BioMedical Admissions Test (BMAT)

Section 2: Chemistry

Topic C14: Metals

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Properties and Uses of Metals

There are some definitions which are useful to know when considering the properties and uses of metals.

- An **alloy** is a combination of two or more metals to combine properties.
    - This is useful as it disrupts the regular metal lattice.
    - This means that the layers cannot slide over each other, increasing the strength of the metal.
- A **malleable** metal can easily be shaped.
- A **ductile** metal can be 'stretched' to form wires.

Some **uses** of specific metals are as follows:

Aluminium

- Pure **aluminium** is soft, malleable and lightweight as well as non-toxic and corrosion free. This means it is used in many products such as drinks cans and conductor cables.
- Alloyed aluminium is much stronger and is used in the aerospace industry.

Iron

Pure **iron** is soft whilst impure iron is brittle.

- Impure iron can be purified and alloyed with varying amounts of carbon to form steel.
- Other metals may be added to make it 'stainless' steel by providing anti-rusting properties. These include nickel or chromium.
- Different strengths of steel are used for different purposes. For example, knives and forks will have a different level of carbon to industrial cutting blades.

Gold

Gold is used not only in jewellery but also as components in electronic circuits.

- This draws on its properties of being a very good conductor, corrosion resistant, and also malleable and ductile.

Silver

Silver is also used in electronics but not often due to economic reasons (it's expensive).

- Other uses include applying the properties of no toxicity and antimicrobial action to medicine and sport.
- Of course, it is also used often in jewellery.

Copper

Copper is used in wires as it easily conducts electricity and is very ductile.

- It is also not very reactive and malleable so is used in water pipes.
- It is also useful that it is a good heat conductor so is used in heaters and on the bottom of pans.

Titanium

Titanium is used extensively in the aerospace and defence industries as alloys due to its ability to produce low density materials and temperature resistant property.

Uses of the metals are summarised in the table below:

Metals	Uses
Pure Aluminium	Drinks cans, conductor cables
Alloyed Aluminium	Aerospace industry
Pure Iron	
Stainless Steel	Cutlery, Drill bits/cutting tools
Gold	Jewellery, electronic components
Silver	Antimicrobial in medicine/sportswear. Jewellery
Copper	Electric wiring, water pipes/heaters, Pans
Titanium	Aerospace/Defence parts

Transition Metals

Transition metals are metals in groups 3 to 12 which are able to form stable ions in different **oxidation states**.

There are some **common properties**:

- High density
- Generally unreactive
- High melting point
- Suitable for alloying – due to similar particle size
- Catalytic activity
- Coloured compounds – can absorb visible light.

A key example to know for **catalytic activity** is the role of Vanadium in the Contact Process.

- It is able to form the V_2O_4 compound with an oxidation state of +4 and V_2O_5 with the oxidation state +5.
- This means that it can catalyse the creation of SO_3 from SO_2 and O_2.

The equations are as follows:

$$V_2O_4 + ½O_2 \rightarrow V_2O_5$$

$$V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$$

$$\text{Overall: } SO_2 + ½O_2 \rightarrow SO_3$$

- The V_2O_2 present at the start of the reaction is re-formed and so is a catalyst rather than being used up in the course of the reaction.

Relative Reactivity of Metals

To react, metals must **lose electrons** from their **outermost shell**.

- To remove 1 electron takes less energy than to remove two (or even three)
- So, along the same period, Group 1 is more reactive than group 2 or group 13 (e.g. Aluminium.
- Transition metals are even less reactive.
- Down a group, reactivity increases.
    - The outermost electrons are further from the nucleus making them easier to remove.
- You **don't** need to know the reactivity series.

Metal extraction

In nature, most metals are found as ores.

- Most often reacted with oxygen to form an oxide.
- Less reactive metals (e.g. Gold) still need purification but will be found unreacted.
- Metals can be extracted by different methods dependent on their reactivity.
    - Oxides of metals less reactive than carbon can be reacted with it to release the metal in a **redox reaction**. This is relatively cheap.
    - Metals more reactive than carbon will require **electrolysis** which is expensive. *(This is explained in more detail in Topic C12 - Electrolysis).*
- The process of extraction chosen is down to economics.
    - The **cheapest viable method** will be selected.
    - This is an area of intensive research all the time to lower costs and find new sources of metal (e.g. from lower-grade ores).

Displacement Reactions

This is a reaction where a less reactive metal is replaced in a compound by a more reactive metal.

This can happen in **solution**, such as zinc replacing iron in a solution of iron oxide.

$$Zn_{(s)} + FeO_{(aq)} \rightarrow Fe_{(s)} + ZnO_{(aq)}$$

A new solid would form and there would be a change in the colour of the solution.

It can also happen in **solids**. For example, aluminium displacing iron(III) oxide in the thermite reaction.

$$Fe_2O_{3\,(s)} + Al_{(s)} \rightarrow Fe_{(s)} + Al_2O_{3\,(s)}$$

This is a very exothermic reaction and so is used to produce the energy for welding train tracks together.

Reactivity and Acid Reactions

The **relative reactivity** of metals can predict whether a metal will react with acids.

- Magnesium, being above hydrogen in the reactivity series, reacts with HCl to form $MgCl_2$.
- Copper, which is below hydrogen in the reactivity series, does not.