

Factors that affect diffusion (agar cubes)

Investigate the factors that influence diffusion, limited to: surface area, temperature, concentration gradient and distance

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). Teacher answers start on a new page.

Name

Date

Aim

To investigate how the size of an agar cube (surface area and distance), the temperature and the concentration gradient affect how quickly acid diffuses into the cube.

Background

Diffusion is the net movement of particles from a region of their higher concentration to a region of their lower concentration (i.e. down a concentration gradient), as a result of their random movement. The energy for diffusion comes from the kinetic energy of random movement of molecules and ions.

Four factors change how fast diffusion happens: **surface area**, **temperature**, **concentration gradient** and **distance**. A larger surface area lets more particles cross at once. A higher temperature gives particles more kinetic energy, so they move faster. A steeper concentration gradient gives a greater net movement. A shorter distance means the particles have less far to travel.

In this practical the agar contains dilute sodium hydroxide and the indicator phenolphthalein, so it is **pink**. When hydrochloric acid diffuses into the agar it neutralises the alkali and the pink colour disappears. The time taken for the cube to become colourless all the way through shows how quickly the acid has diffused to the centre. Bigger cubes have a smaller surface area compared with their volume, and the centre is further from the surface.

Hypothesis

The smaller the agar cube, the less time the acid will take to reach the centre, because a small cube has a larger surface area to volume ratio and a shorter distance for the acid to diffuse. A higher temperature and a more concentrated acid will also make the cube lose its colour faster.

Variables

Independent	Part A: side length of the agar cube / cm. Part B: temperature of the acid / °C. Part C: concentration of the hydrochloric acid / mol/dm ³ (only one of these is changed in each part)
Dependent	Time for the cube to become colourless all the way through / min
Control	- Part A: temperature, volume and concentration of acid, agar from the same block, how the cubes are cut and the colour used as the end point - Part B: size of cube, volume and concentration of acid, agar from the same block - Part C: size of cube, temperature, volume of acid, agar from the same block

Equipment

- Block of pink agar (at least 2 cm thick) containing phenolphthalein indicator and sodium hydroxide, 0.1 mol/dm³, made by the technician
- Dilute hydrochloric acid, 0.4 mol/dm³ (about 1 dm³ for Parts A and B with repeats), and for Part C also 0.2, 0.3 and 0.5 mol/dm³ (100 cm³ of each)
- Scalpel or sharp knife, white tile, ruler graduated in mm, forceps
- 4 beakers, 250 cm³ (more for the temperature series); measuring cylinder, 100 cm³
- Thermometer, -10 °C to +110 °C; water baths set at 20, 30, 40 and 50 °C (beakers of water)
- Stop-clock reading to 1 s; marker pen for writing on glassware; paper towels; eye protection

Risk assessment

Hazard	Risk	Precaution
Scalpel or sharp knife	Cuts to fingers	Cut on a tile, cut away from your hand and fingers, and do not hold the agar in your hand while cutting.
Hydrochloric acid, 0.4 mol/dm ³ , and the agar containing sodium hydroxide, 0.1 mol/dm ³	Irritation to the eyes (and skin if it stays on)	Wear eye protection. Pick up the agar with forceps. Wash any splashes off the skin with plenty of water and tell the teacher about eye splashes at once.
Warm water baths (up to 50 °C)	Minor scalds; glass thermometer could break	Use water no hotter than 50 °C, do not stir with the thermometer, and clear up spills so no one slips.

Method

1. Put on eye protection. Label four beakers 0.5 cm, 1.0 cm, 1.5 cm and 2.0 cm and pour 100 cm³ of hydrochloric acid, 0.4 mol/dm³, at room temperature (about 20 °C), into each.
2. Place the pink agar block on a white tile. Using a scalpel and a ruler, cut cubes with sides of 0.5 cm, 1.0 cm, 1.5 cm and 2.0 cm. Cut the faces flat and straight.
3. Check that each cube is a pink cube with no colourless edges. Trim off any pale edges.
4. Use forceps to put one cube into each beaker so that the cube is completely covered. Start the stop-clock as the first cube goes in, add the others at intervals of 1 minute and note the time at which each one goes in.
5. Observe each cube. Gently turn it with the forceps so you can see the pink centre.
6. Record the time at which each cube becomes completely colourless (no pink left) in the results table, to the nearest 0.5 min.
7. Repeat the whole of Part A at least twice more with new cubes and calculate a mean time for each size.
8. Part B (temperature): use 1.0 cm cubes and 100 cm³ of acid, 0.4 mol/dm³, in beakers placed in water baths at 20, 30, 40 and 50 °C. Leave the acid for 5 minutes so that it reaches the temperature of the bath, check it with a thermometer, add a cube and record the time to become colourless.
9. Part C (concentration gradient): use 1.0 cm cubes and 100 cm³ of hydrochloric acid at 0.2, 0.3, 0.4 and 0.5 mol/dm³ at the same temperature. Record the time to become colourless for each.
10. For each cube size, calculate the surface area ($6 \times \text{side}^2$), the volume (side^3) and the surface area : volume ratio. The distance from the surface to the centre is half the side length.

L1 . Plot your results as graphs and write a conclusion for each factor.

Results

Part A: time for acid to diffuse into agar cubes of different sizes				
side length of cube / cm	surface area / cm ²	volume / cm ³	surface area : volume ratio	time for cube to become colourless / min
0.5				
1.0				
1.5				
2.0				

Graph

Part A: plot time for cube to become colourless / min (y-axis) against side length of cube / cm (x-axis). Use crosses (x) for points, more than half of the grid in both directions, and draw a single smooth best-fit curve. Parts B and C: plot time / min against temperature / °C and against concentration of acid / mol/dm³ in the same way. You may also plot time / min against surface area : volume ratio.



Exam questions 9 questions · 30 marks

- 1** A student investigates how the size of an agar cube affects the time for acid to diffuse into it, as in Part A. (a) State the independent variable and the dependent variable. [2] (b) State two variables that must be kept constant. [2] **[4 marks]**

[illegible]

- 2** A student cuts a cube with sides of 2.5 cm. Calculate the surface area : volume ratio of this cube. Give your answer to 1 decimal place. Show your working. [surface area of a cube = $6 \times \text{side}^2$; volume = side^3] **[3 marks]**

Answer =

[illegible]

- 3** The table shows the results of Part A. (a) State how the axes of a graph of these results should be labelled. [2] (b) Describe the trend shown by the results. Use data from the table in your answer. [2] **[4 marks]**

Time for cubes to become colourless	
side length of cube / cm	time for cube to become colourless / min
0.5	1.5
1.0	5.0
1.5	11.0
2.0	19.5

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4 Explain the results of Part A in terms of diffusion.

[3 marks]

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5 In Part B, 1.0 cm cubes were placed in acid at different temperatures. (a) Describe the trend shown by the results in the table. [2] (b) Explain this trend. [2]

[4 marks]

Part B: effect of temperature

temperature / °C	time for cube to become colourless / min
20	5.0
30	4.0
40	3.2
50	2.6

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6 A student repeated the 1.0 cm cube in Part A four times. The times were 5.0 min, 5.5 min, 8.5 min and 5.0 min. (a) Identify the anomalous result and give a reason. [2] (b) State what the student should do with this result. [1] (c) Calculate the mean time for the 1.0 cm cube. [1]

[4 marks]

Answer =

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- 7** In Part C, 1.0 cm cubes were placed in hydrochloric acid of different concentrations. The [3 marks]
cube in 0.2 mol/dm³ acid took 9.5 min to become colourless. (a) Predict whether the time
in 0.5 mol/dm³ acid would be longer or shorter. [1] (b) Explain your prediction. [2]

- 8** Students found it difficult to decide when a cube had become colourless. (a) Suggest why. [3 marks]
[1] (b) Suggest two ways to make the end point easier to judge consistently. [2]

- 9** Describe two safety precautions that should be taken in this investigation, and give a [2 marks]
reason for each.

Teacher answers

Practical skill 1: Factors that affect diffusion (agar cubes). The example results are practice data, not real measurements.

Example results

Part A example results (practice data), mean of three cubes of each size		
side length of cube / cm	surface area : volume ratio	time for cube to become colourless / min
0.5	12 : 1	1.5
1.0	6 : 1	5.0
1.5	4 : 1	11.0
2.0	3 : 1	19.5

Conclusion

Part A (practice data): the 0.5 cm cube became colourless in 1.5 min but the 2.0 cm cube took 19.5 min. The larger the cube, the longer the acid took to diffuse to the centre. Larger cubes have a smaller surface area to volume ratio (12 : 1 for the 0.5 cm cube but 3 : 1 for the 2.0 cm cube), so less surface is available for each unit of volume that has to be reached, and the distance from the surface to the centre is greater. Part B (practice data, 1.0 cm cubes): the time fell from 5.0 min at 20 °C to 4.0 min at 30 °C, 3.2 min at 40 °C and 2.6 min at 50 °C, because particles have more kinetic energy at higher temperatures, so they move faster and diffuse faster. Part C (practice data, 1.0 cm cubes at 20 °C): the time fell from 9.5 min in 0.2 mol/dm³ acid to 6.5, 5.0 and 4.0 min in 0.3, 0.4 and 0.5 mol/dm³ acid. A steeper concentration gradient between the acid and the inside of the cube gives a greater net movement of acid into the cube.

Errors and improvements

Error	Effect on the results	Improvement
Judging the end point: the pink fades gradually and the centre is hard to see	Times are too short or too long and differ between students, so the results are not reliable	Use the same person to judge each cube against a white tile, or lift each cube out after the set time and cut it in half to inspect the centre.
Cubes are cut with uneven sides or a ruler held at an angle	The surface area and the distance to the centre are not what is recorded, so the points on the graph are not at their true positions	Use a sharp scalpel and a ruler on a white tile, check each side length, and cut all the cubes from the same block.
Acid not at the correct temperature when the cube is added (Part B)	The temperature that is recorded is not the temperature of the acid during the experiment	Leave the acid in the water bath for 5 min, check with a thermometer, and keep the beaker in the bath.
Only one cube of each size is tested	An anomalous result cannot be identified and the result may not be repeatable	Repeat at least three times for each value and calculate a mean, ignoring any anomalous result.

Mark scheme

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

1. [4]

- (a) independent: side length / size / surface area of the cube (1); dependent: time (taken) for cube to become colourless / for the pink colour to disappear (1)
- (b) any two from: temperature (of the acid); volume of acid; concentration of acid; same agar block / same agar; same indicator colour used as the end point (2) allow how the cubes are cut; ignore time / size of cube / amount

2. [3]

- surface area = $6 \times 2.5^2 = 37.5 \text{ (cm}^2\text{)}$ (1)
- volume = $2.5^3 = 15.6 / 15.625 \text{ (cm}^3\text{)}$ (1)
- ratio = $37.5 \div 15.6 = 2.4 \text{ (:1)}$ (1) allow 2.4 : 1; award 3 marks for the correct answer with no working; allow ecf from an incorrect surface area or volume

3. [4]

- (a) x-axis: side length of cube / cm (1); y-axis: time (for cube to become colourless) / min (1) allow time to change colour / min; both quantity and unit needed for each mark; the syllabus convention is the solidus, e.g. time / min
- (b) as the side length increases, the time increases / the larger the cube, the longer the time (1)
- e.g. from 1.5 min for 0.5 cm to 19.5 min for 2.0 cm (1) allow time increases faster / by greater amounts for larger cubes; for the data mark, units are not needed; ignore 'directly proportional'

4. [3]

- larger cubes have a smaller surface area : volume ratio / smaller surface area compared with volume (1)
- the acid has further to diffuse / greater distance to the centre (1)
- so it takes longer for the acid to reach the centre of the cube / the whole cube to be neutralised (1)

5. [4]

- (a) as the temperature increases, the time decreases (1) allow diffusion is faster / rate increases at higher temperature
- data quoted, e.g. from 5.0 min at 20 °C to 2.6 min at 50 °C (1)
- (b) particles / acid molecules (and ions) have more kinetic energy at higher temperatures (1) allow particles move faster
- so more particles diffuse into the cube per minute / the acid reaches the centre sooner (1) ignore 'more collisions' alone

6. [4]

- (a) 8.5 (min) (1); much longer than / does not fit the pattern of the other results (1) allow different from the others by more than 3 min
- (b) ignore it / leave it out of the mean / repeat that measurement (1)
- (c) $(5.0 + 5.5 + 5.0) \div 3 = 5.2 \text{ (min)}$ (1) allow 5.17; reject 6.0 (mean including the anomalous result)

7. [3]

- (a) shorter (1)
- (b) the concentration gradient is steeper / greater difference in concentration between the acid and the inside of the cube (1)
- so there is a greater net movement of acid into the cube / the acid diffuses faster (1)

8. [3]

- (a) the colour fades gradually / the pink core is hard to see through the colourless outer layer / it is subjective (1)
- (b) any two from: use the same person to judge every cube; view against a white tile / background; cut the cube in half after a set time to inspect the centre; compare with a colour standard / uncoloured cube; take a photograph at set times (2) ignore 'be more careful'; ignore 'use a bigger cube'

9. [2]

- wear eye protection because the acid / the agar containing alkali is an irritant / can damage the eyes (1)
- cut on a tile, away from the hand / fingers, to avoid cuts from the scalpel (1)
- pick up the agar with forceps / wash splashes off the skin, to avoid contact with the acid or alkali (1)
- Max 2; each mark needs the precaution and a correct reason

Exam tips

- Describe diffusion as the net movement of particles down a concentration gradient. Write 'net' and 'down a concentration gradient' every time.
- Link size to the ratio. Say 'a smaller surface area : volume ratio' and 'a greater distance to the centre'. Do not just write 'the bigger cube has less surface'.
- On tables and graph axes write the quantity and the unit with a solidus, such as time / min, and do not put units in the body of the table.
- When asked to suggest an improvement, be specific: 'repeat and calculate a mean' or 'cut the cube open to check the centre'. 'Be more careful' gains no mark.
- In the temperature explanation, use 'kinetic energy': particles move faster because they have more kinetic energy.