Chapter: 14. Experimental techniques and chemical analysis
Book/PDF: Chapter-14.pdf
Pages: 221–239
Exam level: Cambridge IGCSE (0610)

1) Big-picture overview

This chapter is your guide to the chemistry lab. It covers the essential tools and techniques you'll use to conduct experiments safely and accurately. You'll learn how to measure fundamental quantities like time, temperature, mass, and volume using the correct apparatus, from stopwatches to burettes (p. 221-223). A major focus is on separating mixtures. You'll explore methods like filtration for solids and liquids, distillation for separating liquids with different boiling points, and chromatography for separating dissolved substances like inks (p. 224-231). Finally, the chapter introduces **qualitative analysis**, a set of chemical detective skills to identify unknown ions and gases based on their unique reactions, colours, and properties (p. 233). Mastering these practical skills is crucial for understanding how chemists gather and interpret data.

2) Syllabus mapping

Outcome code (unofficial)	Outcome description	Where covered (page)
C14.1	Name and demonstrate the use of apparatus for measuring time, temperature, mass, and volume.	221–223
C14.2	Describe and explain methods of separation and purification for different types of mixtures.	224–231
C14.3	Understand the principles of paper chromatography, interpret chromatograms, and calculate Rf values.	230–232
C14.4	Describe and apply tests to assess the purity of a substance using melting/boiling points.	232–233
C14.5	Describe and perform flame tests to identify specified metal cations.	234
C14.6	Describe and perform tests to identify specified aqueous cations using NaOH(aq) and NH_3(aq).	234–235
C14.7	Describe and perform tests to identify specified aqueous anions.	236
C14.8	Describe and perform tests to identify common gases.	236

3) Key terms and definitions

Term	One-sentence definition	First appears (page)	Example/application
Qualitative analysis	The branch of chemistry that identifies the elements or ions present in a sample without measuring quantities[cite: 10, 468].	221	Identifying the metal ion in a salt solution.

Term	One-sentence definition	First appears (page)	Example/application
Meniscus	The curved upper surface of a liquid in a tube, caused by surface tension[cite: 48, 49].	222	Reading the volume of water in a measuring cylinder from the bottom of the curve.
Solvent	A substance that dissolves a solute to form a solution[cite: 182, 188].	225	Water is a solvent for sugar.
Solute	A substance that is dissolved in a solvent[cite: 181, 189].	225	Sugar is the solute when dissolved in water.
Solution	A liquid mixture composed of a solute dissolved in a solvent[cite: 180, 190].	225	Saltwater is a solution of salt (solute) and water (solvent).
Insoluble	A solid that does not dissolve in a particular liquid (solvent)[cite: 185].	225	Sand is insoluble in water.
Filtration	A technique used to separate an insoluble solid from a liquid using a filter paper[cite: 194, 195].	225	Separating sand from water.
Residue	The substance that remains on the filter paper after filtration[cite: 199, 202].	225	The sand collected in the filter paper.
Filtrate	The liquid or solution that has passed through a filter[cite: 199, 203].	225	The water that passes through the filter paper.
Saturated solution	A solution containing the maximum concentration of a solute dissolved in the solvent at a specific temperature[cite: 243, 244, 249].	227	A solution of salt in water where no more salt can dissolve.
Distillation	A process used to obtain a pure solvent from a solution by boiling the liquid and condensing the vapour[cite: 237, 259].	227	Obtaining pure water from salt water.
Immiscible	Liquids that do not mix together to form a single layer, like oil and water[cite: 269, 276].	228	Oil and water.
Miscible	Liquids that mix completely with each other to form a solution[cite: 278, 285].	228	Ethanol and water.
Fractional distillation	A method to separate a mixture of miscible liquids with different boiling points[cite: 285, 287].	228	Separating ethanol from water, or crude oil into fractions.
Chromatography	A technique used to separate mixtures of soluble substances, such as inks and dyes[cite: 345].	230	Separating the different coloured dyes in black ink.
R*ƒ* value	The ratio of the distance travelled by a solute to the distance travelled by the solvent on a chromatogram[cite: 422, 423].	232	Used to identify unknown substances by comparing their R*ƒ* values to known values.
Locating agent	A substance sprayed on a chromatogram to make colourless substances visible by reacting with them[cite: 425, 426].	232	Making amino acids visible on a chromatogram.

4) Core concepts explained

14.1 Apparatus for Measurement (p. 221-224)

- **Time:** Measured in hours (h), minutes (min), and seconds (s)[cite: 33]. For rate of reaction experiments, a **stopwatch** measuring to a hundredth of a second is used for accuracy[cite: 32].
- **Temperature:** Measured in degrees Celsius (^{circ}C) using a thermometer[cite: 43]. The scale is based on water's freezing point ($0^{circ}C$) and boiling point ($100^{circ}C$)[cite: 45]. To ensure accuracy, the eye must be level with the liquid meniscus to avoid **parallax error**[cite: 48].
- **Mass:** Measured in grams (g) and kilograms (kg) using an **electronic balance**[cite: 55]. A typical lab balance has a precision of 0.01 g[cite: 54]. You should wait for the reading to be steady before recording it[cite: 56].
- **Volume of Liquids:** Measured in cubic centimetres (cm^3) or cubic decimetres (dm^3)[cite: 87]. ($1\tilde{d}m^3 = 1000\tilde{c}m^3$) [cite: 88].
    - **Measuring Cylinder:** For approximate measurements[cite: 84].
    - **Pipette:** Used to accurately measure a fixed volume of liquid, e.g., for a titration[cite: 75, 81].
    - **Burette:** Used to accurately measure variable volumes of liquid, often for adding the **titrant** in a titration[cite: 75, 77]. Precision is typically 0.1 cm^3, but can be read to the nearest 0.05 cm^3[cite: 93, 96].
- **Volume of Gases:** Measured using a **gas syringe**, typically up to 100 cm^3[cite: 105, 106]. As gas is produced in a reaction, it pushes the plunger out, and the volume can be read from the scale[cite: 122].

14.2 Separating Mixtures (p. 224-231)

This section covers methods to separate substances based on their different physical properties.

- **Separating an Insoluble Solid from a Liquid**
    - **Filtration:** The mixture is poured through filter paper in a funnel. The insoluble solid (**residue**) is trapped, while the liquid (**filtrate**) passes through[cite: 195, 199]. * **Separating a Soluble Solid from a Solvent**
    - **Evaporation:** The solution is heated, causing the solvent to turn into a gas and leave the dissolved solid behind[cite: 232]. This is used when you don't need to keep the solvent.
    - **Crystallisation:** The solvent is evaporated slowly from a **saturated solution** until crystals of the solute form[cite: 243, 247].
    - **Simple Distillation:** Used to recover the solvent. The solution is boiled, the vapour is cooled in a **Liebig condenser**, and the pure liquid solvent (**distillate**) is collected[cite: 237, 263].
- **Separating Mixtures of Liquids**
    - **Immiscible Liquids:** A **separating funnel** is used. The liquids form separate layers due to different densities; the tap is opened to run off the bottom layer[cite: 269, 271].
    - **Miscible Liquids: Fractional distillation** is used. The liquids must have different boiling points[cite: 285, 287]. The liquid with the lower boiling point evaporates first, rises through a **fractionating column**, condenses, and is collected[cite: 293]. This process is used to separate ethanol and water or fractions of crude oil[cite: 298].
- **Chromatography**
    - Used to separate dissolved substances, like dyes in ink[cite: 345].
    - A spot of the mixture is placed on a **baseline** (drawn in pencil) on chromatography paper[cite: 347, 349].
    - The paper is placed in a beaker with a solvent, ensuring the solvent level is below the baseline[cite: 350].
    - As the solvent moves up the paper, it carries the dyes with it. Dyes that are more soluble in the solvent and less absorbed by the paper travel further[cite: 380, 381]. The final separated pattern is a **chromatogram**[cite: 383].

Criteria for Purity (p. 232)

In chemistry, a **pure substance** is a single element or compound[cite: 436]. Impurities affect physical properties.

Purity Test	Pure Substance	Impure Substance (Mixture)
Melting Point	Melts at a sharp, fixed temperature[cite: 451].	Melts over a range of temperatures[cite: 452].
Boiling Point	Boils at a sharp, fixed temperature[cite: 453].	Boils over a range of temperatures[cite: 454].
Chromatography	Produces a single spot on the chromatogram[cite: 455].	Produces several spots[cite: 456].

14.3 Qualitative Analysis (p. 233-236)

This involves a series of tests to identify unknown ions and gases.

- **Flame Tests for Cations:** A sample is placed in a Bunsen flame, and the colour produced identifies the metal ion[cite: 491].
  - **Lithium (Li^+):** Red [cite: 489]
  - **Sodium (Na^+):** Yellow [cite: 489]
  - **Potassium (K^+):** Lilac [cite: 489]
  - **Calcium (Ca^{2+}):** Orange-red [cite: 489]
  - **Copper (Cu^{2+}):** Blue-green [cite: 489]
- **Tests for Aqueous Cations:** Adding a reagent causes a precipitate (insoluble solid) to form. The colour and behaviour in excess reagent are key identifiers.
  - **Using Sodium Hydroxide (NaOH):** See Table 14.3 (p. 234). For example, adding NaOH to a solution with Cu^{2+} ions gives a light blue precipitate that is insoluble in excess[cite: 502].
  - **Using Aqueous Ammonia (NH_3):** See Table 14.4 (p. 235). For example, adding aqueous ammonia to a solution with Cu^{2+} ions gives a light blue precipitate which dissolves in excess to form a dark blue solution[cite: 509].
- **Tests for Aqueous Anions:** See Table 14.5 (p. 236).
  - **Carbonate (CO_3^{2-}):** Add dilute acid. Effervescence (fizzing) occurs as CO_2 gas is produced[cite: 534, 540].
  - **Halides (Cl^-, Br^-, I^-):** Add dilute nitric acid, then silver nitrate solution. Precipitates form: White for chloride, cream for bromide, yellow for iodide[cite: 535, 540, 541, 542].
  - **Sulfate (SO_4^{2-}):** Add dilute acid, then barium nitrate solution. A white precipitate forms[cite: 537, 545].
- **Tests for Gases:** See Table 14.6 (p. 236).
  - **Hydrogen (H_2):** A lit splint makes a 'squeaky pop' sound[cite: 549].
  - **Oxygen (O_2):** A glowing splint relights[cite: 549].
  - **Carbon Dioxide (CO_2):** Bubbling through limewater (calcium hydroxide solution) turns it cloudy/milky[cite: 549].
  - **Ammonia (NH_3):** Has a pungent smell and turns damp red litmus paper blue[cite: 549].
  - **Chlorine (Cl_2):** Has a choking smell and bleaches damp litmus paper (turns it white)[cite: 549].

5) Diagrams and micrographs (figures)

- **Reading a Thermometer (Figure 14.3, p. 222):** Shows the importance of having your eye level with the top of the liquid to avoid parallax error. Viewing from above gives a higher reading; viewing from below gives a lower reading.
- **Reading a Measuring Cylinder (Figure 14.6, p. 223):** Shows the curved meniscus of a liquid. The volume should be read from the bottom of the curve with the eye at the same level.
- **Gas Collection (Figure 14.8, p. 224):** Depicts a flask where a gas-producing reaction occurs, connected by a tube to a gas syringe. As gas is made, the plunger is pushed out, allowing the volume to be read from the scale on the syringe.
- **Simple Distillation Apparatus (Figure 14.14, p. 227):**
  - **Flask:** Contains the solution to be heated.
  - **Thermometer:** Placed at the neck of the flask to measure the boiling point of the substance that is evaporating.
  - **Liebig Condenser:** A glass tube with an outer jacket through which cold water flows. It cools the vapour, causing it to condense back into a liquid.
  - **Collection Flask/Beaker:** Catches the pure liquid distillate.

- **Fractional Distillation Apparatus (Figure 14.18, p. 229):**
    - Similar to simple distillation but includes a **Fractionating Column** placed between the flask and the condenser.
    - **Fractionating Column:** A glass column packed with glass rods or beads, providing a large surface area for repeated condensation and vaporisation, which separates the liquids more effectively.
- **Paper Chromatography (Figure 14.23, p. 231):**
    - Shows three stages: **Before** (a spot of ink on a pencil baseline), **During** (paper in a beaker with solvent moving up), and **After** (the ink has separated into different coloured spots at different heights).

6) Processes and cycles

Paper Chromatography

1. **Preparation:** Draw a faint pencil line (the **baseline**) about 1 cm from the bottom of a piece of chromatography paper[cite: 347]. A pencil is used because graphite is insoluble and won't interfere with the experiment[cite: 348].
2. **Application:** Place a small, concentrated spot of the mixture (e.g., ink) on the baseline[cite: 349].
3. **Development:** Place the paper in a beaker containing a small amount of a suitable solvent. The solvent level must be **below** the baseline[cite: 350]. Cover the beaker to create a saturated atmosphere and prevent solvent evaporation[cite: 351].
4. **Separation:** The solvent moves up the paper by capillary action. As it passes the baseline, it dissolves the mixture and carries it up the paper[cite: 380].
5. **Result:** The substances in the mixture separate based on their different solubilities in the solvent and attraction to the paper. The most soluble substance travels the farthest[cite: 381, 382]. The resulting paper with separated spots is called a chromatogram[cite: 383].
6. **Analysis:** If the substances are colourless, a **locating agent** is sprayed on the chromatogram to make them visible[cite: 425]. The position of each spot can be used to calculate an **Rf value**.

7) Formulae and calculations

Quantity	Formula	Units	Typical values	Worked example (p. 232)
Retardation factor (Rf)	$R\_f = fractextdistancetravelledbysolutetextdistancetravelledbysolvent$ [cite: 423]	None (it's a ratio)	Between 0 and 1	Distance travelled by glycine = 2.5 cm[cite: 430]. Distance travelled by solvent = 10.0 cm[cite: 431]. $R\_f = frac2.510.0 = 0.25$[cite: 432].

8) Required practicals / experiments

Experiment: Identifying an Unknown Cation and Anion in Compound A (p. 237)

- **Aim:** To use qualitative analysis to identify the ions in an unknown compound A.
- **Apparatus:** Test tubes, beaker, Bunsen burner, measuring cylinder, droppers.
- **Method & Results:**

i. **Appearance:** Dissolve compound A in water. A colourless solution is produced[cite: 567].
ii. **Cation Test 1:** To a sample of the solution, add aqueous sodium hydroxide (NaOH) dropwise, then in excess.
    - **Observation:** A white precipitate forms, which dissolves in excess NaOH[cite: 567].
    - **Conclusion:** This suggests the cation could be Al^{3+} or Zn^{2+}[cite: 502].
iii. **Cation Test 2:** To a second sample, add aqueous ammonia (NH_3) dropwise, then in excess.
    - **Observation:** A white precipitate forms, which is insoluble in excess NH_3[cite: 567].
    - **Conclusion:** This confirms the cation is Al^{3+}. (A Zn^{2+} precipitate would dissolve in excess ammonia) [cite: 509].
iv. **Anion Test:** To a third sample, add aqueous NaOH and aluminium foil, then warm gently.
    - **Observation:** A gas is produced which turns moist red litmus paper blue[cite: 567].
    - **Conclusion:** This is the positive test for the **nitrate ion (NO_3^-)**. The gas produced is ammonia[cite: 536, 544].

- **Final Identification:** The compound A is **Aluminium Nitrate**, $Al(NO\_3)\_3$.
- **Safety:** Eye protection must be worn[cite: 564]. The nitrate test produces ammonia gas, which is pungent and harmful, so it should be done in a fume cupboard[cite: 572].

9) Data handling and graphing

- **Tables of Results:** This chapter relies heavily on interpreting data from tables for qualitative analysis (Tables 14.1-14.6, p. 234-236). Key skills include matching observations (e.g., "light blue precipitate") to the correct ion (e.g., "Cu^{2+}").
- **Chromatograms:** Interpreting a chromatogram involves:
    - Identifying pure substances (one spot) versus mixtures (multiple spots)[cite: 370, 371].
    - Identifying substances by comparing the position of unknown spots with spots of known substances run on the same chromatogram. If two spots travel the same distance, they are likely the same substance[cite: 419, 420].
- **Graphs:** While not shown, the text mentions that data from a gas collection experiment (volume vs. time) can be plotted to show the rate of reaction[cite: 125, 126]. On such a graph, the volume of gas would be on the y-axis and time on the x-axis.

10) Common misconceptions and exam tips

- **Misconception:** Any clear liquid is "pure".
    - **Correct understanding:** In chemistry, purity means consisting of only one compound or element. Saltwater is a mixture, not a pure substance, even though it's clear[cite: 436, 439].
    - **Quick tip:** Remember that pure substances have sharp, fixed melting and boiling points.
- **Misconception:** You can use a pen to draw the baseline in chromatography.
    - **Correct understanding:** Pen ink is a mixture of dyes that will dissolve in the solvent and ruin the experiment. A pencil must be used as graphite is insoluble[cite: 348].
    - **Quick tip: P**encil for **P**aper chromatography.
- **Misconception:** The terms "distillation" and "fractional distillation" are interchangeable.
    - **Correct understanding:** Simple distillation separates a liquid solvent from a dissolved solid. Fractional distillation separates two or more miscible liquids with different boiling points[cite: 237, 285].
    - **Quick tip: Fractional** is for separating **fractions** of a liquid mixture (like crude oil).
- **Exam Tip:** For qualitative analysis questions, always state both the **reagent** you add and the **expected observation**. For example, "Add dilute nitric acid then silver nitrate solution. A white precipitate forms, indicating chloride ions are present."

11) Exam-style practice

Multiple Choice Questions (MCQs)

1. Which piece of apparatus is most suitable for accurately measuring 25.0 cm^3 of a solution for a titration?
   A) Measuring cylinder
   B) Gas syringe
   C) Pipette
   D) Beaker
   Answer: C. A pipette is designed to measure a fixed, accurate volume[cite: 75, 81].
2. A student separates a mixture of sand and salt water. What are the correct names for the sand left on the filter paper and the salt water that passes through?
   A) Filtrate and residue
   B) Solute and solvent
   C) Residue and filtrate
   D) Precipitate and solution
   Answer: C. The solid left behind is the residue, and the liquid that passes through is the filtrate[cite: 199].
3. In a paper chromatogram, a substance moves 4 cm from the baseline while the solvent moves 8 cm. What is the Rf value?
   A) 2.0
   B) 0.5
   C) 4.0
   D) 0.25
   Answer: B. Rf = distance of solute / distance of solvent = 4/8 = 0.5[cite: 423].
4. Which test confirms the presence of oxygen gas?
   A) A lit splint pops.
   B) A glowing splint relights.
   C) It turns limewater cloudy.
   D) It turns damp red litmus paper blue.
   Answer: B. This is the unique test for oxygen[cite: 549].
5. When aqueous sodium hydroxide is added to a solution containing an unknown cation, a red-brown precipitate is formed. Which ion is present?
   A) Fe^{2+}
   B) Cu^{2+}
   C) Fe^{3+}
   D) Ca^{2+}
   Answer: C. Iron(III) ions form a red-brown precipitate of iron(III) hydroxide[cite: 502].
6. Which method is used to separate ethanol (b.p. 78°C) from water (b.p. 100°C)?
   A) Filtration
   B) Evaporation
   C) Simple distillation
   D) Fractional distillation
   Answer: D. Fractional distillation separates miscible liquids with different boiling points[cite: 287].
7. A pure solid substance is heated until it melts. What would be observed?
   A) It melts over a range of temperatures.
   B) It melts at a single, sharp temperature.
   C) It does not melt but sublimes.
   D) The temperature drops as it melts.
   Answer: B. Pure solids have a sharp, characteristic melting point[cite: 451].
8. Which ion gives a lilac colour in a flame test?
   A) Sodium
   B) Lithium
   C) Potassium

D) Calcium

Answer: C. Potassium ions produce a lilac flame[cite: 489].

9. What is the correct test for a sulfate ion, SO_4^{2-}?

   A) Add acid and warm, testing the gas with limewater.

   B) Add aqueous ammonia, look for a white precipitate.

   C) Add nitric acid then silver nitrate, look for a white precipitate.

   D) Add hydrochloric acid then barium chloride, look for a white precipitate.

   Answer: D. Barium sulfate is an insoluble white precipitate, which is the basis for the test[cite: 537].

10. A colourless substance on a chromatogram is made visible by spraying it with another chemical. What is the chemical spray called?

    A) A solvent

    B) A solute

    C) A locating agent

    D) An indicator

    Answer: C. A locating agent reacts with colourless substances to form a coloured product[cite: 425, 426].

Short-Answer Questions

1. **Describe how you would obtain a pure, dry sample of sand from a mixture of sand and salty water.**
   - Pour the mixture through a filter funnel containing filter paper[cite: 196].
   - The sand (residue) will be trapped in the filter paper[cite: 198, 199].
   - Wash the sand with distilled water to remove any remaining salt solution.
   - Remove the filter paper, open it flat, and allow the sand to dry in a warm oven.
2. **Explain why a pencil, not a pen, is used to draw the baseline in paper chromatography.**
   - A pencil mark is made of graphite, which is insoluble in the solvents used[cite: 348].
   - Pen ink is a mixture of soluble dyes which would dissolve in the solvent and separate along with the sample, interfering with the results[cite: 348].
3. **A student has a solution that could be either zinc nitrate or calcium nitrate. Describe a single chemical test to distinguish between them.**
   - **Test:** Add aqueous ammonia dropwise and then in excess to a sample of the solution[cite: 509].
   - **Result with Zinc Nitrate:** A white precipitate will form that dissolves in excess aqueous ammonia[cite: 509].
   - **Result with Calcium Nitrate:** No precipitate (or a very slight one) will form[cite: 509].
4. **State two ways to determine if a sample of water is pure.**
   - **Method 1:** Measure its boiling point. Pure water will boil at a sharp, fixed temperature of 100°C[cite: 453].
   - **Method 2:** Measure its freezing/melting point. Pure water will freeze at a sharp, fixed temperature of 0°C[cite: 451].
5. **Identify the gases described by the following tests:**
   - **(a) Relights a glowing splint:** Oxygen (O_2)[cite: 549].
   - **(b) Turns damp red litmus paper blue:** Ammonia (NH_3)[cite: 549].
   - **(c) Produces a 'squeaky pop' with a lit splint:** Hydrogen (H_2)[cite: 549].

Structured Questions

1. A student is investigating the dyes in a black food colouring, 'E', using paper chromatography. She places spots of 'E' and three known dyes, red (R), blue (B), and yellow (Y), on a baseline. The final chromatogram is shown below.

   * **(a) Explain** why the baseline is drawn in pencil and above the solvent level. [2]

   * **Marking Points:** Pencil is used because it is insoluble and will not run with the solvent [1]. The baseline must be above the solvent so that the spots of dye do not dissolve directly into the solvent at the bottom of the beaker [1].

   - **(b) Identify** the dyes present in the black food colouring 'E'. **Explain** your reasoning. [2]
     - **Marking Points:** 'E' contains blue (B) and yellow (Y) dyes [1]. This is because the spots from 'E' have travelled the same distance up the paper as the spots for B and Y [1].
   - **(c)** The yellow dye (Y) travelled 6.0 cm and the solvent front travelled 8.0 cm from the baseline. **Calculate** the Rf value for the yellow dye. [2]
     - **Marking Points:** Formula: $R\_f =$

$fractextdistancetravelledbysolutetextdistancetravelledbysolvent$ [1]. Calculation: $R\_f = frac6.08.0 = 0.75$ [1].

2. A student is given a green crystalline solid, which is known to be a salt containing iron.
   - **(a) Suggest**, based on the colour, which iron ion is likely present. [1]
     - **Marking Point:** Iron(II) / Fe^{2+} ions, as their salts are often pale green crystals[cite: 488].
   - **(b) Describe** the tests and expected results using (i) aqueous sodium hydroxide and (ii) aqueous ammonia to confirm the identity of this ion. [4]
     - **Marking Points:**
     - (i) **Reagent:** Add aqueous sodium hydroxide [1]. **Observation:** A green precipitate forms, which is insoluble in excess and may turn brown at the surface on standing [cite: 502] [1].
     - (ii) **Reagent:** Add aqueous ammonia [1]. **Observation:** A green precipitate forms, which is insoluble in excess and may turn brown at the surface on standing [cite: 509] [1].
   - **(c)** The student then tests for the anion. She adds dilute nitric acid followed by aqueous silver nitrate to a solution of the salt, but sees no change. She then adds dilute hydrochloric acid followed by aqueous barium chloride and a white precipitate forms. **Identify** the anion and **name** the green crystalline solid. [2]
     - **Marking Points:** The anion is sulfate (SO_4^{2-}) [1]. The solid is iron(II) sulfate [1].

12) Quick revision checklist

- [ ] Can I name the correct apparatus for measuring time, temperature, mass, and volume? (p. 221-223)
- [ ] Do I know how to read a meniscus correctly to avoid parallax error? (p. 222-223)
- [ ] Can I define solute, solvent, solution, filtrate, and residue? (p. 225)
- [ ] Can I describe how to separate an insoluble solid from a liquid by filtration? (p. 225)
- [ ] Can I explain the difference between simple and fractional distillation and when to use each? (p. 227-228)
- [ ] Can I describe the process of paper chromatography, including the role of the baseline and solvent? (p. 230-231)
- [ ] Can I calculate an Rf value from a chromatogram? (p. 232)
- [ ] Do I know how melting points and boiling points indicate the purity of a substance? (p. 232)
- [ ] Can I recall the flame test colours for Li^+, Na^+, K^+, Ca^{2+}, and Cu^{2+}? (p. 234)
- [ ] Can I describe the results of adding NaOH(aq) and NH_3(aq) to solutions containing Cu^{2+}, Fe^{2+}, and Fe^{3+}? (p. 234-235)
- [ ] Can I describe the chemical tests for carbonate, chloride, sulfate, and nitrate ions? (p. 236)
- [ ] Can I recall the tests and positive results for H_2, O_2, CO_2, NH_3, and Cl_2 gas? (p. 236)

13) Flashcards (ready-to-use)

Question	Answer
What apparatus measures mass with a precision of 0.01g?	An electronic balance (p. 222)
How do you avoid parallax error when reading a thermometer?	Keep your eye level with the meniscus (p. 222).
What is the difference between a solute and a solvent?	A solute dissolves in a solvent to make a solution (p. 225).
Name the technique to separate sand from water.	Filtration (p. 225).
What is the liquid that passes through the filter paper called?	The filtrate (p. 225).
What is the solid left on the filter paper called?	The residue (p. 225).
How would you get pure water from salt water?	Simple distillation (p. 227).
How would you separate ethanol (b.p. 78°C) from water (b.p. 100°C)?	Fractional distillation (p. 228).

Question	Answer
Why is the baseline in chromatography drawn in pencil?	Because pencil (graphite) is insoluble and won't move with the solvent (p. 230).
What is the formula for the Rf value?	Rf = (distance moved by spot) / (distance moved by solvent) (p. 232).
How does an impurity affect a solid's melting point?	It lowers the melting point and makes it melt over a range of temperatures (p. 233).
What is the flame colour for a sodium (Na^+) ion?	Yellow (p. 234).
What is the flame colour for a potassium (K^+) ion?	Lilac (p. 234).
What do you add to test for a chloride (Cl^-) ion?	Add dilute nitric acid, then aqueous silver nitrate (p. 236).
What is the result of the test for chloride ions?	A white precipitate forms (p. 236).
What do you add to test for a sulfate (SO_4^{2-}) ion?	Add dilute HCl, then aqueous barium chloride (p. 236).
What is the result of the test for sulfate ions?	A white precipitate forms (p. 236).
What is the test for hydrogen gas?	A lit splint gives a 'squeaky pop' (p. 236).
What is the test for oxygen gas?	A glowing splint relights (p. 236).
What is the test for carbon dioxide gas?	It turns limewater cloudy/milky (p. 236).
What precipitate is formed when NaOH(aq) is added to a solution of Cu^{2+} ions?	A light blue precipitate (p. 234).
What precipitate is formed when NaOH(aq) is added to a solution of Fe^{3+} ions?	A red-brown precipitate (p. 234).
What happens when you add excess aqueous ammonia to the precipitate formed from Cu^{2+} ions?	The precipitate dissolves to form a dark blue solution (p. 235).
What gas is produced when you warm an ammonium salt with NaOH?	Ammonia (NH_3) (p. 235).
What is a locating agent used for in chromatography?	To make colourless spots visible (p. 232).

14) 60-second recap

This chapter covers the foundations of practical chemistry. You learned to use apparatus like pipettes, burettes, and electronic balances to make accurate measurements of volume and mass. You explored key separation techniques: filtration for insoluble solids, distillation to recover a pure solvent or separate liquids with different boiling points, and chromatography to separate dissolved substances. You learned that pure substances have sharp melting and boiling points, which can be used as a test for purity. Finally, you covered qualitative analysis: using flame tests and precipitation reactions with sodium hydroxide and aqueous ammonia to identify metal cations, and specific chemical tests to identify anions like carbonates, sulfates, and halides, as well as common gases like oxygen, hydrogen, and carbon dioxide.

15) References to pages

- **Apparatus & Measurement:** 221, 222, 223, 224
- **Chromatography:** 230, 231, 232
- **Crystallisation:** 227
- **Distillation (Fractional):** 228, 229

16) Excluded "Going further" sections (not summarized)

Section title	Pages
Decanting	226
Centrifuging	226
Desalination plants	228
Separating solid/solid mixtures	229
Paper chromatography of the products of starch hydrolysis	231

Total excluded: 5