Unit Preparation Booklet

C4.3 Quantitative Chemistry

Teacher name:

Science
Mastery

Ark **Curriculum+**

Contents

Steps to Success

		What?	Why?	Who?	Page #
Preparing to teach	1	☐ Print this booklet or save a copy in a personal folder	To allow for engagement during planning and co-planning	*All teachers*	
	2	☐ Engage with the unit preparation checklist	To prepare for delivering the sequence of lessons	*All teachers*	4
	3	☐ Read the scope and sequence for the unit	To review the scope and sequence of the unit	*All teachers*	5
	4	☐ Complete the pre-unit quiz reflections task after administering to class	To plan how to remedy prior knowledge gaps	*New to teaching the unit only*	11
	6	☐ Complete the Mastery Quiz and exam-style questions activity	To learn/revisit the key assessment objectives of the unit	*New to teaching the unit only*	12-21
	7	☐ Complete the misconception activities	To develop a strong understanding of the most common misconceptions for the unit and how to address them	*New to teaching the unit only*	22-24
Delivering the unit	8	☐ Use the lesson by lesson objectives to monitor progression through the unit	To maintain a record of completion and to recognise what needs to be reviewed after each lesson	*Novice teachers only*	25-37

Utilise other features of the booklet	**9**	☐ Complete the advanced subject knowledge activity	To develop an understanding of where the unit can lead	*Non A-level specialists*	39
	10	☐ Engage in the keywords	To identify the correct definitions for keywords throughout the unit	*Novice teachers only*	41

Unit preparation checklist

Resources can and should be tailored to meet your pupils' needs. We have aimed to do as much resourcing as possible so that teachers' time can be spent on co-planning and preparation; however, they are only ready for your pupils once you have decided how to make use of them.

Here is a suggested checklist:

Locate:

- ☐ **Find** the unit resources using MyMastery or SharePoint

Engage:

- ☐ Work through the preparation booklet. Complete the pre-unit quiz and mastery quiz yourself and reflect (all enclosed)
- ☐ Set your class the **pre-unit quiz** (in advance of the unit).
- ☐ Note which topics are **areas of weakness** for the class (space available in this booklet or on the planning pro-forma)
- ☐ **Decide** which topics you will re-visit 'in advance' and which to tackle during the unit (space available in this booklet or on the planning pro-forma)
- ☐ Identify where in the sequence of learning there are opportunities for embedding **guided reading**
- ☐ Use the **lesson planning guidance** to develop a grasp of the purpose of each lesson element

Adapt:

- ☐ Consider key timings for each lesson. Identify which lessons may need to be adapted to account for the length of your lessons or ability level of your class
- ☐ Identify what could be used as **homework** activities to support in-class learning in line with school policy
- ☐ Review the resources ahead of each lesson and ensure you are clear on the objectives of each lesson
- ☐ **Select** appropriate activities for each lesson from the selection within each lesson folder/on the slide deck
- ☐ **Administer** exit tickets and use outcomes of this to plan 'fix-it' tasks to tackle misunderstanding or misconception.
- ☐ Set the **mastery quiz** for your class. Use the information to plan a suitable re-teach lesson and further response, using the resources available.

Scope and Sequence

Scope

This unit covers most of the key ideas about quantitative chemistry, including the mole and reacting masses calculations. It features a review of relative formula mass and percentage by mass and concentration, as well as the chemistry separate science concentration content. The unit also applies quantitative content to acids, alkalis and neutralisation reactions, with separate science students also looking at titrations and volumes of gases.

Sequence

The unit begins with a review of the key content from C3.2, where students met relative formula mass and percentage by mass. Relative atomic mass will be touched upon but there will be other opportunities to revisit this calculation, including in P4.4 Radioactivity. Higher tier students will then be introduced to the concept of the mole and the relationship between the mole, mass and relative formula mass, becoming familiar with this equation that will be required for the rest of the unit. Students then also revisit concentration from C3.2, both in terms of the concept and calculating it in g/dm^3. Separate science students will then also go on to calculate concentration in mol/dm^3, bringing together the concept of the mole with concentration, both of which have been covered now. Separate science students will also look at how balanced chemical equations can be used to determine an unknown concentration using the mole ratio.

Higher tier students then look at the application of the mole, mass and Mr relationship, looking at reacting masses, followed by limiting reactants. Percentage yield and atom economy are not covered in this unit, as that can lead to confusion and overload of equations. Instead, quantitative chemistry will be slightly spread out to allow revisiting, with percentage yield and atom economy introduced at the start of C4.4 Energy Changes, where students will look more at balanced equations and bond energies.

Students then have another review of acid reactions, as they can now use the new content from this topic to apply to acid reactions. This includes content from C2.2 and C4.2, where students looked at acids and displacement reactions. They will then look at acids, alkalis and neutralisation before separate science students use the acid-alkali neutralisation to determine the volume of an acid needed to neutralise a known volume and concentration of alkali. Separate science students will then bring this together with the content from earlier in the unit where they used the mole ratio to calculate an unknown concentration.

Finally, higher tier students will look at strong and weak acids, bringing together many different pieces of knowledge from the unit, before finally separate science students meet the volumes of gases.

A full set of knowledge objectives for this unit can be found as **Appendix 3.**

1	2	3	4

Prior knowledge review: M_r and % by Mass	(HT) Introducing the Mole	(HT) Mole Calculations	Prior Knowledge Review: Concentration
5	**6**	**7**	**8**
Taking it Further Calculating Concentration	Taking it Further Calculating an Unknown Concentration	(HT) Amounts of substances in equations	(HT) Limiting Reactants
9	**10**	**11**	**12**
Prior Knowledge Review: Acid Reactions	Acids, Alkalis and Neutralisation	Taking it Further: RPA Acid-Alkali Titration 1	Taking it Further: RPA Acid-Alkali Titration 2
13	**14**	**15**	**16**
Taking it Further: Titration Calculations	(HT) Strong and Weak Acids	Taking it Further: Volumes of Gases	Feedback Lesson

TASKS:

New teachers: Organise the lesson titles into those you feel most to least confident about *Experienced teachers:* Reflect on prior experience of teaching this unit. Which lessons have gone well? Which would you like to target for improvement this year?

Pre-unit quiz

TASK: Below is the pre-unit quiz available for your pupils. Complete yourself and set for your pupils ahead of starting the unit. There is space to record the key outcomes from marking the quiz for your class. **See Appendix 1 for the mark scheme.**

You should use a periodic table where necessary

1. Below shows a chemical formula of a compound.

$$CaCO_3$$

Choose the correct number of atoms in one molecule. [1]

Tick (✓) **one** box.

A. 1 calcium atom, 1 carbon atom, 3 oxygen atoms ☐

B. 1 calcium atom, 3 carbonate atoms ☐

C. 3 calcium atoms, 3 carbon atoms, 3 oxygen atoms ☐

2. Choose the correct state symbol for an aqueous solution. [1]

Tick (✓) **one** box.

A. (l) ☐

B. (s) ☐

C. (aq) ☐

3. Below shows a symbol equation of a chemical reaction

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$$

When this reaction was carried out in a beaker on a balance, the mass decreased.

Choose the best explanation for why.[1]

Tick (✓) **one** box.

A. Carbon dioxide gas is produced which has no mass ☐

B. Carbon dioxide gas left the beaker ☐

C. Reactants always have a greater mass than the products formed ☐

4. Below shows an incomplete word equation for a chemical reaction.

Calcium carbonate + hydrochloric acid → carbon dioxide + __________ + water

Choose the missing substance. [1]

Tick (✓) **one** box.

A. Chlorine carbonate ☐

B. Calcium chloride ☐

C. Hydrocarbonate ☐

5. 200 g sodium hydroxide was dissolved in water to make 1 dm^3 solution.

   Choose the concentration of this sodium hydroxide solution. [1]

   Tick (✓) **one** box.

   A. 0.2 g/dm^3 ☐

   B. 0.005 g/dm^3 ☐

   C. 200 g/dm^3 ☐

6. Choose the relative formula mass of CO_2. [1]

   (Ar: C = 12; O = 16)

   A. $M_r = 44$ ☐

   B. $M_r = 28$ ☐

   C. $M_r = 56$ ☐

7. Choose the most appropriate equipment for accurately measuring 10 cm^3 water. [1]

Tick (✓) **one** box.

A. 10 cm^3 measuring cylinder ☐

B. 10 cm^3 beaker ☐

C. 10 cm^3 evaporating dish ☐

8. A student investigated how heating calcium carbonate affected its mass.

   Calcium carbonate was heated in a test tube for 1 minute.

   The mass was measured before and after heating, then the change in mass recorded.

   This was repeated four times and the results are shown below.

Repeat number	Change in mass (g)
1	12
2	13
3	10
4	9

   Choose the correct analysis of these results. [1]

   Tick (✓) **one** box.

   A. The change of mass of 9 g is an anomaly ☐

   B. The change in mass is 11 g +/- 2 g ☐

   C. The results are very precise ☐

9. Choose the technique that would separate insoluble copper carbonate from a copper sulfate solution. [1]

   Tick (✓) **one** box.

   A. Filtration ☐

   B. Evaporation ☐

   C. Crystallisation ☐

10. Choose the correct hazard for using dilute hydrochloric acid. [1]

    Tick (✓) **one** box.

A. It is an irritant and could irritate skin ☐

B. Wear safety goggles so acid cannot get into eyes ☐

C. It is quite likely that the acid splashes onto skin and it must be rinsed off immediately ☐

11. Convert 12 dm^3 to cm^3. [1]

Tick (✓) **one** box.

A. 1200 cm^3 ☐

B. 0.012 cm^3 ☐

C. 12000 cm^3 ☐

12. Choose the relative formula mass of $(NH_4)_3PO_4$. [1]

(Ar: N = 14; H = 1; P = 31; O = 16)

Tick (✓) **one** box.

A. $M_r = 123$ ☐

B. $M_r = 121$ ☐

C. $M_r = 149$ ☐

D. $M_r = 144$

13. 300 g of H_2SO_4 is dissolved in water to make 500 cm^3 of solution.

Choose the concentration of this solution. [1]

Tick (✓) **one** box.

A. 600 g/cm^3 ☐

B. 0.6 g/cm^3 ☐

C. 1.66 g/cm^3 ☐

14. Choose the correct compounds that react to make copper sulfate crystals. [1]

Tick (✓) **one** box.

A. Copper and sulfate ☐

B. Copper oxide and sulfuric acid ☐

C. Copper sulfide and oxygen ☐

15. Choose which of the symbol equations below is balanced. [1]

Tick (✓) **one** box.

A. $N_2 + H_2 \rightarrow NH_3$ ☐

B. $3\ N_2 + 3\ H_2 \rightarrow NH_3$ ☐

C. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ ☐

$\overline{\quad 15 \quad}$

Pre-unit quiz reflections

To be completed once you have reviewed your pupils' response to the pre-unit quiz.

What topics are your pupils confident with?

What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout the unit?

Other notes

Mastery Quiz

TASK: Below is the mastery quiz available for your pupils to sit at the end of the unit. Complete yourself and consider the key misconceptions this quiz aims to address. See **Appendix 2** for the mark scheme.

Combined Science

Section A

1. Calculate the relative formula mass (M_r) of $FeBr_3$.
   Relative atomic masses (A_r): Fe = 56 Br = 80

   Tick (✓) **one** box. [1]

   A. 136
   B. 408
   C. 296

2. Which ions do alkalis produce in aqueous solutions?
   Tick (✓) **one** box. [1]

   A. H^+
   B. OH^-
   C. O^{2-}

3. Acids react with alkalis. What is the name given to this type of reaction?
   Tick (✓) **one** box. [1]

   A. Decomposition
   B. Electrolysis
   C. Neutralisation
   D. Redox

4. Universal indicator turns purple when added to potassium hydroxide solution. Which is likely to be the pH of potassium hydroxide solution?

   Tick (✓) **one** box. [1]

   A. 1
   B. 7
   C. 14

5. Below shows a chemical formula of a compound.

$$CaCO_3$$

Choose the correct number of atoms in one molecule. [1]

Tick (✓) **one** box.

A. 1 calcium atom, 1 carbon atom, 3 oxygen atoms ☐

B. 1 calcium atom, 3 carbonate atoms ☐

C. 3 calcium atoms, 3 carbon atoms, 3 oxygen atoms ☐

6. Choose the correct state symbol for an aqueous solution. [1]

Tick (✓) **one** box.

A. (l) ☐

B. (s) ☐

C. (aq) ☐

7. Below shows a symbol equation of a chemical reaction

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$$

When this reaction was carried out in a beaker on a balance, the mass decreased.

Choose the best explanation for why. [1]

Tick (✓) **one** box.

A. Carbon dioxide gas is produced which has no mass ☐

B. Carbon dioxide gas left the beaker ☐

C. Reactants always have a greater mass than the products formed ☐

8. Below shows an incomplete word equation for a chemical reaction.

Calcium carbonate + hydrochloric acid → carbon dioxide + __________ + water

Choose the missing substance.[1]

Tick (✓) **one** box.

A. Chlorine carbonate ☐

B. Calcium chloride ☐

C. Hydrocarbonate ☐

9. 200 g sodium hydroxide was dissolved in water to make 1 dm^3 solution.

Choose the concentration of this sodium hydroxide solution. [1]
Tick (✓) **one** box.

A. 0.2 g/dm^3

B. 0.005 g/dm^3

C. 200 g/dm^3

HIGHER TIER ONLY

10. How many atoms are present in one mole of fluorine atoms?

Tick (✓) **one** box. [1]

A. 19

B. 2.06×10^{23}

C. 6.02×10^{23}

11. Convert 250 cm^3 to dm^3.

Tick (✓) **one** box. [1]

A. 250 dm^3

B. 0.25 dm^3

C. 250000 dm^3

12. A mixture contains 50 g of aluminium and 150 g of iron oxide.
The equation for the reaction is:

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

Which is the limiting reactant?
Relative atomic masses (Ar): O = 16 Al = 27 Fe = 56

Tick (✓) **one** box. [1]

A. Aluminium

B. Iron Oxide

C. Iron

13. Select the **correct** statement.

Tick (✓) **one** box. [1]

A. Ethanoic acid is a weak acid, because it partially ionises in an aqueous solution. ☐
B. Sulfuric acid is a strong acid because it partially ionises in an aqueous solution. ☐
C. Ethanoic acid is a strong acid because it fully ionises in an aqueous solution. ☐

14. Which of the following statements correctly describes a **concentrated** acid?

Tick (✓) **one** box. [1]

A. Little or no water molecules are mixed with the acid molecules. The concentration of H^+ ions is low. ☐
B. Little or no water molecules are mixed with the acid molecules. The concentration of H^+ ions is high. ☐
C. Many water molecules are mixed with the acid molecules. The concentration of H^+ ions is low. ☐

15. Ethanedioic acid ($H_2C_2O_4$) is a solid at room temperature.
Calculate the mass of ethanedioic acid equal to 0.048 moles.
Relative formula mass (M_r): $H_2C_2O_4 = 90$

Tick (✓) **one** box. [1]

A. 4.32 g ☐
B. 0.0005 g ☐
C. 1875 g ☐

Section B

1. A student investigated the law of conservation of mass.

This is the method the student used.

1. Pour sodium carbonate solution into beaker A and pour hydrochloric acid solution into beaker B.
2. Place each beaker on a balance to measure the mass of the beakers and their contents.
3. Pour the solution from beaker B into beaker A.
4. Measure the mass of both beakers and contents again.

This is the equation for the reaction that takes place:

$$Na_2CO_3(aq) \quad + \quad 2HCl(aq) \quad \longrightarrow \quad 2NaCl(aq) \quad + \quad CO_2(g) \quad + \quad H_2O(l)$$

(a) State the law of conservation of mass.

____

____

[1]

(b) The table shows the student's results.

	Mass in g
Beaker A and contents before mixing	68.76
Beaker B and contents before mixing	72.12
Beaker A and contents after mixing	79.23
Beaker B after mixing	56.65

Explain why this reaction does not appear to obey the law of conservation of mass.

____

____

____

[2]

(c) What is the resolution of the balance used to obtain the results in the table?
Tick (✓) **one** box.

0.01 g ☐ 0.1 g ☐ 1 g ☐ 100 g ☐

[1]

(d) Calculate the relative formula mass (M_r) of sodium carbonate Na_2CO_3
Relative atomic masses (A_r): Na = 23 O = 16 C = 12

____

____

Relative formula mass = __________________ [2]

(e) What is the percentage by mass of sodium in sodium carbonate (Na_2CO_3)?

____

Percentage = ________________ [2]

(f) The formula of lithium chromate is Na_2CO_3
The charge on a sodium ion is +1
What is the formula of the carbonate ion?
Tick (✓) **one** box.

CO_3^{+}	☐
CO_3^{2+}	☐
CO_3^{-}	☐
CO_3^{2-}	☐

[1]

(g) Hydrochloric acid (HCl) is a strong acid.

What ions do all acids produce in aqueous solutions?

________________________________ [1]

(h) The student added a few drops of universal indicator to the hydrochloric acid.

What colour will she observe?

________________________________ [1]

HIGHER TIER ONLY

2. A student wanted to make 11.5 g of sodium chloride.

The equation for the reaction is:

$$Na_2CO_3(aq) \quad + \quad 2HCl(aq) \quad \longrightarrow \quad 2NaCl(aq) \quad + \quad CO_2(g) \quad + \quad H_2O(l)$$

Relative atomic masses, A_r: H = 1; C = 12; O = 16; Cl = 35.5; Na = 23

(a) Calculate the mass of sodium carbonate the student should react with dilute hydrochloric acid to make 11.5 g of sodium chloride.

____

____

____

____

Mass of sodium carbonate = ____________________ g [5]

(b) The acid used in this reaction has a concentration of 1.0×10^{-3} mol/dm^3. It has a pH of 2.
What is the pH of a solution of the same acid, with a concentration of 1.0×10^{-5} mol/dm^3?

____

____

pH = __________
[2]

Separate Science

Section A

CHEMISTRY ONLY

1. Calculate the relative formula mass (M_r) of $FeBr_3$.

Relative atomic masses (A_r): Fe = 56 Br = 80

Tick (✓) **one** box. [1]

A. 136 ☐
B. 408 ☐
C. 296 ☐

2. Which ions do acids produce in aqueous solutions?
Tick (✓) **one** box. [1]

A. H^+ ☐
B. OH^- ☐
C. O^{2-} ☐

3. Acids react with alkalis. What is the name given to this type of reaction?
Tick (✓) **one** box. [1]

A. Decomposition ☐
B. Electrolysis ☐
C. Neutralisation ☐
D. Redox ☐

4. Universal indicator turns purple when added to potassium hydroxide solution. What is the pH of potassium hydroxide solution?
Tick (✓) **one** box. [1]

A. 1 ☐
B. 7 ☐
C. 14 ☐

5. Choose the correct state symbol for an aqueous solution.[1]

Tick (✓) **one** box.

A. (l) ☐

B. (s) ☐

C. (aq) ☐

6. 200 g sodium hydroxide was dissolved in water to make 1 dm^3 solution.

   Choose the concentration of this sodium hydroxide solution. [1]
   Tick (✓) **one** box.

   A. 0.2 g/dm^3 ☐

   B. 0.005 g/dm^3 ☐

   C. 200 g/dm^3 ☐

7. How many atoms are present in one mole of fluorine atoms?

   Tick (✓) **one** box. [1]

   A. 19 ☐

   B. 2.06×10^{23} ☐

   C. 6.02×10^{23} ☐

8. Convert 250 cm^3 to dm^3.

   Tick (✓) **one** box. [1]

   A. 250 dm^3 ☐

   B. 0.25 dm^3 ☐

   C. 250000 dm^3 ☐

9. A student carried out an acid-base titration.
   He placed a white tile under the conical flask before he started.
   Why did he do this?

   Tick (✓) **one** box. [1]

   A. The white tile protects the desk from acid ☐

   B. The white tile lifts up the conical flask so it is closer to the burette. ☐

   C. The white tile allows the student to see any colour change clearly ☐

10. A student carried out a titration which involved a neutralisation

reaction between sodium hydroxide solution and hydrochloric acid. She added the acid to the burette, and the alkali to a conical flask. She carefully added the acid to the conical flask until the alkali was neutralised.

This was repeated 5 times.
The table below displays the students results.

Titre	Volume of acid required to neutralise the alkali (cm^3)
1	21.4
2	21.5
3	20.5
4	21.1
5	21.4

Calculate the average titre.

Tick (✓) **one** box. [1]

A. 21.22 ☐

B. 21.43 ☐

C. 21.35 ☐

HIGHER TIER ONLY

11. A mixture contains 50 g of aluminium and 150 g of iron oxide.
The equation for the reaction is:

$$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$$

Which is the limiting reactant?

Relative atomic masses (Ar): O = 16 Al = 27 Fe = 56

Tick (✓) **one** box. [1]

A. Aluminium ☐

B. Iron Oxide ☐

C. Iron ☐

12. Select the **correct** statement.

Tick (✓) **one** box. [1]

A. Ethanoic acid is a weak acid, because it partially ionises in an aqueous solution. ☐

B. Sulfuric acid is a strong acid because it partially ionises in an aqueous solution. ☐

C. Ethanoic acid is a strong acid because it fully ionises in an aqueous solution. ☐

13. Which of the following statements correctly describes a **concentrated** acid?

Tick (✓) **one** box. [1]

A. Little or no water molecules are mixed with the acid molecules. The concentration of H^+ ions is low. ☐

B. Little or no water molecules are mixed with the acid molecules. The concentration of H^+ ions is high. ☐

C. Many water molecules are mixed with the acid molecules. The concentration of H^+ ions is low. ☐

14. Ethanedioic acid ($H_2C_2O_4$) is a solid at room temperature. Calculate the mass of ethanedioic acid equal to 0.048 moles.
Relative formula mass (M_r): $H_2C_2O_4 = 90$

Tick (✓) **one** box. [1]

A. 4.32 g ☐

B. 0.0005 g ☐

C. 1875 g ☐

15. What mass of ethanedioic acid ($H_2C_2O_4$) is needed to make 0.25 dm^3 of a solution with concentration 0.05 mol/dm^3?
Relative formula mass (M_r): $H_2C_2O_4 = 90$

Tick (✓) **one** box. [1]

A. 18 g ☐

B. 1.125 g ☐

C. 0.0125 g ☐

16. A student found that 25.0 cm^3 of sodium hydroxide solution was neutralised by 15.00 cm^3 of 0.0480 mol/dm^3 ethanedioic acid solution.

The equation for the reaction is:

$$H_2C_2O_4 + 2\ NaOH \rightarrow Na_2C_2O_4 + 2\ H_2O$$

0.00072 moles of ethanedioic acid reacted.

a. Use the equation provided to calculate the number of moles of sodium hydroxide solution that reacted.

Tick (✓) **one** box. [1]

A. 0.00072 moles

B. 0.00036 moles

C. 0.00144 moles

b. Another student carried out the same reaction. They reacted 0.5 moles of sodium hydroxide solution with ethanedioic acid. The volume of sodium hydroxide solution reacted was 25.0 cm^3.

Calculate the concentration of the sodium hydroxide solution in mol/dm^3.

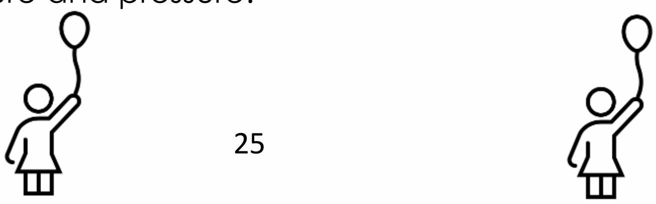
Tick (✓) **one** box. [1]

A. 20 mol/dm^3

B. 0.02 mol/dm^3

C. 0.0125 mol/dm^3

17. Two balloons are filled with a gas. Both balloons are at standard room temperature and pressure.



Balloon A
Filled with 10 g of hydrogen gas (H_2)

Balloon B
Filled with 20 g of helium gas (He)

Relative formula mass (M_r): H = 1 He = 4

Which statement below is correct?

Tick (✓) **one** box. [1]

A. Balloon A will have a greater volume ☐
B. Balloon B will have a greater volume ☐
C. The balloons will have the same volume ☐

Section B

1. (a) A student carried out an acid-base titration.

She used the following equipment:

- A pipette
- 25 cm^3 of potassium hydroxide solution
- A conical flask
- Indicator
- A burette filled with sulfuric acid

Describe how the student could use the equipment listed above to complete the titration.

(b) Hydrochloric acid (HCl) is a strong acid.

What ions do all acids produce in aqueous solutions?

[5]

(c) The student added a few drops of universal indicator to the hydrochloric acid.

What colour will she observe?

[1]

HIGHER TIER ONLY

3. A student wanted to make 11.5 g of sodium chloride.

The equation for the reaction is:

$$Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

Relative atomic masses, A_r: H = 1; C = 12; O = 16; Cl = 35.5; Na = 23

(b) Calculate the mass of sodium carbonate the student should react with dilute hydrochloric acid to make 11.5 g of sodium chloride.

Mass of sodium carbonate = ______________ g

[5]

(b) Another student carried out this reaction and produced 36 g of water. Calculate the number of moles of water he produced.

Number of moles = ______________

[1]

(c) The acid used in this reaction has a concentration of 1.0×10^{-3} mol/dm^3. It has a pH of 2.
What is the pH of a solution of the same acid, with a concentration of 1.0×10^{-5} mol/dm^3?

pH = ______________

[2]

(d) The carbon dioxide was collected at room temperature and pressure.
The volume of one mole of any gas at room temperature and pressure is 24.0 dm^3.
How many moles of carbon dioxide is in 45 cm^3?
Give your answer in three significant figures.

= ______________ mol

[2]

Mastery quiz reflections

Which aspects of this unit are likely to be the most challenging to teach?

What are your pupils likely to find most challenging and why?	
Challenging.....	Because....
E.g. The number of new keywords	*They are abstract words that aren't used in other areas of science*

How can you pre-empt some of the key misconceptions the mastery quiz aims to identify?	
Misconception	**How to avoid**

Exam-style questions

TASK: Using Exampro (or the software used by your exam board), look through the typical exam-style questions for this topic. These sorts of questions are posed throughout the unit and pupils should be prepared to answer similar questions in the end-of-year assessments.

Suggested questions to guide this process:

How is knowledge from this unit typically assessed? What are the most common questions?
Which question types are the most challenging?
What general trends can you spot in the typical errors pupils make (from examiner reports/notes)?
How could you help prepare your students for answering these types of questions?

Common mistakes, errors and misconceptions

How would you tackle the following common mistakes, errors and misconceptions by pupils?

TASK: Consider why each of the following typically seen statements is a mistake/misconception. What possible approaches can you plan to pre-empt and respond to this? Which lessons do these correlate to?

CHALLENGE: Cover the middle column and explain yourself why each is a mistake.

Mistake	**Reason why it's a mistake**	**Possible approaches to pre-empt and respond?**
Strong and concentrated are the same thing	Strength is a measure of ionisation, concentrated is a measure of amount of solute in a given volume.	
Only strength affects pH of an acid	pH is a measurement of the concentration of H+ ions, so is affected by both strength and concentration	
If there is a 1:1 molar ratio between reactants, they will have the same mass	The mass in grams depends on the Mr, not just the number of moles	
A neutralisation reaction is a redox reaction	The oxidation numbers do not change in neutralisation reactions	
The limiting reactant is always the one that has a smaller mass in grams	The limiting reactant has the fewest number of moles, which must take into account the Mr so is not necessarily the smallest mass in grams	
The Mr of a compound in a balanced equation is its Mr multiplied by the coefficient	Although this can be used as a different method for calculating reacting masses, the method used in this unit means that the molar ratio is factored in twice	
Avogadro's number only applies to solid particles	This is a confusion where students often still struggle with the fact that masses have gas	
Avogadro's number is not that large	Many students struggle to comprehend the scale of Avogadro's number	

Planning for the misconceptions

Misconception: The reactant with the smaller mass in grams is the limiting reactant.
The limiting reactant is the reactant with fewer moles than the other when the molar ratio has been taken into account.
Supporting pupil understanding It is very useful for students to have a consistent method for quantitative calculation questions, always starting with number of moles and Mr: if in doubt, calculate number of moles. Once this has been practiced many times with reacting mass calculations, students should be in the habit of always first calculating number of moles. This can then make it easier for them to apply to limiting reactants.

Misconception: pH is a measure of the strength of an acid
pH is a measure of the concentration of hydrogen ions in a solution. This means it is affected both by strength and concentration.
Supporting pupil understanding This can be useful to show students diagrams to explain the difference. So the greater the number of hydrogen ions present in a given volume, the lower the pH (this is always important for students to refer back to). You may want to draw diagrams/dual code the following ideas, highlighting or circling the number of hydrogen ions present in each diagram: - strong acid, showing dissociation of ions (circling hydrogen ions can help students visualise that this has happened) - weak acid, showing that not much dissociation has happened (circling relatively few hydrogen ions) - concentrated and strong acid, lots of acid molecules present which have dissociated, compared to a dilute solution this will have a lower pH - concentrated and weak acid, lots of acid molecules present but not much dissociation, so not many hydrogen ions present - dilute and strong acid, not many acid molecules present but those that are have dissociated, so there are still some present but this will have a higher pH - dilute and weak acid, not many acid molecules present and not much dissociation, so not many hydrogen ions present
Taking it Further
It can be useful to use the same idea/dual coding method to get students to think about alkalis and how the pH of an alkali is affected by strength and concentration.

Science **Mastery**

Unit objectives: knowledge, skills and concepts

As you teach the lessons, track here the objectives you meet.

TKT = to know that   TBAT = to be able to

NOTE: All TKT statements can be found in Appendix 5 of this document

Critical: it is critical that all pupils become proficient; future learning will be very challenging for them if they do not and it is likely they will not come across this content again. These are priority objectives for reteaching, revision, and intervention. Before moving on, discuss a strategy with your HOD if some pupils are not making progress with these objectives.
Core: it is important for all pupils to learn this, and it will be essential for success at GCSE. However, it will not impede them in other units if they are not (yet) proficient in it as they are likely to revisit it again in subsequent units.
Stretch: pupils should have the opportunity to work on this aspect of science. This content is crucial for pupils to achieve the highest GCSE grades and to succeed at A-level.
Key skill: pupils should have the opportunity to develop this key skill as part of this unit.

Intended outcome for separate sciences pupils are denoted in blue and italised.

Lesson 1: Prior Knowledge Review: Relative Formula Mass and Percentage by Mass

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document* **This lesson is a review of content from previously studied units relating to this big idea	
TBAT define relative atomic mass and relative formula mass	Define relative atomic mass Define relative formula mass State where to find the relative atomic mass of an element Describe how to calculate the relative formula mass of a compound
TBAT calculate relative formula mass	Calculate the Mr of carbon dioxide Calculate the Mr of ammonia Calculate the Mr of methane Calculate the Mr of sodium hydroxide
TBAT calculate percentage by mass	Calculate the % by mass of carbon in carbon dioxide Calculate the % by mass of nitrogen in ammonia Calculate the % by mass of carbon methane Calculate the % by mass of sodium in sodium hydroxide
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 2: (HT) Introducing the Mole

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT state that 1 mole of a substance contains 6.02 x 10^{23} particles	State Avogadro's number State the number of particles in 1 mole State the number of atoms in 1 mole of sodium State the number of molecules in 1 mole of carbon dioxide
TBAT convert decimal numbers into standard form	Convert 0.000006 into standard form Convert 66577714 into standard form Write 2.95 x10^6 not in standard form
TBAT calculate the mass of 1 mole of a substance	State the relationship between relative formula mass and the mass in grams of one mole of a substance Calculate the mass of one mole of carbon dioxide
What did the Exit ticket data tell me?	
What do I need to review in future lessons?	

Lesson 3: (HT) Mole Calculations

Intended outcome	Example questions
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT recall the equation linking mass, Mr and number of moles	State the equation that links number of moles, mass and Mr State the units for each quantity
TBAT convert amounts of substance in moles to their mass in grams, given the Mr	Calculate the mass of 0.5 mol of oxygen Calculate the mass of 4 mol of methane
TBAT calculate the amount of substance in a given mass	Calculate the number of moles in 22 g of carbon dioxide Calculate the number of moles in 200 g of calcium carbonate
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 4: Prior Knowledge Review: Concentration

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT define concentration	Define concentration Identify from a diagram a more concentrated and less concentrated solution Define solution, solute and solvent
TBAT convert between dm^3 and cm^3	State how many cm^3 are in 1 dm^3 Convert 0.5 dm^3 to cm^3 Convert 250 cm^3 to dm^3
TBAT calculate concentration from a given mass and volume	State the equation that links concentration, mass and volume State the units for each quantity Calculate the concentration of 500 cm^3 of solution with 25 g of solute dissolved in it
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 5: Taking it Further: Calculating Concentration

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT calculate concentration in mol/dm^3	State the equation that links concentration, number of moles and volume State the units for each quantity Calculate the concentration of 500 cm^3 of solution with 0.5 mol of solute dissolved in it
TBAT calculate the mass of solute from a concentration in mol/dm^3	State the equation that links concentration, number of moles and volume State the units for each quantity State the equation that links number of moles, mass and Mr State the units for each quantity Calculate the mass of solute in 0.5 dm^3 of 2 mol/dm^3 sodium hydroxide solution
TBAT explain how the concentration of a solution is related to the mass of solute and the volume of the solution	Describe how to increase the concentration of a solution Describe how to decrease the concentration of a solution Explain what would happen to concentration if more mass of solute was added Explain what would happen to concentration if a greater volume of solvent was added
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 6: Taking it Further: Calculating an Unknown Concentration

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT deduce the molar ratio of acid: alkali in a neutralisation reaction	Identify the molar ratio from the balanced symbol equation
TBAT use molar ratio to calculate the number of moles of acid that react with a known number of moles of alkali	Calculate the number of moles of acid that reacts with X moles of alkali
TBAT calculate the concentration of one reactant in a neutralisation reaction, when the concentration and volume of the other reactant is known.	Calculate the concentration of 0.2 dm^3 of sodium hydroxide that reacts with 0.35 dm^3 of 0.1 mol/dm^3 hydrochloric acid
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 7: (HT) Amounts of Substances in Equations

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT describe chemical reactions in terms of number of moles	Describe the balanced symbol equation in terms of moles
TBAT calculate number of moles in reactions	Calculate the number of moles in 200 g of calcium carbonate Calculate the number of moles in 1 kg of aluminium oxide
TBAT calculate masses of reactants or products from balanced symbol equations	Calculate the mass of calcium that can be obtained from 200 g of calcium carbonate Calculate the mass of aluminium that can be obtained from 1 kg of aluminium oxide
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 8: (HT) Limiting Reactants

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the [unit overview document]	
TBAT calculate number of moles in reactions	Calculate the number of moles in 200 g of calcium carbonate Calculate the number of moles in 1 kg of aluminium oxide
TBAT use calculations to identify limiting reactants	Identify the limiting reactant when 100 g of oxygen reacts with 25 g of methane Identify the limiting reactant when 10 g of oxygen reacts with 25 g of magnesium
TBAT calculate masses of products	Calculate the mass of carbon dioxide that will be made when 100 g of oxygen reacts with 25 g of methane Calculate the mass of magnesium oxide that will be made when 10 g of oxygen reacts with 25 g of magnesium
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 9: Prior Knowledge Review: Acid Reactions

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT write word equations for reactions with acids	State the general equation for the reaction between an acid and a metal State the general equation for the reaction between an acid and a metal carbonate State the general equation for the reaction between an acid and an alkali
TBAT use reactants to name salts	Name the salt that would be made from sodium hydroxide and sulfuric acid Name the salt that would be made from lithium hydroxide and hydrochloric acid Name the salt that would be made from calcium hydroxide and nitric acid
TBAT predict the products of chemical reactions	State the products of a reaction between hydrochloric acid and calcium carbonate State the products of a reaction between sulfuric acid and magnesium State the products of a reaction between nitric acid and copper oxide
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 10: Acids, Alkalis and Neutralisation

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT use the pH scale to identify acids and alkalis	Explain what the pH scale measures State the pH range of acids State the pH range of alkalis Describe how pH can be measured
TBAT identify ions produced by acids and alkalis in solution	Explain what is meant by an aqueous solution Identify the ion produced by acids in solution Identify the ion produced by alkalis in solution
TBAT describe what happens in a neutralisation reaction	Describe what happens in a neutralisation reaction Write an ionic equation for neutralisation Explain why an acid and metal reaction is not neutralisation
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 11 and 12: Taking it Further Required Practical Activity: Acid-Alkali Titration

Intended outcome	**Example questions**
**These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document*	
TBAT describe a method to carry out a titration	Describe the function of a titration Describe how to carry out a titration Explain how a titration could be used to find the volume of acid that reacts with an alkali
TBAT identify concordant results	Explain what is meant by concordant results Identify concordant results from given titres Describe how to calculate a mean titre
TBAT explain the most appropriate apparatus to use for a given function	Explain when a pipette should be used Explain when a burette should be used Explain why phenolphthalein should be used in a titration instead of universal indicator
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 13: Taking it Further Titration Calculations

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the [unit overview document]	
TBAT explain the purpose of a titration	Explain the purpose of a titration Suggest when a titration would be useful
TBAT use the equation that links concentration, volume and amount of substance	State the equation that links number of moles, concentration and volume State the units for each quantity
TBAT use mole ratios to calculate an unknown concentration	Calculate the concentration of 0.2 dm^3 of sodium hydroxide that reacts with 0.35 dm^3 of 0.1 mol/dm^3 hydrochloric acid Calculate the number of moles of acid that reacts with X moles of alkali
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 14: (HT) Strong and Weak Acids

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT explain the difference between a strong and a weak acid	Define a strong acid Define a weak acid Give an example of a strong acid Give an example of a weak acid
TBAT explain the factors that affect the pH of an acid	Explain what pH is a measure of Explain how strength of an acid affects pH Explain how concentration of an acid affects pH
TBAT explain the difference between strength and concentration	Define a strong acid Define a weak acid Define a concentrated acid Define a dilute acid Explain the difference between a strong and concentrated acid
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Lesson 15: Taking it Further Volumes of Gases

Intended outcome	Example questions
These are the main objectives of the lesson. For a detailed breakdown of the knowledge and skills addressed, please consult the unit overview document	
TBAT state the volume of 1 mole of gas at room temperature and pressure	Explain what is meant by rtp Describe the conditions of rtp Define molar volume State molar volume at rtp
TBAT calculate the volume of different numbers of moles of a gas	State the equation that links molar volume, number of moles and volume of a gas Calculate the volume of 2 mol of oxygen Calculate the volume of 0.1 mol of hydrogen
TBAT use chemical equations to calculate volume and number of moles of gas	Calculate the volume of nitrogen needed to make 12 dm^3 of ammonia Calculate the volume of hydrogen that could be made from 48 g of magnesium reacting with excess acid
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Mastery Quiz re-teach planning

To be completed once you have reviewed your pupils' response to the mastery quiz.

What topics are your pupils confident with?
What topics need to be reviewed?
What are the **highest leverage** piece(s) of knowledge (2-3) to explicitly re-teach?
What could be interleaved throughout another unit? When will that be taught?

Other notes

Lesson 17: Feedback lesson

Intended outcome	Example questions
Edit based upon your classe's performance in the Mastery Quiz	
What did the Exit Ticket data tell me?	
What do I need to review in future lessons?	

Advanced subject knowledge

Where does this learning lead?

In A-level chemistry, many of the fundamental principles of quantitative chemistry are developed into much greater detail, including

- **Mass spectrometry**
- **The mole and Avogadro's constant**
- **Empirical formulae**
- **Ideal gases**
- **Percentage yield and atom economy**

Have a look at the questions below and think about what this means for this unit.

How does learning from this unit develop at KS5?
What content from this unit is fundamental to student understanding at KS5?
How could you check that students have grasped these fundamentals?

Vocabulary and literacy

Acid	A substance that produces H^+ ions in aqueous solutions. *__Acids__ can be neutralised by alkalis.*
Alkali	A substance that produces OH^- ions in aqueous solutions. *An __alkali__ is a soluble base.*
Aqueous solution	A solution in which the solvent is water. *Many chemical reactions take place in __aqueous solutions__.*
A_r	This is the symbol for relative atomic mass. *See __relative atomic mass.__*
Avogadro's number	The constant or number that shows how many particles, molecules, atoms, or ions there are in 1 mole of a substance. *__Avogadro's number__ is 6.02×10^{23}.*
Burette	A piece of equipment used to measure a variable volume in a titration. *A __burette__ is used to add one solution dropwise to another.*
Chemical formula	A series of chemical symbols showing the number of atoms of each element in a compound. *The __chemical formula__ for Magnesium Oxide is MgO.*
Coefficient	The 'big' number or balancing numbers in front of a chemical formula in an equation. *In the equation $2Mg + O_2 \rightarrow 2MgO$, the __coefficient__ in front of magnesium is 2.*
Compound	A substance made up of two or more different elements chemically bonded together. *Water is a __compound__ of hydrogen and oxygen.*
Concentration	The mass of solute dissolved in a given volume of solvent *The __concentration__ of the copper sulfate solution was 0.1 g/cm^3*

Concentrated	If a solution is concentrated, there is a large mass of solute in a given volume of solvent. *The salt water solution was **concentrated** because lots of salt was added to a small volume of water.*
Concordant	Results that fall within 0.2 cm^3 of each other. *When doing a titration, only the **concordant** results should be used to calculate the mean titre**.***
Conservation of Mass	The law of conservation of mass states that the total mass of reactants in any chemical reaction equals the total mass of products *5 g of iron and sulfur reacted together to make 5 g of iron sulfide. This demonstrates the Law of **Conservation of Mass.***
Dilute	*To decrease the concentration of a liquid by mixing it with water or another liquid.* *I plan to **dilute** the acid by adding more water.*
Dissociate	*When an acid or alkali splits into its ions in solution.* *Hydrochloric acid **dissociates** in solution:* *HCl (aq) → H^+ (aq) + Cl^- (aq)**.***
Element	A substance made of only one type of atom. *Oxygen is an example of an **element.***
Excess	The reactant that is not used up in a reaction, so some is left over. *When magnesium burns in **excess** oxygen, the magnesium is used up but the oxygen is not.*
Formulae	Plural of formula *See **chemical formula***
Ionise	*Another way to describe dissociation, or the formation of ions. When an acid or alkali splits into its ions in solution.* *Hydrochloric acid **ionises** in solution:* *HCl (aq) → H^+ (aq) + Cl^- (aq)**.***

Limiting reactant	The reactant that is used up in a reaction, so limits the amount of product that can be made. *When magnesium burns in excess oxygen, the magnesium is the* ***limiting reactant****.*
Mass	The amount of matter in a substance. *In physics, we measure mass in kg but in chemistry we often use smaller masses, so we can measure* ***mass*** *in g instead.*
Molar ratio	The ratio of balancing numbers in front of the chemical formulae in an equation, showing the ratio in which reactants react and products are made. *In the equation* $2Mg + O_2 \rightarrow 2MgO$*, the* ***molar ratio*** *of magnesium to oxygen is 2:1.*
Molar volume	The volume of one mole of any gas at room temperature and pressure. ***Molar volume*** *at rtp is 24* dm^3*.*
Mole	The amount of substance that contains 6.02×10^{23} particles. *1* ***mole*** *of carbon dioxide contains the same number of molecules as 1 mole of oxygen or 1 mole of ammonia.*
Molecule	A small group of non-metal atoms chemically bonded together. *Oxygen gas is made up of many oxygen* ***molecules****, each with the chemical formula* O_2*.*
M_r	This is the symbol for relative formula mass. *See* ***relative formula mass.***
Neutralisation	A chemical reaction in which an acid and a base react with each other. ***Neutralisation*** *reactions produce a salt and water.*
pH	A measure of the acidity or alkalinity of a solution. *Acids have a* ***pH*** *of less than 7.*

pH probe	An instrument used to measure the pH of a solution. *A **pH probe** can give a numerical value for pH whereas universal indicator gives a colour that corresponds to a number on the pH scale.*
Phenolphthalein	An indicator often used in titrations because of its clear colour change. ***Phenolphthalein** is pink in alkaline solutions but turns colourless in acidic solutions.*
Pipette	A piece of equipment used to measure a fixed volume accurately. *A **pipette** allows a more precise volume of liquid to be measured than a measuring cylinder.*
Product	The substance(s) that are made in a chemical reaction. *In the equation $2Mg + O_2 \rightarrow 2MgO$, magnesium oxide is the **product**.*
Reactant	The substance(s) that react in a chemical reaction to form a new substance. *In the equation $2Mg + O_2 \rightarrow 2MgO$, magnesium and oxygen are the **reactants**.*
Relative atomic mass	The relative atomic mass of an element is the average mass of its atoms compared to the mass of a carbon-12 atom. The relative atomic masses for each element are given in the Periodic Table. *The **relative atomic mass** of oxygen is 16.*
Relative formula mass	The relative formula mass of a substance is the sum of the relative atomic masses of its atoms, in the numbers shown in its chemical formula. *The **relative formula mass** of a molecule of H_2O is 18.*
RTP	Room temperature and pressure: 20 °C and 1atm of pressure. *Molar volume at **rtp** is 24 dm^3.*
Solute	A substance that is dissolved in a solvent. *Salt is the **solute** when it is dissolved in water.*

Soluble	A substance is soluble if it can be dissolved in a solvent *Sugar is **soluble** in water.*
Solution	A mixture of a dissolved solute and a solvent. *A **solution** of salt and water was used.*
Solvent	A substance in which a solute can dissolve *Water is a **solvent** because salt can dissolve in it*
Strong	(Of an acid) An acid that fully dissociates in solution. *Hydrochloric acid is an example of a **strong** acid.*
Subscript	The numbers that come after and below a chemical symbol in a chemical formula, to indicate the number of atoms of that element. *The **subscript** number two shown in a molecule of CO_2 indicates that it contains 2 atoms of oxygen.*
Titration	A method of quantitative analysis used to determine the volume of acid/alkali needed to completely neutralise an alkali/acid. *A **titration** can be used to measure the volume of hydrochloric acid needed to neutralise 25 cm^3 of sodium hydroxide.*
Titre	The volume of acid/alkali needed to completely neutralise the alkali/acid in a titration. *The **titre** can be calculated using the starting and final volume readings on a burette.*
Universal Indicator	A solution that changes colour depending on the pH of the solution it is added to. ***Universal indicator** turns green when it is added to a neutral solution.*
Volume	The amount of space a substance takes up. *In chemistry, **volume** is measured in dm^3.*
Weak	(Of an acid) An acid that partially dissociates in solution. *Ethanoic acid is an example of a **weak** acid.*

Appendices

Appendix 1: Mark scheme for pre-unit quiz

Qu	Answer	Marks	Supporting information for fix-it tasks
1	A	1	Answering B suggests the misconception that CO_3 is an atom. *To fix it, ask students to write out which elements are present in $MgCO_3$.* Answering C suggests the misconception that the subscript number refers to all elements in the compound. *To fix it, reteach what the subscript numbers and the coefficients mean and then give students more practice questions to determine the numbers of atoms.*
2	C	1	Answering A suggests the misconception that because an aqueous solution is liquid, then the state symbol is (l). Answering B suggest the misconception that because solution starts with 's' the state symbol is (s). *To fix it, reteach the state symbols and then ask students to write out the state symbols in books. Then give them a symbol equation from Q2 and ask them to add in the state symbols.*
3	B	1	Answering A suggests the misconception that gases do not have mass. Answering C suggests a misconception that reactants have more mass than the products that they form. *To fix it reteach: The law of conservation of mass indicates that mass cannot be created or destroyed. The **total mass reactants = total mass products**, even if a gas is produced. Then give students examples of masses to calculate how much of x is produced to practice applying this.*
4	B	1	Answering A or C suggests a gap in knowledge about how salt compounds are derived from neutralisation reactions. To fix it, *reteach this by modelling how to deduce which metal reacts with what non-metal in a neutralisation reaction to form the salt.*
5	C	1	Answering A shows a gap in knowledge about when to convert units. *To fix it, model how A would be correct if the units were cm and not dm^3. Then give students similar practice questions to do.* Answering B shows a gap in knowledge about how to calculate concentration since this option is concentration/mass. *To fix it, reteach how to calculate concentration, focussing on how the units tell you what concentration is, i.e. 200 g in/per 1 dm^3 of volume. Then ask students to write out this question and label the mass,*

			volume and then show how to calculate concentration i.e. 200/1.
6	A	1	Answering B shows that the relative atomic masses have simply been added which suggests a gap in knowledge about the effect of the subscript number. *To fix it, remind students that the subscript number after an element symbol tells you how many atoms of that element are in the formula. Then ask students to calculate the Mr of CO_3.* Answering C shows a misconception that the number 2 applies to the whole formula which suggests a confusion of the subscript number with coefficients. *To fix it, reteach what these two numbers mean in a chemical formula and then ask students how many atoms of each element are in HCl, $MgCl_2$, H_2SO_4, $(NH_4)_3PO_4$.*
7	A	1	Answering B shows a gap in knowledge of the function of beakers since they are not designed for the accurate measurement of volume. *Show students a beaker and a measuring cylinder and highlight that a measuring cylinder has graduated markings to show volume, whereas beakers don't have that amount of detail.* Ask students to compare *the uses of measuring cylinders and beakers and explain why they are used that way.* Answering C shows a gap in knowledge of the function of evaporating since they are not designed for the accurate measurement of volume. *To fix it, demo an attempt to measure 10cm^3* water *in an evaporating dish and then use a measuring cylinder. Discuss with students which equipment can measure volume accurately and why.*
8	B	1	Answering A shows a misconception that the lowest number is simply the anomaly. *To fix it, reteach how to spot an anomaly using model data and then ask students to explain why there isn't an obvious anomaly in this data.* Answering C shows a gap in knowledge about precise results because these results vary around the mean so are not precise. *To fix it, reteach that precise results don't vary much around the mean then ask students to evaluate whether these results are precise or not.*
9	A	1	Answering B or C suggestions a confusion of the steps of the making salts practical, because evaporation and crystallisation would not allow insoluble copper carbonate to be separated. *To fix it, ask students to write a brief description for the purpose of each of these techniques.*
10	A	1	Answering B suggests a confusion between a hazard and a precaution. *To fix it, recap the difference between a hazard and the precaution to take to prevent the hazard from*

			happening. Then ask students to write the hazard and a precaution for using glassware. Answering C suggests a confusion between a hazard and a risk. *To fix it, recap the difference between a hazard and the risk of that hazard happening. Then ask students to write the hazard and the risk of using glassware.*
11	C	1	Answering A shows an incorrect conversion, although the student has correctly multiplied for the conversion. *To fix it, remind students that the difference between dm and cm is 1000 and then ask students to convert from dm to cm using many practice questions.* Answering B shows a misconception that you divide by 1000 to convert from dm to cm. *To fix it, reteach the order of magnitude of volumes from cm to dm and show that dm is 1000 greater than cm. then model how to do this calculation and then ask students to do a similar calculation showing all their workings.*
12	C	1	Answering A shows a misunderstanding of the use of the subscript outside the brackets – relating it to the PO_4 rather than the NH_4 inside the brackets. Answering B shows students do not understand that the number in subscript after the brackets relates to everything inside the brackets. Answering D shows the student added the subscripts 3 and 4 rather than multiplying. *To fix these issues, reteach what the subscript number means and how brackets affect the number of atoms. Then give more practice questions that include brackets.*
13	B	1	Answering A shows that the student has divided mass by volume to get concentration (and so uses the formula correctly), however has mistakenly converted the volume from cm^3 to dm^3. *To fix it, give students some similar calculations, with a mixture of questions requiring and not requiring unit conversions.* Answering C indicates that student has divided volume by mass instead of the other way around. *To fix it, reteach the equation and how to use this to get the value they need. Give students similar calculations to practise.*
14	B	1	Answering A shows a gap in knowledge about the difference between elements and compounds. To fix it, *reteach the definitions of elements and compounds using examples. Then ask students to write out all the elements and all the compound from the quiz.*

			Answering C shows a gap in knowledge about the reactants needed to make copper sulfate. *To fix it, write out the symbol formulae for B and C to show that copper sulfate can only be produced from option B.*
15	C	1	Answering A suggests a gap in knowledge about balanced equations because there is no attempt to balance A. *to fix it, ask students to write out how many atoms of each element are in the reactants and the products and then explain why it is not balanced.* Answering B suggests a misconception that the subscript 3 in NH_3 applies to the N as well as the H. *to fix it, reteach what the coefficient and the subscript numbers mean and then give practice examples of compound formulae to deduce the number of types of atoms.*

Appendix 2: Mark scheme for mastery quiz

Section A

Qu	Answer	Marks	Supporting information for fix-it tasks

1	C	1	Answering A suggests that the student has added together the relative atomic masses and has not considered that there are three bromines in the formula. Answering B suggests that the student has added together the relative atomic masses and multiplied the answer by 3, thinking that the subscript '3' in the formula refers to both the iron and bromine atoms. *To fix it, model for students how to work out this answer correctly. Then give students similar questions to calculate relative formula masses.*
2	B	1	Answering A or C indicates that students cannot recall the ions present in alkaline solutions. *<u>To fix-it, look at the formulae of some common acids and alkalis and ask students to identify what they have in common.</u>*
3	B	1	Answering A, C or D means students are mixing up different reactions and cannot recall what a neutralisation reaction is. *To fix it, provide an example of each of these types of reaction (in equation form), with a definition of each, and ask students to match these up.*
4	C	1	Answering A or B suggests that students cannot relate the colour of universal indicator with the pH of a solution. *To fix-it, show students a coloured pH scale which demonstrates the colour of universal indicator in various pHs. Give students some unknown solutions to test using universal indicator and identify their pHs.*
5	A	1	Answering B suggests the misconception that CO_3 is an atom. *To fix it, ask students to write out which elements are present in $MgCO_3$.* Answering C suggests the misconception that the subscript number refers to all elements in the compound. *To fix it, reteach what the subscript numbers and the coefficients mean and then give students more practice questions to determine the numbers of atoms.*
6	C	1	Answering A suggests the misconception that because an aqueous solution is liquid, then the state symbol is (l). Answering B suggest the misconception that because solution starts with 's' the state symbol is (s).

			To fix it, reteach the state symbols and then ask students to write out the state symbols in books. Then give them a symbol equation from Q2 and ask them to add in the state symbols.
7	B	1	Answering A suggests the misconception that gases do not have mass. Answering C suggests a misconception that reactants have more mass than the products that they form. *To fix it reteach: The law of conservation of mass indicates that mass cannot be created or destroyed. The* ***total mass reactants = total mass products****, even if a gas is produced. Then give students examples of masses to calculate how much of x is produced to practice applying this.*
8	B	1	Answering A or C suggests a gap in knowledge about how salt compounds are derived from neutralisation reactions. To fix it, *reteach this by modelling how to deduce which metal reacts with what non-metal in a neutralisation reaction to form the salt.*
9	C	1	Answering A shows a gap in knowledge about when to convert units. *To fix it, model how A would be correct if the units were cm and not dm^3. Then give students similar practice questions to do.* Answering B shows a gap in knowledge about how to calculate concentration since this option is concentration/mass. *To fix it, reteach how to calculate concentration, focussing on how the units tell you what concentration is, i.e. 200 g in/per 1 dm^3 of volume. Then ask students to write out this question and label the mass, volume and then show how to calculate concentration i.e. 200/1.*
10	C	1	Answering A suggests that pupils are confusing the mass number of fluorine with the number of atoms in one mole. Answering B suggests students are misremembering Avogadro's number. *To fix-it, use examples of other substances to show the mass of one mole for each. Then point out that one mole of any substance contains exactly Avogadro's number of atoms/particles/molecules.*
11	B	1	Answering A or C suggests that students are unsure how to convert between cm^3 and dm^3. *To fix-it, model for students how to do this conversion, and then give students some similar conversions to try independently.*

12	A	1	Answering C or C suggests that students are unsure how to work out the limiting reactant. Answering C suggests that students are unable to identify a reactant in an equation. *To fix-it, model for students how to work out the number of moles of each reactant, and to compare this to the molar ratio from the equation.*
13	A	1	Answering B suggests that students mistakenly think that strong acids only partially ionise in aqueous solution. Answering C suggests that students have not recognised the name of ethanoic acid (vinegar) as a weak acid. *To fix-it, ask students to sort the names of common acids into strong and weak acids. They should then label one list with 'partially ionises in aqueous solution' and another with 'fully ionises in aqueous solution'.*
14	B	1	Answering A suggests that students can describe concentration in terms of the proportion of water molecules mixed with the acid, but they cannot relate this to the concentration of H^+ ions. Answering C suggests that students are mixing up the descriptions of a weak acid with that of a concentrated acid. *To fix-it, use particle diagrams to explain the difference between weak and concentrated acids. Ask students to explain this back to you by referring to the proportion of water molecules mixed with the acid, and the resulting concentration of H^+ ions.*
15	A	1	Answering B suggests that students have mistakenly divided the number of moles by the relative formula mass, either because they guessed or made a mistake when rearranging the formula that links mass, number of moles and relative formula mass. Answering C suggests that students have mistakenly divided the relative formula mass by the number of moles, either because they guessed or made a mistake when rearranging the formula that links mass, number of moles and relative formula mass.

			To fix-it, give students more practise in using the the formula that links mass, number of moles and relative formula mass. Ensure students are given given enough practise in rearranging this formula to find each unknown.
16	B	1	Answering A suggests that students divided concentration by volume in order to find number of moles, instead of multiplying. Answering C suggests that students have calculated the number of moles, and have not done the additional steps to convert this to a mass. *To fix it, model the steps of this calculation for students, pointing out how two different equations are used to get to the final answer. Give students some similar questions to answer.*
17	C	1	Answering A or B suggests that students are unable to use the equation to determine the molar ratio, and to use this to calculate the number of moles of one substance when given the number of moles of another. *To fix-it, model how to work this out on the board. Substitute the number of moles of ethanedioic acid in the question with another number and repeat to find the number of moles of sodium hydroxide solution that would react with it. Repeat with more numbers. Give students similar questions with different equations to see if they can still apply their learning.*
18	A	1	Answering B or C shows that students are unable to determine the reinforcement and the matrix (binder) in a composite material. To fix-it, give students further examples of composite materials and ask them to determine the reinforcement and the matrix (or binder)
19	C	1	Answering A or B suggests that students are unable to explain the use of a white tile in a titration. *To fix-it, demonstrate a simple colour change both using a white tile and on a dark wooden desk to demonstrate the purpose.*
20	B	1	Answering A suggests that students have used all of the figures to calculate the average titre, and not just those within 0.2 cm^3 of each other.

			Answering C suggests that students have used 4 of the 5 figures to calculate the average titre, even though only three are within 0.2 cm^3 of each other. *To fix-it, give students lists of numbers to circle the ones within within 0.2 cm^3 of each other.*
21	B	1	Answering A or C suggests that students are unable to calculate the volume of a gas using the mass and relative formula mass, and formula *volume of a gas at rtp =number of moles x 24* *To fix-it, model for students how this calculation is made with the formula provided. Give students practice using this formula and a selection of different masses or number of moles of gases.*

Section B

Qu	Model answer	Marks	Supporting information ***Suggestions for fix-it tasks***
1 (a)	The mass of the products is equal to the mass of the reactants. *Allow atoms are not created or destroyed in a chemical reaction.*	1	To fix-it, use a simple chemical reaction (such as burning magnesium ribbon) to show that the mass of reactants always equals the mass of products.
1 (b)	• The total mass of the reactants (Beaker A and contents before mixing + beaker B and contents before mixing) is not equal to the measured mass of beaker A and B and contents after mixing • because a gas (CO_2) is produced (which dissipates into the atmosphere and so its mass is not measured on the balance)	1 1	*To fix-it, demonstrate a reaction where a gas is produced. Carry out the reaction with the reaction vessel sitting on a balance, so that students can see the*

			mass decrease as a gas is produced.
1 (c)	0.01g	1	
1 (d)	(23 x 2) + (12) + (16 x 3) = 106	1 1	*To fix-it, give students a list of common chemical formulae to calculate their relative formula mass.*
1 (e)	(23 x 2) / 106 = 0.434 x 100 = 43.4%	1 1	
1 (f)	CO_3^{2-}	1	
1 (g)	H^+ ions	1	
1 (h)	Red	1	*To fix-it, demonstrate the colour changes of universal indicator in solutions of various pH's. Allow students to use the coloured pH scale to attempt similar questions.*
2 (a)	Mr sodium chloride = 23 + 35.5 = 58.5 g Number of moles sodium chloride: 11.5/58.5 = 0.19658 mol Number of moles sodium carbonate: 0.19658/2 = 0.098 mol Mr sodium carbonate = (2x23)+12+(3x16) = 106 Mass sodium carbonate = 0.098 x 106 = **10.42 g**	1 1 1 1 1	*To fix-it, model the steps taken to solve this calculation for students, giving each step a name. Gove students an opportunity to practise similar calculations with other equations.*

	If students round earlier, they will get 10.39 g. Students should keep answers on calculator for as long as possible.		
2 (b)	1.0×10^{-3} mol/dm^3 is more concentrated than 1.0×10^{-5} mol/dm^3 by a factor of 100 (10 x 10) Therefore the pH of the second solution will be greater by 2. So, the second solution has a pH of 4.	1 1 *Allow an answer of pH 4 with no working for 2 marks*	*To fix-it, ask students to identify the bigger number from two numbers written in standard form. Then from here, explain how to tell by how many factors of 10 is one bigger than the other.*

Separate Science
Section A

Qu	Answer	Marks	Supporting information for fix-it tasks
1	C	1	Answering A suggests that the student has added together the relative atomic masses and has not considered that there are three bromines in the formula. Answering B suggests that the student has added together the relative atomic masses and multiplied the answer by 3, thinking that the subscript '3' in the formula refers to both the iron and bromine atoms. *To fix it, model for students how to work out this answer correctly. Then give students similar questions to calculate relative formula masses.*
2	A	1	Answering B or C indicates that students cannot recall the ions present in acidic solutions.

			To fix-it, look at the formulae of some common acids and ask students to identify what they have in common (a H).
3	B	1	Answering A, C or D means students are mixing up different reactions and cannot recall what a neutralisation reaction is. *To fix it, provide an example of each of these types of reaction (in equation form), with a definition of each, and ask students to match these up.*
4	C	1	Answering A or B suggests that students are unable to relate the pH of a solution to the colours of universal indicator solution. *To fix-it, use the coloured pH scale that comes with the universal indicator to help students to recall the standard colours for acidic, neutral and alkaline substances.*
5	C	1	Answering A or B suggests that students cannot recall the meaning of state symbols. *To fix-it, give students examples of common substances and the state symbols usually associated with them at room temperature. Ask students to suggest the state symbols associated with other substances they are familiar with.*
6	C	1	Answering A shows a gap in knowledge about when to convert units. *To fix it, model how A would be correct if the units were cm and not dm^3. Then give students similar practice questions to do.* Answering B shows a gap in knowledge about how to calculate concentration since this option is concentration/mass. *To fix it, reteach how to calculate concentration, focussing on how the units tell you what concentration is, i.e. 200 g in/per 1 dm^3 of volume. Then ask students to write out this question and label the mass, volume and then show how to calculate concentration i.e. 200/1.*
7	C	1	Answering A suggests that pupils are confusing the mass number of fluorine with the number of atoms in one mole. Answering B suggests students are misremembering Avogadro's number. *To fix-it, use examples of other substances to show the mass of one mole for each. Then point out that one mole of any substance contains exactly Avogadro's number of atoms/particles/molecules.*

8	B	1	Answering A or C suggests that students are unsure how to convert between cm^3 and dm^3. *To fix-it, model for students how to do this conversion, and then give students some similar conversions to try independently.*
9	C	1	Answering A or B suggests that students are unable to explain the use of a white tile in a titration. *To fix-it, demonstrate a simple colour change both using a white tile and on a dark wooden desk to demonstrate the purpose.*
10	B	1	Answering A suggests that students have used all of the figures to calculate the average titre, and not just those within 0.2 cm^3 of each other. Answering C suggests that students have used 4 of the 5 figures to calculate the average titre, even though only three are within 0.2 cm^3 of each other. *To fix-it, give students lists of numbers to circle the ones within within 0.2 cm^3 of each other.*
11	A	1	Answering C or C suggests that students are unsure how to work out the limiting reactant. Answering C suggests that students are unable to identify a reactant in an equation. *To fix-it, model for students how to work out the number of moles of each reactant, and to compare this to the molar ratio from the equation.*
12	A	1	Answering B suggests that students mistakenly think that strong acids only partially ionise in aqueous solution. Answering C suggests that students have not recognised the name of ethanoic acid (vinegar) as a weak acid. *To fix-it, ask students to sort the names of common acids into strong and weak acids. They should then label one list with 'partially ionises in aqueous solution' and another with 'fully ionises in aqueous solution'.*
13	B	1	Answering A suggests that students can describe concentration in terms of the proportion of water molecules

			mixed with the acid, but they cannot relate this to the concentration of H^+ ions. Answering C suggests that students are mixing up the descriptions of a weak acid with that of a concentrated acid. *To fix-it, use particle diagrams to explain the difference between weak and concentrated acids. Ask students to explain this back to you by referring to the proportion of water molecules mixed with the acid, and the resulting concentration of H^+ ions.*
14	A	1	Answering B suggests that students have mistakenly divided the number of moles by the relative formula mass, either because they guessed or made a mistake when rearranging the formula that links mass, number of moles and relative formula mass. Answering C suggests that students have mistakenly divided the relative formula mass by the number of moles, either because they guessed or made a mistake when rearranging the formula that links mass, number of moles and relative formula mass. *To fix-it, give students more practise in using the the formula that links mass, number of moles and relative formula mass. Ensure students are given given enough practise in rearranging this formula to find each unknown.*
15	B	1	Answering A suggests that students divided concentration by volume in order to find number of moles, instead of multiplying. Answering C suggests that students have calculated the number of moles, and have not done the additional steps to convert this to a mass. *To fix it, model the steps of this calculation for students, pointing out how two different equations are used to get to the final answer. Give students some similar questions to answer.*
16a	C	1	Answering A or B suggests that students are unable to use the equation to determine the molar ratio, and to use this to calculate the number of moles of one substance when given the number of moles of another.

			To fix-it, model how to work this out on the board. Substitute the number of moles of ethanedioic acid in the question with another number and repeat to find the number of moles of sodium hydroxide solution that would react with it. Repeat with more numbers. Give students similar questions with different equations to see if they can still apply their learning.
16b	A	1	Answering B suggests that students have used the correct formula to calculate concentration, however haven't correctly converted the units for volume. Answering C suggests that students have converted the unit for volume correctly, but have multiplied this number by the number of moles instead of dividing. *To fix-it, model how to calculate this answer on the board, and then give students some similar calculations to complete independently.*
17	C	1	Answering A suggests that students have been distracted by the formula H_2 and have tried to suggest this would result in double the number of moles of gas being present. Answering B suggests that students have assumed the greater mass of gas has a greater volume, regardless of number of moles. *To fix-it, model for students how this calculation is made with the formula provided. Give students practice using this formula and a selection of different masses or number of moles of gases.*

Section B

Qu	Model answer	Indicative marks	Supporting information ***Suggestions for fix-it tasks***
1 (a)	add potassium hydroxide solution to the conical flask/use a pipette to measure out the correct volume of potassium hydroxide add a few drops of indicator add the sulfuric acid from the burette	5	To fix-it, model the steps to carry out the titration for students

	until the colour of the indicator changes read the volume from the burette		
1 (b)	H^+ ions	1	
1 (c)	Red	1	*To fix-it, demonstrate the colour changes of universal indicator in solutions of various pH's. Allow students to use the coloured pH scale to attempt similar questions.*
2 (a)	1 mole of sodium chloride = 23 + 35.5 = 58.5 g 11.5 grams of sodium chloride = 11.5/58.5 = 0.1965 moles 1 mole of sodium carbonate makes 2 moles of sodium chloride (from the equation) So, 0.098 moles of sodium carbonate make 0.17965 moles of sodium chloride To find the mass of sodium carbonate that is equal to 0.098 moles: 0.098 moles = mass/relative formula mass 0.098 x relative formula mass = mass 0.098 x (106) = **10.42 g** If students round earlier, they will get 10.39 g. Students should keep answers on calculator for as long as possible.	4	*To fix-it, model the steps taken to solve this calculation for students, giving each step a name. Gove students an opportunity to practise similar calculations with other equations.*
2 (b)	H_2O = 1 + 1 + 16 = 18 g • 36/18 = 2 moles	1	

2 (c)	• The solution with a concentration of 1.0 x 10^{-3} mol/dm^3 is more concentrated than the solution with a concentration of 1.0 x 10^{-5} mol/dm^3 by a factor of 100 (10 x 10). Therefore the pH of the second solution will be greater by 2. So, the second solution has a pH of 4.	2	*To fix-it, ask students to identify the bigger number from two numbers written in standard form. Then from here, explain how to tell by how many factors of 10 is one bigger than the other.*
2 (d)	45/1000 = 0.045 dm^3 • 0.045/24.0 = 0.023 moles	2	

Appendix 3: Core knowledge statements

Italics denotes HT content

- Formulae show which elements are in compounds and the ratio of each element in the compound.
- Chemical reactions always involve the formation of one or more new substances.
- The relative atomic mass of an element can be found as the mass number of an element on the periodic table
- Relative atomic mass has the symbol Ar
- The relative formula mass of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula
- Relative formula mass has the symbol Mr
- In a balanced chemical equation, the sum of the relative formula masses of the reactants in the quantities shown equals the sum of the relative formula masses of the products in the quantities shown
- The percentage mass of an element in a compound can be calculated using the relative atomic mass and the relative formula mass, using the formula % by mass = Mr of element/Mr of compound x 100
- *Chemical amounts are measured in moles*
- *The symbol for the unit mole is mol*
- *The mass of one mole of a substance in grams in numerically equal to its relative formula mass*
- *One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance.*
- *The number of atoms, molecules or ions in a mole of a given substance is the Avogadro constant.*
- *The value of the Avogadro constant is 6.02 x 1023 per mole.*

- *The measurement of amounts in moles can apply to atoms, molecules, ions, electrons, formulae and equations*
- *number of moles = mass ÷ relative formula mass*
- *The mass of a substance can be calculated from the number of moles, using the relative formula mass*
- *The equation number of moles = mass ÷ relative formula mass can be rearranged to mass = number of moles x relative formula mass*
- Many chemical reactions take place in solutions
- The concentration of a solution tells you how much solute is dissolved in a given volume of solution
- Concentration can be defined as the mass of solute per unit volume of solvent.
- Volume means the amount of space that a substance takes up, and can be measured in cm3, dm3, m3, L or mL.
- 1 dm3 is equal to 1 L and equal to 1000 cm3
- To convert from dm3 to cm3 the number should be multiplied by 1000
- To convert from cm3 to dm3 the number should be divided by 1000
- The concentration of a solution can be measured in mass per given volume of solution, e.g., grams per dm3 (g/dm3 or g dm-3)
- The mass in grams of solute in a given volume of solution can be calculated from its concentration in g/dm3
- *The masses of reactants and products can be calculated from balanced symbol equations.*
- *Chemical equations can be interpreted in terms of moles. For example: Mg + 2HCl MgCl2 + H2 shows that one mole of magnesium reacts with two moles of hydrochloric acid to produce one mole of magnesium chloride and one mole of hydrogen gas.*
- *The balancing numbers in a symbol equation can be calculated from the masses of reactants and products by converting the masses in grams to amounts in moles and converting the numbers of moles to simple whole number ratios.*
- *A reaction finishes when one of the reactant is all used up. The other reactant has nothing left to react with, so some of it is left over*
- *The reactant that is completely used up is called the limiting reactant because it limits the amount of products.*
- *The reactant that is left over is described as being in excess*
- *In a chemical reaction involving two reactants, it is common to use an excess of one of the reactants to ensure that all of the other reactant is used.*
- *The mass of a product formed in a reaction depends upon the mass of the limiting reactant*
- *The maximum mass of a product formed in a reaction can be calculated using the balanced equation, the mass of the limiting reactant and the relative formula mass of the limiting reactant and the product*
- Acids are neutralised by alkalis (eg soluble metal hydroxides) and bases (eg insoluble metal hydroxides and metal oxides) to produce salts and water, and by metal carbonates to produce salts, water and carbon dioxide.
- The particular salt produced in any reaction between an acid and a base or alkali depends on:
- the acid used (hydrochloric acid produces chlorides, nitric acid produces nitrates, sulfuric acid produces sulfates)
- the positive ions in the base, alkali or carbonate.
- Acids produce hydrogen ions (H+) in aqueous solutions.

- Aqueous solutions of alkalis contain hydroxide ions (OH^-).
- The pH scale, from 0 to 14, is a measure of the acidity or alkalinity of a solution, and can be measured using universal indicator or a pH probe.
- A solution with pH 7 is neutral. Aqueous solutions of acids have pH values of less than 7 and aqueous solutions of alkalis have pH values greater than 7.
- In neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water.
- A neutralisation reaction can be represented by the equation $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
- *A strong acid is completely ionised in aqueous solution.*
- *This means that the acid splits up into its ions. Another word for ionised is dissociated.*
- *Examples of strong acids are hydrochloric, nitric and sulfuric acids.*
- *A weak acid is only partially ionised in aqueous solution.*
- *Examples of weak acids are ethanoic, citric and carbonic acids.*
- *The higher the concentration of H^+ ions in a solution, the lower the pH*
- *The lower the concentration of H^+ ions in a solution, the higher the pH*
- *The higher the concentration of OH^- ions in an alkaline solution, the higher the pH*
- *For a given concentration of aqueous solutions, the stronger an acid, the lower the pH.*
- *As the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10.*
- *In a dilute acid, the acid molecules are mixed with a large volume of water, so there is a low concentration of H^+ ions*
- *In a concentrated acid, little or no water molecules are mixed with the acid molecules. This means the concentration of H^+ ions is high.*

Chemistry Only

- The concentration of a solution can be measured in mol/dm^3
- The amount in moles of solute or the mass in grams of solute in a given volume of solution can be calculated from its concentration in mol/dm^3
- The concentration of a solution in mol/dm^3 is related to the mass of the solute and the volume of the solution.
- If the volumes of two solutions that react completely are known and the concentration of one solution is known, the concentration of the other solution can be calculated.
- The volumes or concentrations of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator.
- A titration is an example of quantitative analysis.
- A pipette is used to accurately measure a certain volume of acid or alkali
- A pipette filler is used to fill the pipette safely
- A conical flask is used to contain the liquid from the pipette.
- A burette is used to add small, measured volumes of one reactant to the other reactant in the conical flask
- Before starting the titration, the burette should be rinsed with the solution it is going to contain and clamped vertically. Once filled the tap should be flushed to remove any air bubbles.
- Only a few drops of indicator should be added to conical flask. This is because many indicators are weak acids or alkalis, and too much would affect the outcome of the titration.
- The indicator shows by a colour change when all of the alkali in the conical flask has been neutralised. This is called the end point.

- A white tile is placed under the conical flask so that any colour change can be seen clearly
- An appropriate indicator to use for an acid-alkali titration is phenolphthalein.
- Phenolphthalein is pink in alkaline solutions and colourless in acidic solutions
- The difference between the burette reading at the start and the reading at the end of the titration gives the volume of acid (or alkali) added.
- This volume is called a titre.
- The first titre is usually ignored, as it is a rough result.
- Results that are within 0.2cm3 of each other are called concordant results.
- Multiple titrations are usually carried out, and an average (mean) titre is calculated for any that are within 0.2 cm3 of each other.
- The chemical quantities can be calculated in titrations involving concentrations in mol/dm3 and in g/dm3.
- Equal amounts in moles of gases occupy the same volume under the same conditions of temperature and pressure.
- Room temperature is 20∘C
- Room pressure is 1 atmosphere
- Rtp' means 'at room temperature and pressure'
- The volume of one mole of any gas at room temperature and pressure is 24 dm3
- This volume (24 dm3) is called the molar volume of a gas
- The volume of gas at rtp = number of moles x 24
- The volumes of gaseous reactants and products can be calculated from the balanced equation for the reaction.
- The volume of a gas at room temperature and pressure can be calculated from its mass and relative formula mass

Disciplinary Knowledge

73. Apply the idea that whenever a measurement is made, there is always some uncertainty about the result obtained.
74. Use the range of a set of measurements about the mean as a measure of uncertainty.
77. Apply the following ideas to evaluate data to suggest improvements to procedures and techniques.
a. An accurate measurement is one that is close to the true value.
b. Measurements are precise if they cluster closely.
c. Measurements are repeatable when repetition, under the same conditions by the same investigator, gives similar results.
d. Measurements are reproducible if similar results are obtained by different investigators with different equipment.
78. a. Measurements are affected by random error due to results varying in unpredictable ways; these errors can be reduced by making more measurements and reporting a mean value.
b. Measurements can also be affected by systematic error.
82. Use ratios
97. Use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.
98. Relate derived quantities with the formulae to calculate those quantities

Practical Skills

23. Measure volumes of liquids accurately

43. Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis
44. Preparation of a pure dry sample of a soluble salt