1 Techniques and Measurements

* Beakers and Erlenmeyer flasks → roughly estimate
* Graduated cylinders, Burets, and Pipets } → more precise

Physical Properties

Intensive
doesn't depend on the amount of substance.
e.g. temperature, density, ...

Extensive
depend on the amount of substance
e.g. volume, heat, mass, ...

$\left(\frac{\text{extensive}}{\text{extensive}} = \text{intensive} \Rightarrow \frac{\text{mass}}{\text{volume}} = \text{density} \right)$

$$\boxed{\text{Density} = \frac{\text{Mass}}{\text{Volume}}}$$

units: g/mL → liquids } غالباً
g/cm³ → solids

- density of water at 4°C = 1.0 g/mL
- density of Osmium = 22.6 g/cm³ (greatest density among elements)

* Factors of density:
  1) Temperature:
     if it increase → the volume increase → the density decrease
  2) Pressure:
     if it increase → the volume decrease → the density increase.

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* Safety Rules (6–10)
* Laboratory Techniques (12–19)
* Significant Figures (149–152)

} Reading

2 Formula of a Hydrate

* Hydrate : is a compound that has crystallized from aqueous solution with weakly bound water molecules contained in the crystal.
  - → Transition metal salts : as $CuSO_4 \cdot 5H_2O$
  - → Non-transition metal salts : as $NaC_2H_3O_2 \cdot 3H_2O$

* Alums : a class of hydrates, with the general formula

$$(M'M'''(SO_4)_2 \cdot XH_2O)$$

M': univalent cation

M''': trivalent cation

example : $KAl(SO_4)_2 \cdot 12H_2O$

* Hydrate $\xrightarrow{\text{heat}}$ anhydrous (without water)

e.g. $\underset{\text{(blue)}}{CuSO_4 \cdot 5H_2O} \xrightarrow{\text{heat}} \underset{\text{(white)}}{CuSO_4} + 5H_2O$

water

Hydrate $\xrightarrow{\text{heat}}$ anhydrous + H_2O (Hydrate or Alum) the same

mass (Hydrate) = mass (anhydrous) + mass (H_2O)

* % of water of crystallization by mass $= \dfrac{\text{mass (water)}}{\text{mass (hydrate)}} \times 100\%$

* value of $X = \dfrac{\text{moles (water)}}{\text{moles (anhydrous)}}$

3. The Empirical Formula of an Oxide

$\underline{\underline{Mg}}$ burned in air (O_2, N_2)

→ $\boxed{Mg_3N_2}$ magnesium nitride

→ $\boxed{MgO}$ magnesium oxide

$$Mg_3N_2 + 6H_2O \longrightarrow 3\underline{\underline{Mg(OH)_2}} + 2\underline{NH_3}\uparrow_{(g)}$$

(NH_3 → (base: red litmus paper → blue))

$$Mg(OH)_2 + Heat \longrightarrow \boxed{MgO} + H_2O$$

→ although the amount of (N_2) in the air is approximately 4 times that of (O_2) more oxide than nitride is formed when an active metal is burned in air → the reason is the superior reactivety of (O_2).

$$\boxed{2Mg + O_2 \longrightarrow 2MgO}$$

mass of (MgO) = mass of Mg + mass of O_2

- to determine the empirical formula:
  1- find masses of Mg, O_2.
  2- then calculate number of moles of Mg, O_2 $\left(\text{moles} = \frac{\text{mass}}{M.m}\right)$
  3- $Mg_{\underline{m}}O_{\underline{n}}$ ($\underline{m}$ → moles of Mg, $\underline{n}$ → moles of O) → اقسم (m ، n) على الاصغر منهما

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mass % of Mg in the oxide (X_1) $= \frac{\text{mass (Mg)}}{\text{mass (MgO)}} \times 100\%$ ⇒ experimentally (من التجربة)

mass % of Mg in the oxide (X_2) $= \frac{\text{Mass (Mg)}}{\text{Mass (MgO)}} \times 100\%$ ⇒ theoritically (من الجدول الدوري)

$$\% \text{ error} = \frac{|X_2 - X_1|}{X_2} \times 100\%$$

(X_2 → true value)

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* cover of the crucible is slightly open → because opening the cover too far allow the metal to <u>enflame</u>.

4. Limiting Reactant

- reaction between two hydrates as the follow:
  ($Na_3PO_4 \cdot 12H_2O$ & $BaCl_2 \cdot 2H_2O$)

$$\boxed{2\,Na_3PO_4 + 3\,BaCl_2 \longrightarrow Ba_3(PO_4)_2 + 6\,NaCl}$$

* طريقة تحديد ال (limiting reactant)

$$\text{moles of } Na_3PO_4 = \frac{\text{mass of } Na_3PO_4}{M.m\,(\underbrace{Na_3PO_4 \cdot 12H_2O}_{\text{كامل}})} = n_{Na_3PO_4}$$

$$\text{moles of } BaCl_2 = \frac{\text{mass of } BaCl_2}{M.m\,(\underbrace{BaCl_2 \cdot 2H_2O}_{\text{كامل}})} = n_{BaCl_2}$$

ثم نقسم عدد مولات كل مادة على معاملها في المعادلة:

$$\frac{n_{Na_3PO_4}}{2} \qquad \frac{n_{BaCl_2}}{3}$$

الناتج الاقل يكون (limiting)
والناتج الاكبر يكون (excess)

ويمكن تحديد (limiting & excess) عملياً بإضافة احدى المادتين الى محلولي ($BaCl_2$ & Na_3PO_4)
فاذا تكون الراسب في احدهما يكون: المادة المضافة ← limiting
(precipitate)
المادة الموجودة في المحلول ← excess

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* Purpose of heating the mixture → to get large particle size.
* Purpose of washing the precipitate with hot water → to ionize NaCl and filter $Ba_3(PO_4)_2$ only.

$$\Rightarrow \text{mass \% of } BaCl_2 \cdot 2H_2O = \frac{\text{mass of } BaCl_2}{\text{total mass (mixture)}} \times 100\%$$

$$\Rightarrow \text{mass \% of } Na_3PO_4 \cdot 12H_2O = \frac{\text{mass } Na_3PO_4}{\text{total mass (mixture)}} \times 100\%$$

} Mixture

5 Determination of Acetic Acid in Vinegar

- Vinegar is a dilute solution of acetic acid (CH_3COOH) in water.

* number of moles (n):

$\longrightarrow$ n = Molarity * Volume (liters)

$n = M * V$ $\longrightarrow$ for a solution

$\longrightarrow n = \frac{mass}{molar\ mass}$

$n = \frac{m}{M.m}$ $\longrightarrow$ for a pure substance.

* Indicator : Phenolphthalein < (colorless) in acid / (pink) in base

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A Standardization of NaOH solution :

↳ because NaOH is secondary standard solution, and it absorbs moisture from atmosphere.

so we standardize it with primary standard (KHP) potassium hydrogen phthalate (has the formula $KHC_8H_4O_4$)

$$KHC_8H_4O_4 + NaOH \longrightarrow \cancel{KH}\ NaKC_8H_4O_4 + H_2O$$

$$n_{NaOH} = n_{KHP}$$

$$M * V = \frac{m}{M.m}$$

B Mass percent of acetic acid in vinegar :

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$$

$$n_{CH_3COOH} = n_{NaOH}$$

$$(M * V)_{CH_3COOH} = (M * V)_{NaOH}$$

mass % of acetic acid in vinegar $= \frac{\text{mass of acetic acid in 1L}}{\text{mass of 1L vinegar}} * 100 = \boxed{\frac{M * M.m}{d * V} * 100\%}$

6 The Neutralizing Capacity of Antacid Tablets

- Antacids are weak bases – because strong bases will react with HCl in an exothermic reaction and strong bases are corrosive substances.

Antacid

- **active ingredients:**
  - **metal hydroxides**
    - $Mg(OH)_2 + 2HCl \rightarrow MgCl_2 + 2H_2O$
    - $Al(OH)_3 + 3HCl \rightarrow AlCl_3 + 3H_2O$
  - **metal carbonates**
    - $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$
    - $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$
    - ⇒ boiling is important:
      - to remove CO_2 which converted to the weak acid (H_2CO_3) [$H_2CO_3 \rightleftharpoons CO_2 + H_2O$] which reacts with NaOH.
- **other ingredients:-**
  1. flavoring agents
  2. substances to soothe the walls and lining of the stomach.
  3. binders to hold tablet together.

HCl total (n_A)
- reacted with antacid (n_{sample})
- excess HCl: titrated with NaOH (n_B) → Back-titration

$$n_{sample} = n_A - n_B$$

$$\text{neutralizing capacity of antacid} = \frac{\text{moles of HCl needed to neutralize antacid}}{\text{mass of antacid}} \quad (mol/g)$$

* Indicator → bromothymol blue
- (yellow) in acidic solution
- (blue) in basic solution

7 Vitamin C Analysis

* Vitamin C ($C_6H_8O_6$):
  - called (ascorbic acid)
  - water soluble.
  - Powerful reducing agent

⇒ reducing properties of vit. C used to analysis (even it is an acid)
⇝ because there are other acids present in foods that would interfere with the selective determination of vit. C.

in this experiment:-
oxidizing agents (get reduced): IO_3^- (strong), I_3^- (mild)
reducing agents (get oxidized): $C_6H_8O_6$, I^-, $S_2O_3^{2-}$

* Equations :-

1- $IO_3^- + 8I^- + 6H^+ \longrightarrow 3I_3^- + 3H_2O$
(excess amount) (acidic solution) (red-brown)

2- $C_6H_8O_{6(aq)} + I_3^- + H_2O \longrightarrow C_6H_8O_7 + 3I^- + 2H^+$

3- $2S_2O_3^{2-}$ + excess $I_3^- \longrightarrow 3I^- + S_4O_6^{2-}$
(Indicator - starch : deep blue ⟶ colorless) (end point)

* Summary :-

$IO_3^- + I^-_{excess} \longrightarrow I_3^-_{total}$ → $C_6H_8O_6$ (I_3^- reacted with vit. C)
excess → $S_2O_3^{2-}$ (I_3^- tirated with $S_2O_3^{2-}$)

$$\boxed{I_3^-_{(\text{reacted with vitamin C})} = I_3^-_{total} - I_3^-_{excess}}$$ (Back-titration)

$\#\, I_3^-_{(total)} = 3 * \#$ moles of IO_3^- ..... from equation 1

$\#\, I_3^-_{(\text{reacted with vitamin C})} = \#$ moles of $C_6H_8O_6$ .... from equation 2

$\#\, I_3{}_{(excess)} = \frac{1}{2} * \#$ moles of $S_2O_3^{2-}$ ..... from equation 3

% mass of vit. C in sample = $\frac{\text{mass vit. C}}{\text{mass sample}} \times 100\%$

mass vit. C = moles of vit. C * M.m vit. C (176 g/mol)

8 Bleach Analysis

- the active ingredient in most chlorine bleaches is sodium hypochlorite $NaOCl$ (or ClO^-).

A Standardization of thiosulfate solution :

- because $S_2O_3^{2-}$ may be oxidized by oxygen or by bacterial action.
- $S_2O_3^{2-}$ standardize with primary standard (e.g. $Cr_2O_7^{2-}$ dichromate).

* Equations ① $Cr_2O_7^{2-} + 9I^- + 14H^+ \longrightarrow 2Cr^{3+} + 3I_3^- + 7H_2O$

② $2S_2O_3^{2-} + I_3^- \longrightarrow 3I^- + S_4O_6^{2-}$

* $\boxed{Cr_2O_7^{2-} + 14H^+ + 6S_2O_3^{2-} \longrightarrow 2Cr^{3+} + 7H_2O + 3S_4O_6^{2-}}$ (net ionic equation)

** moles of $S_2O_3^{2-}$ = 6 * moles of $Cr_2O_7^{2-}$

Colors red $\xrightarrow[(S_2O_3^{2-})]{\text{titration}}$ yellow $\xrightarrow[\text{(starch)}]{\text{indicator}}$ dark blue $\xrightarrow[(S_2O_3^{2-})]{\text{titration}}$ yellow-green (Cr^{3+} color)

$$\boxed{M_{S_2O_3^{2-}} = \frac{\text{moles of } S_2O_3^{2-}}{\text{Volume (Liters)}}}$$

oxidizing agents
ClO^-, I_3^-, $Cr_2O_7^{2-}$
reducing agents
I^-, $S_2O_3^{2-}$

B Analysis of bleach Solution :

* Equations ① $ClO^- + 3I^- + 2H^+ \longrightarrow \underset{\text{red-brown}}{I_3^-} + Cl^- + H_2O$

② $I_3^- + 2S_2O_3^{2-} \longrightarrow \underset{\text{colorless}}{3I^-} + S_4O_6^{2-}$

* $\boxed{ClO^- + 2S_2O_3^{2-} + 2H^+ \longrightarrow Cl^- + S_4O_6^{2-} + H_2O}$ (net ionic equation)

** moles of ClO^- = $\frac{1}{2}$ moles of $S_2O_3^{2-}$

Colors red $\xrightarrow[(S_2O_3^{2-})]{\text{titration}}$ yellow $\xrightarrow[\text{(starch)}]{\text{indicator}}$ dark blue $\xrightarrow[(S_2O_3^{2-})]{\text{titration}}$ colorless

$$\boxed{M_{ClO^-\,\text{diluted}} = \frac{\text{moles of } ClO^-}{\text{Volume (Liters)}}}$$

$$\boxed{M_{ClO^-\,\text{original}} = M_{ClO^-\,\text{diluted}} * \text{dilution factor}}$$

دائماً أكبر من واحد
وقد يكون عدد صحيح
أو عدد كسري

$$\boxed{\text{Mass \% } NaClO^- = \frac{M_{original} * M.m}{\text{density}(d) * 1000} \times 100\%}$$

9 Molar Mass of a Volatile Liquid (Dumas method)

* at STP (standard temperature - pressure) conditions:-

$T = 0\,^{\circ}C = 273\ K$
$P = 1\ atm$
$\Rightarrow$ Volume of ideal gas $= 22.4\ L$

* Gases behave ideally at:
  - very low pressure.
  - very high temperature.

$$\boxed{PV = nRT}$$ ideal gas law

P: Pressure in (atm) $\Rightarrow$ $1\ atm = 760\ mmHg = 760\ torr$

V: Volume in (Liters)

n: number of moles

R: gas constant $= 0.0821\ \frac{L.atm}{mol.K}$

T: temperature in (K) $\Rightarrow$ $K = C + 273$

$$n = \frac{mass\ (m)}{molar\ mass\ (M)} \Rightarrow \boxed{M = \frac{mRT}{PV}}$$

m: in grams
M: (g/mol)

$$density\ (d) = \frac{mass\ (m)}{volume\ (V)} \Rightarrow \boxed{d = \frac{PM}{RT}}$$

d: (g/L)

10. Thermochemistry and Hess's Law

- Heat flows are measured by **Calorimeter**.
- In the calorimeter, a small quantity of heat may be transferred to the calorimeter itself, ~~the~~ the metal wire used for stirring, or to the thermometer. Therefore the calorimeter will be <u>calibrated</u>.

$$q = m * s * \Delta t$$

- q → heat (Joule) $J = kg\, m^2 s^{2-}$
- m → mass
- s → specific heat → quantity of heat required to raise the temperature of one gram of the substance by 1°C (unit → J/g.°C)

A Determination of the heat capacity of calorimeter [Calibration]:

Heat lost = Heat gained → (conservation of energy)

$$q_{warm\ water} = q_{cold\ water} + q_{calorimeter}$$

$$(m * s * \Delta t)_{warm} = (m * s * \Delta t)_{cold} + (C * \Delta t)_{calorimeter}$$

the same

C → calorimeter constant (J/°C) or heat capacity

remember m = volume × density

- Water has very high specific heat (4.184 J/g.°C)
- Stirring water during heating → to ensure that the temperature is uniform.

(C) depends on material
- the higher conductivity the higher C value

e.g. $C_{metal} > C_{plastic}$

B Heat of Acid-Base Reaction:

$$q_{gained} = (m\ s\ \Delta t)_{solution} + C\ \Delta t$$

the same

$\Delta t = t_f - t_i$

- t_f → mixture بعد التفاعل
- t_i → معدل درجة حرارة المادتين المتفاعلتين قبل التفاعل

reaction ① $NaOH + HCl \rightarrow NaCl + H_2O$

enthalpy ← $\Delta H = \dfrac{q_{gained}}{\text{moles of } H_2O}$ ($\Delta H = KJ/mol$)

reaction ② $NH_3 + HCl \rightarrow NH_4Cl$

$\Delta H = \dfrac{q_{gained}}{\text{moles of } NH_4Cl}$

ΔH
- temperature increase (exothermic) → ΔH ⊖
- temperature decrease (endothermic) → ΔH ⊕

Hess's Law:

١. عند ضرب المعادلة برقم ← تضرب ΔH بنفس الرقم

٢. عند عكس المعادلة ← تعكس اشارة ΔH

11. Molar Mass from Freezing Point Depression

→ to determine the molar mass of a nonvolatile solute.

* Solutions differ from pure solvents in these properties:-

1- Vapor pressure.
2- Osmotic pressure.
3- Freezing point depression.
4. Boiling point elevation.

} Colligative properties: depends only on the number of particles of solute not on the type of particles.

$$\boxed{\Delta T_f = K_f\, m}$$

→ used for dilute solutions of non-dissociating and non-associating solutes.

$$m = \frac{\Delta T_f}{K_f}$$

$$\frac{\text{moles of solute}}{\text{mass of solvent (kg)}} = \frac{\Delta T_f}{K_f}$$

$$\frac{\left(\frac{\text{mass of solute}}{M.m}\right)}{\text{mass of solvent (kg)}} = \frac{\Delta T_f}{K_f}$$

$$\boxed{M.m = \frac{K_f \cdot \text{mass of solute (g)}}{\Delta T_f \cdot \text{mass of solvent (kg)}}}$$

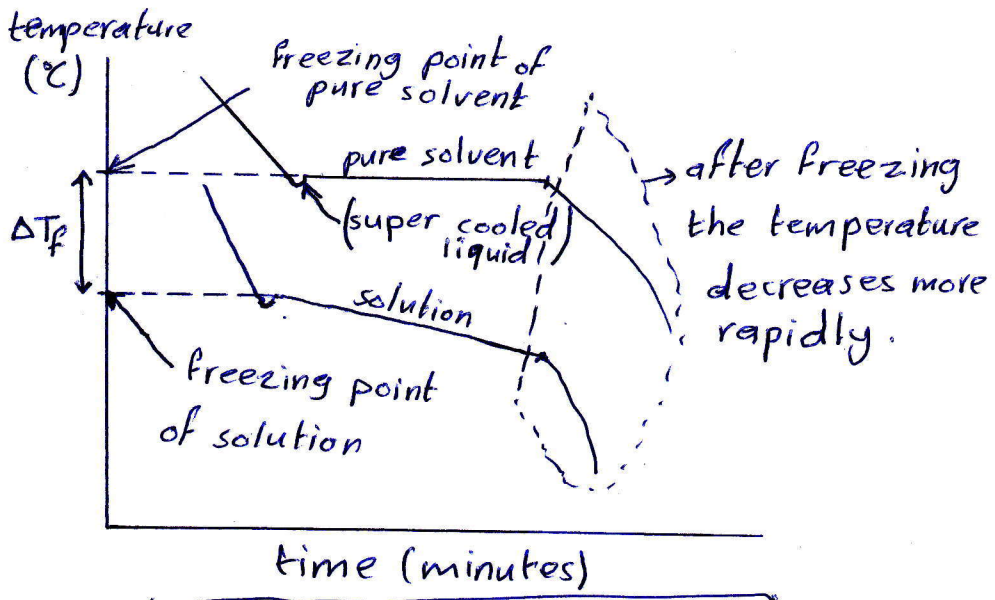
where:-

- ΔT_f (freezing point depression)

  $\Delta T_f = \left(\text{freezing point of solvent} - \text{freezing point of solution}\right)$

- K_f: molal freezing-point depression constant (°C/m)
- m: molal concentration

  $m = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$



* pure solvent: (constant temperature) that occurs while solvent is freezing.

* solution: (inital freezing point) at which only a small fraction of solvent solidifies.

** Questions / Page: 130