Calculations using the mole concept

Objectives:

To introduce the concept of the mole as the unit of measurement for amounts of compounds ; atoms ; molecules and ions .

Introduction:

- -A mole of any substance : is the amount of the substance which contains a number of particles(atoms ; molecules ; etc.)equal to Carbon atoms in 12 grams of Carbon-12 . it is the relative atomic mass expressed in grams .

e.g.

One mole of Carbon-12 is 12 grams .

One mole of Sodium-23 is 23 grams .

- The number of particles in one mole of any substance is equal to *Avogadro's constant* .

A mole of any substance contains the same number of particles : ***Avogadro's constant*** (6.02×10^{23}) .

e.g.

1 mole of Carbon contains 6.02×10^{23} particles .

1 mole of Sodium contains 6.02×10^{23} particles .

- -***The Molar Mass*** of a substance : is the mass of one mole ***(M_r)*** **.** It is the relative mass in grams .

e.g.

M_r of Na =23 grams

M_r of NaOH =23+16+1=40 g .

No. of moles = mass in grams /molar mass

Example :

1-How many moles of CO_2 molecules are present in 11g of CO_2 ?

By formula :

Number of moles = no. of grams/mass of 1 mole.

=11/44

=0.25 mole.

By dimentional analysis :

1 mole ------ 44g

1 mole/44g = 44g/44g = 1

Unit factor = 1 mole/44g

11g x1 mole/44g =0.25 mole.

2-What is the mass of 2 moles of Ethanol molecules? (Ethanol:C_2H_5OH) .

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3-How many atoms are there in 5 moles of Carbon?

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Moles for Gases :

Definition : One mole of molecules of any gas Occupies : 24L at room temp. and pressure or 22.4L at S.T.P.($0^{O}C$ & 273 K) .

No. of moles (at R.T.P) =volume/24L .

No. of moles (at S.T.P) =volume/22.4L .

Molar Solutions:

Is a solution of a substance where one litre contains one mole of the substance dissolved in it .

Molarity =No. of moles x1000 Cm3/Vol. used(Cm3)
=Mass/RAM x1000 Cm3/Vol. used(Cm3)

Exercises:

Complete :

1- A mole of Oxygen atom(O) contains …….atoms.
2- A mole of Oxygen molecule (O_2) contains …….. molecules.
3- A mole of Oxygen molecule (O_2) contains …….. atoms.
4- A mole of Oxygen atom(O) weights ……. g.
5- A mole of Oxygen molecule (O_2) weights …… g.

Change to the power of ten :

1- 520000
2- 0.000874
3- $(0.01)^2$
4- 2^4

Express as numbers without power of ten :

1- 9.6×10^5
2- 6×10^{-3}
3- 22×10^4
4- 10^{-6}

Convert :

1- 5.31 moles of C to grams of C (R.A.M. = 12).
2- 5 moles of Cl^2 to grams of Cl^2 (R.A.M. = 35.453).
3- 100g. of Fe to moles of Fe(R.A.M. = 55.84).
4- 40g. of N2 to moles of N2 (R.A.M. =14).
5- 30ml Hg (d=13.6g/ml)to moles of Hg (R.A.M.= 200.59).

Determination of Emperical formula and Molecular formula of compounds

Objectives:

Determination of Emperical formula and molecular formula of compounds .

Introduction:

When we say that the formula of water is H_2O ; we mean that a molecule of water is composed of two atoms of Hydrogen and one atom of Oxygen .

Key words:

**Relative mass :It is the atomic weight expressed in grams(M_r) .

**Emperical formula :It is the simplest form which expresses the compound composition by mass ;and expresses the ratio of the numbers of different atoms present in the compound.

**Molecular formula :expresses the actual number of each kind of atom present in the compound .

The empirical formula multiplied by a whole number (n) gives the molar mass of the compound .The value of n can be calculated .

Steps for calculating an Emperical formula:

1- Write the mass or the mass % of each element .
Mass%of an element in a compound=

Mass of element in a given mass of compound x100/ Mass of compound

2- Convert these masses to moles .

3- Divide the results of division by the smallest result obtained .
4- The obtained values are the subscripts in the empirical formula .

Example 1

A compound consists of 80% carbon and 20% hydrogen by mass and its relative molecular mass is 30 .Find its empirical formula .(C=12 ;H=1) .

	C	H
s or mass%	80	20
of moles	80/12=6.67	20/1=20
ar ratio	6.67/6.67	20/6.67

3

Emperical formula is CH_3
The relative empirical formula mass =12+3=15
The relative molecular mass = 30
30/15=2
The molecular formula is$(CH_3)_2$ i.e. C_2H_6 .

Exercise :

1- 10.00 grams of a compound was found to consist of 4.34g of Na , 1.10g of C and 4.53g of O . Find its emperical formula (RAM: Na =23 , C=12 , O =16) .

2- The mass % of H and O in a certain compound are 5.9%H and 94.1%O . Calculate the molecular formula (Relative Molecular Mass RMM =34) .

3- Caffeine consists of 49.5% of C ,5.2% of H and 28.8% of N. Calculate the empirical formula (RAM of N =14).

4- Iron Sulfide contains 2.233g Iron and 1.926g of S. Calculate the empirical formula (RAM:Fe =56 ,S=32).

Formula of a hydrate

Objectives:

Determination of mass% of water in a hydrated salt and the no. of molecules of water of crystallization for establishment of mole ratio of salt : water .

Introduction :

Upon heating the hydrated salt loses its content of water e.g. $Mg\ SO4.7H_2O \rightarrow Mg\ SO4 + 7H_2O$.

In some cases heating does not result in loss of water e.g.$FeCl_3.6H_2O$.

Procedure:

- Clean and dry a porcelain crucible .
- Weigh the empty crucible and record the weight.
- Place about 2g of the hydrated salt and weigh the crucible with the sample .
- Put the crucible on a heat source and start heating slowly.
- Continue slow heating for 10-15 minutes.
- Remove from heat and cool to room temperature while covered with lid.
- Weigh your sample in the crucible and record your weight.
- Repeat heating it gently for another 5 minutes . Cool ,reweigh and record your weight until you reach constant weight.
- Find molar ratio of salt:H_2O as follows :

* Mass of crucible = --------.
* Mass of crucible + hydrated salt = …………..
* Mass of crucible + anhydrous salt =…………
* Mass of hydrated salt = …………..
* Mass of anhydrous salt =…………

- Mass of water lost = …………
- Mass % of H2O in hydrated salt =
  mass of water x 100 /mass of hydrated salt =…… .
- Moles of anhydrous salt =
  mass of anhydrous salt/RMM 0F anhydrous salt=……. .
- Moles of water =mass of water lost /RMM of water=……. .
- Molar ratio of anhydrous salt : water =……… : …… .

Estimation of heat changes during a reaction
Heat of Combustion of an alcohol

Objectives:

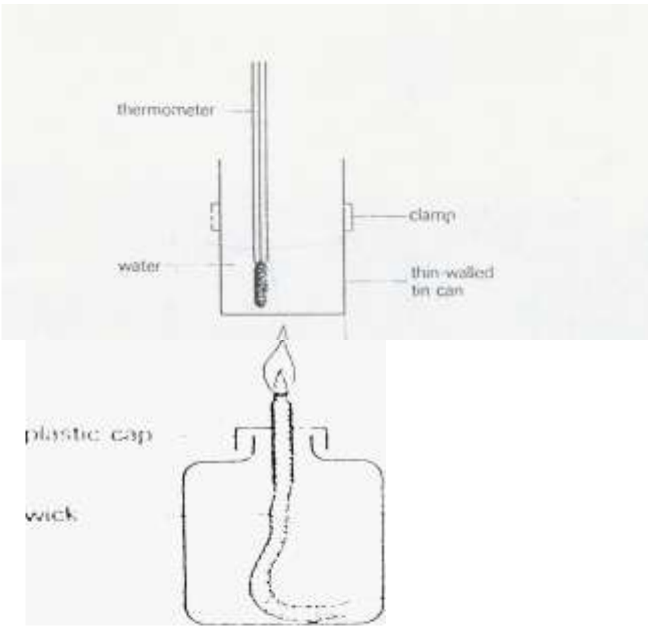
To measure heat of combustion of an alcohol and to calculate the amount of energy evolved for one mole of the alcohol .

Introduction:

The process of combustion involves the burning of a subst substance in oxygen or air. The heat of combustion of a substance is defined as the heat change, which takes place when one mole of the substance is completely burnt in oxygen .

Procedure:

• Set up your experiment as shown in the diagram.



1. Weigh a beaker and fill it with about 100 mL of water.
2. Reweigh the can filled with water.

3. Weigh the lamp filled with alcohol while covered.
4. Record the initial temperature of water.
5. Light the wick of the lamp and clamp the beaker directly above it.
6. Stir the water frequently and when the temperature has increased by approximately 25°C, put out the flame and reweigh the lamp while covered.
7. Record the final temperature.
8. Calculate the heat of combustion of the alcohol.

Calculations:

- Use the following formula and calculate the amount of energy evolved:

Energy released from alcohol = - Energy absorbed by water
= - Mass of water x specific heat capacity of water x ΔT
(Where the specific heat capacity of water = 4.2 J g $^{-1}$ $^{\circ}C^{-1}$).
Calculate for one mole of the alcohol.

Report

1. Mass of water =.. ...g
2. Mass of lamp before heating =.......................g
3. Initial temp. of water =............................ .°C.
4. Final temp. of water =.......................°C .
5. Difference in temp. = ...
6. Mass of lamp after heating = ...g.
7. No. of moles of burnt alcohol =............moles.
8. Heat of combustion of alcohol =..............J / mol.

Questions:

- Determine the possible sources of error in the experiment.

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- Recommend improvement that can be made to this experiment

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Effect of concentration on the rate of a reaction

Objectives:

To investigate the effect of concentration on the rate of a reaction.

Introduction:

In this experiment, you will be asked to investigate, how a change in the concentration of a solution of sodium thiosulphate affects its rate of reaction. The reaction studied is one between sodium thiosulphate and dilute hydrochloric acid. Sodium thiosulphate is decomposed by acid and forms a precipitate of sulphur, which makes the solution go cloudy. Soon it is impossible to see through the solution. In this experiment you will time how long it takes a letter 'X' marked on a piece of paper to be no longer visible as you look through the solution.

Procedure:

1- Label a 10-cnr measuring cylinder 'acid', and a 100-cm measuring cylinder c thiosulphate. You will also need a clock or watch, which can measure in seconds, and a small conical flask.

2- Draw a large letter 'X' on a piece of paper.

3- Measure out 5cm3 of the dilute hydrochloric acid provided as accurately as possible using the measuring cylinder labeled 'acid'. In the same way measure out 40 cm of sodium thiosulphate solution using the other labeled measuring cylinder.

4- Place the small conical flask over the 'X' and pour in the sodium thiosulphate solution. Then add the acid and start timing as the two liquids mix. Swirl the conical flask carefully to thoroughly mix the solutions and replace it as soon as possible on the paper on which the 'X7 has been marked.

5- Stop timing when the cross is no longer visible as you look down through the solution. Write down the time (in seconds) taken for 'X' to disappear. Write down the volume of sodium thiosulphate solution used. (At this point you have not added any water. The entry in your table for the volume of water used 0 cm^3).

6- Wash out the conical flask so that it is ready for the next experiment.

7- Measure out 32 cm of the sodium thiosulphate solution provided as accurately as possible using the measuring cylinder labeled 'thiosulphate', then add 8 cm3 of distilled water to make up the total volume of the mixture to 40 cm3 and pour it into the conical flask.
Measure out 5 cm3 of the dilute hydrochloric acid provided as accurately as possible using the other measuring cylinder.

8- Add the dilute hydrochloric acid to the diluted sodium thiosulphate solution and start timing. Carefully swirl the two liquids to mix them thoroughly and place the conical flask on the marked paper. Stop timing when the 'X' is no longer visible as you look down through the solution, as before. Write down the time (in seconds) taken for 'X' to disappear. Write down the volume of sodium thiosulphate used and the volume of water added.

9- Repeat the experiment three more times, using the same
volume of acid each time, but making the sodium Thiosulphate solution more dilute by using less sodium thiosulphate solution and more water each time. The mixtures you should use are given below:

Volume of $Na_2S_2O_3$	Volume of H_2	Time taken for 'x disappear	Reciprocal of t (s^{-1}) x10^3
40	0		
32	8		
24	16		
16	24		
8	32		

10- Write down the time taken for the 'x' to disappear in each case, and
the volumes of sodium thiosulphate solution and water used.

Working:

1- Work out the reciprocal of the times taken for the cross to disappear(s^{-1}) and fill in the appropriate column in your results table.

Remember the reciprocal of the time = 1 / time

This gives a measure of the rate of reaction for the experiment at each concentration

2- Plot a graph of I/ time (a measure of the rate) onthe vertical axis against volume of sodium thiosulphate on the horizontal axis.

Chemical equilibrium in a solution

Objectives:

To determine the equilibrium constant of a reaction

Introduction:

The reaction between potassium per sulphate and potassium iodide is expressed as:

$K_2S_2O_8 + 2\ KI \rightarrow 2\ K_2SO_4 + I_2$

If KI is present in large excess its concentration may be regarded as constant, and the reaction is kinetically of the first order. Reactions in which more than one molecule species are involved and still satisfy the first order are called Pseudo unimolecular.

Procedure:

1. You are provided with the following solutions:
   - 0.01 N $Na_2S_20_3.\ 5H_20$
   - 0.2 MKI
   - 0.02 M $K_2S_20_8$
   - Starch indicator
2. In a dry conical, mix 50 ml of KI and 50 ml of the persulfate and record the time.
3. After 3 min., withdraw7 10 ml of the solution mixture into a conical flask containing ice or ice-cooled water to stop the reaction.
4. Titrate quickly against 0.01 N Na2S203 solution .
5. When the iodide persulfate mixture becomes straw yellowy add few drops of starch indicator to the mixture where it will become dark blue.
6. Keep on adding the thiosulfate dropwise until the blue colour just disappears.
7. The thiosulfate volume at this point will be the endpoint and corresponds to "x" .

8. Repeat steps 3,4,5,6&7 at time intervals of 10,20,30,45,60 & 90 min. , taking each time the equivalent volume of thiosulfate.

9. The remainder of the reaction mixture should be left for at least three hours to go to completion and the thiosulfate reading will be then regarded as total = a.

10. Record your results in the table .

Time (min.)	$Na_2S_2O_3$ (x)	a-x	ln(a-x)
3			
10			
15			
25			
35			
45			
60			
90			

11. Plot ln (a -x) against time t.

12. Find your slope (specific rate constant "K") and reaction half-life time ($t_{1/2}$).