Rate of reaction and yield conversion | experiment

At the outset, the objective of this experiment is to scrutinize the rate of reaction and the yield conversion. And the foremost principal that should be applied in order to determine both rate of reaction and yield conversion is material balance for batch reactions. As the experiment go on, students are supposed to perceive the factors catering the yield, rate of reaction and also the conversion. According to the hypothesis of the experiment, with the increment of ethyl acetate (reactant) from 0. 1M to 0. 2M the rate of reaction should gradually increase, leading to an augmentation of the rate of reaction as well as the conversion of sodium acetate from sodium hydroxide.

Secondly, the theories that students must be acquainted with is, batch reaction, conversion, rate of reaction, conductivity yield and saponification. Saponification is an essential theory that drive the whole experiment, as it function by hydrolyzing an ester, forming a acidic salt and alcohol. With the absence of the pertinent knowledge of saponification, the experiment will not be successful.

Thirdly, the modus operandi of the experiment, it comprises of 3 focal steps, preparation of reactant, experimental arrangement and procedure to be carried out during experiment. Students are to be particularly vigilant during the experiment, as reactant given, contain some perilous substances that are detrimental to human body.

Subsequently, with the use of two different concentration of acetyl acetate during the experiment, the result and calculation of yield and rate of reaction could be analyzed. The result tabularize based on the two different concentration should show a vast divergence. The 0. 2M of ethyl acetate

should possess a higher yield and rate of reaction according to the hypothesis of the experiment.

Before proceeding to the conclusion, students are supposed to go through some discussion on the experiment. The points to be discussed are namely preventative measure and the factors affecting the rate of reaction.

As a final point, the conclusion, it concludes whether the hypothesis of the experiment corresponds with the actual experiment performed. Tentatively the conclusion should support the hypothesis of the experiment, which is, as the concentration of ethyl acetate increases, the rate of reaction and conversion also increases. (Singapore Polytechnic 2009)

Material balance with chemical reaction

1. Introduction

1. 1 Background

Over the years, heaps of researches have been done to capitalize on the yield, conversion and increase the rate of reaction. These three factors are the point in which have close connection with the profit of the company. By increasing the yield it means more production generate with a standard amount of reactant used. As for rate of reaction, rationally, the faster the rate of reaction the greater the production rate within a certain period. During the experiment, batch process is employed as a medium for chemical reaction between sodium hydroxide and ethyl acetate to take place. The reaction produces sodium acetate and ethanol every thirty minutes, recording was taken every one minutes to note down the conductivity values. The whole process of obtaining the product from sodium hydroxide

and ethyl acetate, consist of batch process, closed system, law of conversion and also saponification reaction.

Batch process, is a process when a fixed charge of raw material is introduced and the products withdrawn before the cycle repeat. A closed system is a system where no material crosses the system boundary. As for The Law of Conservation of Energy it states that energy cannot be created or destroyed, but can change its form. Lastly For unsteady state process, it means, not all of the conditions in the process remain constant with time or the flows in and out of the system can vary with time.

1. 2 Aim

The aim of this experiment on material balance with chemical reaction is to allow students to employ the principle of material balance with chemical reaction for batch reaction by determining the yield, conversion and reaction rate. The purpose is to allow students to understand the change of reaction, when the concentrated NaoH react with ethyl acetate in a reactor as time passes by. With the knowledge of it, we will then be able to understand the saponification reaction of NaoH with ethyl acetate solution.

1. 3 Hypothesis

The hypothesis of the experiment is that during the Saponification reaction between NaOH and Ethyl acetate solution in the reactor, the concentration of NaOH would decrease due to the number of NaOH molecules being used for the reaction to produce sodium acetate. Furthermore, by increasing the concentration of ethyl acetate, the rate of reaction will also be increased

2. Theory

2. 1 Introduction of Theory

The role of the theory below is to give a more detailed explanations on saponification, batch process, conversion, yield, rate of reaction and conductivity, so that is can allow students to have a better perception on the experiment.

2. 2 Batch Process

Batch process is a process in which a fixed charge of raw material is introduced and the product is withdrawn before the cycle repeat. During the experiment, batch process is employed, as reactants are put in to the system for thirty minutes for reaction to take place. After which products are withdrawn and the apparatus used are sluice before another batch of reactant are introduced again. Owing to the change in concentration and production of new product, the reaction is categories under unsteady state. (Singapore Polytechnic 2009)

2. 3 Saponification

Saponification is defined as a process where ester is hydrolyzed, forming an acid salt and an alcohol. For this experiment, students are suppose to apply the knowledge they acquired on saponification and react ethyl acetate and sodium hydroxide and to produce sodium acetate and ethanol as the product of the reaction. Sodium acetate is form due to the displacement reaction which occurred during the overall reaction. The hydrogen in ester is displaced by the sodium ion in the sodium hydroxide, thus forming an acid salt; sodium acetate. The reaction is irreversible, hence once the product is formed, it cannot be re reacted to form the initial state of sodium hydroxide

and ethyl acetate. However, reaction could be accelerated with the use of a strong acid (concentrated sulphuric acid) as the catalyst of the reaction. (Richard Hamner, Green Mountain Soap Company 2006)

2. 4 Conversion

Conversion is a technique, when a feed is converted to products. The term conversion can also be defined mathematically as percentage conversion. Percentage conversion is derived by dividing; moles of key reactant that react, with mole of feed introduced and multiply it with 100%. A 100% conversion is not likely to occur in the lab, this is due to the restrain of mechanism, which deprived the ideal conversion to transpire. (Singapore Polytechnic 2009)

2. 5 Yield

There are copious definitions for yield. The three generally prevalent definitions are yield based on feed, yield based on the reactant consumed and lastly yield based on the theoretical consumption of the limiting reactant. These three definitions are usually employed by chemical engineering industrial to guesstimate the yield of the products. Yield based on feed are exemplify to be; amount of desired product obtained, divided by amount of key reactant (limiting reactant fed). As for yield based on the reactant consumed, it is depict as; amount of desired products obtained, divided by amount of the key reactant consumed. Lastly as for yield based on the theoretical consumption of the limiting reactant; it is elucidate as; amount of product obtained, divided by the theoretical amount of products that would be obtained based on the limiting reactant if limiting reactant

react completely. The usage of the formula varies from the given information. (Singapore Polytechnic 2009)

2. 6 Rate of Reaction

Rate of reaction is the speed of the overall reaction; it can be affected by temperature, conductivity, pressure, concentration surface area, and also catalyst.

2. 6. 1 Temperature

Temperature will radically affect the rate of reaction. The collision of particles is determined by the energy a particle possessed. With a higher temperature, it will cater the particles to have a higher energy, hence increase the effectiveness of collision, and eventually resulting to a faster rate of reaction (Redspot Publishing 2005).

2. 6. 2 Pressure

Pressure is defined as a condition of being compress. The increase of pressure will cater to a faster rate of reaction as the areas the particle have are smaller after compression. This therefore causes particle of be closely packet together which result to a higher frequency of collision between gaseous molecules. However, the increase of pressure is only applicable for gaseous molecules, as liquid and solid cannot be compressed (Redspot Publishing 2005).

2. 6. 3 Concentration

Increases of concentration mean that the presences of particles in a specific volume have increased. While the volume/ space remained constant, the

quantity of the particles increases, these instigate the frequency of collision to be higher, and also enhancing in the effectiveness of collision. This effect on particles collision will encourage a faster rate of reaction during the reaction (Redspot Publishing 2005).

2. 6. 4 Surface Area to Volume Ratio

The bigger the size of the particles, the smaller the surface area for collision of particles, whereas, when the particles sizes are reduced, the chances of particles colliding in to each other will be higher. This is due to the increases in surface area of particles with it size are being reduce. Rate of reaction will therefore increases as frequency of collision increased (Redspot Publishing 2005).

2. 6. 5 Presence of Catalyst

Catalyst is defined as a substance that is capable of reducing the activation energy of particles without itself taking part in the reaction. Therefore with the presence of a catalyst, particles will have a higher energy than the activation energy. These will lead to a higher frequency of collision and also the much more effective collision. Rate of reaction will gradually increases with more collision taking place (Redspot Publishing 2005).

2. 7 Conductivity

The conductivity values of sodium hydroxide is tantamount to the conductivity values of the solution, as the conductivity values of other reactants such as ethyl acetate, sodium hydroxide and ethanol are inconsequential. With the conductivity values of the solution ascertained, the concentration of sodium hydroxide in the reacting mixture can then be

determined. The rate on how fast concentration of sodium hydroxide is depleting can that be easily achieved, by tabulating a graph (Copyright 2009 — Russell Mainstream Supply Ltd)

3. Procedure

3. 1 Preparation of Starting Reactant

Before beginning with the experiment, students should go through and understand the Material Safety Data Sheet (MSDS) of sodium hydroxide and ethyl acetate. The understanding of the data sheet is imperative as, without apposite understanding on the chemical used, perilous hazard might occur. The procedure on handling and disposal of chemical must be habituated before the beginning of the experiment. Students are handling with highly acidic concentrated reactant, therefore, disposable glove and chemical goggles should be putted on at all time during the experiment. 500mL of 0. 01M of sodium hydroxide solution and 500mL of 0. 01M ethyl acetate was the concentration needed to be prepared for this experiment.

500mL of 0. 01M sodium hydroxide are suppose to be prepared, to do so, measuring cylinder was used to measure the required volume of 0. 01M NaOH and poured in to a 500mL volumetric flask. De ionized water is poured in to the 500mL mark on the volumetric flask for dilution purposes. To ensure a fine dilution, flask should be covered with stopper and shake to ensure solution properly mixed.

Preparation of 500mL of ethyl acetate solution was done by pouring 250mL of de ionized water into a 500mL volumetric flask, followed by measuring the stock solution using a micropipettor and dispenses it to the 500mL

volumetric flask. Top up solution up to 500mL mark, and cover it with a stopper and shake the solution to ensure solution is well mixed.

Experimental Setup

- Conductivity meter
- 1-litre reaction beaker
- Magnetic stirring device
- Conductivity probe
- Reacting mixture
- Retort stand

Procedure During Experiment

As the preparation of the sodium hydroxide solution is completed, solution is poured in to the reactor with the reaction conditions adjusted to predetermined level. The reaction conditions are directly related to the overall reactions; hence the recording of the condition is essential. Examples of the condition are, temperature, stirring speed, concentration and volume of reactions. Before the stirring process inaugurate, ensure that the conductivity meter probe is positioned into the reacting mixture and a stopwatch is ready for timing purposes. Ethyl acetate is to be poured in to the reactor, and recording should start immediately. While the solution is being stirred in the reactors, conductivity values are recorded at a regular interval of one minute for thirty minutes. After thirty minutes, reactor is stopped and a magnetic rod is used, to remove the magnetic stir bar in the reactor. The conductivity probe is then withdrawn and sluiced scrupulously with de ionized water. As for the product, it is being disposed into a plastic waste container. The experiment is to be repeated based on the

experimental methodology discussed with lecturer. However, to ensure consistency of the experiment, all glassware is to be rinsed. Once all the experiment is accomplished, all the equipments should be properly cleaned and chemical used are to be disposed in to the plastic waste container. Finally waste will be send to W314 for proper treatment before discarding and glassware used should be placed back to original location.

Result and Calculation

4. 2 Determination of the Yield of Sodium Acetate

Determination of the yield of sodium acetate is associated with the concentration of sodium hydroxide. In tandem with the given information on the concentration of sodium hydroxide, the molar ratio employed can be dexterously deciphered. From here, calculation to verify the yield can be facilely obtained by using the mole, which is calculated using the molar ratio of sodium hydroxide and ethyl acetate. Finally, utilize the formula of yield calculation and the determination of the yield of sodium acetate can be anatomized.

4. 3 Yield and Rate of Conversion of 0. 01M Ethyl Acetate Solution for 15 Minutes.

Concentration of sodium hydroxide at one minute interval

NaOH + CH3COOC2H5 à C2H5OH + CH3COONa

Theoretical Mole of NaOH = 0. 01 X 0. 5L = 0. 005 mol

Actual Mole of NaOH = 0. 00156 X 0. 5L = 0. 00078mol

Number of moles reacted = 0. 005 – 0. 00078 = 0. 00422mol

Conversion of NaOH= 0. 00422/0. 005 X 100%

= 84. 4%

Theoretically, since 1 mole of NaOH react and form 1 mole of CH3COONa, actual mole of CH3COONa= 0. 00078

Yield of CH3COONa= 0. 00078/0. 005

= 0. 156

4. 4 Yield and Rate of Conversion of 0. 02M Ethyl Acetate Solution for 15 Minutes

Figure 4. 4. 2. Graph showing concentration of sodium hydroxide against time (0. 02M of ethyl acetate used)

NaOH + CH3COOC2H5 à C2H5OH + CH3COONa

Set 2

Theoretical mole of NaOH = 0. 02 X 0. 5L = 0. 01 mol

Actual mole of NaOH = 0. 0017 X 0. 5L = 0. 00085mol

Number of moles reacted = 0. 01 – 0. 00085 = 0. 00915mol

Conversion of NaOH= 0. 00915/0. 01 X 100%

= 91. 5%

Theoretically, since 1 mole of NaOH react and form 1 mole of CH3COONa, actual mole of CH3COONa= 0. 00085

Yield of CH3COONa= 0. 00085/0. 01

= 0. 085

4. 5 Rate of Reaction of 0. 01M of Ethyl Acetate

Graph 4. 5. 1. Shows the rate of reaction of sodium hydroxide when 0. 01M of ethyl acetate was added.

Graph shown above is straight line. Gradient= 0. 00265-0. 0012 ÷ 20 – 1 = 0. 0000763 (From the graph)

4. 6 Rate of Reaction of 0. 02M of Ethyl Acetate

Graph 4. 6. 1. Shows the rate of reaction of sodium hydroxide when 0. 02M of ethyl acetate was added.

Graph shown above is straight line.

Gradient= 0. 00275 – 0. 00125 ÷ 20 – 1 = 0. 0000789 (From the graph)

5. Discussion

5. 1 Factors Affecting Rate of Reaction

As indicated above, there are numerous factors that are capable of affecting the rate of reaction however; the only applicable one is the differences in concentration as the rest (temperature and pressure) are kept constant. Based on the experiment did, as the volume and concentration increases, the rate of reaction also increases, this is by virtue of the presence of more particles in the solution, hence increasing the chances of particles colliding to each other, which eventually result in an increase in the rate of reaction.

Below is a graph to further elaborate on the explanation on the difference in concentration.

The judgment on the rate of reaction is based on the steepness of the graph. As shown, the black line which contains 0. 02M of ethyl acetate has a slower rate of reaction as compared to the one in red which is 0. 01M of ethyl acetate. This repudiated the hypothesis of this experiment. The dialectics of this contradiction is, there might be source of contaminant on apparatus or solution used.

5. 2 Factors Affecting Conversion and Yield

The ideal rate of conversion and yield will never be actualize under school environment or even in industries. As, in school students are using eye sight as a gauge for the experiment which indubitably cause error due to parallax error, as for industries, despite being able to afford high cost machines and computer, the cunctation between human and machines will cause an slight differ on the rate of conversion and yield.

5. 3 Factors Affecting Conductivity Values

As mention on the theory section, the conductivity values of ethyl acetate are imperceptible; therefore the conductivity rate of sodium hydroxide is employed instead.

During the experiment, 2 different concentration of ethyl acetate was used. The first set of experiment, we used a concentration of 0. 01M. It produces a constant decreasing rate at every one minute interval. This shows that while the moles of sodium hydroxide are depleting, conductivity value to decreases too.

As for the second set of experiment, the same things occurred but at a same rate as the first set of the experiment. This contravene the theory, as

suppositionally, the increases in concentration to 0. 02M will cause the moles of sodium hydroxide to deplete at a faster rate, which result to a faster decreasing rate for conductivity. Again, the dialectics of this contradiction is, there might be source of contaminant on apparatus or solution used.

5. 4 Precaution in Experiment

As we all know, ethyl acetate are very volatile, it release harmful gas when it is expose to the environments. Therefore, adding of ethyl acetate into the volume metric flask must be carried out in the fume hood to prevent students from inhaling gases produced from ethyl acetate, which is harmful to human body. In addition, safety goggles and rubber gloves should be worn at all times during the experiment. This help to prevent students from having direct contact with the acid which might cause skin irritation of temporary loss of vision.

5. 5 Comparison of Two Different Tests

As two different concentrations were employed during the experiments, the result on yield and conversion rate will be different.

5. 5. 1 Comparison of the Yield of Two Different Tests

Upon completion of experiments, the differences in yield were realised. The yield of 0. 01M ethyl acetate was 0. 156 and the yield of 0. 02M ethyl acetate is 0. 085. Theoretically, due to the increment in concentration, the yield of 0. 02M of ethyl acetate should be higher as, since more reactants is used; it will rightfully result in more products being formed. However, as mention above, there might be chances of the reactants or apparatus used being contaminated, which result in the huge differences between the yields.

5. 5. 2 Comparison of the Conversion Rate

The conversion rate of 0. 01M of ethyl acetate was 84. 4% and the conversion rate of 0. 02M of ethyl acetate was 91. 5%. The result shown was excellent, as high conversion rate will mean that, majority of the reactant was fully utilized, hence saving cost.

6. Conclusion

Based on experiment, I can construe that the higher the concentration of ethyl acetate, it will result to a much faster rate of reaction, and a higher rate of conversion. The conductivity value is interred related and proportioned to the concentration of sodium hydroxide. Therefore, since observation and hypothesis are similar, the hypothesis is true.

The aim of the experiment are also fulfilled, as scrutiny of the experiment have verify that, while the concentration of ethyl acetate got higher, the rate of reaction and rate of conversion increases. In addition, adding of catalyst or increasing surrounding temperature could also result in a faster rate of reaction which tantamount to an increment in rate of conversion.