Chemical analysis

Model answers and marking points

GCSE science 6-mark questions

This topic online

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1 A food lab in Bristol buys benzoic acid, a preservative, from three suppliers. Pure benzoic acid melts at 122 °C. A technician, Ewan, measures the melting range of each sample.

Sample	Starts to melt in °C	Fully melted in °C
X	122	122
Y	114	119
Z	108	117

The label on sample Y says "100% pure, nothing added".

Use the data to decide which samples are pure. Explain what the word "pure" means to a chemist and why the label on Y may be misleading.

(6 marks)

Model answer

To a chemist, a pure substance is a single element or a single compound with nothing else mixed in. A pure substance melts at one sharp, fixed temperature. If there are impurities, the melting point is lowered and the substance melts over a range of temperatures.

Sample X starts and finishes melting at 122 °C, which is exactly the melting point of pure benzoic acid, so X is pure.

Sample Y starts melting at 114 °C and is fully melted at 119 °C. This is below 122 °C and over a 5 °C range, so Y is impure.

Sample Z melts from 108 °C to 117 °C. This is a 9 °C range and starts even lower, so Z is the least pure of the three. The bigger the drop and the wider the range, the more impurity is present.

The label on Y is using the everyday meaning of "pure", which people take to mean natural or with nothing added. In chemistry, pure means only one substance. The melting data show that Y contains something other than benzoic acid, so the label is misleading.

Marking points (credit any 6 relevant points, linked in a sensible order)

- to a chemist a pure substance contains only one element or one compound
- a pure substance melts at a sharp, fixed temperature
- impurities lower the melting point and make it melt over a range of temperatures
- sample X melts sharply at 122 °C, the value for pure benzoic acid, so X is pure
- sample Y melts over a 5 °C range below 122 °C, so Y is impure
- sample Z melts over a 9 °C range starting at 108 °C, so Z is the most impure
- the bigger the drop and the wider the range, the more impurity there is
- in everyday language pure means natural or with nothing added, which is different from the chemical meaning
- the label on Y uses the everyday meaning, but the data show it contains other substances
- melting point data can therefore be used to tell pure and impure samples apart

How it is marked

- 5-6 marks: gives the chemical meaning of pure, uses values to judge all three samples, ranks the impurity and explains the difference between the everyday and chemical meaning for the label.
- 3-4 marks: identifies X as pure and Y and Z as impure with some use of the data, and makes a point about the label or the meaning of pure.
- 1-2 marks: identifies the pure sample or gives a definition of pure with little use of the data.

What loses marks

- saying an impure sample has a higher melting point
- judging the samples without quoting the temperatures
- defining pure as natural or with no chemicals
- not explaining why the label is misleading

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2 Trading standards officers in Cardiff test the red colouring in a bag of imported sweets. They suspect it contains dye D, which is not allowed in UK food. They run a paper chromatogram with water as the solvent. The solvent moves 8.0 cm.

Substance	Number of spots	Distance moved by spots in cm
sweet colouring	2	2.4 and 5.6
allowed dye A	1	2.4
allowed dye B	1	4.8
banned dye D	1	5.6

Evaluate whether the sweets contain the banned dye. Include R_f values in your answer. (6 marks)

Model answer

The R_f value is the distance moved by a spot divided by the distance moved by the solvent. The solvent moved 8.0 cm.

The sweet colouring gave two spots, so it is a mixture of at least two dyes. Their R_f values are 2.4 ÷ 8.0 = 0.30 and 5.6 ÷ 8.0 = 0.70.

For the known dyes, A has R_f 0.30, B has 0.60 and D has 0.70. The lower spot in the sweet matches dye A, which is allowed. The upper spot matches dye D, which is banned. Nothing in the sweet has an R_f of 0.60, so dye B is not there.

The dyes separate because each one has a different balance between being attracted to the paper, the stationary phase, and dissolving in the water, the mobile phase.

However, two different dyes might happen to have the same R_f in water. To be more certain, the officers should run another chromatogram with a different solvent and check that the spot still matches dye D.

Overall the evidence strongly suggests that the sweets contain the banned dye D, mixed with allowed dye A.

Marking points (credit any 6 relevant points, linked in a sensible order)

- R_f = distance moved by the substance divided by distance moved by the solvent
- the sweet colouring has two spots, so it is a mixture of at least two dyes
- R_f values of the sweet spots are 2.4 / 8.0 = 0.30 and 5.6 / 8.0 = 0.70
- R_f of dye A = 0.30, dye B = 0.60, dye D = 0.70
- the lower sweet spot matches dye A, an allowed dye
- the upper sweet spot matches dye D, the banned dye
- no spot matches dye B, so dye B is not present
- different substances move different distances because they differ in how they are attracted to the paper (stationary phase) and dissolve in the solvent (mobile phase)
- limitation: two different dyes could have the same R_f in water, so the test should be repeated with a different solvent to be sure
- conclusion: the evidence strongly suggests the sweets contain dye D

How it is marked

- 5-6 marks: calculates the R_f values correctly, matches each sweet spot to a dye, notes the mixture, gives a limitation and reaches a justified conclusion.
- 3-4 marks: calculates some R_f values or matches spots by distance and concludes dye D is present, with little discussion of reliability.
- 1-2 marks: states that the sweets contain dye D or are a mixture, with no calculation or matching.

What loses marks

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- dividing the solvent distance by the spot distance
- forgetting to give R_f values when asked
- not noticing that two spots means a mixture
- giving a conclusion with no mention of how certain it is

3 A teacher in Belfast has four racks of sealed test tubes, labelled 1 to 4. All the tubes in one rack contain the same gas, but the labels saying which gas it is have fallen off. She knows the gases are hydrogen, oxygen, carbon dioxide and chlorine. All four gases are colourless or nearly colourless in a test tube.

Plan how a student could identify each gas safely. Give the result expected for each gas. (6 marks)

Model answer

The student should wear eye protection, open one tube at a time and work in a fume cupboard, because one of the gases is chlorine, which is toxic.

First, the student should take one tube from each rack and test it for chlorine. Open the tube and hold a piece of damp blue litmus paper just inside the mouth. If the gas is chlorine the paper will be bleached white. Doing this test first means the chlorine is found before any flames are used.

Next, take a fresh tube from each remaining rack and test for hydrogen. Hold a lighted splint at the mouth of the tube. Hydrogen burns with a squeaky pop.

Then take fresh tubes from the racks still not identified and test for oxygen. Push a glowing splint into the tube. Oxygen relights the glowing splint.

To test for carbon dioxide, add a little limewater to a fresh tube from the last rack, put the stopper back and shake it. Carbon dioxide turns the limewater milky.

The student should use a new tube for each test and tick off each rack as its gas is identified. The last rack should still be given its own test, rather than just guessed, to confirm the result.

Marking points (credit any 6 relevant points, linked in a sensible order)

- test one gas at a time on a small sample, and do the chlorine test in a fume cupboard as chlorine is toxic
- test for chlorine: hold damp blue litmus paper in the gas
- chlorine bleaches the damp litmus paper white (it may turn red first)
- test for hydrogen: hold a lighted splint at the mouth of the tube
- hydrogen burns with a squeaky pop
- test for oxygen: put a glowing splint into the tube
- oxygen relights the glowing splint
- test for carbon dioxide: bubble the gas through limewater or shake it with limewater
- carbon dioxide turns limewater milky (cloudy)
- use a fresh sample for each test, and work by elimination so the last gas can be confirmed with its own test

How it is marked

- 5-6 marks: gives a correct test and result for all four gases in a sensible order, with at least one safety point.
- 3-4 marks: gives correct tests and results for two or three gases, or all four with a muddled result.
- 1-2 marks: gives one correct test or result, or names tests without results.

What loses marks

- mixing up the lighted splint (hydrogen) and the glowing splint (oxygen)
- using dry litmus paper for chlorine
- saying carbon dioxide puts out a splint as its test instead of limewater
- no safety point for chlorine

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4 Aisha works in a school prep room in Leicester. She has four white solids in unlabelled jars. They are lithium chloride, sodium bromide, magnesium sulfate and potassium carbonate. All four dissolve in water.

Plan a series of tests Aisha could use to identify each solid. Give the result expected for each test.

Separate science only

(6 marks)

Model answer

First Aisha should do a flame test on each solid. She dips a clean nichrome wire loop into the solid and holds it in a blue Bunsen flame. Lithium chloride gives a crimson flame, sodium bromide gives a yellow flame and potassium carbonate gives a lilac flame. Magnesium sulfate gives no clear colour. She must clean the wire between tests by dipping it in acid and heating it, so the ions from one sample do not mix with the next.

To confirm magnesium, she dissolves each solid in water and adds a few drops of sodium hydroxide solution. Magnesium ions form a white precipitate of magnesium hydroxide.

Then she tests the negative ions. She adds dilute acid to a sample of each. Potassium carbonate fizzes, and if the gas is bubbled through limewater it turns milky, showing carbon dioxide.

She adds dilute hydrochloric acid then barium chloride solution. Magnesium sulfate gives a white precipitate.

Finally she adds dilute nitric acid then silver nitrate solution. Lithium chloride gives a white precipitate and sodium bromide gives a cream precipitate.

Each solid then has two tests that agree.

Marking points (credit any 6 relevant points, linked in a sensible order)

- flame test: dip a clean nichrome wire loop in the solid (or its solution) and hold it in a blue Bunsen flame
- lithium ions give a crimson flame
- sodium ions give a yellow flame
- potassium ions give a lilac flame
- add a few drops of sodium hydroxide solution to a solution of each; magnesium ions give a white precipitate
- carbonate test: add dilute acid; potassium carbonate fizzes and the gas turns limewater milky
- sulfate test: add dilute hydrochloric acid then barium chloride solution; magnesium sulfate gives a white precipitate
- halide test: add dilute nitric acid then silver nitrate solution
- lithium chloride gives a white precipitate; sodium bromide gives a cream precipitate
- clean the wire between flame tests (dip in acid and heat) so ions do not contaminate the next test

How it is marked

- 5-6 marks: uses tests for both the positive and negative ions, gives the correct result for each solid and includes a sensible detail such as cleaning the wire or adding acid first.
- 3-4 marks: identifies the solids with correct tests for either the positive or the negative ions, or for both with some errors in results.
- 1-2 marks: gives one or two correct tests or results with no clear plan.

What loses marks

- mixing up the flame colours, especially lithium (crimson) and potassium (lilac)
- adding sulfuric acid in the sulfate test, which adds sulfate ions
- leaving out the acid before silver nitrate or barium chloride
- testing only the metal ions or only the non-metal ions

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5 A water company in Yorkshire needs to check the amounts of sodium, potassium and calcium ions in drinking water samples. A trainee, Tomasz, suggests using flame tests. His supervisor says the lab should use flame emission spectroscopy.

Compare flame tests with flame emission spectroscopy for this job.

Separate science only

(6 marks)

Model answer

Both methods put a sample into a flame. The metal ions are heated and give out light of particular colours.

In a flame test, a person looks at the colour of the flame and decides which ion is present. In flame emission spectroscopy, the light is passed through a spectroscope, which produces a line spectrum. The lines are compared with reference spectra to identify each ion.

The drinking water contains sodium, potassium and calcium together. In a flame test the colours mix, and the strong yellow from sodium can hide the lilac of potassium and the orange-red of calcium, so the result is unreliable. In spectroscopy each ion gives its own set of lines, so all three can be identified from one sample.

A flame test only tells you which ion is present. Spectroscopy can also measure how much of each ion there is, because the brightness of the lines depends on the concentration, which can be read from a calibration.

Spectroscopy is also more sensitive, so it detects the small amounts found in tap water, and it is quick and accurate for many samples. Flame tests are cheaper and simpler, but for this job spectroscopy is the better choice.

Marking points (credit any 6 relevant points, linked in a sensible order)

- both methods heat the sample in a flame and rely on metal ions giving out light
- in a flame test the colour of the flame is judged by eye
- in flame emission spectroscopy the light is passed through a spectroscope and a line spectrum is produced
- flame emission spectroscopy identifies the ions by comparing the spectrum with reference spectra of known ions
- flame tests only show which ion is there; spectroscopy can also measure the concentration from the intensity of the lines using a calibration
- in a mixture, one flame colour can hide another (yellow from sodium masks others), so flame tests are unreliable for mixtures
- spectroscopy can identify several ions in a mixture because each ion has its own lines
- spectroscopy is more sensitive, so it detects very small amounts of ions in drinking water
- spectroscopy is quicker and more accurate for many samples, but the instrument is expensive; flame tests are cheap and simple
- conclusion: spectroscopy suits this job because the water is a mixture and amounts are needed

How it is marked

- 5-6 marks: makes several point by point comparisons including identification of mixtures, measuring concentration and sensitivity, and links them to the drinking water job.
- 3-4 marks: gives correct features of both methods with some comparison, such as spectroscopy being more accurate or working with mixtures.
- 1-2 marks: describes one method only, or states that spectroscopy is better with no reason.

What loses marks

- describing each method separately with no comparison
- forgetting that flame tests cannot measure concentration
- saying spectroscopy uses a colour chart rather than reference spectra

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- not linking the answer to the water being a mixture

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