CHEMICAL CHANGE

REQUIREMENTS:

- MOLE CONCEPT
- STOICHIOMETRY
- BALANCED EQUATIONS
- CONCENTRATION OF SOLUTIONS

AN INTRODUCTION TO CHEMICAL REACTIONS

EVIDENCE FOR A CHEMICAL REACTION

The evidence for a chemical reaction occurring, is the formation of a substance which is different from the original reactant or reactant, this is often accompanied by changes in energy, which are measured as temperature changes. Thus for the reaction of the silver metal sodium with the green/yellow gas chlorine, the product is a white crystalline solid, which looks very different from either of the reactants. This process also results in a large amount of energy being given off.

WRITING CHEMICAL EQUATIONS

Chemical equations are a convenient short hand notation for describing the reaction that occurs. These are written in terms of chemical formulae. For example the formation of sodium chloride is written as:

For this equation, we define the following;

REACTANT:

PRODUCT:

COEFFICIENTS:

PHASE LABELS:

BALANCING CHEMICAL EQUATIONS

Consider the burning of methane gas:

HINT : First balance the atoms for the elements that occur in only one product or reactant first.

TYPES OF CHEMICAL REACTIONS

There are a large number of chemical reactions; we will look at some common types of reactions.

COMBUSTION REACTIONS

These reactions always have oxygen as a reactant, in this process any hydrogen in the reactant is converted to water, the carbon in the reactant is converted to carbon dioxide.

Consider the combustion of butane:

Hint: In combustion reactions, always balance the oxygen last.

ACID BASE REACTIONS

In these reactions, the H^+ ion of the acid reacts with the OH^-, hydroxide ion of the base, to form a water molecule. An example is the reaction of hydrochloric acid with sodium hydroxide:

$$HCl + NaOH \rightarrow$$

These reactions will be studied in more detail in the section on acids and bases later on in the course.

OXIDATION REDUCTION OR REDOX REACTIONS

These will be done in a later section.

PRECIPITATION REACTIONS

DISPROPORTIONATION REACTIONS

An example of a disproportionation reaction is the formation of nitrogen dioxide from dinitrogen pentoxide :

REACTIONS OF METALS WITH NON METALS

An example is the reaction of sodium metal with chlorine gas, which may be represented as :

TUTORIAL 1

1. Balance the following equations :

1.1 $Cl_2O_7 + H_2O \rightarrow HClO_4$
1.2 $Sn + NaOH \rightarrow Na_2SnO_2 + H_2$
1.3 $P_4O_{10} + H_2O \rightarrow H_3PO_4$
1.4 $Al_2S_3 + H_2O \rightarrow Al(OH)_3 + H_2S$
1.5 $C_6H_6 + O_2 \rightarrow CO_2 + H_2O$
1.6 $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + NaCl$

2. Decide on the basis of the evidence presented in each of the following whether or a not a chemical reaction has taken place :

Copper metal dissolved in nitric acid to form a green solution and a foul smelling brown gas is given off.

Charcoal is allowed to stand on a bench for two days, the colour of the charcoal remains black.

A piece of sodium metal when placed in water generated a large amount of heat, a gas was given off, and the sodium could no longer be seen.

Sodium chloride dissolves in water.

CHEMICAL COMPOSITION

MOLECULAR MASS OR FORMULA MASS

The formula mass of a substance is the sum of the atomic masses of all of the constituent atoms in a formula unit.

Sodium chloride:
Water:
Chloroform:
Iron (III) sulphate:
Glucose :
Sodium thiosulphate tetrahydrate :

THE MOLE CONCEPT

One mole is defined as the quantity of a given substance that contains as many molecules or formula units as the number of carbon atoms in exactly 12 g of carbon-12. This number is known as Avogadro's number, which has the symbol N_A, recent measures of this number give it as 6.0221367×10^{23}.

The number of moles of any substance is calculated from :

In quoting moles, we must specify the formula of the unit to which we are referring : The in 16 g of oxygen, we distinguish between the number of moles of oxygen atoms, and the number of moles of oxygen molecules :

EXAMPLE:

Calculate the number of moles of each formula unit, and each atom in each of the following:

(a) 10 g of nitrogen gas
(b) 10 g of dinitrogen tetroxide
(c) 10 g of sodium carbonate decahydrate

CALCULATION OF NUMBER OF MOLECULES, OR FORMULA UNITS AND NUMBER OF ATOMS

For each of the examples in (a) to (c) above, calculate the number of formula units, and the number of atoms of each element.

CONVERTING MOLES OF SUBSTANCE TO MASS

A chemist calculates that in a certain reaction, she has prepared 0.011 moles of zinc iodide, what is the mass of product produced?

APPLICATION OF THE MOLE CONCEPT TO CHEMICAL REACTIONS

Lead (II) chromate is a yellow pigment used in the paint industry. It is easily prepared from the reaction of potassium chromate with lead (II) nitrate. If 30 g of lead nitrate are treated with sufficient potassium chromate, what mass of the product lead (II) chromate will be formed? What mass of potassium chromate is required?

77 g of octane liquid are combusted using an excess of oxygen. Calculate the masses of the products formed.

CALCULATIONS INVOLVING LIMITING REACTANTS

10 g of sodium hydroxide is treated with 10 g of hydrochloric acid. Calculate the mass of sodium chloride formed. Calculate the mass of the reactant present in excess.

10 g of nitrogen gas is treated with 20 g of hydrogen gas. Calculate the mass of the product ammonia which is formed. Calculate the mass of the reactant which is present in excess. Assume that the reaction goes to completion.

22 g of nitric oxide is reacted with 22 g of oxygen gas. Calculate the mass of product formed if the reaction only occurs to 50% completion.

CALCULATION OF PERCENTAGE COMPOSITION FROM THE FORMULA

Formaldehyde is a toxic gas that dissolves in water to form a solution known as formalin. This is used in the plastics industry, and to preserve biological specimens. Calculate the mass percentages of all of the elements in formaldehyde.
Calculate the mass percentages of all of the elements in ammonium nitrate, which is used as a fertiliser.

Calculate the mass of carbon present in 10 g of urea.

DETERMINATION OF THE EMPIRICAL FORMULA USING ELEMENTAL ANALYSIS

The empirical formula for any substance is the simplest possible ratio of its elements. Thus for glucose, the molecular formula is $C_6H_{12}O_6$, the empirical formula is CH_2O. Elemental analysis is widely used to identify new substances.
EXAMPLE :

Acetic acid is known to contain the elements carbon, hydrogen and oxygen only. A 4.24 g sample of acetic acid is combusted to form 6.21 g of carbon dioxide, and 2.54 g of water.

Calculate the percentage composition of acetic acid, and use this to determine the empirical formula.

EXAMPLE :

An 83.5 g sample of a substance containing the elements S and O only, was found to contain 33.4 g of sulfur. Determine the percentage composition, and thus the molecular formula.

TUTORIAL 2

1. Calculate the formula mass of each of the following :

1.1 Sodium sulfate
1.2 Ammonium dichromate
1.3 Diphosphorus pentoxide
1.4 Acetylene, C_2H_2.
1.5 Oxalic acid $(COOH)_2.2H_2O$
1.6 Potassium permanganate
1.7 Calcium phosphate
1.8 Nitrogen gas

2. Calculate the number of moles, molecules and number of atoms of each element in 10 g of oxalic acid.

3. Calculate the number of moles of the salt in 20 g of sodium sulfate, and the number of moles of sodium ions in this sample.

4. How many moles of water are present in 77 g of oxalic acid?

5. What mass of water is present in 200 g of oxalic acid?

6. What mass of carbon is present in 150 g of butane gas, C_4H_{10}?

7. Two samples of different compounds of sulfur and oxygen have the following compositions :

	Amount of S	**Amount of O**
Compound A	1.210 g	1.811 g
Compound B	1.7383 g	1.779 g

Determine the empirical formula for compounds A and B. Are they the same or not?

8. Two samples of different compounds of phosphorus and chlorine have the following compositions :

	Amount of P	**Amount of Cl**
Compound A	1.156 g	3.971 g
Compound B	1.542 g	5.297 g

Determine the empirical formula for compounds A and B. Are they the same or not?

9. 77 g of butane is combusted with sufficient oxygen. Calculate :

9.1 The mass of oxygen require for the combustion process.
9.2 The mass of carbon dioxide produced.
9.3 The mass of water produced.

9 180 g of chlorine gas is placed in a reactor together with sufficient sodium metal. What mass of sodium chloride is formed?

11. Calculate the mass of each of the following :

11.1 0.3 moles of sodium chloride.
11.2 0.3 moles of sodium sulphate.
11.3 0.3 moles of sodium hydroxide.
11.4 0.3 moles of sodium metal.
11.5 0.3 moles of sodium thiosulphate (look up the formula!)

12. Calculate the number of moles of glucose in each of the following :

12.1 7 g of pure glucose
12.2 110 g of a powder containing 80 % glucose.
12.3 A mixture of 23 g of glucose and 99 g of sodium chloride.
12.4 A mixture containing 9 g of glucose mixed with 90 g of rat poison.
12.5 A mixture of 5 g of glucose and 30 cm^3 of water.

13. 44 g of zinc metal are treated with12 g of chlorine gas. Determine:
The limiting reactant
The reactant present in excess
The mass of product formed
The mass of reactant remaining

14. 180 g of pentane, C_5H_{12}, undergoes combustion using 480 g of oxygen. Calculate :

14.1 The limiting reactant
14.2 The reactant present in excess
14.3 The mass of product formed
14.4 The mass of reactant remaining

15. 22 g of nitrogen gas and 100 g of hydrogen gas are reacted together in the presence of a catalyst to form ammonia. The reaction proceeds to 75 % completion. Calculate:

15.1 The limiting reactant
15.2 The reactant present in excess
15.3 The mass of product formed

15.4 The mass of reactants remaining

16. 56 g of sulfur and 990 g of oxygen gas are reacted together in the presence of a catalyst to form sulfur dioxide. The reaction proceeds to 80 % completion. Calculate:

16.1 The limiting reactant
16.2 The reactant present in excess
16.3 The mass of product formed
16.4 The mass of reactants remaining

SOLUTIONS

A solution is a homogeneous mixture. The component present in larger amount is known as the solvent, and the component present in smaller amount is known as the solute.

TYPES OF SOLUTIONS

There are many different types of solutions :

GAS IN GAS

GAS IN LIQUID

LIQUID IN LIQUID

SOLID IN LIQUID

SOLID IN SOLID

PERCENTAGE CONCENTRATION OF SOLUTIONS

MASS PERCENTAGE OF SOLUTE (% m/m)

This is defined as the mass of solute present in 100 g of solution.

This can be calculated from:

EXAMPLE :

12 g of potassium chloride is mixed with 125 g of water to give a solution. Calculate the concentration of the solution as mass percentage solute.

EXAMPLE :

How should you prepare 425 g of an aqueous solution of sodium acetate, containing 2.4 % by mass sodium acetate?

EXAMPLE :

Calculate the concentration of a solution prepared by dissolving 9 g of potassium dichromate in sufficient water to give a total volume of 350 cm^3.

EXAMPLE :

How should you prepare 2 l of a 10% m/v solution of glucose?

MOLARITY

This is the concentration term most commonly used in chemistry. The molarity of a solution is defined as the number of moles of solute in 1 dm^3 of solution.

Molarity is calculated from:

Hints for doing molarity calculations:

1. First write down the formula, and the formula mass of the solute
2. Write down the mass of the solute in g
3. Calculate the number of moles of solute
4. Write down the volume of the solution in dm^3.
5. Do the calculation!

EXAMPLE :

Calculate the molarity of the following solutions :

1. 16g of sodium chloride in a total volume of 150 cm^3.

2. 42.2 g of potassium permanganate in a total volume of 5 l.

3. 77 g of oxalic acid in a total volume of 1.2 l.

CALCULATION OF THE MASS OF SOLUTE IN A SOLUTION OF KNOWN MOLARITY

EXAMPLE:

Calculate the mass of sodium chloride present in 70 cm^3 of a 0.1 mol dm^{-3} solution.

Hints for doing these calculations;

1. First write down the volume of the solution in dm^3.
2. Write down the molarity of the solution
3. Calculate the number of moles of solute
4. Write down the formula of the solute, and thus the formula mass
5. Viola - do the calculation.

MOLARITY CALCULATIONS FOR CHEMICAL REACTIONS

EXAMPLE :

70 cm^3 of a 0.05 mol dm^{-3} potassium chromate solution is mixed with 20 cm^3 of 0.07 mol dm^{-3} lead nitrate. What mass of product is formed?

DILUTION OF SOLUTIONS

EXAMPLE :

20 cm^3 of a 0.012 mol dm^{-3} hydrochloric acid solution is mixed with sufficient water to give a total volume of 250 cm^3. Calculate the molarity of the final solution.

MIXING OF SOLUTIONS OF DIFFERENT CONCENTRATIONS

EXAMPLE ;

What volumes of 0.1 mol dm^{-3} hydrochloric acid solution and 1.0 mol dm^{-3} hydrochloric acid solution should be mixed in order to prepare 500 cm^3 of a 0.4 mol dm^{-3} solution?

TUTORIAL: 3

1. Calculate the concentration of each of the following solutions

1.1 77 g of sodium chloride in a total volume of 750 cm^3.
1.2 19 g of zinc sulfate in a total volume of 250 cm^3.
1.3 45 g of potassium iodide in a total volume of 1.25 dm^3.

2. How should you prepare the following solutions?

2 dm^3 of 0.1 mol dm^{-3} oxalic acid solution.

3. What volume of 0.1 mol dm^{-3} sodium hydroxide solution contains 77 g of sodium hydroxide?

4. What mass of sodium carbonate is present in 25 cm^3 of 0.05 mol dm^{-3} solution? What mass of sodium is present? What is the mass of carbonate in this sample?

5. Calculate the mass of solute in 200 cm^3 of a 0.1 mol dm^{-3} zinc chloride solution.
6. How would you mix 0.3 mol dm^{-3} sulfuric acid and 2.0 mol dm^{-3} sulfuric acid in order to obtain 10 dm^3 of a 0.5 mol dm^{-3} solution?
7. 75 cm^3 of hydrochloric acid solution is mixed with 25 cm^3 of sodium chloride solution. Assume for this problem that the volumes are additive.

Calculate:

10.1 The concentration of hydrochloric acid in the final solution
10.2 The concentration of sodium chloride in the final solution
10.3 The concentration of chloride ions in the final solution

CHEMICAL EQUILIBRIUM

INTRODUCTION

Chemical equilibrium is defined as the state in which the concentrations of the reactants and products do not change with time, unless an external force is brought to bear upon the system at equilibrium. We distinguish between physical equilibrium, and chemical equilibrium :

Physical equilibrium : water(l) ↔ water (vapour)

Chemical equilibrium : $N_2O_4(g) \leftrightarrow 2\ NO_2(g)$

Most chemical reactions are reversible. This means that the reactants react together to form products in a reaction known as the forward reaction, and the products react together to form reactants in a reaction known as the reverse reaction. These reactions occur simultaneously.

Consider a system in which reactants A and B are placed into a closed container, and allowed to react. The forward reaction occurs, in which A and B react together to form the products C and D according:

$$A + B \leftrightarrow C + D$$

Once the concentration of the products C and D reaches a certain value, C and D react together to form A and B .

After a period of time, the rate at which the forward reaction proceeds is equal to the rate of the reverse reaction. This state is known as equilibrium. This process may be represented graphically as:

Note that once equilibrium has been reached, the concentrations of the reactants and products are constant with time.

EQUILIBRIA IN THE GASEOUS STATE

THE EQUILIBRIUM CONSTANT – CONCENTRATION UNITS

The equilibrium constant when expressed in concentration units is written as K_c. All concentrations are given in units of mol dm^{-3}.

EXAMPLE :

Consider the N_2O_4 / NO_2 system at 25°C.

INITIAL CONCENTRATIONS / mol dm^{-3}		EQUILIBRIUM CONCENTRATIONS / mol dm^{-3}		RATIO OF CONCENTRATIONS AT EQUILIBRIUM
$[NO_2]$	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]/[N_2O_4]$ $[NO_2]^2/[N_2O_4]$
0.000	0.670	0.0547	0.643	
0.0500	0.446	0.0457	0.448	
0.0300	0.500	0.0475	0.491	
0.0400	0.600	0.0523	0.594	
0.200	0.000	0.0204	0.0898	

(In this example, show that the ratio $[NO_2]/[N_2O_4]$ is not constant, whereas the ratio $[NO_2]^2/[N_2O_4]$ is constant at constant temperature, regardless of the initial concentrations)

The equilibrium constant when expressed in concentration units is written as K_c. All concentrations are given in units of mol dm^{-3}.

EXAMPLE:

An 8.00 dm^3 vessel at 491^oC contains 0.650 mol H_2, 0.254 mol I_2, and 3.00 mol HI. Assume that the system is at equilibrium. Use these data to calculate the equilibrium constant for the reaction: $H_2(g) + I_2(g) \leftrightarrow 2 HI(g)$.

EXAMPLE:

Carbon monoxide and hydrogen react according to:

$$CO(g) + 3 H_2(g) \leftrightarrow CH_4(g) + H_2O(g)$$

1 mol of CO and 3.0 mol of H_2 are placed in a 10.0 dm^3 container and heated to 927^oC. Once equilibrium has been established, the product mixture was found to contain 0.387 mol of water. Determine the composition if the equilibrium mixture, and calculate the equilibrium constant for the reaction.

THE EQUILIBRIUM CONSTANT FOR THE SUM OF REACTIONS

Consider the following reactions at 1200 K:

$CO(g) + 3 H_2(g) \leftrightarrow CH_4(g) + H_2O(g)$ – Reaction 1 ; $K_1 = 3.92$

$CH_4(g) + 2 H_2S(g) \leftrightarrow CS_2(g) + 4 H_2(g)$ – Reaction 2 ; $K_2 = 3.3x10^4$

The sum of the two reactions is given by:

The overall equilibrium constant is given by :

CHANGING THE CONDITIONS OF A REACTION – LE CHATELIERS PRINCIPLE

Consider the following equilibrium at 300°C:

$PCl_3(g) + Cl_2(g) \leftrightarrow PCl_5(g)$, $K_c = 4.1$ at 300°C.

A sample of 35.8 g of PCl_5 is placed in a 5.0 dm^3 reaction vessel and allowed to come to equilibrium. Calculate:

a) The equilibrium concentration of all of the species in the container.
b) The fraction of PCl_5 which has decomposed.
c) 2.2 mol of chlorine gas is added to the reaction mixture; calculate the concentrations of all species in the reaction vessel once equilibrium has been established.

TUTORIAL 4 EQUILIBRIA IN THE GASEOUS PHASE

1. Which of the following reactions involve homogeneous equilibria, and which involve heterogeneous equilibria :

(a) $2\ NO(g) + O_2(g) \leftrightarrow 2\ NO_2(g)$
(b) $2\ Cu(NO_3)_2(s) \leftrightarrow 2\ CuO(s) + 4\ NO_2(g) + O_2(g)$
(c) $2\ N_2O(g) \leftrightarrow 2\ N_2(g) + O_2(g)$
(d) $2\ NH_3(g) + 3\ CuO(s) \leftrightarrow 3\ H_2O(g) + N_2(g) + 3\ Cu(s)$

2. What would be the effect of an increase in pressure on each of the following reactions:

(i) $CH_4(g) + 2\ S_2(g) \leftrightarrow CS_2(g) + 2\ H_2S(g)$
(ii) $H_2(g) + Br_2(g) \leftrightarrow 2\ HBr\ (g)$
(iii) $CO_2(g) + C(s) \leftrightarrow 2\ CO(g)$
(iv)

3. At a temperature of 107°C, the reaction : $CO(g) + 2H_2(g) \leftrightarrow CH_3OH(g)$, reaches equilibrium at a pressure of 1.59×10^6 Pa. The vessel is known to contain 0.122 mol of carbon dioxide and 0.298 mol of hydrogen present at equilibrium in a volume of 1.04 dm^3.

3.1 Calculate the total number of moles of gas in the container.
3.2 Calculate the number of moles of methanol in the container.
3.3 Calculate K_c

4. Phosphorus pentachloride dissociates at high temperatures to give phosphorus trichloride and chlorine. 83.4 g of phosphorus pentachloride are

placed in a volume of 9.23 dm^3, at equilibrium, 11.1 g of chlorine are produced.
5.1 Calculate the concentration of each of the components at equilibrium.
5.2 Calculate K_c.
5.3 If the total pressure in the container at equilibrium is 250 kPa, calculate the temperature at which the reaction was carried out.

5.1.00 mol of dinitrogen tetroxide were placed in a 10.0 dm^3 vessel at a temperature of 70°C. At equilibrium, 50% of the reactant had dissociated.
6.1 Calculate K_c

ACIDS, BASES AND SALTS

Acids, bases and salts are known as electrolytes, as their solutions conduct electricity. They ionise jn solution to form cations and anions.

The simplest theory of acids and bases was developed by Arrhenius :

THE ARRHENIUS THEORY OF ACIDS AND BASES

According to this theory, acids ionise in aqueous solution to produce H^+ ions.

This theory works well for many substances that display acidic behaviour. These include acids such as hydrochloric acid, sulfuric acid and acetic acid.

It does not work for substances such as $AlCl_3$ which display acidic behaviour in solution.

According to this theory, bases ionise in aqueous solution to produce OH^- ions.

This theory works well for many substances that display basic behaviour. These include bases such as sodium hydroxide and calcium hydroxide.

It does not work for substances such as NH_3 which display basic behaviour in solution.

THE LEWIS THEORY OF ACIDS AND BASES

The Arrhenius theory of acids does not explain the behaviour of all acidic substances, we therefore use a theory which is broader. In this theory the acid is seen as any species which can accept an electron pair in an acid base reaction. Consider the reaction of boron triflouride with ammonia:

This theory explains the behaviour of bases such as ammonia.

THE SELF IONISATION OF WATER

Although pure water is considered to be a non electrolyte, precise measurements show a small amount of conductivity, resulting from the self-ionisation, or autionisation of water. This is a reaction in which two like molecules react together to form ions in solution.

The self ionization of water is given by:

The dissocation constant may be written as:

This dissociation constant is known as K_w, and has a value of 1.0×10^{-14} at 25^oC. This ionization constant varies with temperature, for example at body temperature, 37^oC; it has a value of 2.5×10^{-14}.

STRONG ACIDS AND STRONG BASES

Strong acids are defined as acids which dissociate completely in solution.

EXAMPLE : (Provide example)

Strong bases are defined as bases which dissociate completely in solution.

EXAMPLE : (Provide example)

WEAK ACIDS

Weak acids are defined as acids which do not dissociate completely in solution. Examples of weak acids include: hydrofluoric acid, hydrogen sulfide, phosphoric acid, boric acid, sulfurous acid and organic acids such as acetic acid, benzoic acid and lactic acid.

Consider a weak acid HA :

The equilibrium constant is called the acid dissociation constant K_a.

DISSOCIATION CONSTANTS FOR SELECTED WEAK ACIDS

WEAK ACID	FORMULA	K_a
Acetic acid		1.7×10^{-5}
Benzoic acid		6.3×10^{-5}
Boric acid		5.9×10^{-10}
Hydrocyanic acid		4.9×10^{-10}
Hydrofluoric acid		6.8×10^{-4}
Hydrogen sulfide		8.9×10^{-8} 1.2×10^{-13}
Phosphoric acid		6.9×10^{-3} 6.2×10^{-8} 4.8×10^{-13}

CALCULATING CONCENTRATIONS OF SPECIES IN WEAK ACID SOLUTIONS USING K_a VALUES – APPROXIMATION METHOD

Consider a 0.1 mol dm^{-3} solution of the weak acid acetic acid. Calculate the concentration of the following species in solution:

H^+
CH_3COO^-
CH_3COOH

Calculate the pH of the solution.

STRONG BASES AND WEAK BASES

Strong bases are bases that dissociate completely in aqueous solution.

Examples include NaOH, KOH, $Mg(OH)_2$

Weak bases are defined as bases which do not dissociate completely in solution. Instead they dissociate to a small extent as governed by the equilibrium constant for the process, known as the base dissociation constant, K_b. This constant is constant for a given base at 25°C.

EXAMPLE: (Provide solutions)

Consider the dissociation of the weak base ammonia.

The equilibrium constant for the process is written as :

The equilibrium constant is known as the base dissociation constant, K_b.

DISSOCIATION CONSTANTS FOR SELECTED WEAK BASES

WEAK BASE	FORMULA	K_b
Ammonia		$1.8x10^{-5}$
Aniline		$4.2x10^{-10}$
Dimethylamine		$5.1x10^{-4}$
Ethylamine		$4.7x10^{-4}$
Pyridine		$1.4x10^{-9}$

CALCULATING CONCENTRATIONS OF SPECIES IN WEAK BASE SOLUTIONS USING K_b VALUES – APPROXIMATION METHOD

Consider a 0.1 mol dm^{-3} solution of the weak base ammonia. Calculate the concentration of the following species in solution:

OH^-
H^+
NH_4^+
NH_3

Calculate the pH of the solution.

SALTS OF STRONG ACIDS AND STRONG BASES

Sodium chloride is the salt of a strong acid, hydrochloric acid, and a strong base sodium hydroxide. The pH of these solutions is 7.00, regardless of the concentration of the solution. The ionisation of the salt in solution is given by :

SALTS OF WEAK ACIDS AND STRONG BASES

Consider the salt sodium acetate; this is the salt of a weak acid, acetic acid, and a strong base, sodium hydroxide. The salt ionises completely in solution to give:

The acetate anion undergoes further dissociation according to: **Provide example**

We write the equilibrium constant for the process as:

The pH of the solution is calculated from:

EXAMPLE: Calculate the pH of a 0.1 mol dm^{-3} sodium acetate solution.

SALTS OF WEAK BASES AND STRONG ACIDS

Consider the salt ammonium chloride, it is prepared from the weak base ammonia and the strong acid, hydrochloric acid. Solutions of these salts are acidic, less than 7. The ionisation of the salt is given by:

The ammonium cation undergoes further dissociation according to**: Provide example**

We write the equilibrium constant for the process as:

The pH of the solution is calculated from:

EXAMPLE: Calculate the pH of a 0.1 mol dm^{-3} ammonium chloride solution.

ACID BASE REACTIONS – NEUTRALISATION REACTIONS

The simple acid base reactions which occur in aqueous solution involve the reaction between the H^+ ion donated from the acid with the OH^- ion donated by the base. This is known as a neutralisation reaction.

EXAMPLE: (Provide solutions)

Consider the reaction of sulfuric acid with sodium hydroxide;

Consider the reaction of hydrochloric acid with sodium tetraborate ;

Consider the reaction of ammonia with hydrochloric acid :

Consider the reaction of sulfuric acid with sodium carbonate :

TUTORIAL 5 ACID BASES AND SALTS

1. Calculate the pH of the following solutions :

   1.1 0.05 mol dm^{-3} hydrochloric acid solution
   1.2 0.05 mol dm^{-3} ammonia solution
   1.3 0.05 mol dm^{-3} sodium acetate solution
   1.4 0.05 mol dm^{-3} sulfuric acid solution
   1.5 0.05 mol dm^{-3} methylamine solution
   1.6 0.05 mol dm^{-3} ammonium chloride solution
   1.7 0.05 mol dm^{-3} sodium hydroxide solution
   1.8 0.05 mol dm^{-3} potassium chloride solution
   1.9 0.05 mol dm^{-3} propanoic acid solution

1.10 0.05 mol dm^{-3} nitric acid solution

1. Calculate the pH of the resulting solution when each of the following mixtures are prepared :

2.1 100 cm^3 of 0.05 mol dm^{-3} hydrochloric acid solution is mixed with 100 cm^3 of 0.05 mol dm^{-3} sodium hydroxide solution.

2.2 100 cm^3 of 0.05 mol dm^{-3} hydrochloric acid solution is mixed with 50 cm^3 of 0.05 mol dm^{-3} sodium hydroxide solution.

2.3 100 cm^3 of 0.05 mol dm^{-3} hydrochloric acid solution is mixed with 100 cm^3 of water.

2.4 100 cm^3 of 0.05 mol dm^{-3} acetic acid solution is mixed with 100 cm^3 of 0.05 mol dm^{-3} sodium hydroxide solution.

2.5 100 cm^3 of 0.05 mol dm^{-3} hydrochloric acid solution is mixed with 100 cm^3 of water.

2.6 100 cm^3 of 0.05 mol dm^{-3} ammonia solution is mixed with 100 cm^3 of 0.05 mol dm^{-3} hydrochloric acid solution.

2.7 100 cm^3 of 0.05 mol dm^{-3} sodium hydroxide solution is mixed with 600 cm^3 of water.

2.8 100 cm^3 of 0.05 mol dm^{-3} ammonia solution is mixed with 400 cm^3 of 0.05 mol dm^{-3} hydrochloric acid solution.

2.9 100 cm^3 of 0.05 mol dm^{-3} ammonia solution is mixed with 100 cm^3 of 0.05 mol dm^{-3} sodium hydroxide solution.

2.10 100 cm^3 of 0.05 mol dm^{-3} sulfuric acid solution is mixed with 400 cm^3 of water.

SOLUBILITY EQUILIBRIA

THE SOLUBILITY PRODUCT

When an ionic compound is dissolved in water, it goes into solution in the form of ions. When an excess of a slightly soluble ionic compound is mixed with water, equilibrium occurs between the solid material, and the ions in the saturated solution.

(Provide Solutions)

Consider the salt silver chloride:

The equilibrium constant is written as:

The equilibrium constant is known as the solubility product of the salt, K_{sp}.

EXAMPLES:

Write the solubility product expressions for the following salts ;

a) silver chromate
b) mercury(I)chloride
c) calcium phosphate

SOLUBILITY PRODUCT CONSTANTS FOR SELECTED SALTS AT 25^oC.

SALT	FORMULA	K_{sp}
Barium chromate		$1.2x10^{-10}$
Calcium carbonate		$3.8x10^{-9}$
Calcium phosphate		$1.0x10^{-26}$
Iron(III)hydroxide		$2.5x10^{-39}$
Lead(II)sulfide		$2.5x10^{-27}$
Magnesium oxalate		$8.5x10^{-5}$
Silver chloride		$1.8x10^{-10}$
Silver bromide		$5.0x10^{-13}$
Silver iodide		$8.3x10^{-17}$
Silver chromate		$1.1x10^{-12}$

EXAMPLES :

Calculate the concentrations of all the ions present in a saturated solution of the salts in the table above.

SOLUBILITY AND THE COMMON ION EFFECT

Consider 1 dm^3 of a saturated solution of calcium oxalate, in equilibrium with the solid.
Consider the addition calcium oxalate solid to 1 dm^3 of a 0.01 mol dm^{-3} calcium chloride solution:

EXAMPLE :

Calculate the solubility of lead (II) iodide in each of the following:

a) Water
b) 0.01 mol dm^{-3} sodium iodide solution
c) 0.01 mol dm^{-3} lead(II)nitrate solution

THE EFFECT OF pH ON SOLUBILTY

Calculate the solubility of magnesium hydroxide in each of the following :

a) water
b) a 0.01 mol dm^{-3} sodium hydroxide solution
c) a 0.01 mol dm^{-3} hydrochloric acid solution

Electrochemistry Quiz

1. Find oxidation number of the underlined element in each of the following formulae.

$\underline{S_8}$, $\underline{S}O_2$; $H_2\underline{S}O_4$, $\underline{P}_4O_{10}$; $\underline{P}Cl_5$; $K\underline{Mn}O_4$

2. Which of the following reactions are oxidation-reduction reactions (redox reactions)?

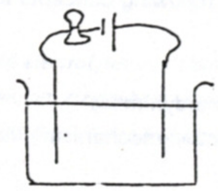
$HOCl + H_2S \rightarrow H_3O^+ + Cl^- + S$

$CO_3^{2-} + NH_4^+ \rightarrow HCO_3^- + NH_3$

$Na_2SO_4(aq) + BaCl_2(aq) \rightarrow NaCl\ (aq) + BaSO_4(s)$

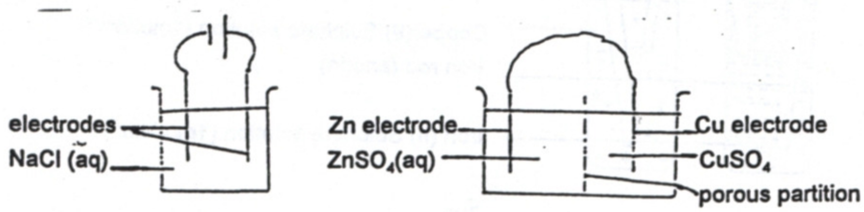
3. In the circuit represented below, the bulb glows brightly, then from the list below, select what could be in the beaker.

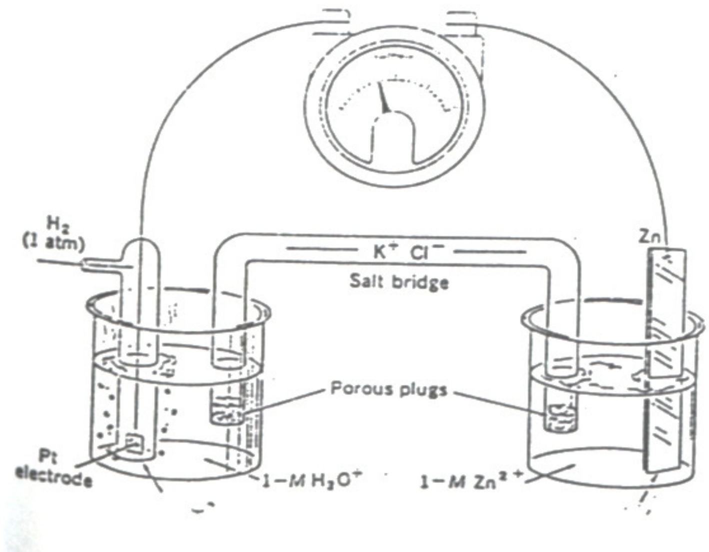
(a) potassium sulfate dissolved in water
(b) sugar dissolved in pure water
(c) molten sugar
(d) dilute sulfuric acid
(e) molten potassium bromide



4. The mechanism of electrical conduction in metals is:
   a) the same as in solid electrolytes
   b) the same as in molten electrolytes
   c) dependent on the movement of ions
   d) dependent on the movement of valence electrons
   e) dependent on the movement of atoms

5. Which cell (left or right) shown below is an electrochemical cell or a galvani
c cell?





2.1 Label the anode
2.2 Label the cathode
2.3 Show the direction of electron flow
2.4 Write the half-reaction occurring at the anode
2.5 Write the half-reaction occurring at the cathode
2.6 What would be the reading on the volumeter?
2.7 What is the function of the salt bridge?

6. Look at the diagram below and answer the questions

Equilibrium Quiz

1. Do you think that both the forward and the backward reaction actually take place if a system is at equilibrium?

2. Suppose that both reactions do indeed take place. What can you then say about their respective rates?

<u>Say if the following statements are true or false. If false, write the correct statement</u>

3. A reaction reaches equilibrium when the concentrations of the products and reactants are equal.

4. If sulfur dioxide reacts with oxygen in an open container, equilibrium is reached after a while.

<u>Answer by writing down the correct option</u>

5. The following reaction is in equilibrium in a closed container:

$PC\ell_5(g) \rightleftharpoons PC\ell_3(g) + C\ell_2(g)\ \Delta H < 0$

Which ONE of the following statements regarding the equilibrium is TRUE?

A. Addition of a catalyst favours the forward reaction.
B. Increasing the temperature has no effect on the yield of products.
C. An increase in the concentration of $PC\ell_5(g)$ causes an increase in the concentration of the products.
D. Increasing the temperature causes the value of the equilibrium constant to increase.

6. Look at the equilibrium reaction set up by the following equation.

$$\underset{\text{(colourless)}}{N_2O_4\,(g)} \rightleftharpoons \underset{\text{(brown)}}{2NO_2\,(g)}$$

Which of the following criteria would help you to find out **directly** by **experiment** that the reaction has reached equilibrium? More than one answer may be correct.

A. The colour does not change.
B. The reaction in both directions is equal.
C. The equilibrium that is established is dynamic.
D. All microscopic changes are constant at equilibrium
E. The pressure exerted by the reaction mixture is constant.

7. Choose from the following responses the one that best explains the reason why catalysts are so extensively used in industrial chemical processes involving equilibrium reactions.

F. Catalysts have no effect on the reverse rate.
G. Catalysts decrease the reverse rate
H. Catalysts cause the formation of a higher percentage of product in the equilibrium mixture.
I. Catalysts can be used to drive the equilibrium in the desired direction.
J. The catalyst speeds up the time to reach equilibrium.

8. For the equilibrium

$$2SO_2\,(g) + O_2\,(g) \rightleftharpoons 2SO_3\,(g) \qquad \Delta H°_{rxn} = -198 \text{ kJ}$$

What will be the effect on the **equilibrium constant**, K_c, of each of the following changes?

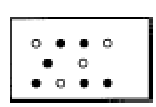
A. Doubling the volume of the reaction vessel.
B. Increasing the temperature at constant volume
C. Adding more O_2 to the reaction vessel
D. adding He *(g)* to the reaction vessel at constant volume

9. In which direction will the following equilibrium shift in response to each of the following changes in conditions:

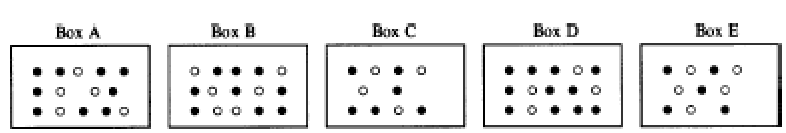
$$C\,(s) + 2H_2\,(g) \rightleftharpoons CH_4\,(g) \qquad \Delta H°_{rxn} = -75 \text{ kJ}$$

A. increasing the temperature
B. increasing the concentration of hydrogen
C. increasing the volume of the reaction vessel
D. adding more carbon

10. The **exothermic** reaction ○(g) ⇌ ●(g) was allowed to come to equilibrium, as represented in the box below:



equilibrium system



a. Some ● was added to the system at equilibrium. Which box (A–E) best represents the new position of equilibrium

b. The temperature of the system at equilibrium was increased. Which box (A–E) best represents the new position of equilibrium?

c. The pressure of the system at equilibrium was increased. Which box (A–E) best represents the new position of equilibrium?

PRACTICAL WORK

SCHOOL PHYSICAL SCIENCE LABORATORY SAFETY GUIDELINES

Introduction

These guidelines have been developed to assist schools to improve safety measures in laboratories and improve safety of learners. The guidelines have been developed taking into account some of the basic requirements and best practice in laboratory work.

1. Design of a laboratory

Constructions, extensions, renovations and/or refurbishment of laboratory buildings, must comply with standards for such structures as set out by the South African Bureau of Standards. These include at a minimum the following:

- Proper plans for such buildings;
- Materials used in such buildings especially for shelving and workstations.

2. Use of gas in laboratories

a) Installation

Make sure that the installation of gas from the cylinders to the laboratories is done by a person qualified to do so. Use of small gas canisters must be closely supervised by the teacher.

b) Storage

Gas cylinders/canisters to be stored under safe conditions where they are not vulnerable to hazards caused by impact, fire hazards or damage by the elements;

c) Handling and Use

All personnel using the gas cylinders/canisters need to be trained in the proper way of handling and using these cylinders;

d) Examination and Maintenance

Cylinders/gas canisters must be examined and tested by the appropriate inspection body, in accordance with relevant regulations and at intervals specified by the inspection body;

e) Filling of gas

The gas cylinders/canisters should only be filled by an approved agency. The cylinders must only be filled with the contents they were intended for.

3. Rules of the laboratory

- Every laboratory must have a code of conduct for learners on how to deal with prevention of injury as well as what to do in case of accidents.
- All learners entering a laboratory must be familiar with rules of the laboratory.
- The rules of the laboratory must be displayed in venues where experiments take place, or each learner handed a copy.
- All laboratories must have safety cards (see Annexure A) on all chemicals in the laboratory. These can be found on the Internet and other resources or chemical companies. These can be kept in a file or laminated and filed in the laboratory.

4. Responsibilities of Head of school, Head of Department and Educator

- The Head of the school, the Head of Department for Physical Sciences and the educator must ensure that there are safety cards for every chemical in the laboratory. These can be kept in a file or laminated and kept as cards in a safe place in the laboratory. A CD containing safety cards on common chemicals used at schools has been given to provinces. These CDs should be made available to all schools.
- Learners must be made aware of the dangers associated with every chemical that they use. Safety audits advising students on precautions and on what to do in case of accidents must be discussed before the experiment is carried out.
- Necessary precautions must at all times be taken during experiments.
- Educators performing experiments must ensure that they makes available to students information on the dangers of chemicals used, precautionary measures and safety measures in case of an accident.
- Cleaners and general workers in venues where experiments are taking place need to be made aware of the dangers associated with chemicals as well as equipment and taught how to deal with emergencies.

5. Learners' responsibilities

- Learners must undertake to observe the rules of the laboratory. Undertaking by learners who enter the laboratory must be done at the beginning of the phase when they choose to study Physical Sciences.
- Learners must know the dangers associated with the chemicals that they are using.

6. Parents' responsibility

- Parents must ensure that their children who are offering Physical Science are aware of the inherent dangers of chemicals, abide by the rules of the school and have proper protective clothing.

7. Storage of chemicals.

- Chemicals must first be stored by compatibility. Further separation is at the discretion of the teacher using suggested safety guidelines.
- Nitric acid must be stored separately from acids and all chemicals. Acids must be stored on the floor.
- Proper materials should be used for shelving.
- All chemicals must be labeled.
- All schools must have an inventory list. This must be updated at least once a year

8. Laboratory Apparatus

Learners must be made aware of the proper use of all laboratory equipment.

9. Disposal of chemical waste.

Proper methods in the disposal of chemicals must be followed. The local municipality or Department of Environmental Affairs a well as Health should be contacted in case of doubt.

10. First aid kits

All laboratories must have kits that are always stocked with the relevant supplies in order to handle emergencies in the laboratory. The emergency kit must be stored in a place that can be easily accessed during an emergency. The contents of the kit must be clearly marked. Expired materials must be replaced. The kit must be refilled on a regular basis.

11. Fire kits

Every laboratory must have a fire extinguisher and all the necessary equipment for the handling of fires. All users of the laboratory must be taught how to use the fire extinguisher

Annexure A

MERCURY	**ICSC: 0056** **April 2004**
Quicksilver Liquid silver	
CAS No: 7439-97-6 RTECS No: OV4550000 UN No: 2809 EC No: 080-001-00-0	Hg Atomic mass: 200.6

TYPES OF HAZARD / EXPOSURE	ACUTE HAZARDS / SYMPTOMS	PREVENTION	FIRE FIGHTING
FIRE	Not combustible. Gives off irritating or toxic fumes (or gases) in a fire.		In case of fire in the surroundings: use appropriate extinguishing media.
EXPLOSION	Risk of fire and explosion.		In case of fire: keep drums, etc., cool by spraying with water.
EXPOSURE		**STRICT HYGIENE! AVOID EXPOSURE OF (PREGNANT) WOMEN! AVOID EXPOSURE OF ADOLESCENTS AND CHILDREN!**	**IN ALL CASES CONSULT A DOCTOR!**
Inhalation	Abdominal pain. Cough. Diarrhoea. Shortness of breath. Vomiting. Fever or elevated body temperature.	Local exhaust or breathing protection.	Fresh air, rest. Artificial respiration if indicated. Refer for medical attention.
Skin	MAY BE ABSORBED! Redness.	Protective gloves. Protective clothing.	Remove contaminated

			clothes. Rinse and then wash skin with water and soap. Refer for medical attention.
Eyes		Face shield, or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
Ingestion		Do not eat, drink, or smoke during work. Wash hands before eating.	Refer for medical attention.

SPILLAGE DISPOSAL	PACKAGING & LABELLING	
Evacuate danger area in case of a large spill! Consult an expert! Ventilation. Collect leaking and spilled liquid in sealable non-metallic containers as far as possible. Do NOT wash away into sewer. Do NOT let this chemical enter the environment. Chemical protection suit including self-contained breathing apparatus.	T Symbol N Symbol R: 23-33-50/53 S: (1/2-)7-45-60-61 UN Hazard Class: 8 UN Pack Group: III	Special material. Do not transport with food and feedstuffs.

EMERGENCY RESPONSE	STORAGE
Transport Emergency Card: TEC (R)-80GC9-II+III	Provision to contain effluent from fire extinguishing. Separated from food and feedstuffs. Well closed.

IMPORTANT DATA	
Physical State; Appearance ODOURLESS, HEAVY AND MOBILE SILVERY LIQUID METAL. **Chemical dangers** Upon heating, toxic fumes are formed. Reacts violently with ammonia and halogens causing fire and explosion hazard. Attacks aluminum and many other metals forming amalgams. **Occupational exposure limits** TLV: 0.025 mg/m³ as TWA; (skin); A4; BEI issued; (ACGIH 2004).	**Routes of exposure** The substance can be absorbed into the body by inhalation of its vapour and through the skin, also as a vapour! **Inhalation risk** A harmful contamination of the air can be reached very quickly on evaporation of this substance at 20°C. **Effects of short-term exposure** The substance is irritating to the skin. Inhalation of the vapours may cause

MAK: 0.1 mg/m³; Sh; Peak limitation category: II(8); Carcinogen category: 3B; (DFG 2003).	pneumonitis. The substance may cause effects on the central nervous system and kidneys. The effects may be delayed. Medical observation is indicated. **Effects of long-term or repeated exposure** The substance may have effects on the central nervous system and kidneys, resulting in irritability, emotional instability, tremor, mental and memory disturbances, speech disorders. May cause inflammation and discoloration of the gums. Danger of cumulative effects. Animal tests show that this substance possibly causes toxic effects upon human reproduction.

PHYSICAL PROPERTIES	ENVIRONMENTAL DATA
Boiling point: 357°C Melting point: -39°C Relative density (water = 1): 13.5 Solubility in water: none Vapour pressure, Pa at 20°C: 0.26 Relative vapour density (air = 1): 6.93 Relative density of the vapour/air-mixture at 20°C (air = 1): 1.009	The substance is very toxic to aquatic organisms. In the food chain important to humans, bioaccumulation takes place, specifically in fish.

NOTES
Depending on the degree of exposure, periodic medical examination is indicated. No odour warning if toxic concentrations are present. Do NOT take working clothes home.

For further information please contact the International Occupational Safety and Health Information Centre
at Tel: +41.22.799.6740, Fax: +41.22.799.8516 or E-mail: cis@ilo.org

[SafeWork Home | Protection Home]

International Labour Organization (ILO): Contact us | Site map |

**Permission to use safety cards has been given to the Department of Education*

MAKE YOUR OWN SOAP

LABORATORY TECHNIQUES AND RULES

ORIENTATION

Chemistry is a fundamental science – some even call it a central science because it touches almost all aspects of our lives, culture, and even the environment we live in. Laboratory work is enjoyable and an important part of any science course, since it attempts to interacts theory with practice. I hope that as you progress with experiments in this module you will discover that chemistry is indeed exciting to learn and furthermore it has an important relationship to the world around you.

LABORATORY SAFETY

Although laboratory work is meant to be enjoyable, it involves a certain amount of risk. In some experiments in this module, you will be using some household materials. However, many chemicals in the laboratory are poisonous, corrosive or flammable (catch fire) and chemical experiments are sometimes dangerous. Safety precautions therefore have to be taken when working in a laboratory. The following are some of the important safety rules:

1.Never run or rush about in a laboratory.
2.Never eat, drink or smoke in the laboratory.
3.Talk quietly in the laboratory, never shout or scream.
4.Wear eye protection (safety goggles), laboratory coats and leather shoes at all times in a laboratory.
4.Only perform experiments that you are told to do.
5.Never work alone in the laboratory (especially those who are asthmatic).
6.Never taste chemicals or allow them to come into contact with your body. If you accidentally spill chemicals on your hands, wash immediately with plenty of water.
7.Do not heat flammable liquids with a naked flame, use hot plates; heating mantles; water-baths or sand-bath.
8.When heating liquids in test tubes, do not point them at yourself or anybody else.
8.Do not apply force to any glass apparatus as it may break.
9.Do not smell chemicals by holding them directly near your nose. Use your hands as a fan to direct the vapour, diluted with air, towards your nose.
10.Use small amount of chemicals when carrying out reactions, and be cautious.
11.If poisonous or corrosive substances are produced in a reaction, use a small amount of chemicals and work in a fume cupboard.
12.Do not pipette poisonous or corrosive substances using the mouth.
13.If a chemical gets in the eye, or burns the skin, wash immediately and repeatedly with water for at least 15 minutes.
14.When diluting acids, pour a strong acid into water slowly, while stirring constantly.

EXPERIMENT 1: PREPARATION OF SOAP (SAPONIFICATION)

INTRODUCTION:

The preparation of soap from fat and lye has been, historically, a household task. Only in the last century has the making of soap become a commercial undertaking. Our ancestors made soap by boiling animal fats with the lye obtained from leaching wood ashes. In this experiment, we will make soap by the same process, called **saponification**, but will use modern ingredients. In the process of making soap, animal fat, which is a triglyceride, is hydrolyzed by the action of a strong base, such as sodium hydroxide, and heat. The resulting products are **soap** and **glycerol**:

CAUTION: Safety goggles must be worn throughout this experiment. Sodium hydroxide is very caustic, and can cause severe burn to the skin, especially when hot.

This is an investigative lab of the SAPONIFICATION process. If you wish to make soap in volume, search the web for a web page dealing with the making of soap as a craft.

EXPERIMENT 1.1: PREPARATION OF SOAP (COLD PROCESS)

MATERIALS NEEDED:

*80 ml of 6 Molar NaOH solution (Lye)

15 grams of lard (holsum,)

10 grams of sweet almond oil

7 grams of olive oil

2 grams of coconut oil/caster oil

(sweet almond oil, olive oil, coconut oil/caster oil: optional)

75 ml of distilled water

**300 ml hot sodium chloride solution

100-ml graduated cylinder

Wire screen

Ring stand

Ring

Wire gauze

Burner

Tongs

Stirring rod

400-ml beaker

250-ml beaker

* To make 6 molar sodium hydroxide, dissolve **19.2 grams** of NaOH in enough water to make a total volume of 80 ml.
** This is just a saturated solution of NaOH.

PROCEDURE:

1. Obtain **80 ml** of 6 molar NaOH and **15 grams** of lard (you may **add 15 grams** sweet almond; **7 grams** olive oil and **2 grams** coconut/caster oil), and place **40 ml** of the NaOH solution and the lard in a 400-ml beaker.

2. Heat to boiling, on a standard ring stand set-up, and then continue boiling the mixture over the lowest flame that will sustain the boiling process. Stir the mixture constantly to avoid spattering. If Spattering occurs, remove the flame and continue stirring the mixture. Replace the flame and continue heating after the spattering stops.

3. Continue boiling and stirring for about 20 minutes, or until it appears that most of the water has been evaporated. Then carefully add the remaining **40 ml** of NaOH solution and continue boiling for an additional 20 minutes or until most of the water has boiled off. **DO NOT LET IT BOIL DRY.**

4. As the crude soap cools, a waxy solid should form. Add to it about **25 ml** of distilled water and about **100 ml** of hot, saturated sodium chloride solution. Stir the mixture, breaking up lumps with your stirring rod. Decant the wash solution by pouring it through a wire screen, which will trap small soap particles.

5. Repeat the wash process twice. After the final washing, press the soap between two sheets of paper toweling to expel as much water as possible.

YOU HAVE MADE LYE SOAP.

EXPERIMENT 1.2: PREPARATION OF SOAP (HOT PROCESS)

MATERIALS NEEDED:

10 grams of NaOH pellets (you may also use KOH)

10 grams of lard (holsum,)

10 grams of sweet almond oil
7 grams of olive oil
2 grams of coconut oil/caster oil

} optional

200 ml of distilled water

50 ml of 95% ethanol or methanol

**300 ml hot sodium chloride solution

100-ml graduated cylinder

Hot plate

Tongs

Stirring rod

400-ml beaker

250-ml beaker

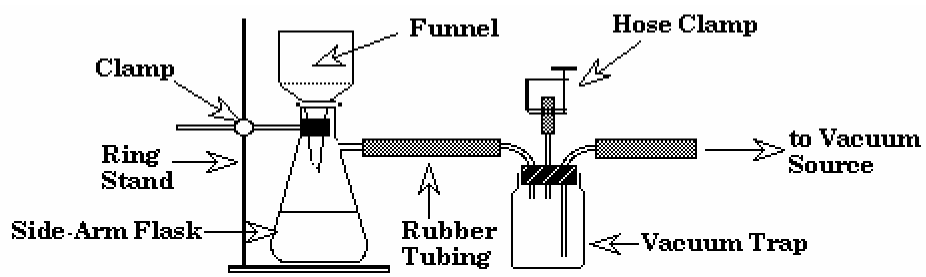


Figure 1: Suction trap

PROCEDURE:

1. Plug in a hot plate and set it on HIGH. Half fill a 400 ml beaker with hot water from the sink and place on the hot plate. When the water begins to boil, adjust the heat, so that the water boils gently, but continuously. While waiting for the water to boil, weigh a 250ml Erlenmeyer flask on a triple beam balance and add 10g of fat (holsum) to it. In a 150ml beaker prepare 100 ml of a 50-50 solution of alcohol-water, by mixing 50 ml of water and 50 ml of 95% ethanol or methanol. Weigh another 150 ml beaker on the triple beam balance, and add 10g of NaOH pellets to the beaker. Handle NaOH with care as NaOH can burn the skin and is especially harmful to the eyes. In the hood, mix the NaOH with 36 ml of the of the 50-50 alcohol-water solution to it. Stir the mixture until a transparent solution is formed. <u>Caution:</u> the beaker will get very hot as the lye dissolves.

2. Pour the lye solution into the Erlenmeyer flask containing the fat and mix well using a stirring rod or by swirling with a beaker tongs. Clamp the Erlenmeyer in the boiling-water bath and with occasional stirring; allow it to cook for at least 30 minutes. While the mixture boils, some foam will form (due to soap formation). Try to minimize <u>excessive</u> foaming, by adding small adding small portions of your alcohol-water solution. The reaction is complete when oil globules are no longer visible when the reaction mixture is stirred.

3. Half fill a 600 ml beaker with 300 ml of clear (filtered) saturated salt (NaC1) solution and 50 ml of water. Pour the still hot reaction mixture containing soap, glycerine, excess NaOH, and alcohol into the salt solution. Stir the resulting mixture and allow standing for 5-10 minutes. The soap will collect as a white layer on the surface of the salt water in the beaker.
4. Prepare a suction trap (**Figure 1**) from the vacuum flask, which will be used later to filter the soap preparation. Bend a long piece of glass tubing into a right angle (instructor will demonstrate), and push one leg of the bend through a one-hole rubber stopper fitted for the mouth of the flask. When inserted, the glass tube should extend to about ½ inch from the bottom of the flask. The exposed leg of the bend should be cut off at about 3 inches from the bend, and, by means of a piece of rubber connector tubing, be attached to a 12-inch length of glass tubing. The side-arm of the vacuum

flask is now connected to the vacuum outlet with pressure tubing. When the suction is turned on, this device will act like a vacuum cleaner, sucking up liquid instead of dust.

5. Make sure the suction is OFF, before proceeding. Bring the beaker containing the soap preparation next to the suction trap, and place the “spout” of the trap into the beaker having it touch the bottom. Slowly turn on the suction, and watch the bottom (aqueous) layer being drawn into the vacuum flask. Draw off most, but not all, of the bottom layer. Be ready to stop the suction instantly, if it appears that some of the soap crystals are being sucked up. You can stop the suction quickly by pulling the pressure tubing away from the outlet, then turning off the vacuum. Caution: At no time should the vacuum flask be allowed to fill more than half-the trap, and pour out its contents.
6. When most of the aqueous layer in the beaker has been drawn off, filter the remaining mixture of soap and liquid through a Buchner funnel (with filter paper attached) to the suction flask. Wash the crystals on the filter with 5 ml portions of ice-cold water. Press out any remaining moisture from the cake of filtered crystals on the funnel with the flat end of a clean cork, or the clean bottom of a small beaker. Allow the product to suck dry for 10-15 minutes.
7. Turn off the suction, detach the Buchner funnel, and with the help of a clean spatula, transfer the soap crystals to a large sheet of smooth paper. Pick up the sheet and slide the cystals into a clean, dry 150 ml beaker. Leave the beaker stand, uncovered in your drawer for several days to air-dry the product.

REPORT SHEET
EXPERIMENT 1: PREPARATION OF SOAP (SAPONIFICATION)

Report Sheet Cold Process

Name________________lab section _____________Date

Type of fat used ________________________

Weight of fat taken _____________________g

Weight of NaOH used ___________________g

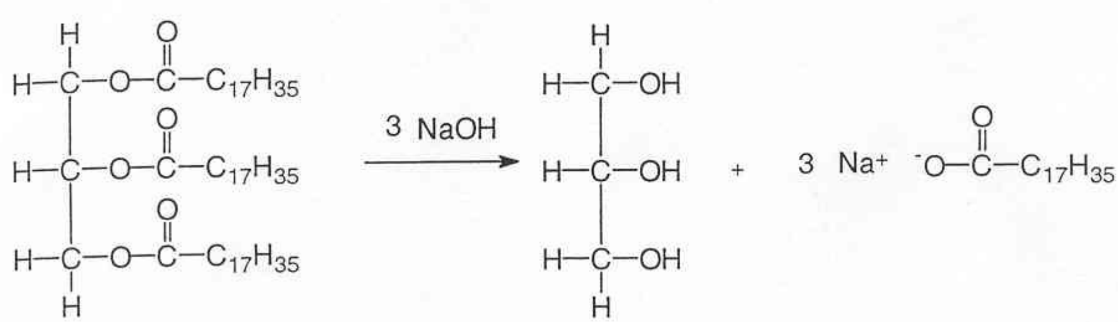
Weight of soap formed ___________________g

Use the weight of fat taken and the reaction to find the theoretical yield (weight) of soap bar?

Theoretical yield
_____________g

% yield = (actual yield (weight of soap formed)/theoretical yield) X 100=
_____________%

Saponification Reaction of Glyceryl Tristearate



$C_{54}H_{110}O_6 + 3\ NaOH \longrightarrow C_3H_8O_3 + 3\ C_{18}H_{35}O_2Na$

Weights: 854 amu | 3 x 40 amu | 92 amu | 3 x 306 amu

Report Sheet Hot Process

Name________________lab section _____________Date

Type of fat used ________________________

Weight of fat taken _____________________g

Weight of NaOH used ___________________g

Weight of soap formed ___________________g

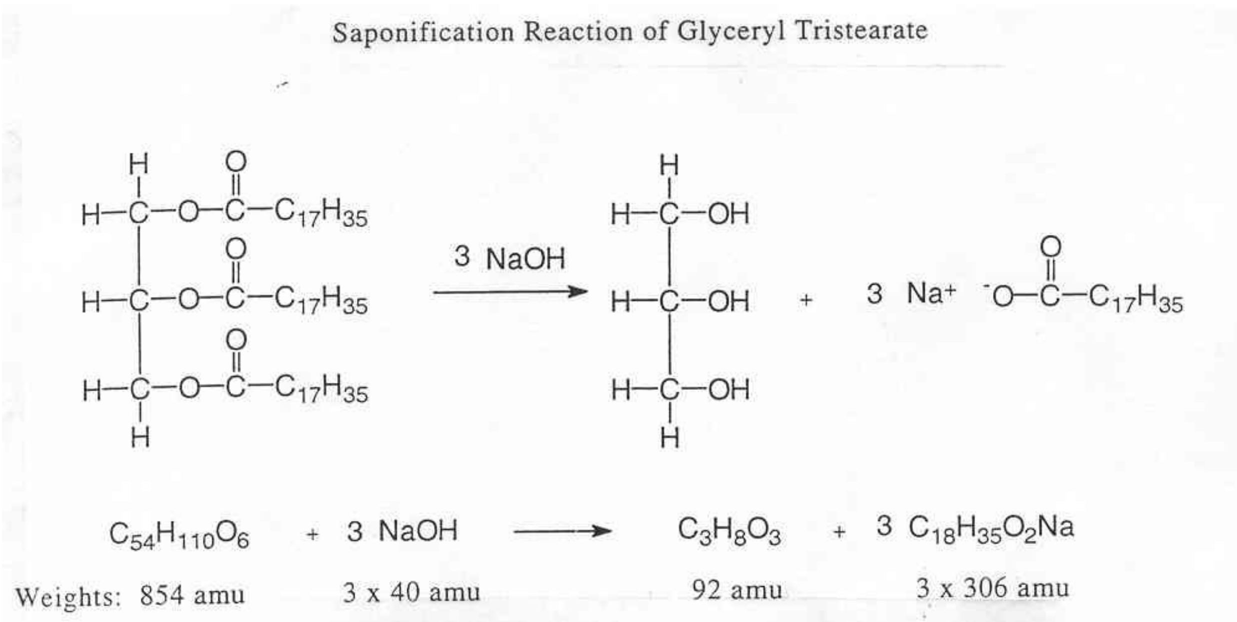
Use the weight of fat taken and the reaction to find the theoretical yield (weight) of soap bar?

Theoretical yield

_____________g

% yield = (actual yield (weight of soap formed)/theoretical yield) X 100=

_____________%



Questions

1. Why do long chain fatty acids melt higher than short chain acids?
2. Why may you use the same weight of fat in your soap preparation regardless of the type of fat-saturated or unsaturated- employed?
3. Why are vegetables fats (oils) liquid, while animal fats are solid?
4. Why are naturally occurring fatty acids even-chained?

5. Why do waxes, Vaseline and mineral oil all feel greasy like fats, even though they are not triglycerides?
6. What is soda ash? How does it form? Why is it useful in water softening?
7. Using the same weights of fat and alkali, would you get more or less soap by using KOH

Instead of NaOH? SIMPLE LABORATORY PREPARATION OF SIMPLE POLYMERS (NYLON)

NYLON EXPERIMENTS

OBJECTIVES:

1. To be able to make simple polymers (e.g. Nylon 66).

2. To learn how functional groups (monomers) interact with each other.

3. To prepare and study some of the properties of a polymer.

Theory

The word nylon is used to identify a group of polyamides made by condensation polymerization. It is a copolymer since two different monomers are used. NYLON was originally a trademark name of the DuPont Company and was discovered in 1935. Stockings made of nylon were first sold in 1938. The word nylon has come to be a generic name for linear polymers that have almost no cross-linking. This absence of cross-linking gives nylon more flexibility and the ability to be molded or become fine threads. There are many types of nylon and they are produced by several methods. Our method requires no heat or special apparatus. In this experiment, nylon 66 is prepared using simple laboratory chemicals.

The synthetic procedure uses a two-liquid-phases system in which the reactants separately dissolved in two immiscible solvents. The polymer is formed as a film at the interface of the two liquid layers.

PREPARATION OF NYLON 66

PRODUCTION OF CUPRAMMONIUM RAYON

MATERIALS:

- $CuSO_4.5H_2O$*
- NaOH
- Concentrated NH_3 Solution
- 1.6 M H_2SO_4 (88.8 mL of concentrated H_2SO_4 solution diluted to 1.00 L with distilled water)

- 11.0 cm filter paper*

MODIFICATIONS/SUBSTITUTIONS:

1. $CuSO_4.5H_2O$ can be purchased as root killer at a garden supply store.
2. NaOH can be purchased as lye in grocery stores.
3. Sulfuric acid is available from auto supply stores as battery acid. This solution is 4.8 M.
4. Paper towels could be substituted for the shredded filter paper in this reaction.

EQUIPMENT:

- 250-mL Erlenmeyer flask ; 1000-mL beaker ; Syringe or bulb/pipet combination
- Funnel ; Filter paper ; Funnel support ; Magnetic stirrer (optional)
- Buchner funnel and filtering flask (optional)

HAZARDS
Avoid skin contact with all reagents. > Use caution when making NaOH and H2SO4 solutions -- both are exothermic. Avoid breathing NH3 vapors and work in a hood, if possible. Goggles must be worn for this demonstration.

PROCEDURE:

1. Dissolve 25.0 g of $CuSO_4.5H_2O$ in 100 mL distilled water. Heat the water to accelerate the dissolving process.
2. Dissolve 8.0 g of NaOH in 200 mL of distilled water.
3. Mix the cooled NaOH solution with the copper sulfate solution. Collect the resultant gelatinous precipitate of $Cu(OH)_2$ by filtration. Wash the precipitate with three 10-mL portions of distilled water. If using 11.0 cm filter paper, several filtrations will be required because of the large amount of precipitate produced.
4. Measure 70-mL concentrated NH_3 (aq) into a 250-mL Erlenmeyer flask. Shred four pieces of 11.0-cm filter paper. Add the $Cu(OH)_2$ precipitate carefully along with the filter paper to this flask and stir. This should result in a deep purplish-blue solution of tetraaminecopper (II) hydroxide, referred to as Schweizer's reagent. Stopper the flask and stir periodically for 24 hours. Use a magnetic stirrer, if available.
5. Take up the contents of the 250-mL Erlenmeyer flask in 10-mL increments in a 10-mL or 50-mL syringe. Squeeze out the contents into a 1000-mL beaker contained 300 mL of 1.6 M sulfuric acid. Be sure that the tip of the

syringe or pipet is under the surface of the acid. A crude 'thread' should form.

6. The clumps of threads can be washed free of the solution to show the white color of rayon.

DISPOSAL:

Flush the ammonia solution and the sulfuric acid solution down the drain with copious amounts of water. Dispose of rayon with solid waste.

References

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