Atomic & molecular weights, mole concept and Equivalent Weights

1. The smallest particle of an element that takes part in a chemical reaction is an atom.
2. The smallest particle of a substance that can exist in the free State is a molecule.
3. Atomic weight or atomic mass of an element is a relative mass and is expressed in Atomic mass units or atomic weight units (a.m.u. or u).
4. The latest standard for determining Atomic masses is $_6C^{12}$ which is assigned a mass of 12 a.m.u. So, one a.m.u. is 1/12 part of the mass of $_6C^{12}$ atom.
5. One a.m.u. is also known as one Dalton or one Aston or Avogram.

   1 a.m.u=$1.66X10^{-24}$gm
6. Atomic mass of an element is the average of the isotopic masses (in a.m.u) of the Isotopes present in it.

   E.g. Natural Neon consists of two Isotopes with Isotopic masses 20 and 22 in the percentage abundance of 90: 10.

   Hence the Atomic mass of Neon = (90×20 + 10×22)/100 = 20.2
7. Molecular weight (or) Molecular mass is also a relative mass expressed in a.m.u..
8. The numerical value of the molecular mass expressed in grams is called a gram - molecular weight or a gram molecule or a gram mole or a molar mass or a mole of that substance.

E.g.: 1 mole of oxygen is 32g of oxygen.

1 mole of Nitrogen is 28g of Nitrogen.

9. Number of moles (n) = mass of the substance/molar mass.

10. One mole of any substance (or one mole of a mixture of substances) contains the same number of molecules namely 6.023×10^{23} molecules. This number is known as Avogadro number (N).
11. One mole of any gas or Vapour (or a mixture of gases) at STP occupies a volume of 22.4 litres. This is known as Gram Molar Volume (G.M.V.)
12. One mole = Numerical value of the molecular weight of the substance expressed in grams. = mass of 6.023×10^{23} molecules of the substance

    = mass of 22.4 lit of gas (or) vapour at STP

    *No. of molecules in 1cc of a gas at S.T.P= $2.67X10^{19}$.
13. The numerical value of the atomic weight of an element expressed in grams is known as a gram atomic weight (GAW) or a gram atom of that element.

    E.g.: One gram atom of carbon =12 grams of carbon
14. One gram atom of any element contains 6.023×10^{23} atoms of the element.
15. Number of gram - atoms (n) =Mass of element/ gram atomic weight.
16. One gram -atom = Numerical value of the atomic weight of the element expressed in grams = Mass of 6.023×10^{23} atoms of the element.
17. Mass of one atom= GAW/6.023×10^{23}.
18. The numerical value of the formula weight of an ion expressed in grams is called one gram ion.

    One gram - ion or a mole of ions contains 6.023×10^{23} ions.
19. A mole of molecules means 6.023×10^{23} molecules, a mole of atoms means 6.023×10^{23} atoms and a mole of ions means 6.023×10^{23} ions.
20. Vapour density of a gas or vapour = $\frac{\text{Density of the gas}}{\text{Density of Hydrogen}}$

21. The ratio of densities, the ratio of vapour densities and the ratio of molecular weights of two gases are equal.

$$\frac{d_A}{d_B} = \frac{D_A}{D_B} = \frac{M_A}{M_B}$$

22. Molecular weight = density of the gas at STP in g/L × 22.4

23. Vapour density of a gas = density of the gas at STP × 11.2

24. Molecular weight =2 × vapour density.

25. Equivalent weight of an element =Atomic weight/valency.

Element	Atomic Mass	Valency	Equivalent Weight
Hydrogen	1	1	1
Sodium	23	1	23
Magnesium	24	2	12
Aluminium	27	3	9
Carbon	12	4	3
Zinc	65.4	2	32.7
Silver	108	1	108
Oxygen	16	2	8
Chlorine	35.5	1	35.5
Nitrogen	14	3	4.67
Phosphorus	31	3	10.33
Potassium	39.1	1	39.1
Sulphur	32	2	16
Bromine	80	1	80

26. In a balanced chemical equation, always two substances are in 1:1 ratio of their equivalents.

27. The equivalent weight of a substance need not necessarily be a fixed value.

28. Equivalent weight of an acid $= \frac{\text{Formula weight}}{\text{Basicity}}$

Equivalent weights of some acids

Acid	Formula	Formula Weight	Basicity	Equivalent Weight
Hydrochloric acid	HCl	36.5	1	36.5
Sulphuric acid	H_2SO_4	98	2	49
Nitric acid	HNO_3	63	1	63
Acetic acid	CH_3COOH	60	1	60
Oxalic acid	$H_2C_2O_4.2H_2O$	126	2	63
Phosphoric acid	H_3PO_4	98	3	32.67
Phosphorous acid	H_3PO_3	82	2	41
Hypo phosphorus acid	H_3PO_2	66	1	66
Perchloric acid	$HClO_4$	100.5	1	100.5

29. Equivalent weight of base $= \frac{\text{Formula weight of base}}{\text{Acidity of base}}$

Equivalent weights of some bases

Base	Formula	Formula Weight	Acidity	Equivalent Weight
Sodium hydroxide	NaOH	40	1	40
Potassium hydroxide	KOH	56	1	56
Calcium hydroxide	$Ca(OH)_2$	74	2	37
Aluminium hydroxide	$Al(OH)_3$	78	3	26
Ferrous hydroxide	$Fe(OH)_2$	90	2	45
Ferric hydroxide	$Fe(OH)_3$	107	3	35.67
Ammonium hydroxide	NH_4OH	35	1	35
Chromic hydroxide	$Cr(OH)_3$	103	3	34.33

30. Equivalent weight of salt

$$E_{salt} = \frac{\text{Formula weight of the salt}}{\text{Total charge of the cation or anion of the salt}}$$

$E_{Al2(SO4)3} = F/6 = 342/6 = 57$

31. Equivalent weight of Ion= $\frac{\text{Formula weight}}{\text{Charge / Valency}}$, $E_{Fe^{+2}} = \frac{56}{2} = 28$

32. Equivalent weight of oxidising agent = $\frac{\text{Formula weight of oxidant}}{\text{Electrons gained by one molecule of oxidant}}$

E.g.: $KMnO_4$ acts as oxidant in acidic, basic and also in neutral medium.

1. In acidic medium : $KMnO_4 + 8H^+ + 5e^- \rightarrow K^+ + Mn^{2+} + 4H_2O$

One molecule of $KMnO_4$ gains five electrons. Hence, the equivalent weight of $KMnO_4$

$= \frac{\text{Mol.wt.of } KMnO_4}{5} = \frac{158.04}{5} = 31.608$

2. In neutral as well as weakly basic medium:

$KMnO_4 + 2H_2O + 3e^- \rightarrow K^+ + 4OH^- + MnO_2$

One molecule of $KMnO_4$ gains three electrons.

Hence the equivalent weight of

$KMnO_4 = \frac{\text{Mol.wt.of } KMnO_4}{3} = \frac{158.04}{3} = 52.68$

3. In strongly alkaline medium: $MnO_4^- + e^- \rightarrow MnO_4^{2-}$

Then the equivalent weight of $KMnO_4 = \left\{\frac{\text{Mol.wt.of } KMnO_4}{1}\right\} = 158.04$

33. Equivalent weight of reducing agent

$E_{\text{reductant}} = \frac{\text{Formula weight of reductant}}{\text{Electrons lost by one molecule of reductant}}$

Mohr's salt is ferrous ammonium sulphate

Formula = $FeSO_4.(NH_4)_2SO_4.6H_2O$

Formula weight = 392

$Fe^{2+} \rightarrow Fe^{3+} + e^-$

The equivalent weight of Mohr's salt is 392/1 =392