Reactivity Series I

What does the *Reactivity Series* show?
List the Reactivity Series, showing the positions of Carbon and Hydrogen.

Which metals will react with water and hydrochloric acid?
Give equations.

Which metal oxides can be reduced by carbon?
Give equations.

How does the position of a metal in the reactivity series affect the voltage of an *Electrochemical Cell*?
Which way will the electrons flow?

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The Reactivity Series:

Shows the tendency of a metal to form its positive ion when reacting with aqueous ions (or oxides) of the other metals

Potassium, K
Sodium, Na
Calcium, Ca
Magnesium, Mg
[Carbon]
Zinc, Zn
Iron, Fe
[Hydrogen]
Copper, Cu

increasing reactivity

Hydrogen and Carbon are non-metals, but you need to know their positions to determine some reactions of metals

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Reaction with Water:

Only metals **above hydrogen** in the reactivity series will react with water:

Metal + Water ⟶ Metal Hydroxide + Hydrogen

e.g. $2Na_{(s)} + 2H_2O_{(l)} \longrightarrow 2NaOH_{(aq)} + H_{2\,(g)}$

Reaction with Hydrochloric Acid:

Only metals **above hydrogen** in the reactivity series will react with dilute hydrochloric acid:

Metal + Hydrochloric Acid ⟶ Salt + Hydrogen

e.g. $Mg_{(s)} + 2HCl_{(aq)} \longrightarrow MgCl_{2\,(aq)} + H_{2\,(g)}$

Reaction with Carbon:

Carbon will only **reduce** the oxides of metals **below** it in the reactivity series:

Metal Oxide + Carbon ⟶ Metal + Carbon Dioxide

e.g. $2PbO_{(s)} + C_{(s)} \xrightarrow[\text{Lead oxide is Reduced}]{\text{Carbon is Oxidised}} 2Pb_{(s)} + CO_{2\,(g)}$

Electrochemical Cells:

- The larger the difference in the reactivity of the two metals used as electrodes, the larger the voltage produced
- Electrons will flow from the **most reactive** metal to the **least reactive** metal

Reactivity Series II

Describe the following reactions of metal compounds, giving equations:

Displacement

Thermal Decomposition of Carbonates

Thermal Decomposition of Hydroxides

Thermal Decomposition of Nitrates

Why is Aluminium not as reactive as expected?

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Displacement:

A more reactive metal will displace a less reactive metal from its oxide (or from solutions of its compounds):

More Reactive Metal + Compound of Less Reactive Metal ⟶ Compound of More Reactive Metal + Less Reactive Metal

e.g. $Ca_{(s)} + ZnO_{(s)} \xrightarrow[\text{Zinc is Reduced}]{\text{Calcium is Oxidised}} CaO_{(s)} + Zn_{(s)}$

e.g. $Fe_{(s)} + CuSO_{4\,(aq)} \xrightarrow[\text{Copper is Reduced}]{\text{Iron is Oxidised}} FeSO_{4\,(aq)} + Cu_{(s)}$

Thermal Decomposition of Carbonates:

Metal Carbonate $\xrightarrow{\text{Heat}}$ Metal Oxide + Carbon Dioxide

e.g. $CuCO_{3\,(s)} \xrightarrow{\text{Heat}} CuO_{(s)} + CO_{2\,(g)}$

Sodium carbonate and potassium carbonate do not decompose upon heating

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Thermal Decomposition of Hydroxides:

Metal Hydroxide $\xrightarrow{\text{Heat}}$ Metal Oxide + Water

e.g. $Cu(OH)_{2\,(s)} \xrightarrow{\text{Heat}} CuO_{(s)} + H_2O_{(l)}$

Sodium hydroxide and potassium hydroxide do not decompose upon heating

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Thermal Decomposition of Nitrates:

Most nitrates decompose to an oxide, nitrogen dioxide and oxygen:

Metal Nitrate $\xrightarrow{\text{Heat}}$ Metal Oxide + Nitrogen Dioxide + Oxygen

e.g. $2Cu(NO_3)_{2\,(s)} \xrightarrow{\text{Heat}} 2CuO_{(s)} + 4NO_{2\,(g)} + O_{2\,(g)}$

The nitrates of **sodium** and **potassium** decompose to nitrites and oxygen:

e.g. Sodium Nitrate $\xrightarrow{\text{Heat}}$ Sodium Nitrite + Oxygen

$2NaNO_{3\,(s)} \xrightarrow{\text{Heat}} 2NaNO_{2\,(s)} + O_{2\,(g)}$

Aluminium:

Aluminium is not as reactive as expected because it is coated in a thin film of unreactive aluminium oxide

Redox Reactions

Explain the terms:

Oxidation

Reduction

Redox

Oxidising Agent

Reducing Agent

What does the mnemonic OILRIG stand for?

Extracting Metals

How does the position of a metal in the reactivity series determine the method used to extract it from its ore?

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Redox Reactions:

*Oxidation – any of the following:

- Gain of oxygen
- Loss of electrons
- Increase in oxidation number

*Reduction – any of the following:

- Loss of oxygen
- Gain of electrons
- Decrease in oxidation number

*Redox: A reaction in which both oxidation and reduction occur

*Oxidising Agent:

- A substance which oxidises another substance in a redox reaction
- It is reduced
- It gains electrons

*Reducing Agent:

- A substance which reduces another substance in a redox reaction
- It is oxidised
- It loses electrons

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

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Extraction of Metals:

Unreactive Metals:

Found native or uncombined so extraction is easy, e.g. silver & gold

Reactive Metals:

Found combined in compounds, so the metal must be chemically extracted:

Metals less reactive than Carbon: Reduction in a blast furnace
e.g. Zinc, Copper

Metals more reactive than Carbon: Electrolysis, e.g. Aluminium

Refining using Electrolysis: Some metals which are extracted by reduction may be purified using electrolysis, e.g. Copper

Iron & Steel

How is iron extracted from its ore?

Name the apparatus and raw materials. Describe the 4 stages in the extraction process, giving equations.

What is *Steel*?
How is the pig iron from the blast furnace purified?
What is added to make steel and why does this make it more useful than iron?

Describe uses of ***Iron*** *(*in the form of ***Mild Steel*** and ***Stainless Steel)***.

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Iron Extraction:

Apparatus: Blast furnace

Raw Materials: Iron ore (hematite), carbon (coke) and limestone ($CaCO_3$)

Step 1: Coke is burned, giving off heat and carbon dioxide:

$$C_{(s)} + O_{2\,(g)} \longrightarrow CO_{2\,(g)}$$

Step 2: Carbon dioxide reacts with more coke to make carbon monoxide:

$$C_{(s)} + CO_{2\,(g)} \longrightarrow 2CO_{(g)}$$

Step 3: Iron oxide is reduced by carbon monoxide to iron:

$$Fe_2O_{3\,(s)} + 3CO_{(g)} \longrightarrow 2Fe_{(l)} + 3CO_{2\,(g)}$$

Step 4: Limestone decomposes thermally to form calcium oxide:

$$CaCO_{3\,(s)} \longrightarrow CaO_{(s)} + CO_{2\,(g)}$$

The main impurity is silicon dioxide (sand, SiO_2). This reacts with the calcium oxide to form **slag** (calcium silicate, $CaSiO_3$):

$$CaO_{(s)} + SiO_{2\,(s)} \longrightarrow CaSiO_{3\,(s)}$$

Steel:

Composition: Steel is an alloy of iron with other elements

Purification of Pig Iron from the blast furnace:

- Carbon and sulfur impurities are reacted with oxygen to form CO_2 & SO_2 gases
- Silicon and phosphorus impurities react with the oxygen, forming acidic oxides
- Acidic oxides are reacted with CaO, producing slag which is skimmed off

Making Steel: Other elements (e.g. carbon, nickel, chromium) are added to the pure iron to produce the alloy steel

Steel has more desirable properties (e.g. harder and stronger than iron, rust-resistant)

Uses of Iron:

Mild Steel:

- Constructing buildings
- Making vehicles (e.g. ships, cars) and machinery

Stainless Steel:

- Making cutlery (it is hard and rustproof)
- Making equipment for use in chemical factories (it is hard and rustproof)

Zinc

What form is zinc found in naturally?
List the steps required to extract zinc from this compound, giving equations.

Give uses of zinc.

Copper

Describe how copper is refined.

Give uses of copper, stating which properties make it useful for each purpose.

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Zinc:

Natural Form: Zinc sulfide, ZnS (also known as "zinc blende")

Extraction Technique: Reduction

Step 1: Zinc sulfide is roasted in air to produce zinc oxide and sulfur dioxide:

$$2ZnS_{(s)} + 3O_{2\,(g)} \longrightarrow 2ZnO_{(s)} + 2SO_{2\,(g)}$$

Step 2: Zinc oxide is reduced with carbon monoxide:

$$ZnO_{(s)} + CO_{(g)} \longrightarrow Zn_{(s)} + CO_{2\,(g)}$$

Step 2 (alternative): Zinc oxide is dissolved in sulfuric acid to produce zinc sulfate, which can be electrolysed:

$$Zn^{2+}_{(aq)} + 2e^- \xrightarrow{\text{Electrolysis}} Zn_{(s)}$$

Uses:

- Galvanising iron (to stop it rusting)
- Making alloys (e.g. brass)

Copper:

Refining Technique: Electrolysis is used to refine (purify) copper which has been extracted by smelting

Cathode: Made of **pure** copper

Anode: Made of **impure** copper

Electrolyte: Dilute solution of copper(II) sulphate

Result: Copper (99.9% pure) will be deposited at the cathode

Uses:

- Electrical wiring (it is a good conductor of electricity)
- Cooking utensils (it is a good conductor of heat)
- Water pipes (it does not react with water)