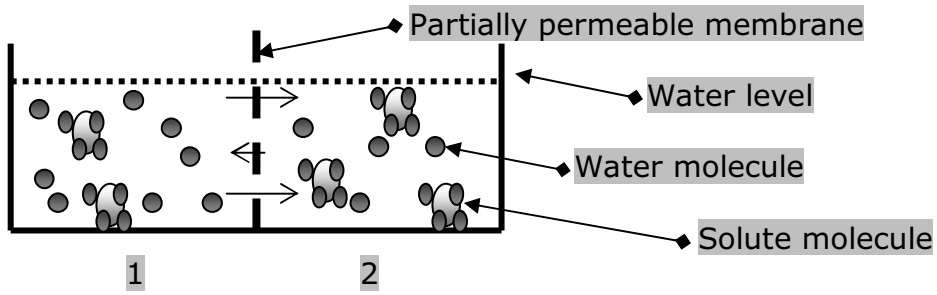
☺Determine the water potential of potato tuber cell with the varying affect☺ ☺of solute concentration☺

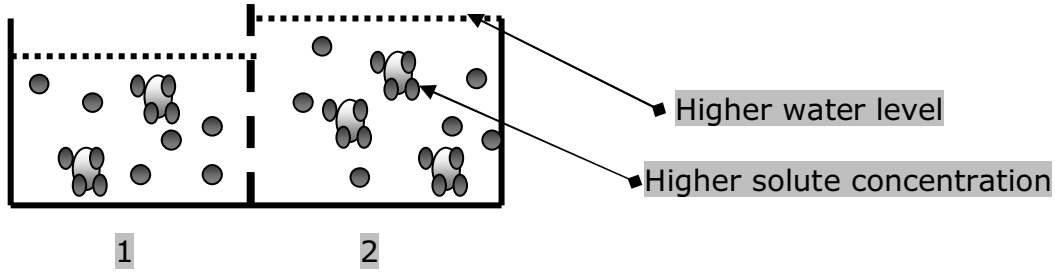
Introduction☺

This investigation will try to determine the water potential of potato tuber cells. This will be carried out by using a potato cylinder and bathing it in different solutions of solute with different molarities and distilled water, which is pure. We will be able to find the water potential of the potato tuber cell by finding on the graph the equilibrium point where no water enters or leaves the potato. Osmosis has a very important role in this experiment. It is safe to say that osmosis is a unique type of diffusion, however only concerning with water molecules when they pass through a partially permeable membrane. When talking about the components of osmosis, the solvent (the water) and the solute (the sugar) added together make up the solution. In osmosis we always have a partially permeable membrane (the potato). It is known as this because it only allows certain molecules pass through like in our case the water molecules, just like a membrane in real life.

Looking at the diagram below, we can see that sample 1 has a lower concentration of solute molecules which means it is a more dilute solution since there is a higher concentration of water molecules. Sample 2 is more concentrated since there are more solute molecules. If all the molecules could pass through the membrane, there would be a net movement of solute molecules from 2 to 1 via diffusion due to the higher concentration of solute molecules in sample 2. The solute molecules would go in between the spaces available which is why there would be a net movement.



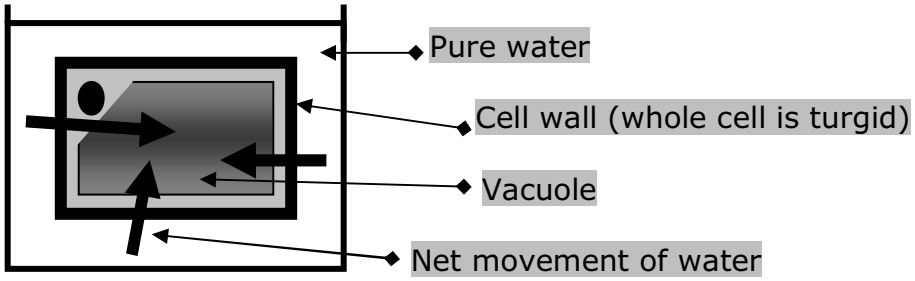
We know that only the water molecules can pass through the membrane so what was said above would only count if the membrane was removed. Physically the larger solute molecules are too large to pass through the membrane however the water molecules are the right size. This means that it is only possible for the water molecules to pass through the membrane. This will mean that there will be a net movement of water from sample 1 to 2. However this net movement will not continuously carry on because when sample 1 has the same concentration of water and solute molecules in total as sample 2, equilibrium will be reached. Due to this effect of osmosis, the water level of 1 will fall and 2 will rise even though they have the same water concentration!



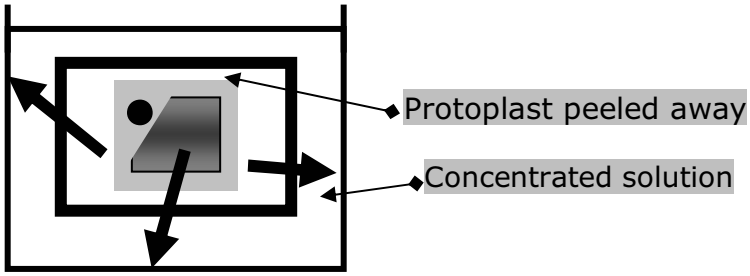
In this case the partially permeable membrane will be the potato as it is a plant cell (potato tuber cell) and sucrose will be the liquids along with distilled water as the purest sample.

Water potential (ψ) is also an important part of the theory just as osmosis is. The best way to describe water potential is by saying it is a measure of the tendency of the water molecules to want to move from one area to another (just like from the potato to the surroundings). Water has a peculiar feature. This is the tendency to move from places of a high to low water potential thus moving along or down the water potential gradient. As mentioned before, this osmotic affect will continue until equilibrium, when the water potential is equal in both places thus there will not be any net movement of water molecules. From the first diagram above you are able to see that sample 1 has the higher water potential as there is a higher concentration of water thus water is moving from 1 to 2. This means that the 'aim' of the solutes is to lower the water potential. So with water potential, we can say that this osmotic affect occurs when there is a net movement of water from a solution of high to low water potential. When there is a solute present in the solution, it always lowers the water potential. This means that since the water potential of water is 0, the solute will make the potential less than 0 making it a minus figure. Solute potential (ψs) is the amount that the solute molecules lower the water potential of a solution, it is therefore always negative. It is confusing to remember but sample 2 has the lower solute potential.

Pressure potential (ψp) is also important however in this case it is not applied due to the fact that no external pressure is applied. In plant cells osmosis happens in them directly. Before we were only talking about water passing through the cell membrane. With pressure potential we can concentrate more on the plant cells themselves. If a plant cell is placed in pure water, the water will have a higher water potential than the cell. This means that there will be a net movement of water into the cell. If it were an animal cell, the cell would burst due to the amount of water since a lot of water is needed to reach equilibrium. However plant cells have a cell wall which is elastic enough to prevent the cell from bursting therefore making it **turgid**. Turgid is used when the cell is fully inflated.



On the other hand, if we put the same cell in a very concentrated solution, the opposite will happen. Instead of becoming turgid, the cell will become plasmolysed. This only happens in solutions with lower water potential then the cell. As the net movement of water goes out of the cell the protoplast peels away from the cell wall until equilibrium has been reached "Foundation biology" (Cambridge modular sciences 2001).

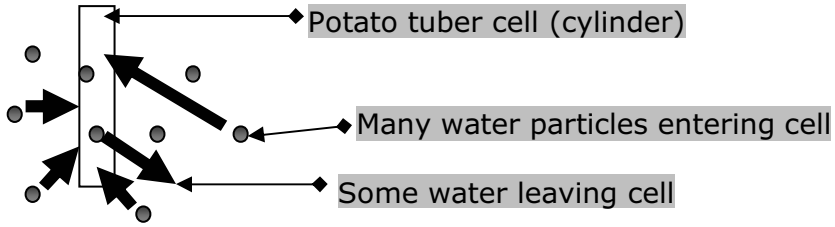


The reason why we use a potato cylinder is because it is made up of plant cells plus the fact that it has a partially permeable membrane. So to be able to determine the water potential it is essential to know the structure of the plant cell membrane.

Prediction☺

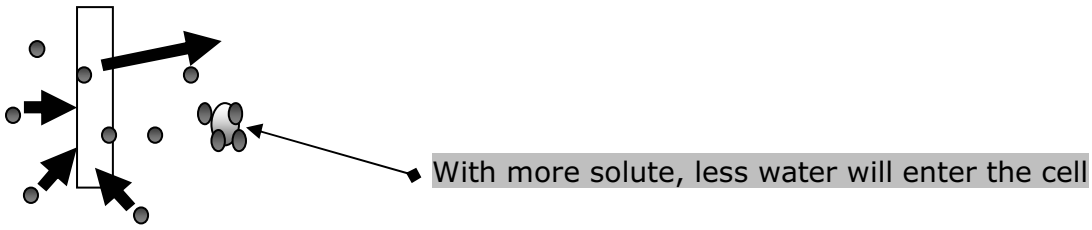
In this part of the investigation, predictions will be made using scientific knowledge and understanding. Pressure potential will not be included as there is no external pressure applied.

For distilled (0.00 mol dm^{-3}) water I predict that the change in mass will be quite significant as I predict that it will gain a lot of mass. I predict this because I know that the distilled water will have a much higher water potential than the potato. As explained in the introduction, this will mean a net movement of water from the outside into the inside until equilibrium is reached or until the potato tuber cell is fully turgid. I also predict that the increase in mass will be the most out of all solutions however I predict that the change in mass will not be the most out of all solutions.



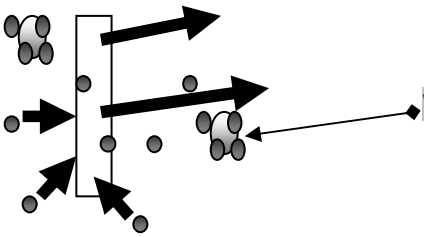
The high concentration of water and almost no solute means that there is a higher concentration of water outside the cell, so water will move in as a net movement. Using my scientific knowledge and some preliminary work I will predict that the change in mass will be around +0.20g. I cannot make a percentage change prediction because I do not know the initial masses of the potatoes yet.

For the 0.2 mol dm^{-3} sucrose solution, I predict that there will again be an increase in mass. However this time due to the increase in concentration, I predict that the change in mass will not be as much. I predicted this because now there is a higher concentration of solute molecules in the solution. This means that now there is a lower concentration of water outside the cell which will mean that less water will go in the cell. Despite this there is still a higher concentration of water outside the cell so I predict that there will still be a gain in mass.

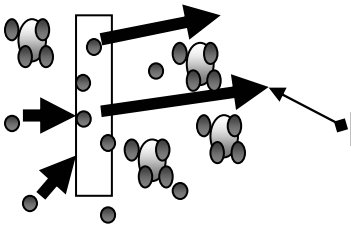


With the information provided plus my knowledge I predict that the change in mass will be around +0.13g

My next prediction is for the 0.4 mol dm^{-3}. For this sucrose concentration I predict that there will still be an increase in mass of the cylinder. However this time the change in mass will be very small due to the fact that the solute concentration has increased more. This means that even thought the concentration of water is still more on the outside than on the inside if the cell, it has gone down a lot due to the increase in solute concentration. This means that the potato is closer to equilibrium and so less water will enter the cell since the concentration of the water molecules is less since the solute molecules take up space. Since the gain in mass will be the least (or so I predict) I predict that the gain in mass will be very low at +0.04g

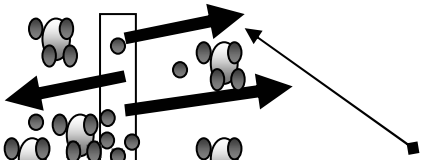


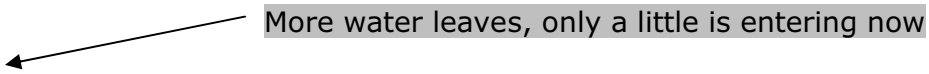
Now I will make my predictions for the 0.6 mol dm^{-3} sucrose solution. For this concentration my prediction will slightly change. Now with this concentration I predict that instead of the cylinder gaining mass, it will now loose mass. I predict this because there is such a high solute concentration outside the cylinder which means that the water concentration will be more on the inside of the cylinder than on the outside because the solute molecules take up so much space. As explained above, because water molecules move down the concentration gradient, it will mean a net movement of water will be going out of the cell. This basically happens because the concentration of water outside the cell is less than on the inside.



However even though I predict that there will be a loss of mass, I also predict that the loss will only be a little since the cylinder is almost at equilibrium. This means that I predict that the rate of water entering the cylinder will be quite close to the rate of water going out of the cylinder. Even with the distilled water, some water does leave the cylinder as the rest enters. Now that I predict there is a loss of mass I predict that the loss of mass will be around -0.15g.

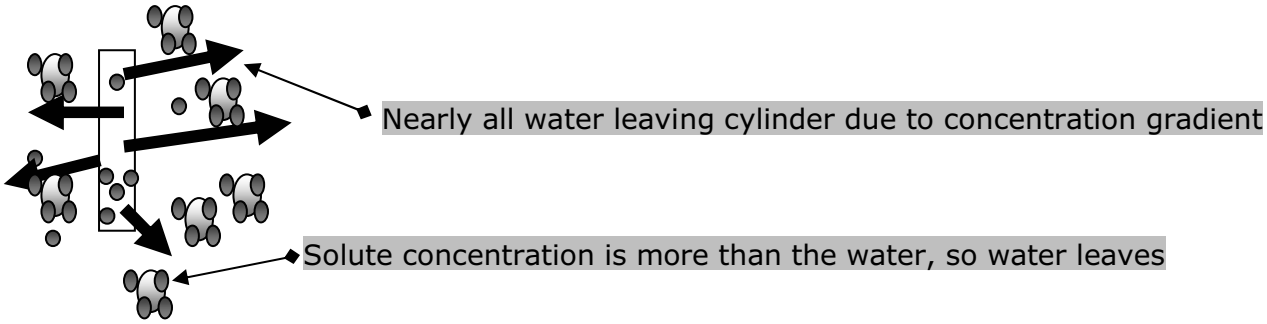
This prediction will be for the 0.8 mol dm^{-3} sucrose solution. I predict that now there will be a larger loss of water therefore loss of mass for this solution. I have predicted this because now the concentration is now much higher and the dilution is low. This means that water will leave the cylinder plus I predict that the mass loss will be more than that of the 0.6 mol dm^{-3} solution because now the concentration of water is much less on the outside than on the inside of the potato tuber cells or cylinder. Since water always (in osmosis) moves down the concentration gradient, it means that more water will move out of the cell since there is less water in the solution (surrounding medium).





This is a high concentration so the water loss will be greater and so I predict that the loss of mass will be around -0.18g.

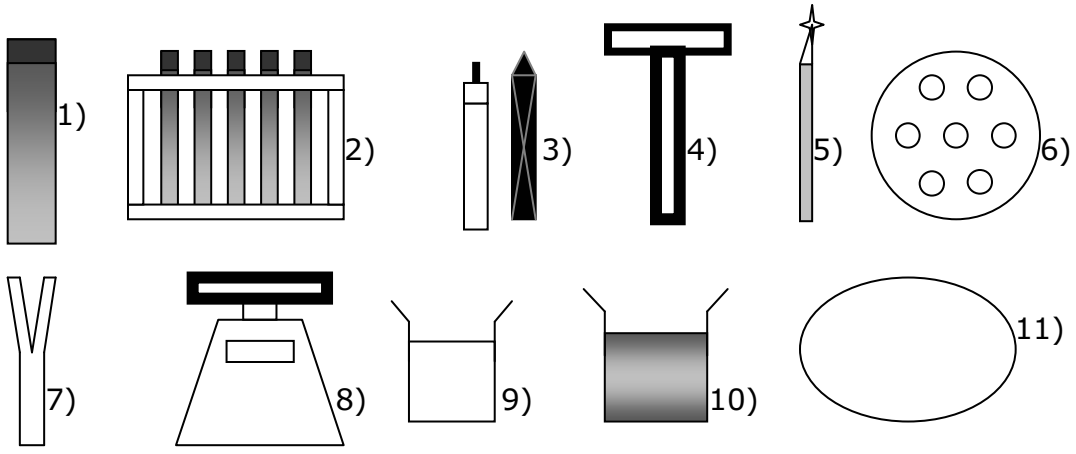
Finally for my last quantitative prediction I will make predictions on the 1.0 mol dm^{-3} sucrose solution. For this sucrose solution I predict that the cylinder will loose mass even more than previously. I predict that this solution will cause the potato to loose the most amount of mass or the most water loss. I predict this is because now with this high concentration, the concentration of solute molecules is now very high outside the cylinder. This literally means that the solute molecules have taken up all the space in the total solution and that now there is very little water left in the solution. This means that the concentration of the water molecules is much less than that of the inside of the cell. Thus the water will move down the water gradient due to its high water potential and therefore move out of the cell and decrease the mass. I also predict that the percentage mass will be the largest out of all solutions even the distilled water. I predict this because the concentrated solution will give more water potential than the pure water.

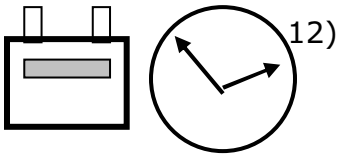


Since this is the highest concentration I predict that the loss of mass will be around ----0.28g. "My scientific knowledge / preliminary work / Encarta Encyclopedia" (Hassan Zaman – 2001)

Method☺

In this part of the investigation I will give a clear account on how to do the experiment. (Apparatus) "List from check list" (the weighing method).

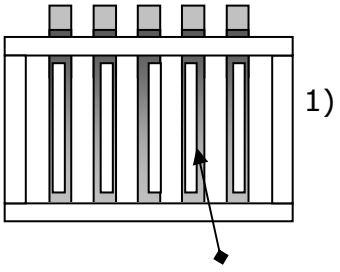


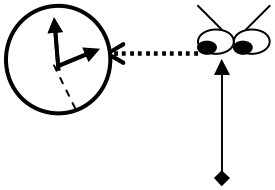


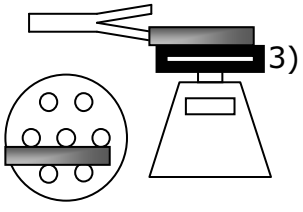
1) Normal test tubes with bungs (x6)
2) Test tube rack
3) Permanent marker (not recommended) / Wax pencil (method refers to this)
4) Cork borer (10mm in diameter)
5) Razor blade (WARNING: sharp object, handle with care)
6) Filter paper (x6)
7) Forceps
8) Electronic measuring scale (very accurate scale)
9) Distilled water (amounts may vary / 0.00 mol dm^{-3})
10) Sucrose solutions (0.2, 0.4, 0.6, 0.8, 1.0 mol dm^{-3} / Amounts may vary)
11) Potato tuber (large)
12) Stop watch or normal clock

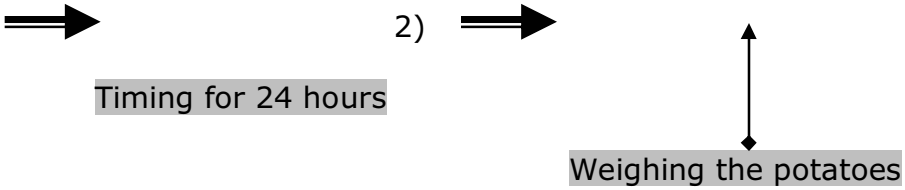
(Observations)
Before we continue you must make the correct observations and measurements. The data you collect will be the change in mass or percentage change in mass for the potato after the time limit. You will measure the amounts of liquids you use such as the distilled water and all the sucrose solutions. The only weighing you will do is the potato at the beginning and end.

(Implementation)
(1) First using your wax pencil (3) label your 6 test tubes (1) from distilled water or DW, 0.2, 0.4 0.6 0.8 and 1.0 mol^{-3}. For each tube, mark the half way mark with the pencil as well, then fill each tube with there appropriate solutions up to the half mark. You need to remember to place the bungs (1) on firmly or some of the water from the solutions will evaporate away changing there concentration due to the heat.
(2) Use your cork borer (4) and bore out 6 potato cylinders and with the blade (5) cut the edges straight, each one should be 50mm long and 10mm in diameter. Now label 6 filter papers (6) with DW, 0.2, 0.4, 0.6, 0.8, and 1.0 mol^{-3} and place one cylinder on each one.
(3) Now take your cylinders on the paper to the measuring scale (8). For each potato measure there weight with the paper and record the mass on the paper with the pencil. You should then move your cylinders (one at a time) to there appropriate test tubes WITHOUT TOUCHING THEM, so use your forceps (7) and remember to bung the tubes. Then record the mass of the paper on its own, now that you have the total mass, and the mass of the paper calculate the mass of the potato by itself (total – paper =). Note the time that you put each cylinder in the tube.
(4) After roughly 24 hours for each cylinder, remove the appropriate cylinder from the tube in the same order you put them in. Using the forceps, place the cylinder on the paper and roll the cylinder around to remove any excess water, however do not squeeze them or they will loose water. Now weigh the potatoes again and as before calculate the mass of the potato for the final mass. When ready, everything should be looking like this as the reaction takes place 1), you time for 25 minutes 2) and record the final masses 3). This is basically how the experiment is set up.









(Dilution process / table)
Since the dilutions were directly done by us, it was vary important to calculate the dilutions and then plot them in a table to make it easier.
We were given a 1.0 molar solution and had to dilute this into the concentrations that were desired. Since 25cm^3 of sucrose solution were used in each test tube, this will used to calculate the dilution. If the 0.6 solution was desired for example use this method:

$$\frac{1}{0.6} = 1.666666667 \text{ (the dilution factor)}$$

$$\frac{25}{1.666666667} = 14.9$$

When dividing the 1 (which is the mole of the solution) by the 0.6 (which is the concentration we want) you find the dilution factor. Then you divide the 25 (amount of sucrose solution) by the factor which gives you the dilution. This means to get the 0.6 solution you need 15cm^3 of the sucrose and 10cm^3 water. Using the same calculations a table can be drawn.

Concentration desired (m)	Amount of sucrose solution (cm^3)	Amount of water cm^3	Ratio– sucrose : water
0.2	5	20	1:4
0.4	10	15	3:2
0.6	15	10	2:3
0.8	20	5	4:1
1.0	25	0	5:0

(Data collection)
Firstly, work out the percentage and normal change in mass of the potato. For percentage change you need to: change in mass x 100 / by original mass. For change in mass you simple divide the change in mass by the original mass. For the percentage mass, you simply plot this against the molarity of the sucrose solutions. The Y axis will have at the top the increases in mass, no change in mass in the middle and the decreases in mass at the bottom (under the X axis). Join the X's you mark with straight lines. After this you need to calculate the water potential of the potato cells like this: on your graph find the point where the line you made crosses the X axis (place on Y axis where there is no change in mass). At this point read off the molarity on the X axis of the sucrose solutions. "List from check list" (the weighing method).

Molarity (mol dm^{-3})	Solute potential (kPa)
0.10	-130
0.20	-540
0.30	-860

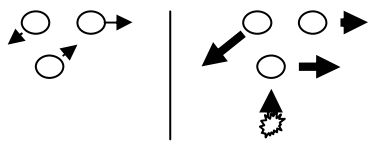
0.40	-1120
0.50	-1450
0.60	-1800
0.70	-2180
0.80	-2580

Find the sucrose water potential of that molarity. If that molarity is not there, the full table will be supplied. THIS WILL BE THE WATER POTENTIAL OF THE POTATO TUBER CELL AFTER PLOTTING AGAINTS THE GRAPH! The highlighted example above shows how if on your graph the line crosses at 0.40, then go along the graph and that will be your water potential. Express your final answer in kPa. Your normal results table should look like this:

Molarity of solution (M)		Initial mass of cylinder (g)	Final mass of cylinder (g)	Change in mass (g)	% change in mass
Distilled H_2O	0.00				
Sucrose	0.20				
Sucrose	0.40				
Sucrose	0.60				
Sucrose	0.80				
Sucrose	1.00				

(Variables)
In this investigation there are not many variables because most of these factors must remain constant in order to obtain fair results. One variable which is included in this experiment is the concentrations of the solute solutions. Firstly we will have distilled water in one test tube, and then we will have the 0.20 mol dm^{-3} solute in the other test tube and so on. This means that we have to vary the concentration of the solutes. This variation must be controlled. I will do this by making sure the solution is not changed once it is at the desired concentration. This means keeping it in a sealed container and not mixing it with other solutions.

Another variable is the temperature. This is all to do with the room temperature and the amount of light in the room. It is very important to keep this particular variable constant because varying temperature will give varying results. If we have one tube with a low temp and a tube with a high temp, we would have an unfair result because using the collision theory we know that when molecules get more heat energy they have more kinetic energy which means that they move around much more and therefore have more collisions. With the extra energy and collisions, the reaction happens at a faster rate. This means that if I leave the substance for 24 hours, I must ensure that it does not come directly under sunlight at this will change the rate of reaction. To control this I will place my solution under a cloth. Plus for as long as I can I will monitor the temperature using a thermometer.



HEAT

(Errors)

During the preliminary work it was found that the analogue measuring scale was an error because it was not accurate enough and that it was not to scale. This meant that we could only record certain readings such as 1 to 1.5 to 2. However from learning from this mistake we have decided to correct it by using an electronic measuring scale which is much more accurate as you can record much more precise results.

Another error that preliminary work showed was in the potato cylinders. From my previous results it is clear that the initial masses of all the cylinders were different. This means that cylinders with a larger mass would have a different amount of osmosis than the smaller ones due to the increased surface area. The larger surface area means that more osmosis can take place so to compare the potatoes would be unfair as they are not all the same. A correction for this mistake would be to make sure that the potatoes have the same mass or as close as possible.

An error which also present is heat and light. The solute solutions are given to us. This means that they may have been left open in the light for a while which means that the heat has had enough time to evaporate some of the solutions. As this happens the concentrations of the solutions changes and becomes more concentrated as more water is taken away. A way to correct this error is to ensure that the solutions are made personally and that they are concealed and kept cool.

In the final evaluation of this investigation, these errors will be looked at in more detail.

(The need for safe working)

Safety is very important in this experiment even though the experiment seems to be relatively safe. This is why it is taken into consideration. A very sharp knife is going to be used which could seriously hurt someone if it is not handled with caution and care. Also, caution must be taken to make sure the solutions are not swallowed because we are not fully aware of the damage it could do to us. Plus some other harmful chemicals from other experiments could be mixed with the solution somehow and can seriously harm us. Goggles should also be worn to make sure no acids from previous experiments harm your eyes, or so that you don't cut your eyes with the knife.

(Extra points on fair testing)

We must make sure that this test is fair because if it is not a fair test we will be obtaining the wrong results. First of all, and most importantly, we will have to get the measurements and the weights of the solutions and the potatoes as exact, and as accurate as possible. We will try and get the measurements of the potatoes as accurate as possible. One of the most important steps in this fair testing is to make sure that the potato is fully covered by the solution. This is because the potato should fully submerge, by having total contact with the solution for the full osmotic affect. When using the balance, we will make sure that the balance is reading zero before you begin and make sure to subtract the weight of the filter paper to figure out the weight of the potato or you will be adding extra weight which will give you the wrong percentage change

Preliminary work / Pilot run☺

In this part of the investigation I will comment on previous work (preliminary work) and pilot runs and state how it has identified weaknesses in the initial method and perhaps possible modification.

Having done this experiment before, I have been able to identify weaknesses in the experiment and learn more about the experiment. Firstly I have learnt that using potato tuber cells in the form of cylinders in inadequate as the surface area is not large enough. This is because we have a lot of the potato on the inside which means that that whole area is not contributing to the osmosis. In previous experiment using the cylinder, it was learnt that potato discs would give a more accurate result since there is more surface area. However even with potato discs, we still have the problem that not the whole potato is contributing to the osmosis. A way to solve this would be to liquidise the potato which would give a very high accuracy due to the large surface area. Another thing I learnt was that when making the cylinders, all the initial masses were different. This means that the larger cylinders will have a larger osmotic affect due to their larger surface area and the smaller ones will have a smaller change in mass altogether. Ways to improve upon this is to measure the percentage change in mass (which is what we are doing anyway) and to try my best to make the cylinder as equal as possible.

Results☺

In this part of the investigation, the results will be shown on graphs and tables plus the water potential will be found. I will also point out anonymous results in the graph.

Table 1: showing the initial results of the experiment

Molarity of solution (M)	Initial mass of cylinder (g)	Final mass of cylinder (g)	Change in mass (g)	% change in mass
Distilled H_2O 0.00	2.51	2.69	+0.18	7.17
Sucrose 0.20	2.52	2.63	+0.11	4.36
Sucrose 0.40	2.61	2.69	+0.08	3.06
Sucrose 0.60	2.72	2.59	-0.13	-4.77
Sucrose 0.80	2.49	2.23	-0.26	-10.44
Sucrose 1.00	2.56	2.22	-0.34	-13.28

To find out the water potential, we need to use an equation which tells us the water potential ($\Psi = \Psi s + \Psi p$). However in this experiment we ourselves did not add any external pressure. This is why each cylinder has the same pressure so we count it as zero. This means that when you look at the graph and find the solute potential you have automatically found the water potential since there is no pressure potential.

$$\Psi = \Psi_s + \cancel{\Psi_p}$$

((Graph goes here))

Table 2: Showing the solute potential and molarity

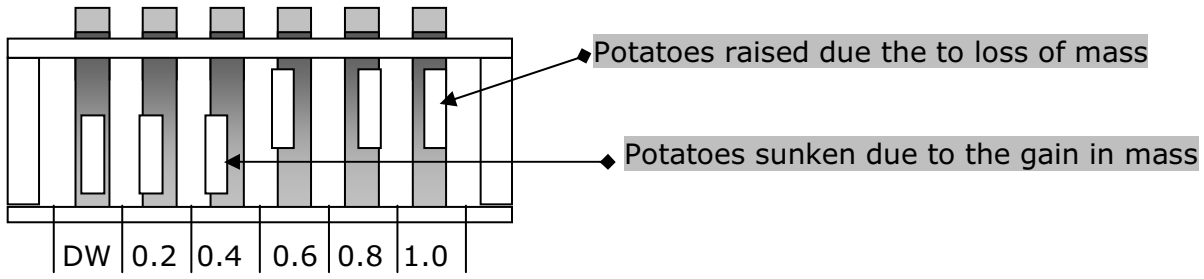
Molarity (mol dm^{-3})	Solute potential (kPa)
0.05	-130
0.10	-260
0.15	-410

0.20	-540
0.25	-680
0.30	-860
0.35	-970
0.40	-1120
0.45	-1280
0.50	-1450
0.55	-1620
0.60	-1800
0.65	-1980
0.70	-2180
0.75	-2370
0.80	-2580
0.85	-2790
0.90	-3000
0.95	-3250
1.00	-3500

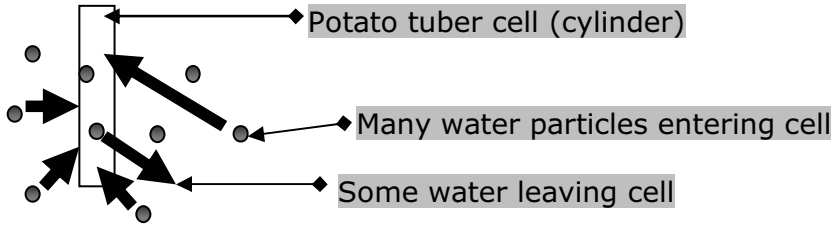
(Anonymous results)
From looking at table 1, my results show that in general they were very good. However there does seem to be some anonymous results which have been identified on the graph by 1)⊛ and 2)⊛. Number 1) seems to be slanting to the right because the gain of mass has not decreased enough. The same principle goes for 2).

Conclusion☺

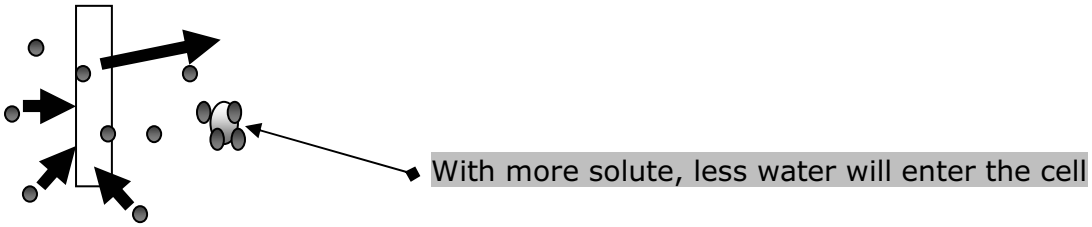
From the beginning of the experiment I knew that my predictions were correct. I knew this because when I placed the cylinders in the distilled water, 0.2 and 0.4 sucrose solutions I found that they sank to the bottom. With the 0.6, 0.8 and 1.0 solutions I found that the cylinders rose to the top. I knew that this meant that my predictions were correct because in the first three solutions the water concentration is much higher on the outside which means a net movement of water goes into the cylinder and increases their masses making them sink. The last three solutions (0.6, 0.8 and 1.0) made the cylinders rise because there was a higher concentration of water in the cylinders so the water molecules diffused out of the cell (osmosis) making the cylinders loose mass which made them rise.



For my first prediction I predicted that that the change in mass will be quite significant as plus there will be a gain of mass. This was a correct prediction because I knew that the distilled water would have a much higher water potential than the potato. This will mean a net movement of water from the outside into the inside until equilibrium is reached or until the potato tuber cell is fully turgid. I also predicted that the increase in mass would be the most out of all solutions however I also said that the change in mass would not be the most out of all solutions. I knew that this prediction would be correct because the high concentration of water and almost no solute means that there would be a higher concentration of water outside the cell, so water would move in as a net movement. My prediction on the gain of mass being around +0.20g was also very close as the result was +0.18g. My preliminary work helped me to predict this.

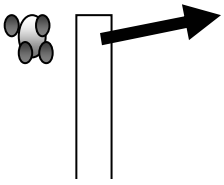


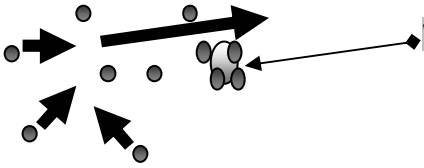
My next prediction was for the 0.2 mol dm^{-3} sucrose solution. For this prediction I predicted that again there will be a gain in mass but this time less then before. This also turned out to be correct because I knew that since there is a higher concentration of solute molecules in the solution it means that now there is a lower concentration of water outside the cell which will mean that less water will go in the cell.



My quantitative prediction was also very good as I predicted the gain in mass would be +0.13g when it was actually +0.11g. Again my preliminary work helped me predict this.

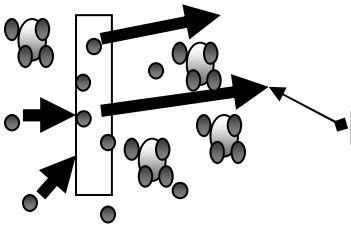
My third prediction for the 0.4 mol dm^{-3} solution was also essentially correct. I predicted that there would still be an increase in mass of the cylinder. However this time the change in mass would be very small due to the fact that the solute concentration has increased more. This prediction was correct as the change in mass was very small at only +0.08g.
I made this good prediction because I knew that even though the concentration of water was still more on the outside than on the inside if the cell, it had gone down a lot due to the increase in solute concentration. This meant that the potato is closer to equilibrium and so less water would enter the cylinder since the concentration of the water molecules is less since the solute molecules take up space. My quantitative prediction was a little wrong by saying there would an increase of +0.04g. This may have happened because I used my preliminary work which was not very accurate.





With more solute, less water will enter and more will leave

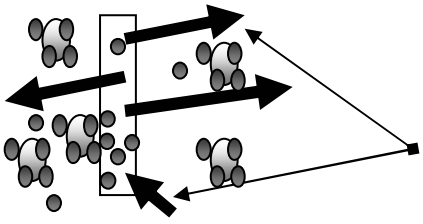
For the 0.6 mol dm^{-3} sucrose solution I predicted that with this concentration, instead of the cylinder gaining mass, it will now loose mass. This was correct and I knew that it would because there is such a high solute concentration outside the cylinder which means that the water concentration will be more on the inside of the cylinder than on the outside because the solute molecules take up so much space. Due to the fact that water molecules move down the concentration gradient, it would mean a net movement of water going out of the cell.



Lower water concentration so water moves out

I had also predicted that the loss of mass would be the least out of all the cylinders since it is almost at equilibrium and this was correct. You can see this by looking at table 1. I knew this prediction was correct because the rate of water entering the cylinder will be quite close to the rate of water going out of the cylinder. I also predicted that the loss of mass would be -0.15g which is very surprisingly accurate. Its surprising because I used my own scientific knowledge plus my preliminary work which I knew was not very accurate.

Next was the prediction fro the 0.8 mol dm^{-3} sucrose solution. I predicted that there will be a larger loss of water therefore loss of mass for this solution. From looking at the results you can see that I was correct in saying this because the concentration is now much higher then the dilution. This meant that water would leave the cylinder plus the mass loss will be more than that of the 0.6 mol dm^{-3} solution because now the concentration of water is much less on the outside than on the inside of the potato tuber cell. Since in osmosis water always moves down the concentration gradient, it means that more water will move out of the cell since there is less water in the solution.

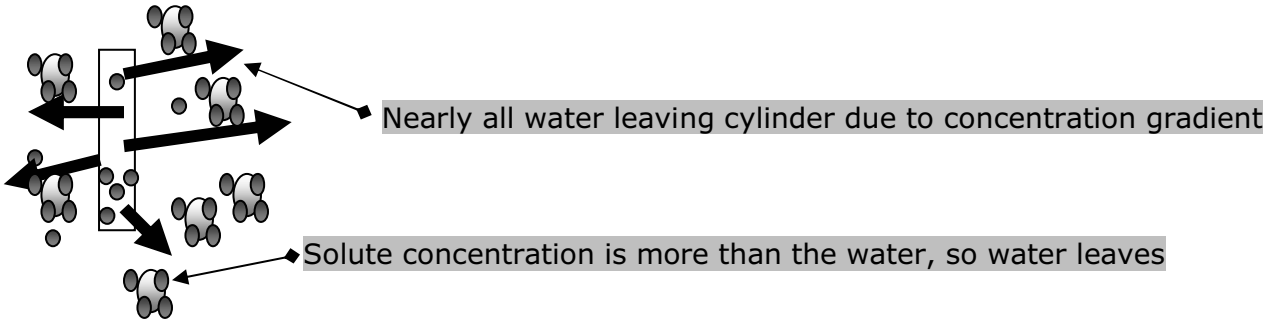


More water leaves, only a little is entering now

Finally I made predictions for the 1.0 mol dm^{-3} sucrose solution. For this solution I had predicted that the cylinder would loose mass even more than previously. I predicted

that this solution will cause the potato to loose the most amount of mass or the most water loss. This was correct again because now with this low dilution, the concentration of solute molecules is now very high outside the cylinder. This literally means that the solute molecules have taken up all the space in the total solution and that now there is very little water left in the solution. This meant that the concentration of the water molecules was much less than that of the inside of the cell. This meant the water moved down the water gradient due to its high water potential and therefore move out of the cell and decreased its mass.

I also predicted that the percentage mass would be the largest out of all solutions even the distilled water. This was correct again because the concentrated solution will give more water potential than the pure water.



"Some information from Encarta Encyclopedia" (Deluxe 2001)

(Variables)
To have obtained a fair test, certain aspects of the experiment would have to be kept the same whilst one key variable was changed which was obviously the concentrations of the solutions. This gave the varied results needed in order to find the water potential of the potato tuber cell. If any of the variables below or as explained before (method) were not kept constant, it would mean we would have an unfair test. For example, if one of the potato cylinders were 0.5cm longer than the others, the surface area of the cylinder would be larger and there would therefore be more space for osmosis to occur and so compared to the other cylinders, would not be correct as it is larger.

The temperature is another variable which must be kept constant. As explained earlier, with more temperature, the water particles have more kinetic energy which means they move and collide more which also means they will diffuse through the semi – permeable membrane faster. The temperature must remain constant because if one test tube's temperature is higher than another we will have an unfair result. To keep this variable constant I will leave the solutions at room temperature and not allow any extreme heat or cold hear the tubes.

The same principle would apply to the light intensity. This is because with more light we have more heat. This means that the water will start to heat up and perhaps evaporate away which will make the solution more concentrated as there is less water. Looking at this in more detail, if ALL the test tubes are at the same light intensity weather it be high or low, then it will not matter as they are all being affected equally. Plus it is still possible to find the water potential even if this does happen. However to keep it under control a cloth could be placed over it or you could just leave it out of the light.

Another variable that must be kept in mind is the mass of the potato which makes it a dependant variable. Due to this fact I will measure its mass in grams through out the experiment. The potato cylinder will be measured before it is put in the

solution, and after. This will allow us to see whether osmosis has taken place, and to what extent.

One obvious variable is the amount of solution in the test tube. This MUST remain constant because if one has more solution than another, then the osmotic affect will be more because there is more water or vice versa with the solute. Also the cylinders must be totally submerged in the solutions because if any of the potato is not in the solution, osmosis will not occur there since there is no liquid which is the same as shortening the length of the potato. Keeping this variable constant can be done by measuring out with a measuring cylinder the same amount for each solution.
"Preliminary work / my scientific knowledge" (Hassan Zaman 2001)

The variables that will be taken into account during the experiment are the solution concentration, surface area, solution volume, length of experiment (time), temperature, types of solutions (sucrose and distilled water), conditions (light intensity / humidity) and preliminary results.

Finally after saying all of the above, it can be concluded that the water potential of the potato tuber cell has been determined with varying solute concentrations and by using the formula $\Psi = \Psi s + \Psi p$. The water potential is 1380 kPa.

Evaluation☺

Over all the method (in theory) is accurate. However in practise this is not so as there are many errors in the experiment even though I personally felt that the experiment went well.

One source of error that occurred was in the measuring scale. It was initially planned to use the electronic weighing scale as you can see from my planning (method etc). However due to a lack of resources we were forced to use an analogue weighing scale. Not only was the scale analogue, it was a hand use scale. This meant that when you added your weight, you had to role the knob to the lower, nearest number i.e. if it was above 5g, you would role it down to five and then it would tell the weight. This was very inaccurate due to the fact that you ad to rely on yourself for finding the weight and the scale was not electric. A way to improve this would be to actually use the electronic scale which is much more accurate and measures to two decimal places, plus it does not rely on your self to do the job.

Another error is in the sunlight. As I mentioned before the sunlight can directly shine on the solutions which means they will heat up and therefore some of the water in the solution will evaporate away. So say for example the 0.2 solution was left in the light, and some of the water evaporates away, it would mean that the concentration would NOT be 0.2 mol dm^{-3}. This is a very common error that sometimes people to do not see.

In the end the final results obtained were very reliable due to the precautions I took to make this a fair test. Looking at the overall experiment I have thought of a number of improvements, including the ones above, to give more and better accurate results. First of all when the potato was dried (the excess liquid) to remove surface liquid it was not necessarily done the same on each potato, a more accurate and organised way of drying them would improve the accuracy further. This could be done by leaving all the cylinders out to dry for the same amount of time. Another improvement that could have been done to improve my results would have been to measure the diameter change of the potato, which in turn would have helped to find

out the volume, before and after the experiment, of the potatoes, which would also help to explain the results obtained.

To make this experiment more accurate and easier to handle, one test at a time could have been done i.e. only one cylinder at a time. This would allow me to reduce the time difference when having to move the potato from the test tube to the balance. Between this, the potatoes must be dried just enough, and then put on the balance. When doing this for one set of cylinders, writing down the results at the same time, while the other five sets are on the tissue paper, the water outside the potato tissue is going to vary. Therefore, it would be easier to concentrate more on one of the sets, instead of trying to finish all of them as quickly as possible.

Another improvement would have been to have got more people to do the experiment, so that the tasks can be organised, and then be able to divide the tasks helping to get more accurate results.

Also using more types of molar sucrose solutions would have helped to obtain better results, and more accurate results, so that it can be made sure that the results are totally correct.

Experimenting with the cylinders for a longer period of time for each set would lead to better results say four to five days instead of the minimum of 24 hours, because the osmosis action would reach its maximum and therefore show how much water could be transferred for each solution. Not only this but further work could be carried out to include concentrations that increased in 0.05 M rather than 0.2 each time. Even though my graph is very accurate (hand drawn plus small intervals) this would increase the accuracy and improve the graph. Other investigations could include using different varieties of potato or different plant tissues e.g. carrot, apple, pineapple, strawberry and tomatoes. I could also extend this experiment by repeated exactly as before to get an average. However this time I could take more results at the molarity levels from 0.00 up to 0.20 in single digits then 0.21, 0.22, 0.23, all the way up to 1.0 M. This would produce much more accurate results.

This is going into much further detail but is required for more scientific knowledge and accuracy. Other variables in the experiment could be changed such as instead of changing the mass of the potato, the species of the potato could be changed. For example a new potato, a really old potato, a different kind of potato or even a different vegetable could be used. Also the shape and size could be changed. However this would not affect the results much. This is because the variable would only change the rate of osmosis because of a different weight and size. We could have used potato discs which would give much more surface area plus more accuracy. Even liquidised potato could be used for the same reasons.

For even more demand for accuracy the temperature could be changed. For example the samples could be placed in different water baths and brought up to different temperatures. This would see if temperature played a part in the osmosis of potatoes.

A preliminary experiment could be set up beforehand to find out how long the experiment should be kept going because if the concentration of the potatoes equalises then the weight of the potatoes will be almost exactly the same.

But overall, given the apparatus that I got to carry out the test, I think this experiment turned out to be very successful, and I'm very please with my results.

Bibliography☺

- "My own scientific knowledge" (Hassan Zaman) this was the main source of information.

- "Knowledge from Biology 1" (Cambridge 2001) this helped with the prediction and a portion of the predictions and theory.

- "Preliminary work" (Determine the water potential of potato tuber cell with the varying affect of solute concentration) this also helped in the prediction and helped me to conclude the investigation

- "Check list" (the weighing method) this gave me the method provided and gave me the solute potential table (table 2)

- "Encarta Encyclopedia" (C-D rom 2000) simply helped with some theory

Hassan Zaman