Master

Kirkcaldy High School

N4/5 Chemistry

Unit 1 - part 5

Reacting quantities

Name: ______________________

Class: ______________________

Teacher: ______________________

Assessment Page

End of topic questions

Topic title	Date	Mark/Total Mark
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Homework

Homework title	Date	Mark/Total Mark
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Check tests

Test title	Date	Mark/Total Mark
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Teacher comments

Date: _______________

Mass, moles and gram formula mass calculations

Learning Intentions

- To learn about mass, moles and GFM.

Success Criteria

☐ I can calculate GFM.

☐ I can use the n, m, GFM formulae to perform calculations.

Introduction to moles

A "mole" is a unit chemists use to count particles, like atoms or molecules. It's similar to how we might use "dozen" to mean 12 of something. However, instead of a specific number like 12, a mole represents a large collection of particles.

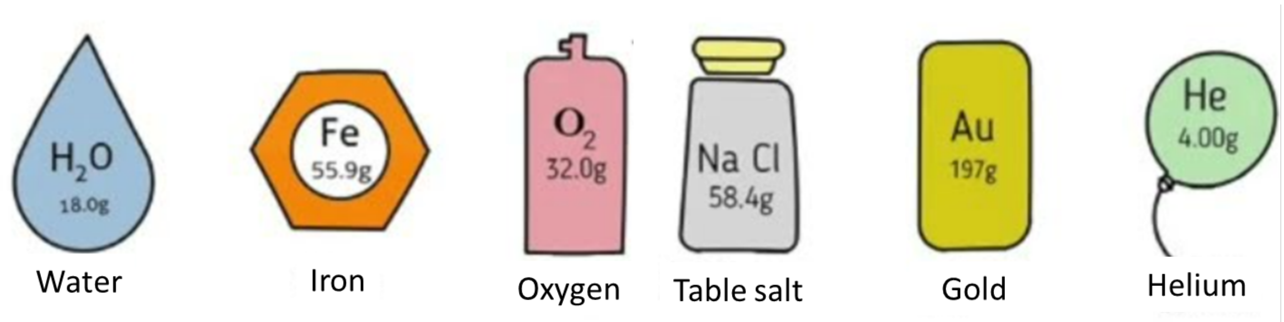
The “mole” is a tool chemists use to work with specific numbers of particles. Since we can't see individual particles with our eyes, we rely on measurements like weight or volume. By using moles, chemists ensure they have the right ratio of particles, allowing them to calculate the precise mass or volume needed for their experiments.

Moles and Mass

Every substance has a specific weight for one mole of its particles. This weight is known as the **gram formula mass (GFM)** and is measured in **grams per mole (g/mol).**

Examples:

1. **Oxygen (O_2):** One mole of oxygen molecules has a molar mass of about 32 g/mol. So, if we have a mole of oxygen, it will weigh 32 grams.
2. **Water (H_2O):** One mole of water molecules has a molar mass of about 18 g/mol. If we have a mole of water, it will weigh 18 grams.



Calculating GFM

To calculate GFM we need to use the **relative atomic masses** of the elements involved in the formula. These can be found on page 7 of your data booklet.

Element	Symbol	Relative atomic mass	Density (g cm^{-3})	Date of Discovery
Actinium	Ac	227	10.1	1899
Aluminium	Al	27	2.70	1825
Americium	Am	243	12.0	1944
Antimony	Sb	122	6.68	Ancient
Argon	Ar	40	0.0018	1894
Arsenic	As	75	5.75	~1250

To calculate the **gram formula mass (GFM)** we add up all the **relative atomic masses** of each atom in the formula. If there is a bracket you multiply the number of atoms inside the brackets by that number.

Complete the following with your teacher.

H_2O

1 x ___

2 x ___

GFM = ______ g / mol

NH_3

3 x ___

1 x ___

GFM = ______ g / mol

$Mg(NO_3)_2$

6 x ___

2 x ___

1 x ___

GFM = ______ g / mol

SO_2

___ x ___

___ x ___

GFM = ______ g / mol

PCl_3

___ x ___

___ x ___

GFM = ______ g / mol

$Al_2(SO_4)_3$

___ x ___

___ x ___

___ x ___

GFM = ______ g / mol

Calculate the GFM of each of the following substances given the formula.

O_2	CH_4	NH_3
N_2	HCl	$Ca(OH)_2$
CO_2	$MgCl_2$	NH_4NO_3
$NaCl$	C_3H_8	$Zn_3(PO_4)_2$
H_2SO_4	$CaCO_3$	$(NH_3)_2CO_3$

Why Do We Use Mass, Moles, and GFM in Chemistry?

Mass:

- Mass is a measure of the **amount of matter** in an object or substance.
- In a laboratory setting, it is determined using an instrument called a **balance**.

Moles:

- Atoms and molecules are **tiny**, so we use moles to **count** them in a practical way.
- It standardises how chemists worldwide communicate substance **amounts**, like how we use "dozen" for eggs.

GFM (Gram Formula Mass):

- It's the bridge between the atomic (**micro**) and real-world (**macro**) levels.
- By knowing the GFM, we can work out **how much** of a substance we need to ensure the right **number** of **particles** are present for a reaction.

Questions

1. **Define** mass in the context of a lab measurement.

2. **Identify** the instrument used in a lab to measure the mass of a substance.

3. **Explain** the reason chemists use the term "moles" for atoms and molecules.

4. **Describe** the importance of GFM in assisting chemists in real-world scenarios.

5. **Determine** what information about a reaction can be inferred by a chemist if they know the GFM of a substance.

Mass, moles, GFM calculation Triangle

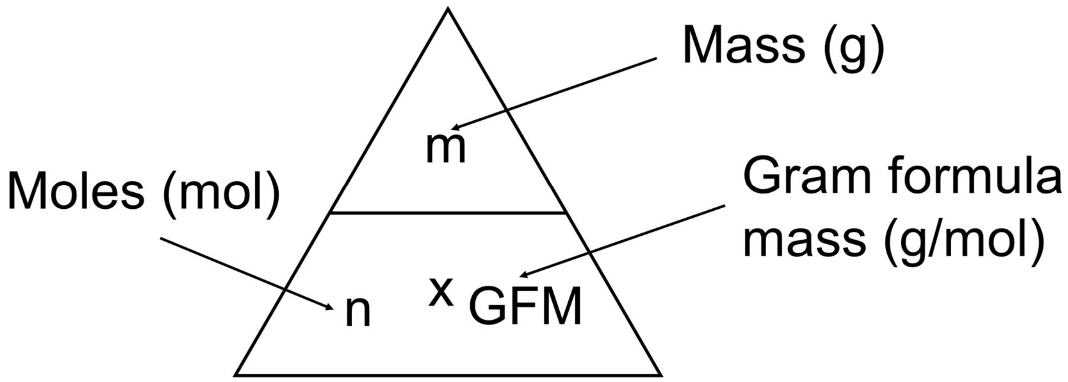
Using mass, moles and GFM we can calculate the appropriate mass needed to be weighed to perform chemical reactions. The relationship between these is shown below.

$$m = n \times GFM$$

Where:

- *m* is the mass of the substance in grams.
- *n* is the number of moles.
- *GFM* is the gram formula mass in grams per mole (g/mol).

This relationship can be put into a calculation triangle:



Using this calculation triangle we can find all of the relationships:

$$m = n \times GFM$$

This calculates the **mass** given the **moles** and **GFM**.

$$n = \frac{m}{GFM} \quad (n = m \div GFM)$$

This calculates the **moles** given the **mass** and **GFM**.

$$GFM = \frac{m}{n} \quad (GFM = m \div n)$$

This calculates the **GFM** given the **mass** and **moles**.

Calculating Moles from Mass: To find out how many moles of a substance you have based on its mass:

$$n = \frac{m}{GFM} \qquad (n = m \div GFM)$$

Example

If you have 29 grams of NaCl (sodium chloride) and its GFM is 58 g/mol, then:

$$n = \frac{m}{GFM}$$

$$n = \frac{29}{58}$$

$$n = 0.5\,mol$$

Questions

Calculate the number of moles of the following substances given the mass and GFM. <u>SHOW ALL OF YOUR WORKING.</u>

1. Given that the GFM of water (H_2O) is 18 g/mol, calculate how many moles are present in a 36 g sample.

2. Given that the GFM of carbon dioxide (CO_2) is 44 g/mol, calculate how many moles are present in a 44 g sample.

3. Given that the GFM of oxygen gas (O_2) is 32 g/mol, calculate how many moles are present in a 64 g sample.

4. Given that the GFM of nitrogen gas (N_2) is 28 g/mol, calculate how many moles are present in a 28 g sample.

5. Given that the GFM of methane (CH_4) is 16 g/mol, calculate how many moles are present in a 32 g sample.

6. Given that the GFM of ethanol (C_2H_5OH) is 46 g/mol, calculate how many moles are present in a 46 g sample.

7. Given that the GFM of sodium chloride (NaCl) is 58 g/mol, calculate how many moles are present in a 58 g sample.

8. Given that the GFM of ammonia (NH_3) is 17 g/mol, calculate how many moles are present in a 34 g sample.

9. Given that the GFM of hydrogen gas (H_2) is 2 g/mol, calculate how many moles are present in a 16 g sample.

10. Given that the GFM of calcium oxide (CaO) is 56 g/mol, calculate how many moles are present in a 40 g sample.

You will need to calculate the GFM yourself in the following questions.

1. Calculate the moles of a 36 g sample of water (H_2O). Note: You'll need to determine the GFM first.

2. Calculate the moles of a 22 g sample of carbon dioxide (CO_2). Note: You'll need to determine the GFM first.

3. Calculate the moles of a 128 g sample of oxygen gas (O_2). Note: You'll need to determine the GFM first.

4. Calculate the moles of a 42 g sample of nitrogen gas (N_2). Note: You'll need to determine the GFM first.

5. Calculate the moles of a 4 g sample of methane (CH_4). Note: You'll need to determine the GFM first.

6. Calculate the moles of a 2 g sample of ethanol (C_2H_5OH). Note: You'll need to determine the GFM first.

7. Calculate the moles of a 2.9 g sample of sodium chloride (NaCl). Note: You'll need to determine the GFM first.

8. Calculate the moles of a 238 g sample of ammonia (NH_3). Note: You'll need to determine the GFM first.

Calculating mass from moles: To find out the mass a substance you have based on its moles:

$$m = n \times GFM$$

Example

If you have 1.5 moles of NaCl (sodium chloride) and its GFM is 58 g/mol, then:

$$m = n \times GFM$$

$$n = 1.5 \times 58$$

$$n = 87\ g$$

Questions

1. Calculate the mass of a 2 mole sample of water (H_2O). Note: You'll need to determine the GFM first.

2. Calculate the mass of a 1 mole sample of carbon dioxide (CO_2). Note: You'll need to determine the GFM first.

3. Calculate the mass of a 1.5 mole sample of oxygen gas (O_2). Note: You'll need to determine the GFM first.

4. Calculate the mass of a 1 mole sample of nitrogen gas (N_2). Note: You'll need to determine the GFM first.

5. Calculate the mass of a 2 mole sample of methane (CH_4). Note: You'll need to determine the GFM first.

6. Calculate the mass of a 2.5 mole sample of ethanol (C_2H_5OH). Note: You'll need to determine the GFM first.

7. Calculate the mass of a 1 mole sample of sodium chloride (NaCl). Note: You'll need to determine the GFM first.

8. Calculate the mass of a 3 mole sample of ammonia (NH_3). Note: You'll need to determine the GFM first.

9. Calculate the mass of a 4 mole sample of hydrogen gas (H_2). Note: You'll need to determine the GFM first.

10. Calculate the mass of a 1.5 mole sample of calcium oxide (CaO). Note: You'll need to determine the GFM first.

Date: _______________

Calculations involving balanced chemical equations - mass

Learning Intentions

- To learn how to perform calculations from balanced chemical equations.

Success Criteria

- ☐ I can determine the molar ratio of two given substances in a chemical equation.
- ☐ I can perform a molar ratio calculation.
- ☐ I can perform a calculation from a balanced chemical equation.

Introduction to calculations involving balanced chemical equations

When you have a chemical reaction, it's useful to know how much of each substance you need and how much you'll end up with at the end. A balanced chemical equation helps with this.

The numbers we have been placing at the beginning of a formulae when balancing chemical equations are the **molar ratio coefficients**. These tell us the “recipe” for the reaction. It tells you how many **moles** of one **substance** you **need** (or **get**) **compared** to another.

If we look at the balanced chemical equation below we can see that we need **1** mole of **CH_4** for every **2** moles of **O_2**. This gives us a molar ratio of **1:2**.

We can also see for every **1** mole of **CH_4** we will produce **1** mole of **CO_2**. This gives us a ratio of **1:1**.

1 mol:2 mol

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

1 mol:1 mol

Calculating the moles of substances using the molar ratio

We can use the **molar ratio** to calculate the **number** of **moles** of **other** substances in the chemical equation.

Molar ratios tell us if we must **multiply** or **divide** our **number** of moles.

Fill in the table with the molar ratio and what must be done to the number of moles.

Molar Ratio	Stays the same/multiply by x/divide by x
1:1	**Stays the same**
1:2	**Multiply by 2**
1:3	**Multiply by 3**
2:1	**Divide by 2**
3:1	**Divide by 3**
2:2	**Stays the same**
2:3	**Divide by 2 multiply by 3**
3:2	**Divide by 3 multiply by 2**

Let's take our example from the previous page. If we know we fully reacted 5 moles of CH_4 with oxygen, we can use the molar ratio to find the moles of the other substances in the equation.

1 mol:2 mol

Multiply moles by 2

5 mol CH_4:**10** mol O_2

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

1 mol:1 mol

Moles stays the same

5 mol CH_4:**5** mol CO_2

So, now we know the **number** of moles of **O_2** and **CO_2** involved in the reaction. As long as you know the number of moles of one substance you can find out the rest.

Questions

1. **Carbon and Oxygen Reaction**

Given the reaction:

$$C + O_2 \rightarrow CO_2$$

With 3 moles of C, how many moles of CO_2 are formed?

Molar Ratio ______________________

same, multiply by x, or divide by x ______________________

Calculated Moles of CO_2: ______________________

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2. **Combustion of Hydrogen**

Given the reaction:

$$2H_2 + O_2 \rightarrow 2H_2O$$

If you have 4 moles of H_2, how many moles of O_2 are required?

Molar Ratio ______________________

same, multiply by x, or divide by x ______________________

Calculated Moles of O_2: ______________________

---

3. **Ammonia Formation**

Given the reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

With 2 moles of N_2, how many moles of NH_3 are produced?

Molar Ratio ______________________

same, multiply by x, or divide by x ______________________

Calculated Moles of NH_3: ______________________

---

4. **Combustion of Methane**

Given the reaction:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

With 5 moles of CH_4, how many moles of H_2O are formed?

Molar Ratio ______________________

same, multiply by x, or divide by x: ______________________

Calculated Moles of H_2O: ______________________

5. **Decomposition of Water**

Given the reaction:

$$2H_2O \rightarrow 2H_2 + O_2$$

With 6 moles of H_2O, how many moles of H_2 are formed?

Molar Ratio ______________________

same, multiply by x, or divide by x ______________________

Calculated Moles of H_2: ______________________

---

6. **Formation of Sulfur Dioxide**

Given the reaction:

$$S + O_2 \rightarrow SO_2$$

With 7 moles of S, how many moles of SO_2 are produced?

Molar Ratio ______________________

same, multiply by x, or divide by x ______________________

Calculated Moles of SO_2: ______________________

---

7. **Decomposition of Calcium Carbonate**

Given the reaction:

$$CaCO_3 \rightarrow CaO + CO_2$$

With 8 moles of $CaCO_3$, how many moles of CO_2 are formed?

Molar Ratio ______________________

same, multiply by x, or divide by x ______________________

Calculated Moles of CO_2: ______________________

---

8. **Reaction of Iron with Oxygen**

Given the reaction:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

With 11 moles of Fe, how many moles of Fe_2O_3 are produced?

Molar Ratio ______________________

same, multiply by x, or divide by x ______________________

Calculated Moles of Fe_2O_3: ______________________

Calculations involving balanced chemical equations – complete

Before you continue can you:

- ☐ Calculate the GFM of a substance given the formula?
- ☐ Calculate the moles of a substance given the mass?
- ☐ Perform a molar ratio calculation?
- ☐ Calculate the mass of a substance given the moles?

Now that we've mastered the necessary skills, let's delve into calculations where we're given the mass of one substance and need to determine the mass of another substance within the same chemical equation.

Your teacher will now demonstrate how to perform these calculations below:

$$2H_2 + O_2 \rightarrow 2H_2O$$

Using the equation above, suppose we're given 4 grams of H_2 and asked to find the mass of H_2O produced.

Questions

1. For the reaction:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Given 14 g of N_2, determine the mass of NH_3 produced.

2. For the reaction:

$$C + O_2 \rightarrow CO_2$$

Given 12 g of C, determine the mass of CO_2 produced.

3. For the reaction:

$$H_2O \rightarrow 2H_2 + O_2$$

Given 36 g of H_2O, determine the mass of H_2 produced.

4. For the reaction:

$$CaCO_3 \rightarrow CaO + CO_2$$

Given 100 g of $CaCO_3$, determine the mass of CO_2 produced.

5. For the reaction:

$$Na + Cl_2 \rightarrow 2NaCl$$

Given 46 g of *Na*, determine the mass of *NaCl* produced.

6. For the reaction:

$$P_4 + 5O_2 \rightarrow P_4O_{10}$$

Given 124 g of P_4, determine the mass of P_4O_{10} produced.

7. For the reaction:

$$K + F_2 \rightarrow 2KF$$

Given 78 g of K, determine the mass of KF produced.

8. For the reaction:

$$H_2 + Cl_2 \rightarrow 2HCl$$

Given 2 g of H_2, determine the mass of HCl produced.

9. For the reaction:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

Given 224 g of Fe, determine the mass of Fe_2O_3 produced.

Date: ________________

Percentage by mass

Learning Intentions

- To learn how to calculate the percentage by mass of an element in a compound.

Success Criteria

☐ I can calculate the percentage by mass of an element in a given compound.

Introduction to percentage by mass calculations

To find the percentage by mass of a given element in a formula, we must first calculate the **GFM** of the substance and use the following equation:

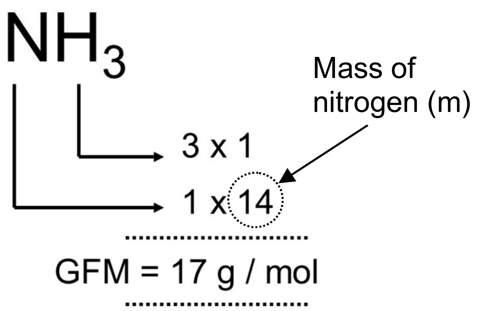
$$percentage\ by\ mass = \frac{m}{GFM} \times 100$$

Where m = the total mass of the given element in the formula.

Example

Calculate the percentage by mass of nitrogen (N) in ammonia (NH_3).

Step 1: calculate the GFM



Step 2: Use the percentage by mass formula

$$percentage\ by\ mass = \frac{m}{GFM} \times 100$$

$$percentage\ by\ mass = \frac{14}{17} \times 100$$

$$percentage\ by\ mass = 82.4\ \%$$

Questions

1. What is the percentage by mass of calcium in calcium carbonate ($CaCO_3$)?

2. Calculate the percentage by mass of hydrogen in water (H_2O).

3. Find the percentage by mass of oxygen in glucose ($C_6H_{12}O_6$).

4. Determine the percentage by mass of nitrogen in ammonium nitrate (NH_4NO_3).

5. What is the percentage by mass of chlorine in sodium chloride ($NaCl$)?

6. Calculate the percentage by mass of carbon in ethanol (C_2H_5OH).

7. Find the percentage by mass of sulfur in sulfuric acid (H_2SO_4).

8. Determine the percentage by mass of magnesium in magnesium oxide (MgO).

9. What is the percentage by mass of iron in hematite (Fe_2O_3)?

10. Calculate the percentage by mass of silicon in silicon dioxide (SiO_2).

Date: ________________

Moles, concentration, and volume

Learning Intentions

- To learn how to calculate the moles of solutions.

Success Criteria

☐ I can calculate the moles of a solution given the concentration and volume.

☐ I can calculate the concentration of a solution given the moles and volume.

What is a Solution?

A solution is a mixture where one substance is dissolved into another. The result is a single-phase system, typically liquid, where you cannot distinguish the components with the naked eye. e.g. salt water, tea, coffee, etc.

Components of a Solution:

1. **Solute:** The solute is the substance that is dissolved in the solvent. It can be a solid, liquid, or gas. For instance, in a saltwater solution, the salt is the solute.

2. **Solvent:** The solvent is the substance that dissolves the solute. It is typically present in a greater amount than the solute. Using the previous example, water is the solvent in a saltwater solution.

3. **Solution:** The solution is the final homogenous mixture of solute and solvent. It has the same properties throughout, and you cannot see the separate components.

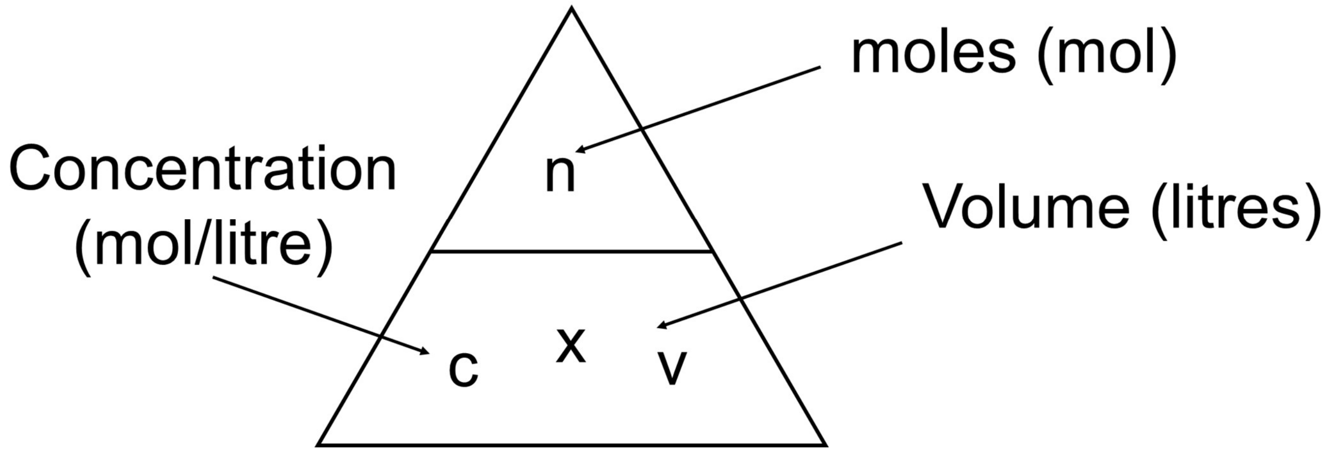
Concentration can be measured in **moles per litre** (mol l^{-1} or mol/l). This is also known as **molarity** (M).

If there is a **greater** volume of solvent and **less** moles of solute the solution will be **less concentrated**. This is referred to as a **dilute** solution.

If there is a **lower** volume of solvent and **more** moles of solute the solution will be **more concentrated**. This is referred to as a **concentrated** solution.

Calculations involving solutions

The relationship between moles, concentration and volume is shown in the calculation triangle below:



Using this calculation triangle, we can find all the relationships:

$$n = c \times v$$

This calculates the **moles** given the **concentration** and **volume**.

$$c = \frac{n}{v} \quad (c = n \div v)$$

This calculates the **concentration** given the **moles** and **volume**.

$$v = \frac{n}{c} \quad (v = n \div c)$$

This calculates the **volume** given the **moles** and **concentration**.

Converting cm^3 to litres

Notice the calculation uses **litres** as the volume. If you are given **cm^3** you must convert this to **litres.**

To convert cm$_3$ into litres you must **divide** by **1000.**

e.g. 20 cm^3 = 0.02 litres

<u>You must ensure you have converted to litres in every question.</u>

Questions – calculating moles from concentration and volume

1. If you have 250 cm³ of a 0.1 mol l^{-1} HCl solution, how many moles of HCl are present?

2. Calculate the number of moles in 500 cm³ of a 2 mol l^{-1} NaOH solution.

3. What is the number of moles in 150 cm³ of a 1.5 mol l^{-1} KNO_3 solution?

4. Find the moles of solute in 75 cm³ of a 0.5 mol l^{-1} $CuSO_4$ solution.

5. How many moles are there in 300 cm³ of a 0.25 mol l^{-1} $CaCl_2$ solution?

6. Determine the number of moles in 1000 cm³ of a 0.2 mol l^{-1} $C_6H_{12}O_6$ solution.

7. What are the moles of NaCl in 200 cm³ of a 1 mol l^{-1} NaCl solution?

8. Calculate the moles of NH_3 in 400 cm³ of a 0.75 mol l^{-1} NH_3 solution.

9. How many moles of CH_3COOH are in 600 cm³ of a 0.5 mol l^{-1} CH_3COOH solution?

10. Find the number of moles in 450 cm³ of a 0.33 mol l^{-1} H_2SO_4 solution.

Questions – calculating concentration from moles and volume

1. Calculate the concentration when 0.5 moles of NaCl is dissolved in 250 cm³ of water.

2. What is the concentration of a solution with 1 mole of KCl in 500 cm³ of water?

3. Find the concentration if 0.25 moles of $Ca(NO_3)_2$ is dissolved in 750 cm³ of water.

4. Determine the concentration when 2 moles of H_2SO_4 is dissolved in 1000 cm³ of water.

5. What is the molarity of a solution containing 0.75 moles of $CuSO_4$ in 300 cm³ of water?

6. Calculate the concentration when 1.5 moles of $C_6H_{12}O_6$ is dissolved in 2000 cm³ of water.

7. Find the molarity of a solution with 0.2 moles of NH_3 in 100 cm³ of water.

8. What is the concentration of a solution with 3 moles of CH_3COOH in 1500 cm³ of water?

9. Determine the molarity when 0.05 moles of $MgCl_2$ is dissolved in 500 cm^3 of water.

10. Calculate the concentration of a solution that has 0.1 moles of Na_2SO_4 in 400 cm^3 of water.

Extension questions:

Chemcord purple books (N5): page 41-43

SCHOLAR

Topic	2015	2016	2017	2018	2019
Reacting Quantities	MC – 9 S2 – 7b	MC – S2 – 3c,4b, 12d	MC – 8,9 S2 – 10b,12c	MC – S2 –3b, 13a(ii)	MC – 10 S2 – 1c,5c

MC = multiple choice section, S2 = section 2, the written section.