AL-Mustansiriyah University College of Science Chemistry Department

# Practical Physical Chemistry

Second stage First course

Subject teacher -Assistant Professor/*Athraa Salman Ahmed* - Lecturer/*Shaimaa Hamed Jaber* 

## **First Course experiments**

- 1- Finding the molecular weight of a volatile liquid (Domas method).
- 2- Relationship of gas volume to temperature and finding absolute zero
- 3- Finding the viscosity of the liquid.
- 4- Finding the calorimeter constant.
- 5- Finding the heat of neutralization (strong acid and strong base).
- 6- Finding the heat of neutralization (weak acid and strong base).
- 7- Finding the electrode potential of magnesium by a thermodynamic method



1

## Introduction

Chemistry is the science that deals with the formula and composition of substances as well as the changes that occur in the composition of substances. As for physical chemistry, it is that branch of chemistry that is concerned with the study of the physical properties and composition of matter and the laws that control chemical reactions. For physical chemistry is first the synthesis of empirical information whose main objective is to We need them to determine the properties of gases, liquids, solids, solutions, and the dispersion of colloidal solutions, as well as provide us with theoretical foundations in the form of laws.



## **First experience**

#### Finding the molecular weight of a volatile liquid using the Dumas method

#### The theoretical part

The importance of this method is reflected in finding the molecular weight of a volatile liquid when the molecular formula of the compound is not known under normal conditions of pressure and temperature. The general gas law is applied (assuming that volatile liquid gas is an ideal gas).

## PV=nRT

PV=nRT

PV=Wt/M.Wt RT

Whereas:

P=atmospheric pressure

V= beaker volume =Vapor volume

Number of moles = weight/molecular weight

R= General constant for gases

T= absolute temperature

A good Dumas method for obtaining good results is based on finding the vapor weight of a volatile liquid that fills a given volume under standard conditions.

#### The method of work:

- 1- Take a clean, dry round flask and close it with aluminum foil (the paper is pierced with a pin (to get rid of air and to equal the internal and external pressure) and weigh the flask with aluminum foil while it is empty and the weight is recorded.
- 2- We put (3ml) of the volatile liquid (unknown) in the round, then put aluminum foil on the round and put it in a water bath (temperature up to the boiling point 100 °C) and wait until the liquid boils and the last drop of it evaporates.
- 3- Close the hole by hand, weigh the beaker and record the weight that represents (the weight of the beaker with the weight of the liquid vapor).
- 4- We take the round flask and put water in it to the end of the nozzle, then put the water into a cylinder the listed and we measure volume of water = volume of the flask is equal to the volume of steam



## Calculations

We apply the general gas law:

PV=nRT PV=Wt/M.Wt RT

P= (1 atm) atmospheric pressure

V = volume of steam = volume of the flask in (ml) (converted to lit)

n=number of moles= Wt.M/Wt where:

Wt = weight of liquid vapor = (weight of the beaker with steam - weight of the beaker empty) and its units (gm)

M.Wt = the molecular weight which is required by the experiment and its units (gm/mol)

R= L.atm/mol.K and its units 0.082=for gases year constant

T =boiling point of water bath = K (273+100)

## Second experience

#### The relationship of gas volume to temperature and finding absolute zero

#### The theoretical part:

The scientist Charles noticed that the volume of any gas constant pressure expands in the Same proportion of under its initial volume (by zero degrees Celsius) for every increase In temperature by one degree Celsius, the volume of the gas at zero order (volume increase By 1/ 273 degree Celsius).

First: the volumetric expansion coefficient must be deduced. Scientist have found that we Take two different gases such as ( $O_2$  and  $CO_2$ ) and we put each gas in a beaker, close the Beaker with stoppers, and take out a capillary tube from the stopper, and put a thread Of mercury about (20 cm) and then put the beakers in a hot water bath at a certain Temperature, we will notice that the mercury moved by the same in both beakers, meaning That the two gases increased by the same amount.



6

We conclude from this that when the

Pressure is constant, the volume of certain amount of gas increases with an increase in

Temperature, so the volumetric expansion coefficient  $(\alpha_v)$  is known: equal volumes of Different gases expand by the same amount when the pressure is constant. This is the Volumetric expansion coefficient, which is constant for all gases.

When the temperature is raised from (0 °c) to (t °c) with constant pressure, the volume Increase by ( $\Delta V$ ).

 $\Delta V \alpha V \circ$ 

 $\Delta V \alpha \Delta t$ 

 $\Delta V \alpha \; V \circ \Delta t$ 

 $\Delta \mathbf{V} = \mathbf{const} \cdot \mathbf{V} \circ \Delta t$ 

 $\Delta V = _{\alpha v} V \circ \Delta t$ 

 $\alpha v = (\Delta V / V \circ - \Delta t)$ 

 $\alpha v_{=} (Vt_{-}V_{-}) / (V_{-}\Delta t) = 1/273 = 1/k = k^{-1}$ 

 $\alpha v = 3.66*10^{-3} k^{-1}$ 

 $\alpha v = (V t V \circ) / (V \circ t)$  This law is used only when one of the degrees = zero  $\alpha v \cdot V \circ t = V t V \circ$ 

$$\mathbf{V} \mathbf{t} = \mathbf{V} \circ + \mathbf{V} \circ \mathbf{.} \alpha \mathbf{v} \mathbf{.} \mathbf{t}$$

## The volumetric expansion coefficient

- 1- Therefore the volumetric expansion coefficient is known: the amount of increase in a Unit of gas at zero degree Celsius when the pressure remains constant.
- 2- Volume expansion coefficient: it is the ratio between the volume of the gas to the Original the increase in volume at (zero Celsius) when the pressure remains constant.
- 3- Volume expansion coefficient: it is the amount of increase in a unit volume of gas at Zero degrees for each increase in temperature by one degree Celsius at constant pressure.

The reason for this is that all gases consist of molecules as if they are free particles independent of each other, and then the dimensions between the gas molecules greatly exceed their radii, and this is a general characteristic of gases in general. Therefore, the smallness of the forces acting between the divergent gas molecules and their small size in relation to the total volume of the gas is one of the factors that have no value in the expansion of the gas. For these reasons, except for (pressure and temperature) in which the gas approaches the state of liquidity, all gases behave similarly and share similar physical properties It is noted from the definition of the volumetric expansion coefficient ( $\alpha$ v) for gases, we have determined the temperature, because gases are not like other materials in their expansion, as the volume of the gas changes according to the change in temperature as the volume in degree 100°C When it is intended to solve any problem related to the volume of a gas, it must first calculate its volume, which is at zero degrees, and then consider the coefficient = 1/273

Vo= volume A specific mass of gas at zero degrees Celsius.

Vt= volume of a given mass of gas in degree t.



at a certain pressure  $(V_1, V_2)$  there the volume of the same mass of gas at two degrees $(t_1, t_2)$ 

$$V1 = Vo (1 + \alpha v t1) \qquad \longrightarrow (3)$$

 $V2=Vo (1+\alpha v t2) \longrightarrow (4)$ 

And by dividing equation 3 by equation 4 we get:

$$V1 / V2 = Vo (1 + \alpha v t1) / Vo (1 + \alpha v t2) \longrightarrow (5)$$

In short, the value of Vo becomes:

 $V1 / V2 = (1 + \alpha v t1) / (1 + \alpha v t2)$  (6)

Substituting in the value  $\ddot{y} = 273$  we get:

 $V1 / V2 = (1 + t1/273) / (1 + t2/273) \longrightarrow (7)$ 

V1 / V2 = (273 + t1) / (273 + t2) (8)

T1= (273+t1): that where T2=(2<u>73</u>+t2)

 $\begin{array}{ccc}
V1 \\
V2 \\
\hline
V2 \\
\hline
T2 \\
\hline
\end{array} \xrightarrow{(9)}$ 

According to equation (9), the volume of any amount of gas at a constant pressure is directly proportional to the temperature. **This is Charles law**.

Absolute

Temperature

According to equation (8), absolute zero on the new scale is at t = -273

Where T=0

According to Charles law, we get:

 $V \alpha T$ 

 $V=K_PT \longrightarrow (10)$ 

Equation (10) indicates that if absolute T = zero at temperature Celsius t = -273The volume v=0, while in reality it is not possible to obtain this state, because any gas turns into a liquid and then solidifies before reaching absolute zero at a certain temperaturAnd the law fails and becomes

#### The method of work:

1- A device consisting of two burettes called (Hempel burettes) is used, so the ends of the two burettes are broken and tied together by a rubber tube used to close the glass beaker where the burette is filled with water where the water level in the burette (A) is 50 (open burette) and burette (B). at zero (closed burette).

2 - We close the clean and dry round flask with the rubber stopper and note the water drop in the closed burette. We equalize the water level in the two burettes and read the volume from the burette (B) The measured volume represents the leakage in the device. (V) The leaked volume

3- We put the beaker in a water bath and heat slowly while stirring the water by a glass motor until the temperature rises to  $(30C^{\circ})$  equal to the level

Water in the two burettes, i.e. moving the burette (A) and (B) and it is read in the burette (B). The volume (V) is recorded, which represents the increase in the volume of trapped air and Subtract the value of (V) The size of the leakage - V) The process is repeated at degrees (40, 50, 60, 70, 80, 90).

4- At the end of the experiment, he takes the circular flask and fills it with water to the extent of entering the rubber seal, pouring water into the graduated cylinder and reading the volume that represents the volume of air.





#### The third experience

## Finding the viscosity of a volatile liquid and finding the absolute and relative density of a volatile liquid

#### The theoretical part:

Viscosity is defined as the impedance that a fluid exhibits during its flow, and it is measured by a simple instrument called a viscometer. So that the concept of viscosity becomes clear to us, we take the stratigraphic flow of the river as we note that the water layers near or adjacent to the shore are static, but when the distance from the shore increases, the velocity of water flow increases and becomes at the greatest end at the center of the river. The moving layer tries to slow down the movement of the neighboring layer, so there is a kind of friction force between the two layers.

On this basis, the fluid that moves through a tube can be considered as consisting of uniform axis layers that move at different speeds, and the layers sticking to the sides of the tube can be considered stable and the speed increases as we approach from the center of the tube, and so there will be a gradient in velocity between the layers as a result of the effective frictional force between the different layers. This force is responsible for the viscosity of the liquid. It has been shown by experiment that the force (F) necessary to obtain a constant difference between the speed of parallel layers of a liquid moving in the same direction varies directly with the difference in The velocity ( $\alpha$ u) and the area (A) of the contact surface of the two layers and inversely with the distance (d) between the two layers.



(n) is the proportionality constant and is pronounced (eta) and it is called the coefficient of Viscosity

The unit of measure for viscosity is the poise, which is equal to  $(dyn.cm^{-2}.sec)$  (the force required to move a layer of fluid area) cm<sup>2</sup>. Its speed is (1cm/sec) next to another layer at a distance of (1cm).

The name (Al Bawaz) was named after the Boiselescientist who created the idea of viscosity. Viscosity is determined in two general ways, and these two methods were based on the (Stokes equation) and (Boiselli's equation). t (at constant pressure (p) and length 1cm(L.)



Where (V) expresses the appropriate volume of fluid through the capillary tube, if the times of flow of equal volumes of two fluids through the same capillary tube and measured under the same conditions would be:





Viscosity is measured as mentioned previously using a device called a viscometer. Viscometer is also used to measure the viscosity of polymeric solutions, including them to find their molecular weights. There are three types of latching devices:

1-Latches for measuring very high viscosity

2-Latches for measuring high viscosity

3-Latches for measuring very low viscosity



#### The method of work

- 1- A clean, dry viscometer is taken and placed in it from the tip (C) liquid Volatile to fill the bulge (B.)
- 2- The liquid is withdrawn by means of a rubber tube from the end (B) so that it reaches the mark (a) and then we calculate the time of descent of the liquid from mark (a) to mark (b) and the step is repeated several times until we are sure of the time of descent (t1) measured in units (sec.)
- 3- Step No. (2) is repeated after the viscometer has dried and we calculate the time of descending the water in the same way (t2) (measured in (sec) units).



t1 = liquid descending time (sec)

t2 = water descending time (sec)

d1 =liquid density (Kg/m<sup>3</sup>)

d2 = density of distilled water(Kg/m<sup>3</sup>)

Density must be converted from g/m<sup>3</sup> to Kg/m<sup>3</sup>

#### Finding the absolute density and relative density of a volatile liquid

Absolute density is defined as the mass of a unit volume, and it is measured in kg/m3 or g/cm3

Absolute Density = Mass/Volume

Relative Density: The density of a substance (volatile liquid) relative to the density of a known

Substance (distilled water), which is abstracted from units.

Relative density = density of volatile liquid / density of distilled water

Density is measured using a simple tool called a pycnometer or a density bottle.

#### Method of work:

- 1- We take a clean, dry density bottle. Weight it, and record the weight of the density bottle when is it is empty
- 2- Fill the density bottle with the volatile liquid first to the end of the nozzle and close it with the cap is dried from the outside and the density bottle is weighed with the volatile liquid and the weight is recorded. (Weight of the density bottle with the liquid)

[(weight of density bottle with liquid)- (weight of density bottle empty with cap)]=weight of liquid

3- Pour the volatile liquid and leave the bottle to dry, then repeat the step

No. (2), but by using distilled water and recording the weight.

**Calculations:** 

## Law of absolute density and relative density

Absolute density of volatile liquid = w1/v (g/cm<sup>3</sup>)

absolute density water= w2/v (g/cm3)

w1 = weight of the volatile liquid

w2 = weight of distilled water

v= The volume of the liquid, which is equal to the volume of the density bottle Relative density of the volatile liquid = d1/d2 or w1/w2

Note: You must convert the density from kg/m3 g/cm<sup>3</sup>

By multiplying it by 1000

After calculating the absolute density and the relative density, the values should be equal or close to each other.

## Fourth experiment

## Finding the calorimeter constant

## The theoretical part:

Most chemical reaction are accompanied by the emission or absorption an amount of Heat proportion to:

- 1- The amount of material used
- 2- The physical state of matter
- 3- It does not depend on the course of the reaction

(**heat q**): is transmitted to and from the system due to the difference It is defined as the energy that : in temperature between the system and the surroundings. Heat is often considered a form of energy .resulting from the random movement of particles

## heat capacity (C):

ount of matter, which is the amount of heat needed to raise the It does not depend on the am temperature of a quantity of matter by one degree. It is measured in  $J/C^{10}$  **specific heat (Cs):** 

The amount of heat required to raise the temperature of one gram of a substance by one degree Celsius, measured in J/ gk or J/gC  $^{10}$ .

use what is The amount of heat is called (enthalpy or enthalpy) and to measure this type of heat we called (calorimeter)it is a simple tool used to measure the change in thermal energy and it is : .completely isolated so that the transfer of energy to the external environment is as low as possible ated with silver from the It is a hollow metal container with two layers of glass, emptied of air, and co .inside, and placed in an iron vessel that contains insulating wood.



#### :Working principle of the calorimeter

The principle of energy conservation in a closed, isolated system, so that energy does not enter this system or leave it. As a result, if the energy of a certain part of the system increases, the energy of the .other part must decrease by the same amount

The reaction heat is measured by conducting a reaction between a mixture of known amounts of :in the calorimeter, where it is reactants

## The amount of heat released or absorbed by the reaction = the amount of heat emitted or absorbed by the calorimeter.

Each calorimeter has its own constant, called the calorimeter, data or heat capacity(C) as mentioned earlier.

The amount of heat released or absorbed in a chemical reaction at a constant pressure called the enthalpy ( $\Delta H$ ) which is the same (q) the amount of heat.

Specific heat = heat capacity / mass

 $Cs = \frac{c}{m} \dots C = Cs.m$ C = heat capacity , m = mass of matter

 $q = Cs.m. \Delta T$ q = amount of heat

 $q_p = C.\Delta T \dots(1)$   $q_p = as$  the measurement takes place at constant pressure  $\Delta H_= qp \dots(2)$  $\Delta H = C. \Delta T$ 

$$\mathbf{C} = \frac{\Delta H}{\Delta T}$$

Where as : C = colorimeter constant ( cal /C  $^{\circ}$  or Kcal / k)  $\Delta H$  = enthalpy (Kcal or cal )  $\Delta T$  = temperature difference (C  $^{\circ}$  ) or k (T <sub>F</sub> - T <sub>I</sub>) T <sub>I</sub> = initial temperature T <sub>F</sub> = final temperature

## The method of work

- **1-** Clean the calorimeter well and place (100ml) of distilled water in it and stir it continuously by a glass motor, and read the temperature every 30sec until stability.
- 2- 3ml of concentrated sulfuric acid is added to the distilled water. The temperature rises at the moment of adding the acid and then decreases. We record the temperature every 30sec until stability.
- **3-** We withdraw with a pipette (10ml) of the solution and put it in a conical flask, add two drops of pheno-naphthalene and wipe with (NaOH 1N) until the pink color appears and the volume is recorded.

## **Calculations:**

1- We draw the graphic relationship between temperature (temp) and time (in the case of distilled water only and in the case of adding (H2SO4 ) to it)



2- We calculate the titer of  $(H_2SO_4)$  from the scaling process with (NaOH) through the dilution law

## N1V1=N2V2

#### (NaOH) = (H2SO4)

## $1N \times V$ of Burette = $N2(?) \times 10ml$

3- It is calculated ( $\Delta$ H) from the table based on the calculated normality value. If it is present enthalpy and replace it in the law of calorimeter constant

The normality of the final solution	Amount of heat released (∆H)
Eq. L <sup>-1</sup>	(Kcal)
)	0.945
1.100	0.784
0.918	0.718
0.842	0.473
0.552	0.242
0.227 0.217	0.191

But if it is otherwise, the relationship between the values of  $(\Delta H)$  and the normality in the table is drawn, and the value of  $(\Delta H)$  is determined through the drawing and is compensated in the law of the calorimeter constant to find the constant.



The calorimeter constant is calculated

 $C = kcal/ K \text{ or } c^{\circ}$ 

 $(\Delta H)$  is extracted from the table or graph, and  $(\Delta t)$  is extracted from the graph between  $(H_2O)~~and~(H_2SO_4)$ 

#### Finding the equivalent heat for a strong acid and a strong base

#### The theoretical part:

**Neutral heat:** The change in enthalpy is known when one gram equivalent of the acid is neutralized with one gram equivalent of the base in a dilute solution with the neutralization temperature of the acid.

It has been shown that the neutralization heat of any strong acid with a strong base has a constant value.

 $Hcl(aq) + NaOH (aq) \longrightarrow NaCl(aq) + H_2O \Delta H = -13.7 \text{ Kcal}$   $HNO_3 (aq) + NaOH (aq) \longrightarrow NaNO3 (aq) + H_2O \Delta H = -13.7 \text{ Kcal}$ 

(-13.7) k.cal represents the neutralization temperature of a strong acid and a strong base, and this value is constant, because it represents neutralization for all acids:

 $H++OH- \longrightarrow H_2O \Delta H=-13.7 \text{ Kcal}$ 

For this reason, every neutralization reaction involves the union of  $H^+$  and  $OH^-$  form water non-ionized ions that are relative to the strong acid.

As for the base, the value of the heat of neutralization is different, as for the weak acid with that for the strong acid, because the weak acid suffers dissociation first and then the union of the positive ion H<sup>+</sup> with negative ion OH<sup>-</sup> shown below:

 $CH_3COO^-H^+ + Na^+ + OH^- \longrightarrow CH_3COONa + H_2O$ 

In fact, the process is in two stages:

1- CH3COOH  $\longrightarrow$  CH3COO<sup>-</sup> + H+ D= $\Delta$ H2 (Dissociation stage) Heat of dissociation 2- H<sup>+</sup> +OH<sup>-</sup>  $\longrightarrow$  H2O  $\Delta$ H3= -13.7 Heat (Neutralization stag) of neutralization of the acid

By adding these two equations (dissociation phase and neutralization phase), we get  $\Delta H_1$ 

 $\Delta H_1$  nut=  $\Delta H_2$ (Diss.) +  $\Delta H_3$ (Ion.)

 $\Delta H_1$  nut= D + (-13.7)

Therefore, the heat of dissociation (ionization) of a weak acid can be calculated from knowing the heat of neutralization, meaning that:

**Heat of Neutralization = Heat of Ionization ± 13.7** 

## The method of work

- 1- We mix 3.5 ml of distilled water with 6.5 ml of concentrated nitric acid to prepare 10 ml of nitric acid solution. This is the most important step in the method of work and a graduated cylinder must be used because the acid is very strong (the prepared acid contains 50% water).
- 2- Clean the calorimeter well and put (33) ml of hydroxide solution in it sodium 1N (NaoH) and 66 ml) of distilled water H<sub>2</sub>O and mixed well by a glass stirrer and the temperature recorded every (30 sec) until stability.
- 3- To the contents of the calorimeter (3.3 ml) of the diluted nitric acid solution prepared in step (1) is added, and the temperature is recorded every (sec 30) until stability.
- 4- Add two drops of the orange example to the contents of the calorimeter and note the following:

(a) If the color of the contents of the calorimeter is yellow, this means that part of the base is not neutral with nitric acid, and in this case we take (10 ml) of the contents and titration with acid (0.1 N) Hcl until reaching the neutral point. (b) If the color of the calorimeter contents is red, this means that all With acid and we do not need stinging with (0.1 N) HCl.

The previous reaction is two reaction

The first reaction is (acid + water), so we get a heat of dilution

The second reaction is (acid + base), so we get the heat of neutralization

Therefore, the heat of dilution (the heat of the solution) must be found and subtracted from the total value in order to obtain the neutralization heat only.

Total value = heat of dilution + heat of neutralization

5- To calculate the dilution temperature, the contents of the calorimeter are poured, cleaned well, and placed in (99 ml) distilled water, and the temperature is recorded every (sec 30) until stability. Then (3.3 ml) of nitric acid prepared in step 1 is added, the contents of the calorimeter are stirred, and the temperature is recorded every (30sec) until confirmation.



## Calculations

1- In the work method, step 2 and 3, we draw a graphic relationship between time and temperature (temp)



We calculate the increase in temperature as a result of equilibrium and equal to:

 $\Delta \mathbf{t} = \Delta \mathbf{t1} - \Delta \mathbf{t2}$ 

3- In step No. (4-):



4- We calculate the equilibrium heat

$$\Delta H = \frac{C. \_ \Delta t}{v}$$

 $\Delta H = Equivalent Heat (Kcal/eq)$ 

C = calorimeter constant 0.1( Kcal/c or k)

Y = number of base equivalents (eq)

 $\Delta t$  = difference in temperature due to break-even

## Sixth experiment

## Finding the neutralization heat of a weak acid and a strong base Finding the heat of dissociation of a weak acid

#### The theoretical part:

The theoretical part of the experiment is similar to the theoretical part of the fifth experiment

#### The method of work:

- 1- Take a calorimeter with a known constant and put in it (25ml) of (1N) NaOH, then mix with (75ml) of distilled water and record the temperature every 30 sec until stability.
- 2- Open the calorimeter plug and add to the base solution above (25ml) of (1N)CH3COOH and the temperature is measured every 30 Sec until stability.

#### The calculations

1- We draw the graphic relationship between Temp (temperature in Celsius) and time (time in seconds) until we get  $\Delta t$ .



**3**- We extract the heat of dissociation and it is symbolized by (D)

$$- \Delta H = D + (-13.7)$$
  
D=(?)

Note that:

 $\Delta H$  = - 13.7 is the heat of equalization or union

D = heat of acid dissociation

 $H^{\text{+}} \textbf{+} OH^{\text{-}} \rightarrow H_2 O$ 

## **Seventh experiment**

Finding the electrode potential of magnesium by a thermodynamic method

#### The theoretical part:

The electrode potential can be extracted by the electrical method, as it is easier than any other method because it is a direct method, but in our experience this will be measured in a thermodynamic way, using values and thermodynamic laws

The interaction is:

 $Mg_{(s)} + 2H_{(aq)} \longrightarrow Mg+2(aq) + H_2(g)$ 

To fin,d the electrode potential (° E) requires finding  $\Delta G^{\circ}$ ,  $\Delta H^{\circ}$ ,  $\Delta S^{\circ}$ 

#### The method of work:

- 1- In a clean calorimeter, 100 ml of sulfuric acid is placed at a concentration of 1 N, and stirred by a glass motor, and the temperature is recorded every (30 Sec) until stability.
- 2- Weigh (25.0 gm) from the magnesium tape and add it to the acid. We notice a rise in temperature immediately after adding it. The (rise temperature) is recorded, and then the temperature is measured every (Sec 30). Until stability.

We extract the standard heat of reaction ( $\Delta H^{\circ}$ ) for each mole of magnesium, which represents the amount of heat emitted by adding the magnesium strip to the sulfuric acid.

 $\Delta \mathbf{H}^\circ = \mathbf{C}. \Delta \mathbf{t} / \mathbf{y}$ 

Whereas:

C = calorimeter constant (0.1 Kcal/c)

```
\Delta \mathbf{H}^{\circ} = standard heat of reaction (Kcal / mol)
```

 $\Delta \mathbf{t}$  = different in temperature before and after adding magnesium

Number of Mg moles (y) = the weight / the atomic weight 0.25 / 24.3

The calculated molar entropy is used at a degree (298 K°) and equal to (20.5 J / mol.K)

Whereas:

 $\Delta S^{\circ} = (S^{\circ} \text{ product} - S^{\circ} \text{ reactants})$ 

 $\Delta S^{\circ} = (S^{\circ}_{H2} + S^{\circ}_{Mg+2}) - (S^{\circ}_{Mg} + 2S^{\circ}_{H})$ 

3- Calculate the change in standard energy

 $\Delta \mathbf{G}^{\mathsf{o}} = \Delta \mathbf{H}^{\mathsf{o}} - \mathbf{T} \ \Delta \mathbf{S}^{\mathsf{o}}$ 

Where (T) is the highest temperature that the thermometer reaches when the tape is added (t  $c^{\circ}$ + 273) absolutely.

 $\Delta H^{o}$  convert from (Kcal/mol) to ( J/mol)

 $\text{Kcal} \longrightarrow \text{Cal} \longrightarrow J$ 

Unit conversion  $\Delta G^{o} = J/mol$ 

We calculate the value of the electrode potential (E) in volts.

$$\mathsf{E}^{\circ} = \frac{-\Delta \mathsf{G}}{\mathsf{n}^{\circ} \mathsf{F}}$$

Whereas  $n=2(oxidative number) Mg^{+2}$ 

F = Faraday's constant 96500 coulombs

E = electrode voltage Mg (in volts)

We draw the graphic relationship between temperature and time.

