Biology coursework

Investigating the rate of photosynthesis in Elodea canadensis

INTRODUCTION

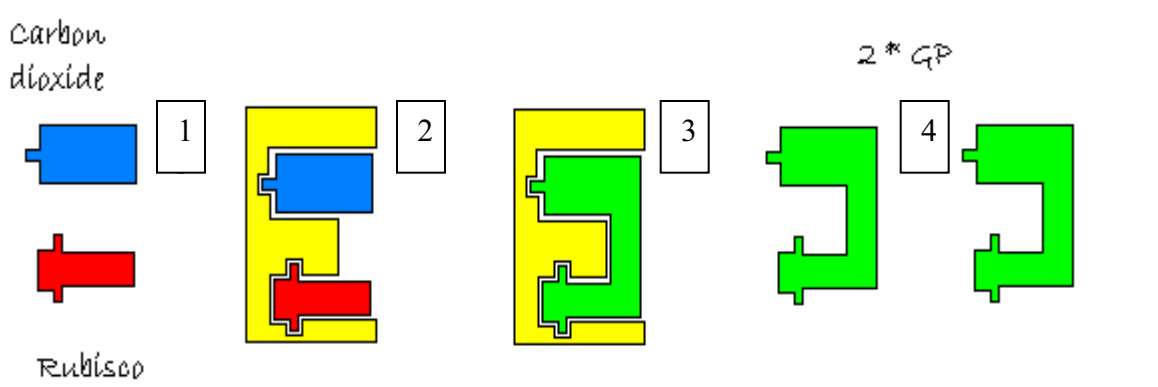
AIM:

The aim of this experiment is the effect of temperature on the rate of photosynthesis in Elodea canadensis.

BACKGROUND KNOWLEDGE:

As level: From Biology 1 (2000) JONES, FOSBERY + TAYLOR

From AS level we learnt about enzyme structure and how products are formed.



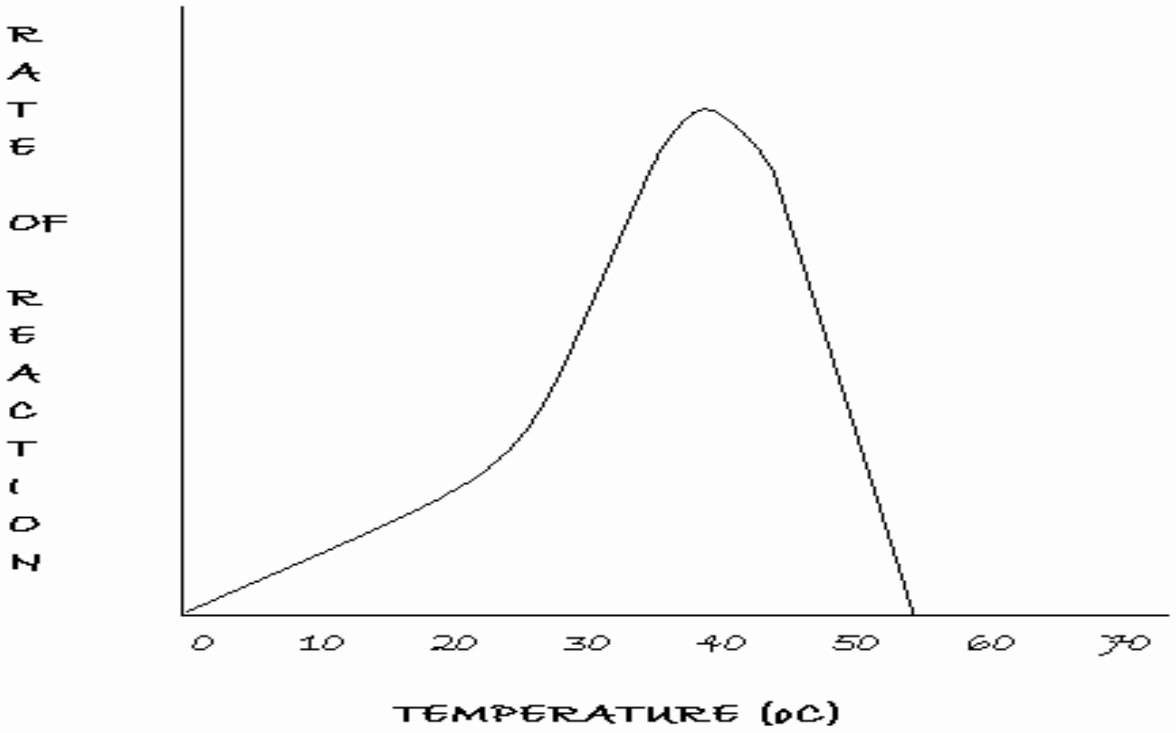
When carbon dioxide comes into contact with Rubisco it is converted to 2 X Glycerol-3-Phosphate. The yellow object is an enzyme. Enzyme's act as a catalyst to speed up the reaction and remains unchanged at the end of the process. With an enzyme present it increases the likelihood of a collision of the substrates to form a product.

Enzymes are globular proteins and are coiled into three-dimensional shape, which have hydrophilic side chains on the outside to make sure they are soluble.

In picture 1, we have a carbon dioxide molecule and a Rubisco molecule. These are called the substrate molecules. In picture 2, we have carbon dioxide and a Rubisco molecule combined with an enzyme. The enzyme is there to combine both molecules together. It is now called an enzyme-substrate complex. It is held together by temporary bonds between the substrate and side chains of the enzyme. In picture 3, the two molecules are combined and have now formed our product, Glycerate-3-phosphate. Picture 4 just demonstrates the products out of the enzyme.

When an enzyme is present, the likelihood of a collision between the two substrates increases. The enzyme increases the rate that chemical reactions take place. When a substrate is converted to a product, (In our case when carbon dioxide and Rubisco is converted to glycerol-3-phosphate (GP)) energy is required, this is called the activation energy. An enzyme reduces the activation energy, when the substrates come in contact with the enzyme its shape changes briefly to encourage the two substrates to combine to form our product, Glycerol-3-phosphate. If an enzyme was not present, we would have to find another way to encourage the two substrates to combine.

One way is to heat them. The graph below shows the effect of temperature on the rate of reaction:



When the temperature is fairly low, there is not much energy present to allow the reaction to take place and therefore it takes a long time to manufacture products. As the tempreture increases so does the rate of reaction until it reaches an optimum temperature of around 35-40 °C. After this temperature, the enzyme's cell membranes get affected and therefore become de-natured and cease to work.

A2 Level: Biological sciences 1+2, 3RD Edition (1997), TAYLOR, GREEN + STOUT.

The limiting factors that affect the rate of photosynthesis are: Carbon dioxide concentration, light intensity, temperature, chlorophyll concentration inside the chloroplast and water.

From A2 level we learnt about the two different types of photosynthesis and how they occur.

The first type of photosynthesis is the LIGHT-DEPENDENT REACTIONS, whereby the plant needs light to be able to carry out photosynthesis to form a carbohydrate and oxygen. The general formula for this is:

$n\,CO_2 + n\,H_2O$ -- LIGHT ENERGY PRESENCE IN CHLOROPHYLL --> $(CH_2O)\,n + n\,O_2$

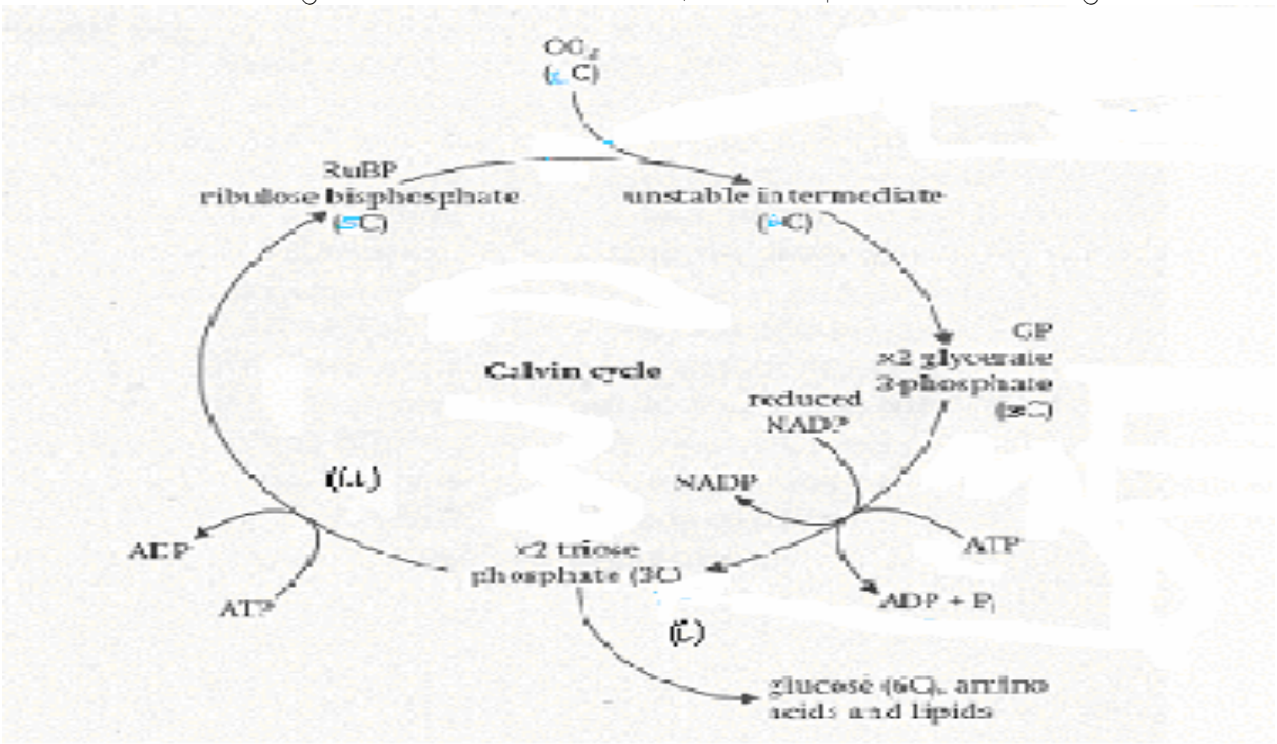
The light-dependent reactions n[illegible] to be able to split water into hydrogen and oxygen ions, and also to provide energy for ATP synthesis and to reduce NADP. This will only occur when light is present. This reaction occurs in the presence of a pigment called chlorophyll

which absorbs light. There are two types of light-dependent reactions to do with photosynthesis; CYCLIC PHOTOPHOSPHORYLATION, NON-CYCLIC PHOTOPHOSPHORYLATION and there is also a process called PHOTOLYSIS which supplies photosystem II with electrons to power it.

Cyclic Phosphorylation occurs in the thylakoid membrane inside the chloroplast. When light hits photosystem I (Also known as P700) it causes it to emit high energy electrons which in turn supplies energy to phosphorylate ADP to ATP by a process called chemiosmosis. The electrons are then returned to photosystem I to be repeated.

Non-cyclic Phosphorylation also occurs in the thylakoid membrane. Photosystem II emits high energy electrons too to an electron carrier which passes it down to photosystem I and also supplies energy to phosphorylate an ADP molecule to an ATP. The electrons emitted from photosystem I are passed up to an electron carrier and is combined with $2H^+$ and a $NADP^+$ to form NADPH and H^+. The two H^+ molecules have come from a process inside photosystem II called photolysis. It splits water (H_2O) into two molecules of H^+ and $\frac{1}{2}$ O_2.

The second type of photosynthesis is the LIGHT INDEPENDENT reactions. These do not require light to progress as they are supplied with the energy manufactured in the light dependent reactions. This process is a cycle and as long as the products are available it will continue. It is known as the Calvin cycle. It occurs in the stoma of the chloroplast. Below is the cycle.



Above CO_2 is combined with Ribulose Biphosphate to form a six-sugar unstable compound, this is then converted to 2 glycerate-3-phosphate (GP), in turn an ADP is turned into an ATP and a reduced NADP molecule is converted to a normal NADP, after this, it is converted to 2 triose phosphate molecules. There are two pathways triose phosphate can take from here, it can either be

condensed to a glucose six carbon sugar compound or it will synthesis another ADP molecule to an ATP and become a Ribulose Biphosphate molecule and restart this process again.

PREDICTION

PREDICTION

As we know this is an enzyme controlled reaction, enzyme's work best at an optimum temperature of around 35/40°C. So I believe that between 0 and 25°C progress will be slow, between 25 and 40°C it will be at its optimum temperature and therefore manufacture more Ribulose Biphosphate to combine with CO_2 and the reaction will move faster. As temperature rises the two molecules will combine easier. At 0°C, water is a solid and as we all know water is an important part of photosynthesis. There will also be no diffusion of O_2 or CO_2 so no photosynthesis will occur. Above 40°C enzymes become denatured and begin to malfunction and therefore stop manufacturing Ribulose Biphosphate.

In an experiment carried out a while ago, many students investigated the rate of reaction against temperature. They tried it at 4 different temperatures: 10°C, 30°C, 40°C and 45°C. The results are as follows:

Water Temperature (°C)	Number of Oxygen bubbles produced in 5 min.	Oxygen bubbles produced per min.
10	56	56 /5 =11.2
30	147	147/5=29.4
40	6	6/5=1.2
45	2	2/5= 0.4

As we can see from this experiment the optimum water temperature is 30°C. The optimum temperature is calculated by an equation known as the Q_{10}.

$$Q_{10} = \frac{\text{Rate of reaction at temperature t + 10°C}}{\text{Rate of reaction at temperature t}} = 2$$

In the biological sciences book, we learnt that rate of reaction doubles every 10°C from 25°C to 35°C. Even though it says that the plant grows better at 25°C due to other factors.

VARIABLES

VARIABLE

The variable I will change will be temperature. I will use values between 0°C and 60°C. This is because below 0°C water is a solid and therefore no photosynthesis will occur, and above 60°C the enzyme involved will become denatured and therefore no photosynthesis will occur.

CONSTANT

The things I will keep constant are:

- The same species of plant and if possible from the same source.
- Similar mass of Elodea Canadensis so the calculations at the end will be a little easier.
- Light in excess

An experiment carried out to see when light would be in excess, the results are as follows:

How many lamp's of 60 watt?	Wattage	Bubble size (mm)
5	300	30
4	240	26
3	180	31
2	120	22

The temperature for this experiment was 340c, it was carried out in a 2 litre beaker, the bubble length was calculated every 3 min, the Elodea canadensis was 100mm long and weighed 1.82g, and 2g of $NaHCO_3$ was used to allow CO_2 to be in excess. As we can see from the table unlimited light would be around 180 watts to 200 watts.

- CO_2 in excess

In another experiment carried out students wanted to find out when CO_2 was in excess, the results are as follows:

Mass of $NaHCO_3$ (g)	Length in bubble (mm)
0.0	8
0.5	10
1.0	8.5
1.5	11.5
2..0	12
2.5	12

The temperature for this experiment was 24°C, the plant weighed 2.63g, it was also measured in a 2 litre beaker, light was in excess at 240 watts and the length of each bubble was recorded at 3 min intervals. From this experiment unlimited CO_2 looks like it would be in excess when at least 2 grams of $NaHCO_3$ is present. Water Plants can use $NaHCO_3$ ions as a substrate instead of CO_2 concentration. I think a good estimate for $NaHCO_3$ ions to be used is 1 gram per 1 litre of water.

- Volume of water to remain constant at 2 litres.
- The water used will be distilled water and will come from the same tank.
- When doing the experiment the environment is to stay the same.
- I think it could be an idea to use oxygenated water to help with the synthesis of CO_2.

MEASURING TECHNIQUES

The measuring technique I will use will be collecting the bubbles and measuring the volume of the bubbles collected per minute, this will be more accurate then counting the bubbles because it is much harder and less accurate then the first method. If you decide you want to count the bubbles, you will find it extremely hard as a lot of bubbles will be leaving the plant and you will have to be very quick not to miss any. The apparatus I will use to measure the volume of the bubbles collected will be a gas burette designed to trap bubbles of oxygen.

PRELIMANARY WORK

PRELIMANARY WORK

When doing an experiment like this many things are to be carried out before. For example collecting secondary data to see how and why an experiment maybe carried out and what the results maybe like in different circumstances. For my preliminary work, I used a few sources, examples of these would be: the light in excess experiment, the CO_2 in excess experiment, how to measure the O_2 collected, how the length/weight of the plant will affect the results, how the temperature affects the overall production of O_2 bubbles.

From past experiments using a gas burette and collecting O_2 bubbles is to cut the plant at an angle under a tap, this is because it will stop the plant getting air bubbles inside the phloem and xylem and it will cease to work or take a long time to work, which in turn will work against us. Also from past work I have found that an experiment like this may take up to 10mins for the plant to start photosynthesising, this is because the plant is somewhere foreign and has to adapt to its new surroundings before it feels safe to do so.

I have also found that the different types of light can have an effect on how much photosynthesis it will and can carry out. If using a water bath and a lamp and we are measuring the effect of light on rate of photosynthesis, the light will affect the temperature of the water bath as the rays of light will hit the water before it hits the plant and therefore increasing the temperature, which is what we are not testing. To prevent this happening you can use a heat shield which absorbs the heat from the light rays but still allows light through.

SECONDARY SOURCES

The secondary sources I used to aid me in my plan and prediction are:

- Biology 1 book from AS level: For information about enzymes, (2000) JONES, FOSBERY and TAYLOR.
- Biological Sciences 1 + 2: For the formula of photosynthesis, (1997) TAYLOR, GREEN and STOUT.
- Biology 2 book from A2 level: For information concerning light-dependent reactions such as cyclic and non-cyclic photophosphorylation and photolysis, and the light independent reactions such as the Calvin cycle.
- Rate of reaction against Temperature experiment: This was used so I could get some idea of the likely outcome of what my experiment would be like, PREVIOUS STUDENT'S WORK.
- Biology revision guide A2: For the Q_{10} optimum value,
- Light in excess experiment results: This Is so we can have light in excess when we come to carry out this experiment, PREVIOUS STUDENT'S WORK.
- Carbon Dioxide in excess experiment: This was so we knew that when we carried out this experiment CO_2 would not be a limiting factor, PREVIOUS STUDENT'S WORK.

METHOD

STEP BY STEP METHOD

1. Collect a beaker and fill it up with 2 litres of distilled water and record the temperature. This will now be known as the water bath.
2. Next add ice to lower the temperature to 0°C.
3. Collect 3 lamps of 60 watts each and plug in to a socket.
4. Collect a heat shield and position between the lamps and the water bath.
5. Switch them on.
6. Allow for the temperature to adjust.
7. Collect a gas burette and a syringe.
8. Fill up the gas burette with water (Tap water will do), make sure no air bubbles get in and plunge the syringe until the end.
9. Put this tube inside the water.
10. Add 2g's of Sodium Hydrogen Carbonate to the distilled water inside the water bath.
11. Next step is to collect an Elodea canadensis plant and separate one column from a source where by we know that it has been well illuminated and is photosynthesising actively.
12. Weigh the mass and record the length of the Elodea canadensis.
13. Next turn on the cold water tap and place the Elodea canadensis under the tap, with the shoot underneath the running water.
14. Cut the plant with a razor blade at an angle of 45 degrees and make sure that no air bubbles get inside.
15. Connect the plant shoot to the gas burette.
16. Check the temperature of the water bath just so it remains constant.
17. Start the timer and allow 5 minutes for it to start photosynthesising
18. Record bubble length at 3 minute intervals.
19. Stop timing at 30 minutes.
20. Repeat all steps for the next temperature of 10oC, then 20°C, then 30°C, then up to 60°C.

JUSTIFICATION

To justify my apparatus and chosen method I will do each individually:

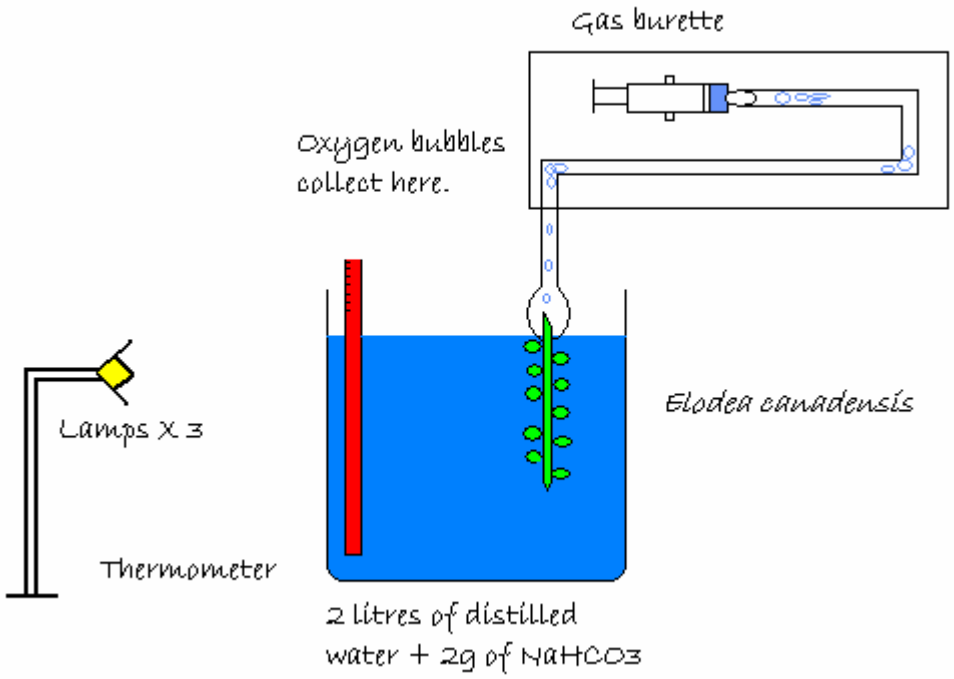
- Using a 2 litre water bath: This is so water is in excess and will have no trouble diffusing into the plants shoot.
- Using a water plant: This is easier at recording O_2 production.
- Using a gas burette: This is also to make it a little easier at measuring O_2 production.
- Using 2 grams of $NaHCO_3$: This is so carbon dioxide is excess.
- Using 180 watts of light: This is so light is in excess.
- Using a heat shield: As I have said before, to prevent heat escaping into the water bath and increasing the temperature.
- Record it at 3 min intervals: This is because it allows the plant to produce O_2 bubbles and then dividing that by 3 gives us an average,

QUANTITIES

The equipment I will use will be as follows:

- 14 litres of distilled water, 2 litres for each experiment.
- 2 litre beaker.
- A syringe for the gas burette.
- 3 lamps of 60 watts each.
- 14 grams of Sodium Hydrogen Carbonate ($NaHCO_3$), 2g's for each experiment.

DIAGRAM



VARIABLE CHANGE

The variable I will be changing is the temperature of the water. The different values I will use are: 0°C, 10°C, 20°C, 30°C, 40°C, 50°C and 60°C. My reasons for this is that the optimum temperature for enzymes are around 35/40°C, so I decided to go down 35°C and up 20°C. Using 7 values from 0°C to 60°C gives me a broad idea of rate of photosynthesis against temperature. The first experiment I will do will be the 0°C because that way the enzymes inside the plant don't start to become denatured before the experiment has a chance to begin.

REPEAT EXPERIMENTS

Repeating this experiment would give us a good average of rate of photosynthesis against temperature. I will repeat this experiment 10 times as this is a good value so we can eliminate one or two experiments that have gone a little wrong, but still have some decent values to work into an average.

WHAT IS BEING MEASURED?

I am measuring the volume of O2 produced from Elodea canadensis at different temperatures. The way to calculate this is by using the volume calculation, which is:

$$\text{Volume} = \pi r^2 \text{ X } l$$

r = 0.5mm, π = 3.14, l = length of bubble

As we are measuring it in 3 minute intervals, we divide the answer by 3. Also the weight of the plant, we want to work it so it is measured as: per gram/per min of rate of photosynthesis against temperature. So say for example the weight of the plant is 1.45g at 3 minute intervals, we divide the answer by 3 and then by 1.45 to calculate per gram/per min.

EQUIPMENT NEEDED

- 2 litre beaker.
- A plant of Elodea canadensis from a source where it has been well illuminated and photosynthesising actively.
- A thermometer.
- Ice cubes.
- Hot water from a kettle for the higher temperatures.
- A gas burette.
- A syringe for the gas burette.
- Scales for measuring the weight of the Elodea canadensis.
- A ruler to measure its length.
- A razor blade.
- A stopwatch.
- A heat shield.
- 14 litres of distilled water, 2 litres for each experiment.
- 2 litre beaker.
- A syringe for the gas burette.
- 3 lamps of 60 watts each.
- 14 grams of Sodium Hydrogen Carbonate ($NaHCO_3$), 2g's for each experiment.

SAFETY

The safety aspects to this experiment are:

- Using a plug socket: Always make sure you have dry hands when using electrics as there is a chance of electric shock.
- Using a razor blade: A razor blade is sharp, use with caution and do not leave it somewhere where someone may hurt themselves.
- Beaker size: As the size of the beaker we are using is a 2 litre one, be careful not to knock it off the edge of a table.
- Using an irritant ($NaHCO_3$): From the Haz Card, Sodium Hydrogen Carbonate is an irritant, so take care with handling it, for example wear eye protection and use a spatula when handling it.