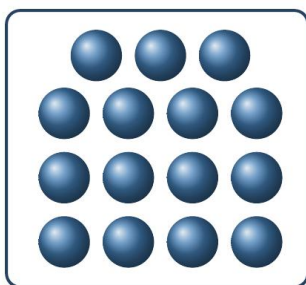




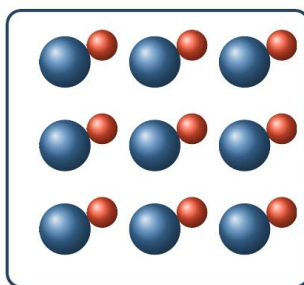
G C S E C h e m i s t r y

Pure Substances, Formulations & Paper Chromatography

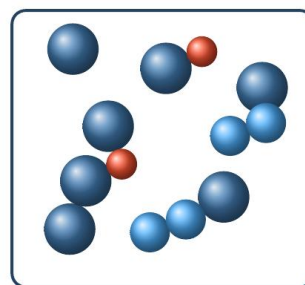
AQA specification 8.1 · Higher and Foundation



Pure element
one type of atom only



Pure compound
one type of molecule only



Mixture
two or more different
substances together

Revision Notes

Written for LearnWell Academy students

What you will learn in this topic

By the time you have worked through these notes, you should be able to:

- Explain what chemists mean by a pure substance, and why this is different from the everyday meaning of "pure"
- Use melting point and boiling point data to decide whether a substance is pure or a mixture
- Explain what a formulation is, and give examples of formulations used in everyday life
- Describe how paper chromatography separates the substances in a mixture
- Identify the stationary phase and the mobile phase, and explain why different substances travel different distances
- Calculate an R_f value from a chromatogram, and use it to help identify a substance
- Explain how a chromatogram shows whether a sample is a pure substance or a mixture

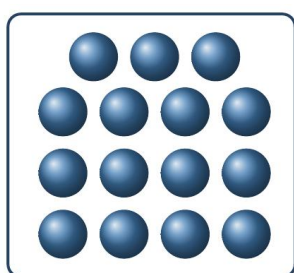
Part 1 · Pure Substances

What "pure" really means

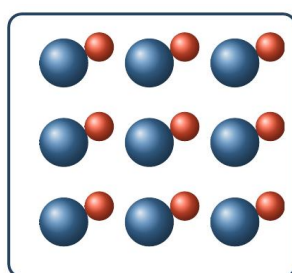
You have probably seen bottled water advertised as "pure", or a carton of orange juice labelled "pure orange juice". In everyday language, pure means nothing has been added. A chemist means something much stricter.

In chemistry, a pure substance is a single element or a single compound, not mixed with any other substance.

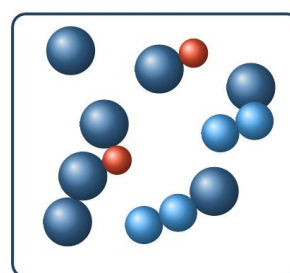
So pure water contains nothing but water molecules. Nothing else at all. Bottled spring water, on the other hand, contains water plus dissolved mineral ions, so to a chemist it is a mixture, not a pure substance. Orange juice contains water, sugars, acids, vitamins and colouring compounds, so it is very definitely a mixture, however "pure" the carton claims to be.



Pure element
one type of atom only



Pure compound
one type of molecule only



Mixture
two or more different
substances together

Pure substances contain only one type of particle. A mixture contains two or more different substances.

Watch out

Students often lose marks by writing that a pure substance is "one that has nothing added to it". That is the everyday meaning, not the chemical one.

Always write: a pure substance is a single element or compound.

Using melting point to test for purity

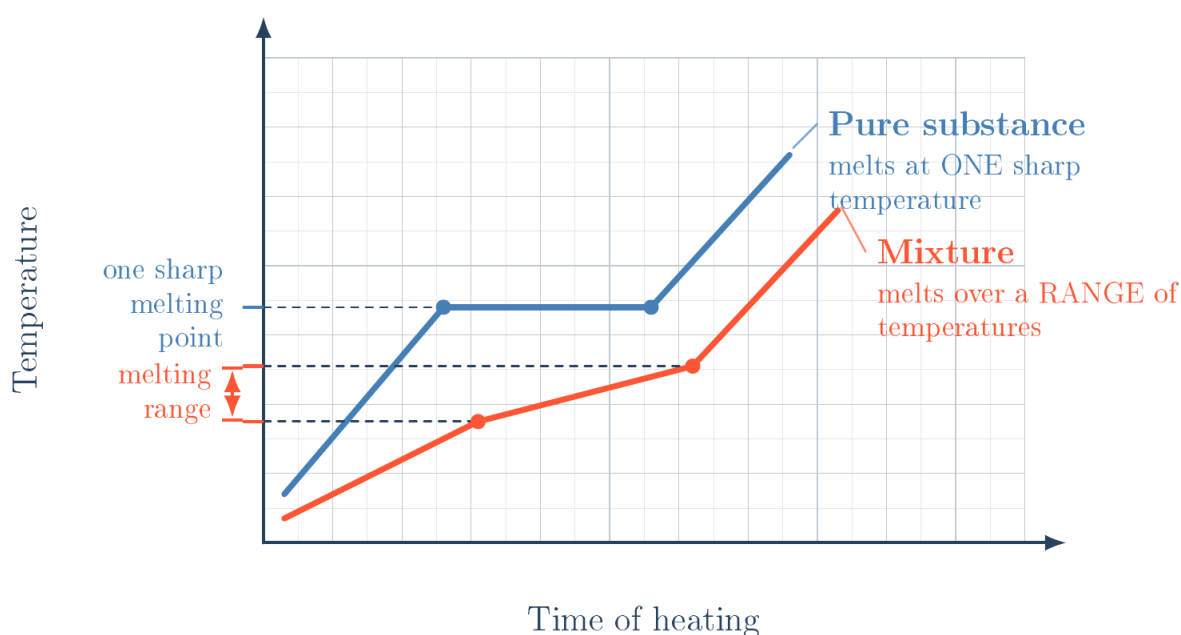
Here is the useful part. Purity is not just a definition to memorise, it is something you can actually measure in the lab, and the test is beautifully simple.

A pure substance melts and boils at one specific, sharp temperature.

Pure ice melts at exactly 0 °C. Pure water boils at exactly 100 °C at normal atmospheric pressure. The temperature stops rising while the substance changes state, then carries on rising once the change is complete. On a graph you see a flat plateau at a single temperature.

A mixture melts and boils over a range of temperatures.

Mixtures behave differently. The impurity gets in the way of the particles packing into their regular arrangement, so melting begins at a lower temperature than expected and continues over a spread of several degrees. Instead of a flat plateau you see a section that slopes gently upwards.



The shape of the heating curve tells you immediately whether you have a pure substance or a mixture.

This gives chemists two ways to test a sample. First, does it melt sharply or over a range? Second, is the melting point the value it should be? Both matter, because an impurity lowers the melting point as well as spreading it out.

Reading melting point data

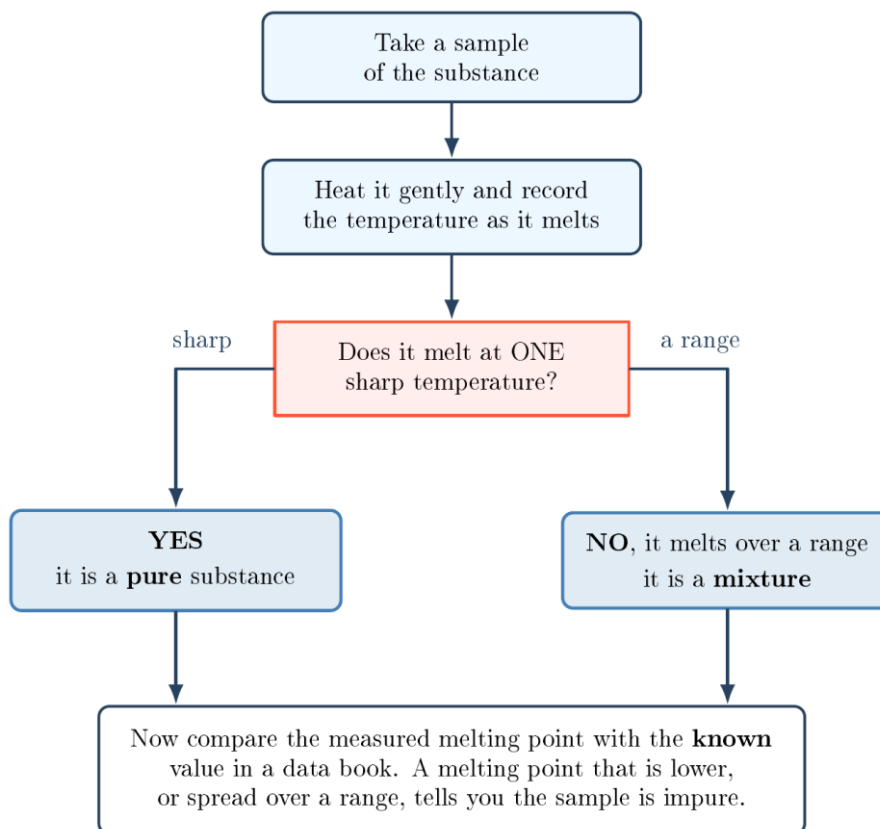
Exam questions often give you a table of measurements and ask you to decide which samples are pure. Work through this one before reading on.

Sample	Melting point measured	Pure or impure?	How you can tell
A	0 °C exactly	Pure	Sharp, single temperature, and it is the correct value for water
B	from -3 °C to 0 °C	Impure	Melts over a range, and begins below 0 °C
C	from 52 °C to 58 °C	Impure	A 6 °C range, so it cannot be a single substance
D	113 °C exactly	Pure	One sharp temperature

Sample A is pure water. Sample B is water with something dissolved in it, perhaps salt.

The theory as a flowchart

Here is the whole purity test as a single decision. If you can follow this, you can answer any question on it.



Deciding whether a sample is pure from its melting behaviour.

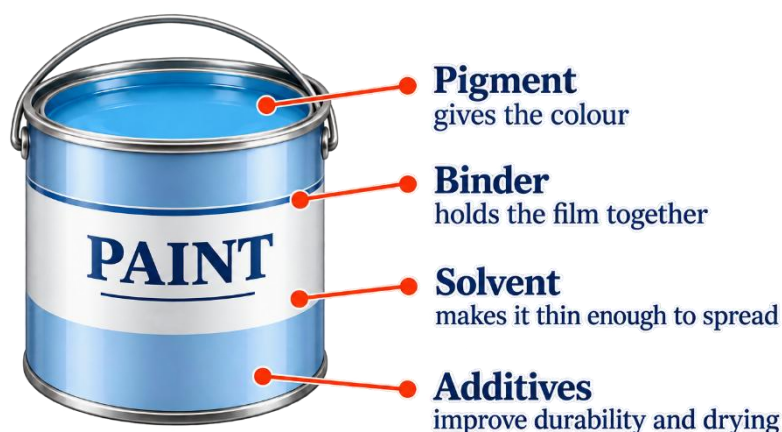
Part 2 • Formulations

What makes a mixture a formulation

Not every mixture is a formulation. Muddy water is a mixture, but nobody designed it. A formulation is a mixture that has been deliberately made to a recipe.

A formulation is a mixture that has been designed as a useful product, in which every component is present in a measured quantity and contributes to the properties of the product.

Two ideas are doing the work in that definition. The quantities are measured, not accidental. And each component has a job. Change the proportions and you change how the product behaves, which is exactly why manufacturers guard their recipes so carefully.



Every component is present in a **measured quantity**, chosen so the finished product has exactly the properties it needs. That is what makes it a formulation.

Paint is a formulation. Each component is measured, and each one has a job to do.

Formulations you already use

Once you know what to look for, you will spot formulations everywhere. Every one of these is a mixture made to a precise recipe:

Formulation	What it is designed to do	Why the proportions matter
Paints	Cover a surface with a coloured, durable film	Too much solvent and it runs; too little and it will not spread
Fuels	Release energy in a controlled way	The blend is adjusted for the engine and the season
Cleaning agents	Lift grease and dirt without damaging the surface	Too much detergent irritates skin; too little will not clean
Medicines	Deliver an exact dose of a drug to the body	The dose must be safe and effective, so it is measured precisely
Alloys	Give a metal improved strength or resistance to corrosion	Small changes in composition change the hardness a great deal
Fertilisers	Supply plants with the nutrients they need	The ratio of nitrogen, phosphorus and potassium is matched to the crop
Foods	Taste, look and keep well	Recipes are followed exactly so every batch is the same

Examiner's tip

If a question asks you to explain why something is a formulation, you need BOTH halves of the definition to get full marks:

1. it is a **mixture** of several components
2. each component is present in a **measured quantity** and affects the properties of the product

Saying only "it is a mixture" will not be enough.

Part 3 • Paper Chromatography

What chromatography is for

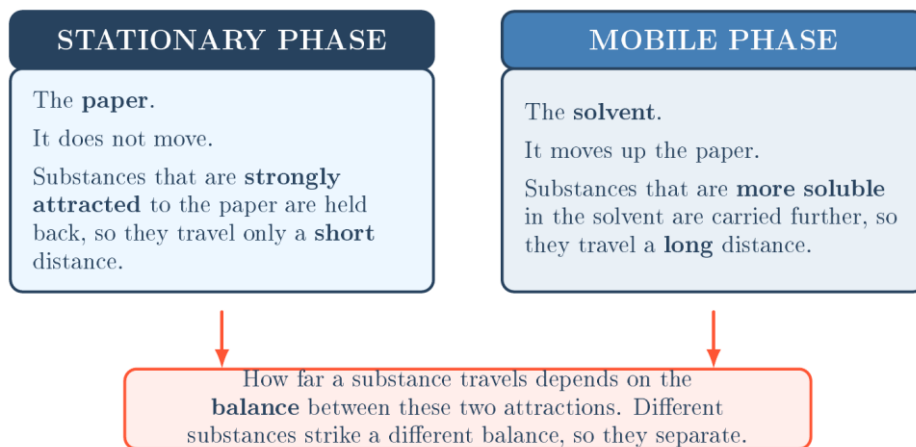
Suppose you have a sample of green ink and you want to know what is in it. Chromatography lets you separate the substances in that mixture and then work out what they are.

Paper chromatography separates the substances in a mixture, and gives information that helps you identify them.

It works because different substances are attracted to the paper and to the solvent by different amounts. That difference is the whole basis of the technique, so it is worth understanding properly rather than just memorising the method.

The two phases

Every chromatography experiment has two phases, and the exam will expect you to name both.

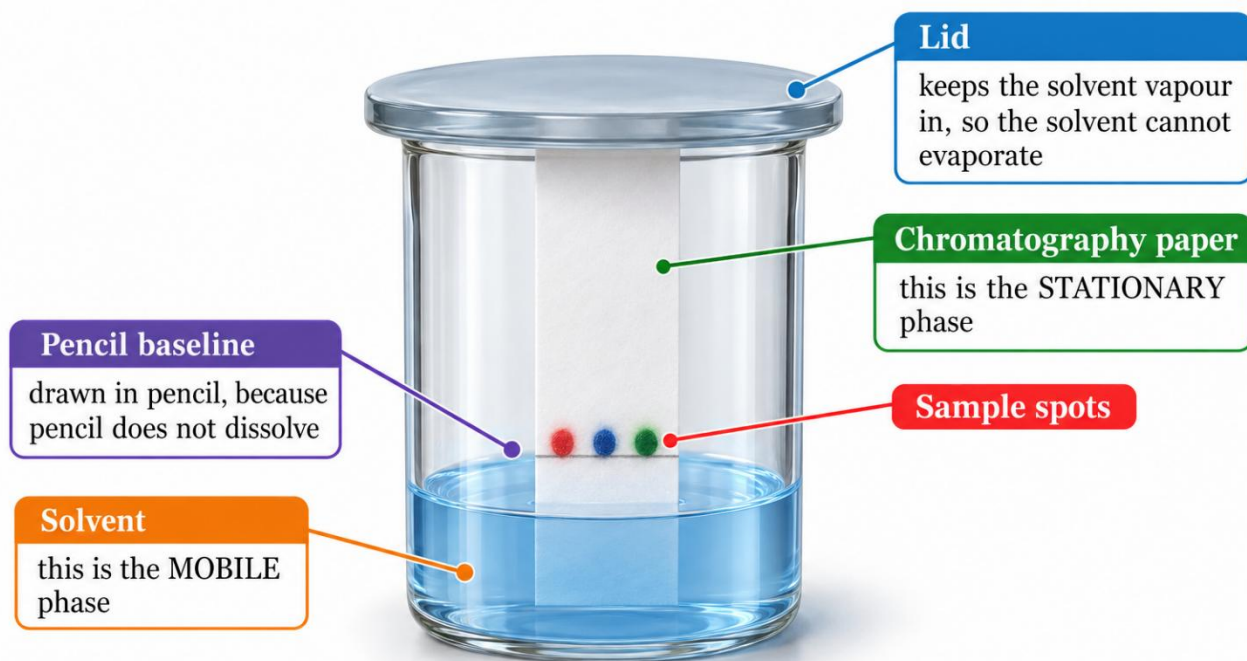


Separation happens because each substance strikes its own balance between these two attractions.

So a substance that clings tightly to the paper barely moves. A substance that dissolves readily in the solvent gets carried a long way up the paper. Everything else sits somewhere in between, and that is why the components spread out into separate spots.

The apparatus

This is a required practical, so you need to know the set-up and, more importantly, the reason behind each detail.



The solvent must start **below the baseline**. If it starts above, the spots dissolve straight into the solvent and nothing separates.

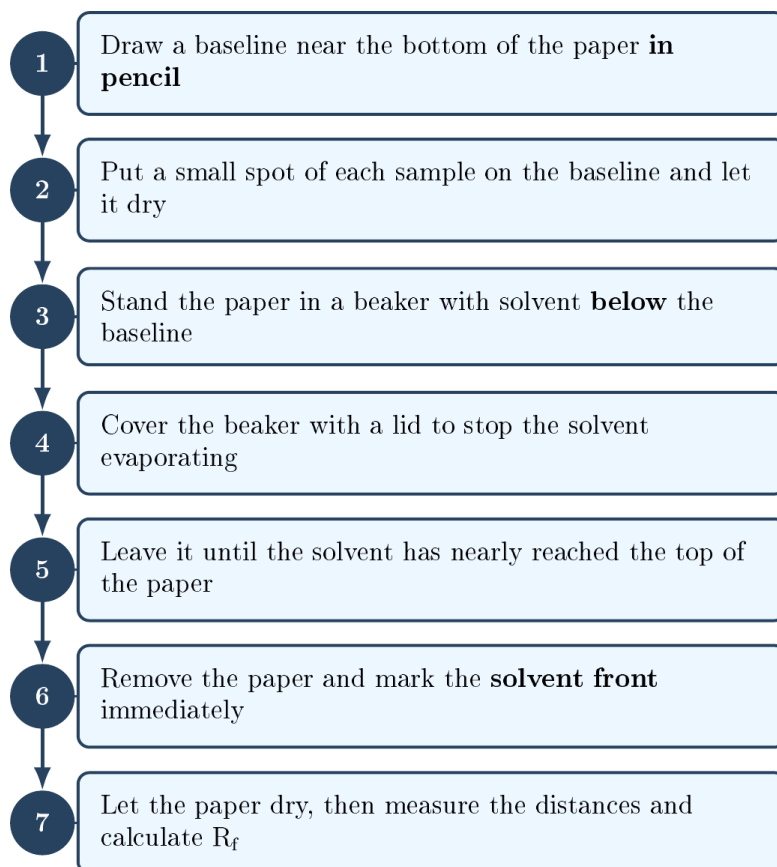
Paper chromatography apparatus. Every detail here exists for a reason.

Why each detail matters

Detail of the method	The reason for it
The baseline is drawn in pencil	Pencil is insoluble, so it will not dissolve and travel up the paper with the solvent. Ink would separate and ruin the result
The solvent starts below the baseline	If the solvent covered the spots, they would dissolve straight into it instead of travelling up the paper
The spots are kept small	Small spots stay compact, so they separate cleanly instead of smearing into each other
A lid is put on the beaker	It stops the solvent evaporating, which would change the concentration and make the run unreliable

Detail of the method	The reason for it
The solvent front is marked immediately	Once the paper dries you can no longer see how far the solvent reached, and you need that distance for the calculation

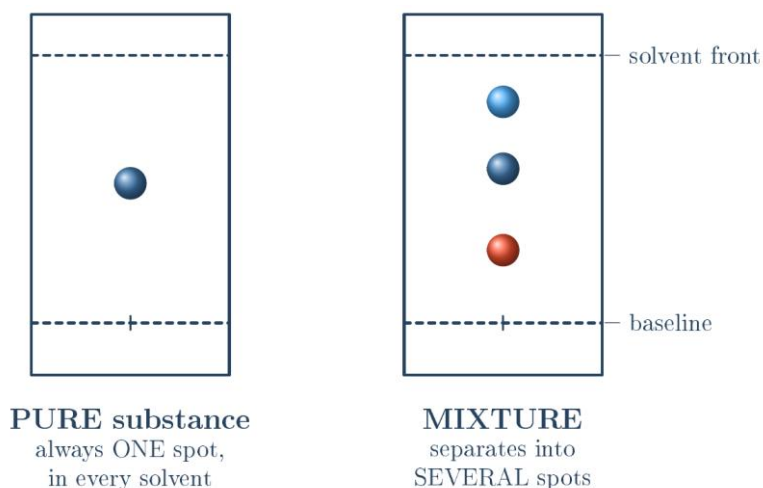
The method as a flowchart



The seven steps of paper chromatography, in order.

Reading a chromatogram

When the run has finished and the paper has dried, what you are left with is called a chromatogram. It tells you two things straight away: how many substances were in the sample, and how far each one travelled.



A pure substance gives a single spot. A mixture separates into several spots.

Key point

A pure substance gives one spot in every solvent you try.

That last part matters. A mixture might happen to give a single spot in one particular solvent if two of its components travel the same distance. So if you want to prove a substance is pure, you must run the chromatogram in more than one solvent.

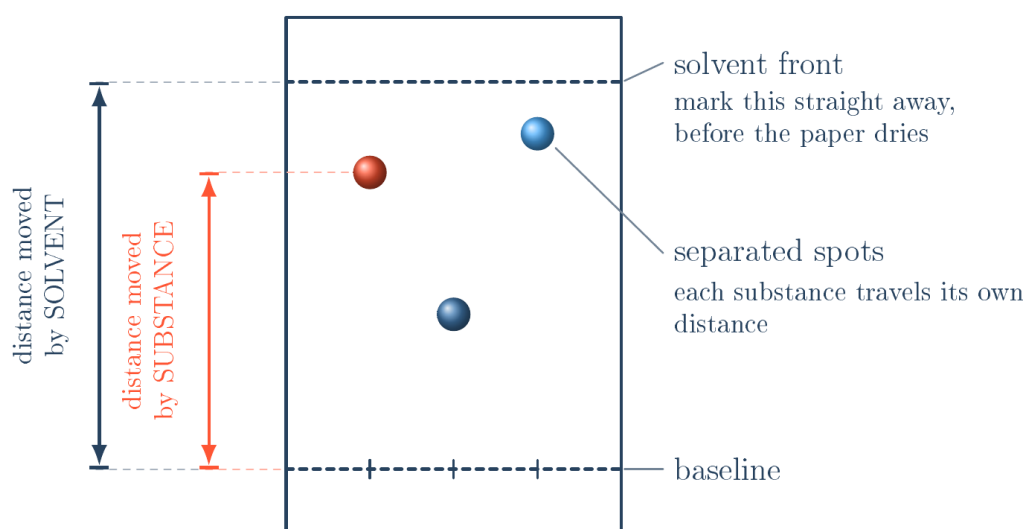
Part 4 • R_f Values

Why we need R_f

Measuring how far a spot travelled in centimetres is not much use on its own, because it depends on how long you left the paper in the solvent and how big the paper was. What we need is a number that stays the same every time, so we can compare results with other people's.

That number is the **R_f** value. It compares how far the substance moved with how far the solvent moved.

$$R_f = \frac{\text{distance moved by the substance}}{\text{distance moved by the solvent}}$$



Always measure to the **centre** of a spot, never to its edge.

Measure both distances from the baseline, and always to the centre of the spot.

Watch out

Because the substance can never travel further than the solvent, an R_f value is always between 0 and 1.

R_f has **no units**. It is a ratio of two lengths, so the units cancel out.

If you calculate an R_f greater than 1, you have divided the wrong way round.
Check which distance went on top.

Worked examples

Worked example 1

A spot of dye travels 3.6 cm from the baseline. In the same time, the solvent travels 8.0 cm from the baseline. Calculate the R_f value of the dye.

Step 1 Write down the equation.

$$R_f = \frac{\text{distance moved by the substance}}{\text{distance moved by the solvent}}$$

Step 2 Substitute the two distances, both measured from the baseline.

$$R_f = \frac{3.6 \text{ cm}}{8.0 \text{ cm}} = 0.45$$

Step 3 Check the answer is sensible. It is between 0 and 1, and it has no units.

$$R_f = 0.45$$

Worked example 2

A substance is known to have an R_f value of 0.72 in a particular solvent. In an experiment the solvent travels 9.5 cm. How far would you expect the substance to travel?

Step 1 Rearrange the equation to make the substance distance the subject.

$$\text{distance moved by substance} = R_f \times \text{distance moved by solvent}$$

Step 2 Substitute the values you have been given.

$$0.72 \times 9.5 \text{ cm} = 6.84 \text{ cm}$$

$$\text{distance} = 6.8 \text{ cm (2 s.f.)}$$

Worked example 3

A mixture of two food colourings, A and B, is separated by paper chromatography. The solvent travels 7.5 cm. Colouring A travels 2.1 cm and colouring B travels 5.4 cm. Calculate the R_f value of each colouring, and use the data table to identify them.

Step 1 Calculate each R_f value separately, using the same solvent distance for both.

$$R_f(A) = \frac{2.1}{7.5} = 0.28$$

$$R_f(B) = \frac{5.4}{7.5} = 0.72$$

Step 2 Compare your values with the known values in the table.

Food colouring	Known R_f value in this solvent
Tartrazine	0.28
Sunset yellow	0.45
Carmoisine	0.58
Brilliant blue	0.72

Step 3 Match them up and state the conclusion clearly.

A is tartrazine and B is brilliant blue

Examiner's tip

R_f values only match if the **same solvent** was used. A substance has a different R_f value in a different solvent, so a table of values is useless unless the solvent is stated.

This is why exam questions always tell you which solvent was used, and why you should say so in your answer.

Sample Questions

Work through these without looking back at the notes. Answers, with full working, are on the last page.

1. Give the chemical meaning of the term pure substance. **[1 mark]**
2. A student tests two samples of a white solid. Sample X melts at 80 °C exactly. Sample Y melts between 74 °C and 79 °C. State which sample is pure, and explain how the data tells you this. **[3 marks]**
3. Explain why the baseline in paper chromatography must be drawn in pencil rather than in ink. **[2 marks]**
4. Define the term formulation, and explain why paint is described as a formulation. **[3 marks]**
5. In a chromatography experiment, a spot travels 4.2 cm from the baseline while the solvent travels 10.5 cm. Calculate the R_f value of the substance. **[2 marks]**
6. A dye has an R_f value of 0.35 in a particular solvent. In an experiment using the same solvent, the solvent front is 8.4 cm from the baseline. Calculate how far the dye travels. **[2 marks]**
7. A student obtains a chromatogram of a black ink that shows four separate spots. Explain what this tells you about the ink, and explain why the student cannot be certain that each spot is a single pure substance. **[4 marks]**

Answers

1

A single element or a single compound, not mixed with any other substance. (1)

2

Sample X is pure. (1) It melts at one sharp temperature, which is what a pure substance does. (1) Sample Y melts over a range of 5 °C, which shows it is a mixture; the impurity also lowers the temperature at which melting begins. (1)

3

Pencil is insoluble in the solvent, so the baseline stays where it was drawn. (1) Ink would dissolve in the solvent and travel up the paper, separating into its own spots and ruining the result. (1)

4

A formulation is a mixture designed as a useful product, in which each component is present in a measured quantity and contributes to the properties of the product. (2) Paint qualifies because it contains pigment, binder, solvent and additives, each measured out so the paint has the right colour, spreads properly and dries to a durable film. (1)

5

Substitute the two distances into the equation: (1)

$$R_f = \frac{4.2}{10.5} = 0.40$$

R_f = 0.40 (1) No units, and correctly less than 1.

6

Rearrange, then substitute: (1)

$$\text{distance} = 0.35 \times 8.4 = 2.94 \text{ cm}$$

distance = 2.9 cm (2 s.f.) (1)

7

Four spots show that the ink is a mixture (1) of at least four different substances. (1)
The student cannot be certain each spot is pure because two substances may happen to travel the same distance in this particular solvent and so appear as one spot. (1) To check, the chromatogram should be run again using a different solvent; a substance that is genuinely pure gives a single spot in every solvent. (1)

Before you move on, check you can

define a pure substance the way a chemist would

use melting point data to decide whether a sample is pure

define a formulation and justify an example

describe the chromatography method and give a reason for each step

calculate an R_f value and use it to identify a substance