Quantitative Chemistry Mastery Booklet

Quantitative Chemistry is how chemists work out how much substance is used and made in a chemical reaction.

Conservation of mass

Recap questions:

1. What is the law of conservation of mass?
2. Look at the reaction below:
   $Na + Cl_2 \rightarrow NaCl$
   Explain how you know it is not balanced
3. Balance the equation
4. If 20g of Na is used, and 110g of NaCl is formed. What is the mass of Cl_2 used?
5. Explain your answer
6. Look at the reaction below:
   $Mg(s) + HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$
   Balance the equation
7. What do the state symbols in the equation stand for?
8. Identify all elements and compounds in the equation
9. What are the reactants and what are the products?
10. A student adds 10g of Mg to a flask which has 100g of HCl in it. The mass of the flask at the end is less than 110g. Explain why.

In chemical reactions, the mass is conserved. This means that the mass of the reactants = the mass of the products. Sometimes it can look like the mass is changing, but it is usually down to a gas being involved:

- If the mass appears to decrease, it is because a gas is formed which escapes the container
- If the mass appears to increase, it is because atoms from a gas in the atmosphere have been added

In a reaction, marble powder is mixed with hydrochloric acid

11. The formula for marble powder is $CaCO_3$ and its name is calcium carbonate. Which atoms are present in calcium carbonate?
12. Is calcium carbonate an element or a compound? Explain your answer.
13. Calcium carbonate is an ionic substance. Predict the properties of calcium carbonate
14. Below is a symbol equation for the reaction.
    $CaCO_3 + HCl \rightarrow CaCl_2 + CO_2 + H_2O$
    Copy the equation into your exercise book and balance it
15. Explain why the mass of this reaction appears to decrease

Magnesium can be heated in the air to react with oxygen

16. Oxygen in the air is a simple molecular substance. Predict its properties.
17. The magnesium and oxygen form magnesium oxide. Write a word equation for this reaction. Identify the reactants and the product.
18. Magnesium oxide has a formula MgO. Use this information to write a symbol equation for this reaction.
19. Balance the symbol equation.
20. The diagrams below show what is occurring during the reaction. White circles are atoms of oxygen, and grey ones are atoms of magnesium.
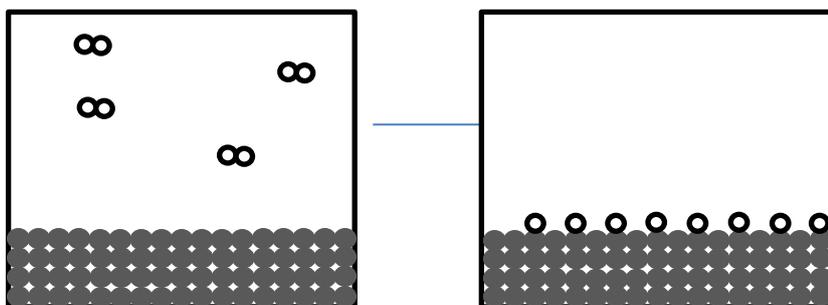
    a. Label two elements in the diagrams
    b. Label a compound in the diagrams
    c. Name all the elements and compounds
    d. Use the number of particles to prove that **mass has been conserved** in this reaction

    e. Use the number of particles to explain why the mass of the product is greater than the mass of the initial magnesium

Part 1: Relative formula mass

Remember that the relative atomic mass of an atom can be found by using the mass numbers of the periodic table. The relative formula mass of a compound is the sum of the relative atomic masses of the atoms involved. It is often given by the symbol M_r

Worked example 1:

What is the M_r of $CaCO_3$?

$CaCO_3$ has one calcium atom, one carbon atom and three oxygen atoms. The relative mass of calcium is 40, carbon is 12 and oxygen is 16. To calculate the total:

40 + 12 + (3 x 16) = 100

Worked example 2:

What is the M_r of $Ca(OH)_2$?

$Ca(OH)_2$ has one atom of calcium, two atoms of oxygen and two atoms of hydrogen (remember that everything in the brackets is multiplied by the little number. To calculate the total:

40 + (2 x 16) + (2 x 1) = 74

21. For each of the compounds below calculate their M_r
   a. CO
   b. MgO
   c. H_2O_2
   d. SO_2
   e. Na_2O
   f. Al_2O_3
   g. $Al(OH)_3$
   h. $Mg(NO_3)_2$
   i. $CuSO_4$
   j. K_2SO_4
   k. $Al_2(SO_4)_3$
22. *Challenge: a substance has an Mr of 180. A student knows that it has atoms of carbon, hydrogen and oxygen in it. What is its formula?*

Part 2: The mole

We will return to M_r soon. In everyday life, there are some words we can use which represent a number. For example:

A score   = 20
A dozen   = 12
A baker's dozen   = 13
A gross   = 144
A great gross   = 1728

These words exist because in different contexts those words are more useful than the numbers they represent. Someone selling eggs will refer to them "by the dozen" as eggs come in containers of six or twelve. So "dozen" is more useful than "twelve."

23. How many eggs in:
   a. Two dozen
   b. Three dozen
   c. A quarter of a dozen
   d. Four and a half dozen
   e. Two gross
   f. Seven gross
   g. One twelfth of a gross
   h. A score of baker's dozens

In chemistry, we have a similar word called a "mole." A "mole" is a word which represents a number just like "dozen" represents "twelve." A mole represents the number 6.022×10^{23}. This number is called The Avogadro Constant. This number is useful to chemists because when you are talking about atoms or molecules, you are normally referring to an enormous number of them, so it is useful to have a word which can represent enormous numbers.

24. How many atoms are in:
   a. One mole of atoms
   b. Two moles of atoms
   c. Seven moles of atoms
   d. Half a mole of atoms
   e. A dozen moles of atoms
   f. A score of moles of atoms
25. How many:
   a. Electrons are in one mole of electrons?
   b. Protons are in one mole of protons?
   c. Electrons are in two and a half moles of electrons?

26. **Worked example:** Sodium has 11 electrons in each atom. How many electrons are in one mole of sodium atoms?
    Answer: one mole of atoms is 6.022×10^{23}. If each atom has 11 electrons then there must be 11 x 6.022×10^{23} electrons in total which = 6.62×10^{24}
27. How many electrons are in:
    a. One mole of lithium atoms
    b. Two moles of carbon atoms
    c. One mole of carbon dioxide molecules
    d. Half a mole of methane molecules
28. *Challenge: A sample of iron metal is found to have 4.85×10^{26} electrons in it. How many **moles** of iron atoms are present?*

Part 3: moles and M_r

We can now combine parts 1 and 2. This is because the M_r of a substance represents the **mass** of one mole of that substance.

For example: water has the formula H_2O. Each molecule of water has two hydrogen atoms and one oxygen atom. Its M_r is 18. This means that 18 grams of water, contains **one mole** of water molecules.
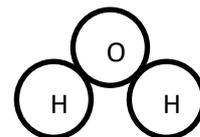
This leaves us with a formula relating moles, mass and M_r:

$$moles = \frac{mass}{Mr}$$

Worked example 3

How many moles are in 30g of CO_2?

The M_r of CO_2 is

12 + (16x2) = 44

*Moles = 30/44 = **0.68***

Worked example 4

How many moles are in 175g of Na_2CO_3?

M_r = (2 x 23) + 12 + (3 x 16) = 106

*Moles = 175/106 = **1.65***

29. How many moles are in:
    a. 10g CO_2
    b. 20g CO_2
    c. 150g CH_4
    d. 12g NH_3
    e. 45g Cl_2
    f. 40g NH_4Cl
    g. 0.8g Na_2SO_4
    h. 35g of water
    i. 11g H_3PO_4
    j. 500g $Mg(NO_3)_2$
    k. 1kg NaF
    l. 1.2kg $Ca(OH)_2$

The equations can be rearranged to:

$$mass = moles \times Mr \qquad \text{and} \qquad Mr = \frac{mass}{moles}$$

30. What is the mass of:
    a. 5 moles of Cl_2 (answer is 355g – you need to work it out)
    b. 0.2 moles of Al_2O_3
    c. 0.01 moles of Ag
    d. 0.002 moles of $(NH_4)_2SO_4$
    e. 0.3 moles of Na_2CO_3
31. An experiment was carried out to find the Mr of vitamin C (ascorbic acid). It was found that 1 g contains 0.00568 moles of Vitamin C molecules. Calculate the Mr of vitamin C.

Part 4: manipulating ratios

We can use all of the above to make important chemical calculations. But before that, we must understand how to use ratios. On a youth camp, there must be a ratio of at least one leader to six children. This can be written as a ratio of 1:6

If there are 12 children, there must be at least 2 leaders. This is because in a ratio you can multiply or divide either side to get to a target number. If the target is 12 children, we must multiply 6 by 2. But we must also multiply the other side by 2. This can be represented as

x 2   1:6   x 2
2: 12

However, this becomes a bit more complicated when we use different numbers. If there are 100 children, how many leaders do we need?

The easiest way to do this is in two steps. First divide the ratio by the original target side (in this case 6). Then multiply by 100 to get to your target of 100:

÷6   1:6   ÷6
0.17 : 1

This shows that if we have 100 children, we need 17 leaders.

This simple method can be applied to any ratio.

32. Using the ratio above of 1:6, how many leaders are needed for:
    a. 40 children
    b. 81 children
    c. 600 children
    d. 700 children
    e. 87 children
    f. A dozen children
    g. A score of children
    h. A mole of children
33. How many children can be supervised by:
    a. 8 leaders
    b. 51 leaders
    c. 23 leaders
34. A different youth camp has different rules and requires 3 leaders for every 11 children. How many leaders are needed for:
    a. 22 children
    b. 100 children
    c. 230 children
    d. 80 children
35. How many children can be supervised by:
    a. 36 leaders
    b. 45 leaders
    c. 10 leaders
    d. 79 leaders

Part 5: Balanced equations

The above becomes relevant when we start to look at balanced equations. Take the equation as an example:

$2H_2 + O_2 \rightarrow 2H_2O$ can be shown as:
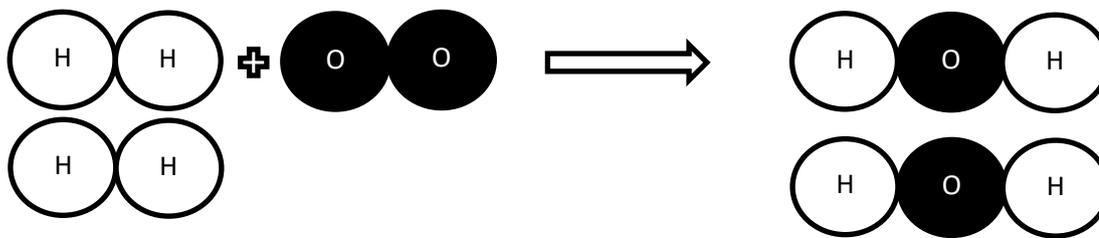
We can see that two molecules of hydrogen react with one molecule of oxygen to form two molecules of water. This can be expressed as a ratio:

H_2	O_2	H_2O
2	1	2

Using part 4 we could therefore establish that if we had four molecules of hydrogen and two of oxygen, we would obtain four of water. If I used a dozen hydrogen molecules, I would need half a dozen oxygen molecules and would obtain a dozen water molecules.

H_2	O_2	H_2O
A dozen	Half a dozen	A dozen

When we do a chemical reaction we do not use such tiny amounts, we use much larger amounts, which we can represent with the mole. If I have **two moles** of hydrogen I would need **one mole** of oxygen and would obtain **two moles of water** as below:

H_2	O_2	H_2O
Two moles	One mole	Two moles

If I was starting with 8 moles of hydrogen then it is obvious I would need 4 moles of oxygen. But it is more complicated if we use different numbers. If I started with 13.87 moles of hydrogen, how many moles of oxygen would I need?

÷2

x 13.87

H_2	O_2	H_2O
2	1	2
1	0.5	
13.87	6.94	

We can also now predict how much water we would expect to obtain from the reaction:

÷2.

x 13.87

H_2	O_2	H_2O
2	1	2
1	0.5	1
13.87	6.94	13.87

4

Worked example 4:

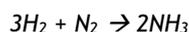Hydrogen and nitrogen react together to make ammonia (NH_3). Write a balanced symbol equation for this reaction and calculate how much nitrogen would be needed to react with 19.30 moles of hydrogen and how much ammonia would be produced.

First, we write the equation:

$H_2 + N_2 \rightarrow NH_3$

Then balance:

$3H_2 + N_2 \rightarrow 2NH_3$
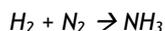
Then we calculate our ratio:

	H_2	N_2	NH_3
	3	1	2
÷3	1	0.33	0.67
x 19.30	19.30	6.37	12.93

So 6.37 moles of nitrogen would be needed and would produce 12.93 moles of ammonia.

Guided practice:

36. Methane (CH_4) reacts with oxygen to make carbon dioxide and water.
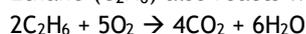   a. Write a balanced symbol equation for this reaction:
       $CH_4 + \_\_O_2 \rightarrow CO_2 + \_\_H_2O$
    b. Fill in the top row of the table below with the numbers from your balanced equation
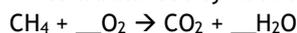
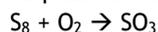|	CH_4	O_2	CO_2	H_2O
÷____				
x _____				

    c. If you started with two moles of CH_4, how much O_2 would you need? (the answer is 4, but you must use a calculation to prove this)
    d. If you started with 3.5 moles of CH_4, how much O_2 would you need?
    e. If you started with 3.5 moles of CH_4, how much CO_2 would you expect?
37. Ethane (C_2H_6) also reacts with oxygen to produce carbon dioxide and water, the equation being:
    $2C_2H_6 + 5O_2 \rightarrow 4CO_2 + 6H_2O$
    a. If 4 moles of ethane are used, show that 8 moles of CO_2 are produced
    b. If 5 moles of ethane are used, show that 15 moles of H_2O are produced
    c. If 7 moles of ethane are used, show that 21 moles of H_2o are produced.
    d. If 19 moles of oxygen is used, how much water is produced?
    e. How many moles of oxygen and ethane would you have to use to generate 43 moles of water?
38. Sulphur reacts with oxygen to make sulphur trioxide as below:
    $S_8 + O_2 \rightarrow SO_3$
    a. Balance the equation
    b. How many moles of sulphur would be required to produce 12 moles of sulphur trioxide?
    c. A chemist uses 17 moles of sulphur. How much oxygen would they need for a complete reaction?
    d. How much sulphur dioxide would be produced?

**Part 6: moles and masses**

In the questions above you were given a number of moles of one substance (e.g. hydrogen) and asked to work out the moles of another substance (e.g. water). Normally, instead of being given the number of moles you will be given a mass. Using the equation from part 3 you will have to use that mass to calculate the number of moles for yourself.

Worked example 5:

A student reacts 45g of lithium with oxygen to make lithium oxide. What mass of lithium oxide is produced?

Step 1: Construct the symbol equation:
$4Li + O_2 \rightarrow 2Li_2O$
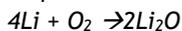
Step 2: work out the moles using moles = mass ÷ M_r

45g of lithium, with an M_r of 7

Moles = 45 ÷ 7 = 6.43

Step 3: manipulate the ratio

	Li	O_2	Li_2O
	4	1	2
÷ 4	1		0.5
x 6.43	6.43		3.22

Step 4: work out mass using moles x M_r

Moles Li_2O = 3.22, M_r of Li_2O = 30

*Mass = 3.22 x 30 = **96.60g of Li_2O produced**.*

Guided example:

Magnesium reacts with oxygen to form magnesium oxide (MgO). Calculate how much magnesium oxide is produced from 13.60g of magnesium.

Step 1: Construct the symbol equation:
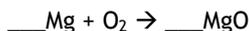
___Mg + O_2 → ___MgO

Step 2: work out the moles using moles = mass ÷ M_r

13.60g of Mg, M_r of Mg is _____

Step 3: manipulate the ratio

	Mg	O_2	MgO
	___	___	___
÷ ___	1		
x ___			

Step 4: work out mass using moles x M_r

Answer should come out as: **22.67g**

Step by step summarised:

Step 1: Construct the symbol equation
Step 2: work out the moles using *moles = mass ÷ M_r*
Step 3: manipulate the ratio
Step 4: work out mass using *moles x M_r*
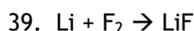
39. Li + F_2 → LiF
    a. Show that 31g of Lithium produces approximately 115g of lithium fluoride
    b. Show that 90g of fluorine produces approximately 123g of lithium fluoride
    c. How much lithium was used if 87g of lithium fluoride is produced?

40. $Ca + O_2 \rightarrow CaO$
    a. Show that approximately 107g of calcium needed to produce 150g of calcium oxide
    b. Show that the amount of calcium oxide produced from 1kg of calcium is approximately 1400g. (change everything into grams!)
    c. Calculate the amount of calcium oxide formed from 0.82g of oxygen
41. $P_4 + O_2 \rightarrow P_2O_5$
    a. Show that the amount of product formed from 43g of phosphorous is just less than 100g.
    b. 21g of oxygen is used. How much product is formed?
    c. How much oxygen would be needed for 90g of product?
42. $Al + Cl_2 \rightarrow Al_2Cl_3$
    a. 1.3kg of aluminium is used. How much aluminium chloride is produced?
    b. How much chlorine is required to react with 77g of aluminium?
43. $K + H_2O \rightarrow KOH + H_2$
    a. How much hydrogen is produced from a reaction using 132g of water?
    b. How much potassium is required to produce 0.55g of potassium hydroxide?
44. *Challenge: C_4H_{10} reacts with oxygen in complete combustion to produce carbon dioxide and water. It reacts with oxygen in incomplete combustion to produce carbon monoxide (CO) and water. Use this information to show the difference in the mass of oxygen between the two reactions if in each one we start with 15g of butane.*

Part 7: Going the other way

In all of the above, we used a balanced equation to work out masses. We can also go in reverse by using a mass to work out how to balance an equation.

Worked example 6:

Sodium nitrate, $NaNO_3$, decomposes to give sodium nitrite, $NaNO_2$, and oxygen gas. When 8.5g of sodium nitrate is used, 6.9g of sodium nitrite and 1.6g of oxygen is produced. Construct and balance an equation for this reaction.

Step 1: write an unbalanced symbol equation
$NaNO_3 \rightarrow NaNO_2 + O_2$

Even though we could balance this now, the question wants us to use the masses to balance it
Step 2: work out M_r of everything in the equation
$NaNO_3 \rightarrow NaNO_2 + O_2$

85   69   32

Step 3: work out the number of moles of everything you have using mass ÷ M_r
$NaNO_3 \rightarrow NaNO_2 + O_2$

8.5/85   6.9/69   32/1.6

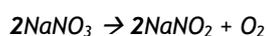*=0.1   =0.1   =0.05*

Step 4: convert to whole number ratio by dividing by smallest number

0.1/0.05   0.1/0.05   0.05/0.05

=2   =2   =1

Step 5: put these numbers into the equation
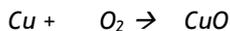
2NaNO₃ → 2NaNO₂ + O₂

Which you can now see is balanced.

Worked example 7:

Copper reacts with oxygen to form copper oxide, CuO. In an experiment 6.35g of copper reacts with 1.60g of oxygen. Balance an equation for this reaction.
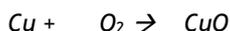
Step 1: write an unbalanced symbol equation

$Cu + O_2 \rightarrow CuO$

Step 2: work out M_r of everything in the equation

63.5   32   79.5

Step 3: work out the number of moles of everything you have using mass ÷ M_r

$Cu + O_2 \rightarrow CuO$

6.35/63.5   1.6/32   9.55/9.5
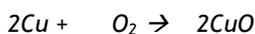
0.1   0.05   0.1

Note that we worked out the mass of copper oxide from combining the mass of the reactants – this is the law of conservation of mass.

Step 4: convert to whole number ratio by dividing by smallest number

0.1/0.05   0.05/0.05   0.1/0.05

= 2   =1   =2

Step 5: put these numbers into the equation

$2Cu + O_2 \rightarrow 2CuO$

Which you can now see is balanced.

45. Potassium nitrate (KNO_3) decomposes (breaks down) on heating to give potassium nitrite (KNO_2) and oxygen. When 4.04 g of KNO_3 is heated, 3.40 g of KNO_2 is produced. Construct a balanced equation for this reaction. When you have finished, check that you got it right by seeing if the equation is balanced.

46. Iron(III) oxide (Fe_2O_3 reacts with carbon (C) to give iron metal (Fe) and carbon dioxide (CO_2). When 480 g of Fe_2O_3 is heated with carbon, 336 g of Fe and 198 g of CO_2 are produced. Construct a balanced equation for this reaction.

47. *Challenge: 0.01 moles of Z are burnt completely in oxygen. The word equation is:*
    Z + oxygen → carbon dioxide + water
    The symbol equation is:
    $C_xH_y + O_2 \rightarrow \_\_\_CO_2 + \_\_\_H_2O$ *(where x and y are unknown numbers*

    c. *1.76g of carbon dioxide and 0.90g of water are produced. Use this information to work out the balancing numbers of CO_2 and H_2O*

    d. *Use this information to establish x and y*

**Part 8: limiting reactants**

All of the above assumed that we had enough of both reactant to do a perfect reaction with no reactant left over. In reality, one reactant is usually left over at the end and is referred to as an **excess reactant**. The other reactant is all used up and because there isn't more of it limits the reaction. It is therefore called the **limiting reactant**.

Worked example 8:

3 moles of magnesium reacts with 7 moles of oxygen. Which is the limiting reactant?

Step 1: construct and balance an equation
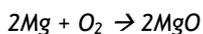
$2Mg + O_2 \rightarrow 2MgO$

*Step 2: manipulate the ratio using the number of moles for **one of the reactants***

In this case we will choose magnesium, but it doesn't really matter so long as you only pick one.

	Mg	O_2	MgO
	2	1	2
÷ 2	1	0.5	
x 3	3	1.5	

This shows us that if we start with 3 moles of magnesium, we only need 1.5 moles of oxygen. In out case we have 7 moles of oxygen.
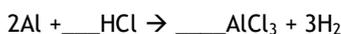
*Step 3: Assign the **excess** and **limiting** reactants*

We have a lot more oxygen than we need which means that it is the excess and magnesium is the limiting reactant

Guided example:

4 moles of aluminium reacts with 3 moles of hydrochloric acid. Which is the limiting reactant?

Step 1: construct and balance an equation

$2Al + \underline{}HCl \rightarrow \underline{}AlCl_3 + 3H_2$

Step 2: manipulate the ratio using the number of moles for **one of the reactants**

	Al	HCl	$AlCl_3$	H_2
	2	——	——	3
÷ 2	1			
x 4	4			

Step 3: Assign the excess and limiting reactants

In this case, do we have more or less HCl than we need?

48. Nitrogen reacts with hydrogen to form ammonia: $N_2 + H_2 \rightarrow NH_3$
    e. Balance the equation
    f. For each of the below conditions, prove what the limiting reactant is:
        i. 0.5 moles of N_2 + 3 moles of H_2, show that nitrogen limiting
        ii. 3 moles of N_2 + 7 moles of H_2, show that hydrogen limiting
        iii. 0.5 moles of N_2 + 2.0 moles of H_2, show that nitrogen limiting
    g. *Challenge: For each of the above, work out how many moles of ammonia will be produced*
49. Sulphur dioxide reacts with oxygen to make sulphur trioxide.
    h. Construct and balance an equation for this reaction
    i. For each of the below conditions, work out what the limiting reactant is:
        iv. 3 moles of SO_2 + 3 moles of O_2
        v. 3 moles of SO_2 + 2 moles of O_2
        vi. 2.0 moles of SO_2 + 0.4 moles of O_2

As before, sometimes you will only be provided with masses and will need to calculate moles for yourself

50. 5.00 g of iron and 5.00 g of sulphur are heated together to form iron (II) sulphide. Show that Fe is limiting.
    $Fe + S \rightarrow FeS$
51. In the Solvay process, ammonia is recovered by the unbalanced equation shown. If 2kg of ammonium chloride and 0.5kg of calcium oxide show that CaO is limiting
    $NH_4Cl + CaO \rightarrow CaCl_2 + H_2O + NH_3$
52. 17g of methane reacts with 20g of oxygen to make carbon dioxide and water.
    a. Show that O_2 is limiting
    b. *Challenge: What mass of carbon dioxide would you expect to obtain from this reaction? Remember to use the number of moles of your **limiting reactant** to calculate this.*
53. 28g Aluminium reacts with 49g of fluorine gas to form aluminium fluoride (AlF_3).
    c. What is the limiting reactant?
    d. *Challenge: What mass of aluminium fluoride would you expect to obtain from this reaction?*
54. In the manufacture of titanium, what mass of titanium can theoretically be formed when 0.5 kg of titanium chloride reacts with 0.1 kg of magnesium?
    $TiCl_4 + 2\ Mg \rightarrow Ti + 2\ MgCl_2$
55. In the manufacture of sulphur trioxide, what mass of sulphur trioxide can theoretically be formed when 1 kg of sulphur dioxide reacts with 0.5 kg of oxygen?
56. *Challenge: Hydrazine (N_2H_4) was used as the rocket fuel for the Apollo missions to the moon. It is by reaction of ammonia with sodium chlorate. What mass of hydrazine is made by reaction of 100 g of ammonia with 100 g of sodium chloriate?*
    $2\ NH_3 + NaOCl \rightarrow N_2H_4 + NaCl + H_2O$

Part 9: concentrations of solution

The concentration of a solution tells us how much substance there is dissolved in the water. High concentration means lots of substance and low concentration means less. We measure concentration in g/dm^3.

A dm^3 is a decimetre cubed. This is $1000cm^3$. To convert from one to the other:

So $1cm^3 = 1/1000dm^3 = 0.001dm^3$
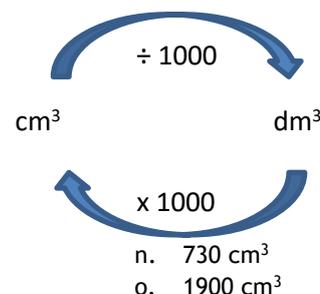
57. Convert the below to dm^3
    j. $10cm^3$
    k. $100\ cm^3$
    l. $200\ cm^3$
    m. $0.03\ cm^3$
    n. $730\ cm^3$
    o. $1900\ cm^3$
58. Convert the below to cm^3
    p. $1dm^3$
    q. $10dm^3$
    r. $70\ dm^3$
    s. $0.8\ dm^3$

Calculating concentration

To calculate the concentration we divide the mass by the volume and give units of g/dm^3

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

Worked example 9

43g of sodium chloride is dissolved in $500cm^3$ of water. What is the concentration?

First, change the volume into dm^3

$500 \div 1000 = 0.5dm^3$

Then, divide the mass by the volume $43/0.5 =$ **$86g/dm^3$**

59. Calculate the concentration of:
    t. 40g solute in $350cm^3$
    u. 100g solute in $77cm^3$
    v. 0.08g solute in $20cm^3$
    w. 90g solute in $780cm^3$

You may also need to rearrange the equation in order to answer questions.

60. Using 83g of solute, how much water is needed to:
    x. Make a $34g/dm^{-3}$ solution
    y. Make a $0.1g/dm^{-3}$ solution
    z. Make a $83g/dm^{-3}$ solution
    aa. Make a $79g/dm^{-3}$ solution
61. What mass of solute is in:
    bb. $25cm^3$ of a $2.3g/dm^3$ solution (remember to convert to dm^3)

cc. 250cm³ of a 71g/dm³ solution

dd. 2.3dm³ of a 61g/dm³ solution

62. For each of the below, calculate the concentration in g/dm³. You will need to convert the moles to masses first.

ee. 3 moles HCl in 100cm³ water

ff. 8 moles Na_2SO_4 in 750cm³ water

gg. 4 moles nitric acid in 300cm³ water

hh. 4 moles nitric acid in 0.83dm³ water

Percentage by mass

The percentage by mass of an element in a compound tells us what mass of a particular compound is due to a particular element. For example, in CO_2, there is one carbon atom and two oxygen atoms. The total M_r is 44, but carbon accounts for 12 of that 33. By mass, its percentage is therefore (12/44) x 100 = 12.3%.

The steps are:

Step 1: calculate total Mr
Step 2: calculate Mr of one of the elements
Step 3: divide your answer to step 2 by step 1 and multiply by 100
Step 4: repeat for any other element you have been asked about

Worked example:

Calculate the percentage by mass of every element in H_2SO_4.

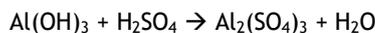|	
Step 1:	total Mr = 2(1) + 32 + 4(16) = 98
Step 2:	there are two hydrogens, each with a mass of 1 so total of 1 + 1 = 2.
Step 3:	(2/98) x 100 = 2%
Step 4:	Sulfur = (32/98) x 100 = 33%
	Oxygen = ((4 x 16)/98) x 100 = 65%

63. Go back in your booklet to question 21. Calculate the % by mass of every element in each of the compounds.

Summary question:

Aluminium hydroxide reacts with sulphuric acid as below

$Al(OH)_3 + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2O$

64. Balance the equation
65. If the sulphuric acid is made by dissolving 6 moles of H_2SO_4 in 755cm³, what is its concentration?
66. How many moles of aluminium hydroxide are in 35g of it?
67. How many moles of aluminium sulphate are produced from a reaction involving 35g of aluminium hydroxide?
68. What mass of water is produced from a reaction involving 12g of sulphuric acid?
69. 41g of aluminium hydroxide is reacted with 41g of sulphuric acid. Which is in excess and which is limiting?

Extra questions

1. What is the atomic number of an atom?
2. Explain in terms of electrons what occurs when magnesium bonds with oxygen
3. What is the name for a substance made of billions of oppositely charged ions joined together?
4. How are the electrons in a phosphorous atom arranged?
5. Explain why ionic compounds conduct electricity in solution
6. What is graphene?
7. Explain in terms of electrons what occurs when lithium bonds with chlorine
8. Why did Mendeleev put some elements in groups?
9. What is an atom?
10. Will NaCl (l) conduct electricity?
11. Explain in terms of electrons what occurs when sodium bonds with oxygen
12. Define inert
13. What are groups in the periodic table?
14. What charge will an ion of beryllium take?
15. Explain why pure metals are soft
16. Explain in terms of electrons what occurs when beryllium bonds with oxygen (3 marks)
17. How many electrons can go in the first shell?
18. What charge will an ion of lithium take?
19. What charge will an ion of oxygen take?
20. In terms of electrons, what do group 0 elements have in common?
21. What is a fullerene?
22. Name KOH
23. How do you calculate the number of neutrons in an atom?
24. Explain why ionic compounds do not conduct electricity when solid
25. What is an element?
26. Give a reason for alloying a metal
27. In ionic bonds, electrons are _____
28. How many electrons are in a given element?
29. Why don't sulphur ions and oxygen ions form ionic bonds with each other?
30. What charge do electrons have?

Summary problem 2

A student conducts the reaction below between aluminium chloride and sodium to form sodium chloride and aluminium:

$Na + AlCl_3 \rightarrow NaCl + Al$
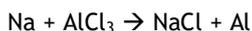
1) Balance the equation
2) Identify reactants, products, elements and compounds
3) This reaction is called a **displacement reaction**. What is a displacement reaction?
4) If this reaction can take place, what can you conclude about the relative reactivity of sodium and aluminium?
5) Sodium is a reactive metal, but is less reactive than potassium.
    a. Draw the full atomic structure of sodium and potassium
    b. Use your diagrams to explain why sodium is less reactive than potassium.
6) Solid sodium conducts electricity. Explain why with reference to its structure and bonding.
7) Solid sodium chloride does not conduct electricity. Explain why with reference to its structure and bonding.
8) If the student wanted sodium chloride to conduct electricity, what could they do?
9) Explain your answer to question 8.
10) Aluminium chloride has a high melting point, but when chlorine is an element (not a compound) it has a very low melting point.
    a. Describe the structure and bonding in elemental chlorine (Cl_2)
    b. Draw a diagram of a covalent molecule
    c. Explain why chlorine has a low boiling point
    d. Explain why aluminium chloride has a high boiling point
11) In terms of electrons, explain how $AlCl_3$ is formed from aluminium and chlorine atoms
12) Explain why aluminium chloride has three chlorines in it but sodium chloride only has one
13) Give the formulae of sodium and aluminium ions
14) How many electrons are there in one aluminium **ion**?
15) How many electrons are there in 15 aluminium ions?
16) How many electrons are there in one mole of aluminium ions?
17) Calculate the M_r of every substance involved in the reaction above
18) If 5 moles of Na and 5 moles of $AlCl_3$ are used, which one is in excess and which one is limiting?
19) If 30g of Na and 25g of $AlCl_3$ are used, which one is in excess and which one is limiting?
20) 90g of sodium is fully reacted with aluminium chloride.
    a. What mass of aluminium is produced?
    b. What mass of aluminium chloride will have been required?
    c. What mass of sodium chloride is produced?

Mixed practice sets

The questions below are designed to be used after specific points in the booklet as additional practice. Your teacher will tell you when to do each one.

Set 1: after conservation of mass

1) A sample of magnesium is heated in air and the mass increases. Explain why.
2) A sample of magnesium is added to acid and it starts bubbling. What will happen to the mass? Explain your answer.
3) A student mixes two colourless and clear solutions together, and a white solid forms. The mass stays the same. Explain why.
4) A student reacts 20g of solid with a gas and the mass of the resulting solid is found to be 30g. What mass of gas reacted?
5) The student actually started with 25g of gas. Explain why the mass did not increase to 45g.

Set 2: after relative formula mass

6) Calculate the relative formula mass of:
    a. KCl
    b. HNO_3
    c. VF_5
    d. $KMnO_4$
    e. LiO
    f. H_2O_2
    g. $Ba(OH)_2$
    h. $(NH_4)_2SO_4$
7) In the reaction below, K and LiBr react together to form KBr and a second substance. Calculate the Mr of the reactants and the known product:
    $K + LiBr \rightarrow KBr + ?$
8) Calculate the Mr of the unknown substance by subtracting the Mr of KBr from the Mr of the reactants.
9) Identify the unknown substance

Set 3: after the mole

10) How many atoms are in a mole of atoms?
11) How many atoms are in two moles of atoms?
12) How many electrons are in ten moles of electrons?
13) How many electrons are in 0.8 moles of electrons?
14) One mole of atom A has a mass of 32g. What would the mass of 0.06 moles of atom A be?
15) A molecule has 12 electrons. How many electrons are in one mole of that molecule?
16) How many electrons would be in 20 moles of that molecule?
17) Calculate the number of electrons in H_2SO_4
18) How many electrons would be in 2 moles of H_2SO_4?
19) How many electrons would be in 12 moles of $(NH_4)_3PO_4$?
20) What is the Mr of $(NH_4)_3PO_4$?
21) What is the Mr of Li_2O?

Set 4: after moles and Mr

22) How many moles are in 40g of $K_2Cr_2O_7$?
23) What is the Mr of a substance if 3.2 moles has a mass of 100g?
24) What is the mass of 4 moles of a substance with an Mr of 84?
25) Calculate the Mr of a substance with a mass of 250g that contains 8 moles
26) What is the mass of 0.8 moles a substance with an Mr of 25?
27) How many moles are in 25g of CO_2?
28) How many atoms of H are there in 2 moles of HBr?

Set 5: after moles and Mr

29) Draw a molecule of oxygen gas (O_2)
30) How many moles are in 200g of oxygen gas?
31) How many electrons are in 200g of oxygen gas?
32) How many electrons are in 150g of oxygen gas?
33) Ozone has three oxygen atoms all chemically bonded. What is its Mr?
34) What is the mass of 10 moles of O_3?
35) How many more atoms are in 30g of O_3 compared to 25g of O_2?

Set 6: after ratios

36) Balance the equation: $N_2 + H_2 \rightarrow NH_3$
37) What is the ratio of nitrogen molecules to hydrogen molecules?
38) If 6 H_2 molecules are used, how many NH_3 molecules can be formed?
39) If 4 moles of N_2 are used, how much H_2 is needed?
40) If 7.2 moles of H_2 are used, how much N_2 is needed and how much NH_3 can be formed?

41) How many moles of H_2 are required to form 15 moles of NH_3?
42) What is the mass of 15 moles of NH_3? (remember to use the formula on page 3)

Set 7: after ratios

43) Balance the equation: $AlCl_3 + F_2 \rightarrow AlF_3 + Cl_2$
44) 2 moles of $AlCl_3$ are used. How much F_2 is needed?
45) What is the Mr of $AlCl_3$?
46) What mass of AlF_3 equates to 43 moles?
47) How many atoms are in 43 moles of AlF_3?

Set 8: after reacting masses

48) Balance the equation: $KCl + F_2 \rightarrow KF + Cl_2$
49) How many moles of F_2 are required to produce 11.8 moles of KF?
50) What is the mass of 11.8 moles of KF?
51) What is the mass of 5 moles of F_2?
52) 10g of F_2 are used. What mass of KCl is required?
53) What mass of KF will be produced?
54) What mass of Cl_2 will be produced?
55) A student wants to make 39.2g of KF. What mass of KCl and F_2 are required?

Set 9: after reacting masses

56) Balance the equation: $Na + Al_2O_3 \rightarrow Na_2O + Al$
57) What mass of Al will be produced from 10g of Al_2O_3?
58) What mass of Na would be required?
59) What mass of Al_2O_3 is required for 946g of Na_2O?
60) How many atoms are in 15g of Al_2O_3?

Set 10: after going from masses → balanced equations

61) 150g of C_2H_6 reacts with 400g of O_2 to make 440g of CO_2 and 270g of H_2O. use this information to construct a balanced symbol equation for this reaction.

Set 11: after going from masses → balanced equations

62) Oxygen reacts with glucose $(C_6H_{12}O_6)$ to produce carbon dioxide and water. Construct an unbalanced symbol equation for this reaction.

63) 18g of glucose reacts with 19.2g of oxygen to make 26.4 g of carbon dioxide and 10.8g of water. Use this information to construct a balanced symbol equation for this reaction.

Set 12: after limiting and excess

64) Balance the equation: $P_4 + O_2 \rightarrow P_2O_5$
65) 5 moles of P_4 are used and 3 moles of O_2. Which is in excess and which is limiting?
66) 6 moles of P_4 are used with 6.5 moles of O_2. Which is excess and which is limiting?
67) 10g of P_4 are used with 15g of O_2. Which is excess and which is limiting? (remember to convert to moles first.
68) If 20g of P_4 are used in an excess of oxygen, what mass of P_2O_5 will be produced?

Set 13: after limiting and excess

69) In the reaction $S_8 + O_2 \rightarrow SO_3$, 332.8g of S_8 is reacted with 499.2g of O_2. Use this information to construct a balanced symbol equation.
70) If 150g of S_8 had have been used with 200g of O_2 what would be the excess and what would be limiting?