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Diffusion, a real beaker and a particle diagram, random movement

1. What diffusion is

Drop a crystal of purple **potassium manganate(VII)** into a beaker of **still water**. It dissolves, and the purple slowly spreads out through the water on its own. Nobody stirs it.

The purple colour shows where the purple **particles** are. Where the colour is dark, there are lots of particles in a small volume: a **high concentration**. **Concentration** is the amount of a substance in a given volume.

Diffusion is the net movement of particles from an area of higher concentration to an area of lower concentration.

- Diffusion happens in **solutions** (a substance dissolved in a liquid) and in **gases**. A smell spreading across a room is diffusion in a gas.
- Diffusion does not need energy from respiration. The particles move on their own.
- Substances move into and out of cells across the **cell membrane** by diffusion (B1 L1: the cell membrane controls the movement of substances into and out of the cell).

Watch out: diffusion happens in gases **and** in solutions. Water crossing a cell membrane is a special case of diffusion, called **osmosis** (B1 L9 Osmosis).

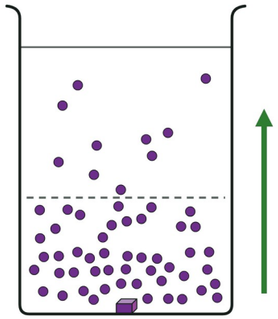
2. A real beaker and a particle diagram

Exam questions use **particle diagrams**. A particle diagram is a model, simplified on purpose:

- **Particles:** real particles are far too small to see, even with a light microscope. The diagram draws each one as a dot.
- **No line:** in the beaker the colour fades gradually. The diagram may draw a dashed line to split the water into two areas. The line is not a barrier.
- **How many:** a beaker holds billions of billions of particles. A diagram draws a few dozen.



A real beaker



A particle diagram

Particles are far too small to see: the dots in the diagram are a model. The purple colour shows where the particles are.

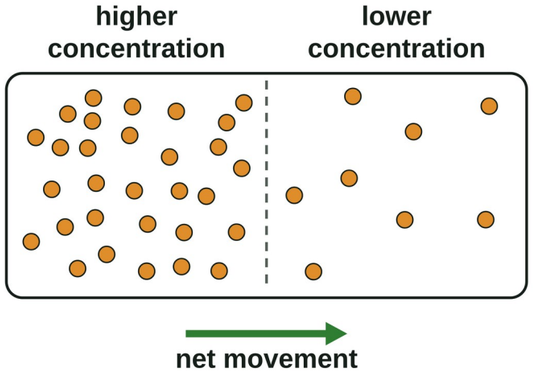
- **Movement:** each real particle moves at random. The arrow in a diagram shows only the net movement.
- **3D:** the real colour spreads in every direction. A diagram is flat.

Both show the same science: a higher concentration at the bottom and a net movement upwards.

3. Particles move at random

- Particles in a liquid or a gas are always moving, at **random**, in all directions.
- They cross from one area to the other **both ways**.
- There are more particles in the crowded area, so more of them move out of it than move into it.
- **Net movement** is the overall movement in one direction, after taking away the movement the other way.

Worked example: in one second, 30 particles cross from the left to the right and 8 cross back. The net movement is 30 − 8 = **22 particles to the right**.



Each dot is a particle. Real particles are far too small to see.

A **concentration gradient** is the difference in concentration between two areas. A bigger, or steeper, concentration gradient (a bigger difference in concentration) gives a faster net movement.

Watch out: particles do not "want" to spread out, and they do not all move one way. They move at random. Diffusion is a **net** movement.

4. Evenly spread: no net movement

As the particles spread out, the difference in concentration gets smaller, so the net movement slows down.

When the particles are **evenly spread**, they **keep moving**. The same number cross each way, so the concentration stays the same everywhere. There is **no net movement**.

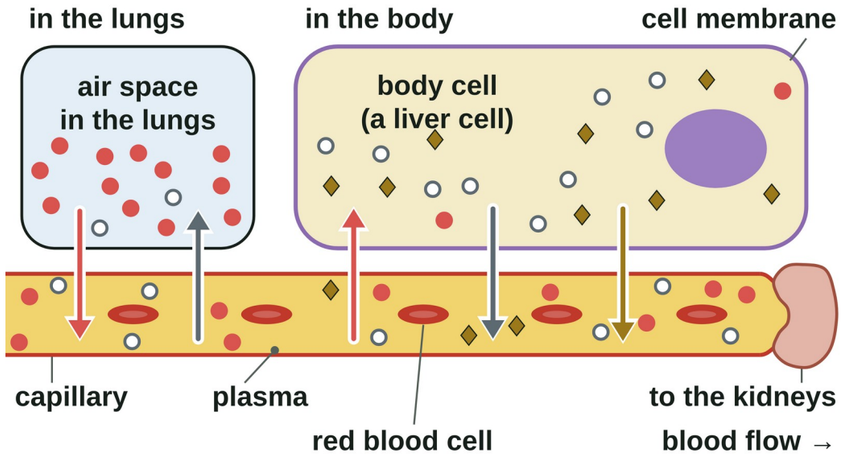
This is why the purple beaker ends up an even pale purple, not clear.

Watch out: evenly spread particles do **not** stop moving. Only the net movement stops.

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Diffusion in the body, urea, keeping the gradient steep

5. Diffusion into and out of cells



(the blood goes through the heart: B2 L6 The heart and circulation)

● oxygen ○ carbon dioxide ◆ urea. A diagram is simplified. Real particles are far too small to see.

Substance	Diffuses from	Diffuses to	Why
oxygen	the air in the lungs	the blood	there is more oxygen in the air
oxygen	the blood	respiring body cells	cells use oxygen in respiration
carbon dioxide	respiring body cells	the blood (then out in the lungs)	cells make carbon dioxide in respiration
urea	cells (mostly liver cells)	the blood plasma	cells make urea as a waste product

Each substance diffuses from where **its** concentration is higher to where it is lower. Several substances can diffuse across the same membrane at the same time, in different directions.

Respiration is a chemical reaction in every living cell that releases energy. It uses oxygen and makes carbon dioxide (B4 Bioenergetics).

Watch out: water crossing a partially permeable membrane, such as a cell membrane, is a special case of diffusion called **osmosis** (B1 L9 Osmosis).

6. Urea and excretion

Urea is a waste product that diffuses from cells into the blood plasma and is removed from the body by the kidneys. Most urea is made in liver cells.

- **Plasma** is the pale yellow liquid part of the blood, which carries blood cells and dissolved substances.
- The blood carries the urea to the **kidneys**. The kidneys remove it from the blood, in **urine**.
- **Excretion** is the removal of waste products made in the body.

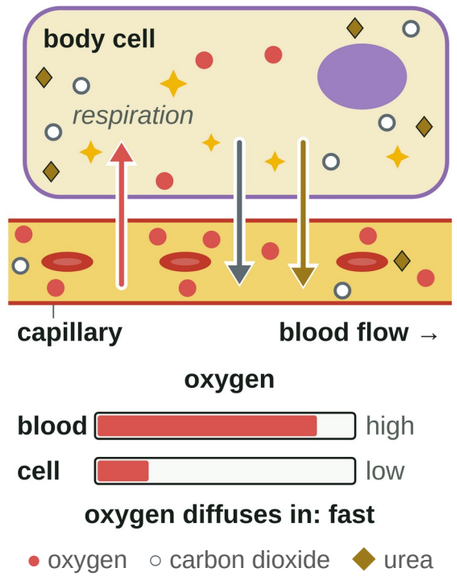
If the kidneys stopped removing urea, it would build up in the blood. The difference in concentration between the cells and the blood would get smaller, so urea would diffuse out of the cells more slowly.

7. Keeping the gradient steep

Diffusion stays fast only while the concentration gradient stays steep. In the body:

- Cells **use oxygen** in respiration all the time, so the oxygen concentration inside them stays low.
- **Flowing blood** keeps bringing oxygen, so the oxygen concentration in the blood stays high.
- Flowing blood **carries away** carbon dioxide and urea, so their concentration next to the cells stays low.
- The heart keeps the blood moving (B2 L6 The heart and circulation).

If the blood stopped flowing, the difference in concentration would shrink and diffusion would slow down.



Watch out: diffusion needs **no** energy from respiration. Respiration only keeps the gradient steep, by using oxygen. Energy is **released** by respiration; never write that it is "made".

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The rate of diffusion

8. Four factors that affect the rate of diffusion

AQA lists three factors: the difference in concentration (concentration gradient), the temperature, the surface area of the membrane. The distance is a fourth. A bigger concentration gradient, a higher temperature, a larger surface area and a shorter distance each make diffusion faster.

Factor	Diffusion is faster when ...	Why
concentration gradient	the difference in concentration is bigger (a steeper gradient)	more particles move out of the crowded area than move back
temperature	the temperature is higher	the particles have more energy and move faster
surface area of the membrane	the surface area is larger	more particles can cross at the same time
distance	the distance is shorter (a thin membrane)	the particles have less far to go

Exchange surfaces in the body, such as the alveoli in the lungs, have a large surface area and a thin membrane: B1 L10 Active transport and exchange surfaces explains them.

> **Watch out:** when they are heated, particles do **not** expand or get bigger. They have more energy and move faster.

9. Measuring the rate of diffusion

A coloured dye spreads into clear **agar jelly**. Jelly is still, so there are no currents: the dye moves only by diffusion.

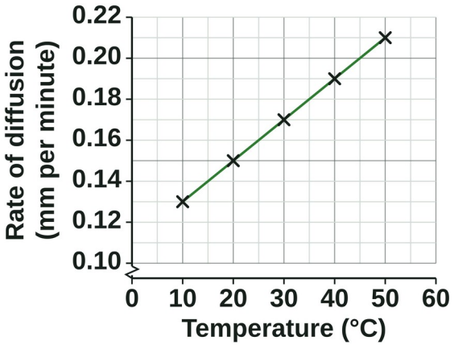
1. Half-fill five test tubes with agar jelly.
2. Stand them in water baths at 10, 20, 30, 40 and 50 °C.
3. Add the same volume of the same dye on top of each.
4. After 60 minutes, measure how far the colour has moved down, with a ruler (mm).

- **Independent variable:** the temperature. **Dependent variable:** the distance the dye moves (or the rate).
- **Control variables:** the same dye, the same concentration and volume of dye, the same jelly, the same size of tube, the same time.
- Safety: wear eye protection; take care with hot water.

10. Maths skills: the rate of diffusion

rate of diffusion = distance ÷ time

Temperature (°C)	Distance moved in 60 minutes (mm)	Rate of diffusion (mm/min)
10	7.8	0.13
20	9.0	0.15
30	10.2	0.17
40	11.4	0.19
50	12.6	0.21



Reading the graph: go up from 35 °C to the line, then across: the rate is about 0.18 mm per minute.

Worked example 1: a dye moves 8.4 mm in 35 minutes.

- Rate = 8.4 ÷ 35 = **0.24 mm per minute**. Check: 0.24 × 35 = 8.4 mm.

Worked example 2 (change the units first): a dye moves 1.1 cm in 1 hour 40 minutes.

- 1.1 cm = 11 mm (1 cm = 10 mm). 1 hour 40 minutes = 100 minutes (1 hour = 60 minutes).
- Rate = 11 ÷ 100 = **0.11 mm per minute**.

Always show your working and give the unit (mm per minute).

This is a **mean** (average) rate. The dye slows down as it spreads further, because the difference in concentration gets smaller.

11. Apply it: muscles during exercise

During exercise, muscle cells **respire faster**:

- They use oxygen faster, so the oxygen inside them falls lower. The oxygen gradient is steeper, so oxygen diffuses in faster.
- They make more carbon dioxide, so it builds up inside them. The carbon dioxide gradient is steeper, so it diffuses out faster.
- Working muscles get a little warmer (about 39 °C), so the particles move faster.

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Key words, exam tips and check yourself

Key words

Cell membrane: a thin layer around the cell that controls the movement of substances into and out of the cell.

Concentration: the amount of a substance in a given volume.

Concentration gradient: the difference in concentration between two areas.

Diffusion: the net movement of particles from an area of higher concentration to an area of lower concentration.

Excretion: the removal of waste products made in the body.

Net movement: the overall movement in one direction, after taking away the movement the other way.

Particle: a tiny piece of a substance, far too small to see.

Plasma: the pale yellow liquid part of the blood, which carries blood cells and dissolved substances.

Rate of diffusion: how quickly diffusion happens, such as the distance a substance spreads in one minute.

Respiration: a chemical reaction in every living cell that releases energy.

Urea: a waste product that diffuses from cells into the blood plasma and is removed from the body by the kidneys.

Exam tips

- Write "net movement" and "from a higher concentration to a lower concentration": never just "from high to low".
- Say what moves and where: "oxygen diffuses from the blood into the cell".
- Particles move at random. Never write that they "want" to spread out. Diffusion needs no energy from respiration.
- Temperature: "the particles have more energy and move faster". Never "the particles expand".
- A steeper concentration gradient means a bigger difference in concentration.
- Rate = distance ÷ time. Change cm to mm and hours to minutes first, and give the unit.

Check yourself

Cover the answers, then check.

1. Write the definition of diffusion.
2. Diffusion happens in gases. Where else does it happen?
3. What is a concentration gradient?
4. Particles are evenly spread. Are they still moving? Is there a net movement?
5. Does diffusion need energy from respiration?
6. Name three substances that diffuse into or out of cells in the body.
7. Give the four factors that affect the rate of diffusion.
8. A dye moves 5.6 mm in 20 minutes. Calculate the rate of diffusion.

Answers

1. The net movement of particles from an area of higher concentration to an area of lower concentration.
2. In solutions (substances dissolved in a liquid).
3. The difference in concentration between two areas.
4. Yes, they keep moving. No, there is no net movement.
5. No. The particles move on their own, at random, using their own (kinetic) energy.
6. Oxygen, carbon dioxide and urea.
7. The difference in concentration (concentration gradient), the temperature, the surface area of the membrane, and the distance.
8. 5.6 ÷ 20 = 0.28 mm per minute.