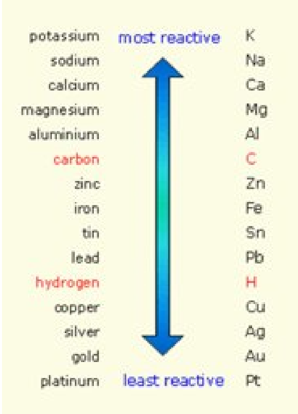
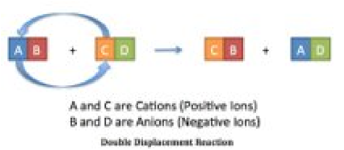
C5 Chemical Changes

Year 11 – Chemistry / Chemical Changes – HT1

Displacement reactions and metal extraction



Reactivity depends on tendency to form metal ion



HT: OILRIG
Oxidation Is Loss of electrons
Reduction Is Gain of electrons

Metal + Oxygen → Metal Oxide

Metal + Water → Metal Hydroxide + hydrogen

Metal + acid → Metal salt + Hydrogen

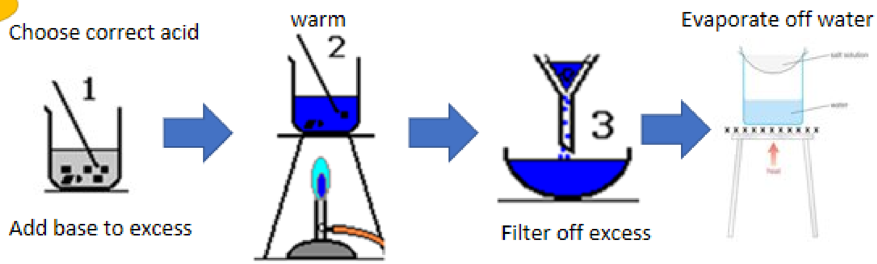
Reactions of acids

Acid+metal → salt + hydrogen
Acid + alkali → salt + water
Acid + insoluble base → salt + water
Acid + carbonate → salt + water + carbon dioxide

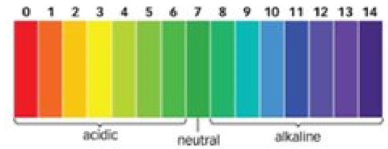
HT: OILRIG
e.g. $2HCl + Mg \rightarrow MgCl_2 + H_2$
Magnesium is oxidised
$Mg \rightarrow Mg^{2+} + 2e^-$

Hydrochloric Acid → Chlorides
HCl
Nitric Acid → Nitrates
HNO_3
Sulphuric Acid → Sulphates
H_2SO_4

RP: Preparation of a dry sample of a soluble salt



Neutralisation

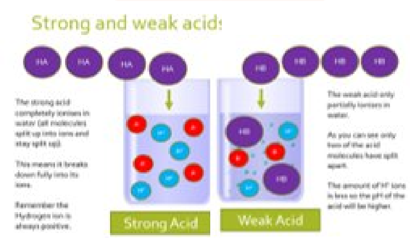


Acids produce H^+ ions
Alkalis produce OH^- ions

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

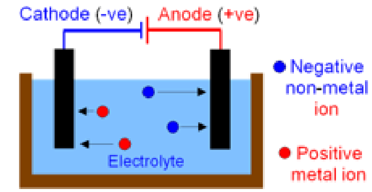
HT: Strong and Weak acids

Concentration of hydrogen ions in mol/dm³	pH
0.10	1.0
0.010	2.0
0.0010	3.0
0.00010	4.0



Electrolysis

..of molten:

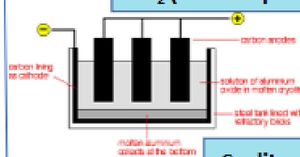


Higher:
At the cathode
$Pb^{2+} + 2e^- \rightarrow Pb$

Higher:
At the anode
$2Br^- \rightarrow Br_2 + 2e^-$
or
$2Br^- - 2e^- \rightarrow Br_2$

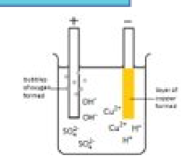
..to extract aluminium:

Oxygen goes to anode → CO_2 (needs replacing)



Cyolite reduces the melting point

..of solutions:



At the anode:	At the cathode:
Halide (Gp7) Oxygen	Least reactive

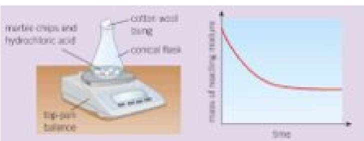
C8 Rates and Equilibrium

Measuring Rate

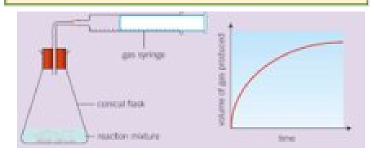
To measure the rate of a reaction you can:

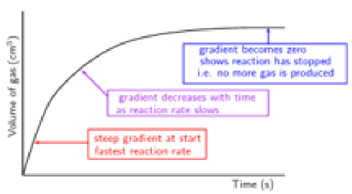
- **Measure how fast the reactants are used up**
- **Measure how fast the products are made**

e.g. Measure mass lost due to gas formed



e.g. Measure volume of gas made

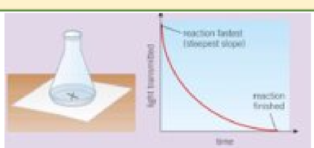




Rate = volume of gas ÷ time

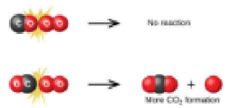
cm^3/s

e.g. Measure time for insoluble product to form



Collision theory

For a reaction to happen reactants must:
collide with **enough energy** (activation energy)



A successful collision is one that leads to a reaction

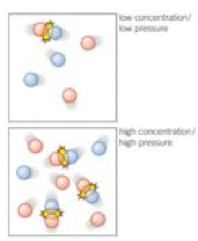
So to increase the rate of a reaction you must either

- **Increase the frequency of collisions**
- **Increase the energy of the collisions**
- **Decrease the energy needed for a collision to be successful**

Factors affecting rate

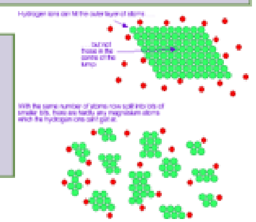
Concentration and Pressure

More particles in the same space.
More frequent collisions



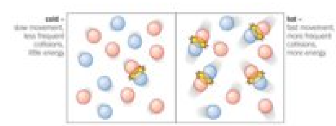
Surface area

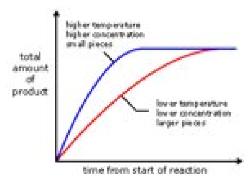
More particles available to react.
More frequent collisions



Temperature

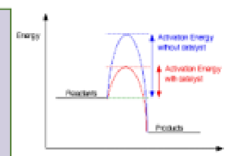
Particles **move faster**.
So they **collide more frequently**.
Particles collide **with more energy**.
So more of the collisions are **successful**.





Catalysts

Lower the energy needed for successful collisions. (Activation energy)
Not used up.
Biological catalysts are called **enzymes**



Reversible reactions

Can go in both directions.

$$A + B \rightleftharpoons C + D$$

If a reaction is exothermic in one direction it is endothermic in the other direction.

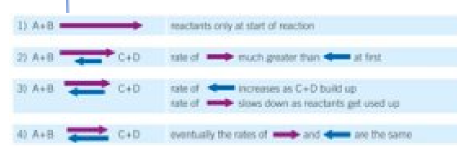
endothermic (in forward reaction) →

hydrated copper(II) sulfate (blue) ⇌ anhydrous copper(II) sulfate (white) + water

$$CuSO_4.5H_2O \rightleftharpoons CuSO_4 + 5H_2O$$

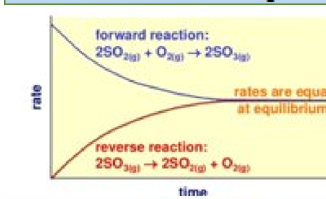
← exothermic (in reverse reaction)

In a **closed system** (where nothing can get in or out) an **equilibrium** is reached where **the rate of reaction is the same in both directions.**



At equilibrium:

- Rate of forward reaction = rate of reverse reaction.
- Mount of products and reactants don't change.



Year 11 – Chemistry / Rates and Equilibrium – HT1

Chemical Calculations Knowledge Organiser

Section 1: Key Terms

1 Relative atomic mass	Usually expressed as A_r, this is the mass number of an element.
2 Relative formula mass	Usually expressed as M_r, this is the mass number of all the elements in a compound combined.
3 Mole	The relative atomic mass of an element or formula mass of compound in grams.
4 Avogadro constant	The amount of atoms, molecules or ions in 1 mole of a substance. The number is always 6.022×10^{23}.
5 Limiting reactant	A reactant that stops the reaction from happening as it is all used up.
6 Percentage yield	The actual mass of a product divided by the theoretical yield, times by 100.
7 Atom economy	The relative mass of the product wanted over the relative mass of all the products formed, times by 100.
8 Concentration	The amount of a solute over the amount of solution.
9 Titration	A technique to find out the concentrations of an unknown substance.

Section 2: Working out relative atomic masds and relative formula mass

You can calculate the relative atomic mass A_r of an element given the percentage abundance of its isotopes, for example, copper has two isotopes,

^{63}Cu (abundance = 69%) and ^{65}Cu (31%).

To work out the relative atomic mass of copper from this data, imagine you had 100copper atoms. 69 copper atoms would have a relative mass of 63, and the other 31 copper atoms would have a mass of 65. then calculate the mean relative mass of these 100 atoms :

$$A_r \text{ of Cu} = \frac{(69 \times 63) + (31 \times 65)}{100} = 63.5$$

You also need to know how to work out the relative formula mass of more complex ionic compounds such as aluminium sulfate, $Al_2(SO_4)_3$

Aluminium has an A_r of 27, the A_r of sulfur is 32, and the A^r of oxygen is 16. in this case you must multiply any atoms within the brackets by the sub-script number after the brackets. This means that the M_r of aluminium sulphate is.

(27 x 2) + (32 x 3) + (16 x 12) = 54 + 96 + 192 = 342

Section 3—Mole calculations

Moles from masses

Chemists prefer to use the mole when describing relative numbers of particles (atoms, molecules, or ions) in a certain mass of substance.

They use the equation:

$$\textbf{Number of moles} = \frac{\text{mass (g)}}{A_r} \quad \text{or} \quad \frac{\text{mass (g)}}{M_r}$$

Masses form moles

Sometimes you will have to work out the mass of a substance from a given number of moles.

By re-arranging:

$$\text{Number of moles} = \frac{\text{mass (g)}}{A_r} \quad \text{or} \quad \frac{\text{mass (g)}}{M_r}$$

You can calculate the mass of a certain number of moles of substance using the equation:

Mass (g) = number of moles x A_r or number of moles x M_r

Section 4—Equations

$$\text{Percentage yield} = \frac{\text{actual mass of product produced}}{\text{Maximum theoretical mass of product possible}} \times 100\%$$

$$\text{Percentage atom economy} = \frac{\text{relative formula mass of the desired product from equation}}{\text{Sum of the relative formula masses of the reactants from equation}} \times 100\%$$

$$\text{Concentration (g/dm}^3) = \frac{\text{amount of solute (g)}}{\text{Volume of solution (dm}^3)}$$

Chemical Calculations Knowledge Organiser

Section 5—Worked Examples

When lead is extracted from its ore, galena, the first stage is the roasting of lead sulphide, PbS, to convert it to lead oxide, PbO. The lead oxide is then reduced to form lead metal. The balanced symbol equation for the first stage, with state symbols is:

$2Pb(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$

Calculate the percentage atom economy of this first stage in the process of extracting lead.

(A_r values: Pb = 207, S = 32,) = 16)

Solution

$$\text{\% atom economy} = \frac{\text{Relative formula mass of the Desired product from equation}}{\text{Sum of the relative formula masses of the reactants from equation}} \times 100\%$$

$$= \frac{M_r\,(2PbO)}{[M_r\,(2PbS) + M_r\,(3O_2)]} \times 100\%$$

$$= \frac{2 \times (207 + 16)}{[2 \times (207 + 32)\,] \;+\; [3 \times (16 \times 2)\,]} \times 100\%$$

$$= \frac{2 \times (207 + 16)}{[2 \times (207 + 32)] \;+ [3 \times (16 \times 2)]} \times 100\%$$

$$= \frac{446}{(478 + 96)} \times 100\%$$

$$= 77.7\%$$

Limestone is mainly made of calcium carbonate. In the production of calcium oxide, crushed lumps of limestone are heated in a rotating lime kiln. The calcium carbonate decomposes to make calcium oxide, and carbon dioxide gas is given off. A company processes 200tonnes of limestone a day. It collects 98.0 tonnes of calcium oxide, the useful product. What is the percentage yield of the reaction in the kiln, assuming limestone contains only calcium carbonate? (A_r values: Ca = 40, C = 12, O = 16)

Solution

Calcium carbonate → calcium oxide + carbon dioxide

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Work out the relative formula masses of CaO_3 and CaO:

M_r of $CaCO_3$ = 40 + 12 + (16 x 3) = 100

M_r of CaO = 40 + 165 = 56

So the balanced symbol equation tells you that 100 tonnes of $CaCO_3$ could make 56 tonnes of CaO, assuming 100% yield.

Therefore 200 tonnes of CaO_3 could make a maximum of (56 x 2) tonnes of CaO = 112tonnes (theoretical yield in this case).

$$\text{So percentage yield} = \frac{\text{Mass of product produced}}{\text{Maximum mass of product possible}} \times 100\%$$

$$= \frac{98.0}{112} \times 100\% = 87.5\%$$

Chemical Calculations Knowledge Organiser

Section 6—Titration (Required Practical)

A titration is carried out using a number of steps:

1.If the sample is a solid, it is **weighed** using an accurate balance, and then **dissolved** to make up a known volume of solution (usually 100cm^3).

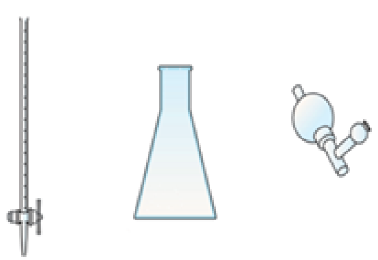
2.A **pipette** is used to measure accurately a volume of this solution - for example, 10cm^3. A safety pipette filler is used to draw solution into the pipette. This is emptied into a **conical flask**.

3.A few drops of an **indicator** may be added to the conical flask. This will show a change of colour when the titration is complete.

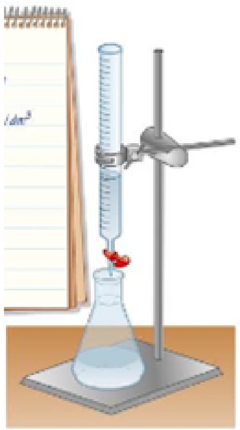
4.A second chemical is placed in a **burette**. This other solution is of a chemical that will react with the synthesised chemical sample in the conical flask. Often the solution in the burette is an **acid or alkali**, and it must be of a precise, known concentration.

5.The solution from the burette is run into the conical flask. The solution is added one drop at a time, with swirling to mix the solutions as the end-point is approached. Eventually, a colour change shows that the correct amount has been added to react completely with the synthesised chemical in the sample.

6.The volume of solution added from the burette is noted. The titration results can then be used to calculate the amount of the synthesised chemical in the sample, and therefore find its purity.



Apparatus required for titration (from left to right): burette, conical flask, safety pipette filler and pipette.



Section 7—Titration Calculations

You should be able to use **titration** results to calculate the concentration of an acid or **alkali**. If several runs have been carried out, any irregular titres should be ignored before calculating the **mean** titre.

Example

27.5 cm^3 of 0.2 mol/dm^3 hydrochloric acid is needed to titrate 25.0 cm^3 of sodium hydroxide solution. What is the concentration of the sodium hydroxide solution?

Step 1: Convert all volumes to dm^3

27.5 cm^3 = 27.5 ÷ 1000 = 0.0275 dm^3

25.0 cm^3 = 25.0 ÷ 1000 = 0.025 dm^3

Step 2: Calculate the number of moles of the substance where the volume and concentration are known

number of moles = concentration × volume

number of moles of hydrochloric acid = 0.2 × 0.0275 = 0.0055 mol (5.5 × 10^{-3}mol)

Step 3: Calculate the unknown concentration

We can say that 0.0055 mol of acid will react with 0.0055 mol of alkali

concentration of alkali = moles ÷ volume = 0.0055 ÷ 0.025 = **0.22 mol/dm^3**

A quick check

You can check your answer using this quick method (but which misses out the chemical understanding that may attract full marks).

unknown concentration = known concentration × $^{\text{volume of known}}/_{\text{volume of unknown}}$

In the example above, this would be:

unknown concentration = 0.2 × $^{27.5}/_{25.0}$ = **0.22 mol/dm^3**

Crude Oil and Fuels, Organic Reactions and Polymers   Knowledge Organisers

Knowledge		Key words	
1	fractional distillation is a way to separate liquids from a mixture of liquids by boiling off the substances at different temperatures, then condensing and collecting the liquids	1	**alkane** saturated hydrocarbon with the general formula C_nH_{2n+2}, for example, methane, ethane, and propane
2	Saturated hydrocarbon describes a hydrocarbon with only single bonds between its carbon atoms. This means that it contains as many hydrogen atoms as possible in each molecule	2	**Alkene** unsaturated hydrocarbon which contains a carbon–carbon double bond. Its general formula is C_nH_{2n}, for example, ethene, C_2H_4
3	unsaturated hydrocarbon a hydrocarbon whose molecules contains at least one carbon– carbon double bond	3	**cracking** the reaction used in the oil industry to break down large hydrocarbons into smaller, more useful one
4	functional group is an atom or group of atoms that give organic compounds their characteristic reactions	4	**double bond** a covalent bond made by the sharing of two pairs of electrons
5	addition polymerisation is a type of reaction where monomers join together, end to end, to form long polymer chains. The polymer produced is called an addition polymer	54	**flammable** easily ignited and capable of burning rapidly
6	Condensation polymerisation involves monomers with two functional groups. When these types of monomers react they join together, usually losing small molecules such as water, and so the reactions are called condensation reactions	6	**hydrocarbon** a compound containing only hydrogen and carbon
7	monomers are small reactive molecules that react together in repeating sequences to form a very large molecule (a polymer)	7	**Viscosity** the resistance of a liquid to flowing or pouring; a liquid's 'thickness'
8	nucleotides the basic repeating units, or monomers, that join together to form DNA	8	**fraction** hydrocarbons with similar boiling points separated from crude oi
9	Alkenes are more reactive than alkanes and react with bromine water, which is used as a test for alkenes	9	**homologous series** a group of related organic compounds that have the same functional group
10	Some properties of hydrocarbons depend on the size of their molecules, including boiling point, viscosity and flammability. These properties influence how hydrocarbons are used as fuels	10	**polymer** a substance made from very large molecules made up of many repeating units
11	Cracking can be done by various methods including catalytic cracking and steam cracking.The products of cracking include alkanes and another type of hydrocarbon called alkenes.	11	**Amino acids** have two different functional groups in a molecule. Amino acids react by condensation polymerisation to produce polypeptides
12	Alkenes are used to produce polymers and as starting materials for the production of many other chemicals.	12	**DNA** (deoxyribonucleic acid) a large organic molecule that encodes genetic instructions for the development and functioning of living organisms and viruses
13	Many useful materials on which modern life depends are produced by the petrochemical industry, such as solvents, lubricants, polymers, detergents	13	

Quantitative Chemistry Knowledge Organiser

Know the facts		Key words	
1	The law of conservation of mass states that no atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants.	1	**Avogadro constant** the number of atoms, molecules, or ions in a mole of any substance (i.e., 6.02×10^{-23} per mol)
2	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.	2	**mole** the amount of substance in the relative atomic or formula mass of a substance in gramThe symbol for the unit mole is mol
3	When a metal reacts with oxygen the mass of the oxide produced is greater than the mass of the metal	3	**concentration** the amount of a substance dissolved in a given volume of liquid
4	In thermal decompositions of metal carbonates carbon dioxide is produced and escapes into the atmosphere leaving the metal oxide as the only solid product.	4	**limiting reactant** the reactant in a chemical reaction that when used up causes the reaction to stop
5	The masses of reactants and products can be calculated from balanced symbol equations.Chemical equations can be interpreted in terms of moles $Mg + 2HCl : MgCl_2 + H_2$ shows that one mole of magnesium reacts with two moles of hydrochloric acid to produce one mole of magnesium chloride and one mole of hydrogen gas.	5	**percentage yield** the actual mass of product collected in a reaction divided by the maximum mass that could have been formed in theory, multiplied by 100 The amount of a product obtained is known as the yield . $\% Yield = \frac{Mass\ of\ product\ actually\ made}{Maximum\ theoretical\ mass\ of\ product}$ $x\ 100$
6	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.	6	**relative formula mass M_r** the total of the relative atomic masses, added up in the ratio shown in the chemical formula, of a substance
7	The percentage atom economy of a reaction is calculated using the balanced equation for the reaction as follows: $\frac{Relative\ formula\ mass\ of\ desired\ product\ from\ equation}{Sum\ of\ relative\ formula\ masses\ of\ all\ reactants\ from\ equation}\ x\ 100\%$	7	**relative atomic mass A_r**the average mass of the atoms of an element compared with carbon-12 (which is given a mass of exactly 12). The average mass must take into account the proportions of the naturally occurring isotopes of the element

Exmouth Community College
Academy Trust

Rates and Equilibrium Knowledge Organiser

Year 11 – Chemistry / Rates and Equilibrium – HT1

Required Practical – Effect of concentration on rate

1—Increasing concentration will mean more particles available to react

2 — This will mean more collisions

3—This will mean more successful collisions

4– Therefore a faster rate of reaction

Two ways:

Investigate the concentration of HCl with marble chips

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2\ (aq) + CO_2\ (g) + H_2O(l)$

You can find the rate of a reaction by plotting the volume of carbon dioxide gas given off as the reaction progresses over time. You can measure the volume of gas at regular time intervals. Alternatively, you might choose to time how long it takes to collect a fixed volume of gas.

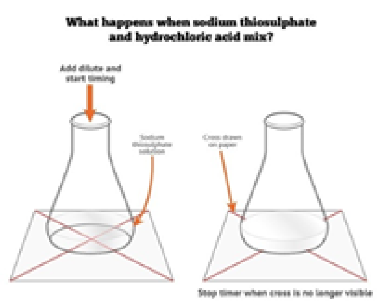
The reaction between sodium thiosulphate and dilute hydrochloric acid:

$Na_2S_2O_3(aq) + 2HCl(aq)$ à $2NaCl(aq) + SO_2(aq) + S(s) + H_2O(l)$

Your timing method should use the increasing cloudiness (turbidity) of the reaction mixture as the reaction proceeds.

Effect of conditions on rate

Effect of conditions on rate		
Temperature	Increase	Decrease
Rate	Increase—more kinetic energy, more chance of collisions	Decrease—less kinetic energy, less chance of collisions
Pressure/ concentration	Increase	Decrease
Rate	Increase, more particles to collide	Decrease, less particles to collide
Surface area	Increase	Decrease
Rate	More particles available to react	Less particles available to react
Catalyst	Present	Not Present
Rate	Faster, provides an alternative route with a lower activation energy	Slower



Keyword	Definition
1. Reversible	A reaction that can turn reactants into products and products into reactants.
2. Dynamic Equilibrium	A reaction in which the forwards and backwards reactions occur at the same rate and the concentrations of reactants and products are constant.
3. Forwards reaction	The reaction that is forming products from reactants.
4. Backwards reaction	The reaction that is forming reactants from products.
5. Exothermic	A reaction that releases heat energy to the surroundings.
6. Endothermic	A reaction that takes in heat energy to the surroundings.
7. Rate of reaction	Change in concentration of reactants or products over unit time
8. Catalyst	A substance that is not used up that provides an alternate pathway for a reaction with a lower activation energy, speeding up the rate of reaction
9. Collision theory	Reactions only occur when particles collide with **enough energy.**
10. Surface area	Area of surface that has particles available to react
11. Closed system	No conditions can be changed externally.

Rates and Equilibrium Knowledge Organiser

*Le Chatelier's principle – 1888

"If a change occurs to a system in dynamic equilibrium, the position of equilibrium shifts in a direction to oppose the change."

Effect of conditions on equilibria		
Temperature	Increase	Decrease
Change in equilibrium	Moves in the endo-thermic direction	Moves in the exothermic direction
Pressure	Increase	Decrease
Change in equilibrium	Moves to the side with least moles	Moves to side with more moles
Concentration	Increase	Decrease
Change in equilibrium	Removes the sub-stance that you've added, moving the equilibrium in the opposite way	Makes more of the sub-stance you've removed
Catalyst	Present	Not Present
Change in equilibrium	No effect—however, will make it so the rate to reach equilibrium is faster	

Worked Example

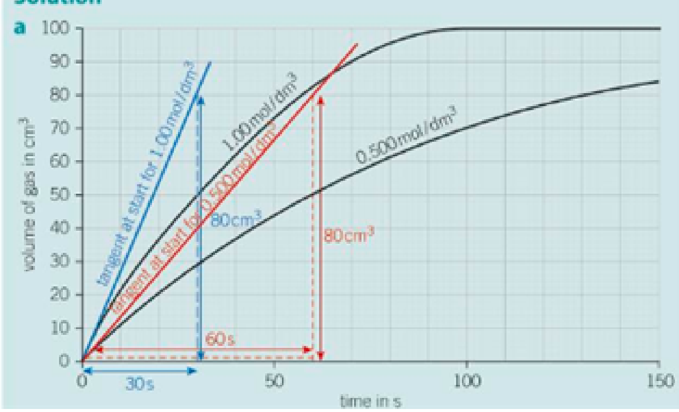
An investigation was carried out to find how the concentration of dilute hydrochloric acid affected the rate of its reaction with calcium metal. The volume of hydrogen gas given off was monitored over 150 seconds using a gas syringe. One test was carried out using 0.167g of calcium with an excess of 1.00mol/dm³ dilute hydrochloric acid, and this was repeated using the same volume of 0.500mol/dm³acid, also in excess. The results were plotted on a graph – see the two curves in the graph below.

a. use the results on the graph to find the initial rates of reaction, i.e. at the start when time = 0 seconds.

b. Draw a conclusion from part **a.**

Solution

a



Draw tangents from the origin to work out the gradient (change in the y axis / change in the x axis)

Then do concentration/ time = rate

The units for rate will depend on how you measure concentration: if it's measured in moldm^{3}, then you will have divided this by seconds, so it would be moldm^{3}/s