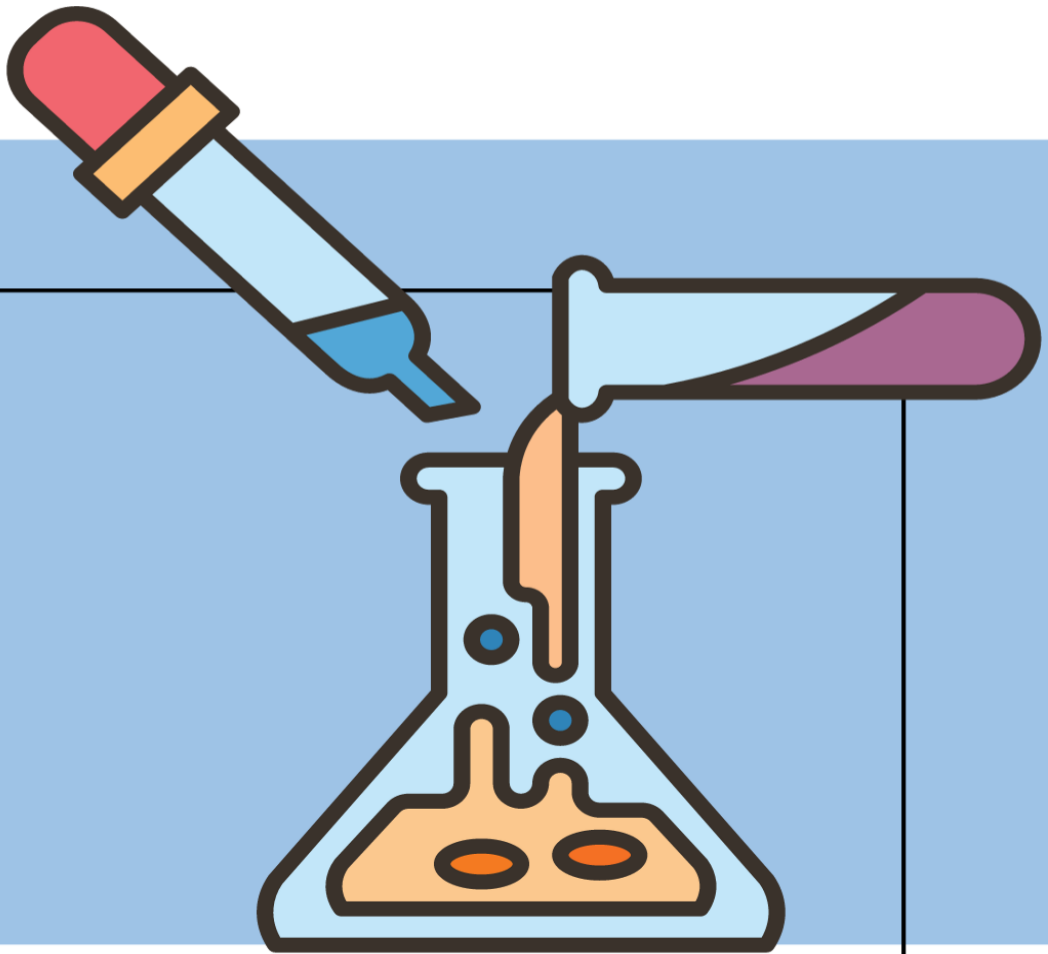


Student Booklet

C4.3 Quantitative Chemistry

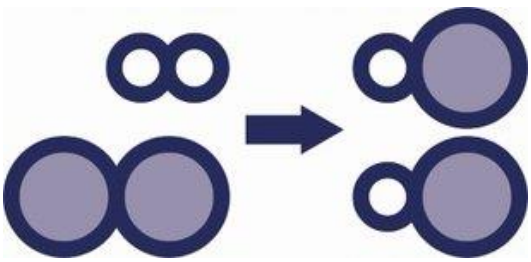
Separate Science (Chemistry)

Science
Mastery

ArkCurriculum+

The Big Idea

Quantitative Chemistry



What does it mean to have an amount of a substance? How can I use information about different elements and compounds to predict the outcomes of reactions? How could we use this information in industrial processes to calculate how much of a reactant we need to make a certain amount of product?

Quantitative chemistry allows us to do calculations to find out about quantities of substances. This is a very important application of chemistry that is used in industry and research. Using the relative formula mass and number of moles of a substance we can look closely at the amount of reactants and productions in chemical reactions.

This is the **fourth** unit we are studying as part of the big idea: **Reactions Rearrange Matter**

In this unit, we will begin by recapping the ideas of relative atomic mass and relative formula mass, as well as how we can use relative formula mass to determine the percentage by mass of an element in a compound. We will then look at the concept of moles in chemistry and how we can use them in chemical equations to calculate reacting masses and limiting reactants.

We will also review the idea of concentration and learn how to calculate the concentration of different solutions. We will also look at acids, alkalis and neutralisation and the difference between strong and weak acids. Separate science students will also look at titrations of acids and alkalis and the volume of gases.

In this unit, we will revisit some key skills including balancing equations, calculating percentages and substituting into and solving equations.

TASKS:

What subject will this unit focus on? BIOLOGY CHEMISTRY PHYSICS

(circle the correct subject)

There are lots of keywords underlined above. List these into the two columns:

Words I know	Words I haven't seen before

To answer before the unit:

1. What are you most excited to learn about in this topic?

_____

_____

_____

2. What do you already know about this topic?

_____

_____

_____

3. Why do you think it's important to learn how reactions rearrange matter?

_____

_____

_____

4. What knowledge from previous science lessons might help us?

_____

_____

_____

5. What questions do you have about this topic?

_____

_____

_____

To answer at the end of the unit:

1. Tick off any words in the 'words I haven't seen before' column that you are now confident with. Circle any you still need more practice to use.
2. What have you most enjoyed about this unit?

_____

_____

_____

3. What more would you like to learn about reactions as part of the big idea: 'Reactions Rearrange Matter'?

_____

_____

Pre-Test

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.
(Ar: C = 12; O = 16) [1]

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 $(NH_4)_3PO_4$.
(Ar: N = 14; H = 1; P = 31; O = 16) [1]
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. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$ ☐

15

Qu	Answer	Marks
1	A	1
2	C	1
3	B	1
4	B	1
5	C	1
6	A	1
7	A	1
8	B	1
9	A	1
10	A	1
11	C	1
12	C	1
13	B	1
14	B	1
15	C	1

End of Unit Pre-Test. Turn over to see the answers. Give yourself a mark out of 10.

Knowledge Organiser

Relative Formula Mass

1. **Formulae** show which elements are in compounds and the ratio of each element in the compound.
   For example:
   $CaCO_3$ contains one calcium atom, one carbon atom and 3 oxygen atoms
2. Chemical reactions always involve the formation of one or more new substances
3. The **relative atomic mass** of an element can be found as the mass number of an element on the periodic table
4. Relative atomic mass has the symbol $\mathbf{A_r}$
5. 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
6. Relative formula mass has the symbol $\mathbf{M_r}$
7. For example, the M_r of CaCO3 is 40+12+(16x3) = 100
8. 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
9. The percentage by mass of an element in a compound can be calculated using the relative atomic mass and the relative formula mass, using the formula:

$$\%\ \text{by mass} = \frac{\text{mass of element}}{\text{mass of compound}} \times 100$$

The Mole (HT only)

10. *Chemical amounts are measured in **moles***
11. *The symbol for the unit mole is mol*
12. *The **mass of one mole** of a substance in grams is numerically **equal** to its **relative formula mass***
13. *One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance*
14. ***One mole** of a substance contains **6.02 x 10^{23}** particles*
15. *This number is the Avogadro constant or Avogadro's number*
16. *The measurement of amounts in moles can apply to atoms, molecules, ions, electrons, formulae and equations*
17. *The mass of a substance can be calculated from the number of moles, using the relative formula mass:*

$$\text{number of moles} = \frac{\text{mass}}{\text{Mr}}$$

18. *This equation can also be written as:*

$$\text{mass} = \text{number of moles} \times \text{Mr}$$

19. *The masses of reactants and products can be calculated from balanced symbol equations*

20. *Chemical equations can be interpreted in terms of **moles**. For example:*
    $Mg + 2HCl \rightarrow MgCl_2 + H_2$
    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.
21. *The **coefficients** show the **molar ratio** in which reactants react and products are made which can be used to calculate the mass of a reactant or product*
22. *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.*
23. *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*
24. *The **reactant** that is completely **used up** is called the **limiting reactant** because it limits the amount of products*
25. *The reactant that is **left over** is described as being **in excess***
26. *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*
27. *The mass of a product formed in a reaction depends upon the mass of the **limiting reactant***
28. *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, Alkalis and Neutralisation

29. **Acids** are **neutralised** by **alkalis** (e.g. soluble metal hydroxides) and bases (e.g. insoluble metal hydroxides and metal oxides) to produce **salts** and **water**, and by metal carbonates to produce salts, water and carbon dioxide.
30. 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.
31. Acids also react with metals to produce a salt and hydrogen gas This is not a neutralisation reaction
32. **Acids** produce **hydrogen ions (H^+)** in aqueous solutions
33. Aqueous solutions of **alkalis** contain **hydroxide ions (OH^-)**
34. 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**
35. 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**
36. In neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water
37. A neutralisation reaction can be represented by the equation **$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$**

Strong and Weak Acids (HT only)

38. 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.
39. Examples of strong acids are hydrochloric, nitric and sulfuric acids.
40. A **weak** acid is only **partially ionised** in aqueous solution.
41. Examples of weak acids are ethanoic, citric and carbonic acids.
42. The **higher the concentration of H^+ ions** in a solution, the **lower the pH**
43. The higher the concentration of OH^- ions in an alkaline solution, the higher the pH
44. For a **given concentration** of aqueous solutions, the **stronger** an **acid**, the **lower** the **pH**
45. As the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10
46. In a **dilute** acid, the acid molecules are mixed with a **large volume** of **water**, so there is a low concentration of H^+ ions
47. In a **concentrated** acid, **few** or no **water molecules** are mixed with the acid molecules. This means the concentration of H^+ ions is high.

Concentration

48. Many chemical reactions take place in **solutions**
49. The concentration of a solution tells you how much solute is dissolved in a given volume of solution
50. Concentration can be defined as the **mass of solute per unit volume** of solvent.
51. Volume means the amount of space that a substance takes up, and can be measured in cm^3, dm^3, m^3, L or mL.
52. 1 dm^3 is equal to 1 L and equal to 1000 cm^3
53. To convert from dm^3 to cm^3 the number should be multiplied by 1000
54. To convert from cm^3 to dm^3 the number should be divided by 1000
55. The concentration of a solution can be measured in mass per given volume of solution, e.g., grams per dm^3 (**g/dm^3**)
56. The mass in grams of solute in a given volume of solution can be calculated from its concentration in g/dm^3
57. The equation that links concentration, mass of solute and volume is:

$$\text{Concentration} = \frac{\text{mass}}{\text{volume}}$$

Concentration (Chemistry only)

58. The concentration of a solution can be measured in **mol/dm^3**
59. 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
60. The equation that links concentration, amount of substance and volume is:

$$\text{Concentration} = \frac{\text{number of moles}}{\text{volume}}$$

61. The concentration of a solution in mol/dm^3 is related to the **mass** of the solute and the **volume** of the solution
62. 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

Titration (Chemistry only)

63. The volumes or concentrations of acid and alkali solutions that react with each other can be measured by **titration** using a suitable **indicator**
64. A titration is an example of **quantitative** analysis
65. A **pipette** is used to accurately measure a **certain volume** of acid or alkali
66. A pipette filler is used to fill the pipette safely
67. A conical flask is used to contain the liquid from the pipette
68. A **burette** is used to add small, **measured volumes** of one reactant to the other reactant in the conical flask
69. 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
70. 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
71. 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**
72. A **white tile** is placed under the conical flask so that any colour change can be seen clearly
73. An appropriate indicator to use for an acid-alkali titration is **phenolphthalein**.
74. Phenolphthalein is **pink** in **alkaline** solutions and **colourless** in **acidic** solutions
75. 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.
76. This **volume** is called a **titre**.
77. The first titre is usually ignored, as it is a rough result.
78. Results that are within 0.2 cm^3 of each other are called **concordant** results.
79. Multiple titrations are usually carried out, and an average (mean) titre is calculated for any that are within 0.2 cm^3 of each other.

Volumes of Gases (Chemistry only)

80. **Equal amounts in moles** of gases **occupy** the **same volume** under the same conditions of temperature and pressure.
81. Room temperature is 20 ºC
82. Room pressure is 1 atmosphere
83. Rtp' means 'at room temperature and pressure'
84. The **volume** of **one mole** of any gas at room temperature and pressure is **24 dm^3**
85. This volume (24 dm^3) is called the **molar volume** of a gas
86. The volume of gas at rtp can be calculate using the equation:

$$\text{Volume} = \text{number of moles} \times 24$$

87. The volumes of gaseous reactants and products can be calculated from the balanced equation for the reaction.
88. The volume of a gas at room temperature and pressure can be calculated from its **mass** and **relative formula mass**

Glossary

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 x10^{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 → 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 sulphate 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:* *$HCl\ (aq) \rightarrow H^+\ (aq) + Cl^-\ (aq)$.*
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:* *$HCl\ (aq) \rightarrow H^+\ (aq) + Cl^-\ (aq)$.*

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.*

Prior Knowledge Review: Relative Formula Mass and Percentage by Mass

Do Now

1. State the chemical symbol for nitrogen.
2. State how many atoms of each different element are present in $CaCO_3$.
3. State where metals are found on the periodic table.
4. Explain the difference between an element and a compound.
5. State the mass number of oxygen.

Drill:

1. Calculate 65% of 120.
2. A sample is made up of 40 g of water and 12 g of sugar. Calculate the percentage of the sample that is sugar.
3. Write the chemical symbol for potassium.

Read Now:

The relative atomic mass of an element is the average mass of the atoms in the element compared to the mass of carbon-12. This means that relative atomic mass takes into account the mass of different isotopes of an element and how much of each isotope exists. The relative formula mass is the sum of the relative atomic masses of the elements in a compound. This is calculated using the relative atomic mass of each element present and how many of each atom are present in an element or compound. The relative atomic mass is taken from the mass number on the periodic table. The relative atomic mass of hydrogen is 1 and the relative atomic mass of oxygen is 16. Water has the formula H_2O, so its relative formula mass is 18 because it has two hydrogen atoms and one oxygen atom.

1. Define relative atomic mass.
2. Explain what is meant by isotopes.
3. Define relative formula mass.
4. State the relative formula mass of water.
5. Explain where this number comes from.

Relative Atomic Mass

What does relative mean?

Define relative atomic mass (RAM/Ar)

State the relative atomic mass (A_r) for the following elements.

1. Potassium
2. Iron
3. Neon
4. Hydrogen
5. Gold
6. Sulfur
7. Helium
8. Magnesium
9. Carbon

Relative Formula Mass

Define relative formula mass (RFM/Mr)

Calculate the relative formula mass of Magnesium nitrate, $Mg(NO_3)_2$ using the table

Element	Ar	Number of atoms	Total mass
Mg			
N			
O			
Total mass (Mr)			

Calculate the M_r for the following compounds.

(A_r: H = 1; C = 12; N = 14; O = 16; K = 39)

a. NH_3

b. O_2

c. H_2O

d. KOH

Use your understanding of the conservation of mass to find the M_r of CaO. (M_r: $CaCO_3$ = 100; CO_2 = 44)

$CaCO_3 \rightarrow CaO + CO_2$

Percentage by mass

What is the formula for percentage by mass?

$$\% \ by \ mass = \frac{\qquad\qquad\qquad\qquad\qquad\qquad}{\qquad\qquad\qquad\qquad\qquad\qquad} \times 100$$

What is the percentage by mass of carbon in CO_2?

- A. $\frac{12}{16}$ X 100 = 75%
- B. $\frac{24}{32}$ X100 = 75%
- C. $\frac{12}{32}$ X100 = 37.5 %
- D. $\frac{12}{44}$ X 100 = 27.3%

Drill

1. Define relative atomic mass.
2. State the relative atomic mass of carbon.
3. State the relative atomic mass of oxygen.
4. Define relative formula mass.
5. Calculate the relative formula mass of CO_2.
6. Calculate the relative formula mass of KOH.
7. State the equation to calculate percentage by mass.
8. Calculate the percentage by mass of potassium in potassium hydroxide (KOH).
9. Calculate the percentage by mass of chlorine in calcium chloride ($CaCl_2$).

Exit Ticket

1. Choose the correct definition of relative formula mass.

- ❑ A. The average mass of atoms of an element compared to the mass of arbon-12
- ❑ B. The sum of relative atomic masses in a compound
- ❑ C. The percentage of a compound is made of a particular element

2. Calculate the relative formula mass of carbon dioxide (CO_2).
   C = 12, O = 16

- ❑ A. 28
- ❑ B. 44
- ❑ C. 56

3. Calculate the percentage by mass of oxygen in carbon dioxide.

- ❑ A. 27.27%
- ❑ B. 36.36%
- ❑ C. 72.72 %

Introducing the Mole (HT only)

Do Now

1. Define relative atomic mass.
2. Define relative formula mass.
3. Calculate the Mr of ammonia (NH_3). N=14, H=1
4. Calculate the Mr of calcium hydroxide ($Ca(OH)_2$). Ca=40, O=16, H=1
5. Calculate the percentage by mass of hydrogen in ammonia.

Drill:

1. Write 58230000 in standard form.
2. Convert 3.07×10^4 from standard form.
3. Write 0.0006 in standard form.

Read Now:

In chemical reactions, there are a huge number (think many, many trillions!) of atoms in reactants that rearrange to form the products. Remember in a chemical reaction, mass is conserved, so no atoms are made or lost during a chemical reaction, only rearranged. So that scientists can keep track of the numbers of atoms involved in different substances without having to write out huge numbers, scientists use a quantity called 'the mole'. As with many things in chemistry, we use carbon as the reference. 12 g of carbon contains 6.02×10^{23} atoms. This number of atoms is called Avogadro's number and is the number of atoms in one mole. As a definition, we can say that a mole is the number of atoms contained in 12 g of carbon.

1. State the law of conservation of mass.
2. State Avogadro's number.
3. Define a mole.
4. State the relative atomic mass of carbon.

Introducing the mole

Symbol	Cu	S
A_r	64	32

What would the ratio of the masses of these atoms be?

Is it possible to weigh one atom in our lab?

How should all standard form numbers look?

Which of these numbers is correct? Why?

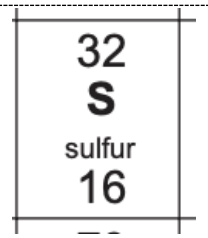
2.38×10^{10} or 23.8×10^{9}

Which value is avogadro's number?

What do we call this value as a unit?

Decimal	**Standard Form (Scientific Notation)**
67,000,000,000	
40,000,000,000,000,000	
4,300,000	
65,430,000	
0.00000000004	
0.0000000654	
0.002	

The relative formula mass of sulfur is 32.



How many atoms would there be in 32 g of sulfur?

How many moles are there in 32 g of sulfur?

How many atoms would there be in 64 g of sulfur?

How many moles would there be in 64 g of sulfur?

True or false?

1. One mole of carbon contains the same number of atoms as one mole of copper.
2. 1 gram of carbon contains the same number of atoms as 1 gram of copper.
3. Atoms are very small.
4. 6 g of carbon contains the same number of atoms as 29 g of copper.
5. The symbol for the unit mole is mol.
6. 1 mole of carbon contains 6.02×10^{23} atoms.
7. The number of atoms present in an object are very small.
8. 12 g of carbon contain the same number of atoms as 63.5 g of copper.

Drill

1. State the relative atomic mass of carbon.
2. State Avogadro's number.
3. State how many atoms would be in 12 g of carbon.
4. State how many moles would be in 12 g of carbon.
5. State the relative atomic mass of calcium.
6. State how many atoms would be in 40 g of calcium.
7. State how many moles would be in 40 g of calcium.

We: Moles and atoms

One mole of any substance contains 6.02×10^{23} atoms or molecules of that substance.

Methane has the chemical formula CH_4.

What is the relative formula mass of methane?

What mass in grams would contain 6.02×10^{23} molecules of methane?

What mass in grams would contain one mole of methane?

Stretch: what mass in grams would contain two moles of methane?

You: Moles, molecules and atoms

One mole of any substance contains 6.02×10^{23} atoms or molecules of that substance.

Ammonia has the chemical formula NH_3.

What is the relative formula mass of ammonia?

What mass in grams would contain 6.02×10^{23} molecules of ammonia?

What mass in grams would contain one mole of ammonia?

Stretch: what mass in grams would contain two moles of methane?

Stretch: how many <u>atoms</u> are there in one mole of ammonia?

Exit Ticket

1. Which of the following is **true**?
    - ❑ A. The symbol for mole is mol.
    - ❑ B. The symbol for mole is moles.
    - ❑ C. The symbol for moles is m.

2. How many molecules in 1 mole of CO_2?
    - ❑ A. 44
    - ❑ B. 6.02×10^{23}
    - ❑ C. 1

3. Which number is the same as 6×10^3?
    - ❑ A. 60300
    - ❑ B. 63000
    - ❑ C. 6000

Mole Calculations (HT only)

Do Now

1. State the relative atomic mass of boron.
2. State how many particles are in one mole of a substance.
3. State the mass in grams of boron that would contain this many particles.
4. Calculate the M_r of copper carbonate ($CuCO_3$). Cu=63.5, C=12, O= 16
5. Calculate the percentage by mass of oxygen in copper carbonate.

Drill:

1. State Avogadro's number.
2. Calculate 3 x 4.83 $x10^{11}$. Write your answer in standard form.
3. Calculate 0.25 x 4.83 $x10^{11}$. Write your answer in standard form.

Read Now:

In one mole of any substance there are 6.02 $x10^{23}$ particles. This can be atoms, molecules or ions. For example, one mole of water contains 6.02 $x10^{23}$ molecules of water and one mole of potassium contains 6.02 $x10^{23}$ atoms of potassium. The relative atomic mass of an element tells you the mass of that element (in grams) that contains exactly this number of atoms. The relative atomic mass of Neon is 20, so 20 g of Neon contains one mole (6.02 $x10^{23}$ atoms). The relative formula mass of a compound tells you the mass of the compound in grams that contains exactly this number of molecules or particles. The relative formula mass of sulfur dioxide (SO_2) is 64 (S=32, O=16), so 64 g of sulfur dioxide contains one more (6.02 x 10^{23}) molecules of sulfur dioxide.

1. State how many particles are in one mole of a substance.
2. Describe the relationship between relative atomic mass and the mass in grams that contains one mole of a substance.
3. Show how the relative formula mass of sulfur dioxide is 64.
4. Explain the difference between relative atomic mass and relative formula mass.

What is the relationship between moles, mass and M_r?

1 mole of carbon dioxide (M_r = 44)	44 g
2 moles of carbon dioxide (M_r = 44)	g
0.5 moles of carbon dioxide (M_r = 44)	g

1 mole of water (M_r = 18)	18 g
0.25 mole of water (M_r = 18)	g
2 moles of X (M_r = 36.5)	g
0.5 moles of Y (M_r = 80)	g

How can we use the equation to calculate the mass or number of moles?

$$\text{Number of moles} = \frac{\text{mass}}{M_r}$$

What is the amount of substance in 64.0 g of O_2? (M_r = 32)

Number of moles = mass ÷ M_r

= 64.0 g ÷ 32

= 2 mol

What is the mass (g) of 0.5 moles of $MgCO_3$? (M_r = 84)

What is wrong with the following answers? Re-write them correctly. (Q5 has more than one issue).

1. The student measured out the amount of HCl using a measuring cylinder.
2. The relative formula mass of MgO is 20.
3. The symbol for the mole is m.
4. 2 moles of water molecules has a mass of 9 g (M_r = 18).
5. What is the amount of substance in 15 g of Li_2O?

M_r of Li_2O = 7 + 16 = 23

Number of moles = mass ÷ Mr

= 15 g ÷ 23

= 0.65 mole

Drill

1. State the unit for moles.
2. State the equation that links number of moles, mass and relative formula mass.
3. State the unit for mass.

4. Calculate the relative formula mass of sodium hydroxide (NaOH).
5. Calculate the number of moles in 120 g of sodium hydroxide.
6. Calculate the relative formula mass of magnesium chloride ($MgCl_2$).
7. Calculate the mass of 0.25 moles of magnesium chloride.

I: Calculating number of moles

A scientist has a sample of 40.8 g of aluminium oxide.

What is the chemical formula for aluminium oxide?

What is the relative formula mass of aluminium oxide?

How many moles does the scientist have in their sample?

We: Calculating number of moles

A scientist has a sample of 2.5 moles of phosphorus pentachloride. The chemical formula for phosphorus pentachloride is Cl_5P.

What is the relative formula mass of phosphorus pentachloride?

What mass does the scientist have in their sample?

Stretch: how many atoms does the scientist have in their sample?

You: Moles, molecules and atoms: Baking a mole cake

A chemist has written a cake recipe in moles! Convert the amount of substance to mass (0 d.p) for each of these ingredients. (A_r: C = 12; O = 16; H = 1; Na = 23)

Ingredient	Formula	M_r	Mass (g)

0.585 moles of caster sugar	$C_{12}H_{22}O_{11}$	342	
0.641 moles of margarine	$C_{20}H_{40}O_2$		
1.250 moles of flour	$C_6H_{10}O_5$	160	
0.040 moles of baking powder	Na_2CO_3		

Exit Ticket

1. What is the relative formula mass of NO_2? (A_r: N = 14; O = 16)
   - ❑ A. 30
   - ❑ B. 44
   - ❑ C. 46

2. What is the mass of 0.02 mol of Na_2CO_3? (M_r: 106)
   - ❑ A. 2.12 g
   - ❑ B. 21.2 g
   - ❑ C. 5 300 g

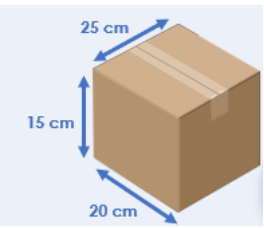
3. What is the amount of substance in 26.5 g of Na_2CO_3? (M_r: 106)
   - ❑ A. 4 mol
   - ❑ B. 0.25 mol
   - ❑ C. 2 809 mol

Prior Knowledge Review: Concentration

Do Now

1. State how many particles there are in 1 mole of a substance.
2. Calculate the M_r of calcium carbonate ($CaCO_3$). Ca=40, C=12, O=16
3. Calculate the number of moles in 200 g of calcium carbonate.
4. Calculate the mass of 0.75 moles of calcium carbonate.

Drill:



1. State the unit of mass (in chemistry).
2. Calculate the volume of this box.
3. Convert this to dm^3.

Read Now:

Concentration is the mass of a solute per unit volume of a solution. When sugar is dissolved in water, sugar is the solute, water is the solvent and the sugary water is the solution. The mass of sugar in the given volume of solution is its concentration, so the greater the mass of sugar that is dissolved in the solution, the more concentrated it is. We can calculate concentration in terms of mass per unit volume using the equation: concentration = mass/volume.

1. Define concentration.
2. Explain the difference between a solute and a solvent.
3. Describe the relationship between the mass of a solute that is dissolved in a solution and its concentration.
4. State the equation that links concentration, mass and volume.

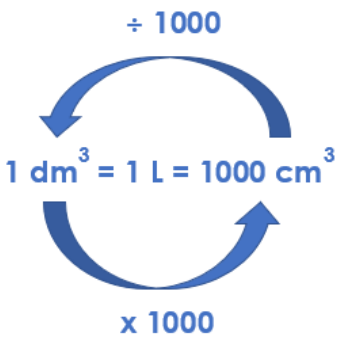
Which is more concentrated?

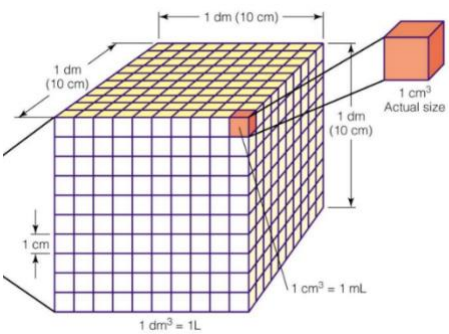
Volume is the amount of space that a substance or object takes up.

How many units of volume can you think of?

How do you calculate concentration?

Converting between units of volume





Convert these volumes

1000 cm^3 = _____ dm^3

5000 cm^3 = _____ dm^3

2403 cm^3 = _____ $dm^{3/@\#i9}$

145 cm^3 = _____ dm^3

1 dm^3 = _____ cm^3

10 dm^3 = _____ cm^3

179 dm^3 = _____ cm^3

0.2 dm^3 = _____ cm^3

True or false?

1. To convert cm^3 into dm^3 you need to multiply by 1000.
2. 250 cm^3 = 0.25 dm^3
3. 250 cm^3 of a 4 g/dm^3 solution contains 1 g of solute.
4. 0.5 dm^3 = 5000 cm^3
5. 5.5 g of copper sulfate is dissolved in 500 cm^3 to form a 11 g/dm^3 solution.

Drill

1. Define concentration.
2. State the equation that links concentration, mass and volume.
3. State the unit for mass.
4. State the unit for volume
5. State the unit for concentration.
6. Convert 5000 cm^3 into dm^3.
7. Define solute.
8. Define solvent.
9. Define solution.

I: Calculating concentration

A scientist makes a solution of salt water. They dissolve 750 g of salt to make up a solution of 1000 cm^3.

What is the solute?

What is the solvent?

What is the solution?

What is the concentration of the solution?

We: Concentration, mass and volume

A manufacturer makes a solution of squash by dissolving 114 g of squash to make 2 dm^3 of solution.

What is the concentration of the solution?

You: Concentration, mass and volume

A scientist makes up a sample of calcium hydroxide solution. 24 g of calcium hydroxide is added to water to make up 200 cm^3 of solution.

What is the solute?

What is the solution?

What is the volume in dm^3?

What is the concentration of the sample?

Exit Ticket

1. Select the answer below which is equal to 0.05 dm^3.
   - ❑ A. 500 cm^3
   - ❑ B. 50 cm^3
   - ❑ C. 0.00005 cm^3

2. 10 g of a solute was used to make a solution with a volume of 25 dm^3. What was the concentration of the solution?
   - ❑ A. 250 g/dm^3
   - ❑ B. 0.4 g/dm^3
   - ❑ C. 2.5 g/dm^3

3. 200 cm^3 of a solution has a concentration of 25 g/cm3. What mass of solute was dissolved in it?
   - ❑ A. 5000 g
   - ❑ B. 125 g
   - ❑ C. 5 g

Taking it Further:

Calculating Concentration

Do Now

1. Define concentration.
2. State a unit used to measure concentration.
3. Calculate the concentration of 500 cm3 of solution that has 20 g of solute dissolved in it.
4. State Avogadro's number.
5. State the equation that links number of moles, mass and relative formula mass.

Drill:

1. State the unit for amount of substance.
2. Calculate the mass of 1 mole of carbon.
3. Calculate the number of moles in 48 g of carbon

Read Now:

Concentration can be measured in terms of grams of solute per unit volume, or in moles per unit volume (usually mol/dm^3). We know that concentration = mass/volume, and number of moles = mass/relative formula mass. We can always calculate relative formula mass using the relative atomic masses from the periodic table. This means that we can use these two equations together to work between concentration, volume, mass and number of moles. For example, we want to calculate the mass of sodium hydroxide dissolved in 500 cm^3 of 12 mol/dm^3 solution, so we can first calculate the amount of substance (number of moles) that would be present in this volume, then use the relative formula mass of sodium hydroxide to determine the mass of this number of moles.

1. State the equation that links concentration, mass and volume.
2. State the equation that links number of moles, mass and relative formula mass.
3. Describe how to calculate the relative formula mass of a compound.
4. State the two different units that can be used for concentration.

Concentration

State the two equations to calculate concentration.

Give the two units for concentration.

Worked example: Calculating concentration

A scientist adds 9.75 g of sodium chloride to make 250 cm^3 of salt solution.

What is the **concentration** of the solution in **mol/dm^3**?

Mass = 9.75 g **Mr_r (NaCl) = 23 + 35.5**

$$\text{Number of moles} = \frac{\text{mass}}{\text{Mr}} \qquad \text{Number of moles} = \frac{9.75}{58.5} \qquad \text{Number of moles} = 0.167 \text{ mol}$$

$$\text{Concentration} = \frac{\text{number of moles}}{\text{volume}} \qquad \text{Concentration} = \frac{0.167}{0.25} \qquad \text{Concentration} = 0.67 \text{ mol/dm } 3$$

We do: Calculating concentration

Some glucose ($C_6H_{12}O_6$) was dissolved in 500 cm^3 of water.
The concentration of the solution was 0.4 mol/dm^3.

What mass of glucose was dissolved in the solution?

Drill

1. State the equation that links concentration, mass and volume.
2. State the equation that links concentration, number of moles and volume.
3. State the equation that links number of moles, mass and relative formula mass.
4. Define relative formula mass.
5. Calculate the relative formula mass of sodium hydroxide (NaOH).
6. State the unit for mass.
7. State the unit for volume.
8. Convert 50 cm^3 to dm^3.
9. State the two units that can be used for concentration.

I:

A scientist makes 500 cm^3 of copper sulfate solution by dissolving 31.9 g of copper sulfate ($CuSO_4$) in water. They want to calculate the concentration of the solution in mol/dm^3.

What is M_r of copper sulfate?

What is the number of moles in the solution?

What is the concentration of the solution in mol/dm^3?

We:

A student makes 750 cm^3 of a solution of sodium chloride by dissolving 65 g of sodium chloride.

What is M_r of sodium chloride?

What is the number of moles in the solution?

What is the concentration of the solution in mol/dm^3?

You:

A scientist makes up 250 cm^3 of calcium hydroxide solution by adding 24 g of calcium hydroxide ($Ca(OH)_2$) to water.

What is M_r of calcium hydroxide?

What is the number of moles in the solution?

What is the concentration of the solution in mol/dm^3?

Exit Ticket

1. Calculate the concentration of a 750 cm^3 solution that contains 1.5 mol of solute.
   - ❑ A. 1.5 mol/dm^3
   - ❑ B. 0.02 g/dm^3
   - ❑ C. 2 mol/dm^3

2. Calculate the number of moles in 2 dm^3 of 0.5 mol/dm^3 solution.
   - ❑ A. 4 mol
   - ❑ B. 1 mol
   - ❑ C. 0.25 mol

3. 80 g of sodium hydroxide (M_r = 40) is dissolved in solution. How many moles of solute are in the solution?
   - ❑ A. 2 mol
   - ❑ B. 0.5 mol
   - ❑ C. 3200 mol

Taking it Further: Calculating Unknown Concentrations

Do Now

1. State the quantity that is measured with the unit mol/dm^3.
2. Calculate the concentration (in mol/dm^3) of a solution that has 2 moles of solute dissolved in 100 cm^3 of solution.
3. Complete the following general equation: Acid + Alkali →
4. What type of reaction is described in question 3?
5. State the colour of universal indicator in an acidic solution.

Drill:

1. What type of solution would have a pH of 10?
2. What type of ions would be present in a solution with a pH of 10?
3. Which electrode would these ions travel towards in electrolysis?

Read Now:

Depression is a serious risk to the mental health of people around the world. Low vitamin D levels in the blood are associated with a greater risk of depression. This is especially concerning for those of us living in the UK and Ireland. This is because humans naturally get our vitamin D from sunlight, which we don't get a lot of in our countries, especially in winter! Those of us who spend a lot of time indoors, or who wear clothes that cover up most of our skin, are at a greater risk of vitamin D deficiency. Doctors recommend that most people living here take a vitamin D supplement, especially during the winter months when we get the least amount of sunlight. Scientists recently carried out a study to investigate the blood concentration of vitamin D in 56 patients (aged 18-60 years), all of whom had mild to moderate depression. They found that following 8 weeks of vitamin D supplementation, a significant proportion of patients reported a reduction in the severity of their depression.

1. What is the relationship between vitamin D and depression?
2. Why is this relationship especially important for us to understand in the UK and Ireland?
3. Why do doctors recommend that people take vitamin D supplements in the winter months?
4. What did scientists find out in their study?

Neutralisation

acid + alkali → _____ + _____

What pH will the product of a neutralisation have?

How many moles are reacting in each example?

$KOH + HCl \rightarrow KCl + H_2O$

____ mole(s) of KOH is/are reacting with _____ mole(s) of HCl to produce _____ mole(s) of KCl and _____ mole()s of water.

$2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

____ mole(s) of NaOH is/are reacting with _____ mole(s) of sulfuric acid to produce _____ mole(s) of sodium sulfate and _____ mole()s of water.

Drill

1. State the equation that links concentration, mass and volume.
2. State the equation that links concentration, number of moles and volume.
3. State the equation that links number of moles, mass and relative formula mass.
4. Write a unit of volume.
5. Write a unit of concentration.
6. State the mole ratio of acid to alkali for the equation $NaOH + HCl \rightarrow NaCl + H_2O$
7. Calculate the number of moles for a solution with a volume of 50 cm^3 and a concentration of 0.5 mol/dm^3.
8. Calculate the volume of a solution that contains 0.5 moles of solvent in a solution of concentration 1.5 mol/dm^3

Steps to success for calculations

1. Write the equation
2. Find the number of moles of the reagent of known concentration.
3. Deduce the number of moles of the unknown solution
4. Calculate the concentration of unknown solution

I: Calculating an unknown concentration

50 cm^3 of 0.1 mol/dm^3 lithium hydroxide reacts with 30 cm^3 of hydrochloric acid.

The equation for the reaction is:

$LiOH + HCl \rightarrow LiCl + H_2O$

How many moles of lithium hydroxide reacted?

What is the mole ratio of alkali to acid in this reaction?

How many moles of hydrochloric acid reacted?

What is the concentration of the hydrochloric acid?

We: Calculating an unknown concentration

50 cm^3 of 0.1 mol/dm^3 lithium hydroxide reacts with 30 cm^3 of sulfuric acid.

The equation for the reaction is:

$2\ LiOH + H_2SO_4 \rightarrow$ _____ + _____

How many moles of lithium hydroxide reacted?

What is the mole ratio of alkali to acid in this reaction?

How many moles of sulfuric acid reacted?

What is the concentration of the sulfuric acid?

You: Calculating an unknown concentration

25 cm^3 of 0.5 mol/dm^3 barium hydroxide reacts with 20 cm^3 of hydrochloric acid.

The equation for the reaction is:

$Ba(OH)_2 + 2\,HCl \rightarrow BaCl_2 + 2\,H_2O$

How many moles of barium hydroxide reacted?

What is the mole ratio of alkali to acid in this reaction?

How many moles of hydrochloric acid reacted?

What is the concentration of the hydrochloric acid?

Exit Ticket

1. What is the equation that links concentration, number of moles and volume?
   - ❑ A. $\textbf{Concentration} = \frac{\textbf{number of moles}}{\textbf{volume}}$
   - ❑ B. $\textbf{Number of moles} = \frac{\textbf{concentration}}{\textbf{volume}}$
   - ❑ C. $\textbf{Concentration} = \textbf{number of moles} \times \textbf{volume}$

2. Calculate the number of moles in 100 cm^3 of 0.2 mol/dm^3 solution.
   - ❑ A. 20 mol
   - ❑ B. 2 mol
   - ❑ C. 0.02 mol

Sodium hydroxide reacts with hydrochloric acid:

$NaOH + HCl \rightarrow NaCl + H_2O$

3. What is the mole ratio of alkali to acid in this reaction?
   - ❑ A. 1:1
   - ❑ B. 4:2
   - ❑ C. Need more information

(HT) Amounts of Substances in Equations

Do Now

1. Define relative formula mass.
2. Calculate the relative formula mass of magnesium chloride ($MgCl_2$). Mg = 24, Cl = 35.5
3. Calculate the percentage by mass of chlorine in magnesium chloride.
4. Calculate the number of moles in 47.5 g of magnesium chloride.

Drill:

1. Calculate the M_r of potassium sulfate (K_2SO_4). K=39, S=32, O=16
2. Calculate the M_r of aluminium hydroxide ($Al(OH)_3$). Al=27, O=16, H=1
3. Calculate the M_r of calcium nitrate ($Ca(NO_3)_2$). Ca=40, N=14, O=16

Read Now:

1. State the number of particles that are present in 1 mole of a substance.
2. Describe the reaction between hydrogen and oxygen to form water in terms of moles.
3. Describe the reaction between hydrogen and oxygen to form water in terms of molecules.
4. Explain why chemical equations must be balanced.

Chemical equations must be balanced because atoms cannot be created or destroyed in a chemical reaction, only rearranged. A balanced chemical equation shows us the ratio in which reactants react or products or made. For example, in the reaction $2H_2 + O_2 \rightarrow 2H_2O$, we can see that two molecules of hydrogen react with every oxygen molecule to produce two molecules of water. In real chemical equations, it would be extremely unlikely to just have a couple of molecules reacting, so instead we can use the balanced chemical equation to show us the ratio of moles that are involved. This means that 2 moles of hydrogen react with1 mole of oxygen to produce 2 moles of oxygen. Remember that 1 mole of any substance contains 6.02×10^{23} particles.

Mole Ratios

Complete the tables to show the mole ratios

N_2 + 3 H_2 → 2 NH_3		
1 mol		2 mol
	0.6 mol	
		0.1 mol

3 C + 2 Fe_2O_3 → 4 Fe + 3 CO_2			
3 mol			
	0.5 mol		
		0.1 mol	

Moles, Mass and M_r

2 Mg + O_2 → 2 MgO

Name the steps to calculate the mass of magnesium oxide that could be made from reacting 12 g of magnesium with oxygen.

Identify the mistake(s) in this working.

2 H_2 + O_2 → 2 H_2O

Calculate the mass of water that could be made from reacting 8 g of hydrogen with oxygen.

mole ratio = 2 : 2

mole ratio = 1: 1

$$\text{number of moles hydrogen} = \frac{\text{mass}}{\text{Mr}} \qquad \text{number of moles H2} = \frac{8}{4} \qquad \text{number of moles H2} = 2 \text{ mol}$$

$$\text{number of moles H2O} = 2 \text{ mol}$$

$$\text{number of moles H2O} = \frac{\text{mass}}{\text{Mr}} \qquad 2 \text{ mol} = \frac{\text{mass}}{36} \qquad \text{mass} = 72 \text{ g}$$

Drill

1. State the equation that links number of moles, mass and M_r.
2. Define relative formula mass.
3. State the units for mass.
4. State the units for number of moles.
5. Calculate the relative formula mass of ammonia (NH_3).
6. Calculate the relative formula mass of sodium oxide (Na_2O).
7. Calculate the number of moles in 34 g of ammonia.
8. Calculate the number of moles in 15.5 g of sodium oxide.
9. Calculate the mass of 0.1 moles of ammonia.
10. Calculate the mass of 0.05 moles of sodium oxide.

I: calculating reacting masses

CH_4 + 2 O_2 → 2 H_2O + CO_2

*Calculate the mass of **methane** that burns to produce 5.5 g of **carbon dioxide**.*

mole ratio =

Moles of carbon dioxide =

Moles of methane =

Mass of methane =

We: calculating reacting masses

*Calculate the mass of **aluminium oxide** needed to make 108 g of **aluminium**.*

Al_2O_3 + 2 Fe → Fe_2O_3 + 2 Al

mole ratio =

Moles of aluminium =

Moles of aluminium oxide =

Mass of aluminium oxide =

You: calculating reacting masses

N_2 + 3 H_2 → 2 NH_3

*Calculate the mass of **hydrogen** needed to make 120 g of **ammonia**.*

mole ratio =

Moles of ammonia=

Moles of hydrogen=

Mass of hydrogen =

Exam question

1. Read the question and the student's answer carefully.

2. Use the mark scheme to award the student a number of marks and annotate their answer with suggestions to improve.

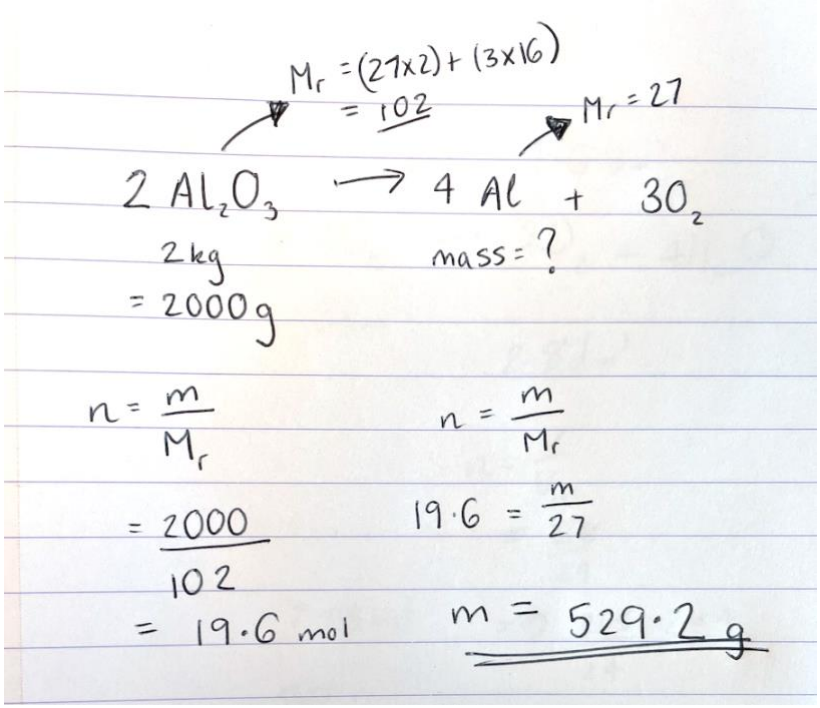
Stretch: Rewrite the answer to show how it should be done!

Question:

Aluminium can be separated from its ore by electrolysis. The equation for the reaction is:

$$2\ Al_2O_3\ (l) \rightarrow 4\ Al\ (s) + 3\ O_2\ (g)$$

Calculate the mass of aluminium that could be obtained from 2 kg of aluminium oxide. **(6)**



Marks awarded= _____ **Mark scheme:**

Point	**Mark**
Mr Al_2O_3 = 102	1 (answer, can also be shown in working of next point)
Number of moles Al_2O_3 = m/Mr 2000/102	1 (substitution)
Number of moles Al_2O_3 = 19.6.078…mol	1 (answer)
Mole ratio= 2:4 Number of moles Al = 39.2156…	1 (number of moles Al)
Mass Al = n x Mr = 39.2156 x 27	1 (substitution)
1 058.82 g	1 (answer)

Exit Ticket

1. 12 g of magnesium burns in oxygen. Calculate the number of moles of magnesium that reacted.
   - ❑ A. 12 mol
   - ❑ B. 2 mol
   - ❑ C. 0.5 mol
2. Calculate the number of moles of oxygen that would have reacted.
   - ❑ A. 1.0 mol
   - ❑ B. 0.5 mol
   - ❑ C. 0.25 mol
3. Calculate the mass of oxygen that would have reacted.
   - ❑ A. 4 g
   - ❑ B. 8 g
   - ❑ C. 128 g

(HT) Limiting Reactants

Do Now

1. State which side of a chemical equation the reactants are found on.
2. Explain why chemical equations must be balanced.
3. Calculate the relative formula mass of sodium carbonate (Na_2CO_3).
4. Calculate the mass of 0.2 moles of sodium carbonate.
5. Calculate the number of moles in 100 g of sodium carbonate.

Drill:

1. Calculate the M_r of lithium nitrate ($LiNO_3$). L=7, 7=14, O=16
2. Calculate the M_r of copper carbonate ($CuCO_3$). Cu=63.5, C=12, O=16
3. Calculate the M_r of calcium phosphate ($Ca_3(PO_4)_2$). Ca=40, P=31, O=16

Read Now:

We can use mole ratios to determine the numbers of particles involved in chemical reactions. We can use a given mass of a reactant to determine the number of moles that were reacting and therefore the number of moles of product that would be made. In reactions where there are two or more reactants, the reactant that has the fewest number of moles is the limiting reactant. This means that it will limit the amount of product that can be made. For example a car factory has made 10 car frames and 100 wheels. This would be enough wheels to make 25 cars, because each car needs 4 wheels, but there are only enough frames to make 10 cars. In this case, the car frame is the limiting reactant, because it determine the maximum amount of product (cars) that can be made.

1. Explain what is meant by a limiting reactant.
2. Identify the limiting reactant in the car factory example.
3. Explain why this is the limiting reactant.
4. Suggest which would be the limiting reactant if the car factory had made 30 car frames instead.

Limiting Reactants

How many cars can be made in each scenario?

Identify what is in excess, and what is the limiting reactant

1.  **+** 

2. 

+ 

3. 

+ 

Calculate the mass of potassium oxide that can be made from 78 g of potassium and 32 g of oxygen.

4 K + O_2 → 2 K_2O

mole ratio =

Moles of K=

Moles of O_2 =

Moles of oxygen needed to react with 78g K =

Moles of K needed to react with 32g oxygen =

Limiting reactant = Reactant in excess =

Moles of K_2O made =

Mass of K_2O made

Drill

1. State the equation that links number of moles, mass and M_r.
2. Explain what is meant by a limiting reactant.
3. Explain what it means for a reactant to be in excess.
4. Describe where reactants and products are found in a chemical equation.
5. State the units for number of moles.

I: using limiting reactants in calculations

CH_4 + 2 O_2 → 2 H_2O + CO_2

Calculate the mass of carbon dioxide that would be formed when 32 g of methane burns in 100 g of oxygen.

mole ratio =

$$\text{n } \mathbf{CH_4} = \frac{\text{mass}}{\text{Mr}} \qquad \text{n } \mathbf{CH_4} = \text{—} \qquad \text{n } \mathbf{CH_4} = \text{ mol}$$

$$\text{n } \mathbf{O_2} = \frac{\text{mass}}{\text{Mr}} \qquad \text{n } \mathbf{O_2} = \text{—} \qquad \text{n } \mathbf{O_2} = \text{ mol}$$

number of moles of $\mathbf{O_2}$ needed to react with 32g $\mathbf{CH_4}$ = mol

number of moles of $\mathbf{CH_4}$ needed to react with100g of $\mathbf{O_2}$ = mol

Mole ratio limiting reactant: deisired product =

number of moles $\mathbf{CO_2}$ = mol

$$\text{number of moles } \mathbf{CO_2} = \frac{\text{mass}}{\text{Mr}} \qquad \text{mol} = \frac{\text{mass}}{\text{}}$$

mass = g

We: using limiting reactants in calculations

Al_2O_3 + 2 Fe → Fe_2O_3 + 2 Al

Calculate the mass of aluminium that could be made from 180 g of aluminium oxide and 180 g of iron.

mole ratio =

$$\text{n } \mathbf{Al_2O_3} = \frac{\text{mass}}{\text{Mr}} \qquad \text{n } \mathbf{Al_2O_3} = \text{—} \qquad \text{n } \mathbf{Al_2O_3} = \text{ mol}$$

$$\text{n } \mathbf{Fe} = \frac{\text{mass}}{\text{Mr}} \qquad \text{n } \mathbf{Fe} = \text{—} \qquad \text{n } \mathbf{Fe} = \text{ mol}$$

number of moles of **Fe** needed to react with 180g $\mathbf{Al_2O_3}$ = mol

number of moles of $\mathbf{Al_2O_3}$ needed to react with 180g of **Fe** = mol

Mole ratio limiting reactant: deisired product =

number of moles **Al** = mol

$$\text{number of moles } \mathbf{Al} = \frac{\text{mass}}{\text{Mr}} \qquad \text{mol} = \frac{\text{mass}}{}$$

mass = g

You: using limiting reactants in calculations

N_2 + 3 H_2 → 2 NH_3

Calculate the mass of ammonia that could be made from 50 g of nitrogen and 50 g of hydrogen.

mole ratio =

$$\text{n } \mathbf{N_2} = \frac{\text{mass}}{\text{Mr}} \qquad \text{n } \mathbf{N_2} = \text{—} \qquad \text{n } \mathbf{N_2} = \text{ mol}$$

$$\text{n } \mathbf{H_2} = \frac{\text{mass}}{\text{Mr}} \qquad \text{n } \mathbf{H_2} = \text{—} \qquad \text{n } \mathbf{H_2} = \text{ mol}$$

number of moles of $\mathbf{H_2}$ needed to react with 50g $\mathbf{N_2}$ = mol

number of moles of $\mathbf{N_2}$ needed to react with50g of $\mathbf{H_2}$ = mol

Mole ratio limiting reactant: deisired product =

number of moles $\mathbf{NH_3}$ = mol

$$\text{number of moles } \mathbf{NH_3} = \frac{\text{mass}}{\text{Mr}} \qquad \text{mol} = \frac{\text{mass}}{}$$

mass = g

Exit Ticket

$2\ Mg + O_2 \rightarrow 2\ MgO$ 48 g of magnesium burns in 100 g of oxygen

1. Calculate the number of moles of magnesium present.
   - ❑ A. 0.5 mol
   - ❑ B. 1 mol
   - ❑ C. 2 mol

2. Calculate the number of moles of oxygen present.
   - ❑ A. 6.25 mol
   - ❑ B. 3.125 mol
   - ❑ C. 0.32 mol

3. Which is the limiting reactant?
   - ❑ A. Mg
   - ❑ B. O_2
   - ❑ C. MgO

Prior Knowledge Review:

Reactions of Acids

Do Now

1. Calculate the M_r of sulfuric acid (H_2SO_4). H=1, S=32, O=16
2. Calculate the percentage by mass of hydrogen in sulfuric acid.
3. Name another acid.
4. State the pH range of acids.
5. State the colour that Universal Indicator would turn in an alkaline solution.

Drill:

1. State the chemical formula for water.
2. State the chemical formula for carbon dioxide.
3. Use calculations to show whether water or carbon dioxide contains a greater percentage by mass of oxygen.

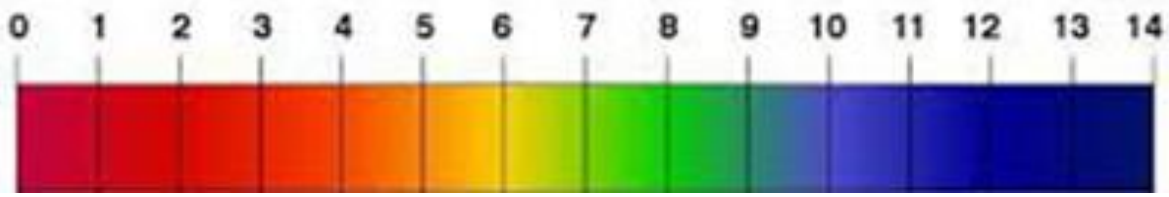
Read Now:

Acids can be neutralised by alkalis (which are usually soluble metal hydroxides, like sodium hydroxide) and bases (which are insoluble metal hydroxides, like calcium hydroxide, metal oxides, like copper oxide and metal carbonates, like potassium carbonate). The reaction between an acid and a metal or a metal compound always produces a salt. If an acid reacts with a metal oxide or hydroxide, a salt and water are formed and if an acid reacts with a metal carbonate, a salt, water and carbon dioxide are formed. Sodium chloride is one example of a salt, but a salt is any compound made from a reaction between a metal and an acid.

1. Define a salt.
2. Write a general equation for a reaction between an acid and a metal oxide.
3. Write a general equation for a reaction between an acid and a metal hydroxide.
4. Write a general equation for a reaction between an acid and a metal carbonate.
5. Give an example of a salt.

The pH scale

Label acid, neutral and alkaline on the scale



Complete the equations for neutralisation reactions

Acid + alkali → _____ + _____

Acid + base → _____ + _____

Acid + Metal Carbonate→ _____ + _____ +_____

Most bases are i_____. Alkalis are _____ bases

Oxides are _____

Carbonates are _____.

Naming salts

Name of acid	**Ending of salt name**
Hydrochloric acid	
	Nitrate
Sulfuric acid	
	Phosphate

Acids and Metals

Acids react with metals to product **s**_____ ___ and **h**_____

_____ + hydrochloric acid → magnesium chloride + _____

This is not a _____ reaction.

It is a d_____ or r_____ reaction

Testing for Gases

Complete the table for the gas tests

Name of gas	Test method	Positive result
Hydrogen		
Carbon dioxide		

(HT) Writing ionic equations

Positive ions		Negative ions	
Name	Formula	Name	Formula
Hydrogen	H^+	Chloride	Cl^-
Sodium	Na^+	Bromide	Br^-
Silver	Ag^+	Fluoride	F^-
Potassium	K^+	Iodide	I^-
Lithium	Li^+	Hydroxide	OH^-
Ammonium	NH_4^+	Nitrate	NO_3^-
Barium	Ba^{2+}	Oxide	O^{2-}
Calcium	Ca^{2+}	Sulfide	S^{2-}
Copper(II)	Cu^{2+}	Sulfate	SO_4^{2-}
Magnesium	Mg^{2+}	Carbonate	CO_3^{2-}
Zinc	Zn^{2+}		
Lead	Pb^{2+}		
Iron(II)	Fe^{2+}		
Iron(III)	Fe^{3+}		
Aluminium	Al^{3+}		

Ionic equations tell us only what has reacted, not all the ions present. For example:

$Mg_{(s)} + H_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + H_{2(g)}$

Look at this chemical equation:

We can use **2 steps** to write this as an ionic equation:

Step 1: Split up the aqueous (aq) substances into their ions

$Mg_{(s)} + 2H^+_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow Mg^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} + H_{2(g)}$

Step 2: Delete the spectator ions (the ones that appear on both sides) – in this case the sulfate ions

$$Mg_{(s)} + 2H^+_{(aq)} \rightarrow Mg^{2+}_{(aq)} + H_{2(g)}$$

Magnesium has lost electrons, has been oxidised, to magnesium ions.

Hydrogen has gained electrons, been reduced, to hydrogen atoms which then form molecules

Drill

1. State the general equation for the reaction between an acid and an alkali.
2. State the general equation for the reaction between an acid and an metal carbonate.
3. State the general equation for the reaction between an acid and a metal.
4. Describe a positive test for hydrogen.
5. Describe a positive test for carbon dioxide.
6. True or false: the reaction between an acid and a metal is an example of neutralisation.

I: predicting the products of a reaction

A student reacts hydrochloric acid with magnesium carbonate.

What salt would be produced in this reaction?

What would the other product(s) of this reaction be?

Write this as a word equation.

How could you test for the presence of carbon dioxide?

What type of reaction is this?

We: predicting the products of a reaction

A student reacts copper oxide with sulfuric acid.

What salt would be produced in this reaction?

What would the other product(s) of this reaction be?

Write this as a word equation.

What would the products of these show for the squeaky pop test?

What type of reaction is this?

You: predicting the products of a reaction and comparing

A student reacts nitric acid with zinc.

What salt would be produced in this reaction?

What would the other product(s) of this reaction be?

Write this as a word equation.

How could you test for the presence of hydrogen?

What type of reaction is this?

Compare: ***to outline the similarities and/or differences between things***

Compare the products of a reaction between an acid and an alkali and an acid and a metal carbonate.

To 'compare', your answer should:

- Give similarities.
- Write paired statements that show differences relating to the same feature.
- Use the term 'whereas' to link your statements.

Exit Ticket

1. Name the salt that would be produced when hydrochloric acid reacted with potassium hydroxide.
   - ❑ A. Potassium hydride
   - ❑ B. Potassium chloride
   - ❑ C . Potassium chlorine

2. The products of which reaction would give a positive squeaky pop test?
   - ❑ A. Nitric acid + calcium oxide
   - ❑ B. Nitric acid + calcium carbonate
   - ❑ C. Nitric acid + calcium

3. Which of these is <u>not</u> a neutralisation reaction?
   - ❑ A. Acid + metal
   - ❑ B. Acid + metal hydroxide
   - ❑ C. Acid + metal carbonate

Acids, Alkalis and Neutralisation

Do Now

1. State the chemical formula for hydrochloric acid.
2. State the general equation for the reaction between an acid and an alkali.
3. Name the salt that would be produced from a reaction between calcium hydroxide and sulfuric acid.
4. Calculate the M_r of sodium hydroxide (NaOH). Na=23, O=16, H=1
5. Sodium hydroxide is an alkali. What colour would Universal Indicator turn when added to sodium hydroxide solution?

Drill:

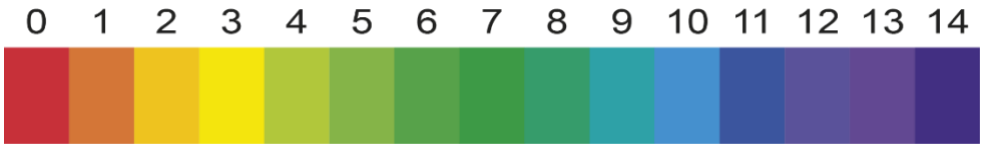
1. State the pH of a neutral solution.
2. A substance has a pH of 4.7. It is an acid or a base?
3. Is a pH of 4.7 likely to be detected from Universal Indicator or a pH probe?

Read Now:

The pH scale is a measure of the acidity or alkalinity of a solution. It measures from 0-14, where pH 7 is neutral, pH values lower than 7 are acidic and pH values greater than 7 are alkaline. The pH scale is an unusual scale in that a one point increase is equivalent to a ten-fold increase or decrease in acidity or alkalinity. For example, pH 2 is 10 times more acidic than pH 3. Litmus paper can be used to show whether a substance is acidic or alkaline but cannot give a pH value. pH values can be measured using Universal Indicator or a pH probe. Universal Indicator turns different colours in acidic and alkaline solutions which can be matched to a colour chart. A pH probe gives a more precise measurement, as it can give a value with a decimal place.

1. Explain what the pH scale measures.
2. Explain why the pH is an unusual scale.
3. State the pH of a neutral solution.
4. Describe two ways that pH can be measured.
5. Give an advantage of a pH probe over Universal Indicator.

The pH Scale and indicators



Name two ways to measure pH

_____

What colour would universal indicator turn in a solution of:

a) pH 7

b) pH 3

c) pH 9

d) pH 0

Which ion do acids produce in aqueous solutions? _____

Which ion do alkalis produce in aqueous solutions? _____

What is the ionic equation for neutralization? _____ _____

Complete the table for naming salts

Name of acid	**Ending of salt name**
	Chloride
Nitric acid	Nitrate
Sulfuric acid	
	Phosphate

Name the salts that would be produced in each reaction

1. Sodium hydroxide + hydrochloric acid→
2. Potassium hydroxide + nitric acid →
3. Lithium hydroxide + sulfuric acid →
4. Barium hydroxide + hydrochloric acid →
5. Sodium hydroxide + sulfuric acid→
6. Lithium hydroxide + nitric acid →

Drill

1. State the pH of neutral solutions.
2. State the pH of acidic solutions.
3. State the pH of alkaline solutions.
4. Describe two ways of measuring pH.
5. Name the ion that acids produce in aqueous solutions.
6. Name the ion that alkalis produce in aqueous solutions.
7. State the general equation for the reaction between an acid and an alkali.
8. Name the type of salts formed from hydrochloric acid.
9. Name the type of salts formed from sulfuric acid.
10. Name the type of salts formed from nitric acid.

I: determining chemical formula

A student reacts hydrochloric acid with lithium hydroxide.

What salt would be produced in this reaction?

What would the other product(s) of this reaction be?

Write this as a word equation.

Use the ion sheet to determine the chemical formula of the salt.

How is the water formed?

Positive ions		Negative ions	
Name	Formula	Name	Formula
Hydrogen	H^+	Chloride	Cl^-
Sodium	Na^+	Bromide	Br^-
Silver	Ag^+	Fluoride	F^-
Potassium	K^+	Iodide	I^-
Lithium	Li^+	Hydroxide	OH^-
Ammonium	NH_4^+	Nitrate	NO_3^-
Barium	Ba^{2+}	Oxide	O^{2-}
Calcium	Ca^{2+}	Sulfide	S^{2-}
Copper(II)	Cu^{2+}	Sulfate	SO_4^{2-}
Magnesium	Mg^{2+}	Carbonate	CO_3^{2-}
Zinc	Zn^{2+}		
Lead	Pb^{2+}		
Iron(II)	Fe^{2+}		
Iron(III)	Fe^{3+}		
Aluminium	Al^{3+}		

We: determining chemical formula

A student reacts potassium hydroxide with sulfuric acid.

What salt would be produced in this reaction?

What would the other product(s) of this reaction be?

Write this as a word equation.

Use the data sheet to determine the chemical formula of the salt.

You: determining chemical formula

A student reacts nitric acid with barium hydroxide.

What salt would be produced in this reaction?

What would the other product(s) of this reaction be?

Write this as a word equation.

Use the data sheet to determine the chemical formula of the salt.

Read the exam style question carefully, then fill in each section below.

Question: A student reacts different alkalis with different acids.

a. Write a word equation to show the reaction between sodium hydroxide and sulfuric acid. **(2)**

b. Barium hydroxide reacts with nitric acid. The equation for the reaction is:

$Ba(OH)_2 + HNO_3 \rightarrow Ba(NO_3)_2 + H_2O$

Balance this equation. **(1)**
Calculate the relative formula mass of nitric acid. **(2)**
Calculate the percentage by mass of oxygen in nitric acid. **(3)**

Section 1: At first glance

1. What **command words** are used in this question? Circle them clearly.

2. Underline the key information in the question above.

3. How many marks is this question worth?

Section 2: Thinking ahead

Read the question again.

What do you need to know in order to answer this question really well?

Can you split the question into two or more parts?

Are there any labelled diagrams that might help you to show your answer?

What are the key words that you should include in your answer?

Section 4: Space to plan

Use this space to plan your answer.

Section 4: Answer the question

Exit Ticket

1. Identify the ion that is produced by acids in aqueous solutions.
   - ❑ A. H^+
   - ❑ B. OH^-
   - ❑ C. H_2O

2. Name the salt that would be produced when sulfuric acid reacts with lithium hydroxide?
   - ❑ A. Lithium hydride
   - ❑ B. Lithium sulfide
   - ❑ C. Lithium sulfate

3. What is the correct ionic equation when an acid is neutralised by an alkali?
   - ❑ A. $H_2O \rightarrow H^+ + OH^-$
   - ❑ B. $H + OH \rightarrow H_2O$
   - ❑ C. $H^+ + OH^- \rightarrow H_2O$

Taking it Further: RPA Determining an Unknown Concentration by Titration

Do Now

1. State the formula for sulfuric acid.
2. Calculate the relative formula mass of sodium hydroxide (NaOH).
3. Write a word equation for the reaction between sulfuric acid and sodium hydroxide.
4. What type of reaction is this?
5. Name the salt that would be produced in a reaction between hydrochloric acid and potassium hydroxide.

Drill:

1. Describe three ways to tell if a substance is acidic.
2. State the colour that Universal Indicator would turn in an acid.
3. Give a disadvantage of Universal Indicator.

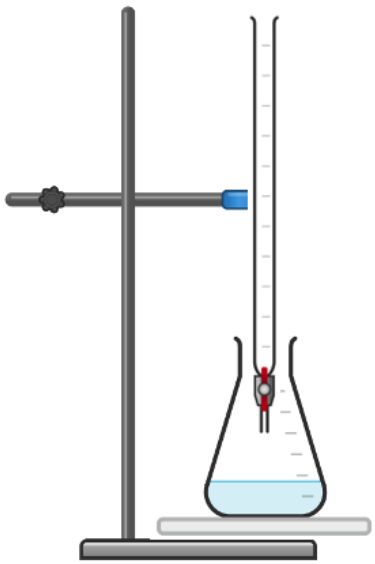
Read Now:

Titrations are a method of quantitative analysis. This means that they provide numerical information, unlike in a qualitative analysis. For example, in a titration, you can determine a volume of acid required to neutralise an alkali. This is a numerical quantity. However, in a qualitative analysis, a numerical value is not given. An example of a qualitative analysis that we have seen already is using different food tests to identify the presence of different nutrients. Iodine can be used to test for the presence of starch. If starch is present, iodine turns blue-black. These reagents can show whether or not a nutrient is present, but cannot tell you how much of a nutrient is present. The starch test is also useful when identifying if a leaf has produced starch, showing that it has been converted from glucose produced in photosynthesis.

1. Give an example of a quantitative analysis.
2. Explain what is meant by a quantitative analysis.
3. Explain the difference between a quantitative analysis and a qualitative analysis.
4. Describe the result of a positive test for starch.

Titration demonstration – Complete the paragraph to name the pieces of equipment and measurements needed

1. Measure 25 cm^3 of **alkali** using a _____
2. Add the alkali to a _____ _____
3. Set up a _____ with **acid**. Rinse the _____ with the acid solution and flush the tap to remove air bubbles
4. Add a few drops of **indicator** (phenolphthalein) to the _____flask
5. Place the conical flask on a _____ _____
6. Record the starting volume of acid in the _____
7. Open the tap to gradually add **acid** from the _____ to the _____ _____ , while **swirling** the conical flask
8. When the **indicator changes colour**, this is the **end-point** of the titration



9. Use the **starting** and **final** volumes on the burette to determine the **volume of acid** used

Questions about the method and accuracy

What will the colour change be when adding acid to alkali for:

a) Phenolphthalein _____ to _____

b) Methyl orange_____ to _____

Resolution is the smallest _____ on the equipment

The uncertainty is _____ the resolution

What steps do we take to make our measurements as accurate as possible?

The first one has been completed for you

Step taken in the method	**Why does this make the measurement accurate?**
Rinsing the burette	to make sure there is no other solution in the burette that would affect the concentration of the acid
Adding acid from the burette gradually/drop by drop	
Swirling the conical flask while adding acid	
Using a white tile	
Reading volume of liquid from the centre of the meniscus at eye level	

Drill

1. Give the name for the volume of liquid that is measured using a titration.
2. Define concordant results.
3. Describe the function of the indicator in a titration.
4. Describe the function of the white tile in a titration.
5. Define the end-point of a titration.
6. Name the piece of equipment that should be used to measure a fixed volume.
7. Name the piece of equipment that should be used to measure a variable volume.

I: identifying concordant results

A student uses a titration to determine the volume of sulfuric acid needed to neutralise 25 cm^3 of sodium hydroxide solution.

Their results are shown in the table.

Which values from the table are concordant measurements?

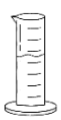
Which might the measurement from titration 1 be different from the others?

What is the mean volume of acid used?

Titration	Volume of acid used (cm^3)
1	34.5
2	31.2
3	31.1
4	31.3
5	31.2

We: measuring volume and uncertainty

Different instruments can be used to measure volumes of liquids.



What instruments could be used to measure the volume of a liquid?

_____

_____

What instruments would allow the most precise measurements to be taken? Why?

_____

_____

_____

*A **measuring cylinder** has a resolution of 1 cm^3. Calculate the uncertainty when using this to measure a liquid.*

_____

*A **pipette** has a resolution of 0.1 cm^3. Calculate the uncertainty when using this to measure a liquid.*

_____

You: explaining the purpose of equipment

They use 40 cm^3 of 0.75 mol/dm^3 nitric acid solution. A student uses a titration to determine the concentration of calcium hydroxide.*What piece of equipment should be used to measure the volume of nitric acid? Why?*

_____

_____

What piece of equipment should be used to measure the volume of calcium hydroxide that is added. Why?

_____

_____

Why is a white tile placed underneath the conical flask?

_____

Why should an indicator such as phenolphthalein or methyl orange be used instead of Universal Indicator?

_____

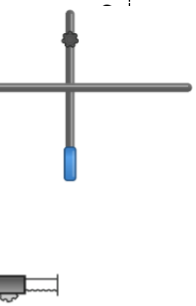
_____

Required Practical Activity: Determining an Unknown Concentration by Titration

Integrated Instructions

Aim: To use a burette and colour-changing indicator to find the reacting volumes of solutions of a strong acid and alkali

Apparatus:

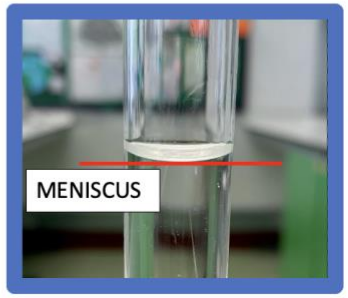


1. Clamp the burette to the retort stand with enough space beneath for the conical flask and white tile.

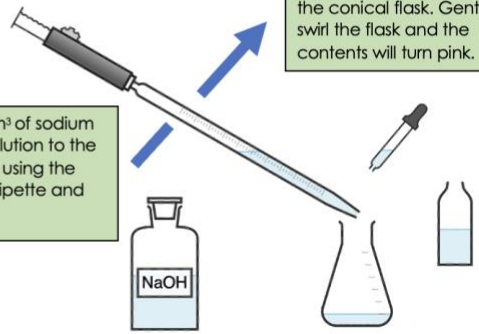
START

2. Check that the burette tap is closed, then use the funnel to help pour in sulfuric acid past the 0.00 cm^3 line. Remove the funnel.

3. Put the bottle of sulfuric acid beneath the burette and slowly open the tap until the bottom of the meniscus of the sulfuric acid reaches the 0.00 cm^3 line.



4. Add 25 cm^3 of sodium hydroxide solution to the conical flask using the volumetric pipette and pipette filler.



5. Add 5-10 drops of phenolphthalein indicator to the sodium hydroxide in the conical flask. Gently swirl the flask and the contents will turn pink.

6. Place the conical flask on a white tile beneath the burette.

7. Slowly and carefully open the burette's tap to allow approximately 10 cm^3 of sulfuric acid into the conical flask, constantly swirling the conical flask the entire time.

8. Close the tap a little so the sulfuric acid enters the conical flask a drip at a time. Eventually, one of these drips will cause the colour a colour change from pink to clear. At this point, immediately shut the tap so no more sulfuric acid is added.

9. Read the level of the sulfuric acid in the burette from the bottom of the meniscus and record this on your table.

10. Repeat the experiment two more times and complete your table. Calculate the mean volume of sulfuric acid needed to neutralise 25 cm^3 of 0.1 mol/dm^3 sodium hydroxide.

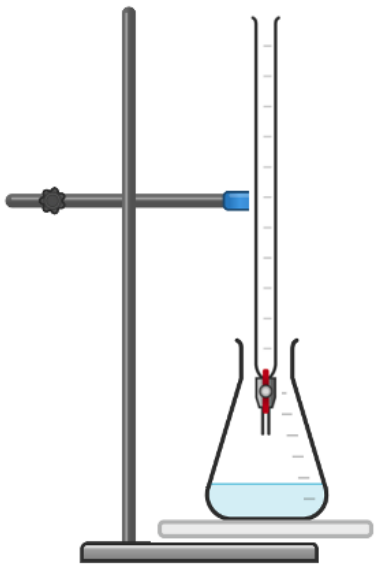
END

- 25 cm^3 volumetric pipette
- Pipette filler
- 50 cm^3 burette
- 250 cm^3 conical flask
- Funnel
- Clamp stand and clamp
- White tile

Chemicals:

- 0.1 mol/dm^3 sodium hydroxide solution (irritant)
- 'Unknown concentration' sulfuric acid
- Phenolphthalein indicator

Method:



1. Clamp the burette to the retort stand with enough space beneath for the conical flask and white tile.
2. Check that the burette tap is closed, then use the funnel to help pour in sulfuric acid past the 0.00 cm^3 line. Remove the funnel.
3. Put the bottle of sulfuric acid beneath the burette and slowly open the tap until the bottom of the meniscus of the sulfuric acid reaches the 0.00 cm^3 line.
4. Add 25 cm^3 of sodium hydroxide solution to the conical flask using the volumetric pipette and pipette filler.
5. Add 5-10 drops of phenolphthalein indicator to the sodium hydroxide in the conical flask. Gently swirl the flask and the contents will turn pink.
6. Place the conical flask on a white tile beneath the burette.
7. Slowly and carefully open the burette's tap to allow approximately 10 cm^3 of sulfuric acid into the conical flask, constantly swirling the conical flask the entire time.
8. Close the tap a little so the sulfuric acid enters the conical flask a drip at a time. Eventually, one of these drips will cause the colour a colour change from pink to clear. At this point, immediately shut the tap so no more sulfuric acid is added.
9. Read the level of the sulfuric acid in the burette from the bottom of the meniscus and record this on your table.
10. Repeat the experiment two more times and complete your table. Calculate the mean volume of sulfuric acid needed to neutralise 25 cm^3 of 0.1 mol/dm^3 sodium hydroxide.

Results:

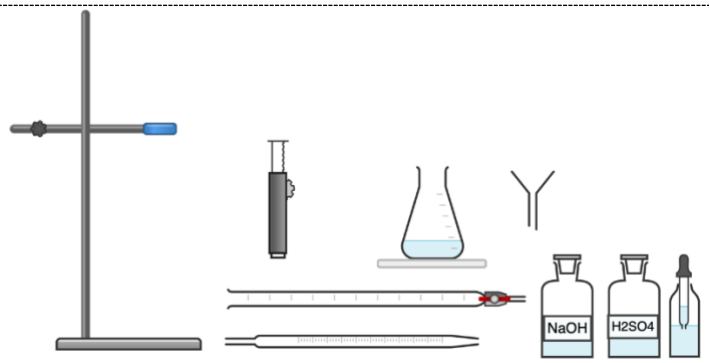
Rec0rd your results in the following table.

Titre	**1**	**2**	**3**	**4**	**5**	**Mean**
Volume of acid needed to neutralise alkali (cm^3)						

Identify concordant results (results that are within 0.2 cm^3 of each other) and use these to calculate the mean volume of acid needed to neutralise the alkali.

Read the exam style question carefully, then fill in each section below.

Question: A student wants to determine the volume of a sample of sodium hydroxide that reacts with 25 cm^3 of 0.1 mol/dm^3 sulfuric acid. The apparatus they can use is shown below.



a) Describe a method that could be used to find the volume of sodium hydroxide that reacts with the sulfuric acid. **(6)**

b) Describe how they could use measurements to calculate the concentration of the sodium hydroxide. **(3)**

Section 1: At first glance

1. What **command words** are used in this question? Circle them clearly.

2. Underline the key information in the question above.

3. How many marks is this question worth?

Section 2: Thinking ahead

Read the question again.

What do you need to know in order to answer this question really well?

Can you split the question into two or more parts?

Are there any labelled diagrams that might help you to show your answer?

What are the key words that you should include in your answer?

Section 4: Space to plan

Use this space to plan your answer.

Section 4: Answer the question

Exit Ticket

1. What is the end point of a titration?
    - ❑ A. When the acid/alkali has been completely neutralised
    - ❑ B. When all of the acid/alkali has been used up
    - ❑ C. The volume used to complete the titration

2. Which explains why an indicator such as phenolphthalein is used for titration rather than Universal Indicator?
    - ❑ A. It has an obvious colour change
    - ❑ B. It speeds up the reaction
    - ❑ C. It is cheaper and easier to obtain

3. Which is the most appropriate piece of apparatus to measure a volume of 25 cm^3?
    - ❑ A. A measuring cylinder
    - ❑ B. A conical flask
    - ❑ C. A pipette

Taking it Further:
Titration Calculations

Do Now

1. State two possible units for concentration.
2. Define concentration.
3. State the equation that links amount of substance (number of moles), concentration and volume.
4. Calculate the relative formula mass of sodium hydroxide (NaOH).
5. Calculate the concentration when 0.25 mol of sodium hydroxide is dissolved to make 200 cm^3 of solution.

Drill:

1. State the unit for amount of substance.
2. State the unit for volume.
3. Convert 50 cm^3 to dm^3.

Read Now:

Titrations are used to determine the concentration of reactant, based on the known concentration of another reactant. However, these titrations rely on colour changes being seen from the action of an indicator, such as phenolphthalein. But what happens for scientists that are colour-blind or visually impaired? Scientists at the Indian Institute of Science Education and Research in Kolkata have designed a smartphone app that can be used as a multi-sensory tool for detecting the end point of a titration. The app uses the phone's camera to identify the end point of the titration, notifying the investigator that the titration is complete.

1. Describe the function of a titration.
2. Explain what is meant by the end point of a titration.
3. Explain the function of an indicator in a titration.
4. Briefly describe how this app could be useful to visually impaired scientists.

Which values should we use?

Titration	Volume of alkali used (cm^3)
1	24.2
2	21.80
3	21.75
4	21.80
5	21.75

They obtain these results for the volume of alkali needed to neutralise a known volume and concentration of acid. A student performs a titration 5 times.

The student want to use the values to determine the concentration of the alkali.

What values should they use? Why?

_____

How should they use these results?

_____

What is the name for these results?

_____

What do these results fall within?

_____

Drill

1. Describe the function of a titration.
2. Give the name for the volume of liquid that is measured using a titration.
3. Define concordant results.
4. State the equation that links concentration, number of moles and volume.
5. State the unit for concentration.
6. State the unit for number of moles.
7. State the unit for volume that should be used in calculations.
8. Convert 25 cm^3 to dm^3.

Titration	Volume of alkali

I: calculating an unknown concentration

A student uses a titration to determine the concentration of lithium hydroxide. They use 25 cm^3 of 0.5 mol/dm^3 hydrochloric acid.

They repeated the titration 5 times, and their results for the volume of alkali needed to neutralise the acid are shown in the table.

	used (cm^3)
1	27.20
2	26.40
3	26.45
4	26.10
5	26.50

The equation for the reaction is:

$LiOH + HCl \rightarrow LiCl + H_2O$

Which values from the table should be used?

_____

What is the mean volume of alkali used?

How many moles of acid reacted? $\boldsymbol{concentration = \frac{number\ of\ moles}{volume}}$

How many moles of alkali reacted?

Mole ratio = $\mathbf{number\ of\ moles} =$

What is the concentration of alkali?

$\mathbf{concentration = \frac{number\ of\ moles}{volume}}$ $\mathbf{concentration =}$ _____ **=**

We: calculating an unknown concentration

A student uses a titration to determine the concentration of a sulfuric acid sample.

They use 50 cm^3 of 0.1 mol/dm^3 sodium hydroxide solution.

They required 34.5 cm^3 of sulfuric acid to neutralise the sodium hydroxide.

The equation for the reaction is:

$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$

How many moles of alkali reacted? $\boldsymbol{concentration = \frac{number\ of\ moles}{volume}}$

How many moles of acid reacted?

Mole ratio = $\mathbf{number\ of\ moles} =$

What is the concentration of acid?

$\mathbf{concentration = \frac{number\ of\ moles}{volume}}$ $\mathbf{concentration =}$ _____ **=**

You: calculating an unknown concentration

A student uses a titration to determine the concentration of calcium hydroxide.

They use 40 cm^3 of 0.75 mol/dm^3 nitric acid solution.

They required 19.5 cm^3 of calcium hydroxide to neutralise the nitric acid.

The equation for the reaction is:

$Ca(OH)_2 + 2\ HNO_3 \rightarrow Ca(NO_3)_2 + 2\ H_2O$

How many moles of acid reacted? $\boldsymbol{concentration = \frac{number\ of\ moles}{volume}}$

How many moles of alkali reacted?

Mole ratio = $\mathbf{number\ of\ moles =}$

What is the concentration of alkali?

$\mathbf{concentration = \frac{number\ of\ moles}{volume}}$ $\mathbf{concentration =}$ _____ **=**

What mass of alkali was dissolved in the given volume of solution?

Exit Ticket

1. What is the purpose of a titration?
   - ❑ A. To determine an unknown concentration
   - ❑ B. To determine how long it takes for an acid to react with an alkali
   - ❑ C. To produce a neutralisation reaction

2. What is the function of an indicator in a titration?
   - ❑ A. To signify the end point of a titration
   - ❑ B. To speed up the titration
   - ❑ C. To show the concentration of a substance

3. What is the concentration of 25 cm^3 sodium hydroxide solution that neutralises 20 cm^3 of 0.2 mol/dm^3 hydrochloric acid solution?
   The equation for the reaction is:
   $NaOH + HCl \rightarrow NaCl + H_2O$
   - ❑ A. 0.004 mol/dm^3
   - ❑ B. 0.00001 mol/dm^3
   - ❑ C. 0.16 mol/dm^3

(HT) Strong and Weak Acids

Do Now

1. State the chemical formula for hydrochloric acid.
2. State the chemical formula for sulfuric acid.
3. State the pH range of acids.
4. Calculate the relative formula mass of nitric acid (HNO_3).
5. Calculate the percentage by mass of hydrogen in nitric acid.

Drill:

1. Name the salt that would be produced in a reaction between hydrochloric acid and copper oxide.
2. Name the salt that would be produced in a reaction between nitric acid and calcium hydroxide.
3. Name the salt that would be produced in a reaction between sulfuric acid and lithium carbonate.

Read Now:

When a solute dissolves in a solvent, a solution is formed. Acids in solution are another example of a solute being dissolved in a solvent. The concentration of the solution is a measure of how much solute is present per unit volume. A concentrated solution has lots of solute per unit volume and a dilute solution has much less solute per unit volume. The concentration of an acid affects its pH, but pH is also affected by the strength of an acid. A strong acid, such as hydrochloric acid, is one which fully dissociates into ions solution. This means that in solution, it splits completely into H^+ and Cl^- ions. A weak acid, such as ethanoic acid, is one which does not fully dissociate into ions in solution.

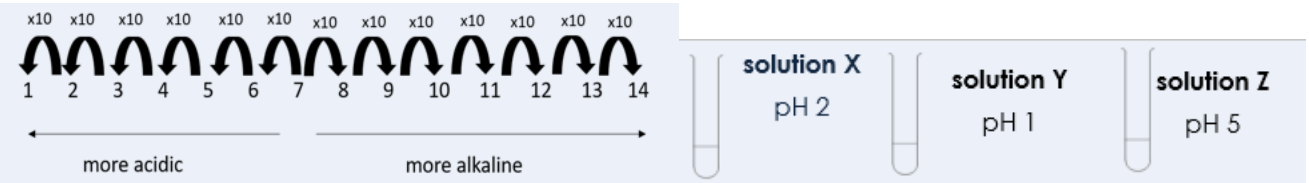
1. Define a solution.
2. Explain the difference between a concentrated and a dilute solution.
3. Explain what is meant by a strong acid.
4. Give an example of a strong acid.
5. Explain what is meant by a weak acid.
6. Give an example of a weak acid.

pH

What does pH tell us? _____

Which ion is produced by all acids? _____

Name the two factors that affect pH _____



1. How does the hydrogen ion concentration of Solution X and Y compare?
    a. Y has twice the hydrogen ion concentration of X
    b. Y has 10 times the hydrogen ion concentration of X
    c. X has 10 times the hydrogen ion concentration of Y

2. How does the hydrogen ion concentration of Solution X and Z compare?
    a. X has 1000 times the hydrogen ion concentration of Z
    b. Z has 1000 times the hydrogen ion concentration of X
    c. X has three times the hydrogen ion concentration of Z

3. How does the hydrogen ion concentration of Solution Y compare with Z?
    a. Y has four times the hydrogen ion concentration of Z
    b. Z has 10 000 times the hydrogen ion concentration of Y
    c. Y has 10 000 times the hydrogen ion concentration Z

pH and strength

A strong acid _____ _____ in solution

Three examples of strong acids are _____

_____

If a strong acid was written as HX, what would be the equation for how it would dissociate in solution?

HX

A weak acid _____ _____ in solution

Three examples of weak acids are _____

_____

If a weak acid was written as HX, what would be the equation for how it would dissociate in solution?

HX

Drill

1. Define a strong acid.
2. Give an example of a strong acid.
3. Define a weak acid.
4. Give an example of a weak acid.
5. State the pH range of acids.
6. Name the ion found in all acids.
7. Explain what it means for an acid to dissociate.

I:

Explain how it is possible for ethanoic acid to be weak and concentrated.

_____
_____
_____

We:

Explain how it is possible for sulfuric acid to be strong and dilute.

_____
_____
_____

You:

Explain the factors that affect the pH of an acid.

_____
_____
_____

Exit Ticket

1. What is a strong acid?
    - ❑ A. An acid that contains lots of solute per unit volume
    - ❑ B. An acid that has lots of H+ ions
    - ❑ C. An acid that fully dissociates in solution

2. Which of these is <u>not</u> a strong acid?
    - ❑ A. Hydrochloric acid
    - ❑ B. Sulfuric acid
    - ❑ C. Ethanoic acid

3. Which of these will have the lowest pH?
    - ❑ A. 1 mol/dm^3 ethanoic acid
    - ❑ B. 1 mol/dm^3 hydrochloric acid
    - ❑ C. 2 mol/dm^3 hydrochloric acid

Taking it Further:
Volumes of Gases

Do Now

1. State the unit of volume in chemistry.
2. Convert 50 cm^3 to dm^3.
3. State the number of particles in 1 mole of a substance.
4. Calculate the relative formula mass of ammonia (NH_3).
5. Calculate the percentage by mass of hydrogen in ammonia.

Drill:

1. Calculate the relative formula mass of methane (CH_4).
2. Calculate the mass of 1 mole of methane.
3. Calculate the number of moles in 48 g of methane.

Read Now:

Avogadro's law states that one mole of any gas has the same volume. This is because one mole of any substance contains 6.02×10^{23} particles. For some gases, such as the Noble gases, 1 mole of gas contains 6.02×10^{23} atoms. For other gases, such as carbon dioxide or oxygen (O2), 1 mole of gas contains 6.02×10^{23} molecules. As the mole is the number of particles present, if there are the same number of particles present, they will occupy the same volume of space. This law applies if gases are at standard temperature and pressure, which is room temperature (20°C) and 1 atmosphere (atm) of pressure. You should remember from physics that temperature and pressure both affect the volume of a gas, so these must remain constant for 1 mole of two different gases to have the same volume.

1. State Avogadro's Law.
2. State the number of particles found in one mole of a substance.
3. Describe the conditions of standard temperature and pressure.
4. Describe the two factors that must remain constant for Avogadro's law to apply.

Reacting Gases

One mole of any substance contains the same number of _____

Room temperature is _____ and standard pressure is _____

One mole of any gas has a volume of _____

Volume = _____ x _____

Number of moles = _____

Drill

1. State room temperature.
2. State room pressure.
3. Explain what is meant by 'rtp'.
4. Define molar volume.
5. State the unit of volume.
6. State molar volume at rtp.
7. State the equation that links volume, molar volume and number of moles.

I: Calculating volume of a gas

Nitrogen reacts with hydrogen to form ammonia, according to the equation:

N_2 **(g)** + 3 H_2 **(g)** → 2 NH_3 **(g)**

Calculate the volume of ammonia that could be made from 100 cm^3 of nitrogen if hydrogen is in excess.

Mole ratio =

100 cm^3 of nitrogen : _____ cm^3 of ammonia

Calculate the volume of ammonia that could be made from 240 cm^3 of hydrogen if nitrogen is in excess.

Mole ratio =

240 cm^3 of hydrogen: _____cm^3 of ammonia

We: using volume of gas in an equation

Sodium reacts with chlorine to form sodium chloride, according to the equation:

2 Na **(s)** + Cl_2 **(g)** → 2 NaCl **(s)**

If 750 cm^3 of chlorine reacted with excess sodium, how many moles of sodium chloride would be formed?

number of moles= _____

number of moles = _____

number of moles = mol

Mole ratio =

number of moles of sodium chloride = mol

What mass of sodium chloride would be formed?

number of moles = $\frac{\text{mass}}{\text{Mr}}$ = _____ = mass = *g*

You: calculating volume of gas from an equation

Sodium hydroxide reacts with carbon dioxide according to the equation:

2 NaOH (s) + CO_2 (g) → Na_2CO_3 (s) + H_2O (l)

40 g of sodium hydroxide reacts completely with carbon dioxide. How many moles of sodium hydroxide react?

number of moles= _____ number of moles = — number of moles = mol

How many moles of carbon dioxide react?

Mole ratio =

number of moles of carbon dioxide = mol

What volume of carbon dioxide reacts?

number of moles= $\frac{\text{volume}}{\text{molar volume}}$

Exit Ticket

1. What is the volume of one mole of gas at rtp?
   - ❑ A. 22 dm^3
   - ❑ B. 24 dm^3
   - ❑ C. 6.02×10^{23} dm^3

2. Calculate the number of moles in 0.12 dm^3 carbon dioxide gas at rtp.
   - ❑ A. 0.0027 mol
   - ❑ B. 0.005 mol
   - ❑ C. 200 mol

3. What two factors must remain constant for 1 mole of two different gases to have the same volume?
   - ❑ A. Temperature and pressure
   - ❑ B. Temperature and mass
   - ❑ C. Pressure and mass

Independent Practice

Prior Knowledge Review: Relative Formula Mass and Percentage by Mass

Relative Formula Mass

Answer the following questions.

1. Circle the correct word to complete the sentence.

    a. Relative atomic mass can also be written as **M_r / A_r**

    b. Relative formula mass can also be written as **M_r / A_r**

    c. The relative atomic mass of an **element / compound** can be found using the Periodic Table

    d. The relative atomic mass can be found next to the chemical symbol, on a Periodic Table, and it is always the **bigger / smaller / top / bottom** number.

2. State the relative atomic mass for the following elements:

    a. Nitrogen

    b. Bromine

    c. Neon

    d. Thallium

    e. Vanadium

    f. Helium

    g. Hydrogen

    h. Oxygen

    i. Carbon

    j. Osmium

    k. Gold

    l. Copper

3. Calculate the relative formula mass of each of the following compounds. Show your working.
    a. Cl_2

b. H_2

c. H_2O

d. CO_2

e. HCl

f. $CuSO_4$

g. NaOH

h. Al_2O_3

i. $Zn(OH)_2$

j. $Mg(NO_3)_2$

k. $Ca(HCO_3)_2$

l. $(NH_4)_2SO_4$

4. Prove that the M_r of products = M_r of reactants using the following equation.
   (Ar: Mg = 24; Cu = 63.5; S = 32; O = 16)

   $Mg + CuSO_4 \rightarrow MgSO_4 + Cu$

5. A metal oxide has the formula MO, where M is the chemical formula for the metal and O is oxygen.
   The relative formula mass for this compound is 40.
   What is the metal?

Percentage Composition Calculation

$$\%\ by\ mass = \frac{A_r\ x\ number\ of\ atoms\ in\ a\ compound}{M_r\ of\ the\ compound} \times 100$$

Answer the questions below.

1. Calculate the percentage by mass of carbon in carbon monoxide, CO.

2. Calculate the percentage by mass of hydrogen in HCl.

3. Calculate the percentage composition of sodium in sodium chloride, NaCl.

4. Calculate the percentage composition of sodium in sodium hydrogen carbonate, $NaHCO_3$.

5. Calculate the percentage of oxygen in sodium hydrogen carbonate, $NaHCO_3$.

6. Calculate the percentage by mass of lithium in lithium hydroxide, LiOH.

7. Calculate the percentage by mass of hydrogen in lithium hydroxide, LiOH.

8. Which makes up the greater percentage by mass in lithium hydroxide (LiOH), oxygen or lithium? Show your working.

9. Calculate the percentage by mass of carbon in calcium carbonate, $CaCO_3$.

10. Calculate the percentage by mass of oxygen in potassium permanganate, $KMnO_4$.

Stretch:

11. In a sample of water with a mass of 10 g, what percentage of that mass is made of hydrogen atoms?

12. The percentage by mass of oxygen in a compound is 66.7%. The compound has the formula XO, where X is a metal and O is oxygen. What is the compound?

Mole Calculations

Section A:

1. State the definition of relative formula mass.

   _____

   _____

2. Which of these statements is correct?

   Tick one box.

   One mole of a substance contains 6.02×10^{23} particles ☐

   One mole of a substance always has the same mass ☐

   One mole of a substance will have the as many particles as its mass in grams ☐

3. What are the correct units for amount of substance?

   Tick one box.

   mol ☐

   g ☐

   g/mol ☐

4. In the box below, write the equation that links number of moles, mass and relative formula mass.

   ☐

Section B

Answer the following questions, showing all working:

5. Here is the equation for fermentation.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Glucose → Ethanol + Carbon dioxide

In an experiment 60 g of glucose were fermented.
(Ar: C = 12, H = 1, O = 16)

a. Describe the equation in words, include the word 'mole' in your answer.

_____
_____
_____

b. Calculate the relative formula mass of glucose ($C_6H_{12}O_6$).

_____
_____
_____

c. Calculate the amount of substance in 60g of glucose.

_____
_____
_____
_____

6. Calculate the **amount of substance** in the following.
(Ar: Ca = 40; Si = 28; Ag = 108; Cl = 35.5; K = 39; H = 1; O = 16; Li = 7)

   a. 40 g of Ca

   b. 14 g of Si

   c. 216 g Ag

   d. 35.5 g of Cl_2

   e. 14 g of KOH

   f. 12 g of LiH

7. Calculate the **mass** of the following.
(Ar: Mg = 24; Cl = 35.5; Fe = 56; Co = 59; O = 16; H = 1)
   a. 0.5 moles of Mg

b. 4 moles of Cl_2

c. 2 moles of Fe

d. 1 mole of $CoCl_2$

e. 0.5 moles of O_2

f. 0.5 moles $Mg(OH)_2$

Section C

8. A scientist is looking at the chemical reaction between magnesium and oxygen.

   a. State the word equation for the reaction that would occur between magnesium and oxygen.
   b. Draw the electronic configuration of an oxygen atom.
   c. State the type of bond that would be formed in this reaction. Explain your answer.
   d. Describe what happens to the atoms when magnesium and oxygen bond. You may wish to use a diagram.
   e. The scientist has 48 g of magnesium. Calculate the amount of substance they have.
   f. The scientist has 3 moles of oxygen. Calculate the mass of oxygen they have.

Prior Knowledge Review: Concentration

Unit Conversions Student Sheet

Convert each of the units to fill the blanks in the table.

seconds	minutes	hours
3600	60	1
60		0.16
	300	
2600		
		5
	540	
30		

g	kg
1000	1
5000	
15000	
	11
	0.5
	0.05
5	

cm^3	dm^3	L
1000	1	1
6000		
	5	
		0.5
	0.03	
500		
50		

Section A:

1. Choose the correct words from the box below to complete the sentence.

volume	grams	solution	mass	weight	amount

Concentration is the _____ of solute in a given _____ of solution.

2. What are the correct units for concentration?

Tick one box.

dm^3 ☐

g/dm^3 ☐

dm^3/g ☐

3. A student has three test tubes, each containing 100 cm^3 of water. They add different masses of salt to each. Which of these statements is correct?

Tick one box.

All the salt solutions will have the same concentration ☐

The salt solution with the greatest mass of salt dissolved will have the highest concentration ☐

The salt solution with the smallest mass of salt dissolved will have the highest concentration ☐

4. In the box below, write the equation that links concentration, mass and volume.

☐

5. A student has a solution which has a concentration of 0.5 g/dm^3. Which action would make the solution less concentrated?

Tick one box.

Adding more water ☐

Adding more solute ☐

Splitting the solution between two test tubes ☐

6. A person adds sugar to glass of water. Identify the solute, solvent and solution.

Solute: _____

Solvent: _____

Solution: _____

Section B

7. A student has two samples of sodium hydroxide solution. One has a concentration of 24 g/dm^3 and the other has a concentration of 12 g/dm^3. Both have a volume of 200 cm^3.
   a. Identify the sample with the higher concentration.

_____

   b. Explain what it means for one sample to be more concentrated than the other.

_____
_____
_____

   c. The student adds water to make the 24 g/dm^3 solution up to a volume of 400 cm3. Compare the concentrations of the samples now.

_____
_____
_____

8. Describe and explain how the concentration of a solution could be increased.

_____
_____
_____

9. Describe and explain how the concentration of a solution could be decreased.

_____
_____
_____

Show all working for the following questions:

10. Calculate the concentration (in g/dm^3) of:
    a. 40 g solute in 350 dm^3

_____
_____
_____

    b. 100 g solute in 77 dm^3

_____

c. 0.08 g solute in 20 cm^3

d. 90g solute in 780 cm^3

11. The mass of H_2SO_4 is 32.5 g and the volume of the solution is 0.400 dm^3. Calculate the concentration of the solution formed in g/dm^3.

12. A 750 cm^3 solution of sodium chloride contains 25 g of solute. Calculate the concentration of the solution.

13. Calculate the mass of solute in:

a. 25 cm^3 of a 2.3 g/dm^3 solution.

b. 250 cm^3 of a 71 g/dm^3 solution

c. 2.3 dm^3 of a 61 g/dm^3 solution

14. A solution of sodium chloride has a concentration of 400 g/dm^3. Calculate the mass of sodium chloride in 0.8 dm^3 of solution.

15. Using 83g of solute, how much water is needed to:
    a. Make a 34 g/dm^3 solution?

    b. Make a 0.1 g/dm^3 solution?

    c. Make a 83 g/dm^3 solution?

    d. Make a 79 g/dm^3 solution?

Section C

16. A person has eaten a big meal recently and has digested many large carbohydrates to produce glucose.
    a. Calculate the relative formula mass of glucose ($C_6H_{12}O_6$).
    b. Calculate the percentage by mass of carbon in glucose.
    c. State the substrate that is broken down to form glucose.
    d. Name the enzyme that catalyses (speeds up) this reaction.
    e. In the person's small intestine, there is 30 g of glucose in a 320 cm^3 solution. Calculate the concentration of glucose in g/dm_3.
    f. In a sample of blood from the person's bloodstream, there is 50 μg of glucose in 25 cm^3 of blood. Calculate the concentration of glucose in this blood sample.
    g. Compare the concentration of glucose in the small intestine and the bloodstream.
    h. Describe and explain what will happen to the glucose molecules.
    i. Describe two adaptations of the small intestine that make it well suited for this function.

Taking it Further: Calculating Concentration:

Section A:

1. Match the quantities below with their correct units.

Mass	mol
Number of moles	g/dm^3 or mol/dm^3
Volume	g
Concentration	dm^3

2. What is the correct relative formula mass for calcium hydroxide ($Ca(OH)_2$)?

   Tick one box.

   58 ☐

   74 ☐

   114 ☐

3. In the box below, write the equation that links concentration, mass and volume.

4. In the box below, write the equation that links concentration, number of moles and volume.

5. In the box below, write the equation that links number of moles, mass and relative formula mass.

Section B

Use a periodic table and show all working for the following questions:

6. 0.20 moles of NaOH is dissolved in 250 cm^3 of water.
    a. Calculate the concentration in mol/dm^3.

b. Calculate the concentration in g/dm^3.

7. 5.0 g of KNO_3 is dissolved in 100 cm^3 of water.
    a. Calculate the concentration in g/dm^3.

b. Calculate the concentration in mol/dm^3 .

8. Calculate the concentration of the following solutions in **g/dm^3** .
    a. 0.100 mol/dm^3 NaOH.

b. 0.250 mol/dm^3 CH_3COOH

c. 1.50 mol/dm^3 HNO_3

9. The concentration of ethanoic acid (CH_3COOH) in a bottle of vinegar is 0.85 mol/dm^3.

Calculate the mass of ethanoic acid that would be in 200 cm^3 of this vinegar.

10. A scientist has a bottle of 2 mol/dm^3 copper sulfate solution.
    a. Describe and explain how they could increase the concentration of the solution.

    b. Describe and explain how they could decrease the concentration of the solution.

Section C

11. Normal blood glucose concentration is below 140 mg/dm^3. Glucose has the formula $C_6H_{12}O_6$.
    a. Calculate normal blood concentration in $mmol/dm^3$.
    b. Glucose is transported around the body in blood. Describe the different components of blood and their functions.
    c. Explain the importance of glucose for cells.
    d. State the word equation for aerobic respiration.
    e. Explain the difference between aerobic and anaerobic respiration.
    f. Describe and explain the changes that occur to the body during exercise.

Taking it Further: Calculating Unknown Concentration

Section A:

For any calculations, round final answers to two decimal places.

1. Calculate the number of moles in the following masses of substance:
   a. 21 g of hydrogen gas (H_2)
   b. 60 g of carbon
   c. 88 g of lithium
   d. 100 g of calcium carbonate ($CaCO_3$)
   e. 1 kg of glucose ($C_6H_{12}O_6$)

2. What is the mass of the following?
   a. 5 moles of CO_2
   b. 0.5 moles of HCl
   c. 0.005 moles of NaOH
   d. 11 moles of BeCl
   e. 1 mole of H_2

3. Calculate the number of moles of solute that must be dissolved to make the following solutions:
   a. 200 dm^3 of 1 mol/dm^3
   b. 150 dm^3 of 5 mol/dm^3
   c. 2 litres of 0.25 mol/L
   d. 5 cm^3 of 10 mol/dm^3
   e. 100 cm^3 of 1 mol/dm^3

4. Calculate the volume of each of the following solutions of lithium chloride (LiCl) in dm^3.
   a. 1 mol/dm^3 solution containing 3 moles of solute
   b. 2 mol/dm^3 of solution containing 1 mole of solute
   c. 0.05 mol/dm^3 of solution containing 5 moles of solute
   d. 0.002 mol/dm^3 of solution containing 0.5 moles of solute
   e. 0.125 mol/dm^3 of solution containing 12 moles of solute

5. Convert each of the answers to question 5 to cm^3.

6. The equations below describe neutralisation reactions. State the mole ratio of acid:alkali in these reactions.
   a. $NaOH + HCl \rightarrow NaCl + H_2O$
   b. $HBr + KOH \rightarrow KBr + H_2O$
   c. $HNO_3 + KOH \rightarrow KNO_3 + H_2O$
   d. $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$
   e. $Al(OH)_3 + 3HNO_3 \rightarrow Al(NO_3)_3 + 3H_2O$

Section B

7. Calculate the mass of substance needed to make each of the following solutions:
   a. 0.25 dm^3 of sodium nitrate solution ($NaNO_{3(aq)}$), with a concentration of 0.3 mol/dm^3
   b. 0.2 dm^3 of hydrochloric acid solution, with a concentration of 0.5 mol/dm^3
   c. 50 cm^3 of sodium hydroxide solution with a concentration of 5 mol/dm^3
   d. 200 cm^3 of sulfuric acid, with a concentration of 0.25 mol/dm^3
   e. 1 L of $NaOH_{(aq)}$ with a concentration of 0.2 mol/dm^3
8. The equation below describes a neutralisation reaction:

$HF + KOH \rightarrow KF + H_2O$

a. State the mole ratio of acid: alkali in this reaction
b. A scientist carried out this reaction with 0.025 dm^3 of potassium hydroxide, with a concentration of 0.05 mol/dm^3. Calculate the number of moles of potassium hydroxide that reacted.
c. Calculate the number of moles of hydrogen fluoride that reacted.
d. Calculate the concentration of hydrogen fluoride in this reaction, if 0.02 dm^3 of hydrogen fluoride reacted.

9. A student carried out the following neutralisation reaction:
$H_2SO_4 + 2LiOH \rightarrow Li_2SO_4 + 2H_2O$
   a. State the mole ratio of acid: alkali in this reaction
   b. A scientist carried out this reaction with 0.5 dm^3 of lithium hydroxide, which had a concentration of 0.01 mol/dm^3. Calculate the number of moles of lithium hydroxide that reacted.
   c. Calculate the number of moles of sulfuric acid that reacted.
   d. Describe what a student would observe if they added a few drops of universal indicator solution to the lithium hydroxide solution.
   e. Calculate the concentration of sulfuric acid in this reaction, if 0.003 dm^3 of sulfuric acid reacted.

10. 35.0 cm^3 of 0.100 mol/dm^3 sodium hydroxide solution is exactly neutralised by 20.0 cm^3 of a dilute solution of hydrochloric acid. Calculate the concentration of the hydrochloric acid solution.

11. 25.0 cm^3 of 0.400 mol/dm^3 sodium hydroxide solution is exactly neutralised by 25.0 cm^3 of a dilute solution of sulfuric acid. Calculate the concentration of the sulfuric acid solution.

(HT) Amount of Substance in Equations

Section A:

1. Match the quantities below to their correct units.

Mass	no units
M_r	mol
Number of moles	g

2. In the box below, write the equation that links number of moles, mass and relative formula mass.

3. Define relative formula mass.

_____

_____

For any calculations, round final answers to 2 decimal places.

4. Calculate the relative formula mass of the following elements and compounds.
   a. Oxygen (O_2)
   b. Ammonia (NH_3)
   c. Methane (CH_4)
   d. Sodium hydroxide (NaOH)
   e. Ammonium hydroxide (NH_3OH)
   f. Lithium carbonate (Li_2CO_3)

5. Calculate the number of moles in:
   a. 34 g of ammonia

_____

_____

   b. 120 g of sodium hydroxide

_____

_____

   c. 100 g of lithium carbonate

_____

_____

6. Calculate the mass of:

a. 0.25 moles of methane

b. 0.75 moles of ammonium hydroxide

c. 0.1 moles of oxygen

Section B

7. Magnesium reacts with hydrochloric acid according to the equation:

$$Mg\ (s) + 2\ HCl\ (aq) \rightarrow 2\ MgCl_2\ (aq) + H_2\ (g)$$

a. Explain what is meant by the state symbol (aq).

b. Calculate the mass of magnesium chloride that could be made from 50 g of magnesium.

8. Titanium metal can be obtained from a reaction between molten magnesium and titanium chloride. The equation for the reaction is:

$$TiCl_4\ (l) + 2\ Mg\ (l) \rightarrow 2\ MgCl_2\ (l) + Ti\ (s)$$

a. Explain what is meant by the term molten.

b. Calculate the mass of titanium chloride needed to produce 800 g of titanium.

9. Propane is a fuel that can be burned to release energy. The equation for the reaction is:

$$C_3H_8\ (g) + 5\ O_2\ (g) \rightarrow 3\ CO_2\ (g) + 4\ H_2O\ (l)$$

a. Calculate the mass of carbon dioxide that is produced when 250 g of propane is burned.

_____
_____
_____
_____
_____
_____

b. Explain why the reaction would need to be carried out in a closed vessel to verify the mass of carbon dioxide produced.

_____
_____

Section C

10. Aluminium can be extracted from aluminium oxide by electrolysis. The equation for the process is:

$$2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2$$

a. Calculate the relative formula mass of aluminium oxide.
b. Calculate the mass of aluminium oxide required to produce 1 kg of aluminium.
c. Explain what has to happen to the aluminium oxide before it can be electrolysed.
d. Describe what happens at the positive electrode.
e. Write the half equation for this reaction.
f. Explain why electrolysis is not used to extract less reactive metals.

(HT) Limiting Reactants

Section A:

1. Which is the correct definition of a limiting reactant?
   Tick one box.
   The reactant that will make less product ☐
   The reactant that will run out first ☐
   The reactant that there is more of ☐

2. How can the reactant that is not the limiting reactant be described?
   Tick one box.
   There is too much of it ☐
   It is in the correct mole ratio ☐
   It is in excess ☐

3. Balance this equation:

   $$Ca + O_2 \rightarrow CaO$$

4. Explain why chemical equations have to be balanced.

   _____

   _____

5. Carbon reacts with oxygen, which can be represented by the following equation:

   $$C + O_2 \rightarrow CO_2$$

   a. Calculate the relative formula mass of CO_2.

   _____

   b. If there are 0.5 moles of carbon and 0.1 moles of oxygen present, which is the limiting reactant?

   _____

For any calculations, round final answers to 2 decimal places.

Section B

6. A scientist has a mixture of aluminium and iron oxide. It contains 1.5 kg of aluminium and 2.8 kg of iron oxide.
   The equation for the reaction is:

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

a. Use calculations to identify which is the limiting reactant.

b. Use your answer to calculate the maximum mass of iron that could be obtained.

7. Magnesium can be used to displace copper from its ore. The equation for the reaction is:

$$Mg + CuO \rightarrow MgO + Cu$$

a. Use calculations to identify which is the limiting reactant when a reaction mixture contains 750 g of magnesium and 750 g of copper oxide.

b. Use your answer to calculate the maximum mass of copper that could be obtained.

8. Iron can be used to displace copper from copper sulfate solution. The equation for the reaction is:

$CuSO_4$ (aq) + Fe (s) → Cu (s) + $FeSO_4$ (aq)

Calculate the mass of iron needed to displace all the copper from 100 cm^3 of copper sulfate solution.

The concentration of the copper sulfate solution is 50 g/dm^3.

Section C

9. The chemical equation for aerobic respiration is:

$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$$

   a. Calculate the relative formula mass of glucose.
   b. A muscle tissue contains 40 μg of glucose and 75 μg of oxygen. Calculate the number of moles of each present.
   c. Identify which is the limiting reactant.
   d. Calculate the mass of water that could be made.
   e. Explain what happens when the muscle tissue cannot get enough oxygen.
   f. Compare the two processes of respiration.

Prior Knowledge Review: Acid Reactions

Section A:

1. Complete the table to show the salts that would be produced in a reaction between each acid and each alkali/base.

Name of acid	**Name of alkali/base**	
	Sodium hydroxide	Copper oxide
Hydrochloric Acid		
Nitric Acid		
Sulfuric Acid		

2. Complete the following word equations:

a. nitric acid + _____ → potassium nitrate + water

b. _____ + sodium hydroxide → sodium sulfate + water

c. Calcium hydroxide + _____ → calcium nitrate + _____

d. Magnesium oxide + _____ → _____ sulfate + _____

3. Complete the table to show the chemical names and their chemical formulae.

Chemical name	**Chemical Formula**
Hydrochloric Acid	
Nitric Acid	
	H_2SO_4
	H_2
Calcium chloride	$CaCl_2$
Sodium Hydroxide	NaOH
	NaCl
Copper carbonate	$CuCO_3$
Copper sulfate	$CuSO_4$
	CuO
Potassium carbonate	K_2CO_3
Potassium nitrate	KNO_3

Section B

4. Use the chemical formulae in the table above to complete the word equation for each reaction and write a balanced symbol equation.

   a. Calcium + hydrochloric acid →

   b. Hydrochloric acid + sodium hydroxide →

   c. Sulfuric acid + copper carbonate →

   d. Hydrochloric acid + copper oxide →

   e. Nitric acid + potassium carbonate →

Higher Tier only

5. Copper reacts with hydrochloric acid.

   a. Write the word equation for this reaction.

   _____

   b. Write the **balanced** chemical symbol equation for this reaction.

   _____

   c. Cross out any spectator ions in the equation in part (b)

   d. Write the ionic equation for this reaction.

   _____

   e. Identify the species that has been oxidised and the species that has been reduced.

   _____

6. Magnesium reacts with sulfuric acid.

   a. Write the word equation for this reaction.

   _____

   b. Write the **balanced** chemical symbol equation for this reaction.

_____

c. Cross out any spectator ions in the equation in part (b)

d. Write the ionic equation for this reaction.

_____

e. Identify the species that has been oxidised and the species that has been reduced.

_____

7. Iron reacts with hydrochloric acid.

a. Write the word equation for this reaction.

_____

b. Write the **balanced** chemical symbol equation for this reaction.

_____

c. Cross out any spectator ions in the equation in part (b)

d. Write the ionic equation for this reaction.

_____

e. Identify the species that has been oxidised and the species that has been reduced.

_____

Acids, Alkalis and Neutralisation

Section A:

1. Which ion do acids produce in aqueous solutions?
   Tick one box.

   H^+ ☐

   OH^- ☐

   H^- ☐

2. Which ion do alkalis produce in aqueous solutions?
   Tick one box.

   H^+ ☐

   OH^- ☐

   H^- ☐

3. Add labels to this pH scale to show the pH of acidic, alkaline and neutral solutions.

1	2	3	4	5	6	7	8	9	10	11	12	13	14

4. Which colour would Universal Indicator turn when added to an alkaline solution?
   Tick one box.

   Red/orange ☐

   Green ☐

   Purple/blue ☐

5. Which colour would Universal Indicator turn when added to an acidic solution?
   Tick one box.

   Red/orange ☐

   Green ☐

   Purple/blue ☐

Section B

6. Lots of different everyday substances can be classified as acids, bases or salts. Car batteries contain sulfuric acid, some cleaning products contain sodium hydroxide and table salt contains sodium chloride.

    a. Explain how Universal Indicator could be used to identify each of these substances.

_____
_____
_____
_____
_____
_____

    b. Describe another way that the pH of each substance could be measured.

_____
_____

    c. Explain the difference between a base and an alkali.

_____
_____

Sodium chloride can be made from a reaction between sodium hydroxide and hydrochloric acid.

    d. Name this type of reaction.

_____

    e. Write a balanced chemical equation for this reaction.

_____ (aq) + _____(aq) → _____ (aq) + _____ (l)

    f. What does the state symbol (aq) mean?

_____

    g. Describe how the salt could be separated from the other product of this reaction.

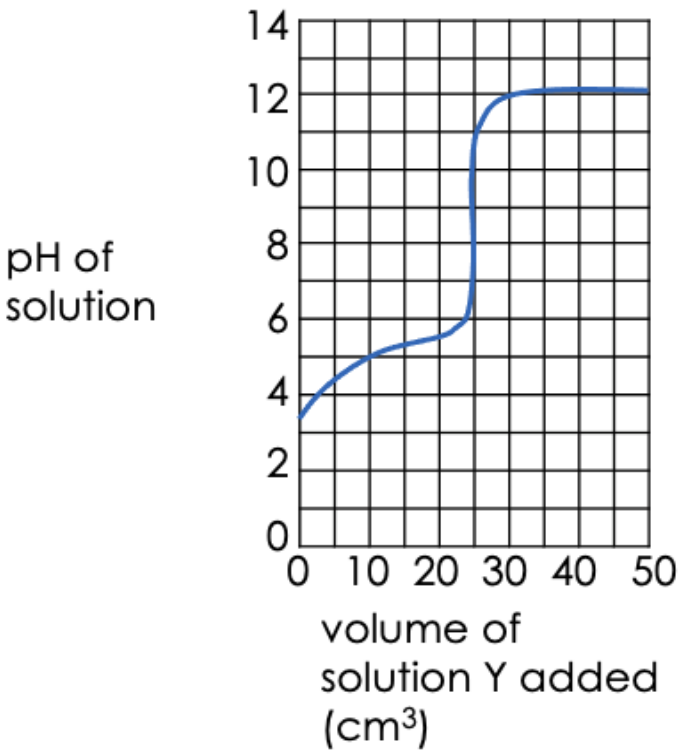
_____
_____
_____
_____

    h. A scientist wants to make sodium sulfate instead of sodium chloride. Which acid should they use?

_____

    i. Determine the chemical formula of sodium sulfate.

7. A student added solution Y to a beaker containing solution X. The graph shows how the pH of the resulting solution changed.



   a. What was the pH of solution X before solution Y was added to it?

   b. Was solution Y acidic, alkaline or neutral? Explain your answer.

   c. What volume of solution Y was needed to completely react with solution X?

8. Explain what happens when an acid reacts with an alkali in terms of ions and molecules.

9. Complete the word equation for each reaction and write a balanced symbol equation.

   a. Barium hydroxide + hydrochloric acid →

   b. Sulfuric acid + sodium hydroxide →

c. Lithium hydroxide + nitric acid →

10. Calculate the relative formula mass of each of the salts in Q9.

Section C

11. Sodium hydroxide reacts with hydrochloric acid.
    a. What is the alkali in this reaction?
    b. Write a word equation for this reaction.
    c. Write a balanced symbol equation for this reaction.
    d. Write the ionic equation for neutralisation.
    e. Name the salt produced in this reaction.
    f. Calculate the relative formula mass of this salt.
    g. Calculate the percentage by mass of sodium in this salt.
    h. Compare the physical properties of the elements that make up this salt with the properties of the salt as a compound.
    i. Identify the type of bonding in this salt.
    j. Draw a diagram to show how this bonding takes place.

Taking it Further: Acid-Alkali Titration

A student investigates the volume of hydrochloric acid solution that reacts with 25.0 cm^3 of sodium hydroxide solution.

a. Which piece of equipment could the student use to measure 25.0 cm^3 of sodium hydroxide most accurately?
Tick (✓) **one** box.

Beaker	☐
Evaporating basin	☐
Pipette	☐
Test tube	☐

This is the method used:

- Pipette 25.0 cm^3 of sodium hydroxide solution into a conical flask.
- Add a few drops of thymol blue indicator to the sodium hydroxide solution.
- Thymol blue is blue in alkali and yellow in acid.
- Add hydrochloric acid solution from a burette until the end-point was reached.

b. Explain what would happen at the end-point of this titration. You should mention the acid, the alkali and the indicator in your answer.

_____
_____
_____
_____
_____
_____

c. Complete the word equation for the reaction:

Sodium hydroxide + hydrochloric acid → _____ + _____

d. Explain why a pipette is used to measure the volume of sodium hydroxide solution but a burette is used to measure the volume of hydrochloric acid.

_____
_____

The pipette was labelled as 25.0 ± 0.05 cm^3.

e. State the resolution of the pipette.

f. Calculate the percentage uncertainty in the volume measured using the pipette. Use the equation:

$$\text{percentage uncertainty} = \frac{\text{uncertainty}}{\text{volume measured}} \times 100$$

g. The higher the concentration of a sample of hydrochloric acid, the greater the volume of sodium hydroxide will be needed to neutralise the sample of acid.

Describe how titrations could be used to find out which of two samples, X or Y, is a more concentrated acid.

Taking it Further: Titration Calculations

Section A:

1. Match each quantity below with the correct units.

Concentration	g/dm^3
Mass	dm^3
Volume	g
Amount of substance	mol
	mol/dm^3

2. Which of these is the correct definition of concentration?
   Tick one box.

   The amount of solute per unit volume of solvent ☐

   The amount of space a solution takes up ☐

   The amount of substance in a solution ☐

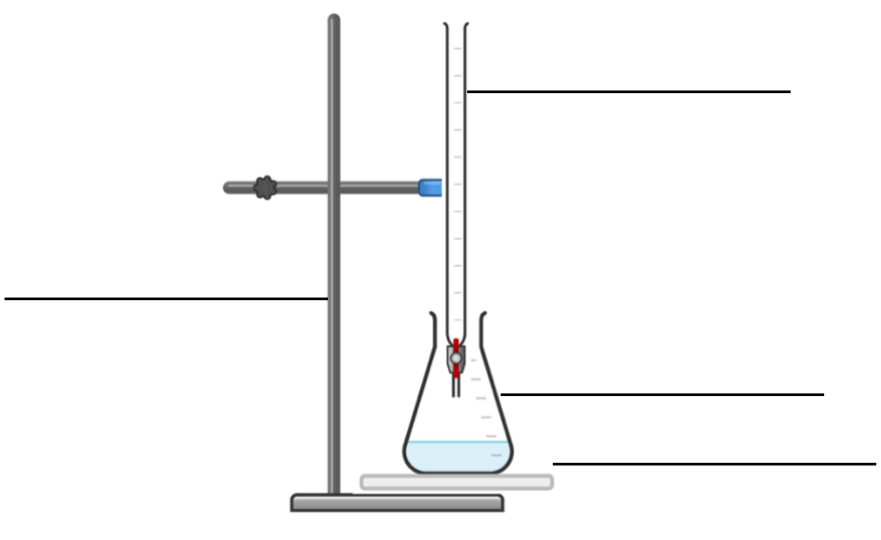
3. Which is the correct function of an indicator in a titration?
   Tick one box.

   To measure the concentration of an unknown reactant ☐

   To signify the end point of a reaction ☐

   To speed up the rate of reaction ☐

4. Label the following pieces of apparatus that are involved in a titration.



Section B

5. A student is investigating the concentration of a sample of sodium hydroxide solution using titration. They use citric acid solution as the acid and phenolphthalein as the indicator.
   a. Explain why phenolphthalein is used rather than Universal Indicator.

_____
_____
_____

The equation for the reaction is:

$$3\ NaOH + C_6H_8O_7 \rightarrow C_6H_5O_7Na_3 + 3\ H_2O$$

   b. Identify the chemical formula for citric acid.

_____

   c. The student required 12.5 cm^3 of 0.1 mol/dm^3 citric acid to neutralise 20 cm^3 of sodium hydroxide solution.
   Calculate the concentration of the sodium hydroxide solution in mol/dm^3.

_____
_____
_____
_____
_____
_____

   d. Explain how the student could make their results more reliable.

_____
_____
_____

6. Another student uses a similar method to find the concentration of an unknown citric acid solution using 25 cm^3 of sodium hydroxide. The equation for the reaction is:

$$3\ NaOH + C_6H_8O_7 \rightarrow C_6H_5O_7Na_3 + 3\ H_2O$$

The table below shows the student's results.

Titration	**1**	**2**	**3**	**4**	**5**
Volume of citric acid solution (cm^3)	12.50	12.15	11.75	12.10	12.10

   a. State the word used to describe the volume of citric acid.

b. 3 of these results are concordant. Explain what is meant by concordant results.

c. Use the concordant results to calculate the mean volume of citric acid required. Write your answer to 2 decimal places.

d. The concentration of sodium hydroxide was 0.15 mol/dm^3. Calculate the concentration of citric acid solution. Write your answer to 2 significant figures.

7. A student carried out a titration to determine the concentration of a sulfuric acid sample. They found that 27.1 cm^3 of sulfuric acid was needed to neutralise 25 cm^3 of 0.1 mol/dm^3 of sodium hydroxide.
   The equation for the reaction is:

$$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$$

   a. Calculate the concentration of the sulfuric acid sample.

   b. Calculate the mass of sodium hydroxide that would have been dissolved to produce 25 cm^3 of 0.1 mol/dm^3 solution.

_____
_____
_____
_____
_____

Section C

8. Scientists can use titration to determine the concentration of sulfuric acid in a sample of rainwater to provide evidence of acid rain.
    a. Briefly describe a method that could be used to determine the concentration of sulfuric acid in a rainwater sample.
    b. Describe how acid rain is formed.
    c. Suggest some environmental impacts of acid rain.
    d. One of the main causes of acid rain is the burning of fossil fuels. Explain what fossil fuels are.
    e. Suggest why people continue to burn fossil fuels even though they are aware of the environmental consequences.

(HT) Strong and Weak Acids

Section A:

1. Which ion do acids produce in aqueous solutions?
   Tick one box.
   H^+ ☐
   OH^- ☐
   H^- ☐

2. Which of these is a strong acid?
   Tick one box.
   Citric acid ☐
   Ethanoic acid ☐
   Nitric acid ☐

3. Acids react with alkalis. What kind of reaction is this?
   Tick one box.
   Redox ☐
   Combustion ☐
   Decomposition ☐
   Neutralisation ☐

4. A student has a sample of hydrochloric acid. Which is likely to be the pH?
   Tick one box.
   pH 3 ☐
   pH 7 ☐
   pH 10 ☐

Section B

5. A scientist has a sample of concentrated citric acid.
   a. Citric acid is a weak acid. Explain what this means.

   _____
   _____
   _____

   b. Explain how an acid can be described as concentrated and weak.

_____
_____
_____

6. Hydrogen chloride dissolves in water to form hydrochloric acid. Hydrogen chloride molecules all ionise in water.
   Ethanoic acid also dissolves in water. Only a small fraction of ethanoic acid molecules ionise in water.

   a. 0.5 g of hydrogen chloride is dissolved in to make 0.5 dm^3 of solution.
      Calculate the concentration of this solution.

_____
_____
_____

   b. Which correctly describes the solution that has been made?
   Tick one box.

   A concentrated solution of strong acid ☐

   A dilute solution of strong acid ☐

   A concentrated solution of weak acid ☐

   A dilute solution of weak acid ☐

   c. Explain how the concentration of the solution could be increased without changing the amount of acid.

_____
_____
_____

   d. Which of these solutions would have the lowest pH?
   Tick one box.

   0.5 mol/dm^3 hydrochloric acid solution ☐

   0.5 mol/dm^3 ethanoic acid solution ☐

   2.0 mol/dm^3 hydrochloric acid solution ☐

   2.0 mol/dm^3 ethanoic acid solution ☐

Hydrochloric acid reacts with calcium hydroxide. This reaction can be represented with the following equation.

____ HCl + _____ $Ca(OH)_2$ → _____ $CaCl_2$ + _____ H_2O

e. Balance this equation.

f. Name the salt produced in this reaction.

_____

g. Calculate the mass of salt made when 84 g of calcium hydroxide reacts with excess acid.

_____
_____
_____

h. This question is for Chemistry only.
Ethanedioic acid ($H_2C_2O_4$)is a solid that can be dissolved to make a solution. Calculate the mass of ethanedioic acid required to produce 150 cm^3 of solution with a concentration of 0.2 mol/dm^3.

_____
_____
_____
_____
_____

7. Explain the factors that affect the pH of an acid.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Section C

8. A scientist has added sulfuric acid to water in a beaker.
    a. Is this solution a compound or a mixture? Explain your answer.
    b. Describe and explain a method the scientist could use to separate the water from the acid different acid solutions.
    c. Is sulfuric acid a strong acid or a weak acid? Explain your answer.
    d. State the chemical formula for sulfuric acid.
    e. Calculate the relative formula mass for sulfuric acid.
    f. Calculate the percentage by mass of hydrogen in sulfuric acid.
    g. Is sulfuric acid solution likely to conduct electricity? Explain your answer.

Taking it Further: Volumes of Gases

Section A:

1. What are the conditions of rtp?

   Tick one box.

   Room temperature (22 °C) and 2 atm of pressure ☐

   Room temperature (22°C) and 1 atm of pressure ☐

   Room temperature (20 °C) and 1 atm of pressure ☐

2. What is the molar volume of a gas at rtp?

   Tick one box.

   20 dm^3 ☐

   22 dm^3 ☐

   24 dm^3 ☐

3. In the box below, write the equation that links number of moles, volume and molar volume.

   ☐

4. State the two factors that must remain constant for 1 mole of two different gases to occupy the same volume.

   _____

   _____

Section B

Use a periodic table and show all working for the following questions:

5. Assuming rtp, calculate the volume of:
   c. 2 mol of CO_2.

   _____

   _____

d. 0.25 mol of ammonia (NH_3).

6. Assuming rtp, calculate the amount of substance present in:.
   c. 0.75 dm^3 of steam.

   d. 200 cm^3 of hydrogen.

7. A scientist reacts hydrochloric acid with lithium hydroxide.
   a. Name the salt that would be formed in this reaction.

   b. Write a balanced symbol equation for this reaction.

   c. Describe a method that could be used to obtain crystals of the salt produced in this reaction.

   d. The scientist then makes zinc chloride by heating zinc in chlorine gas. The equation for the reaction is shown below:

$$Zn\ (s) + Cl_2\ (g) \rightarrow ZnCl_2\ (s)$$

   Calculate the volume of chlorine needed to react completely with 11 g of zinc.

8. Aluminium oxide can be electrolysed according to the following equation:

$$Al_2O_3\ (s) \rightarrow 4\ Al\ (s) + 3\ O_2\ (s)$$

   a. Calculate the mass of aluminium that would be produced when 800 kg of aluminium is completely electrolysed.

   b. Calculate the volume of oxygen that would be produced when 800 kg of aluminium is completely electrolysed.

Section C

9. Avogadro's law states that equal volumes of gases, at the same temperature and pressure, have the same number of molecules.
   g. State molar volume at rtp.
   h. Compare the movement of particles in a solid and in a gas.
   i. Explain what causes gas pressure.
   j. Describe and explain the relationship between temperature of a gas and pressure.
   k. Describe and explain the relationship between volume of a gas and pressure.
   l. 2 dm^3 of oxygen gas at 27 Pa of pressure is compressed to a quarter of its original volume. Calculate the pressure at the new volume.