Equivalent weight (Eq.wt):- also known as gram equivalent or equivalent mass, is the formula weight divided by the number of reacting units.

الوزن المكافئ (Eq.wt): المعروف أيضًا بالجرام المكافئ أو الكتلة المكافئة، هو صيغة الوزن مقسومة على عدد الوحدات المتفاعلة.

Equivalent weight (Eq.wt) = $\frac{\text{formula weight}}{\text{no. of reacting units}}$

Reacting units:

- (H^+ or OH-) for acid and base
- Number of electrons for oxidation-reduction reaction
- Number of cations or anions multiplied by charge of ion.

$(\mathbf{Eq.wt})(\frac{\mathbf{g}}{\mathbf{Eq}})\ \mathbf{for\ acid-base\ reaction} = \frac{\mathbf{formula\ weight\ (F.wt)}}{\mathbf{(No.of\ H^+\ or\ OH^-)react}}$
$(\mathbf{Eq.wt})(\frac{\mathbf{g}}{\mathbf{Eq}})\ \mathbf{for\ redox\ reaction} = \frac{\mathbf{formula\ weight\ (F.wt)}}{\mathbf{No.of\ electron}}$
$(\mathbf{Eq.wt})\left(\frac{\mathbf{g}}{\mathbf{Eq}}\right)\ \mathbf{for\ salt\ reaction} = \frac{\mathbf{formula\ weight\ (F.wt)}}{\mathbf{No.of\ (cation\ or\ anion) * charge\ of\ ion}}$

***Example* (1):-**Calculate the equivalent weight of the following substances: (a) NH_3, (b) H_2SO_4, (c) $H_2C_2O_4$ (in reaction with NaOH), (d) $KMnO_4$ [Mn^{7+} is reduced to Mn^{2+}], and (e) $Al_2(SO_4)_3$

Solution:

(a) Base NH_3

$$NH_3 + H_2O \longleftrightarrow NH_4^+ + OH^-$$

$$\text{Eq wt} = \frac{\text{Mwt}}{\text{No. of H}^+ \text{ or OH}^-} = \frac{17.03}{1} = 17.03 \frac{\text{g}}{\text{Eq.}}$$

(b) Strong acid H_2SO_4

$$H_2SO_4 \longrightarrow 2H^+ + SO_4^{-2}$$

$$\text{Eq wt} = \frac{98}{2} = 49\ \frac{\text{g}}{\text{Eq.}}$$

(C) Weak acid $H_2C_2O_4$ (in reaction with NaOH)

$H_2C_2O_4 + NaOH \longrightarrow Na_2C_2O_4 + 2H_2O$

$$\text{Eq wt} = \frac{90.04}{2} = 45.02\ \frac{\text{g}}{\text{Eq.}}$$

(d) $KMnO_4$ [Mn^{7+} is reduced to Mn^{2+}]

$$MnO_4^- + 8H^+ + 5e = Mn^{+2} + 4H_2O$$

$$\text{Eq wt} = \frac{\text{M. wt}}{\text{No. of electron}} = \frac{158.04}{5} = 31.608\ \frac{\text{g}}{\text{Eq.}}$$

(e) Salt $Al_2(SO_4)_3$

$Al_2(SO_4)_3 \longleftrightarrow 2Al_3^{+} + 3SO_4^{2-}$

$$\text{Eq wt} = \frac{\text{formula weight (F. wt)}}{\text{No. of (cation or anion)} * \text{charge of ion}} = \frac{342}{2 * 3} = 57\ \frac{\text{g}}{\text{Eq.}}$$

Homework : *Example* (2**):-**Calculate the equivalent weight of the following substances: (a) Na2CO3, (b) Ba(OH)2.

Normality (N): Normal concentration: Number of equivalent solute in solution volume in litre.

التركيز النورمالي (العيارية) : وهي صيغة اخرى من صيغ التركيز: هو عدد الأوزان المكافئة للمذاب في واحد لتر من المحلول

عدد المكافئات **No. of Eq**= $\frac{wt}{Eq.wt}$
الوزن المكافيء **Eq.wt** = $\frac{Mwt}{n}$
وحدات حجم اللتر $\mathbf{N} = \frac{\text{No.of equivalent(Eq)}}{\text{Solution Volumn (L)}}$
No. of Eq= N ×V(L)
$\mathbf{N} = \frac{\mathbf{wt}}{\mathbf{Eq.wt}} \times \frac{\mathbf{1}}{\mathbf{V\ (L)}}$
وحدات حجم مل $\mathbf{N} = \frac{\text{No. of equivalent(meq)}}{\text{Solution Volumn (ml)}}$
No. of meq= N ×V(ml)
$\mathbf{N} = \frac{\mathbf{wt}}{\mathbf{Eq.wt}} \times \frac{\mathbf{1000}}{\mathbf{V\ (mL)}}$
$\mathbf{N} = (\frac{\mathbf{Eq.}}{\mathbf{L}}) = (\frac{\mathbf{meq.}}{\mathbf{mL}})$
قانون تحويل نورمالية الى مولارية وبالعكس **N=nM**

ملاحظات مفيدة بالحل :

1- الحوامض 3 انواع هي

- **الحوامض المعدنية (تكون H^+بالبداية) مثل HCl و $HClO_4$ و H_2SO_4**
- **الحوامض العضوية (تكون H^+ بالاخير) مثل CH_3COOH**
- **الحوامض العضوية متعدد البروتون مثل حامض الاوكزاليك**

CH2-COOH
|
CH2-COOH

2- القواعد تنتهي دائما ب OH^- مثل NaOH, $Mg(OH)_2$, $Bi(OH)_2$

3 – الاملاح: الأملاح تتكون من أيونات موجبة (كاتيونات) على اليسار وأيونات سالبة (أنيونات) على اليمين مثال NaCl (الصوديوم على اليسار ايون موجب والكلور على اليمين ايون سالب)

4- في معادلات الاكسدة والاختزال يجب ان يتم موازنه المعادلة ثم ايجاد عدد الالكترونات المفقودة او المكتسبة

***Example*(3):**-Calculate the normality of the solutions containing the following: (a) 5.300gm/L Na_2CO_3 (when the CO_3^{-2} reacts with two protons), (b) 5.267 gm/L $K_2Cr_2O_7$ (the Cr^{6+} is reduced to Cr^{3+}).

***Solution* :**(a)

M.wt Na_2CO_3 = (23*2)+ 12+(16*3)= 106 $\frac{g}{mol}$

$$Na_2CO_3 \longrightarrow 2Na^+ + CO_3^-$$

$$\mathbf{Eq.wt = \frac{formula\ weight\ (F.wt)}{No.of\ (cation\ or\ anion) * charge\ of\ ion}}$$

$$\mathbf{Eq.wt = \frac{106}{2*1} = 53}$$

$$\mathbf{N = \frac{wt}{Eq.wt} \times \frac{1}{V\ (L)}}$$

نقوم بترتيب القانون لان اعطى بالسؤال الوزن بوحدات 5.300 g/L

$$\mathbf{N = \frac{wt(g)}{V\ (L)} \times \frac{1}{Eq.wt}}$$

$$\mathbf{N = 5.3\ \frac{g}{L} \times \frac{1}{53} = 0.10\ Eq/L}$$

(b) M.wt $K_2Cr_2O_7$ = (39*2)+ (5282)+(16*7)= 294 $\frac{g}{mol}$

$$\mathbf{Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow\ 2Cr^{3+} +\ 7H_2O}$$

$$\mathbf{(Eq.wt)(\frac{g}{Eq})\ for\ redox\ \ reaction = \frac{formula\ weight\ (F.wt)}{No.of\ electron}}$$

$$\mathbf{Eq.wt = \frac{294}{6} = 49}$$

$$\mathbf{N = \frac{wt}{Eq.wt} \times \frac{1}{V\ (L)}}$$

نقوم بترتيب القانون لان اعطى بالسؤال الوزن بوحدات **gm/L** 5.267

$$\mathbf{N = \frac{wt}{V\ (L)} \times \frac{1}{Eq.wt}}$$

$$\mathbf{N = 5.267\ \frac{g}{L} \times \frac{1}{49} = 0.1074\ Eq/L}$$

***Example* (4):**-How many millilitres of a 0.25M solution of H_2SO_4 will react with 10mL of a 0.25N solution of NaOH.

Solution:

لدينا التراكيز مختلفة احدها نورمالي والاخر مولاري لذالك يجب ان يتم التوحيد

$$\mathbf{N = nM \quad (n = No.of\ equivalent\ ,\ \ H^+, OH^-, or\ electron)}$$

$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$

n =عدد ذرات H^+ هو 2

$$\mathbf{N_{H_2SO_4} = 2 \times 0.25 = 0.5\ N}$$

قاعدة + حامض ⟶ ملح+ ماء

H_2SO_4 + 2NaOH ⟶ $2H_2O$ + Na_2SO_4

$$\mathbf{Meq\ H_2SO_4 = Meq\ NaOH}$$
$$\mathbf{(N \times V)_{H_2SO_4} = (N \times V)_{NaOH}}$$

$$\mathbf{(0.5 \times V)H_2SO_4 = (0.25 \times 10\ mL)NaOH}$$
$$\mathbf{V_{H_2SO_4} = 5.0\ mL}$$

***Example*(5):-**A solution of sodium carbonate is prepared by dissolving 0.212 gm Na_2CO_3 and diluting to 100mL. Calculate the normality of the solution (a) if it is used as a monoacidic base, and (b) if it is used as a diacidic base.

Solution **:**(a)

M.wt Na_2CO_3 = (23*2)+ 12+(16*3)= 106 $\frac{g}{mol}$

$$\mathbf{N = \frac{wt}{Eq.wt} \times \frac{1000}{V\ (mL)} = \frac{0.212}{\frac{106.0}{1}} \times \frac{1000}{100} = 0.020\ meq/mL}$$

(b)

$$\mathbf{N = \frac{0.212}{\frac{106.0}{2}} \times \frac{1000}{100} = 0.040\ meq/mL}$$

***Example*(6):-**Iodine (I_2) is an oxidizing agent that in reactions with reducing agent is reduced to iodide (I^-). How many grams I_2 would you weigh out to prepare 100mL of a 0.10N I_2 solution?

Solution **: (M.Wt I2= 254 g/mol)**

$$\mathbf{I_2 + 2e \rightarrow 2I^-}$$

$$\mathbf{N = \frac{wt}{Eq.wt} \times \frac{1000}{V\ (mL)}} \Rightarrow \mathbf{0.1 = \frac{wt}{\frac{254}{2}} \times \frac{1000}{100}}$$

$$\mathbf{wt = 1.27g}$$

Example (7):-Calculate the normality of a solution of 0.25 g/L $H_2C_2O_4$, both as an acid and as a reducing agent.(M.wt $H_2C_2O_4$= 90 g/mol)

Solution:

$$H_2C_2O_4 \rightarrow 2CO_2 + H_2O$$

$$N = \frac{wt}{Eq.wt} \times \frac{1}{V\,(L)}$$

نقوم بترتيب القانون لان اعطى بالسؤال الوزن بوحدات 0.25 g/L

$$N = \frac{wt(g)}{V\,(L)} \times \frac{1}{Eq.wt}$$

$$N = 0.25\,\frac{g}{L} \times \frac{1}{\frac{90}{2}} = 0.00555\ meq./mL$$

***Example*(8):-**How many milliequivalents (meq) are involved in 43.50 mL of 0.1379N $K_2Cr_2O_7$?

***Solution*:**

$$no.\,of\ milliequivalents = N \times V$$

$$meq = N \times V(ml)$$

$$= 0.1379\,\frac{meq.}{mL} \times 43.50\ mL$$

$$= 5.9987\ meq$$

Example (9): What is normality of 0.3 M H_3PO_4 when it undergoes the following reaction?

$H_3PO_4 + 2OH^- \longrightarrow HPO_4^{2-} + 2H_2O$

Solution:

Normality = molarity x 2 = 0.3 x 2 = 0.6 N

Homework: What is normality of 0.3 M H_3PO_4?

Solution:

$H_3PO_4 \longrightarrow 3H^+ + PO_4^{-3}$

Normality = molarity x 2 = 0.3 x 3 = 0.9 N

Example (10): Calculate the number of mg present in 1 ml of 0.3 N H_2SO_4 (Mwt = 98 g/mol) solution.

Solution:

$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$

$$\text{Eq wt} = \frac{98}{2} = 49\ \frac{\text{g}}{\text{Eq.}}$$

$$\mathbf{N = \frac{wt}{Eq.wt} \times \frac{1000}{V\ (mL)}}$$

$$\mathbf{0.3 = \frac{wt}{49} \times \frac{1000}{1} = 0.0147\ g}$$

(g=1000 mg)
wt= 0.0147 *1000=14.7 mg

Exercise

1. Calculate the normality of the solution obtained by dissolving 0.321 g of the salt sodium carbonate (Na_2CO_3) in 250 mL water. (Assuming the salt solution is being used in a complete neutralisation by a strong acid).

2. What is the normality of a- 0.138 M NaOH, b-0.052 M H_3PO_4 and c-0.34 M $Ca_3(PO_4)_2$?

3. Determine the normality for each of the following solutions:

- 0.44 mol of $CoCl_2$ in 0.654 L of solution

- b. 0.87 g of phosphoric acid, H_3PO_4, in 1.00 L of solution (dibasic reaction)
- c. 0.23 g of calcium hydroxide, $Ca(OH)_2$, in 48.00 mL of solution
- d. 9 kg of $Na_2SO_4 \cdot 10H_2O$ in 15.34 L of solution

4. In the following reaction, calculate and find the normality when it is 1.0 M H_3PO_4: $H_3AsO_4 + 2NaOH \rightarrow Na_2HASO_4 + 2H_2O$

5. What is the molar concentration of aluminium in a 3.0 N solution of aluminium sulfate ($Al_2(SO_4)_3$)?

6. What volume of a 0.20 N of K_2SO_4 solution contains 57 g of K_2SO_4?