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Definitions

A mole is:

- The SI unit of "amount of substance"
- Avogadro's Number (N_A) ($6.022x10^{23}$) of "elemental entities"
- As many entities (atoms, molecules, ions, things) as there are C atoms in 12 g of ^{12}C

Atoms and the mole

Take a reaction:
Hydrogen reacts with Chlorine to form Hydrogen Chloride.
Observe:
1g Hydrogen reacts with 35.5 g Chlorine to give 36.5 g Hydrogen Chloride (or in this ratio ….. Mixing 2 g Hydrogen with 35.5 g Chlorine results in 36.5 g Hydrogen Chloride and 1 g Hydrogen left over …..

Atoms and the mole

Dalton : supposed 1 g H to contain *N* particles (each weighing 1/*N* g); and 35.5g Cl also to contain *N* particles. In the reaction $\rightarrow$ HCl one H particle "pairs off" with one Cl.

Such particles are called ATOMS

An atom is the smallest particle of an element that retains the characteristic CHEMICAL properties of that element.

All atoms of the same element have the same chemical properties; Atoms of different elements have different chemical properties.

During chemical reactions atoms are conserved.

Atoms and the mole

Avogadro observed gases react chemically in simple ratios by volume …… and suggested that at equal p and T, equal volumes of gas contain equal numbers of molecules.

Need to consider NUMBER of molecules/atoms/ions available ……… and since the numbers are LARGE so is N_A.

Equal numbers of atoms of different kinds (H, Cl) will have MASSES in proportion to the masses of the different kinds of atoms ……

“the mole”

The chemist’s unit of amount of substance is the mole; frequently abbreviated as mol – so 1 mol means “one mole” and is the Molar Mass (atomic weight for atoms; molecular weight for molecules; formula weight for other materials) in g

Some examples of 1 mol

1 mol of C is 12 g

1 mol of salt (NaCl) is 58.45 g (almost exactly 2 oz)

1 mol of lead is 207 g

1 mol of water is 18 g (or 18 cm^3)

1 mol of gas is 22.4 dm^3 at S.T.P. (or about 5 gallons at room T and p)

1 mol of sugar ($C_{12}H_{22}O_{11}$) is 342 g (about 12½ oz)

Molecules - and "the mole" again

N_A molecules of HCl is called 1 mol of HCl; the mass (in g) of 1 mol of molecules is the molecular weight (or **Relative Molar Mass**) One mole of HCl (36.5g) occupies ≈22.4 dm^3 at S.T.P.; so does one mole of He (4g) or Ne or Ar atoms BUT 1g of Hydrogen, 35.5 g of Chlorine or 16g of Oxygen only occupy half this volume ......WHY?

Molecules - and "the mole" again

Molecules of H/Cl/O consist of **two** atoms of the element i.e. are H_2, O_2, Cl_2.

SO: statements such as "1 mole of hydrogen" are ambiguous ..... unless the context makes it clear, **SPECIFY THE ENTITY** :-

1 mole of H = 1 mole of H atoms and weighs 1g

1 mole of H_2 = 1 mole of H_2 molecules and weighs 2g

Molecules : molecular formulae

- Empirical formula : for any substance the empirical formula is the SIMPLEST whole number ratio, compatible with the composition, of the atoms combining to make up the pure substance (e.g. the empirical formulae of hydrogen, helium, hydrogen peroxide and ethane are H, He, HO and CH_3 respectively)
- Molecular formula : gives the actual numbers of each kind of atom present in a single molecule of any molecular substance (e.g. H_2, He, H_2O_2 and C_2H_6 for the same four substances)
- Molar mass is the sum of the masses of the atoms in the formula – ALL of them!!

Atoms, Molecules and the Mole

- Matter is composed of atoms.
- Atoms are **conserved** during any chemical reaction - and therefore, so is **mass**.
- Chemical symbols : the meaning must be taken from the context so that e.g. H may mean the element hydrogen; one atom of hydrogen or 1 mole of hydrogen atoms. H_2O may mean water, one molecule of water, or 1 mole of molecules.

Which leads to CHEMICAL EQUATIONS

e.g.	H_2	+	Cl_2	=	2 HCl
&	$2H_2$	+	O_2	=	2 H_2O

Chemical Equations

A convenient shorthand to describe the changes that occur during a chemical reaction - and the basis for **stoichiometric calculations** (*i.e. "chemical arithmetic"*)

Form of equation :

Reagents = Products

or: Reagents $\rightarrow$ Products

Consider : $H_2 + O_2 = H_2O$ .... (1)

(1) is NOT a chemical equation because it is **unbalanced**. Since atoms are conserved, all H and O atoms in reagents **must** be present in products (and ***vice versa***). In this case, "balancing" is simple - addition of extra mole of product (to equalize with O in reagent) requires extra mole of $H_2 \Rightarrow$

$2\ H_2 + O_2 = 2\ H_2O$

Stoichiometric coefficients

*In this example, the stoichiometric coefficients are 2 for H_2 and H_2O and 1 (**N.B. : omitted!**) for O_2*

Chemical Equations (ii)

$$2\,H_2 \quad + \quad O_2 \quad = \quad 2\,H_2O \quad ..... \quad (2)$$

- This means
  - 4g of H_2 react with 32g O_2 to produce 36g of H_2O
  - 2 mol of H_2 react with one mol of O_2 to produce 2 mol of H_2O
- **Q:** How many moles of O_2 react with <u>ONE</u> mole of H_2 & what is produced?
  A: $H_2 + \frac{1}{2}\,O_2 = H_2O$ .... (3)
- (3) is just as valid as (2). Note that the **ratios** of the stoichiometric coefficients are the same in (2) and (3). It is **ONLY** these ratios that have fundamental importance in a balanced chemical equation

Chemical Equations (iii)

A balanced chemical equation tells us the relative MOLAR ratios (i.e. relative numbers of moles - and therefore relative amounts by mass) of reagents consumed and products produced during a chemical reaction.

The equation gives **NO** information on

(a) The way the reaction takes place at the molecular/atomic level (and so equation (2) does **not** imply that 2 molecules of hydrogen react with one molecule of oxygen!)

(b) The rate of the reaction

Things to understand about Avogadro's number.

- It is a *number*, just as is "dozen", and thus is dimensionless; you can think of Avogadro's number as the "chemist's dozen".

- It is a *huge* number, far greater in magnitude than we can readily visualize.

- Its practical use is limited to counting tiny things like atoms, molecules,"formula units", electrons, or photons.

- Its value can be known only to the precision that the number of atoms in a measurable weight of a substance can be estimated.

- Because large numbers of atoms cannot be counted directly, a variety of ingenious indirect measurements have been made involving such things as Brownian motion and X-ray scattering.

How large is Avogadro's Number?

A mole of marbles would cover the United States to a height of seventy miles

A mole of 'full stops' laid end-to-end is larger than the radius of the galaxy

Moles in Solutions

Moles = Mass / Molar mass

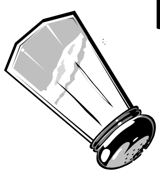
Table salt (Sodium Chloride)

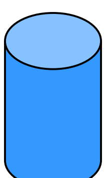
Formula = NaCl

Molar Mass = 22.99g/mol + 35.45 g/mol = 58.44 g/mol

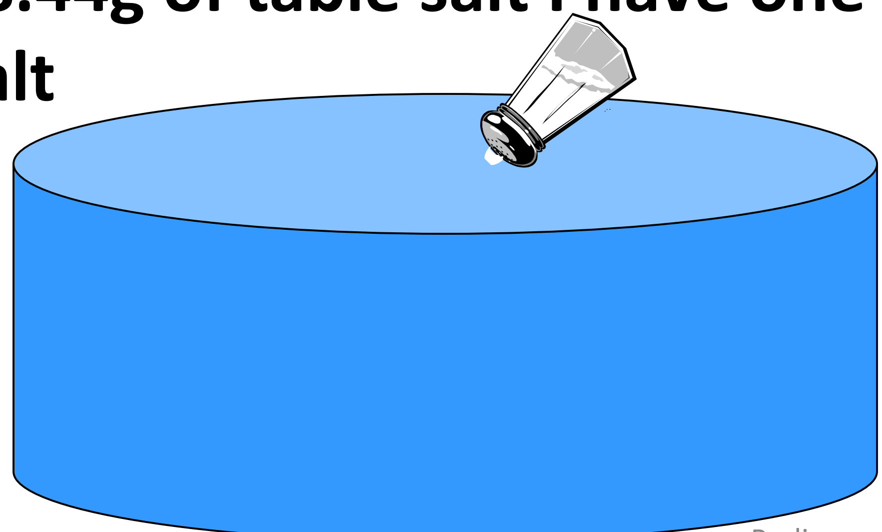
How much does one mole weigh? 1 mole x 58.44 g/mol = 58.44g

If I weigh out 58.44g of table salt I have one mole of table salt





Very salty water



Not as salty (more dilute)

Moles and Molarity

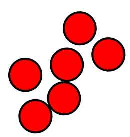
Molar Concentration (Molarity): refers to a certain number of moles in a certain volume of solution

$$\text{Molarity (M)} = \frac{\text{no. of moles}}{\text{volume (litres)}}$$

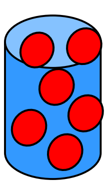
$$\text{Moles} = \frac{\text{Mass (g)}}{\text{Molar mass (g/mol)}}$$

$$1\text{M} = \frac{1\ \text{mol}}{1\ \text{litre}}$$

$$1\text{M NaCl} = \frac{58.44\text{g (1 mole)}}{1\ \text{litre}}$$

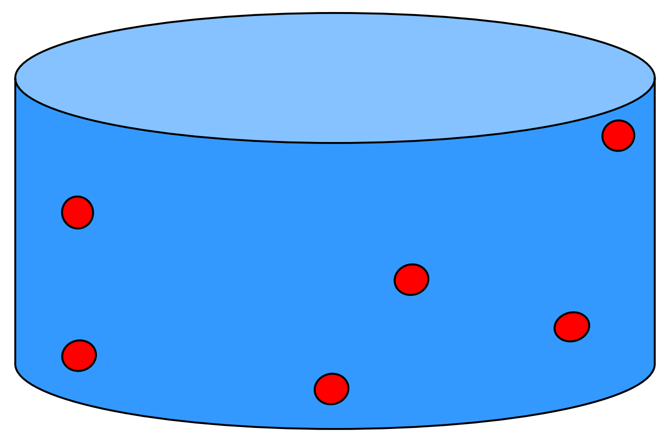


X moles



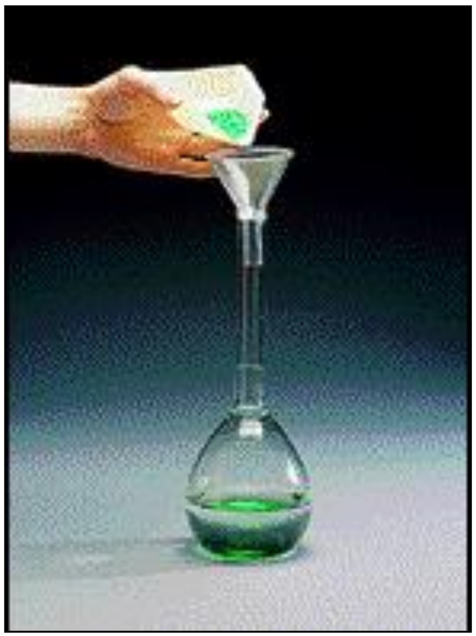
Small volume of liquid – concentrated solution

Larger volume of liquid – dilute solution



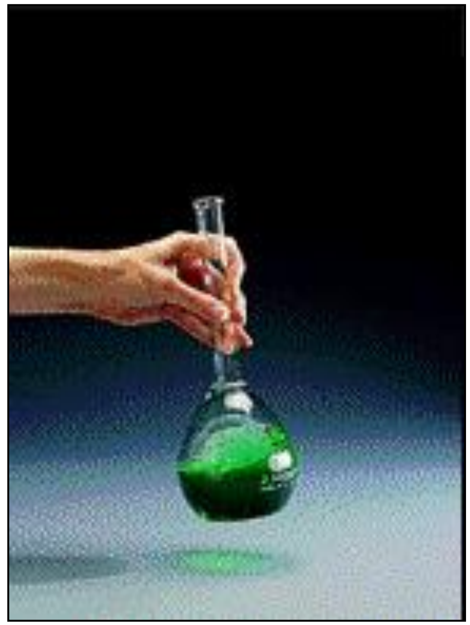
No. of moles does not change.

Laboratory preparation of molar solutions.



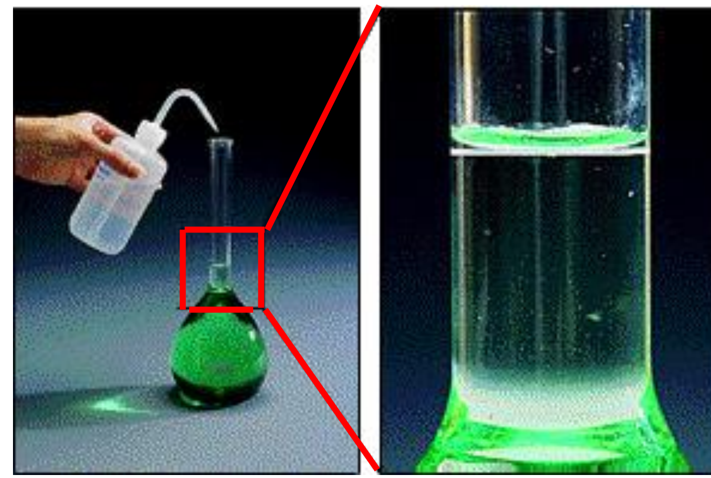
A

•Weigh the solid needed.
•Transfer the solid to a volumetric flask that contains about half the final volume of solvent.



B

Dissolve the solid thoroughly by swirling.

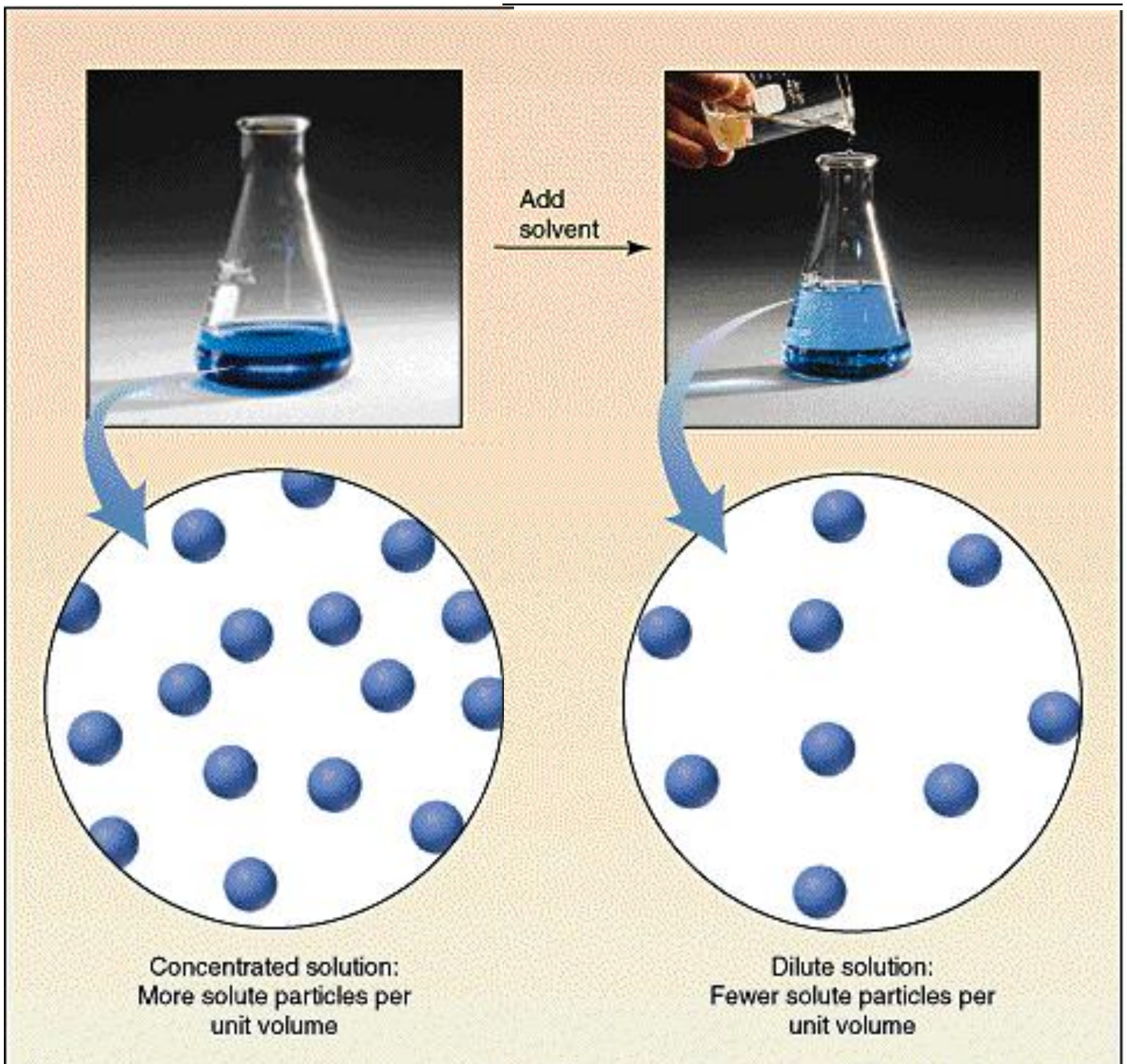


C

Add solvent until the solution reaches its final volume.

Read to the **bottom** of the meniscus here and in pipettes, burettes etc. ….

Converting a concentrated solution to a dilute solution.



e.g. by how much must I dilute a 1M aqueous solution to give (a) 0.25M and (b) 0.1M solutions, starting with 100 ml in each case?

Answer:

(a) This is ¼ of the concentration of the original – and so must have 4 times the volume (i.e.400 ml) so add 300 ml of water

(b) Similarly, add 900 ml – to give 10x original volume ……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