

Methods of purification and analysis: practice questions

Twenty original practice questions, worth 60 marks, on the experimental techniques and chemical analysis topic of Cambridge O Level Chemistry 5070 and Cambridge IGCSE Chemistry 0620: naming measuring apparatus, choosing a method of separation and purification, assessing purity from melting and boiling points, paper chromatography with R_f calculations and locating agents, and the tests for gases, cations and anions. In both current syllabuses this is Topic 12, Experimental techniques and chemical analysis: sections 12.1 (experimental design), 12.3 (chromatography), 12.4 (separation and purification) and 12.5 (identification of ions and gases); titration (12.2) is not tested here. For 0620, the R_f equation and locating agents are Extended (Supplement) content only: Core candidates may omit Q3, Q11(c), Q12 and Q18(a) and (d), which are marked "0620 Extended". Every question applies to 5070, which has no Core/Extended split. Section A has 8 multiple-choice questions (8 marks), Section B has 8 short-answer questions (24 marks) and Section C has 4 structured questions (28 marks). Allow about 70 minutes.

Key ideas you need

- Measuring apparatus: stop-watch for time, thermometer for temperature, balance for mass; for volume, a measuring cylinder (approximate), a burette (variable volumes, accurate), a volumetric pipette (one fixed volume, very accurate) and a gas syringe (volume of a gas).
- Definitions: a **solvent** dissolves a **solute** to give a **solution**; a **saturated solution** contains the maximum concentration of solute that can dissolve in the solvent at a specified temperature. In filtration the solid left on the paper is the **residue** and the liquid that passes through is the **filtrate**.
- Match the method to the physical properties: filtration (insoluble solid from a liquid); crystallisation (dissolved solid from its solution); simple distillation (solvent from a solution); fractional distillation (miscible liquids with different boiling points); a suitable solvent (dissolves one solid in a mixture but not the other).
- A pure substance melts and boils at a fixed, sharp temperature. An impurity lowers the melting point, raises the boiling point and makes both happen over a range of temperatures.
- In paper chromatography the baseline is drawn in pencil and the solvent starts below it. R_f = distance moved by substance $\div$ distance moved by solvent front. Worked example: a spot moves 4.5 cm and the solvent front 9.0 cm, so $R_f = 4.5 \div 9.0 = 0.50$ (no units). R_f is never greater than 1 and is the same for a given substance in the same solvent, on the same paper and at the same temperature, so it identifies substances. Colourless substances are shown up with a locating agent.
- Gas tests: hydrogen pops with a lighted splint; oxygen relights a glowing splint; carbon dioxide turns limewater milky; ammonia turns damp red litmus paper blue; chlorine bleaches damp litmus paper; sulfur dioxide turns acidified aqueous potassium manganate(VII) from purple to colourless.
- Flame colours: lithium red, sodium yellow, potassium lilac, calcium orange-red, barium light green, copper(II) blue-green.

- Cations with NaOH(aq) and NH₃(aq): Al³⁺, Zn²⁺ and Ca²⁺ all give white precipitates with NaOH(aq); in excess NaOH(aq) the Al³⁺ and Zn²⁺ precipitates dissolve but the Ca²⁺ precipitate does not. With NH₃(aq), Al³⁺ gives a white precipitate insoluble in excess, Zn²⁺ a white precipitate that dissolves in excess, and Ca²⁺ no precipitate. Cu²⁺: light blue precipitate, insoluble in excess NaOH(aq) but dissolving in excess NH₃(aq) to give a dark blue solution. Fe²⁺ green and Fe³⁺ red-brown precipitates, insoluble in excess of either reagent. Cr³⁺: green precipitate that dissolves in excess NaOH(aq); grey-green precipitate with NH₃(aq), insoluble in excess. NH₄⁺: ammonia given off on warming with NaOH(aq).
- Anion tests: carbonate, dilute acid gives carbon dioxide; chloride, bromide and iodide, dilute nitric acid then aqueous silver nitrate gives white, cream and yellow precipitates; sulfate, dilute nitric acid then aqueous barium nitrate gives a white precipitate; sulfite, dilute hydrochloric acid and warm gently, sulfur dioxide is given off (it turns acidified aqueous potassium manganate(VII) from purple to colourless); nitrate, warm with NaOH(aq) and aluminium foil, ammonia is given off.

Section A: multiple choice

One mark for each question. Choose the one correct answer.

1. Which method is used to obtain pure water from seawater? [1]

- **A** crystallisation
- **B** filtration
- **C** simple distillation
- **D** fractional distillation

2. A pure sample of a compound melts sharply at 125 °C. A student's sample of the same compound starts to melt at 118 °C and has completely melted at 124 °C. What does this show about the student's sample? [1]

- **A** It is pure.
- **B** It is impure.
- **C** It is a different pure compound.
- **D** It has decomposed on heating.

3. (0620 Extended) On a paper chromatogram a spot moves 3.2 cm from the baseline while the solvent front moves 8.0 cm. What is the R_f value of the spot? [1]

- **A** 0.40
- **B** 0.60
- **C** 2.5
- **D** 4.8

4. Which gas bleaches damp litmus paper? [1]

- **A** ammonia
- **B** carbon dioxide
- **C** chlorine

- **D** hydrogen

5. A compound gives a yellow colour in a flame test. Which metal ion does it contain? [1]

- **A** calcium
- **B** copper(II)
- **C** potassium
- **D** sodium

6. Aqueous sodium hydroxide is added, a little at a time, to a solution of a salt. A white precipitate forms and then dissolves when the sodium hydroxide is in excess. With aqueous ammonia, a white precipitate forms which does not dissolve in excess. Which cation is in the salt? [1]

- **A** aluminium
- **B** ammonium
- **C** calcium
- **D** zinc

7. Which pair of reagents is used to test a solution for sulfate ions? [1]

- **A** dilute hydrochloric acid, then limewater
- **B** dilute nitric acid, then aqueous barium nitrate
- **C** dilute nitric acid, then aqueous silver nitrate
- **D** aqueous sodium hydroxide, then aluminium foil

8. Which piece of apparatus should be used to measure out exactly 25.0 cm³ of a solution? [1]

- **A** beaker
- **B** conical flask
- **C** measuring cylinder
- **D** volumetric pipette

Section B: short answer

9. A mixture contains potassium nitrate, which is soluble in water, and powdered chalk (calcium carbonate), which is insoluble in water. Describe how you would obtain pure, dry crystals of potassium nitrate from the mixture. [4]

10. The table shows the solubility of two solids, P and Q, in two solvents.

Solid	Solubility in water	Solubility in ethanol
P	soluble	insoluble
Q	insoluble	soluble

Describe how you would obtain a pure, dry sample of Q from a mixture of P and Q. [3]

11. In a paper chromatography experiment:

(a) Explain why the baseline is drawn in pencil and not in ink. [1]

(b) Explain why the level of the solvent must be below the baseline at the start. [1]

(c) (0620 Extended) State what a locating agent is used for. [1]

12. (0620 Extended) In a chromatography experiment a dye moves 5.6 cm from the baseline while the solvent front moves 7.0 cm.

(a) Calculate the R_f value of the dye. [1]

(b) A second dye, run in the same solvent on the same type of paper, also has an R_f value of 0.80. State what this suggests about the two dyes. [1]

13. For each of the gases hydrogen, oxygen and carbon dioxide, describe the test and state the result of a positive test. [3]

14. Solutions X, Y and Z each contain one of the cations Cu^{2+} , Fe^{2+} and Zn^{2+} . The table shows what happens when aqueous sodium hydroxide and aqueous ammonia are added to each solution until in excess.

Solution	With NaOH(aq)	With NH_3 (aq)
X	white precipitate, dissolves in excess	white precipitate, dissolves in excess
Y	light blue precipitate, insoluble in excess	light blue precipitate, dissolves in excess to give a dark blue solution
Z	green precipitate, insoluble in excess	green precipitate, insoluble in excess

Identify the cation in each solution. [3]

15. Describe a test to show that a solution contains nitrate ions. Give the reagents, the conditions and the result of a positive test. [3]

16. Dilute hydrochloric acid is added to a white solid. The solid fizzes and the gas given off turns limewater milky.

(a) Name the gas. [1]

(b) Name the anion present in the solid. [1]

(c) A second white solid is warmed gently with dilute hydrochloric acid. The gas given off turns acidified aqueous potassium manganate(VII) from purple to colourless. Name the anion present in the second solid. [1]

Section C: structured questions

17. A student has a mixture of powdered copper(II) sulfate and sand. Copper(II) sulfate is soluble in water; sand is insoluble. The student adds water to the mixture, stirs, and then separates the sand from the blue solution.

(a) (i) Name the process used to separate the sand from the solution. [1]

(ii) Name the residue and the filtrate in this process. [1]

(b) State what is meant by a *saturated solution*. [1]

(c) Describe how the student obtains crystals of copper(II) sulfate from the blue solution. [3]

(d) Explain why the solution should not be heated until all the water has evaporated. [1]

18. A student uses paper chromatography to find out which dyes are present in two orange-coloured drinks, X and Y, by running them alongside three permitted food dyes, P, Q and R. All five are spotted on the same baseline and run in the same solvent. The solvent front moves 8.0 cm from the baseline.

Sample	Distance moved by spot(s) from baseline / cm
P	2.0
Q	4.4
R	6.0
X	2.0 and 6.0
Y	4.4

- (a) (0620 Extended) Calculate the R_f value of dye Q. [1]
 (b) Identify the dyes present in drink X. Explain how you know. [2]
 (c) The label on drink Y states that it contains "a mixture of colours". State whether the chromatogram supports this, and explain your answer. [1]
 (d) (0620 Extended) The student then tries to separate a mixture of amino acids by the same method. After the paper has dried, no spots can be seen. Explain why, and state what the student should do to see the spots. [2]

19. Salt Z is a white solid that dissolves in water to give a colourless solution. A student carries out the tests in the table.

Test	Observation
1 Flame test on solid Z	orange-red flame
2 Aqueous sodium hydroxide added, a few drops at a time, to a solution of Z until in excess	white precipitate, does not dissolve in excess
3 Aqueous ammonia added, a few drops at a time, to a fresh solution of Z until in excess	no precipitate
4 Dilute nitric acid added to a solution of Z, then aqueous silver nitrate	cream precipitate

- (a) Identify the cation in Z. Explain how tests 2 and 3 show that the cation is not zinc or aluminium. [3]
 (b) Name the anion in Z. [1]
 (c) Explain why an acid is added before the aqueous silver nitrate in test 4, and why dilute nitric acid rather than dilute hydrochloric acid is used. [2]
 (d) Give the formula of Z and write an ionic equation, with state symbols, for the reaction that forms the cream precipitate in test 4. [2]

20. A student has a mixture of ethanol (boiling point 78 °C) and water (boiling point 100 °C). The two liquids are completely miscible.

- (a) Name the method used to separate ethanol from this mixture, and explain why simple distillation is less suitable. [2]
 (b) Describe how the apparatus separates the ethanol. Refer to the fractionating column, the thermometer and the condenser in your answer. [3]

- (c) The student measures the boiling point of the first liquid collected. The temperature stays at 78 °C while the liquid boils. State what this shows. [1]
- (d) A second sample, collected later in the experiment, boils between 82 °C and 90 °C. Explain this observation. [1]

Answers

Accept the name or the formula of an ion or compound unless the question asks for one in particular. Marks are shown after each marking point.

Section A

- 1 C. Water boils off, is condensed and collected; the salt stays behind. [1]
- 2 B. An impurity lowers the melting point and makes the solid melt over a range. [1]
- 3 A. $R_f = 3.2 \div 8.0 = 0.40$. [1]
- 4 C. Ammonia turns damp red litmus blue, carbon dioxide turns damp blue litmus (slightly) red, hydrogen has no effect; only chlorine bleaches the paper. [1]
- 5 D. Potassium gives lilac, calcium orange-red, copper(II) blue-green. [1]
- 6 A. Zinc would also dissolve in excess aqueous ammonia; calcium would not dissolve in excess sodium hydroxide and gives no precipitate with aqueous ammonia. [1]
- 7 B. A white precipitate of barium sulfate forms. [1]
- 8 D. A volumetric pipette delivers one fixed volume very accurately. A measuring cylinder is much less accurate, and beakers and conical flasks are not used to measure volumes. [1]

Section B

- 9
- Add water to the mixture and stir, warming it, so that the potassium nitrate dissolves and the chalk does not. [1]
 - Filter: chalk stays on the filter paper as the residue; potassium nitrate solution passes through as the filtrate. [1]
 - Heat the filtrate in an evaporating basin to evaporate some of the water until the solution is saturated (crystals form on a glass rod dipped in and removed). [1]
 - Leave the hot solution to cool so that crystals form (potassium nitrate is much less soluble in cold water); filter off the crystals and dry them between filter papers or in a warm oven. [1]

Heating the filtrate to dryness gives a powder rather than crystals: it can earn the third mark but not the fourth.

10

- Add water to the mixture and stir, so that P dissolves and Q does not. [1]
- Filter: Q is left on the filter paper as the residue; P passes through in the filtrate. [1]
- Wash the residue with a little distilled water to remove any solution of P, then dry it in a warm oven or between filter papers. [1]

Alternative route for full marks: dissolve Q in ethanol [1]; filter off P as the residue [1]; evaporate the ethanol from the filtrate gently on a warm water bath, away from flames [1].

11

- (a) Pencil (graphite) does not dissolve in the solvent, so the line stays put; ink would dissolve and move up the paper with the spots. [1]
- (b) If the solvent were above the baseline the spots would dissolve into the solvent in the beaker instead of being carried up the paper. [1]
- (c) To show up colourless substances: it reacts with them on the paper to give coloured spots. [1]

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- (a) $R_f = 5.6 \div 7.0 = 0.80$ [1]
- (b) They are probably the same substance, because a substance always has the same R_f value in the same solvent (on the same paper, at the same temperature). [1]

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Gas	Test	Result
hydrogen	hold a lighted splint at the mouth of the tube	burns with a squeaky pop [1]
oxygen	put a glowing splint into the gas	splint relights [1]
carbon dioxide	bubble the gas through limewater	limewater turns milky (cloudy white) [1]

One mark for each correct test and result together.

14 X: zinc, Zn^{2+} [1]; Y: copper(II), Cu^{2+} [1]; Z: iron(II), Fe^{2+} [1]

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- Add aqueous sodium hydroxide, then aluminium foil (or aluminium powder). [1]
- Warm the mixture gently. [1]
- Ammonia gas is given off, which turns damp red litmus paper blue. [1]

16

- (a) carbon dioxide [1]
- (b) carbonate, CO_3^{2-} (accept hydrogencarbonate, HCO_3^-) [1]

(c) sulfite, SO_3^{2-} (the gas is sulfur dioxide) [1]

Section C

17

(a) (i) filtration [1]

(ii) residue: sand; filtrate: copper(II) sulfate solution (both needed) [1]

(b) A solution that contains the maximum concentration of solute that can dissolve in the solvent at a specified temperature (no more solute will dissolve at that temperature). [1]

(c) Heat the solution gently in an evaporating basin to evaporate some of the water. [1] Stop heating when the solution is saturated (crystals form on a glass rod dipped in and allowed to cool).

[1] Leave the solution to cool slowly so that crystals form, then filter off the crystals and dry them between filter papers. [1]

(d) Any one: soluble impurities would be left in the solid; heating slowly to the crystallisation point gives larger, purer crystals; (0620 Extended) heating to dryness drives off the water of crystallisation, leaving white anhydrous copper(II) sulfate powder instead of blue hydrated crystals. [1]

18

(a) $R_f = 4.4 \div 8.0 = 0.55$ [1]

(b) P and R. [1] The two spots from X have moved the same distances (so have the same R_f values) as P and R in the same solvent. [1]

(c) No: Y gives only one spot, which matches dye Q, so it appears to contain a single dye rather than a mixture. [1]

(d) Amino acids are colourless, so their spots cannot be seen. [1] Spray the dried chromatogram with a locating agent, which reacts with the amino acids to give coloured spots. [1]

19

(a) calcium, Ca^{2+} [1] Test 2: the white precipitates from zinc and aluminium ions dissolve in excess sodium hydroxide, but the precipitate from Z does not. [1] Test 3: zinc and aluminium ions both give a white precipitate with aqueous ammonia (the zinc precipitate dissolving in excess), but Z gives no precipitate at all. [1]

(b) bromide, Br^- (the cream precipitate is silver bromide) [1]

(c) The acid removes carbonate (or hydroxide) ions, which would otherwise also form a precipitate with silver ions and could be mistaken for a halide. [1] Hydrochloric acid contains chloride ions, which would give a white precipitate of silver chloride with the silver nitrate and so give a false result; nitric acid adds no ions that precipitate with silver. [1]

(d) CaBr_2 [1]; $\text{Ag}^+(\text{aq}) + \text{Br}^-(\text{aq}) \rightarrow \text{AgBr}(\text{s})$ [1]

20

(a) fractional distillation [1] The boiling points are fairly close, so with simple distillation water vapour would pass over with the ethanol; a fractionating column gives repeated evaporation and condensation and a better separation. [1]

(b) The vapour rises into the fractionating column, which is packed with glass beads to give a large surface area. [1] The column is cooler towards the top, so water vapour condenses and runs

back into the flask while ethanol vapour (lower boiling point) reaches the top. [1] The thermometer reads 78 °C while ethanol distils; the vapour passes into the water-cooled condenser, condenses and is collected. [1]

(c) The liquid is pure ethanol: a pure substance boils at a fixed temperature (the thermometer reading stays steady), and 78 °C is the boiling point of ethanol. [1]

(d) The sample is impure: it contains water, and an impurity raises the boiling point and makes the liquid boil over a range of temperatures. [1]