Project title: Factor affecting the rate of fermentation

Aim: To find out the relationship between the concentration of glucose solution and rate of fermentation.

Introduction:

Fermentation is the process by which the living cell is able to obtain energy through the breakdown of glucose and other simple sugar molecules without requiring oxygen. The process allows respiration to occur in the absence of oxygen. Biologically, it allows cells to obtain energy from fuel molecules (e.g., glucose) anaerobically. Glycolysis, the breakdown of glucose, is a form of fermentation. Alcoholic fermentation occurs when yeast cells convert carbohydrate sources to ethanol and carbon dioxide. Fermentation reactions are common in muscle cells, yeasts, some bacteria, plants, beer and also wine.

Fermentation occurs under anaerobic conditions. There are lots of factors that can affect the Rate of the fermentation.

Factors might affect the rate of fermentation:

- Temperature of the glucose solution
- Concentration of the glucose solution
- Volume of glucose solution
- Amount/ surface area of the catalyst

In this experiment, we are going to observe how does the concentration of glucose solution affect the rate of fermentation. We are going to use different concentration of glucose solution (0.5 moles, 1.0 moles, 1.5 moles, 2.0 moles), and we will keep the solutions in the same water bath in 41℃, because the yeast will work better at that temperature (if it is too hot, the yeast will denature, if it is too cold, the yeast will be inactive), we use the same amount of the yeast (3 grams), and we add two drops of $NaHCO_3$ solution in each boiling tubes that contains the yeast and glucose solution, because $NaHCO_3$ solution can speed up the fermentation, the yeast works better in a alkaline condition. We keep all the factors the same, except the concentration of the glucose solution, so if there is some differences between the results, we can know that the concentration of the glucose solution can affect the rate of fermentation.

I will expect the 2 moles glucose solution will have the highest rate of fermentation, because there are more glucose molecules in the solution, so there will be more chance to let yeast breaks down the glucose molecules into ethanol and carbon

dioxide and release out energy, so I will expect there will be a higher rate of reaction.

Apparatus:

- Flasks
- Boiling tubes
- Cylinders
- Cotton
- Rubber Corks
- Rubber tubes
- Water Bath
- Clam and Stand
- Short glass tube

Materials:

- Warm Water
- Yeast
- Glucose solution
- $NaHCO_3$ solution

Safety:

- Clear out the surrounding (around 1 meter).
- No eating or drinking in the lab
- Don't run around or play in the lab, you might have an accident.
- Be careful when using $NaHCO_3$
- Always wear a lab coat to provide protection for clothing.
- When something get into eyes, flush it out by water immediately.
- Girls should always tie back their long hair.
- Wash hands thoroughly before leave the lab after all lab work is finished.

Fair Test:

As we have known, there are lots of factors that can affect the rate of fermentation, such as :The temperature of the glucose solution, the concentration of the glucose solution, and the amount of the catalyst (yeast). In this experiment, we keep the temperature of the glucose solution the same by putting all the boiling tubes into the same water baths, which fills the warm water, this is not only to keep the environment the same, but also faster the fermentation, because the yeast works better at the temperature around 45℃. We use the same amount of yeast for each boiling tubes (3 grams of yeast), this can keep the amount of the catalyst the same, and we use the

same size of boiling tube to ensure the surface area for reaction is the same. The only variable in this experiment is the concentration of the glucose solution, we use different concentration of glucose solution in this experiment (0.5 Mole, 1.0 Mole, 1.5 Mole, 2.0 Mole), this is the only factor that we didn't keep the same, so if there is difference between each results, we can know that the concentration of glucose solution can affect the rate of reaction. And we can know which boiling tube has the fastest reaction by compare the results -> observe the water level dropping, the more water level dropped the faster fermentation take place. We keep all the factors that might affect this experiment the same, except the concentration of glucose solution, to ensure the accuracy.

Method 1:

Preparation:

- Draw a result table.
- Tie back long hair.
- Wear lab coats and goggles if it's necessary.
- Set up the apparatus as the diagram has shown.

Technique:

- Mix water with glucose solution (2 moles), to dilute it into 0.5 Mole, 1.0 Mole and 1.5 Mole.
- Measure 3g of the yeast
- Put the yeast into the boiling tube.
- Pour warm water into the water bath (41℃)
- Surround the water bath by cotton to keep the water warm.
- Fill up the measuring cylinders with water.
- Place the measuring cylinders in the water bath which fills water and hold it by clam and stand.
- Use dropper pump some air into the cylinders, let all the cylinders are at the same water level (in this experiment we fix the water level at 10ml).
- Use another clam to hold the boiling tubes on the stand, and let the boiling tube surrounding by the warm water which has fill in the water bath.
- Connect the rubber tubes from the boiling tube to the cylinders, make sure the air can be collect in the cylinders.
- Label the boiling tube (which boiling tube is which concentration of glucose solution.)
- Pour the different concentration of glucose solution into the boiling tube.
- Shake the boiling tubes for a few minutes.

- Put the rubber corks on at the boiling tubes
- Start the timers at the same time while put the rubber corks on the boiling tubes.
- Observe the water level drops.
- Write down the water level each minutes.
- Compare the results of different concentration of glucose solutions.

Cleanup and disposal:

- Wash all the apparatus.
- Bring all the apparatus back to the place that it placed before.
- Wipe the table.
- Wash hands after the experiment.

Method 2 (improvement):

Preparation:

- Draw a result table.
- Tie back long hair.
- Wear lab coats and goggles if it's necessary.
- Set up the apparatus as the diagram has shown.

Technique:

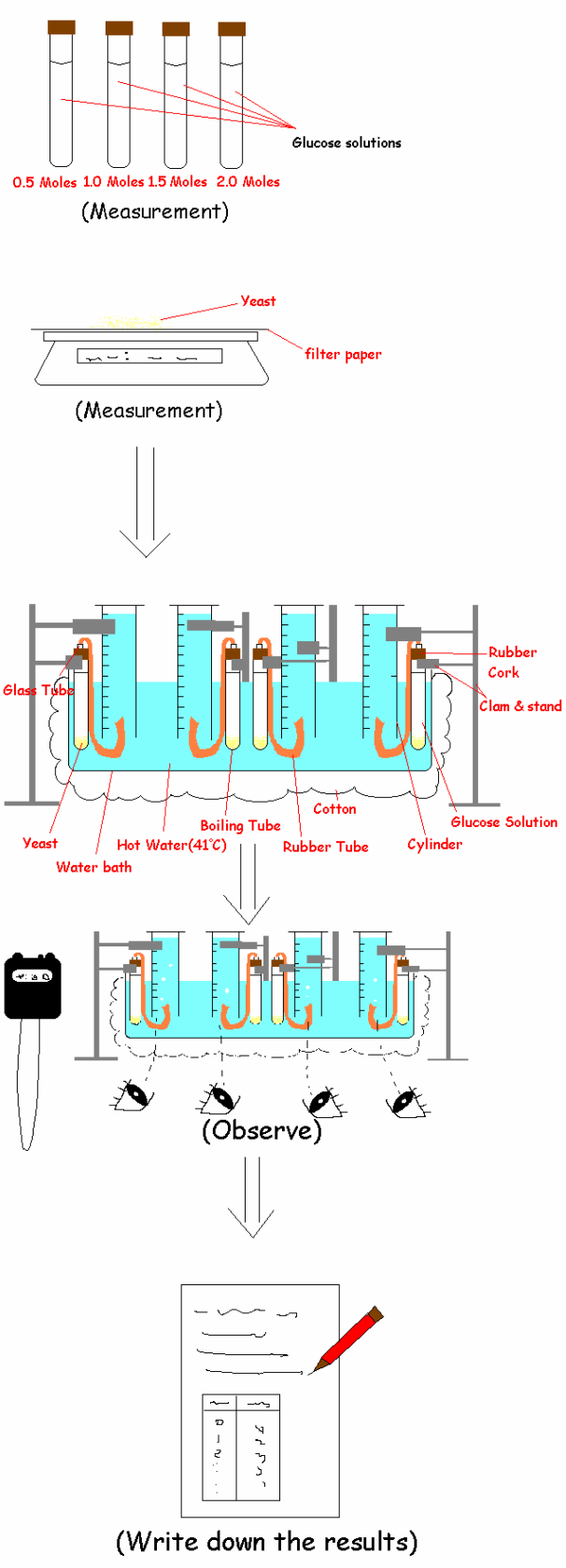
- Measure 3g of the yeast on the filter paper.
- Mix water with glucose solution (2 moles), to dilute it into 0.5 Mole, 1.0 Mole and 1.5 Mole.
- Pour warm water into the water bath (41℃)
- Surround the water bath by cotton to keep the water warm.
- Fill up the measuring cylinders with water.
- Place the measuring cylinders in the water bath and hold it by clam and stand.
- Use dropper pump some air into the cylinders, let all the cylinders are at the same water level.
- Use another clam to hold the boiling tubes on the stand, and let the boiling tube surrounding by the warm water which has fill in the water bath.
- Blow the rubber tubes, ensure it's not stuck.
- Connect the rubber tubes from the boiling tube to the cylinders, make sure the air can be collect in the cylinders.
- Label the boiling tube (which boiling tube is which concentration of glucose solution.)
- Pour the different concentration of glucose solution into the boiling tubes.
- Put the yeast into the boiling tubes.

- Drop two drops of $NaHCO_3$ solution into each boiling tubes.
- Shake the boiling tubes for a few minutes.
- Put the rubber corks on at the boiling tubes
- Start the timers at the same time while put the rubber corks on the boiling tubes.
- Observe the water level drops.
- Write down the water level each minutes.
- Compare the results of different concentration of glucose solutions.

Cleanup and disposal:

- Wash all the apparatus.
- Wash hands after the experiment.
- Wipe the table.
- Bring all the apparatus back to the place that it placed before.

Diagram:


Glucose solutions
0.5 Moles 1.0 Moles 1.5 Moles 2.0 Moles
(Measurement)
Yeast
filter paper
(Measurement)
Rubber Cork
Clam & stand
Glass Tube
Cotton
Glucose Solution
Boiling Tube
Yeast
Hot Water(41°C)
Rubber Tube
Cylinder
Water bath
(Observe)
(Write down the results)

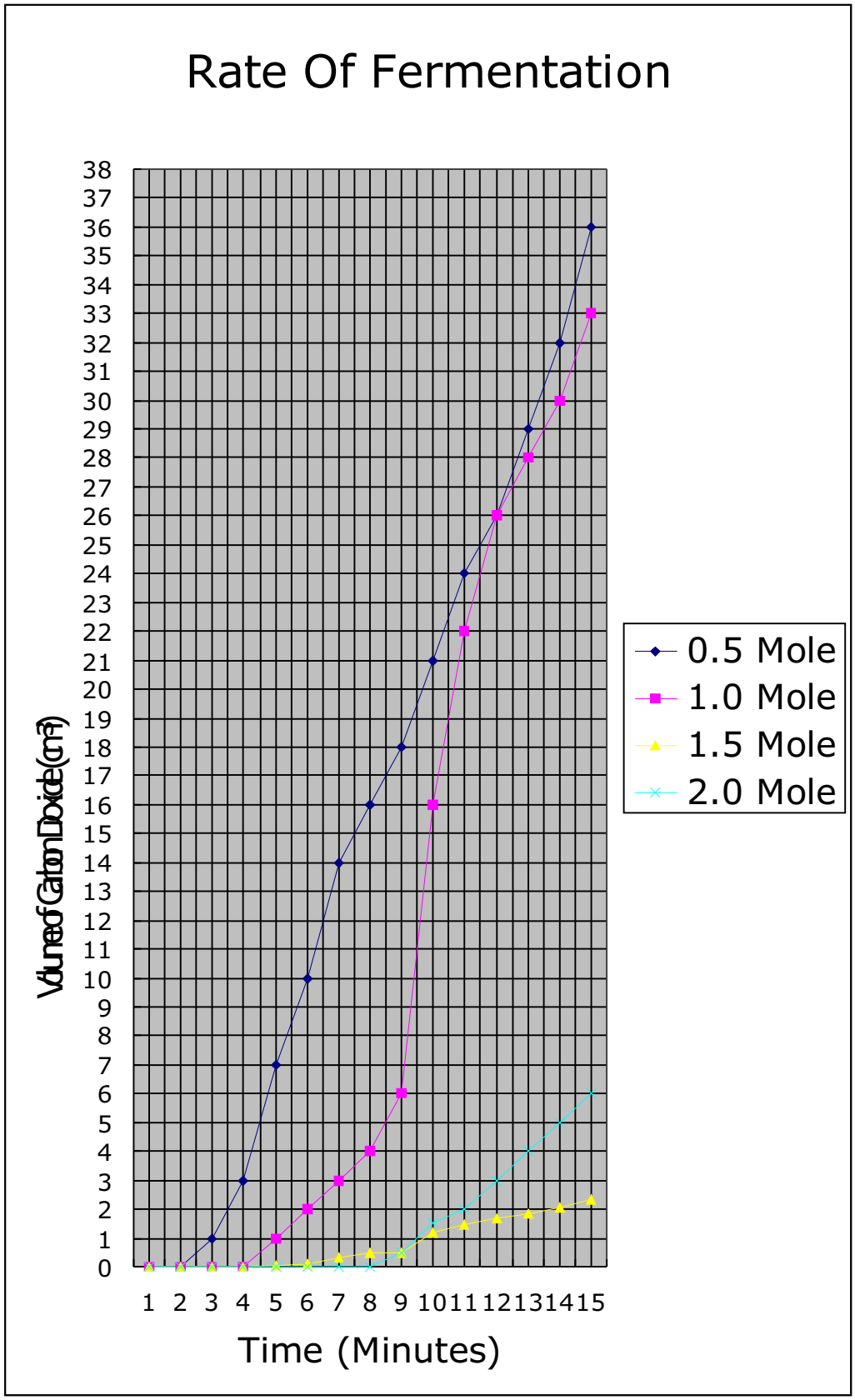
Result 1:

Dec 13th

0.5 M		**1 M**		**1.5 M**		**2 M**	
Time (Minutes)	Volume of Carbon Dioxide (cm^3)	Time (Minutes)	Volume of Carbon Dioxide (cm^3)	Time (Minutes)	Volume of Carbon Dioxide (cm^3)	Time (Minutes)	Volume of Carbon Dioxide (cm^3)
0	0.00	0	0.00	0	0.00	0	0.00
1	0.00	1	0.00	1	0.00	1	0.00
2	0.00	2	0.00	2	0.00	2	0.00
3	0.00	3	0.00	3	0.00	3	0.00
4	0.00	4	0.00	4	0.00	4	0.00
5	0.00	5	0.00	5	0.00	5	0.00
6	0.00	6	0.00	6	0.00	6	0.00
7	0.00	7	0.00	7	0.00	7	0.00
8	1.00	8	0.00	8	0.00	8	0.00
9	3.00	9	0.00	9	0.00	9	0.00
10	7.00	10	1.00	10	0.05	10	0.00
11	10.00	11	2.00	11	0.10	11	0.00
12	14.00	12	3.00	12	0.30	12	0.00
13	16.00	13	4.00	13	0.50	13	0.00
14	18.00	14	6.00	14	0.50	14	0.50
15	21.00	15	16.00	15	1.20	15	1.50
16	24.00	16	22.00	16	1.45	16	2.00
17	26.00	17	26.00	17	1.70	17	3.00
18	29.00	18	28.00	18	1.85	18	4.00
19	32.00	19	30.00	19	2.05	19	5.00
20	36.00	20	33.00	20	2.35	20	6.00

They all start at 10mL (be more accurate). The temperature was 41℃, yeast at 3g.

Result graph 1:



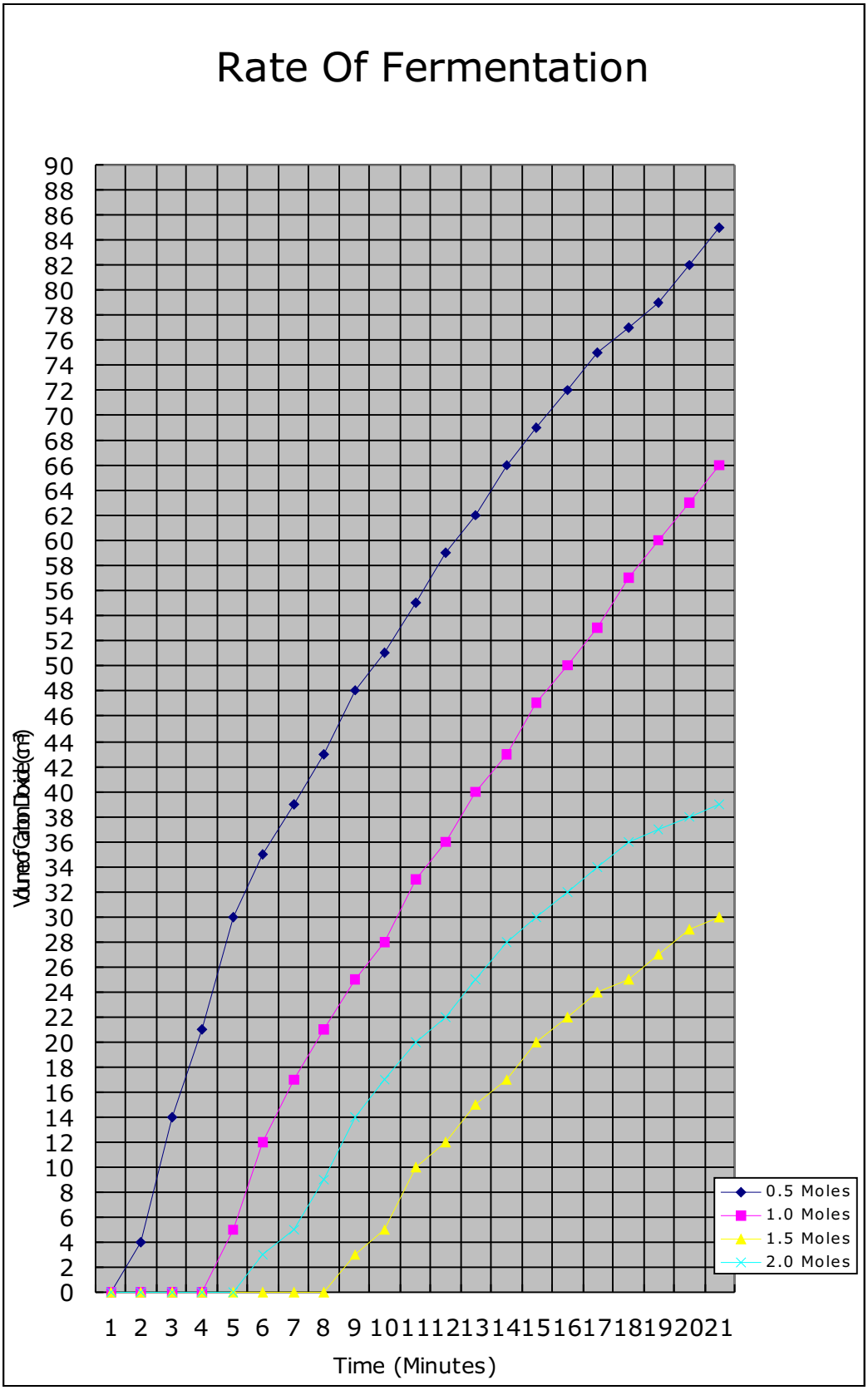
Result 2 (improvement):

Dec 20th

0.5 M		**1 M**		**1.5 M**		**2 M**	
Time (Minutes)	Volume of Carbon Dioxide (cm^3)	Time (Minutes)	Volume of Carbon Dioxide (cm^3)	Time (Minutes)	Volume of Carbon Dioxide (cm^3)	Time (Minutes)	Volume of Carbon Dioxide (cm^3)
0	0.00	0	0.00	0	0.00	0	0.00
1	4.00	1	0.00	1	0.00	1	0.00
2	14.00	2	0.00	2	0.00	2	0.00
3	21.00	3	0.00	3	0.00	3	0.00
4	30.00	4	5.00	4	0.00	4	0.00
5	35.00	5	12.00	5	0.00	5	3.00
6	39.00	6	17.00	6	0.00	6	5.00
7	43.00	7	21.00	7	0.00	7	9.00
8	48.00	8	25.00	8	3.00	8	14.00
9	51.00	9	28.00	9	5.00	9	17.00
10	55.00	10	33.00	10	10.00	10	20.00
11	59.00	11	36.00	11	12.00	11	22.00
12	62.00	12	40.00	12	15.00	12	25.00
13	66.00	13	43.00	13	17.00	13	28.00
14	69.00	14	47.00	14	20.00	14	30.00
15	72.00	15	50.00	15	22.00	15	32.00
16	75.00	16	53.00	16	24.00	16	34.00
17	77.00	17	57.00	17	25.00	17	36.00
18	79.00	18	60.00	18	27.00	18	37.00
19	82.00	19	63.00	19	29.00	19	38.00
20	85.00	20	66.00	20	30.00	20	39.00

They all start at 10mL (be more accurate). The temperature was 41℃, yeast at 3g and two drops of NaHCO3 (1M).

Result graph 2:



Observations (For experiment1) :

- Not much reaction at first few minutes.
- After the reaction start, it reacts not very fast, and after a period of time, it start to react slower.
- Yeast sink at the bottom of the boiling tubes.
- After the experiment, the boiling tubes become a little bit warm.
- Yeast came out → milky water (just for the boiling tube that contain the 0.5 mole glucose solution → the rapidest reaction.)
- Bubbles produced out from the rubber tubes.(the boiling tube that contain the 0.5 Mole of glucose solution produce the bubbles most rapidly.)

Observations (For experiment2) :

- Yeast sink at the bottom of the boiling tubes.
- React faster than experiment 1, slow down reaction after a period of time.
- Yeast came out → milky water.
- The boiling tube that contain 0.5 Mole of glucose solution react rapidest.
- At 18 minutes: 2.0 Mole: clear, no yeast
  1.5 Mole: yeast, murky
  1.0 Mole: murky with bubbles
  0.5 Mole: murky with bubbles
- At 20 minutes: 2.0 Mole: milky
  1.5 Mole: milky with bubbles
  1.0 Mole: milky with bubbles
  0.5 Mole: yeast, milky
- After the experiment, the boiling tubes become a little bit warm.

Discussion:

What is fermentation?

Fermentation is the process by which the living cell is able to obtain energy through the breakdown of glucose and other simple sugar molecules without requiring oxygen. In alcoholic fermentation, such as occurs in brewer's yeast and some bacteria, the production of lactic acid is bypassed, and the glucose molecule is degraded to two molecules of the two-carbon alcohol, ethanol, and to two molecules of carbon dioxide.

Glucose -> Ethanol + Carbon Dioxide + Energy ($C_6H_{12}O_6$ => 2 C_2H_5OH +2 CO_2 + 2 ATP +heat)

How come after the experiment, the boiling tubes are warmer than before?

The boiling tubes became warmer is because we placed it into the warm water bath, and while the fermentation take place, there will release some energy, so after the experiment, we can notice that the boiling tubes is warmer than before.

Why should we add a few drops of $NaHCO_3$ solution into each boiling tubes in experiment 2?

The reason why we add a few drops of $NaHCO_3$ solution into the boiling tubes is because the yeast work better in the alkaline environment, so we add a few drops of $NaHCO_3$ solution into the boiling tube, to make the glucose solution change into a higher pH, then the yeast can work more efficiently

Why did we put all the boiling into the water bath?

The temperature of the glucose solution is one of the factor that can affect the rate of reaction, if the temperature is too high, the yeast will denature, if the temperature is too low, the yeast will be inactive. Yeast will not work very efficiently at the room temperature, so if we do this experiment at the room temperature, that might took very long time, so we put the boiling tubes into warm water (41℃), too let the yeast work more efficiently. And we put all of the boiling tubes into the same water bath, to ensure that all the boiling tubes are keeping in the same environment.

Why the water bath has to surround by the cotton?

The reason why we surround the water bath with cotton is to keep the water's temperature. The water that is contained in the water bath is 41℃. If we didn't put the cotton around the water bath, there will be more heat lost, and the temperature will drop very fast, that might affect the accuracy of the experiment, so we surround the water bath with lots of cotton to ensure there will be less heat lost.

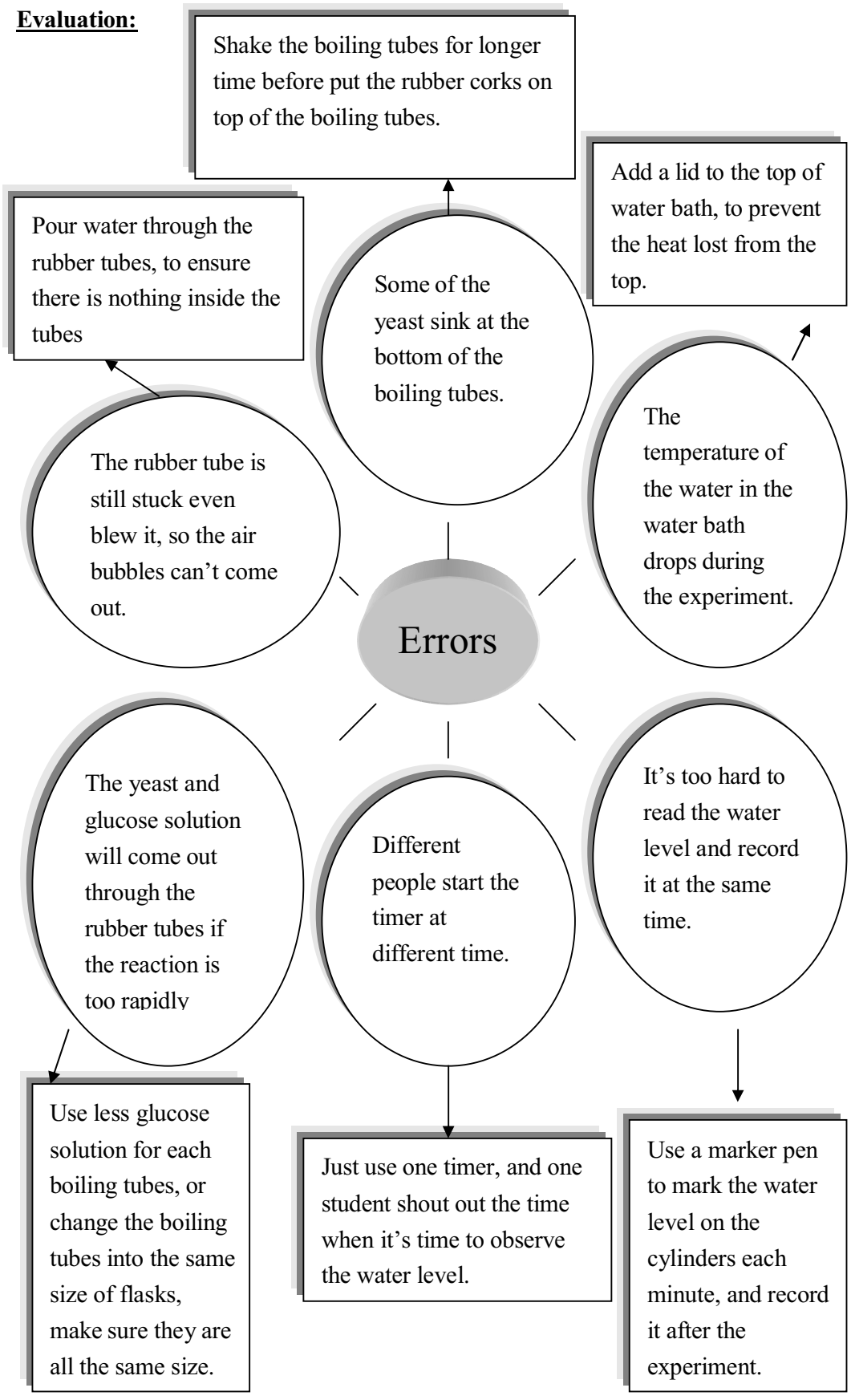
Conclusion:

Fermentation is caused by yeasts and enzymes. Alcohol fermentation is the formation of alcohol from sugar. Yeast, when under anaerobic conditions, convert glucose to pyruvic acid via the glycolysis pathways, then go one step farther, converting pyruvic acid into ethanol, a C -2 compound. Yeast cells will use oxygen if it is present, and break down sugars all the way to CO_2 and H_2O. In the absence of oxygen, yeast will switch to an alternative pathway that does not require oxygen. The end products of this pathway are CO_2 and ethanol. The first pathway yields a lot more energy per sugar molecule consumed, and so it is the "preferred" pathway if oxygen is present.

- **Glucose + Oxygen = Carbon Dioxide + Water + Energy**
- **Glucose => Ethanol + Carbon Dioxide + Energy (**$C_6H_{12}O_6$ => 2 C_2H_5OH +2 CO_2 + 2 ATP +heat)

In this experiment, we can see that the lower concentration the higher rate of fermentation from the results, the water level drops the most in the 0.5 Mole cylinder. There is more fermentation take place while the yeast is in a lower concentration of glucose solution. This is because, there is less glucose molecules in the less concentrated glucose solution, so the surface area for yeast to react with is much bigger than in concentrated glucose solution. The yeast changes the glucose into ethanol, carbon dioxide and energy, the fermentation took place. There will be more yeast work on one glucose molecule in the less concentrated glucose solution, because there are less glucose molecules in the solution, so the rate of fermentation will be much faster than that in the concentrated glucose solution.

Evaluation:


Errors
Some of the yeast sink at the bottom of the boiling tubes.
Shake the boiling tubes for longer time before put the rubber corks on top of the boiling tubes.
Pour water through the rubber tubes, to ensure there is nothing inside the tubes
The rubber tube is still stuck even blew it, so the air bubbles can't come out.
Add a lid to the top of water bath, to prevent the heat lost from the top.
The temperature of the water in the water bath drops during the experiment.
The yeast and glucose solution will come out through the rubber tubes if the reaction is too rapidly
Use less glucose solution for each boiling tubes, or change the boiling tubes into the same size of flasks, make sure they are all the same size.
Different people start the timer at different time.
Just use one timer, and one student shout out the time when it's time to observe the water level.
It's too hard to read the water level and record it at the same time.
Use a marker pen to mark the water level on the cylinders each minute, and record it after the experiment.