mass of 34.0 grams.

Try Problems # 1-15 on pages 289-296