Edexcel GCSE Chemistry

Your notes

Transition Metals, Alloys & Corrosion

Contents

Your notes

Transition Metals

Properties

- Most of the known metals are **transition** metals and they have typical properties of metals
- They are very **lustrous**, they are hard, strong and are good conductors of **heat** and **electricity**
- They are highly **dense** metals and have very **high melting** points
- Transition metals can have more than one **oxidation state** as they can lose a different number of electrons, depending on the chemical environment they are in
- The melting point, density and common ions of the elements Cr, Mn, Fe, Co, Ni and Cu are shown below

Transition Metals Table

Metal	Melting point / °C	Density / gcm^{-3}	Common ions
Chromium	1890	7.19	Cr^{2+}, Cr^{3+} and Cr^{6+}
Manganese	1240	7.20	Mn^{2+}, Mn^{3+}, Mn^{4+}, Mn^{6+} , Mn^{7+}
Iron	1538	7.87	Fe^{2+}, Fe^{3+}
Cobalt	1492	8.90	Co^{2+}, Co^{3+}
Nickel	1453	8.90	Ni^{2+}
Copper	1083	8.92	Cu^{+} , Cu^{2+}

- Compounds containing transition elements in different oxidation states will have different **properties** and **colours** in aqueous solutions

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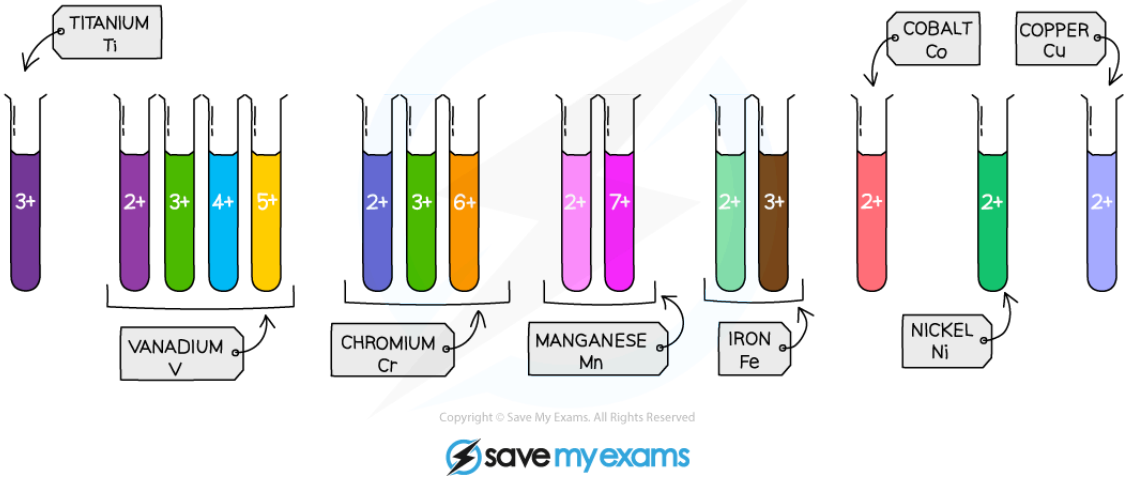

The colours produced by ions of the transition elements

Examiner Tips and Tricks

Note that transition metals themselves do not display a range of colours, it is the **compounds** they form that are colourful

Applications

Catalysis

- The transition elements are used extensively as **catalysts** which are substances that speed up the rate of a reaction without being used up in the process
- They do not take part in the reaction
- Their catalytic characteristics stem from their ability to interchange between a range of oxidation states
- This allows them to form complexes with reagents which can easily **donate** and **accept** electrons from other chemical species within a reaction system
- Common transition metal catalysts include:
  - Iron which is used in the **Haber Process**
  - Vanadium pentoxide (V_2O_5) which is used in the **Contact Process** to produce sulfuric acid

- Nickel which is used in the hydrogenation of alkenes

Medicine

- The transition metals are also used in **medicine** and **surgical** applications such as limb and joint replacement
- Titanium in particular is useful as it is the only element that can bond with bones due to its high biocompatibility

Other Industrial Applications

- They are also used to form coloured compounds in **dyes** and **paints** for both household and industrial applications
- They are used in creating **stained** glass, **jewellery** and in anti-corrosive materials

Examiner Tips and Tricks

You should be able to recall the typical properties of the transition elements including melting points, density, coloured compounds and catalytic activity.

Your notes

Corrosion of Metals

Your notes

Oxidation of Metals

- Corrosion is the destruction of materials by chemical substances in their environment which act on them over a period of time
- Most metals can corrode in the presence of **oxygen** to form the corresponding metal oxide
- Corrosion is caused by **redox** reactions:
  - The metal loses electrons and is **oxidised** while the oxygen gains electrons and is **reduced**
- **Rusting** is the name given specifically to the corrosion of iron in the presence of water and oxygen from the air:

iron + water + oxygen ⟶ hydrated iron(III)oxide

Examiner Tips and Tricks

Corrosion and rusting are **not** the same process. Corrosion is the general term used to describe the degradation of metal surfaces. Rusting is the specific type of corrosion that happens only to iron.

Rusting of Iron

Barrier Methods

- Rust can be prevented by coating iron with barriers that prevent the iron from coming into contact with water and oxygen
- However, if the coatings are washed away or scratched, the iron is once again exposed to water and oxygen and will rust
- Unlike some other metals, once iron begins to rust it will continue to corrode internally as rust is porous and allows both air and water to come into contact with fresh metal underneath any barrier surfaces that have been broken or scratched
- Common barrier methods include: paint, oil, grease and plastic

Barrier Methods for Preventing Corrosion of Metals

Common barrier methods	
Grease	Oil
Paint	Plastic

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Galvanising / Sacrificial protection

- Iron can be prevented from rusting making use of metals higher in reactivity than iron
- **Galvanising** is a process where the iron to be protected is coated with a layer of zinc
- $ZnCO_3$ is formed when zinc reacts with oxygen and carbon dioxide in the air and protects the iron by the barrier method
- If the coating is damaged or scratched, the iron is still protected from rusting because zinc preferentially corrodes as it is higher up the reactivity series than iron
- Compared to iron it loses its electrons more readily:

$$Zn \rightarrow Zn^{2+} + 2e^-$$

- The iron stays protected as it accepts the electrons released by zinc, remaining in the reduced state and thus it does not undergo oxidation
- The electrons donated by the zinc react with hydrogen ions in the water producing hydrogen gas:

$$2H^+ + 2e^- \rightarrow H_2$$

- Zinc therefore reacts with oxygen and water and corrodes instead of the iron

Sacrificial corrosion

- Sacrificial corrosion occurs when a more reactive metal is intentionally allowed to corrode
- An example of this occurs with ships' hulls which sometimes have large blocks of magnesium or magnesium alloys attached
- The blocks slowly corrode and provide protection to the hull in the same way the zinc does by pushing electrons onto the iron which prevents it from being oxidised to iron(III) ions

Electroplating

- Electroplating is a process where the surface of one metal is **coated** with a layer of a different metal

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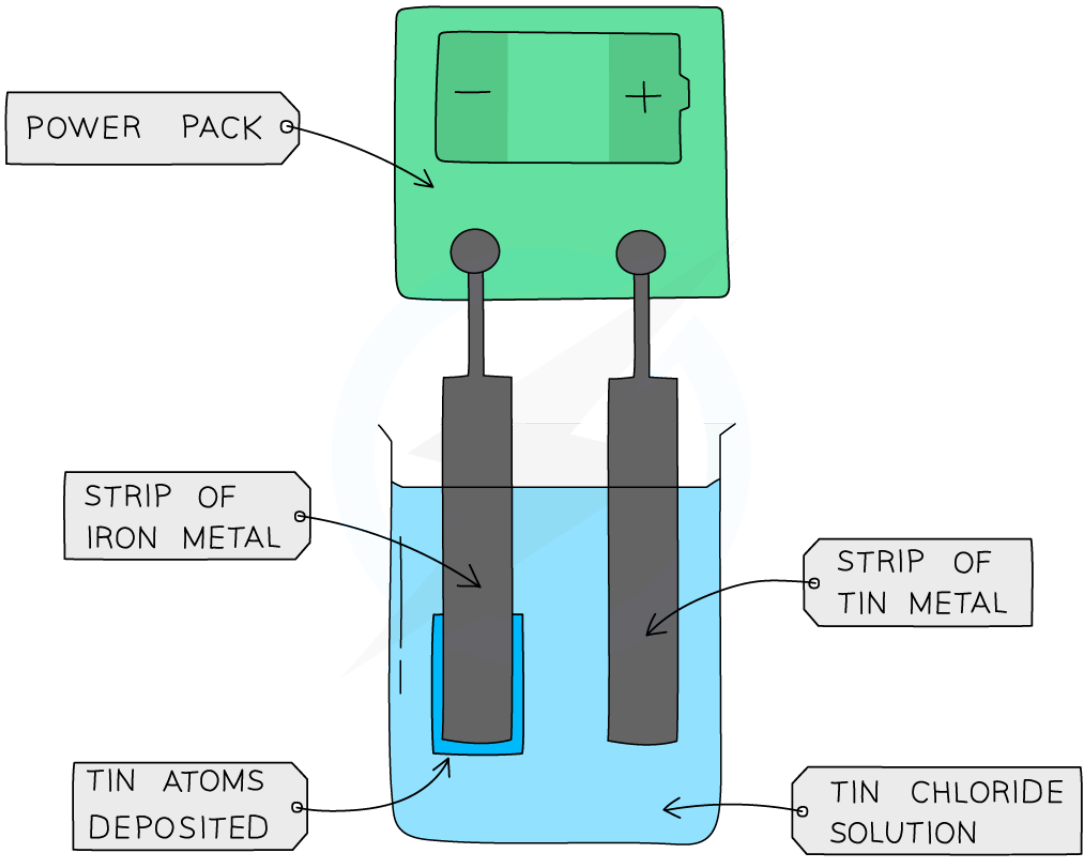
- The metal being used to coat is a less reactive metal than the one it is covering
- The **anode** is made from the **pure** metal used to coat
- The cathode is the **object** to be electroplated
- The electrolyte is an aqueous solution of a soluble salt of the pure metal at the anode



A piece of iron being electroplated with tin. The electrolyte is tin(II) chloride, a water-soluble salt of tin

Uses of electroplating

- Electroplating is done to make metals more **resistant** to corrosion or damage, e.g. chromium and nickel plating

- When people talk about a 'tin can', the amount of tin is very small (only about 1%). The can is made from steel and has a very thin coat of tin on the interior surface that resists corrosion from the liquids inside
- It is also done to improve the appearance of metals, e.g. silver plating cutlery and jewellery

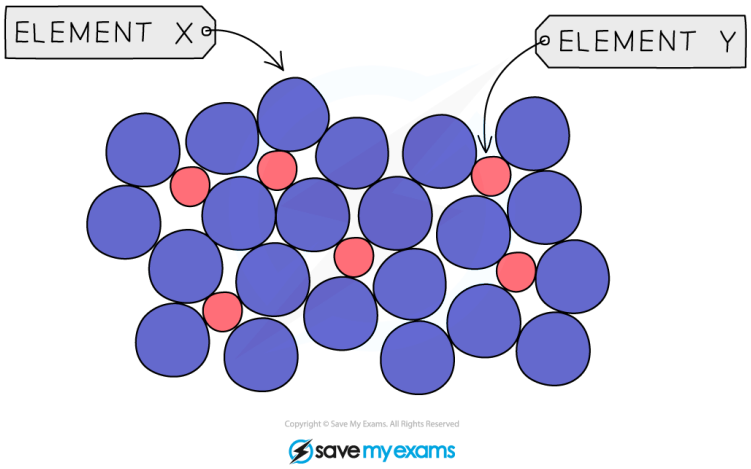

Your notes

Alloys

Your notes

Alloys

- Alloys are **mixtures** of metals, where the metals are mixed together physically but are not chemically combined
- They can also be made from metals mixed with nonmetals such as carbon
- Alloys often have **properties** that can be very **different** to the metals they contain, for example they can have greater **strength, hardness** or **resistance** to **corrosion** or extreme **temperatures**
- Alloys contain atoms of **different** sizes, which **distorts** the regular arrangements of atoms
- This makes it more difficult for the layers to **slide** over each other, so they are usually much harder than the pure metal
- Brass is a common example of an alloy which contains 70% copper and 30% zinc



Particle diagram showing a mixture of elements in an alloy. The different sizes of the two types of atoms prevent the layers of atoms from sliding over each other, so the alloy becomes less malleable than the pure metal

Examiner Tips and Tricks

Questions on this topic often give you a selection of particle diagrams and ask you to choose the one which represents an alloy. It will be the diagram with uneven sized particles and distorted layers or rows of particles.

Your notes

Steel Alloys

Steel Alloys

- Iron from a blast furnace is an alloy of 96% iron, with carbon, phosphorus, silicon and sulfur impurities
- It is called **cast iron** and is too **brittle** for many uses, so most of it is converted into **steel** by removing some of the impurities
- Not all of the carbon is removed as steel contains some carbon, the percentage of which depends on the **use** of the steel
- Alloys of steel are made from adding other metals to steel such as **chromium, manganese** or **nickel**
- By carefully controlling the amounts added, the particular type of alloy required can be produced
- Steel alloys are used in construction, transport, manufacturing and other industries

Steel Alloys & their Uses

Type of steel	Iron alloyed with	Use	Most important property
Mild steel	0.25% carbon	Car body panels, wires	Soft and malleable
High carbon steel	0.5–1.4% carbon	Tools and chisels	Hard
Low alloy steel	1–5% of other metals (Cr, Ni, Ti)	Construction, bridges, high speed tools	Hard and strong, low ductility and malleability
Stainless steel	20% chromium and 10% nickel	Cutlery and sinks, chemical plants	Strong and resistant to corrosion

Examiner Tips and Tricks

Alloys are mixtures of substances, they are not chemically combined and an alloy is **not** a compound.

Your notes

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Using Metals

Aluminium Alloys

- Aluminium is mixed with copper, manganese and silicon for aircraft body production as aluminium alloys tend to be **stronger** and **lighter** than pure aluminium
- Aluminium and magnesium (5%) make an interesting alloy called **magnalium** which is also used extensively in automobile and aircraft construction
- As well as being lighter and stronger, it is also more **corrosion resistant** than aluminium.
- Magnalium with 50% magnesium is used in the production of **fireworks** as it is more **stable** than pure magnesium but still burns brightly

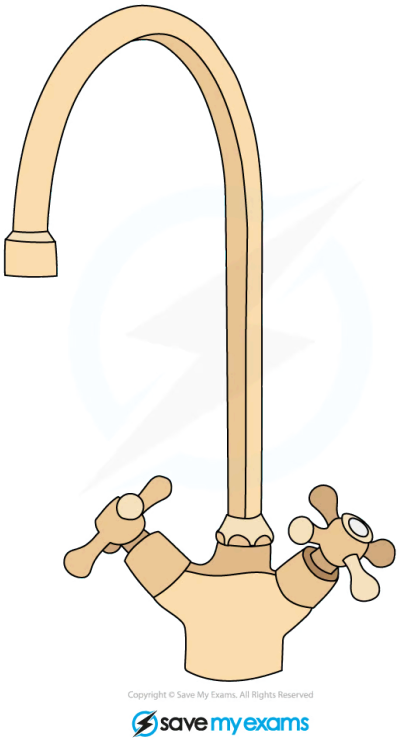
Uses of Aluminium

Use	Most important property
Aeroplane bodies	High strength–to–weight ratio (low density)
Overhead power cables	Good conductor ofelectricity
Saucepans	Good conductor of heat
Food cans	Non–toxic, resistant to corrosion and acidic food stuffs
Window frames	Resistant to corrosion

Copper Alloys

- **Bronze** is an alloy made of copper and tin. It is harder than copper and is used to make ornaments and medals
- **Brass** is a common example of an alloy which contains 70% copper and 30% zinc. It is decorative and corrosion resistant and is used for low friction ornamental purposes such as **plumbing** and **carpentry**

fittings



Brass is used extensively in modern kitchen and bathroom fittings

Uses of Copper

Use	Most important property
Electrical wires	Good conductor of electricity and malleable
Water pipes	Easy to work with and bend, non-toxic and unreactive (does not react with water)

Gold Alloys

- Gold alloys are used to make jewellery

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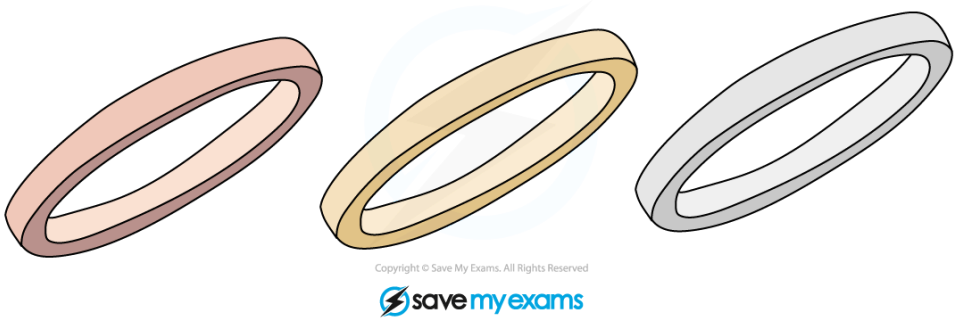
- Gold metal is relatively **soft** and **malleable** so other metals such as copper, zinc and silver are added to provide **strength** and **toughness**
- **Carats** are used to express the purity of gold jewellery
- Pure gold with nothing else added is said to be **24 carat**
- A 12 carat piece of gold jewellery therefore contains **50% gold**
- For example a 12 carat necklace that weighs 50 g contains 25 grams of gold



Rose, yellow and white gold are alloys of gold with varying proportions of copper, silver and other metals. White gold is a good imitation of platinum which is a very expensive precious metal

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