The Mole: Chemistry's #1 Tool Made Simple

There are 4 different definitions to describe the mole depending on how it is used. Interestingly they all interrelate, even though they are different.

Definition 1: Quantity of Particles

Everyone knows that a dozen represents 12 items such as eggs or donuts. Just like a dozen, the mole represents a numerical value. When you "know the mole" you will remember that a mole will always equal 6.02×10^{23} items. With such a huge number, the items that we are counting are very small, such as atoms, formula units or molecules.

Definition 2: Volume (Gases Only)

People who "know the mole" remember that 1 mole of any gas will always have a volume of 22.4 Liters when the gas is at standard temperature & pressure or STP (the gas is at 0°C and sea level air pressure or 1 atmosphere).

Remember: Even if the 1 mole of gas is moving around in the form of small atoms or huge gas molecules, both volumes will be 22.4 L since there are 6.02×10^{23} atoms or molecules of gas.

Not all gases are at STP. In these instances you most often use the Ideal Gas Law, $PV = nRT$, to calculate the number of moles of the gas present. You could even use this for a gas at STP but that might mean extra calculations that you did not have to do.

Definition 3: Mole to Mole Ratios

When you "know the mole" you will realize that the number of moles of one substance can be compared to another. These mole comparisons can be within a formula or between two formulas within a balanced equation. This is accomplished by using the formula's subscripts (small numbers in the lower right corner) &/or coefficient (large number in front of the formula).

Hint: The total number of moles for each element can be calculated by multiplying the coefficient by the subscript.

Examples:

A) CO_2 : There is 1 mole of C & 2 moles of oxygen to make 1 mole of CO_2

B) 4 Fe_2O_3 : There are 8 moles of Fe and 12 moles of oxygen in 4 moles of Fe_2O_3

C) The balanced equation for burning ethane is: $2\ C_2H_6 + 7\ O_2 \longrightarrow 6\ H_2O + 4\ CO_2$

To do examples 1 - 3 below, use the balanced equation above.

1) When comparing oxygen to water, there are 7 moles of O_2 needed to make 6 moles of H_2O.

2) When comparing carbon dioxide to ethane, to make 4 moles of CO_2 you need 2 moles C_2H_6.

3) When comparing ethane to oxygen, to have the ethane burn perfectly it will require a ratio of 2 moles of C_2H_6 to 7 moles of O_2.

Definition 4: Mass of the Mole (Molar Mass)

When the world "knows the mole" we will all understand that the mass in grams of 1 mole of any substance is the same number as its atomic mass (the decimal number in the Periodic Table).

Examples:

1 atom of carbon = 12.01 atomic mass units

1 mole of carbon = 12.01 grams (Because there are 6.02×10^{23} atoms of carbon).

1 molecule of H_2O = (H-1.008 + H-1.008 + O-16.00) = 18.02 atomic mass units

1 mole of H_2O = 18.02 grams (Because there are 6.02×10^{23} molecules of water)

The molar mass can then be used either by itself or to further calculate the number of moles of a substance from its mass.

Addendum: Volume (Liquids Only)

When you talk about liquids, you most often also talk about these in terms of volume. However, there is no easy method to go from volume to moles unlike what we have learned about gases at STP.

What we do know, though, is the density of the liquid. Remembering that density is defined as the mass of the liquid divided by its volume leads us to be able to calculate the mass of the sample from the volume and density. Once we have the mass we can use the molar mass to calculate moles.