

Diffusion and osmosis in living and non-living systems

investigate diffusion and osmosis using living and non-living systems

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. Teacher answers start on a new page.

Name

Date

Aim

To investigate osmosis in a living system (potato) and diffusion and osmosis in non-living systems (Visking tubing and agar cubes).

Background

Diffusion is the net movement of particles from a region of higher concentration to a region of lower concentration, down a concentration gradient. **Osmosis** is the diffusion of water from a dilute solution to a more concentrated solution through a **partially permeable membrane**.

Potato tissue is a **living system**: its cells have partially permeable membranes. Cylinders placed in sugar solutions gain mass when water enters by osmosis and lose mass when water leaves. At the concentration where the mass does not change, the solution has the same concentration as the cell contents.

Visking tubing and agar are **non-living systems**. Visking tubing is a partially permeable membrane with tiny pores that let small molecules such as water and glucose through but not large molecules such as starch. Agar jelly cubes show how the size of an object affects how quickly a substance diffuses into it, because bigger cubes have a smaller surface area to volume ratio and a longer distance to the centre.

Hypothesis

Potato cylinders will gain mass in dilute solutions and lose mass in concentrated solutions. Small molecules will diffuse through Visking tubing but starch will not, and smaller agar cubes will change colour throughout faster than larger cubes because they have a larger surface area to volume ratio.

Variables

Independent	Part A (potato): concentration of sucrose solution (mol/dm^3). Part B (Visking tubing): none (observing which substances pass through the tubing). Part C (agar): side length of the cube (cm)
Dependent	Part A: percentage change in mass of the potato cylinder (%). Part B: results of the Benedict's and iodine tests on the water outside the tubing. Part C: time for the cube to become completely colourless (min)
Control	- Part A: the same potato, cylinder length and diameter, volume of solution, time in the solution and temperature - Part B: the same volume of liquid in the tubing and water in the beaker, same time and temperature - Part C: agar from the same batch, the same volume and concentration of hydrochloric acid, and the same temperature

Equipment

- Part A: large potato, cork borer (about 1 cm diameter), white tile, scalpel or knife, ruler, paper towels, electronic balance (to 0.01 g), 6 boiling tubes or small beakers with labels
- Part A: sucrose solutions of 0.0 (distilled water), 0.2, 0.4, 0.6, 0.8 and 1.0 mol/dm³, 20 cm³ of each
- Part B: Visking tubing (about 10 cm lengths) soaked in water, thread or clips, 100 cm³ beaker, starch and glucose solution mixed, distilled water
- Part B: Benedict's solution, iodine solution, test tubes, hot water bath and test tube holder
- Part C: pink agar jelly made by the technician with phenolphthalein indicator and dilute sodium hydroxide (0.1 mol/dm³); ruler, scalpel and white tile; dilute hydrochloric acid (0.4 mol/dm³), 50 cm³ per beaker; 3 beakers (100 cm³)
- Stopwatch or timer, marker pen and eye protection

Risk assessment

Hazard	Risk	Precaution
Cork borer and scalpel	Cuts to fingers	Cut on a tile, away from your hand, push the cork borer in with a twisting motion, and do not hold the potato in the hand while cutting.
Dilute hydrochloric acid (0.4 mol/dm ³) and the alkaline agar	Can irritate the eyes, and skin if left on it	Wear eye protection; handle the agar with forceps; wash any splashes off with plenty of water.
Benedict's solution, iodine solution and hot water bath	Irritants; scalding by hot water	Wear eye protection, use a water bath not a flame, and handle hot tubes with a holder.

Method

1. Part A (potato): put on eye protection. Use a cork borer to cut 6 cylinders from one potato and trim each to the same length (for example 3.5 cm), removing any skin.
2. Blot each cylinder dry, measure its mass to 0.01 g, and record it as the initial mass.
3. Put 20 cm³ of one sucrose solution in each labelled tube, from 0.0 to 1.0 mol/dm³, and add one cylinder to each.
4. Leave the cylinders for the same length of time, at least 1 hour, at room temperature.
5. Remove each cylinder, blot it dry with a paper towel in the same way, and measure its final mass. Calculate the percentage change in mass: (final mass – initial mass) ÷ initial mass × 100.
6. Part B (Visking tubing): tie one end of a soaked length of Visking tubing, fill it with a mixture of starch and glucose solution, and tie the other end.
7. Rinse the outside of the tube under the tap and place it in a beaker of distilled water.
8. After 20–30 minutes, remove a sample of the water from the beaker into each of two test tubes. Test one with Benedict's solution (heat in a water bath) and the other with iodine solution.
9. Test a sample of the liquid left inside the tubing with iodine solution and with Benedict's solution as a comparison. Record the results.
10. To show osmosis, tie a second length of Visking tubing filled with concentrated sugar solution, dry the outside, record its mass, place it in distilled water for 30 minutes, then dry it and record the mass again.

- L1 . Part C (agar cubes): on a tile, cut pink agar cubes with sides of 1 cm, 2 cm and 3 cm, using a ruler and a sharp scalpel.
- L2 . Using forceps, place each cube in a separate beaker containing 50 cm³ of dilute hydrochloric acid, so the cube is covered, and start the stopwatch.
- L3 . Record the time for each cube to become completely colourless, gently turning the cube to check (the 3 cm cube may take up to an hour). Repeat if time allows.

Results

Part A: percentage change in mass of potato cylinders in sucrose solutions				
Concentration of sucrose solution (mol/dm ³)	Initial mass (g)	Final mass (g)	Change in mass (g)	Change in mass (%)
0.0				
0.2				
0.4				
0.6				
0.8				
1.0				

Graph

Part A: plot change in mass (%) on the y-axis against concentration of sucrose solution (mol/dm³) on the x-axis, with the y-axis including negative values. Draw a smooth curve of best fit. Read off the concentration where the line crosses 0% change: at this concentration the solution has the same concentration as the potato cell contents. Part C: record the side length, surface area : volume ratio and time for each cube in a table; you can plot time (min) against side length (cm) as a line graph.



Exam questions 10 questions · 31 marks

1 Define osmosis. [3 marks]

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2 In the potato cylinder investigation, state the independent variable and the dependent variable. [2 marks]

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3 Explain why the potato cylinders are blotted dry before they are weighed. **[2 marks]**

4 A potato cylinder has an initial mass of 2.80 g. After 1 hour in a sucrose solution its mass is 2.30 g. Calculate the percentage change in mass. Give your answer to 1 decimal place. **[3 marks]**

Answer =

5 Explain why percentage change in mass is calculated rather than just the change in mass. **[2 marks]**

6 A student draws a graph of percentage change in mass against sucrose concentration. The line crosses the x-axis at 0.37 mol/dm³. Explain what this shows. **[3 marks]**

7 Visking tubing containing starch and glucose solution was placed in water. After 30 minutes the water gave a positive result with Benedict's solution but a negative result with iodine solution. Explain these results. **[3 marks]**

- 8** The table shows the times taken for agar cubes of different sizes to become colourless. **[3 marks]**
Describe and explain the pattern in the results.

Time for agar cubes to change colour		
Side of cube (cm)	Surface area : volume ratio	Time to become colourless (min)
1	6 : 1	5
2	3 : 1	19
3	2 : 1	43

- 9** Suggest how the agar cube investigation could be improved to give more reliable results. **[4 marks]**

- 10** Describe how you would use potato cylinders to find the concentration of sugar solution that has the same concentration as the potato cell contents. Include how you would obtain valid results. **[6 marks]**

Teacher answers

Practical 4: Diffusion and osmosis in living and non-living systems. The example results are practice data, not real measurements.

Example results

Part A example results (practice data), after 1 hour				
Concentration of sucrose solution (mol/dm ³)	Initial mass (g)	Final mass (g)	Change in mass (g)	Change in mass (%)
0.0	3.00	3.54	+0.54	+18.0
0.2	2.90	3.19	+0.29	+10.0
0.4	3.10	3.04	-0.06	-1.9
0.6	3.00	2.64	-0.36	-12.0
0.8	2.80	2.30	-0.50	-17.9
1.0	3.00	2.37	-0.63	-21.0

Conclusion

Part A: potato cylinders gained mass in the most dilute solutions (+18.0% in pure water) and lost mass in the concentrated solutions (-21.0% in 1.0 mol/dm³). In dilute solutions water moved into the cells by **osmosis** through the partially permeable cell membranes, from the dilute solution to the more concentrated cell contents; in concentrated solutions water moved out. The line of best fit crosses 0% change at about 0.37 mol/dm³ (accept 0.35–0.40), where the solution has the same concentration as the potato cell contents, so there is no net movement of water. Part B (practice results): the water outside the Visking tubing gave a brick-red colour with Benedict's solution but stayed orange-brown with iodine, whereas the liquid inside the tubing still turned iodine blue-black. Glucose molecules are small enough to **diffuse** through the pores but starch molecules are too large. A tube filled with concentrated sugar solution gained mass as water entered by osmosis. Part C (practice results): the 1 cm cube (surface area : volume = 6 : 1) became colourless in about 5 minutes, the 2 cm cube (3 : 1) in about 19 minutes and the 3 cm cube (2 : 1) in about 43 minutes. Larger cubes have a smaller surface area to volume ratio and a longer distance for the acid to diffuse to the centre, so diffusion takes longer.

Errors and improvements

Error	Effect on the results	Improvement
Surface water left on the cylinders or tubing when weighing	The final mass is too high, so percentage change is overestimated	Blot every cylinder in the same way for the same time before weighing.
Cylinders cut from different potatoes or different parts of a potato	The cell sap concentration varies, so results are not comparable	Cut all cylinders from the same potato and repeat each concentration, calculating a mean.
Different initial masses and lengths of cylinders	Raw changes in mass cannot be compared fairly	Calculate percentage change in mass and cut every cylinder to the same length.
Judging when the agar cube is colourless is subjective, and cutting is imprecise	Times vary, and cube sizes are not exact, so the SA : V ratios are not accurate	Cut with a sharp blade against a ruler, cut the cubes in half at the end to check the colour of the centre, and repeat to calculate a mean.
Visking tubing leaks or is not tied tightly	Starch appears in the beaker, giving false results	Check that the tubing is tied tightly and rinse the outside before the tube is placed in the water.

Mark scheme

One mark for each point unless a maximum is given. Words in brackets are not needed for the mark.

1. [3]

- (net) movement / diffusion of water (molecules) (1) reject movement of solute / particles
- from a dilute solution to a more concentrated solution (1) allow from a high to a low concentration of water / high to low water potential
- through a partially permeable membrane (1) allow semi-permeable / selectively permeable

2. [2]

- independent: concentration of the sucrose solution (1)
- dependent: (percentage) change in mass of the potato cylinder (1)

3. [2]

- to remove water on the surface (1)
- because this water would add mass that did not enter by osmosis / would give an inaccurate (final) mass (1)

4. [3]

- $2.30 - 2.80 = -0.50$ (1)
- $-0.50 \div 2.80 \times 100$ (1)
- -17.9 (%) (1) allow 17.9% decrease / loss; award 3 marks for the correct answer with no working

5. [2]

- the cylinders may have different starting masses (1)
- percentage change allows a fair comparison / takes into account the initial mass (1)

6. [3]

- there is no change in mass / no net movement of water at this concentration (1)
- the solution has the same concentration as the potato cell contents (1) allow same water potential
- water moves into and out of the cells at the same rate (1)

7. [3]

- glucose molecules are small enough to pass through the pores of the Visking tubing (1)
- glucose diffused out of the tubing into the water (1) allow down a concentration gradient
- starch molecules are too large to pass through (1) allow so iodine test negative

8. [3]

- the larger the cube, the longer the time taken (1) allow correct use of data
- larger cubes have a smaller surface area to volume ratio (1)
- the acid has a longer distance to diffuse to the centre (1)

9. [4]

- repeat for each cube size and calculate a mean (1)
- cut the cubes accurately using a sharp blade and ruler / cut from the same piece of agar (1)
- keep the temperature the same / use a water bath (1)
- use the same volume and concentration of acid (1)
- cut the cube open at the end to check the centre is colourless / view against a white background (1)
- Max 4

10. [6]

Level 3 5-6	A logical method covering cutting equal cylinders, measuring mass before and after, a range of solutions including pure water, a fixed time and temperature, blotting, percentage change and a graph to find where the line crosses 0%, with at least two control variables
Level 2 3-4	A method with most key steps, such as masses before and after and a range of concentrations, but incomplete control of variables or no use of the graph
Level 1 1-2	A basic description, for example 'put the potato in sugar solutions and see what happens'

Indicative content

- cut cylinders of equal length with a cork borer from the same potato; blot dry and weigh; place in different concentrations of sucrose solution, including 0.0; same volume of solution; leave for the same time at the same temperature; remove, blot and reweigh; calculate percentage change in mass; plot percentage change against concentration; the concentration where the line crosses 0% is where there is no net osmosis, so the solution and the cell contents have the same concentration; repeat to calculate a mean

Exam tips

- Osmosis is about water: say 'water moves from a dilute solution to a concentrated solution through a partially permeable membrane'. Do not write 'the sugar moves into the potato'.
- In percentage change calculations, use the initial mass as the divisor, show the working and keep the minus sign for a loss of mass.
- State that the point where the line crosses the x-axis is where there is no net movement of water, because the solution has the same concentration as the cell contents.
- When asked about agar cubes, link the size to the surface area to volume ratio and the distance the substance has to travel by diffusion.

- Visking tubing is partially permeable because of its pores. Name which molecules pass through (water, glucose) and which do not (starch).