REAL-LIFE CHEMISTRY

Chemical Changes and Structure

Teacher guide

For the National 5 Chemistry workbook



C. Blewis

Blewis LEARNING

Using the workbooks

The National 5 Chemistry workbook for **Chemical Changes and Structure** has six topics. Every topic has learning pages, a practical the learner plans and evaluates, a brain break and an exam-style check-up.

PRACTICALS

Learners plan each investigation (variables, prediction, kit, risk, method), take repeat readings, work out averages, draw graphs with their own scales, and write conclusions and evaluations.

PRACTICAL SAFETY

Every practical has a Stay safe table and a teacher note with hazards, adapted versions and common problems. The Stay safe tables and these notes are a starting point, not a complete risk assessment: the teacher or school must risk assess every practical for their own learners, room and kit before use, following their employer's policies and national guidance (in Scotland, SSERC). Always check learners' care plans and medical information. Activities with flames or microbes are teacher demonstrations, with example results provided.

NO LAB, NO KIT, OR A LEARNER ABSENT

Each practical includes example results so learners can still complete the results, graph, conclusion and evaluation.

EVIDENCE

The practicals develop the skills needed for the assignment and for questions on experimental work in the exam; the learn pages and check-ups build knowledge and problem solving. The skills tracker at the back of each workbook can be signed off as you go. Always check the latest course documents and your centre's arrangements.

Contents

Topic 1	Rates of reaction	**4**
Topic 2	Atomic structure	**6**
Topic 3	Bonding, structure and properties	**8**
Topic 4	Formulae and equations	**10**
Topic 5	The mole and calculations	**12**
Topic 6	Acids and bases	**14**

TEACHER NOTES

Practical 1: Does the concentration of acid change the rate?

Time	One 50-minute lesson in pairs. Four concentrations with three repeats takes about 25 minutes.
Kit per group	Magnesium ribbon cut into 2 cm strips (or a length and scissors), hydrochloric acid at 0.5, 1.0, 1.5 and 2.0 mol l^{-1} (labelled bottles), 25 cm^3 measuring cylinder, 100 cm^3 beakers, stopwatch, ruler, white tile, eye protection.
Prep	Make up the acids in advance and label them clearly. Clean the magnesium with emery paper if it is dull, so the oxide layer does not delay the start.
Expected results	Times of about 2 minutes at 0.5 mol l^{-1} falling to about 30 s at 2.0 mol l^{-1}. Rate (1 ÷ time) rises roughly in proportion to concentration.
Level	N5 plans a fair test, repeats, finds the mean, calculates a rate, draws a graph with a line of best fit and evaluates.

Safety and inclusion

- Eye protection throughout. Hydrochloric acid at these concentrations is an irritant; the 2.0 mol l^{-1} bottle should be handled with care and dispensed by staff if your risk assessment requires it.
- Hydrogen is produced in small amounts: no naked flames nearby. Good ventilation.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.
- Roles can be shared: one learner times, one adds the ribbon, one records; all can be done seated.

Common problems

- **Magnesium floating:** bubbles lift the ribbon; gently swirl in the same way every time.
- **Judging the end:** agree the end as "no ribbon visible" and keep the same judge.
- **Rate unit:** 1 ÷ time gives s^{-1}; remind learners that this is a relative rate.

No lab, no time, or a learner absent?

The sample results let learners complete the means, rates, graph, conclusion and evaluation without the practical.

Assessment link

Evidence of planning, recording, calculating means and rates, graphing and evaluating. Good practice for the assignment: compare with another source and reference it.

Answers: Topic 1

Topic 1: Rates of reaction (N5)

1 Following a reaction

1 Any two: the mass of the beaker or flask (it falls as gas escapes); the volume of gas given off; the time until the fizzing stops.

2 One of the reactants has been used up, so no more gas is made: the reaction has reached its end-point.

3 The solid line (labelled fast). It is steeper at the start and reaches the flat part sooner.

2 Changing the rate

1 The crushed tablet has a larger surface area, so more particles are exposed and there are more collisions each second.

2 The particles move faster, so they collide more often and with more energy, so more collisions lead to a reaction.

3 Manganese dioxide is a catalyst: it speeds up the reaction and is not used up (chemically unchanged).

4 More acid of the same concentration (the concentration does not change).

3 Calculating an average rate

1 Rate = change in volume ÷ change in time = 34 ÷ 20 = 1.7 $cm^3\ s^{-1}$.

2 Change in volume = 78 − 56 = 22 cm^3; change in time = 80 − 40 = 40 s; rate = 22 ÷ 40 = 0.55 $cm^3\ s^{-1}$.

3 The rate falls as the reaction goes on (1.7 $cm^3\ s^{-1}$ at the start, 0.55 $cm^3\ s^{-1}$ later), because the reactants are being used up.

4 By 100 s (between 80 s and 100 s): the volume stops changing at 81 cm^3.

Practical 1: Does the concentration of acid change the rate?

Variables: change the concentration of the acid; measure the time for the magnesium to react completely (then calculate the rate); keep the same: volume of acid, length (mass) of magnesium, temperature, size of beaker, swirling or not.

Prediction, e.g. higher concentration gives a shorter time (faster rate), because there are more acid particles to collide with the magnesium.

Equipment: magnesium ribbon, measuring cylinder, small beaker, stopwatch, ruler, eye protection. Not needed: Bunsen burner.

Hazards, e.g. magnesium ribbon edges and hydrogen gas (keep away from flames, small amounts only); broken glass (report it, do not pick up); acid spills on bench (wipe up).

Method key points: measure 25 cm^3 of acid with a measuring cylinder into a beaker; cut 2 cm strips with a ruler; start the stopwatch as the magnesium touches the acid and stop when it has all gone; repeat three times for each concentration; mean time; rate = 1 ÷ mean time.

Sample results: 0.5 mol l^{-1}: 121.0 s, 0.0083 s^{-1}; 1.0 mol l^{-1}: 61.7 s, 0.016 s^{-1}; 1.5 mol l^{-1}: 41.7 s, 0.024 s^{-1}; 2.0 mol l^{-1}: 31.0 s, 0.032 s^{-1}.

Graph: concentration on x (mol l^{-1}), rate on y (s^{-1}); the points lie close to a straight line through the origin.

Conclusion: as the concentration of acid increased, the rate increased (the rate roughly doubles when the concentration doubles).

Evaluate: (a) a more concentrated acid has more acid particles in the same volume, so there are more collisions with the magnesium each second. (b) The times will not be accurate, because judging the end is difficult; use a white tile under the beaker, or have the same person judge every run, or measure the gas volume instead.

Check-up

1 B (cooling the acid).

2 Change in volume = 75 − 48 = 27 cm^3 and change in time = 30 s (1); rate = 27 ÷ 30 = 0.90 $cm^3\ s^{-1}$ (1, unit needed).

3 (a) Hydrogen gas is made and escapes from the flask (1). (b) The curve is steeper at the start / finishes sooner, but levels off at the same final mass (1); the powder has a larger surface area, so there are more collisions (1).

4 The particles move faster (have more energy) (1), so they collide more often and more of the collisions have enough energy to react (1).

TEACHER NOTES

Practical 2: How do isotopes change the average mass?

Time	About 35 minutes in pairs, plus time for the graph. Five mixtures with three repeats.
Kit per group	At least 40 light and 40 heavy beads (two sizes of plastic bead, two kinds of dried bean, or two sizes of washer), a balance reading to 0.01 g, a small beaker or tray, a container to weigh in.
Prep	Check that the two types differ clearly in mass and that one type is fairly uniform. Weigh 40 of each beforehand so you know the end values.
Expected results	A straight-line rise in average bead mass with the percentage of heavy beads. The exact values depend on the beads used.
Level	N5 plans the model, repeats, finds the mean, draws a line graph, predicts from it and links the model to relative atomic mass.

Safety and inclusion

- Low risk. Beads on the floor are a slip hazard; work over trays. If beans are used, nothing is to be eaten.
- Large beads or washers suit learners who find small objects hard to handle; counting can be shared.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.

Common problems

- **Forgetting to tare:** learners weigh the container too.
- **Miscounting:** count heavy beads first, then make up to 40 with light ones.
- **Too many decimal places:** give the average bead mass to 3 decimal places.

No lab, no time, or a learner absent?

The sample results let learners complete the means, graph, prediction and evaluation without the activity.

Assessment link

Evidence of recording, calculating means, graphing, using a graph to predict and evaluating a model. Links to the relative atomic mass calculation.

Answers: Topic 2

Topic 2: Atomic structure (N5)

1 The periodic table

1 Lithium 2,1; oxygen 2,6; magnesium 2,8,2; chlorine 2,8,7.

2 Group 6 (six outer electrons), period 3 (three shells); a non-metal (it is sulfur).

3 They are both in group 1, so they both have one outer electron.

2 Inside the atom

1 F: 9 protons, 10 neutrons, 9 electrons. Ca^{2+}: 20 protons, 20 neutrons, 18 electrons. S^{2-}: 16 protons, 16 neutrons, 18 electrons.

2 Atomic number 11 is sodium; mass number 11 + 12 = 23, so $^{23}_{11}Na$.

3 It has the same number of protons (positive) as electrons (negative), so the charges cancel.

3 Isotopes and relative atomic mass

1 They have the same atomic number (17 protons) but different mass numbers, because they have different numbers of neutrons (18 and 20).

2 (79 × 50.0) + (81 × 50.0) = 8000; 8000 ÷ 100 = 80.0.

3 (6 × 7.5) + (7 × 92.5) = 45 + 647.5 = 692.5; 692.5 ÷ 100 = 6.925, so 6.9.

4 Most of the atoms (79%) are magnesium-24, so the average is close to 24; the heavier isotopes raise it slightly (it is 24.3).

Practical 2: How do isotopes change the average mass?

Variables: change the percentage of heavy beads; measure the mass of 40 beads (then the average mass of one); keep the same: total number of beads (40), the same bead types, the same balance and container (tared).

Prediction, e.g. more heavy beads give a larger average mass, because a bigger share of the sample is heavier.

Equipment: light and heavy beads, balance (0.01 g), beaker or tray, pencil. Not needed: stopwatch, thermometer.

Hazards, e.g. small beads or beans could be swallowed or put in ears or noses: work under supervision, count the beads back in at the end, and use large beads with learners at risk.

Method key points: count out 40 beads with the right numbers (0, 10, 20, 30, 40 heavy); tare the balance with the empty container; weigh; repeat with a freshly counted sample; mean mass ÷ 40 = average mass of one bead.

Sample results: 0%: 14.00 g, 0.350 g; 25%: 14.20 g, 0.355 g; 50%: 14.40 g, 0.360 g; 75%: 14.60 g, 0.365 g; 100%: 14.80 g, 0.370 g.

Graph: percentage of heavy beads on x, average mass of one bead (g) on y; a straight line rising from 0.350 g to 0.370 g.

Conclusion: as the percentage of heavy beads increased, the average mass of one bead increased steadily (in proportion).

Evaluate: (a) about 0.362 g. (b) Three out of four chlorine atoms are chlorine-35, so the average is pulled towards 35 (like a sample with 25% heavy beads). (c) For example, beads of one type are not all exactly the same mass, but atoms of one isotope are; atoms have far more particles in a sample; beads are not made of protons and neutrons.

Check-up

1 A ($^{24}_{12}Mg^{2+}$).

2 C (2,3).

3 (a) Atoms with the same atomic number but different mass numbers / numbers of neutrons (1). (b) 71 − 31 = 40 (1). (c) (69 × 60.0) + (71 × 40.0) = 6980 (1); 6980 ÷ 100 = 69.8 (1).

4 2,8,8 (1); the sulfur atom (2,8,6) gains two electrons (to have a full outer shell / the arrangement of argon) (1).

TEACHER NOTES

Practical 3: Which type of bonding is in each substance?

Time	One 50-minute lesson in pairs: about 25 minutes of testing, then the bar chart and analysis.
Kit per group	Low-voltage conductivity meter or a 6 V circuit with bulb or LED and two carbon electrodes; samples of sodium chloride, sucrose, copper wire or foil, candle wax, sand, potassium nitrate; six small beakers, spatula, 25 cm^3 measuring cylinder, deionised water, wash bottle, eye protection.
Prep	Test the meter on salt solution and on deionised water. Label the solids clearly. Tap water conducts slightly: use deionised water and test it alone as the control.
Expected results	Only copper conducts as a solid. Sodium chloride and potassium nitrate solutions conduct; sugar solution does not. Wax and sand do not dissolve.
Level	N5 plans the tests, uses a control, records in a table, draws a bar chart from data and links results to bonding.

Safety and inclusion

- Eye protection. Use low voltage only and keep the meter body dry. Potassium nitrate is an oxidiser: small amounts, away from heat, disposed of as your local rules say.
- Melting points are given as data, so no heating is needed.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.
- The result table can be completed with ticks and crosses for learners who find writing slow.

Common problems

- **Contaminated probe:** rinse between tests or sugar solution may appear to conduct.
- **Dry salt conducting:** damp crystals can give a small reading; use dry samples.
- **Bar chart scale:** learners need a scale to about 1800 °C; wax at 55 °C gives a very short bar.

No lab, no time, or a learner absent?

The sample results and melting-point table let learners complete the table, chart, conclusion and evaluation without the practical.

Assessment link

Evidence of planning with a control, recording, presenting data as a bar chart and drawing conclusions. Assignment skill: using and referencing data from another source.

Answers: Topic 3

Topic 3: Bonding, structure and properties (N5)

1 Covalent bonds and shapes

1 Overlapping outer shells of H and Cl with one shared pair (one electron from each atom); chlorine shows three non-bonding pairs (8 outer electrons in total), hydrogen has 2.

2 (a) tetrahedral; (b) trigonal pyramidal; (c) angular.

3 Four electrons (two shared pairs).

2 Molecules, networks and ions

1 Iodine is covalent molecular: only weak forces between molecules have to be overcome. Diamond is a covalent network: many strong covalent bonds must be broken.

2 $K \rightarrow K^+ + e^-$.

3 When molten the ions are free to move and carry the current; in the solid the ions are held in place in the lattice.

3 Using properties

1 P covalent network; Q ionic (lattice); R covalent molecular; S metallic.

2 Towards the negative electrode, because the copper(II) ions are positive and opposite charges attract.

3 It is a covalent network: strong covalent bonds hold every atom in place, so water cannot separate the atoms (no ions to dissolve).

Practical 3: Which type of bonding is in each substance?

Variables: change the substance tested; observe whether it conducts as a solid and in solution (and whether it dissolves); keep the same: volume of water, amount of solid, the same meter and probe, cleaning the probe each time.

Prediction, e.g. the ionic substances will conduct only in solution, because their ions can then move.

Equipment: conductivity meter, small beakers, spatula, measuring cylinder, eye protection. Not needed: stopwatch, thermometer.

Hazards, e.g. electrical meter near water (keep the meter body dry, low voltage only); broken glass (report it); slippery spilt solutions (wipe up).

Method key points: touch the probe on the solid; add one spatula of solid to 25 cm^3 of water and stir; test the solution; rinse the probe with deionised water between tests; test the water alone as a control; repeat any surprising result.

Results: sodium chloride and potassium nitrate: ionic (conduct only in solution). Sugar: covalent molecular (dissolves, no conduction). Copper: metallic (conducts as a solid). Candle wax: covalent molecular. Silicon dioxide: covalent network.

Bar chart: substances on x, melting point (°C) on y, scale to at least 1800 °C; the network and ionic solids and the metal have tall bars, wax and sugar short ones.

Conclusion: the ionic substances were the ones that conducted when dissolved but not as solids, and they had higher melting points than the covalent molecular substances (334–801 °C).

Evaluate: (a) Wax melts at 55 °C (low), so it is molecular with weak forces between molecules; silicon dioxide melts at 1710 °C (very high), so it is a network with strong covalent bonds throughout. (b) Sugar has no ions; it is covalent (molecular), so its solution contains molecules, not ions.

Check-up

1 B (silicon dioxide).

2 C (PCl_3).

3 (a) C in the centre with four overlapping H shells, each overlap holding a shared pair (one electron from C, one from H) (1). (b) Methane is covalent molecular: only weak forces between the molecules need to be overcome (1).

4 (a) $Li \rightarrow Li^+ + e^-$ (1); $F_2 + 2e^- \rightarrow 2F^-$ (1). (b) It is an ionic lattice: the strong (ionic) bonds between oppositely charged ions take a lot of energy to break (1).

TEACHER NOTES

Practical 4: Does the mass change when a precipitate forms?

Time	About 30 minutes in pairs for five volumes, then the graph and analysis.
Kit per group	Copper(II) sulfate solution (0.2 mol l^{-1}), sodium hydroxide solution (0.4 mol l^{-1}), 100 cm^3 beaker, 25 cm^3 and 50 cm^3 measuring cylinders, balance reading to 0.01 g, eye protection.
Prep	Dispense the solutions into labelled bottles. Check balances are level and read to 0.01 g. A ready-mixed demonstration helps learners see the blue precipitate.
Expected results	Changes in mass of 0.00 g or ±0.01 g. The graph of mass after against mass before is a straight line with gradient 1.
Level	N5 plans the test, records masses to 0.01 g, draws a graph, links results to a balanced equation and evaluates.

Safety and inclusion

- Eye protection throughout. Sodium hydroxide solution at 0.4 mol l^{-1} is an irritant; copper(II) sulfate is harmful and an eye irritant. Wash hands afterwards.
- Dispose of the precipitate and solutions as your local rules say.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.
- Pouring can be done by one learner while another reads the balance.

Common problems

- **Forgetting the empty cylinder:** it must go back on the balance for the second reading.
- **Splashes:** pour slowly down the side of the beaker.
- **Gradient confusion:** point out that a straight line with gradient 1 means "after = before". The scales need not start at zero.

No lab, no time, or a learner absent?

The sample results let learners complete the changes in mass, graph, conclusion and evaluation without the practical.

Assessment link

Evidence of planning, recording, graphing and linking results to underlying chemistry, which is an assignment skill.

Answers: Topic 4

Topic 4: Formulae and equations (N5)

1 Formulae from valency

1 K_2S; $CaCl_2$; $AlBr_3$; CuO; $PbCl_4$; N_2O_4.

2 (a) sodium oxide; (b) silicon tetrachloride; (c) iron(III) bromide.

3 Sodium sulfide contains only two elements (sodium and sulfur); sodium sulfate also contains oxygen.

2 Group ions and ionic formulae

1 (a) Na_2CO_3; (b) $(NH_4)_2SO_4$; (c) $Al(NO_3)_3$.

2 $Mg^{2+}(OH^-)_2$; $(K^+)_3PO_4{}^{3-}$.

3 Carbon dioxide is covalent molecular, so its formula shows the atoms in one molecule. Silicon dioxide is a covalent network, so its formula only shows the ratio of atoms (one Si to two O).

3 Balanced equations

1 (a) $2Na + Cl_2 \rightarrow 2NaCl$; (b) $4Al + 3O_2 \rightarrow 2Al_2O_3$; (c) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$.

2 $CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$.

3 Oxygen from the air combines with the magnesium, so the mass of oxygen is added. The total mass of magnesium and oxygen is the same as the mass of magnesium oxide.

Practical 4: Does the mass change when a precipitate forms?

Variables: change the volume of sodium hydroxide solution; measure the total mass before and after mixing; keep the same: volume and concentration of copper(II) sulfate solution, concentration of sodium hydroxide, the same balance and containers.

Prediction, e.g. the total mass stays the same, because no atoms are lost: a precipitate forms but nothing escapes.

Equipment: balance (0.01 g), beaker, measuring cylinders, eye protection. Not needed: Bunsen burner, filter funnel, stopwatch.

Hazards, e.g. copper(II) sulfate is harmful if swallowed and irritates eyes (eye protection, wash hands); broken glass (report it).

Method key points: measure 20 cm³ of copper(II) sulfate into a beaker and the sodium hydroxide into a measuring cylinder; weigh both together; pour the sodium hydroxide into the beaker; put the empty cylinder back on the balance with the beaker; weigh again; repeat for each volume.

Sample results (change in mass): 5 cm³: 0.00 g; 10 cm³: −0.01 g; 15 cm³: 0.00 g; 20 cm³: −0.01 g; 25 cm³: 0.00 g.

Graph: total mass before on x, after on y; all points lie on a straight line with gradient 1 (mass after = mass before), so the line passes through points where both masses are equal.

Conclusion: when the precipitate formed, the total mass stayed the same (within 0.01 g).

Evaluate: (a) $CuSO_4(aq) + 2NaOH(aq) \rightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$: there are the same atoms on both sides and no gas is made, so the mass does not change. (b) The balance reads to 0.01 g, so a drop left in the cylinder or a small reading error gives ±0.01 g; this is too small to change the conclusion. (c) Carbon dioxide gas escapes from an open beaker, so the mass falls.

Check-up

1 C ($Fe(OH)_3$).

2 B (sodium nitrate).

3 $(Al^{3+})_2(SO_4{}^{2-})_3$ (1).

4 SO_3 (1).

5 (a) Correct formulae $ZnCO_3 \rightarrow ZnO + CO_2$ (1); state symbols $ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$ (1).

(b) Carbon dioxide gas is given off and escapes from the tube (1).

6 $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ (1).

TEACHER NOTES

Practical 5: Does the mass of carbon dioxide match the equation?

Time	One 50-minute lesson in pairs. Each run takes about 3 minutes once the fizzing has stopped.
Kit per group	Calcium carbonate powder (precipitated chalk), 1.0 mol l^{-1} hydrochloric acid, 250 cm^3 conical flask, cotton wool, 100 cm^3 measuring cylinder, weighing boats, balance reading to 0.01 g, eye protection.
Prep	75 cm^3 of 1.0 mol l^{-1} acid is 0.075 mol HCl, enough for up to about 3.7 g of calcium carbonate, so it is in excess for every mass up to 2.50 g. Powder reacts quickly; chips are slower but work.
Expected results	About 0.42 to 0.44 g of CO_2 per gram of calcium carbonate, slightly below the theoretical 0.44 g because some CO_2 dissolves.
Level	N5 uses a mole calculation to predict, repeats, finds the mean, draws a graph and compares with the prediction.

Safety and inclusion

- Eye protection. 1.0 mol l^{-1} hydrochloric acid is an irritant. Cotton wool in the neck reduces spray.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.
- The prediction can be scaffolded with the four-step boxes; a calculator is needed.

Common problems

- **Forgetting the weighing boat:** it must be on the balance at both readings, or the "mass lost" includes the powder.
- **Reading too early:** wait until the balance reading is steady.
- **Acid not in excess:** above about 3.7 g the mass of CO_2 stops rising; this can be a useful extension.

No lab, no time, or a learner absent?

The sample results let learners complete the prediction, means, graph and evaluation without the practical.

Assessment link

Evidence of calculation, recording, graphing and comparing an experimental value with a calculated one: a key assignment skill.

Answers: Topic 5

Topic 5: The mole and calculations (N5)

1 Gram formula mass and moles

1 (a) (2 × 23.0) + 12.0 + (3 × 16.0) = 106.0 g; (b) 40.1 + 2 × (16.0 + 1.0) = 74.1 g.

2 GFM = 23.0 + 35.5 = 58.5 g; n = m ÷ GFM = 11.7 ÷ 58.5 = 0.200 mol.

3 GFM = 24.3 + 16.0 = 40.3 g; m = n × GFM = 0.150 × 40.3 = 6.05 g (6.045 g).

2 Solutions and percentage composition

1 V = 0.250 l; c = n ÷ V = 0.040 ÷ 0.250 = 0.16 mol l^{-1}.

2 n = c × V = 0.10 × 0.500 = 0.050 mol; GFM = 39.1 + 16.0 + 1.0 = 56.1 g; m = 0.050 × 56.1 = 2.8 g (2.805 g).

3 GFM = 12.0 + 16.0 + 2 × (14.0 + 2.0) = 60.0 g; mass of N = 28.0 g; % = 28.0 ÷ 60.0 × 100 = 46.7%.

3 Calculations from equations

1 1 mol Fe_2O_3 → 2 mol Fe; GFM Fe_2O_3 = 159.6 g; n = 16.0 ÷ 159.6 = 0.1003 mol; n(Fe) = 0.2005 mol; m = 0.2005 × 55.8 = 11.2 g.

2 2 mol H_2 → 2 mol H_2O (1 : 1); n(H_2) = 0.50 ÷ 2.0 = 0.25 mol; n(H_2O) = 0.25 mol; m = 0.25 × 18.0 = 4.5 g.

Practical 5: Does the mass of carbon dioxide match the equation?

Variables: change the mass of calcium carbonate; measure the mass lost (carbon dioxide); keep the same: volume and concentration of acid (in excess), the same balance, cotton wool in the neck, waiting until the fizzing stops.

Prediction, e.g. more calcium carbonate gives more carbon dioxide, in proportion, because the acid is in excess.

Equipment: calcium carbonate powder, balance (0.01 g), conical flask, measuring cylinder, eye protection. Not needed: thermometer, burette.

Hazards, e.g. spilled acid on the bench (wipe up); glassware on the edge of the bench (keep it central).

Method key points: 75 cm^3 of acid in a 250 cm^3 flask with cotton wool; weigh the flask, acid and a weighing boat of calcium carbonate together; tip the powder in and put the boat back on the balance; weigh again when the fizzing stops; mass lost = mass of CO_2; three repeats for each mass.

Sample means: 0.50 g: 0.21 g; 1.00 g: 0.43 g; 1.50 g: 0.63 g; 2.00 g: 0.85 g; 2.50 g: 1.05 g.

Graph: a straight line through the origin with a gradient of about 0.42 (g of CO_2 per g of $CaCO_3$).

Conclusion: as the mass of calcium carbonate increased, the mass of carbon dioxide increased in direct proportion.

Evaluate: (a) 1 mol $CaCO_3$ → 1 mol CO_2; n = 1.00 ÷ 100.1 = 0.00999 mol; m(CO_2) = 0.00999 × 44.0 = 0.44 g.

(b) 0.43 g measured against 0.44 g predicted, very close; it is a little low because some carbon dioxide stays dissolved in the solution (or some escapes before the first reading). (c) So that all of the calcium carbonate reacts; the mass of CO_2 then depends only on the calcium carbonate.

Check-up

1 C (102.0 g).

2 B (0.20 mol).

3 GFM = 32.1 + 32.0 = 64.1 g (1); 32.1 ÷ 64.1 × 100 = 50.1% (1).

4 1 mol Mg → 1 mol $MgCl_2$ (1); n(Mg) = 2.43 ÷ 24.3 = 0.100 mol (1); GFM $MgCl_2$ = 95.3 g, m = 0.100 × 95.3 = 9.53 g (1).

TEACHER NOTES

Practical 6: What is the concentration of the sodium hydroxide?

Time	One 50-minute lesson for the titration in pairs; the pH curve can be a teacher demonstration with a pH meter or data logger, or use the sample data.
Kit per group	50 cm^3 burette and stand, 25 cm^3 pipette with pipette filler, conical flasks, small funnel, white tile, phenolphthalein or screened methyl orange, 0.120 mol l^{-1} hydrochloric acid, sodium hydroxide solution of about 0.1 mol l^{-1}, eye protection.
Prep	Make up the sodium hydroxide to about 0.1 mol l^{-1} so titres are near 20 cm^3. Check pipette fillers work. Demonstrate reading the meniscus at eye level.
Expected results	Titres of about 20 to 21 cm^3 with concordant pairs within 0.2 cm^3. The pH curve drops sharply from about pH 11 to pH 3 at the end-point.
Level	**N5** carries out a titration, chooses concordant titres, calculates a concentration and interprets a pH curve.

Safety and inclusion

- Eye protection throughout. Sodium hydroxide solution is an irritant at this concentration. Pipette fillers only, never mouth pipetting.
- Fill burettes below eye level (stand them on the floor or a low bench to fill) and remove the funnel before titrating.
- Risk assess for your own class and follow your employer's policies and SSERC guidance.
- Learners with fine-motor difficulties can read and record while a partner controls the tap.

Common problems

- **Air bubble below the tap:** run a little acid through before the start reading.
- **Overshooting:** slow to drop by drop when the colour starts to linger.
- **Litres:** convert cm^3 to litres before using $n = c \times V$.

No lab, no time, or a learner absent?

The sample titres and pH readings let learners complete the graph, calculation and evaluation without the practical.

Assessment link

Evidence of accurate measurement, concordant results, calculation and interpretation of a graph.

Answers: Topic 6

Topic 6: Acids and bases (N5)

1 The pH scale and ions

1 The pH rises towards 7 (but stays below 7), because the $H^+(aq)$ ions are spread out in more water, so their concentration falls.

2 Below 7: carbon dioxide is a non-metal oxide, so its solution has more $H^+(aq)$ than $OH^-(aq)$.

3 It is a base but not an alkali: it neutralises acid, but an alkali must dissolve in water.

2 Neutralisation and salts

1 (a) magnesium sulfate; (b) ammonium chloride; (c) calcium nitrate.

2 zinc carbonate + hydrochloric acid → zinc chloride + water + carbon dioxide.

3 Spectators: $K^+(aq)$ and $SO_4^{2-}(aq)$. Equation: $2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l)$, which simplifies to $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$.

3 Titrations and making salts

1 18.3 and 18.4 cm³ are concordant (18.8 is 0.4 or more away from both); mean = 18.35 cm³.

2 V = 0.0184 l; $n(H_2SO_4) = 0.0500 \times 0.0184 = 0.000920$ mol; ratio 1 : 2, so n(KOH) = 0.00184 mol; c = 0.00184 ÷ 0.0250 = 0.0736 mol l^{-1}.

3 The excess makes sure all the acid reacts, so the salt solution has no acid left in it. He filters off the unreacted zinc oxide and evaporates the filtrate (then leaves it to crystallise).

Practical 6: What is the concentration of the sodium hydroxide?

Keep the same: the volume of alkali (25.0 cm³ by pipette), the same indicator and number of drops, the same concentration of acid, swirling the flask, reading the burette at eye level from the bottom of the meniscus. Reliable: repeat until two titres are within 0.2 cm³.

Prediction, e.g. the pH will fall slowly at first and then drop sharply from about 11 to about 3 at the end-point.

Equipment: burette, pipette, pipette filler, conical flask, small funnel (for filling the burette, then removed), indicator and dropper. Not needed: measuring cylinder (not accurate enough).

Hazards, e.g. filling the burette above eye level (lower it or use a stool safely; use a funnel and remove it); broken glass (report it); acid irritant (eye protection).

Method key points: rinse and fill the burette with acid, read the start volume; pipette 25.0 cm³ of alkali into the flask with a filler; add indicator; add acid while swirling, drop by drop near the end; stop at the first permanent colour change; record the titre; repeat until concordant.

Graph: volume on x, pH on y: a high, gently falling curve, then a near-vertical drop at about 20.6 cm³, then a low, flat section.

Calculate: concordant titres 20.6 and 20.7 cm³ (21.0 is more than 0.2 cm³ from both); mean = 20.65 cm³; n(HCl) = 0.120 × 0.02065 = 0.002478 mol; ratio 1 : 1, so n(NaOH) = 0.002478 mol; c = 0.002478 ÷ 0.0250 = 0.0991 mol l^{-1}.

Evaluate: (a) the pH falls very sharply near the end-point, so one drop of acid changes the pH by several units and the indicator changes colour suddenly. (b) The rough titre is done quickly to find roughly where the end-point is, so it usually overshoots and is less accurate.

Check-up

1 C (sulfur dioxide).

2 B (22.4 and 22.6).

3 n(NaOH) = 0.160 × 0.0125 = 0.00200 mol (1); 1 : 1, so n(HCl) = 0.00200 mol (1); c = 0.00200 ÷ 0.0200 = 0.100 mol l^{-1} (1).

4 (a) Carbon dioxide (1). (b) Some magnesium carbonate is left over and no more bubbles are given off (1).

About the author



C. Blewis has taught for 17 years, including 10 years in Additional Support Needs (ASN) provision, teaching sciences, maths, PE and more.

In many schools, especially smaller and specialist settings, teachers are often asked to teach outside their own subject. These books are written for them, and for the young people they teach: clear, practical and ready to use from the first lesson.