

Inorganic Chemistry

Chapter 10 – Metals

Group Properties:

Group 1 metals properties:

- Are soft and easy to cut, getting softer and more dense as you move down the Group (sodium and potassium do not follow the trend in density)
- Have shiny silvery surfaces when freshly cut
- Conduct heat and electricity
- They all have low melting points and low densities and the melting point decreases as you move down the Group
- As we go down the group the reactivity increases with water

Group 7 properties:

- Are poisonous and include fluorine, chlorine, bromine, iodine and astatine
- Halogens are diatomic, meaning they form molecules of two atoms
- All halogens have seven electrons in their outer shell
- They form halide ions by gaining one more electron to complete their outer shells

Transition Elements:

Properties:

- High melting point
- High densities
- They form coloured compounds
- The metals and compounds are used as catalyst

Halides:

- They are unreactive and diatomic gases as they have 7 electrons in their outermost shell
- They form halide ions by gaining an electron
- As you go down the group the elements become harder
- The colour darkens as you down the group

Noble Gases:

Properties:

- Are monoatomic and colourless gases
- Have very low melting and boiling points
- Have a full outer shell of electron
- Are unreactive and inert

Properties of Metals:

Physical Properties:

- High melting point – have strong metallic bonds so more energy is required to break these bonds
- Good conductors of electricity and heat – There are delocalised (free) electrons that are able to carry a charge.

- Malleable and Ductile – The layers of positive ions can slide over each other easily because there are delocalised electrons that maintain the electrostatic forces thus the atoms can slide over each other.

Reactions with water and acid:

Reactions with water:

- Reaction with cold water



- Reaction with steam



- Reactions with acids



- Unreactive metals such as gold do not react with acid, water or oxygen.

Alloys:

- An alloy is a mixture of two or more metals or a metal and a non-metal.
- Alloys can be different from the metal they contain, they can have more strength, more hardness and resistant to corrosion.

Reactivity Series:

METAL	REACTION WITH WATER	REACTION WITH ACID	REACTION WITH OXYGEN
MOST REACTIVE			
POTASSIUM	REACTS VIOLENTLY	REACTS VIOLENTLY	REACTS QUICKLY IN AIR
SODIUM	REACTS QUICKLY	REACTS VIOLENTLY	REACTS QUICKLY IN AIR
CALCIUM	REACTS LESS STRONGLY	REACTS VIGOROUSLY	REACTS READILY
MAGNESIUM		REACTS VIGOROUSLY	REACTS READILY
ZINC		REACTS LESS STRONGLY	REACTS
IRON		REACTS LESS STRONGLY	REACTS
HYDROGEN			REACTS
COPPER			REACTS
LEAST REACTIVE			

Displacement reactions with metals and metal oxides:

- This means that a more reactive can displace a less reactive metal from its oxide by heating.

- Common examples:

MIXTURE	PRODUCTS	EQUATION FOR REACTION
IRON (III) OXIDE AND ALUMINIUM (THERMIT REACTION)	IRON AND ALUMINIUM OXIDE	$\text{Fe}_2\text{O}_3 + 2\text{Al} \rightarrow 2\text{Fe} + \text{Al}_2\text{O}_3$
SODIUM OXIDE AND MAGNESIUM	NO REACTION AS SODIUM IS ABOVE MAGNESIUM	–
SILVER OXIDE AND COPPER	SILVER AND COPPER(II) OXIDE	$\text{Ag}_2\text{O} + \text{Cu} \rightarrow 2\text{Ag} + \text{CuO}$
ZINC OXIDE AND CALCIUM	ZINC AND CALCIUM OXIDE	$\text{ZnO} + \text{Ca} \rightarrow \text{Zn} + \text{CaO}$
LEAD (II) OXIDE AND SILVER	NO REACTION AS LEAD IS MORE REACTIVE THAN SILVER	–

Displacement reactions with metals and aqueous solution of salts

- Common reactions:

MIXTURE	PRODUCTS	EQUATION FOR REACTION
MAGNESIUM AND IRON(II) SULFATE	MAGNESIUM SULFATE AND IRON	$\text{Mg} + \text{FeSO}_4 \rightarrow \text{MgSO}_4 + \text{Fe}$
ZINC AND SODIUM CHLORIDE	NO REACTION AS SODIUM IS ABOVE ZINC	–
LEAD AND SILVER NITRATE	LEAD (II) NITRATE AND SILVER	$\text{Pb} + 2\text{AgNO}_3 \rightarrow \text{Pb}(\text{NO}_3)_2 + 2\text{Ag}$
COPPER AND CALCIUM CHLORIDE	NO REACTION AS CALCIUM IS MORE REACTIVE THAN COPPER	–

IRON AND COPPER(II) SULFATE	IRON (II) SULFATE AND COPPER	$\text{Fe} + \text{CuSO}_4 \rightarrow \text{FeSO}_4 + \text{Cu}$
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Extraction of metals using carbon:

Extraction of Iron:

- Extraction using carbon is used for metals that are less reactive than carbon and is less expensive than electrolysis.
- Heating of Iron (II) oxide with Carbon in a blast furnace:
 $2\text{Fe}_2\text{O}_3 + 3\text{C} \rightarrow 4\text{Fe} + 3\text{CO}_2$

- Aluminum is extracted using Electrolysis as it is more reactive than Carbon.

Extraction of Zinc:

- $2\text{ZnS} + 3\text{O}_2 \rightarrow 2\text{ZnO} + 2\text{SO}_2$ – Zinc Blende is converted to zinc oxide by heating in air
- $\text{C} + \text{O}_2 \rightarrow$ Formation of Carbon dioxide which is then converted to Carbon Monoxide
- $\text{CO}_2 + \text{C} \rightarrow 2\text{CO}$ → Carbon Monoxide is the reducing agent
- $\text{ZnS} + \text{CO} \rightarrow \text{Zn} + \text{CO}_2$ → Carbon Monoxide is reduced to Zinc from Zinc Oxide
- The Zinc produced is in gaseous state so it is blown over a condensed plate at the top of the furnace.

Advantages and Disadvantages of recycling metals (iron, steel and aluminum)

Advantages

- Raw materials are conserved (bauxite and haematite)
- Energy use is reduced, especially in the electrolysis of aluminium
- Less pollution is produced as both processes contribute to air pollution

Disadvantages

- More transport on roads carrying used metals to recycling centers
- Energy consumed in collecting materials and sorting them per material type

Chapter 11 – Air and Water

- Chemical Test for identifying water: Cobalt (II) Chloride paper turns blue to pink
Equation: $\text{CoCl}_2 + 6\text{H}_2\text{O} \rightarrow \text{CoCl}_2 \cdot 6\text{H}_2\text{O}$
- Anhydrous Copper (II) Sulfate turns white to blue
Equation: $\text{CuSO}_4 + 5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 \cdot 5\text{H}_2\text{O}$

Sewage treatment:

- Filtration is the process used to remove large insoluble particles by passing the water through layers of sand and gravel filters that trap larger particles
- But bacteria and other microorganisms are too small to be trapped by the filters so chlorination is used
- This involves the careful addition of chlorine to the water supply which kills bacteria and other unwanted microorganisms
- Cholera and typhoid are examples of bacterial diseases which can arise by the consumption of untreated water

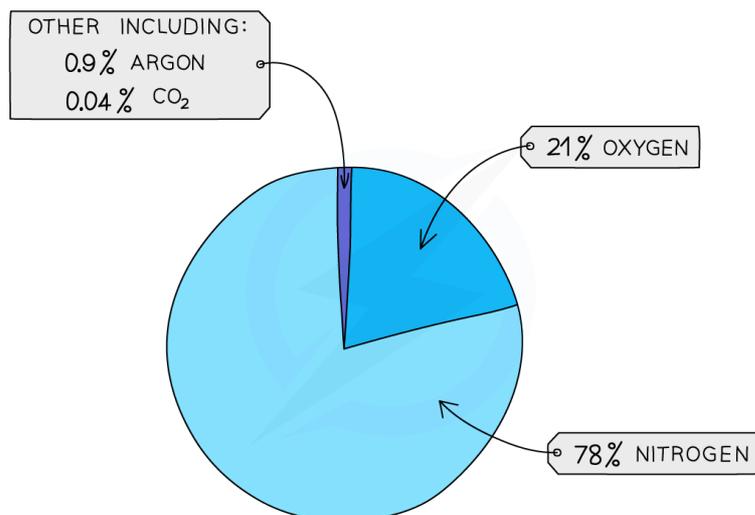
Uses of water:

- Watering crops
- As a solvent in many chemical processes
- Production of Ethanol from Ethene
- Drinking, cooking and washing clothes
- In car radiators

Lack of water supply:

- Results in famine as crops cannot grow because of the lack of water
- Drinking untreated water leads to diseases such as cholera

Composition of air:



Fractional Distillation of Air:

- The air is first filtered to remove dust, and then cooled in stages until it reaches -200°C
- At this temperature the air is in the liquid state
- Water vapour and carbon dioxide freeze at higher temperatures and are removed using absorbent filters
- The Noble gases are still in the gaseous state at -200°C , leaving a mixture of liquid nitrogen and oxygen
- The liquefied mixture is passed into the bottom of a fractionating column
- Note that the column is warmer at the bottom than it is at the top
- Oxygen liquefies at -183°C and nitrogen liquefies at -196°C

- Nitrogen has a lower boiling point than oxygen so it vaporises first and is collected as it rises in the gaseous state to the top of the column
- The liquid O₂ is then removed from the bottom of the column

Air Pollution

• The common pollutants in the air are Carbon Monoxide, sulfur dioxide, oxides of nitrogen and lead compounds

- Source of Carbon Monoxide: the incomplete combustion of carbon-containing substances

Adverse effects: Combines with hemoglobin and prevents it from carrying oxygen

- Sources of Sulfur Dioxide: combustion of fossil fuels which contain sulfur compounds

Adverse effects: Leads to acid rain which corrodes metal structures, increases pH of soil and pollutes aquatic organisms

- Sources of oxides of nitrogen: reaction of nitrogen with oxygen in car engines and high temperature furnaces and as a product of bacterial action in soil

Adverse effects: Produces photochemical smog that leads to asthma and breathing problems

- Sources of Compound of lead: old water pipes, old paints and leaded petrol.

Adverse effects: Causes damage to the nervous system.

Presence of Nitrogen oxides and Catalytic converters

Nitrogen Oxides:

- These compounds (NO and NO₂) are formed when nitrogen and oxygen react in the high pressure and temperature conditions of internal combustion engines and blast furnaces
- Exhaust gases also contain unburned hydrocarbons and carbon monoxide

Catalytic Converters:

- They contain transition metals such as platinum and rhodium

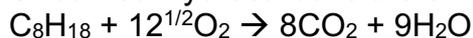
- Reactions occurring in the Catalytic Converters:

Carbon Monoxide is oxidized to Carbon Dioxide: $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$

Nitrogen oxides are reduced to N₂ gas:



Unburned Hydrocarbons are oxidized to Carbon Dioxide and Water:



Rusting of Iron

- Oxygen and water must be present for rust to occur

- Reaction: $4\text{Fe}(\text{s}) + 3\text{O}_2(\text{g}) + 4\text{H}_2\text{O}(\text{l}) \rightarrow 2\text{Fe}_2\text{O}_3 \cdot 4\text{H}_2\text{O}(\text{s})$

How to prevent rusting of iron:

- Paint the surface with oil, paint, grease or cover it with plastic

- **Galvanizing** is a process where the iron to be protected is coated with a layer of zinc
- If the iron is still to be protected after being scratched **Sacrificial** method is used
- The iron is still protected as Zinc is reactive than Iron so it loses electrons:

$$\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^{-}$$
- This helps the iron stay protected as it accepts the electrons from zinc so it does undergo oxidation.

Nitrogen & Fertilizers

- Nitrogen promotes healthy leaves, potassium promotes growth and healthy fruit and flowers and phosphorus promotes healthy roots
- Ammonia can be **displaced** from its salts by the addition of an alkali substance
 Reaction: $2\text{NH}_4\text{Cl} + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCl}_2 + 2\text{NH}_3 + 2\text{H}_2\text{O}$

Manufacture of Ammonia in the Haber Process

Process:

- H_2 and N_2 are obtained from natural gas and the air respectively and are pumped into the compressor through pipes
- The gases are compressed to about 200 atmospheres inside the compressor
- The pressurised gases are pumped into a tank containing layers of catalytic iron beads at a temperature of 450°C . Some of the hydrogen and nitrogen react to form ammonia: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$
- Unreacted H_2 and N_2 and product ammonia pass into a cooling tank. The ammonia is liquefied and removed to pressurized storage vessels.
- The unreacted H_2 and N_2 gases are recycled back into the system and start over again

Conditions:

Temperature 450 degrees

- A higher temperature would favour the reverse reaction as it is endothermic (takes in heat) so a higher yield of reactants would be made.
- If a lower temperature is used it favours the forward reaction as it is exothermic (releases heat) so a higher yield of products will be made.

Pressure 200 atm

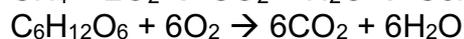
- A lower pressure would favour the reverse reaction as the system will try to increase the pressure by creating more molecules so a higher yield of reactants will be made
- A higher pressure would favour the forward reaction as it will try to decrease the pressure by creating less molecules so a higher yield of products will be made

Greenhouse Gases: Carbon Dioxide and Methane

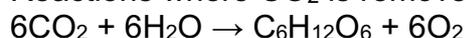
- They both lead to climate change as they trap heat energy from escaping the Earth's atmosphere, leading to global warming
- Sources of Carbon Dioxide: Combustion of wood and fossil fuels, respiration of plants and animals, thermal decomposition of a carbonate and product of the reaction between an acid and a carbonate.
- Sources of Methane: digestive processes of animals, decomposition of vegetation and dead animals or crops

Carbon Cycle:

Reactions where CO₂ is added to the atmosphere:



Reactions where CO₂ is removed from the atmosphere:



- Carbon dioxide dissolves in the water in sea and oceans and is removed by shellfish for making their calcium carbonate shells

Chapter 12: Sulfur

Source of Sulfur

- By-product from the removal of sulfur from **petroleum** and **natural gas**
- Obtained from sulfide ores

Uses of Sulfur

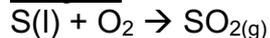
- The main use of Sulfur is to make sulfuric acid which is an important chemical

Uses of Sulfur Dioxide

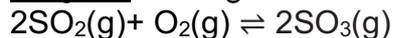
- It is used to bleach wood pulp for paper
- Used as a food preservative

Manufacture of Sulfuric Acid by Contact Process:

Stage 1: Oxidation of Sulfur by burning it in air to make Sulfur Dioxide



Stage 2: Making Sulfur Trioxide by reacting Sulfur Dioxide by more oxygen



The reaction conditions are:

- A catalyst of Vanadium (V) Oxide
- A temperature of 450 degrees
- A pressure of approximately 2 atmospheres (the increase in pressure favours more formation of SO₃. If the pressure is too large there is a risk of an explosion as it is an acidic gas).

Stage 3: Sulfur Trioxide is added to a solution of concentrated (98%) Sulfuric Acid to produce a thick liquid called Oleum.



• Then water is added to Oleum to form Sulfuric acid again



Properties of Sulfuric Acid

- It is a strong dibasic acid as the 2 hydrogen atoms can be replaced by a metal
- Fully dissociates in solution to release H^+ ions
- Concentrated Sulfuric acid is a powerful oxidising and dehydrating agents

• Dilute Sulfuric Acid:

- Used as a catalyst in many organic reactions
- Used to clean surfaces of metals

• Concentrated Sulfuric Acid:

- Used in car batteries, soaps and detergent
- Used to make acid drain cleaners and production of paint.

Chapter 13: Carbonates

Manufacture of Lime

• Lime is Calcium Oxide which is manufactured from the thermal decomposition of Calcium Carbonate



Uses of lime and slaked lime

- Used in neutralizing industrial acidic waste products and used in flue gas desulfurization
- Treating acidic soil to return it to the optimum pH as it is alkaline

Uses of Calcium Carbonate in the manufacture of Cement and Iron

Calcium Carbonate in the manufacture of Iron:

- Helps remove impurities from the iron by reacting with it to form slag

Calcium Carbonate in the manufacture of Cement:

- By heating a mixture of limestone (Calcium Carbonate) and clay in a rotary kiln
- Ingredient in mortar, concrete and other building materials