

# Student Booklet

## C4.3 Quantitative Chemistry Combined Science

Science  
**Mastery**

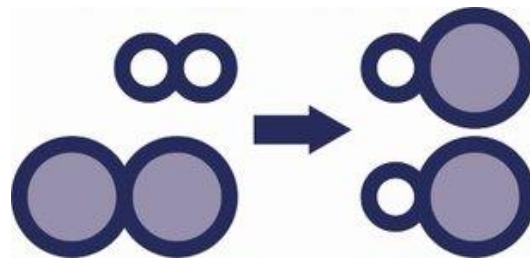


Ark**Curriculum+**

# 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 products 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.

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.



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.



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  $\rightarrow$  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<sup>3</sup> solution.

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

Tick (✓) **one** box.

A. 0.2 g/dm<sup>3</sup>

☐

B. 0.005 g/dm<sup>3</sup>

☐

C. 200 g/dm<sup>3</sup>

☐

6. Choose the relative formula mass of CO<sub>2</sub>.

(Ar: C = 12; O = 16)

[1]

A. M<sub>r</sub> = 44

☐

B. M<sub>r</sub> = 28

☐

C. M<sub>r</sub> = 56

☐

7. Choose the most appropriate equipment for accurately measuring 10 cm<sup>3</sup> water. [1]

Tick (✓) **one** box.

A. 10 cm<sup>3</sup> measuring cylinder

☐

B. 10 cm<sup>3</sup> beaker

☐

C. 10 cm<sup>3</sup> 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<sup>3</sup> to cm<sup>3</sup>. [1]

Tick (✓) **one** box.

A. 1200 cm<sup>3</sup>

☐

B. 0.012 cm<sup>3</sup>

☐

C. 12000 cm<sup>3</sup>

☐

12. Choose the relative formula mass of (NH<sub>4</sub>)<sub>3</sub>PO<sub>4</sub>.

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

Tick (✓) **one** box.

A. M<sub>r</sub> = 123

☐

B. M<sub>r</sub> = 121

☐

C. M<sub>r</sub> = 149

☐

D. M<sub>r</sub> = 144

13. 300 g of H<sub>2</sub>SO<sub>4</sub> is dissolved in water to make 500 cm<sup>3</sup> of solution.

Choose the concentration of this solution. [1]

Tick (✓) **one** box.

A. 600 g/cm<sup>3</sup>

☐

B. 0.6 g/cm<sup>3</sup>

☐

C. 1.66 g/cm<sup>3</sup>

☐

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

Tick (✓) **one** box.

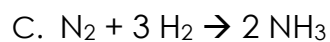
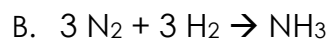
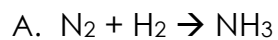
- A. Copper and sulfate  
B. Copper oxide and sulfuric acid  
C. Copper sulfide and oxygen

☐  
☐  
☐

15. Choose which of the symbol equations below is balanced.

[1]

Tick (✓) **one** box.


☐  
☐  
☐

**15**

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

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:  
 $\text{CaCO}_3$  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  **$A_r$**
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  **$M_r$**
7. For example, the  $M_r$  of  $\text{CaCO}_3$  is  $40+12+(16 \times 3) = 100$
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  **$6.02 \times 10^{23}$**  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:

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

18. This equation can also be written as:

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

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:  

$$\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$$
 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<sup>+</sup>)** in aqueous solutions
33. Aqueous solutions of **alkalis** contain **hydroxide ions (OH<sup>-</sup>)**
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  $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{H}_2\text{O}(\text{l})$

### 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<sup>+</sup> ions** in a solution, the **lower the pH**
43. The higher the concentration of OH<sup>-</sup> 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<sup>+</sup> ions
47. In a **concentrated** acid, **few** or no **water molecules** are mixed with the acid molecules. This means the concentration of H<sup>+</sup> 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<sup>3</sup>, dm<sup>3</sup>, m<sup>3</sup>, L or mL.
52. 1 dm<sup>3</sup> is equal to 1 L and equal to 1000 cm<sup>3</sup>
53. To convert from dm<sup>3</sup> to cm<sup>3</sup> the number should be multiplied by 1000
54. To convert from cm<sup>3</sup> to dm<sup>3</sup> 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<sup>3</sup> (**g/dm<sup>3</sup>**)
56. The mass in grams of solute in a given volume of solution can be calculated from its concentration in g/dm<sup>3</sup>
57. The equation that links concentration, mass of solute and volume is:

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

# Glossary

<b>Acid</b>	A substance that produces $\text{H}^+$ ions in aqueous solutions. <i><b>Acids</b> can be neutralised by alkalis.</i>
<b>Alkali</b>	A substance that produces $\text{OH}^-$ ions in aqueous solutions. <i>An <b>alkali</b> is a soluble base.</i>
<b>Aqueous solution</b>	A solution in which the solvent is water. <i>Many chemical reactions take place in <b>aqueous solutions</b>.</i>
<b><math>A_r</math></b>	This is the symbol for relative atomic mass. <i>See <b>relative atomic mass</b>.</i>
<b>Avogadro's number</b>	The constant or number that shows how many particles, molecules, atoms, or ions there are in 1 mole of a substance. <i><b>Avogadro's number</b> is <math>6.02 \times 10^{23}</math>.</i>
<b>Chemical formula</b>	A series of chemical symbols showing the number of atoms of each element in a compound. <i>The <b>chemical formula</b> for Magnesium Oxide is <math>\text{MgO}</math>.</i>
<b>Coefficient</b>	The 'big' number or balancing numbers in front of a chemical formula in an equation. <i>In the equation <math>2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}</math>, the <b>coefficient</b> in front of magnesium is 2.</i>
<b>Compound</b>	A substance made up of two or more different elements chemically bonded together. <i>Water is a <b>compound</b> of hydrogen and oxygen.</i>
<b>Concentration</b>	The mass of solute dissolved in a given volume of solvent <i>The <b>concentration</b> of the copper sulphate solution was <math>0.1 \text{ g/cm}^3</math></i>
<b>Concentrated</b>	If a solution is concentrated, there is a large mass of solute in a given volume of solvent. <i>The saltwater solution was <b>concentrated</b> because lots of salt was added to a small volume of water.</i>

<b>Conservation of Mass</b>	<p>The law of conservation of mass states that the total mass of reactants in any chemical reaction equals the total mass of products</p> <p><i>5 g of iron and sulfur reacted together to make 5 g of iron sulfide. This demonstrates the Law of <b>Conservation of Mass</b>.</i></p>
<b>Dilute</b>	<p>To decrease the concentration of a liquid by mixing it with water or another liquid.</p> <p><i>I plan to <b>dilute</b> the acid by adding more water.</i></p>
<b>Dissociate</b>	<p>When an acid or alkali splits into its ions in solution.</p> <p>Hydrochloric acid <b>dissociates</b> in solution:</p> <p><math>\text{HCl (aq)} \rightarrow \text{H}^+ \text{ (aq)} + \text{Cl}^- \text{ (aq)}.</math></p>
<b>Element</b>	<p>A substance made of only one type of atom.</p> <p><i>Oxygen is an example of an <b>element</b>.</i></p>
<b>Excess</b>	<p>The reactant that is not used up in a reaction, so some is left over.</p> <p><i>When magnesium burns in <b>excess</b> oxygen, the magnesium is used up but the oxygen is not.</i></p>
<b>Ionise</b>	<p>Another way to describe dissociation, or the formation of ions. When an acid or alkali splits into its ions in solution.</p> <p>Hydrochloric acid <b>ionises</b> in solution:</p> <p><math>\text{HCl (aq)} \rightarrow \text{H}^+ \text{ (aq)} + \text{Cl}^- \text{ (aq)}.</math></p>
<b>Limiting reactant</b>	<p>The reactant that is used up in a reaction, so limits the amount of product that can be made.</p> <p><i>When magnesium burns in excess oxygen, the magnesium is the <b>limiting reactant</b>.</i></p>
<b>Mass</b>	<p>The amount of matter in a substance.</p> <p><i>In physics, we measure mass in kg but in chemistry we often use smaller masses, so we can measure <b>mass</b> in g instead.</i></p>
<b>Molar ratio</b>	<p>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.</p> <p><i>In the equation <math>2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}</math>, the <b>molar ratio</b> of magnesium to oxygen is 2:1.</i></p>

<b>Mole</b>	<p>The amount of substance that contains <math>6.02 \times 10^{23}</math> particles.</p> <p>1 <b>mole</b> of carbon dioxide contains the same number of molecules as 1 mole of oxygen or 1 mole of ammonia.</p>
<b>Molecule</b>	<p>A small group of non-metal atoms chemically bonded together.</p> <p>Oxygen gas is made up of many oxygen <b>molecules</b>, each with the chemical formula <math>O_2</math>.</p>
<b>M<sub>r</sub></b>	<p>This is the symbol for relative formula mass.</p> <p>See <b>relative formula mass</b>.</p>
<b>Neutralisation</b>	<p>A chemical reaction in which an acid and a base react with each other.</p> <p><b>Neutralisation</b> reactions produce a salt and water.</p>
<b>pH</b>	<p>A measure of the acidity or alkalinity of a solution.</p> <p>Acids have a <b>pH</b> of less than 7.</p>
<b>pH probe</b>	<p>An instrument used to measure the pH of a solution.</p> <p>A <b>pH probe</b> can give a numerical value for pH whereas universal indicator gives a colour corresponding to a number on the pH scale.</p>
<b>Pipette</b>	<p>A piece of equipment used to measure a fixed volume accurately.</p> <p>A <b>pipette</b> allows a more precise volume of liquid to be measured than a measuring cylinder.</p>
<b>Product</b>	<p>The substance(s) that are made in a chemical reaction.</p> <p>In the equation <math>2Mg + O_2 \rightarrow 2MgO</math>, magnesium oxide is the <b>product</b>.</p>
<b>Reactant</b>	<p>The substance(s) that react in a chemical reaction to form a new substance.</p> <p>In the equation <math>2Mg + O_2 \rightarrow 2MgO</math>, magnesium and oxygen are the <b>reactants</b>.</p>
<b>Relative atomic mass</b>	<p>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.</p> <p>The <b>relative atomic mass</b> of oxygen is 16.</p>

<b>Relative formula mass</b>	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.
<b>Solute</b>	<p>The <b>relative formula mass</b> of a molecule of <math>\text{H}_2\text{O}</math> is 18.</p> <p>A substance that is dissolved in a solvent.</p> <p>Salt is the <b>solute</b> when it is dissolved in water.</p>
<b>Soluble</b>	<p>A substance is soluble if it can be dissolved in a solvent</p> <p>Sugar is <b>soluble</b> in water.</p>
<b>Solution</b>	<p>A mixture of a dissolved solute and a solvent.</p> <p>A <b>solution</b> of salt and water was used.</p>
<b>Solvent</b>	<p>A substance in which a solute can dissolve</p> <p>Water is a <b>solvent</b> because salt can dissolve in it</p>
<b>Strong</b>	<p>(Of an acid) An acid that fully dissociates in solution.</p> <p>Hydrochloric acid is an example of a <b>strong</b> acid.</p>
<b>Subscript</b>	<p>The numbers that come after and below a chemical symbol in a chemical formula, to indicate the number of atoms of that element.</p> <p>The <b>subscript</b> number two shown in a molecule of <math>\text{CO}_2</math> indicates that it contains 2 atoms of oxygen.</p>
<b>Universal Indicator</b>	<p>A solution that changes colour depending on the pH of the solution it is added to.</p> <p><b>Universal indicator</b> turns green when it is added to a neutral solution.</p>
<b>Volume</b>	<p>The amount of space a substance takes up.</p> <p>In chemistry, <b>volume</b> is measured in <math>\text{dm}^3</math>.</p>
<b>Weak</b>	<p>(Of an acid) An acid that partially dissociates in solution.</p> <p>Ethanoic acid is an example of a <b>weak</b> acid.</p>

# 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  $\text{CaCO}_3$ .
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  $\text{H}_2\text{O}$ , 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/ $A_r$ )

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/ $M_r$ )

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

Element	$A_r$	Number of atoms	Total mass
Mg			
N			
O			
Total mass ( $M_r$ )			

Calculate the  $M_r$  for the following compounds.



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

- a.  $\text{NH}_3$
- b.  $\text{O}_2$
- c.  $\text{H}_2\text{O}$
- d.  $\text{KOH}$

Use your understanding of the conservation of mass to find the  $M_r$  of  $\text{CaO}$ . ( $M_r$ :  $\text{CaCO}_3 = 100$ ;  $\text{CO}_2 = 44$ )



### Percentage by mass

What is the formula for percentage by mass?

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

What is the percentage by mass of carbon in  $\text{CO}_2$ ?

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

## 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  $\text{CO}_2$ .
6. Calculate the relative formula mass of  $\text{KOH}$ .
7. State the equation to calculate percentage by mass.
8. Calculate the percentage by mass of potassium in potassium hydroxide ( $\text{KOH}$ ).
9. Calculate the percentage by mass of chlorine in calcium chloride ( $\text{CaCl}_2$ ).

## 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 carbon-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 ( $\text{CO}_2$ ).

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 ( $\text{NH}_3$ ).  $\text{N}=14$ ,  $\text{H}=1$
4. Calculate the Mr of calcium hydroxide ( $\text{Ca}(\text{OH})_2$ ).  $\text{Ca}=40$ ,  $\text{O}=16$ ,  $\text{H}=1$
5. Calculate the percentage by mass of hydrogen in ammonia.

## Drill:

1. Write 58230000 in standard form.
2. Convert  $3.07 \times 10^4$  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  $6.02 \times 10^{23}$  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 <sub>r</sub>	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?

$2.38 \times 10^{10}$       or       $23.8 \times 10^9$



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.

32
<b>S</b>
sulfur
16

*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  $6.02 \times 10^{23}$  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  $6.02 \times 10^{23}$  atoms or molecules of that substance.

Methane has the chemical formula  $\text{CH}_4$ .

*What is the relative formula mass of methane?*



*What mass in grams would contain  $6.02 \times 10^{23}$  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  $6.02 \times 10^{23}$  atoms or molecules of that substance.

Ammonia has the chemical formula  $\text{NH}_3$ .

*What is the relative formula mass of ammonia?*



*What mass in grams would contain  $6.02 \times 10^{23}$  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 atoms 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  $\text{CO}_2$ ?

- ☐ A. 44
- ☐ B.  $6.02 \times 10^{23}$
- ☐ C. 1

3. Which number is the same as  $6 \times 10^3$ ?

- ☐ 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 ( $\text{CuCO}_3$ ).  $\text{Cu}=63.5$ ,  $\text{C}=12$ ,  $\text{O}=16$
5. Calculate the percentage by mass of oxygen in copper carbonate.

#### Drill:

1. State Avogadro's number.
2. Calculate  $3 \times 4.83 \times 10^{11}$ . Write your answer in standard form.
3. Calculate  $0.25 \times 4.83 \times 10^{11}$ . Write your answer in standard form.

#### Read Now:

In one mole of any substance there are  $6.02 \times 10^{23}$  particles. This can be atoms, molecules or ions. For example, one mole of water contains  $6.02 \times 10^{23}$  molecules of water and one mole of potassium contains  $6.02 \times 10^{23}$  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 ( $6.02 \times 10^{23}$  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 ( $\text{SO}_2$ ) is 64 ( $\text{S}=32$ ,  $\text{O}=16$ ), so 64 g of sulfur dioxide contains one mole ( $6.02 \times 10^{23}$ ) 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  $O_2$ ? ( $M_r = 32$ )

$$\begin{aligned}\text{Number of moles} &= \text{mass} \div M_r \\ &= 64.0 \text{ g} \div 32 \\ &= 2 \text{ mol}\end{aligned}$$

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  $Li_2O$ ?

$$M_r \text{ of } Li_2O = 7 + 16 = 23$$

$$\begin{aligned}\text{Number of moles} &= \text{mass} \div M_r \\ &= 15 \text{ g} \div 23 \\ &= 0.65 \text{ mole}\end{aligned}$$

## 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<sub>2</sub>).
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<sub>5</sub>P.

*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. (Ar: C = 12; O = 16; H = 1; Na = 23)

Ingredient	Formula	Mr	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

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

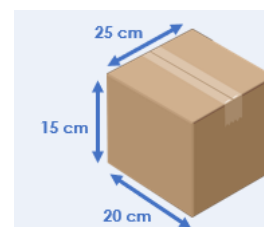
### Concentration

#### Do Now

1. State how many particles there are in 1 mole of a substance.
2. Calculate the  $M_r$  of calcium carbonate ( $\text{CaCO}_3$ ).  $\text{Ca}=40$ ,  $\text{C}=12$ ,  $\text{O}=16$
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  $\text{dm}^3$ .



#### 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:  $\text{concentration} = \text{mass}/\text{volume}$ .

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

$$1000 \text{ cm}^3 = \underline{\hspace{2cm}} \text{ dm}^3$$

$$5000 \text{ cm}^3 = \underline{\hspace{2cm}} \text{ dm}^3$$

$$2403 \text{ cm}^3 = \underline{\hspace{2cm}} \text{ dm}^3$$

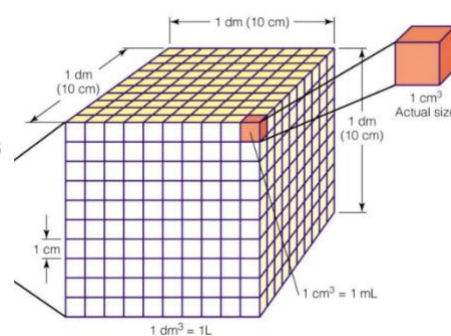
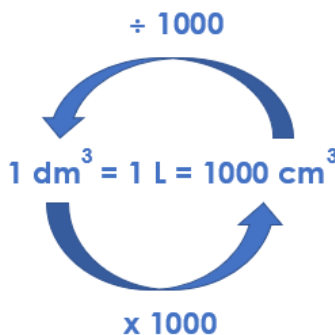
$$145 \text{ cm}^3 = \underline{\hspace{2cm}} \text{ dm}^3$$

$$1 \text{ dm}^3 = \underline{\hspace{2cm}} \text{ cm}^3$$

$$10 \text{ dm}^3 = \underline{\hspace{2cm}} \text{ cm}^3$$

$$179 \text{ dm}^3 = \underline{\hspace{2cm}} \text{ cm}^3$$

$$0.2 \text{ dm}^3 = \underline{\hspace{2cm}} \text{ cm}^3$$



### True or false?

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

*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  $2 \text{ dm}^3$  of solution.

*What is the concentration of the solution?*



## You: Concentration, mass and volume

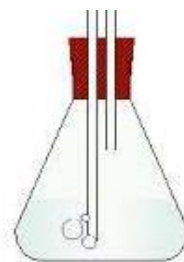
A scientist makes up a sample of calcium hydroxide solution. 24 g of calcium hydroxide is added to water to make up 200 cm<sup>3</sup> of solution.

What is the solute?

What is the solution?

What is the volume in dm<sup>3</sup>?

What is the concentration of the sample?



## Exit Ticket

1. Select the answer below which is equal to 0.05 dm<sup>3</sup>.
  - ☐ A. 500 cm<sup>3</sup>
  - ☐ B. 50 cm<sup>3</sup>
  - ☐ C. 0.00005 cm<sup>3</sup>
2. 10 g of a solute was used to make a solution with a volume of 25 dm<sup>3</sup>. What was the concentration of the solution?
  - ☐ A. 250 g/dm<sup>3</sup>
  - ☐ B. 0.4 g/dm<sup>3</sup>
  - ☐ C. 2.5 g/dm<sup>3</sup>
3. 200 cm<sup>3</sup> of a solution has a concentration of 25 g/cm<sup>3</sup>. What mass of solute was dissolved in it?
  - ☐ A. 5000 g
  - ☐ B. 125 g
  - ☐ C. 5 g

## (HT) Amounts of Substances in Equations

### Do Now

1. Define relative formula mass.
2. Calculate the relative formula mass of magnesium chloride ( $\text{MgCl}_2$ ).  $\text{Mg} = 24$ ,  $\text{Cl} = 35.5$
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 ( $\text{K}_2\text{SO}_4$ ).  $\text{K}=39$ ,  $\text{S}=32$ ,  $\text{O}=16$
2. Calculate the  $M_r$  of aluminium hydroxide ( $\text{Al}(\text{OH})_3$ ).  $\text{Al}=27$ ,  $\text{O}=16$ ,  $\text{H}=1$
3. Calculate the  $M_r$  of calcium nitrate ( $\text{Ca}(\text{NO}_3)_2$ ).  $\text{Ca}=40$ ,  $\text{N}=14$ ,  $\text{O}=16$

### 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 are made. For example, in the reaction  $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$ , 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 with 1 mole of oxygen to produce 2 moles of water. Remember that 1 mole of any substance contains  $6.02 \times 10^{23}$  particles.

### Mole Ratios

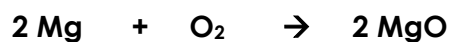


Complete the tables to show the mole ratios

$\text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3$		
1 mol		2 mol
	0.6 mol	
		0.1 mol

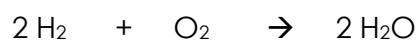
$3 \text{C} + 2 \text{Fe}_2\text{O}_3 \rightarrow 4 \text{Fe} + 3 \text{CO}_2$			
3 mol			
	0.5 mol		
		0.1 mol	

**Moles, Mass and Mr**



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.**



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

$$\text{number of moles hydrogen} = \frac{\text{mass}}{\text{Mr}} \quad \text{number of moles H}_2 = \frac{8}{4} \quad \text{number of moles H}_2 = 2 \text{ mol}$$

$$\text{number of moles H}_2\text{O} = 2 \text{ mol}$$

$$\text{number of moles H}_2\text{O} = \frac{\text{mass}}{\text{Mr}} \quad 2 \text{ mol} = \frac{\text{mass}}{36} \quad \text{mass} = 72 \text{ g}$$

**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 ( $\text{NH}_3$ ).
6. Calculate the relative formula mass of sodium oxide ( $\text{Na}_2\text{O}$ ).
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



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**.



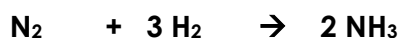
mole ratio =

Moles of aluminium =

Moles of aluminium oxide =

Mass of aluminium oxide =

### You: calculating reacting masses



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.**

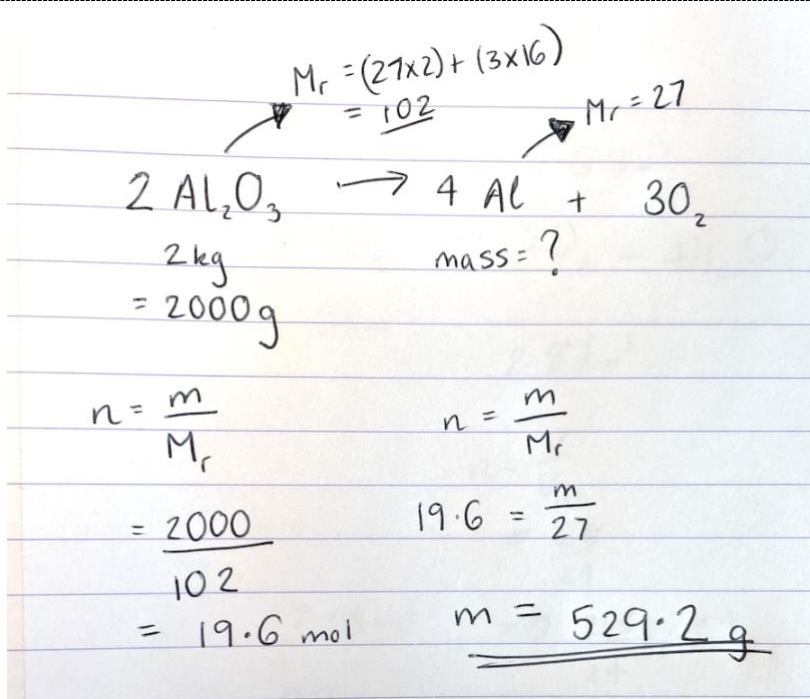
**Stretch: Rewrite the answer to show how it should be done!**

**Question:**

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



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



Marks awarded= \_\_\_\_\_

Mark scheme:

Point	Mark
Mr Al <sub>2</sub> O <sub>3</sub> = 102	1 (answer, can also be shown in working of next point)
Number of moles Al <sub>2</sub> O <sub>3</sub> = m/Mr 2000/102	1 (substitution)
Number of moles Al <sub>2</sub> O <sub>3</sub> = 19.6078...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

- 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
- Calculate the number of moles of oxygen that would have reacted.
  - ☐ A. 1.0 mol
  - ☐ B. 0.5 mol
  - ☐ C. 0.25 mol
- 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 ( $\text{Na}_2\text{CO}_3$ ).
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 ( $\text{LiNO}_3$ ).  $\text{Li}=7$ ,  $\text{N}=14$ ,  $\text{O}=16$
2. Calculate the  $M_r$  of copper carbonate ( $\text{CuCO}_3$ ).  $\text{Cu}=63.5$ ,  $\text{C}=12$ ,  $\text{O}=16$
3. Calculate the  $M_r$  of calcium phosphate ( $\text{Ca}_3(\text{PO}_4)_2$ ).  $\text{Ca}=40$ ,  $\text{P}=31$ ,  $\text{O}=16$

### 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.

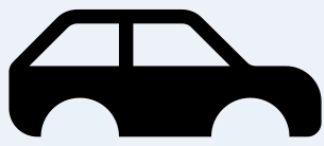



1. Explain what is meant by a limiting reactant.
2. Identify the limiting reactant in the car factory example.
3. Explain why this is the limiting reactant.
4. Suggest which would be the limiting reactant if the car factory had made 30 car frames instead.





## Limiting Reactants





How many cars can be made in each scenario?





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

1.  + 

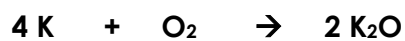
2.  +   

3.  +   

 +   

 +   

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



mole ratio =

Moles of K =

Moles of  $\text{O}_2$  =

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<sub>2</sub>O made =

Mass of K<sub>2</sub>O made

## Drill

1. State the equation that links number of moles, mass and M<sub>r</sub>.
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



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

**mole ratio =**

$$n \text{ CH}_4 = \frac{\text{mass}}{M_r} \quad n \text{ CH}_4 = \text{ — } \quad n \text{ CH}_4 = \text{ mol}$$

$$n \text{ O}_2 = \frac{\text{mass}}{M_r} \quad n \text{ O}_2 = \text{ — } \quad n \text{ O}_2 = \text{ mol}$$

$$\text{number of moles of O}_2 \text{ needed to react with 32g CH}_4 = \text{ mol}$$

$$\text{number of moles of CH}_4 \text{ needed to react with 100g of O}_2 = \text{ mol}$$

Mole ratio limiting reactant: desired product =

$$\text{number of moles CO}_2 = \text{ mol}$$

$$\text{number of moles CO}_2 = \frac{\text{mass}}{M_r} \quad \text{mol} = \frac{\text{mass}}{\text{ — }}$$

$$\text{mass} = \text{ — } \text{ g}$$



**We: using limiting reactants in calculations**

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

**mole ratio =**

$$n \text{ Al}_2\text{O}_3 = \frac{\text{mass}}{\text{Mr}} \quad n \text{ Al}_2\text{O}_3 = \text{ — } \quad n \text{ Al}_2\text{O}_3 = \text{ mol}$$

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

$$\text{number of moles of Fe needed to react with 180g Al}_2\text{O}_3 = \text{ mol}$$

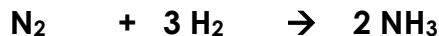
$$\text{number of moles of Al}_2\text{O}_3 \text{ needed to react with 180g of Fe} = \text{ mol}$$

Mole ratio limiting reactant: desired product =

$$\text{number of moles Al} = \text{ mol}$$

$$\text{number of moles Al} = \frac{\text{mass}}{\text{Mr}} \quad \text{mol} = \frac{\text{mass}}{\text{ — }}$$

$$\text{mass} = \text{ — } \text{g}$$

**You: using limiting reactants in calculations**

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

**mole ratio =**

$$n \text{ N}_2 = \frac{\text{mass}}{\text{Mr}} \quad n \text{ N}_2 = \text{ — } \quad n \text{ N}_2 = \text{ mol}$$

$$n \text{ H}_2 = \frac{\text{mass}}{\text{Mr}} \quad n \text{ H}_2 = \text{ — } \quad n \text{ H}_2 = \text{ mol}$$

$$\text{number of moles of H}_2 \text{ needed to react with 50g N}_2 = \text{ mol}$$

$$\text{number of moles of N}_2 \text{ needed to react with 50g of H}_2 = \text{ mol}$$

Mole ratio limiting reactant: desired product =

$$\text{number of moles NH}_3 = \text{ mol}$$

$$\text{number of moles NH}_3 = \frac{\text{mass}}{\text{Mr}} \quad \text{mol} = \frac{\text{mass}}{\text{ — }}$$

$$\text{mass} = \text{ — } \text{g}$$

## Exit Ticket

$2 \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO}$  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.  $\text{O}_2$
- ☐ 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.

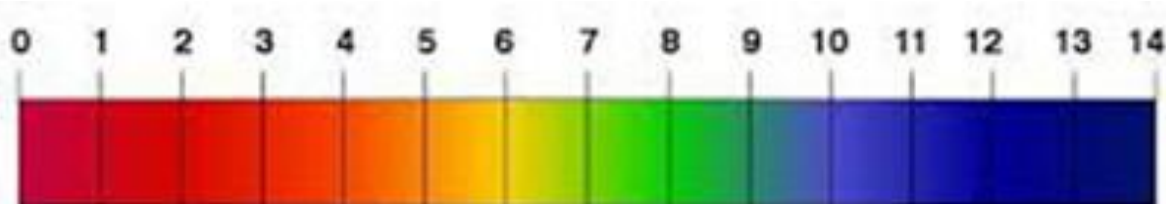
#### Read Now:

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  $\rightarrow$  \_\_\_\_\_ + \_\_\_\_\_

Acid + base  $\rightarrow$  \_\_\_\_\_ + \_\_\_\_\_

Acid + Metal Carbonate  $\rightarrow$  \_\_\_\_\_ + \_\_\_\_\_ + \_\_\_\_\_

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  $\rightarrow$  magnesium chloride + \_\_\_\_\_

This is not a \_\_\_\_\_ reaction.

It is a d \_\_\_\_\_ or r \_\_\_\_\_ reaction

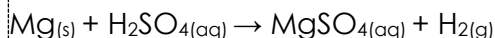
## Testing for Gases

Complete the table for the gas tests

Name of gas	Test method	Positive result
Hydrogen		
Carbon dioxide		

## (HT) Writing ionic equations

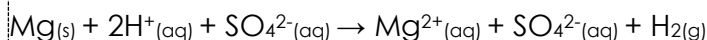
Ionic equations tell us only what has reacted, not all the ions present. For example:



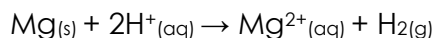
Look at this chemical equation:

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

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



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



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

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

Positive ions		Negative ions	
Name	Formula	Name	Formula
Hydrogen	$\text{H}^+$	Chloride	$\text{Cl}^-$
Sodium	$\text{Na}^+$	Bromide	$\text{Br}^-$
Silver	$\text{Ag}^+$	Fluoride	$\text{F}^-$
Potassium	$\text{K}^+$	Iodide	$\text{I}^-$
Lithium	$\text{Li}^+$	Hydroxide	$\text{OH}^-$
Ammonium	$\text{NH}_4^+$	Nitrate	$\text{NO}_3^-$
Barium	$\text{Ba}^{2+}$	Oxide	$\text{O}^{2-}$
Calcium	$\text{Ca}^{2+}$	Sulfide	$\text{S}^{2-}$
Copper(II)	$\text{Cu}^{2+}$	Sulfate	$\text{SO}_4^{2-}$
Magnesium	$\text{Mg}^{2+}$	Carbonate	$\text{CO}_3^{2-}$
Zinc	$\text{Zn}^{2+}$		
Lead	$\text{Pb}^{2+}$		
Iron(II)	$\text{Fe}^{2+}$		
Iron(III)	$\text{Fe}^{3+}$		
Aluminium	$\text{Al}^{3+}$		

## 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 not 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 ( $\text{NaOH}$ ).  $\text{Na}=23$ ,  $\text{O}=16$ ,  $\text{H}=1$
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

Name	Formula
Hydrogen	H <sup>+</sup>
Sodium	Na <sup>+</sup>
Silver	Ag <sup>+</sup>
Potassium	K <sup>+</sup>
Lithium	Li <sup>+</sup>
Ammonium	NH <sub>4</sub> <sup>+</sup>
Barium	Ba <sup>2+</sup>
Calcium	Ca <sup>2+</sup>
Copper(II)	Cu <sup>2+</sup>
Magnesium	Mg <sup>2+</sup>
Zinc	Zn <sup>2+</sup>
Lead	Pb <sup>2+</sup>
Iron(II)	Fe <sup>2+</sup>
Iron(III)	Fe <sup>3+</sup>
Aluminium	Al <sup>3+</sup>

#### Negative ions

Name	Formula
Chloride	Cl <sup>-</sup>
Bromide	Br <sup>-</sup>
Fluoride	F <sup>-</sup>
Iodide	I <sup>-</sup>
Hydroxide	OH <sup>-</sup>
Nitrate	NO <sub>3</sub> <sup>-</sup>
Oxide	O <sup>2-</sup>
Sulfide	S <sup>2-</sup>
Sulfate	SO <sub>4</sub> <sup>2-</sup>
Carbonate	CO <sub>3</sub> <sup>2-</sup>

**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:



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.  $\text{H}^+$
  - ☐ B.  $\text{OH}^-$
  - ☐ C.  $\text{H}_2\text{O}$
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.  $\text{H}_2\text{O} \rightarrow \text{H}^+ + \text{OH}^-$
  - ☐ B.  $\text{H} + \text{OH} \rightarrow \text{H}_2\text{O}$
  - ☐ C.  $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$

## (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 ( $\text{HNO}_3$ ).
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 in solution. This means that in solution, it splits completely into  $\text{H}^+$  and  $\text{Cl}^-$  ions. A weak acid, such as ethanoic acid, is one which does not fully dissociate into ions in solution.

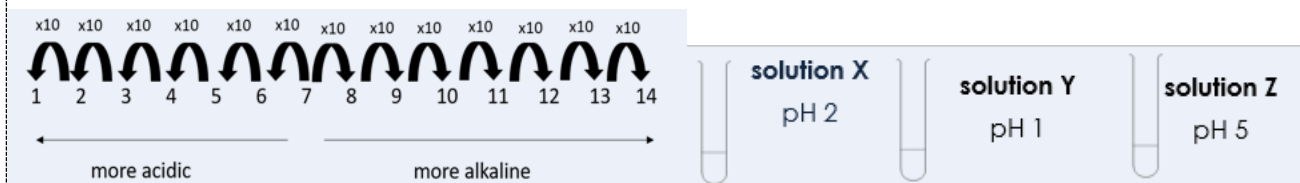
1. Define a solution.
2. Explain the difference between a concentrated and a dilute solution.
3. Explain what is meant by a strong acid.
4. Give an example of a strong acid.
5. Explain what is meant by a weak acid.
6. Give an example of a weak acid.

## 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?



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  $\text{H}^+$  ions
- ☐ C. An acid that fully dissociates in solution

2. Which of these is not a strong acid?

- ☐ A. Hydrochloric acid
- ☐ B. Sulfuric acid
- ☐ C. Ethanoic acid

3. Which of these will have the lowest pH?

- ☐ A.  $1 \text{ mol/dm}^3$  ethanoic acid
- ☐ B.  $1 \text{ mol/dm}^3$  hydrochloric acid
- ☐ C.  $2 \text{ mol/dm}^3$  hydrochloric acid

# Independent Practice

Prior Knowledge Review: Relative Formula Mass and Percentage by Mass .....	59
Mole Calculations.....	62
Prior Knowledge Review: Concentration.....	65
(HT) Amount of Substance in Equations.....	70
(HT) Limiting Reactants .....	73
Prior Knowledge Review: Acid Reactions.....	76
Acids, Alkalis and Neutralisation.....	79
(HT) Strong and Weak Acids .....	83

## Prior Knowledge Review: Relative Formula Mass and Percentage by Mass

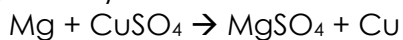
### Relative Formula Mass

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.  $\text{Cl}_2$

- b.  $\text{H}_2$
- c.  $\text{H}_2\text{O}$
- d.  $\text{CO}_2$
- e.  $\text{HCl}$
- f.  $\text{CuSO}_4$
- g.  $\text{NaOH}$
- h.  $\text{Al}_2\text{O}_3$
- i.  $\text{Zn}(\text{OH})_2$
- j.  $\text{Mg}(\text{NO}_3)_2$
- k.  $\text{Ca}(\text{HCO}_3)_2$
- l.  $(\text{NH}_4)_2\text{SO}_4$

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)



5. A metal oxide has the formula  $\text{MO}$ , 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

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

**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<sub>3</sub>.
5. Calculate the percentage of oxygen in sodium hydrogen carbonate, NaHCO<sub>3</sub>.
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<sub>3</sub>.
10. Calculate the percentage by mass of oxygen in potassium permanganate, KMnO<sub>4</sub>.

**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  $6.02 \times 10^{23}$  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.



Glucose  $\rightarrow$  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 ( $\text{C}_6\text{H}_{12}\text{O}_6$ ).

---

---

---

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  $\text{Cl}_2$

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  $\text{Cl}_2$
- c. 2 moles of Fe
- d. 1 mole of  $\text{CoCl}_2$
- e. 0.5 moles of  $\text{O}_2$
- f. 0.5 moles  $\text{Mg}(\text{OH})_2$

### 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.

<b>seconds</b>	<b>minutes</b>	<b>hours</b>
3600	60	1
60		0.16
	300	
2600		
		5
	540	
30		

<b>g</b>	<b>kg</b>
1000	1
5000	
15000	
	11
	0.5
	0.05
5	

<b>cm<sup>3</sup></b>	<b>dm<sup>3</sup></b>	<b>L</b>
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<sup>3</sup>

☐

g/dm<sup>3</sup>

☐

dm<sup>3</sup>/g

☐

3. A student has three test tubes, each containing 100 cm<sup>3</sup> 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<sup>3</sup>. 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<sup>3</sup> and the other has a concentration of 12 g/dm<sup>3</sup>. Both have a volume of 200 cm<sup>3</sup>.

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<sup>3</sup> solution up to a volume of 400 cm<sup>3</sup>. 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<sup>3</sup>) of:

a. 40 g solute in 350 dm<sup>3</sup>

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

b. 100 g solute in 77 dm<sup>3</sup>

\_\_\_\_\_

c. 0.08 g solute in 20 cm<sup>3</sup>

d. 90g solute in 780 cm<sup>3</sup>

11. The mass of H<sub>2</sub>SO<sub>4</sub> is 32.5 g and the volume of the solution is 0.400 dm<sup>3</sup>. Calculate the concentration of the solution formed in g/dm<sup>3</sup>.

12. A 750 cm<sup>3</sup> 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<sup>3</sup> of a 2.3 g/dm<sup>3</sup> solution.

b. 250 cm<sup>3</sup> of a 71 g/dm<sup>3</sup> solution

c. 2.3 dm<sup>3</sup> of a 61 g/dm<sup>3</sup> solution

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

15. Using 83g of solute, how much water is needed to:

a. Make a 34 g/dm<sup>3</sup> solution?

---

---

---

b. Make a 0.1 g/dm<sup>3</sup> solution?

---

---

---

c. Make a 83 g/dm<sup>3</sup> solution?

---

---

---

d. Make a 79 g/dm<sup>3</sup> solution?

---

---

---

### Section C

16. A person has eaten a big meal recently and has digested many large carbohydrates to produce glucose.

- Calculate the relative formula mass of glucose (C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>).
- Calculate the percentage by mass of carbon in glucose.
- State the substrate that is broken down to form glucose.
- Name the enzyme that catalyses (speeds up) this reaction.
- In the person's small intestine, there is 30 g of glucose in a 320 cm<sup>3</sup> solution. Calculate the concentration of glucose in g/dm<sup>3</sup>.
- In a sample of blood from the person's bloodstream, there is 50 μg of glucose in 25 cm<sup>3</sup> of blood. Calculate the concentration of glucose in this blood sample.
- Compare the concentration of glucose in the small intestine and the bloodstream.
- Describe and explain what will happen to the glucose molecules.
- Describe two adaptations of the small intestine that make it well suited for this function.

## (HT) Amount of Substance in Equations

### Section A:

1. Match the quantities below to their correct units.

Mass
$M_r$
Number of moles

no units
mol
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.
- Oxygen ( $O_2$ )
  - Ammonia ( $NH_3$ )
  - Methane ( $CH_4$ )
  - Sodium hydroxide ( $NaOH$ )
  - Ammonium hydroxide ( $NH_3OH$ )
  - 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

---

---

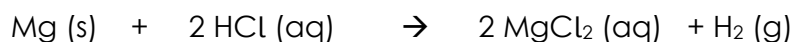
c. 0.1 moles of oxygen

---

---

## Section B

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



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.

---

---

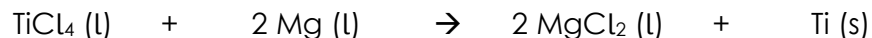
---

---

---

---

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



a. Explain what is meant by the term molten.

---

---

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

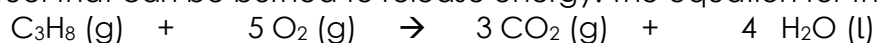
---

---

---

---

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



- 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:



- Calculate the relative formula mass of aluminium oxide.
- Calculate the mass of aluminium oxide required to produce 1 kg of aluminium.
- Explain what has to happen to the aluminium oxide before it can be electrolysed.
- Describe what happens at the positive electrode.
- Write the half equation for this reaction.
- 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:

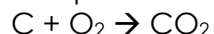


4. Explain why chemical equations have to be balanced.

---

---

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



- a. Calculate the relative formula mass of  $\text{CO}_2$ .

---

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

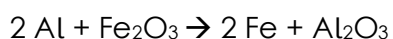
---

**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:



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.

---

---

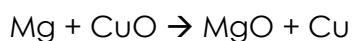
---

---

---

---

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



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.

---

---

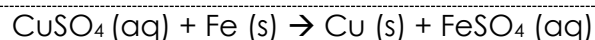
---

---

---

---

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



Calculate the mass of iron needed to displace all the copper from 100 cm<sup>3</sup> of copper sulfate solution.

The concentration of the copper sulfate solution is 50 g/dm<sup>3</sup>.

---

---

---

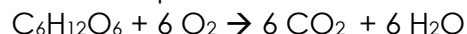
---

---

---

### Section C

9. The chemical equation for aerobic respiration is:



- Calculate the relative formula mass of glucose.
- A muscle tissue contains 40 µg of glucose and 75 µg of oxygen. Calculate the number of moles of each present.
- Identify which is the limiting reactant.
- Calculate the mass of water that could be made.
- Explain what happens when the muscle tissue cannot get enough oxygen.
- 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 <sub>2</sub> SO <sub>4</sub>
	H <sub>2</sub>
Calcium chloride	CaCl <sub>2</sub>
Sodium Hydroxide	NaOH
	NaCl
Copper carbonate	CuCO <sub>3</sub>
Copper sulfate	CuSO <sub>4</sub>
	CuO
Potassium carbonate	K <sub>2</sub> CO <sub>3</sub>
Potassium nitrate	KNO <sub>3</sub>

#### 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.

---

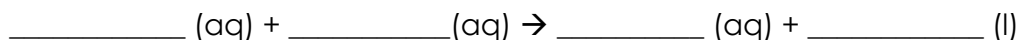
---

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.



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?

\_\_\_\_\_

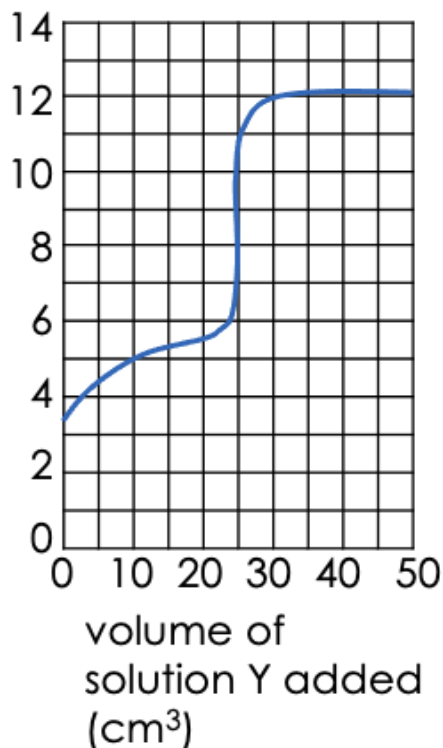
b. Was solution Y acidic, alkaline or neutral? Explain your answer.

\_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

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

\_\_\_\_\_

pH of  
solution



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.

- What is the alkali in this reaction?
- Write a word equation for this reaction.
- Write a balanced symbol equation for this reaction.
- Write the ionic equation for neutralisation.
- Name the salt produced in this reaction.
- Calculate the relative formula mass of this salt.
- Calculate the percentage by mass of sodium in this salt.
- Compare the physical properties of the elements that make up this salt with the properties of the salt as a compound.
- Identify the type of bonding in this salt.
- Draw a diagram to show how this bonding takes place.

## (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<sup>3</sup> 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<sup>3</sup> hydrochloric acid solution

☐

0.5 mol/dm<sup>3</sup> ethanoic acid solution

☐

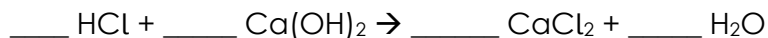
2.0 mol/dm<sup>3</sup> hydrochloric acid solution

☐

2.0 mol/dm<sup>3</sup> ethanoic acid solution

☐

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



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 ( $\text{H}_2\text{C}_2\text{O}_4$ ) is a solid that can be dissolved to make a solution. Calculate the mass of ethanedioic acid required to produce  $150 \text{ cm}^3$  of solution with a concentration of  $0.2 \text{ mol/dm}^3$ .

---

---

---

---

---

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

---

---

---

---

---

---

---

---

---

---

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