Mole

The concept of mole is very important in chemistry, almost all the calculations, at least in general chemistry, involve this concept. Here you will able to count atoms, molecules, and ions through the vehicle of mole.

The mole is one of the base SI units to measure the amount of substance. The symbol for this unit is **mol** not mole (note there is only one difference; e is missing from the symbol). The amount of substance can be measured in three units, namely, amu, grams, and moles depending upon the size of the substance. The mole defined as, *the amount of substance that contains the same number of entities (atoms, molecules, or other particles like ions) as there are in exactly 12.0 gram of carbon-12.* Then, the question is how many atoms are there in 12 gram of carbon-12? It has been experimentally determined that this number is 6.022×10^{23}, which is known as Avogadro's number (N_A) in honor of the Italian physicist Amedeo Avogadro(1776-1856). This is known as one mole. Therefore,

1 mole = 12 g C-12 = 6.022×10^{23} atoms

This means that 6.022×10^{23} C-12 atoms weigh 12 g. Thus, the 12 g is known as the molar mass of C-12 because it represents the mass of one mole of C-12.

Molar mass is the mass in grams of one mole of a substance. The unit for molar mass is g/mol. In other words,

molar mass (g/mol) = mass (g) / mole(mol)

This is a very important expression just like a density expression. Mass can be converted to moles or moles to mass only through the molar mass:

mass(g) = molar mass (g/mol) x mole(mol)

mole(mol) = mass(g) / molar mass(g/mol)

If you are talking about mole of atoms, you can get the molar masses directly from the periodic table; you do not have to do any calculations. The atomic masses given in the periodic table could be either atomic masses (amu unit) or molar masses (g/mol unit). Foe example, copper has an atomic mass of 63.55 amu and a molar mass of 63.55 g/mol. Now you can see that same number 63.55 is used in two different contexts, whether it is an atom or a mole.

Let us say that you went to the supermarket and bought the fruits by dozen. One dozen is 12. Think that you bought one dozen apples, one dozen bananas, and one dozen pears. Do you think one dozen of these fruits weigh the same? No. Even though, they contain the same number (one dozen) their weights are different because they are different fruits. Now you think this in terms of chemical substances. Well, if you take 6.022×10^{23} H atoms, 6.022×10^{23} Al atoms, and 6.022×10^{23} Na atoms, do you think all these have the

same weight? No. In fact they weigh differently because they are different substances. The weights of these you can directly read from the periodic table:

6.022×10^{23} H atoms = 1.008 g = 1 mole
6.022×10^{23} Na atoms = 22.99 g = 1 mole
6.022×10^{23} Al atoms = 26.98 g = 1 mole
6.022×10^{23} Pb atoms = 207.2 g = 1 mole

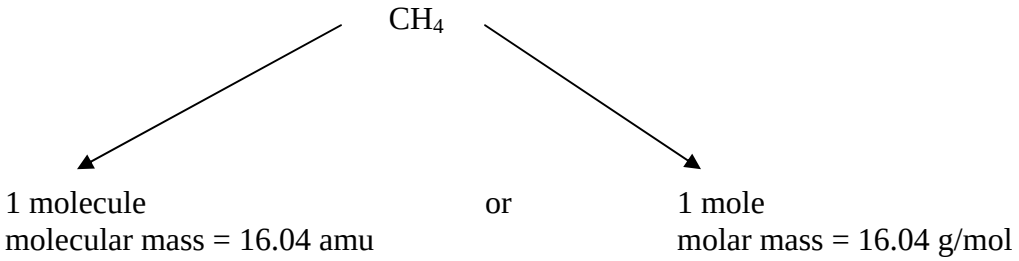
The molar masses depend upon the atomic masses; the heavier the atom, the more mass it takes to make one mole. Therefore you can say that Avogadro's number is chemist's dozen.

One mole of any substance contains the same number of atoms, molecules, or ions present in any other substance. In general,

1 mole = 1 molar mass = 6.022×10^{23} atoms, molecules, or ions

Molar masses of Molecules

All examples given above apply to molar masses of elements because elements contain atoms. Molar mass of a molecule or a compound is calculated from the molar atomic masses. Any given chemical formula means two things, either one molecule or one mole. If you interpret that as a molecule, then mass of that molecule is a molecular mass expressed in amu. If you interpret that as a mole, then the mass of that mole is a molar mass expressed in g/mol. Look at the following examples.



compound	**Molecular mass**	**Molar mass**
C_6H_6	78.11 amu	78.11 g/mol
NaCl	58.44 amu	58.44 g/mo
$C_6H_{12}O_6$	180.15 amu	180.15 g/mol

There is no separate symbol for the mole. It is evident from this table that the molar mass of a compound (in grams) is numerically equal to its molecular mass (in amu).

Converting Mole to Mass

The conversion of mole to mass is the easiest one. What you need is the number of moles (mol) of the substance and also its molar mass (g/mol). The equation to calculate the mass (g) is given below

$$mass(g) = mole(mol)\, x\, molar\ mass(g/mol)$$

Example

How many grams of gold (Au) are there in 15.8 moles of Au?

Answer

Given : moles = 15.8 mol
From the periodic table: molar mass of Au = 197.0 g/mol

Then,

mass(g) of Au = 15.8 mol x 197.0 g/mol = 3,112.6 g = 3.113 x 10^3 g

As you can see the mol in the numerator cancels with that in the denominator.

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Hands on Practice to Convert Mole to Mass

Converting Mass to Mole

To convert mole to mass, you need the molar mass of the substance. Then substitute the values in th following equation.

$$moles(mol) = \frac{mass(g)}{molar\ mass(g/mol)}$$

Example

Find the number of moles of water (H_2O) that has a mass of 75.5 g?

Answer

The molar mass of water is 18.0 g/mol. Then

moles of water = mass of water (g) / molar mass of water (g/mol)
= 75.5 g /18.0 (g/mol) = 4.19 mol

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Hands on Practice to Convert Mass to Mole

Converting Mole to Atoms/Molecules

In order to convert moles to number of atoms/molecules, you simply need is the Avogadro's number. The following expression does the conversion.

$$atoms\,or\,molecules = moles(mol)\,x\,6.022x10^{23}\ (atoms\,or\,molecules\,/\,mol)$$

Example

How many atoms are there in 12.5 moles of platinum (Pt)?

Answer

You do not need the molar mass of platinum because equal numbers of moles of substances contain the same number of atoms/molecules. Therefore, substituting 12.5 moles in the above equation, yields the number of atoms.

Pt atoms = 12.5 mol x 6.022 x 10^{23} Pt atoms /mol = 7.53 x 10^{24} atoms

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Example

Determine the number of molecules in 10.5 moles of silver nitrate ($AgNO_3$).

Answer

$AgNO_3$ molecules = 10.5 mol x 6.022 x 10^{23} $AgNO_3$ molecules / mol
= 6.32 x 10^{24} $AgNO_3$ molecules

Example

Which of the following substances contain the same number of atoms?

10 moles Ca, 10 g Ca, 10 moles of Mg, and 10 g Mg

Answer

10 moles Ca and 10 moles Mg contain the same number because **equal number of moles contains the same atoms regardless of the nature of the chemicals**. The 10 g Ca and 10 g Mg do not have the same number of moles and hence contain different numbers of atoms.

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Hands on Practice to Convert Mole to Atoms/Molecules

Converting Mass to Atoms/Molecules

To convert the mass into atoms/molecules you need two things ;(a) Avogadro's number and molar mass. The equation that does the conversion from mass to atoms/molecules is,

$$atoms\,or\,molecules = mass(g)\,x\,\frac{6.022x10^{23}(atoms\,or\,molecules/mol)}{molar\,mass(g/mol)}$$

Example

How many molecules are there in 5.8 g of $BaCl_2$?

Answer

The molar mass of $BaCl_2$ = 208.60 g/mol. Thus

$$BaCl_2\,molecules = 5.8\,g\,x\,\frac{6.022x10^{23}\,BaCl_2\,molecules/mol}{208.60\,g/mol}$$
$$= 1.67\,x10^{22}\,BaCl_2\,molecules$$

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Hands on Practice to Convert Mass to Atoms/Molecules

Converting Atoms/Molecules to Mole

To get the number of moles, you simply need to divide the given number of atom/molecules with Avogadro's number:

$$mole(mol) = \frac{atoms\ or\ molecules}{6.022x10^{23}(atoms\ or\ molecules\ /\ mol)}$$

Example

Find the number of moles corresponding to 7.7 x 10^{22} CH_4 molecules.

Answer

$$moles\ of\ CH_4 = \frac{7.7x10^{22}\ CH_4\ molecules}{6.022x10^{23}(CH_4\ molecules\ /\ mol)} = 1.28\,x10^{-1}\ mol$$

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Hands on Practice to Convert Atoms/Molecules to Mole

Converting Atoms/Molecules to Mass

To get the mass from atoms or molecules, the molar mass and Avogadro's numbers are needed. The following equation shows how to sep the conversion.

$$mass(g) = atoms\ or\ molecules\ x\ \frac{molar\ mass(g\ /\ mol)}{6.022x10^{23}(atoms\ or\ molecules\ /\ mol)}$$

Example

Mercury (Hg) is the only metal in liquid with silvery color. Calculate the mass (in grams) on one Hg atom.

Answer

The molar mass of Hg is 200.6 g/mol. Substituting this value in the above equation yields the mass of Hg.

$$mass\ of\ 1\ Hg\ atom = 1\ Hg\ atom\ x\ \frac{200.6\ (g\ /\ mol)}{6.022 x 10^{23}\ Hg\ atoms\ /\ mol)} = 3.33\ x 10^{-22}\ g$$

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Hands on Practice to Convert Atoms/Molecules to Mass