Chromatography

4.8.1.3 · Chemical analysis · revision notes

Paper chromatography separates the substances in a mixture and helps identify them using Rf values. It is a required practical, so expect questions on the method, interpreting chromatograms and calculating Rf values.

Key facts

- Stationary phase = paper; mobile phase = solvent
- Measure from the start line to the centre of the spot
- Pure compound: a single spot in all solvents
- Same substance: same Rf value in the same solvent
- Rf = distance moved by substance ÷ distance moved by solvent
- Rf has no units and is between 0 and 1
- Mixture: two or more spots
- Start line in pencil; solvent level below the start line; lid on

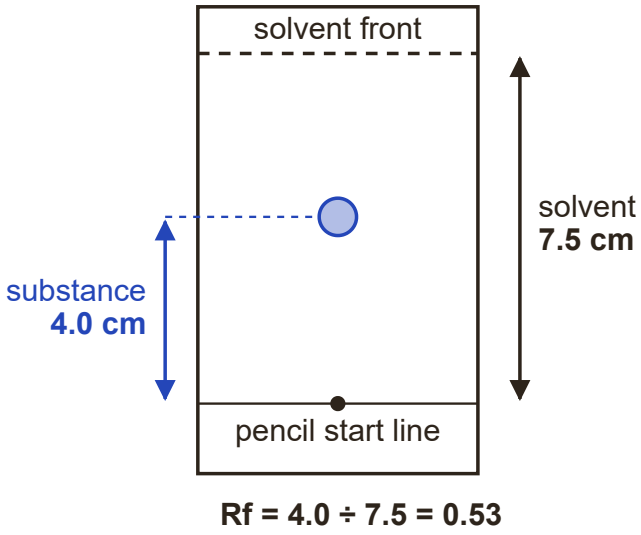
Notes

How paper chromatography works

- Chromatography separates the substances in a mixture and gives information to help identify them.
- It has a **stationary phase**, which does not move (the paper), and a **mobile phase**, which moves (the solvent).
- As the solvent moves up the paper it carries the substances with it. Different substances move different distances, so a mixture separates into several spots.
- Separation depends on the **distribution** of each substance between the two phases. A substance that is more soluble in the solvent, and less attracted to the paper, spends more time in the mobile phase, so it moves further.
- A substance that does not dissolve in the solvent stays on the start line.

Rf values

- Rf = distance moved by substance ÷ distance moved by solvent.
- Measure both distances from the start line: to the **centre** of the spot, and to the solvent front.



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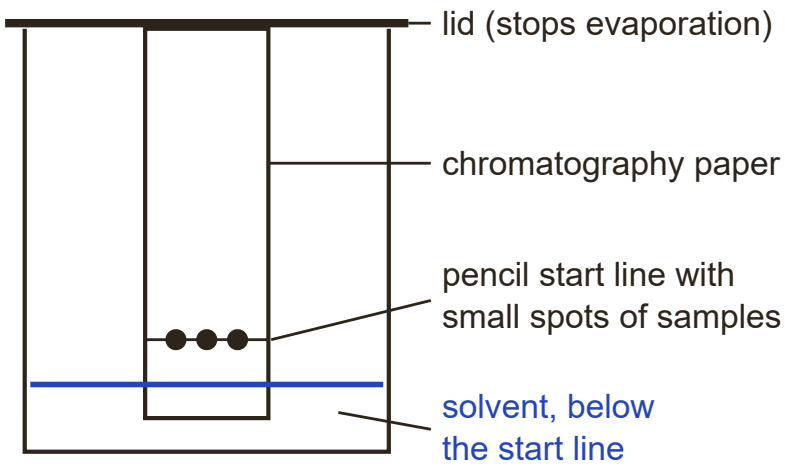
- Rf has no units and is always between 0 and 1, because a spot cannot move further than the solvent.
- Different compounds have different Rf values. A compound's Rf value changes with the solvent, so only compare Rf values measured with the same solvent.

Identifying substances and checking purity

- Run the unknown alongside known reference substances on the same paper. A spot at the same height (same Rf) as a reference suggests the same substance.
- A **pure** compound gives a **single spot** in all solvents. A mixture gives two or more spots.
- Two substances can have the same Rf in one solvent, so a mixture might show one spot. Repeating with a different solvent can separate them.

Required practical: method

- Draw a start line in **pencil** near the bottom of the paper. Pencil does not dissolve in the solvent; ink would run.
- Put small spots of each sample on the line, spaced apart.
- Stand the paper in a beaker of solvent (e.g. water) with the solvent level **below** the start line, so the spots do not dissolve into the solvent. Put a lid on to stop the solvent evaporating.



Solvent level below the pencil line, lid on, spots small and spaced apart.

- Take the paper out before the solvent reaches the top, mark the solvent front in pencil straight away, then let it dry.
- Measure from the start line to the centre of each spot and to the solvent front, then calculate each Rf value and compare it with the reference values.

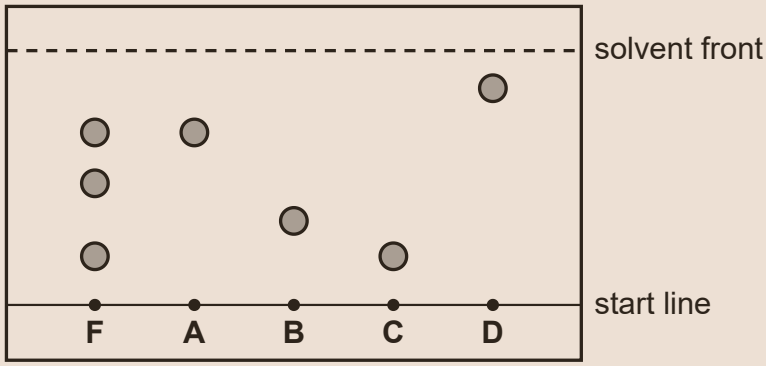
How to answer each type of question

Interpret a chromatogram

1 to 3 marks | Grade 4

1. Count the spots for each sample: more than one spot means a mixture.
2. Compare heights with the reference substances: the same height means probably the same substance.
3. Name the matching substances, and say if any spot matches none of them.

Example. A food colouring, F, was tested on the same chromatogram as four known dyes, A, B, C and D. F produced three spots. Two of its spots were at the same heights as the spots of A and C. The third spot did not match any of the known dyes.



(a) Is F a pure substance? Give a reason.
(b) What can you conclude about the dyes in F?

Model answer.

(a) No, because it produced more than one spot / three spots, so it is a mixture (1)
(b) F contains dyes A and C (1). F also contains a dye that is not A, B, C or D (1).

Calculate an Rf value

2 marks | Grade 5

1. Measure (or read) the distance from the start line to the centre of the spot.
2. Measure (or read) the distance from the start line to the solvent front.
3. Divide: spot distance ÷ solvent distance.
4. Round to the significant figures asked for. No units.

Example. On a chromatogram, the solvent front moved 8.4 cm from the start line. The centre of the spot of dye X moved 2.9 cm.
Calculate the Rf value of dye X. Give your answer to 2 significant figures.

Model answer.

Rf = 2.9 ÷ 8.4 (1)
= 0.345… = 0.35 (1)

Use Rf values to identify a substance

2 marks | Grade 5

1. Calculate the Rf value of the unknown spot.
2. Compare it with the Rf values given for the same solvent.
3. Choose the closest match and name it.

Example. The table gives the Rf values of four food dyes, using water as the solvent.

Dye	P	Q	R	S
Rf value	0.21	0.47	0.66	0.80

A spot from an unknown dye moved 3.3 cm. The solvent front moved 7.0 cm.
Identify the unknown dye. Show your working.

Model answer.

Rf = 3.3 ÷ 7.0 = 0.47 (1)

Dye Q (1)

6-mark: describe the chromatography method

4 to 6 marks | Grade 5

1. Start line in pencil; small spots of the sample and of each reference substance on it.
2. Solvent level below the start line; lid on.
3. Remove the paper before the solvent reaches the top; mark the solvent front.
4. Say how you use the results: compare the heights of the spots, or calculate and compare Rf values.

Example. A student wants to find out whether a green ink contains dye P and dye Q. Samples of P and Q are available.
Describe how the student could use paper chromatography to do this. [6 marks]

Model answer.

Draw a pencil line about 2 cm above the bottom of the chromatography paper. Put a small spot of the green ink, of P and of Q on the line, spaced apart. Stand the paper in a beaker containing a little solvent, e.g. water, with the solvent below the pencil line, and put a lid on. Leave it until the solvent has nearly reached the top, then remove the paper, mark the solvent front and let it dry. If the ink gives spots at the same heights as the spots of P and Q, the ink contains P and Q. The Rf values could also be calculated and compared.

Marked by levels. Level 3 (5–6 marks): a clear, logical method that would work, including how the results show whether P and Q are present. Level 2 (3–4 marks): most of the method, with some steps or the use of the results missing. Level 1 (1–2 marks): one or two relevant steps.

Explain how chromatography separates a mixture 2 to 3 marks **Grade 7**

1. Name the phases: the paper is stationary, the solvent is mobile.
2. Say that each substance is distributed differently between the two phases (different solubility in the solvent, different attraction to the paper).
3. Link this to distance: more time in the mobile phase means it moves further, so the substances separate.

Example. Explain how paper chromatography separates a mixture of two dyes.

Model answer. The solvent (mobile phase) moves up through the paper (stationary phase) (1). The two dyes are distributed differently between the phases / have different solubilities in the solvent and different attractions to the paper (1). The dye that spends more time in the mobile phase moves further up the paper, so the two dyes separate (1).

Don’t lose marks

- Measuring to the top of the spot, or from the bottom of the paper. Measure from the start line to the centre of the spot.
- Giving Rf a unit, or an answer greater than 1.
- Drawing the start line in ink: the ink dissolves and gives extra spots.
- Putting the solvent above the start line: the samples dissolve into the solvent instead of moving up the paper.
- Saying one spot proves a substance is pure. A pure compound gives a single spot in all solvents.
- Thinking a spot left on the start line is pure. It means that substance is insoluble in that solvent.

More tips

Memory tricks

- Rf = spot ÷ solvent: the smaller distance goes on top, so Rf is always less than 1. If you get more than 1, you divided the wrong way round.
- 'Pencil doesn't run, spots don't drown': pencil start line, solvent below it.
- Stationary stays still (paper); mobile moves (solvent).
- Same height, same paper, same solvent: probably the same substance.

Exam technique

- Write the Rf formula first, then substitute: this can earn a mark even if you misread a distance.
- Give Rf values to the significant figures asked for, or 2 significant figures if none are stated.
- When asked 'why' about a step, give the reason, e.g. 'lid on, to stop the solvent evaporating'.
- When comparing samples, refer to the heights or Rf values and name the substances that match.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Tell mixtures from pure substances on chromatograms

A mixture gives two or more spots; a pure substance gives a single spot.

Grade 4

Match spots to known reference substances

Spots of the same substance travel the same distance on the same paper with the same solvent.

Grade 4

Describe the paper chromatography method

Pencil start line, small spots, solvent below the line, lid on, mark the solvent front.

Grade 5

Calculate an Rf value

Rf = distance moved by substance ÷ distance moved by solvent, both measured from the start line.

Grade 6

Name the stationary and mobile phases

The paper is the stationary phase; the solvent is the mobile phase that moves through it.

Grade 6

Give Rf values to suitable significant figures

Rf has no units; give it to the significant figures asked for, usually 2.

Grade 7

Explain how chromatography separates substances

Each substance is distributed differently between the mobile and stationary phases, so each moves a different distance.

Grade 7

Use different solvents to test purity

A pure compound gives a single spot in every solvent; a mixture may only separate in some solvents.

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