All Chemistry Formulas for O levels Chemistry by Ethan Wu

Hydrogen carbonate HCO_3^-
Hydride H^-
Hydroxide OH^-
Carbonate CO_3^{2-}
Nitrate NO_3^-
Nitrite NO_2^-
Nitride N^{3-}
Phosphate PO_4^{3-}
Sulfate SO_4^{2-}
Sulfite SO_3^{2-}
Sulfide S^{2-}
Ammonia NH_3
Ammonium ion NH_4^+

Mole Concept

One mole of any substance contains 6 X 10^{23} particles (Avogadro's number).

$$number\ of\ moles = \frac{number\ of\ particles}{6\ \times 10^{23}}$$

The molar mass of an element is the mass of one mole of atoms of the element.

$$number\ of\ moles\ of\ an\ element = \frac{mass\ of\ the\ element\ in\ g}{molar\ mass\ of\ the\ element\ in\ g/mol}$$

Percentage composition of compounds

$$percentage\ by\ mass\ of\ an\ element\ in\ a\ compound = \frac{number\ of\ atoms\ of\ element\ \times A_r}{M_r\ of\ compound}\ 100\%$$

Empirical formula

Empirical formula of a compound is the simplest formula of the compound

Element	Element 1	Element 2
Mass/g or % by mass		
Relative atomic mass		
Number of moles		
Mole ratio (divide by smallest number)		
Simplest whole number		

To find molecular formula

E.g. let molecular formula of ethane be $(CH_3)_n$
Relative mass of ethane from empirical formula = 15

$$n = \frac{relative\ molecular\ mass\ of\ ethane}{relative\ mass\ of\ ethane\ from\ empirical\ formula}$$

Compiled by Ethan Wu Ying Tang

Molar volume of gases

$$number\ of\ moles\ of\ gas = \frac{volume\ of\ gas\ in\ cm^3 at\ r.t.p.}{24\ 000\ cm^3}$$

Concentration of a solution (can be in terms of mol/dm³ or g/dm³)

$$concentration\ in\ g/dm^3 = \frac{mass\ of\ solute\ in\ g}{volume\ of\ solution\ in\ dm^3}$$

$$concentration\ in\ mol/dm^3 = \frac{number\ of\ moles\ of\ solute}{volume\ of\ solution\ in\ dm^3}$$

$$Percentage\ yield = \frac{actual\ yield}{theoretical\ yield} \times 100\%$$

$$Percentage\ purity = \frac{mass\ of\ pure\ substance\ in\ sample}{mass\ of\ sample} \times 100\%$$

Acids and Base Reactions

Acids react with metals to form salt and hydrogen gas (except lead, insoluble salt)

➔ Initial reaction between lead and hydrochloric acid produce lead (II) chloride or lead (II) sulfate which is insoluble. It will form a coating around metal and protect metal from further attack by acid.

React with carbonates and hydrogen carbonates to form salt, water and carbon dioxide

React with metal oxides and hydroxides to form salt and water

Alkalis heated with ammonium salts give out salt + water +ammonia

Solubility

Soluble salts	Insoluble salts
All sodium salts All potassium salts All ammonium salts All nitrates	
All chlorides	Silver chloride Lead (II) chloride
All sulfates	Barium sulfate Lead (II) sulfate Calcium sulfate (sparingly soluble)
Sodium carbonate Potassium carbonate Ammonium carbonate	

Hydroxide salts of Group I elements are soluble. Hydroxide salts of Group II elements (Ca, Sr, and Ba) are slightly soluble. Hydroxide salts of transition metals and Al3+ are insoluble.

All oxides are insoluble except calcium (sparingly), barium and Group 1 metals but SO_3 is soluble.

Qualitative Analysis

Test for Cations

Cation	Sodium Hydroxide		Aqueous Ammonia	
	On adding a few drops	On adding excess	On adding a few drops	On adding excess
Zinc ion Zn^{2+}	White ppt	Ppt dissolves in excess to form colourless solution	White ppt	Ppt dissolves in excess to form colourless solution
Aluminium ion AL^{3+}	White ppt	Ppt dissolves in excess to form colourless solution	White ppt	Insoluble in excess
Lead(II) ion PB^{2+}	White ppt	Ppt dissolves in excess to form colourless solution	White ppt	Insoluble in excess
Calcium ion Ca^{2+}	White ppt	Insoluble in excess	No ppt	No ppt
Copper (II) ion Cu^{2+}	Light blue ppt	Insoluble in excess	Light blue ppt	Ppt dissolves in excess to form deep blue solution
Iron (II) ion Fe^{2+}	Green ppt	Insoluble in excess	Green ppt	Insoluble in excess
Iron (III) ion Fe^{3+}	Reddish-brown ppt	Insoluble in excess	Reddish-brown ppt	Insoluble in excess
Ammonium ion NH_4^+	No ppt On heating, ammonia gas give off	No change	-	-

The ppt formed in each reaction is the hydroxide of the metal ion.

Test for Anions

Anion	Test	Observations for positive test and inference
Carbonate ion CO_3^{2-}	Add dilute hydrochloric acid Pass the gas given off into limewater	Effervescence observed. Gas forms a white ppt with limewater. Carbon dioxide gas given off
Nitrate ion NO_3^-	Add sodium hydroxide solution, then add a piece of aluminium foil. Warm the mixture. Test the gas given off with a piece of moist red litmus paper.	Effervescence observed The moist red litmus paper turns blue. Ammonia gas given off
Sulfate ion SO_4^{2-}	Add dilute nitric acid, then add barium nitrate solution	A white ppt of barium sulfate formed

Compiled by Ethan Wu Ying Tang

Chloride ion Cl^-	Add dilute nitric acid, then add silver nitrate solution	A white ppt of silver chloride formed
Iodide ion I^-	Add dilute nitric acid, then add silver nitrate solution	A yellow ppt of silver iodide formed

Identifying Gases

Gas	Colour and Odour	Test	Observations
Hydrogen H_2	Colourless and odourless	Place a lighted splint at the mouth of the test tube	The light splint is extinguished with a 'pop' sound
Oxygen O_2	Colourless and odourless	Insert a glowing splint into the test tube	The glowing splint is rekindled
Carbon Dioxide CO_2	Colourless and odourless	Bubble gas through limewater	A white precipitate is formed The ppt dissolves upon further bubbling
Chlorine Cl_2	Greenish-yellow gas with a pungent smell	Place a piece of moist blue litmus paper at the mouth of the test tube	The moist blue litmus paper turns red and is then bleached
Sulfur Dioxide SO_2	Colourless gas with a pungent smell	Place a piece of filter paper soaked with acidified potassium manganate (VII) at the mouth of the test tube	The purple acidified potassium manganate (VII) turns colourless
Ammonia NH_3	Colourless gas with a pungent smell	Place a piece of moist red litmus paper at the mouth of the test tube	The moist red litmus paper turns blue

Redox Reaction

Oxidising agents	**Reducing agents**
Bromine	Carbon
Chlorine	Carbon Monoxide
Concentrated sulfuric acid	Hydrogen
Nitric acid	Hydrogen Sulfide
Oxygen	Metals
Ozone	Potassium Iodide
Potassium Manganate (VII) ($KMnO_4$)	Sulfur Dioxide
Potassium Dichromate (VI) ($Kr_2Cr_2O_7$)	

Reactivity series

Metal	Reaction with cold water	Reaction with steam
Potassium	$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$	React explosively
Sodium	$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$	
Calcium	$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(aq) + H_2(g)$	
Magnesium	$Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(s) + H_2(g)$	$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$

Compiled by Ethan Wu Ying Tang

Zinc	No reaction	$Zn(s) + H_2O(s) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$ Zinc oxide is yellow when hot and white when cold
Iron	No reaction (except rusting)	$3Fe(s) + 4H_2O(g) \rightarrow Fe_3O_4(g)$ Reacts slowly, iron must be heated constantly
Lead Copper Silver	No reaction	No reaction

Most reactive to least reactive
K Na Ca Mg Zn Fe Pb H Cu Ag

A more reactive metal can displace a less reactive metal from its salt solution (redox reaction)
A more reactive metal can reduce the oxide of a less reactive metal

Action of heat on metal carbonates

Metal carbonate	Observation
Potassium carbonate Sodium carbonate	Unaffected by heat
Calcium carbonate Magnesium carbonate Zinc carbonate Iron (II) carbonate Lead(II) carbonate Copper(II) carbonate	Decompose into metal oxide and carbon dioxide on heating
Silver carbonate	Decomposes into silver and carbon dioxide on heating

Extracting iron from haematite

1 Carbon dioxide is produced
$C(s) + O_2(g) \rightarrow CO_2(g)$

2 Carbon monoxide is produced
$C(s) + CO_2(g) \rightarrow 2CO(g)$

3 Haematite is reduced to iron
$Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(l) + 3CO_2(g)$

4 Impurities are removed
$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$
$CaO(s) + SiO_2(s) \rightarrow CaSiO_3(l)$

Compiled by Ethan Wu Ying Tang

Hardest to discharge to easiest to discharge

K^+ Na^+ Ca^{2+} MG^{2+} Zn^{2+} Fe^{2+} Pb^{2+} H^+ Cu^{2+} Ag^+

Hardest to discharge to easiest to discharge

SO_4^{2-} NO_3^- Cl^- Br^- I^- OH^-

Manufacturing ammonia by Haber process

Nitrogen + hydrogen ⇌ ammonia (added in the ratio 1:3)

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Conditions: 250atm, 450°C, iron as catalyst

Only about 10-15% of nitrogen and hydrogen concerted to ammonia (ammonia gas cooled to liquid)

$SO_2 + H_2O \rightarrow H_2SO_3$ sulfurous acid

Sulfurous acid can be oxidized in air to form sulfuric acid

$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$

Reducing pollution

Catalytic converters

$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

$2NO(g) + 2CO(g) \rightarrow N_2(g) + 2CO_2(g)$

$2C_8H_{18}(l) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$

Flue Gas Desulfurisation (remove sulfur dioxide pollution)

$CaCO_3(s) + SO_2(g) \rightarrow CaSO_3(S) + CO_2$

$2CaSO_3(s) + O_2(g) \rightarrow 2CaSO_4(s)$

$CaO(s) + SO_2(g) \rightarrow CaSO_3(s)$

Alkanes

Combustion

Alkane + oxygen -> carbon dioxide + water vapour

Substitution (under ultraviolet light)

E.g. methane + chlorine -> chloromethane + hydrogen chloride

Alkenes

Combustion

Alkene + oxygen -> carbon dioxide + water vapour

As alkenes have higher percentage of carbon than alkanes, alkenes will burn with a sootier flame

Alkenes can also undergo substitution reaction under UV light

An Addition reaction is a reaction in which an unsaturated organic compound combines with another substance to form a single new compound

- Addition of hydrogen

Ethene + hydrogen -> ethane

Conditions: 200°C, nickel as catalyst

Convert vegetable oils to solid margarine

- Addition of bromine

Compiled by Ethan Wu Ying Tang

Ethene + bromine -> 1,2-dibromooethane
Serve as a chemical test to distinguish between alkane and alkene

- Addition of steam

Ethene + steam -> ethanol
Conditions: 300°C, 60 atm, phosphoric (V) acid as catalyst

- Addition polymerization

Ethene -> poly(ethene)
Conditions: High temperature and pressure and catalyst

Alcohol

- Combustion

Alcohol + oxygen -> carbon dioxide + water vapour
Can be used as a fuel
Burnt on some food such as fruit cake to give it a distinct flavor

- Oxidation

Alcohol + oxidizing agent -> carboxylic acid + water
$C_2H_5OH + 2[O] \rightarrow CH_3COOH + H_2O$
(2 ways oxidation by acidified potassium manganate (VII) and oxidation by atmospheric oxygen)
Breathalyzer contains an oxidizing agent that has a colour agent when high level of alcohol detected

Producing ethanol

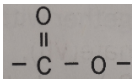
- From catalytic addition of steam to ethene
- Alcohol fermentation Glucose -> ethanol + carbon dioxide

Carboxylic acids

Are weak acids
Reaction with reactive metals (salts of ethanoic acid are known as ethanoates)
Reaction with carbonates
Reaction with bases
Reaction with alcohols to produce ester and water (esterification)

Ester

An ester is a colourless liquid that is insoluble in water
Ethanoic acid + methanol -> methyl ethanoate (concentrated sulfuric acid as catalyst)
First part of name from alcohol
Functional group



Polymerization

Additional polymerization occurs when unsaturated monomers join together without losing any molecules or atoms.

Condensation polymerization occurs when monomers combine to form a polymer with the removal of a small molecule such as water.

Compiled by Ethan Wu Ying Tang