# Principle of material balance with chemical reaction biology essay

The aim of this report is to make use of the principal of material balance with chemical reaction so to able to find out the yield, conversion rate and rate of reaction for the batch process.

The hypothesis made in this experiment was when the concentration of sodium hydroxide decreases, the conductivity values also decreases. The steps for conducting this experiment are to prepare the reagents first. Then allow the reaction between the two reactants sodium hydroxide and ethyl acetate to mix together for reaction. Take note of the time and draw graphs of the reaction and finally find the yield of the reaction.

There are two conditions to be studied in this case and it can be determined by the group itself. In this report, the concentration used is 0. 01M of ethyl acetate and 0. 02M of ethyl acetate solution. The yield calculated was that yield was higher in 0. 02M of ethyl acetate compared to 0. 01M of ethyl acetate.

The rate of reaction is higher also in 0. 02M of ethyl acetate solution based on the steepness of the graph. This is because as more molecules react with each other, more product will form at the same time and therefore in average, more product are formed at the same time and hence rate of reaction increase.

However, the conductivity value was higher in 0. 01M of ethyl acetate compared to 0. 02M of ethyl acetate. This happened as more NaOH is being reacted with 0. 02M of ethyl acetate solution. When this occurs, the conductivity value decreases as NaOH is a best conductor of electricity

among the reactants and if the concentration decreases, the conductivity values also decreases and vice versa.

Overall, the hypothesis made and the aim made for this experiment is correct and it also follows the law of material balance with chemical reaction.

iii

1. Introduction

Background Literature

In the process industry, maximizing the yield is important as not only it save cost of production, but also bring more profits to a company. However, maximizing the yield is closely related to the conversion of units and rate of reaction. This is because with the help of the two factors, then maximizing yield could be done possible (Singapore Polytechnic 2009).

Much time were set apart in this area at the industry to adjust the factors to optimum factors for the maximum yield it can have. Beside maximum yield, maximum reaction is also required between the reactants.

Reaction rate is especially important in the industry as there is a need to know exactly what is the required time needed for the reaction to be complete. It can be calculated by finding the rate of the reaction is going at a constant time and multiply against the amount of reactants used.

In this experiment, the main objective is to look at the saponification of sodium hydroxide and ethyl acetate solution to form the desired product sodium acetate.

Overall, the whole experiment wanted the students to get prepared for the fundamentals of material balance with chemical reaction through the reaction between the reactants to get the final product.

1. 2 Aim

The aim of this experiment is to study and determine the yield, conversion and reaction rate of the starting reagents sodium hydroxide and ethyl acetate. It helps the students to know how to calculate the yield.

1. 3 Hypothesis

In this experiment, the main objective is to find out the relationship between the concentration of NaOH and the conductivity values. According to the theory, as the reaction of ethyl acetate increases, conductivity values will decrease and vice versa.

1

2. Theory

2. 1 Introduction of Theory

In this case, material balance deals with chemical reaction where students associate the product and the reactants. Material balance states that

reactant that goes in to react must come out from the system as a product. The law of

material balance also states that a system must, by conservation of mass, either leave the system or accumulate within the system. (Wikipedia 12 Dec 2009)

The reactants used are sodium hydroxide and ethyl acetate by processing it batch wise in a reactor to produce the desired product sodium acetate and the by- product ethanol.

2. 2 Saponification

Saponification is the hydrolysis of an ester under basic conditions to form an alcohol and the salt of an acid This term is normally associated with the reaction of an alkali (normally metal) with a fat compound to form soap. However, only certain lipids that contain ester linkages can undergo hydrolysis. This reaction is also catalyzed by a strong acid or base. (Wikipedia 12 Dec 2009).

The alkali that is going to be used is sodium hydroxide solution and the ester that is to be used is ethyl acetate solution. After it had reacted, it will form the product sodium acetate. In the past, saponification also refers as soap making as the properties of the reactants is about the same only with the exception that fats or oil is used instead of the ester ethyl acetate.

2. 3 Batch Process

Batch process is an operation where a fixed amount of reactants are being fed into the reactor. It is an unsteady state process where the flow rate of the system is not proportional to the time taken to flow. So therefore, the rate where sodium acetate where it is formed is not constant and the rate of accumulation are also not constant. Accumulation consists of either the reactants which had not been used up during the reaction or the product that are being left inside the reactor. The product will stop producing if any of the reactants is used up. The reactant that is being used up first is the limiting reagent. Normally, limiting reagent is the more expensive reagent. Because it can save up cost of production as it is considered wasteful if there is any expensive reagent not used up. Ethyl acetate, being the more expensive reagent, will be the limiting reagent in wise. There are also two equations relating to the batch process.

Final Output-Initial Output = Generation – Consumption

If there is no reaction,

Initial Input= Final Output (Product= Reactants) (Singapore Polytechnic 2009)

2

2. 4 Conductivity

Conductivity is a measure of an electrolyte of its ability to conduct electricity. (Wikipedia 2009) The S. I unit of conductivity is Siemens per metre (S/m).

Conductivity measurements are usually used in many industrial and environmental applications. This is because it has been proven as a fast, inexpensive way of measuring the ionic content of a solution. For example, the measurement of product conductivity is done so by tracing the performance of the water purification system under close monitor.

In many cases, conductivity is linked directly to the total dissolved solids (T. D. S). High quality deionised water has a conductivity values of about 5. 5 lS/m, drinking water is in the range of five-fifty mS/m while sea water is about 5 S/m. The reason why sea water has such high conductivity because of the ionic compounds dissolved in it and all of them are conductor of electricity. The most basic compound dissolved in seawater is table salt, Sodium Chloride.

For this experiment, the result that is required is the conductivity of sodium hydroxide solution after reacting with ethyl acetate for a certain period of time. The amount of time set for the reaction is twenty minutes and it can be adjusted accordingly.

2. 5 Yield

Yield is the amount of product obtained in a chemical reaction. The units of yield can be given in grams or in moles.

To be exact, yield is also defined as the mole/s of desired product formed per mole of key reactant fed into the reactor.

This experiment also required the students to find out the yield or how much the products it has which is the desired product sodium acetate. Even

though ethanol is still considered as a product, it is a by-product and hence the yield is not required to find out.

3

Procedure (Singapore Polytechnic 2009).

3. 1 Pre- Assessment activity

Before starting the experiment, besides preparing the starting reagents, students have to ensure what are the equipments required for this experiment. After checking it, make sure to rinsed all apparatus with D. I water to ensure no impurities present in any of the equipments. There is also a Material Safety Data Sheet (MSDS) that tell us the nature of NaOH and ethyl acetate. The data sheet also tells us what are the hazards and the safety precaution to take note of for these two compounds.

3. 2 How to Prepare the Starting Reactant

Firstly, students must read how to handle NaOH and ethyl acetate and the recommended way of disposing these two chemicals. Disposable gloves and chemical goggles is a must as even if the chemical spilled out, the glove will prevent the chemicals from harming the students. 500ml of ethyl acetate is to be prepared at this stage as the concentration is being discussed during the pre- assessment activity.

Students may use the measuring cylinder to measure the required volume of both reactants and the volume is the pre-determined during the pre-assessment activity. Then both are being poured into the 500ml volumetric

flask respectively. The solutions are to be filled up to the 500ml mark for both reactants.

3. 3 Experimental Setup

Pour in the NaOH solution to the reactor. Alter the set up condition accordingly by the discussed by the group earlier same as the volume used for the reactants. Make sure it is approved by the lecturer. Remember to record down the reaction of conditions such as the stirring speed of the stirrer, concentrations, temperature and the volume of the reactants.

Make sure the conductivity probe is inside the solution. Pour NaOH in first. Then when ethyl acetate solution is poured in, start the timer immediately. Record the value every 1 minute and this goes on up to 20 minutes. After 20 minutes, stop the stirring device and remove the magnetic bar using the magnetic rod. Clean all the equipments properly (e. g. Clean the conductivity probe with D. I water etc). Before doing so, pour all the unwanted solution to the containers respectively.

Repeat the experiment again with different condition. Repeat the steps mentioned above. Tidy up the workplace and the experiment is considered done.

4

Results And Calculation

4. 1 How to Determine the Yield of Sodium Acetate at 15 Minutes for 0. 01M of Ethyl Acetate?

The yield of sodium acetate at 15 minutes can be determined by the concentration of NaOH. From the concentration, students can find out the amount of mole of NaOH and also by the molar ratio of NaOH and ethyl acetate. By making use of the results form the procedure, students can also find out the concentration of NaOH and ethyl acetate.

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. 2 What Is the Yield When 0. 02M of Ethyl Acetate Solution Used At 15 Minutes?

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

5

4. 3 What Is the Rate of Reaction When 0. 01M And 0. 02M of Ethyl Acetate?

Figure 1: Rate of reaction for 0. 01M of ethyl acetate

Figure: 2 Rate of reaction for 0. 02M of ethyl acetate

6

4. 4 How to Determine Rate Constant

The rate constant can also be determined by the graph except by drawing a tangent line against it as the tangent line mean the rate is going at a constant rate.

Figure 3: Rate constant for 0. 01M of ethyl acetate

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

Figure 4: Rate constant of 0. 02M of ethyl acetate

Graph shown above is straight line.

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

7

Discussion

5. 1 Factors Affecting Rate of Constant

The factor that may affect rate of constant is temperature of the reactor, concentration of the reactants, pressure or volume of the reactants.

Firstly, as temperature rises, it can lead to a higher probability of particles colliding each other. Hence it will increase rate of reaction with an increase of the temperature, the moving speed of the molecules increases, with higher moving speed, it will increase the chances of molecules colliding to each other, therefore increases the rate of reaction. However, during the experiment, the temperature of the reactor was keep constant at a range of 23. 5oC which is at room temperature, therefore, temperature was not taken in to account in this experiment.

Secondly, concentration of the reactors, with a high concentration of the reactant, the rate of reaction with also increases. This is caused by the increasing number of particles in a reactant. With larger amount of particles, the successful rate of particles colliding in to each other are higher, therefore cater to a faster rate of reaction. However, as we are conducting the

experiments, instruction of using a constant concentration of the reactant were told, therefore, concentration of the reactant is also not to be taken in to account.

5. 2 Factors Affecting Conversion and Yield

The equation above have NaOH and ethyl acetate as their reactants and sodium acetate and ethanol as the products formed. As indicated on the lab manual, the amount of NaOH used is fixed at 0. 1M, therefore reactant A is ethyl acetate and the desired product is sodium acetate. The factors that affect the yield of the desired product are the volume and concentration of reactant A which are fed in to the reactor. With an increment of both the volume and concentration of reactant A, the number of moles of the reactant will increase.

Two experiments were done to prove that volume can cater to a different yield. The first trail of the experiment, the volume of ethyl acetate was set to 0. 49cm3 and on the second trial, 0. 92cm3. The yield of the product decreased as the volume increased, this was proven as the yield of the second reaction was lower than the first.

8

Factors Affecting Conductivity Values

Mainly, there are two main factors that are affecting the conductivity values. There are the speed of the stirrer and rate of reaction. When the speed of the stirrer increases, the conductivity values decreases. This is because it introduces more collisions between the particles and hence more products

are formed at the same time. As more NaOH is being converted to sodium acetate, the conductivity value will increase as mainly NaOH is the best conductor of electricity present within the reaction and vice versa. Temperature indeed affects the conductivity values but as the temperature during the reaction is being kept constant, it will not be any of the factors that affect the reaction.

Precautions In Experiment

There are some precautions taken for the experiment. For example, when handle corrosive or volatile chemicals such as NaOH or ethyl acetate, make sure to wear disposable glove and avoid smelling ethyl acetate as it is a volatile liquid. Also, the smell of ethyl acetate is harmful to our body and when are diluting it, it is best to wear a surgical mask while extracting the pure ethyl acetate solution.

While doing the experiment, wear safety goggles at all times to prevent the spurring of the reactants during the chemical reaction. After doing the experiment, also make sure that the magnet is taken out by the magnetic rod and not take it by the hand itself. This is because chemicals present in the beaker may not have reacted completely and traces of reactants may still be found present in the solution. This is a common mistake made by students as some of them will take it out by bare hand after realizing they did not take it out before washing.

Comparison between the Yields of Different Concentration of Ethyl Acetate.

Yield obtained in 0. 01M of ethyl acetate is 78% while yield obtained in 0. 02M of ethyl acetate is 85%. After comparing the yield between the two concentrations of ethyl acetate, 0. 02M of ethyl acetate tends to have higher yield than 0. 01M of ethyl acetate solution. The result is the same as the hypothesis made at the start of the report. This is because as there are more molecules of ethyl acetate present during the reaction. The rate of reaction increases because of the kinetic particle theory. The kinetic particle theory states that as more molecules collide during the reaction, it will form more products. Hence, yield will increase as more products are formed.

9

Comparison between the rates of reaction of different concentration of ethyl acetate.

The curve was smoother in 0. 01M of ethyl acetate compared to 0. 02M of ethyl acetate. This is because with a high concentration of the reactant, the rate of reaction with also increases. This is caused by the increasing number of particles in a reactant. With larger amount of particles, the successful rate of particles colliding in to each other are higher, therefore cater to a faster rate of reaction. Hence, rate of reaction was faster in 0. 02M of ethyl acetate compared to 0. 01M of ethyl acetate.

10

6. Conclusion

In conclusion, the aim that was made at the start of the experiment was successful as students has indeed learnt the fundamentals of material

balance that even though the time required to make the product varies with the amount of products, anything that goes in must also get out is the main point that the students learnt.

There are many factors that can affect the condition studied. This includes temperature, pressure, volume, rate of reaction, conversion and yield etc.

Also, as the NaOH concentration increases, the conductivity values also increases and vice versa. This is the same hypothesis made in this report and therefore it can be concluded that the hypothesis is correct.

11