**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 + Cl2 🡪 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 Cl2 used?
5. Explain your answer
6. Look at the reaction below:  
   Mg(s) + HCl(aq) 🡪 MgCl2(aq)+ H2(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**

1. The formula for marble powder is CaCO3 and its name is calcium carbonate. Which atoms are present in calcium carbonate?
2. Is calcium carbonate an element or a compound? Explain your answer.
3. Calcium carbonate is an ionic substance. Predict the properties of calcium carbonate
4. Below is a symbol equation for the reaction.  
   CaCO3 + HCl 🡪 CaCl2 + CO2 + H2O  
   Copy the equation into your exercise book and balance it
5. Explain why the mass of this reaction appears to decrease

**Magnesium can be heated in the air to react with oxygen**

1. Oxygen in the air is a simple molecular substance. Predict its properties.
2. The magnesium and oxygen form magnesium oxide. Write a word equation for this reaction. Identify the reactants and the product.
3. Magnesium oxide has a formula MgO. Use this information to write a symbol equation for this reaction.
4. Balance the symbol equation.
5. The diagrams below show what is occurring during the reaction. White circles are atoms of oxygen, and grey ones are atoms of magnesium.
   1. Label two elements in the diagrams
   2. Label a compound in the diagrams
   3. Name all the elements and compounds
   4. Use the number of particles to prove that **mass has been conserved** in this reaction
   5. Use the number of particles to explain why the mass of the product is greater than the mass of the initial magnesium

**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 Mr

**Worked example 1:**

What is the Mr of CaCO3?

*CaCO3 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 Mr 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*

1. For each of the compounds below calculate their Mr
   1. CO
   2. MgO
   3. H2O2
   4. SO2
   5. Na2O
   6. Al2O3
   7. Al(OH)3
   8. Mg(NO3)2
   9. CuSO4
   10. K2SO4
   11. Al2(SO4)3
2. *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?*

The Mr of all the reactants must be equal to the Mr of all the products:

**Worked example 3:**

Look at the equation below, and work out the Mr of the product.

C + O2 🡪 ?

C has an Mr of 12, and O2 has an Mr of 2x16 = 32, so a total of 44. The Mr of the product must be 44.

1. Work out the Mr for the substances given by a ? in the questions below:
   1. K + Cl2🡪 ?
   2. Al + O2 🡪 ?
   3. Li + N2 🡪 ?
   4. HCl + Mg 🡪 ?
   5. NaOH + HCl 🡪 NaCl + ?
   6. Ca(OH)­2 + H2SO4🡪 ? + H2O
   7. Al(OH)3 + ? 🡪 AlPO4 + H2O
2. Challenge: for e and f, establish which substance is given by the ?

Sometimes you will need to balance an equation first to work this out:

**Worked example 4:**

Use the equation below to work out the Mr of NaCl

Na + Cl2 🡪 NaCl

First, you need to balance the equation:

2Na + Cl2 🡪 2NaCl

Then, calculate the Mr of:

2Na = 2 x 23 = 46  
Cl2 = 2 x 35.5 = 71

Add these together: 46 + 71 = 117

1. For each of the questions below (similar to before), balance them and work out the Mr of the products by using the Mr of the reactants
2. K + Cl2🡪 KCl
3. Al + O2 🡪 Al2O3
4. Li + N2 🡪 Li3N
5. Be + F2 🡪 BeF2
6. Ca + O2 🡪 CaO

**Concentrations of solutions**

cm3

dm3

÷ 1000

x 1000

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/dm3.

A dm3 is a decimetre cubed. This is 1000cm3. To convert from one to the other:

So 1cm3 = 1/1000dm3 = 0.001dm3

1. Convert the below to dm3
2. 10cm3
3. 100 cm3
4. 200 cm3
5. 0.03 cm3
6. 730 cm3
7. 1900 cm3
8. Convert the below to cm3
9. 1dm3
10. 10dm3
11. 70 dm3
12. 0.8 dm3

**Calculating concentration**

To calculate the concentration we divide the mass by the volume and give units of g/dm3

**Worked example 5**

43g of sodium chloride is dissolved in 500cm3 of water. What is the concentration?

First, change the volume into dm3

500 ÷ 1000 = 0.5dm3

Then, divide the mass by the volume 43/0.5 = **86g/dm3**

1. Calculate the concentration of:
2. 40g solute in 350cm3
3. 100g solute in 77cm3
4. 0.08g solute in 20cm3
5. 90g solute in 780cm3

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

1. Using 83g of solute, how much water is needed to:
2. Make a 34g/dm3 solution
3. Make a 0.1g/dm3 solution
4. Make a 83g/dm3 solution
5. Make a 79g/dm3 solution
6. What mass of solute is in:
7. 25cm3 of a 2.3g/dm3 solution (remember to convert to dm3)
8. 250cm3 of a 71g/dm3  solution
9. 2.3dm3 of a 61g/dm3 solution

**Summary problem**

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

Na + AlCl3 🡪 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. Draw the full atomic structure of sodium and potassium
6. Would lithium be more or less reactive than sodium?
7. Solid sodium conducts electricity. Explain why with reference to its structure and bonding.
8. Solid sodium chloride does not conduct electricity. Explain why with reference to its structure and bonding.
9. If the student wanted sodium chloride to conduct electricity, what could they do?
10. Aluminium chloride has a high melting point, but when chlorine is an element (not a compound) it has a very low melting point.
    1. Describe the structure and bonding in elemental chlorine (Cl2)
    2. Draw a diagram of a covalent molecule
    3. Explain why chlorine has a low boiling point
    4. Explain why aluminium chloride has a high boiling point
11. In terms of electrons, explain how AlCl3 is formed from aluminium and chlorine atoms
12. How many electrons are there in one aluminium **ion**?
13. Calculate the Mr of every substance involved in the sodium and aluminium chloride reaction above
14. In another reaction, 20g of aluminium is reacted with chlorine gas. Aluminium chloride is the product. Write a word equation for this reaction.
15. Explain why the mass of aluminium chloride is greater than 20g