 **NATIONAL 4 AND NATIONAL 5 CHEMISTRY**

**Unit 3: Chemistry In Society**

**Topic 1**

**METAL CHEMISTRY**

**Fe(*l*)**

**HOT AIR BLAST**

**HOT AIR BLAST**

**STAGE 1**

**STAGE 2**

**STAGE 3**

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| **Name \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Class \_\_\_\_\_** |

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| Unit 3: Chemistry In Society |
| Topic 1: Metal Chemistry |

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| LEVEL N4 N5 | **AFTER COMPLETING THIS TOPIC YOU SHOULD BE ABLE TO:** | NOTES (Page) | **How well I have understood (✓)** | | |
| **☺** | **😐** | **☹** |
| N5 | Describe the structure of a metal as a giant lattice of positively charged ions and delocalised outer electrons. | 3 |  |  |  |
| N5 | Describe metallic bonding as the electrostatic force of attraction between the positively charged nuclei and the outer delocalised electrons in metal atoms. | 3 |  |  |  |
| N5 | Explain the properties of a metal (electrical conductivity, malleability and ductility) in terms of the metallic bonding. | 4 |  |  |  |
| N4 | Carry out reactions between metals and oxygen, water and dilute acid to place the metals into an order of reactivity based on the differences in reaction rate. | 5-9 |  |  |  |
| N4 | Write word and chemical equations for the reactions of a metal with: oxygen, dilute acid and water. | 5-9 |  |  |  |
| N5 | State oxidation is a loss of electrons by a reactant, and reduction is gain of electrons by a reactant, in any reaction. | 5-6, 9,10 |  |  |  |
| N5 | State a metal element reacting to form a compound is an example of oxidation. | 6 |  |  |  |
| N5 | Write ion-electron equations for oxidation and reduction reactions. | 9-10 |  |  |  |
| N4 | State ores are naturally occurring compounds of metals. | 10 |  |  |  |
| N4 | State the less reactive metals, including gold, silver and copper, are found uncombined in the Earth’s crust and the more reactive metals have to be extracted from their ores. | 10-11 |  |  |  |
| N4 | Explain why some metals can be obtained from metal oxides by heat alone; some metal oxides need to be heated with other substances, e.g. carbon or carbon monoxide; other metals cannot be obtained by these methods. | 12-17 |  |  |  |
| N4 | Describe how iron is produced from iron ore in the Blast Furnace. | 15 |  |  |  |
| N5 | Describe the extraction of metals from compounds as a reduction reaction. | 12-17 |  |  |  |
| N5 | Describe the reaction taking place at the negative electrode during electrolysis for the extraction of metal as a reduction reaction. | 17 |  |  |  |
| N4 | Give examples of the important uses of alloys, e.g. brass, solder, “stainless” steel. | 17-18 |  |  |  |
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| **N5** | **METALLIC BONDING** | **N5** |

Metals have a high density indicating the metal atoms are closely packed together.

The outer electron(s) on each atom are free to move between the atoms. This results in a regular arrangement (a **LATTICE**) of **POSITIVE IONS** with **NEGATIVE ELECTRONS** moving between the **positive ions**.

|  |  |  |
| --- | --- | --- |
| Free moving outer electrons.  Lattice of **positive ions**. |  | These free moving outer electrons are described as a **“SEA OF ELECTRONS**”. |

The **outer electron(s)** on a metal atom are said to **“DELOCALISED”**, as they are not located on a specific atom.

The electrostatic attraction between the positive ions and the delocalised electrons acts in all 3-dimensions, strongly holding the lattice together.

|  |  |  |
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| Delocalised electron |  | This electrostatic attraction is the **METALLIC BONDING**. |

Most metals have high melting and boiling points. In addition, there is usually a large difference between the melting and boiling point of a metal (**its liquid range**). This indicates **metallic bonding is very strong**.

**CONDUCTION OF HEAT AND ELECTRICITY**

Metals are good conductors of heat and electricity. This is due to the presence of the delocalised electrons.

The movement of the delocalised electrons passes on the **energy** during **conduction of heat**.

During conduction of an electric current, electrons pushed into the metal from the **NEGATIVE ELECTRODE** of a battery or power supply make the delocalised electrons move towards the **POSITIVE ELECTRODE**.

|  |  |  |
| --- | --- | --- |
| **- ve electrode** |  | **+ ve electrode** |

The metal is not affected by the passage of an electric current, as the number of electrons always equals the number of protons in the lattice.

**SHAPING METALS**

Metals can easily have their shape changed, yet they still retain their strength.

**Metals are MALLEABLE as they can be bent and hammered into different shapes.**

**Metals are DUCTILE as they can be pulled and squeezed to produce wires.**

During reshaping the metal ions move position, as do the sea of electrons. The metallic bonding is not affected.

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|  | **RESHAPE** |  |

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| **N4** | **METAL REACTIONS** | **N5** |

The amount of energy given out when a metal reacts gives a measure of its reactivity.

**METALS AND OXYGEN**

All metals react with **oxygen** to make a **METAL OXIDE**.

**Potassium permanganate** (**KMnO4**) gives off **oxygen** when **heated**.

Different metals can be reacted with pure oxygen to observe how well the react.

|  |  |
| --- | --- |
| **HEAT**  **KMnO4**  **ceramic wool**  **metal powder** | **RESULTS**  **Most reactive**  **Least reactive** |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **magnesium** | **+** | **oxygen** |  | **magnesium oxide** |  |
| **2 Mg** | **+** | **O2** |  | **2 MgO** | Magnesium oxide is an **ionic compound**. |

**N5**

**CHEMISTRY**

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| **Ionic equation:** | |  |  |  |
| **2 Mg** | **+** | **2 O2** |  | **2 Mg2+O2-** |

During the reaction **2 electrons** are **lost** from each magnesium atom (**Mg**) to form a magnesium ion (**Mg2+**).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Mg** |  | **Mg2+** | **+** | **2 e-** |

A reaction where a reactant **loses** an **electron** (or **electrons**) is called an **OXIDATION REACTION**. The magnesium atom is **OXIDISED** as it has lost **2 electrons**.

When **metals** react their atoms **lose electrons** **to form their ions**. This means all metals undergo an **OXIDATION REACTION** when they react.

**METALS AND ACIDS**

When a metal reacts with an **acid** the products are a **SALT** and **HYDROGEN**.

The speed of production of hydrogen gives a measure of the reactivity of the metal.

|  |  |
| --- | --- |
| **4 mol *l*-1 hydrochloric or sulfuric acid**  **metal** | **RESULTS**  **Most reactive**  **Least reactive** |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **zinc** | **+** | sulfuric acid |  | **zinc** sulfate | **+** | **hydrogen** |
|  |  |  |  |  |  |  |
| **Zn** | **+** | **H2SO4** |  | **ZnSO4** | **+** | **H2** |
| **N5**  **CHEMISTRY** |  |  |  |  |  |  |

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| --- | --- | --- | --- | --- | --- | --- |
| **Ionic equation:** |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| **Zn** | **+** | **2H+(aq) + SO42-(aq)** |  | **Zn2+(aq) + SO42-(aq)** | **+** | **H2(g)** |
|  |  |  |  |  |  |  |

During the reaction **2 electrons** are **lost** from each zinc atom (**Zn**) to form a zinc ion (**Zn2+**).

The zinc atoms are **OXIDISED** during the reaction with an acid.

In this reaction the sulphate ion **SO42-** is a **spectator ion** as it does take part in the reaction.

**METALS AND WATER**

When a metal reacts with **water** the products are a **METAL HYDROXIDE** solution (**an alkali**)and **HYDROGEN**.

|  |  |  |
| --- | --- | --- |
|  |  | **Mg powder**  **water**  **H2** |
| **potassium** | **calcium** | **magnesium** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **RESULTS** |  |  |  |  |
| **Most reactive** |  | | | **Least reactive** |
|  |  |  |  |  |

Only metals from **groups I (ALKALI METALS),** and **group II (ALKALINE EARTH METALS),** react with **water**.

|  |  |  |  |  |  |  |
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| **REACTIVE METAL (group I or II)** | **+** | WATER |  | **METAL HYDROXIDE (alkali)** | **+** | **HYDROGEN** |

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| --- | --- | --- | --- | --- | --- | --- |
| **sodium** | **+** | water |  | **sodium** hydroxide | **+** | **hydrogen** |
|  |  |  |  |  |  |  |
| **2 Na(s)** | **+** | **2 H2O(*l*)** |  | **2 NaOH(aq)** | **+** | **H2(g)** |

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**CHEMISTRY**

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| --- | --- | --- | --- | --- | --- | --- |
| **Ionic equation** |  |  |  |  |  |  |
| **2 Na(s)** | **+** | **2 H2O(*l*)** |  | **2 Na+(aq) + 2 OH-(aq)** | **+** | **H2(g)** |

During the reaction **1 electron** is **lost** from each sodium atom (**Na**) to form a sodium ion (**Na+**).

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| --- | --- | --- | --- | --- |
| **Na** |  | **Na+** | **+** | **e-** |

The sodium atoms are **OXIDISED** during the reaction with water.

**REACTION SUMMARY**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **REACTIVITY SERIES OF METALS** | | | | | | |
|  | : | |  | |  | |
| **METAL** | **REACTION WITH:** | | | | | |
| **WATER** | | **ACID** | | **OXYGEN** | |
| potassium **(K)** | These metals react with water to produce a **METAL HYDROXIDE** and **HYDROGEN.** |  | These metals react with an acid to produce a **SALT** and **HYDROGEN.** |  | These metals react with oxygen to produce a **METAL OXIDE.** |  |
| sodium **(Na)** |
| lithium **(Li)** |
| calcium **(Ca)** |
| magnesium **(Mg)** |
| aluminium **(Al)** |  | |
| zinc **(Zn)** |  | |
| iron **(Fe)** |  | |
| tin **(Sn)** |  | |
| lead **(Pb)** |  | |
| copper **(Cu)** |  | |  | |
| mercury **(Hg)** |  | |  | |
| silver **(Ag)** |  | |  | |  | |
| gold **(Au)** |  | |  | |  | |

**MAZIT METALS**

The metals in the middle of the reactivity series are called the **MAZIT** metals.

|  |  |  |  |
| --- | --- | --- | --- |
| **M** | **m**agnesium |  | **MAZIT** lists the metals in their order of reactivity. |
| **A** | **a**luminium |  |
| **Z** | **z**inc |  |
| **I** | **i**ron |  |
| **T** | **t**in |  |

**N5**

**CHEMISTRY**

**OXIDATION AND REDUCTION**

When a metal reacts, the **metal atoms lose electrons** and change into metal ions. This is an **OXIDATION REACTION**.

The electrons lost from a metal atom during a reaction have to be **GAINED** by another reactant.

When a metal reacts with oxygen, the electrons lost by the metal are gained by the **oxygen molecules** **(O2)**, changing them into **oxide ions (O2-)**.

The ionic equation for magnesium reacting with oxygen shows this.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **2 Mg** | **+** | **2 O2** |  | **2 Mg2+O2-** |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **O2** | **+** | **4 e-** |  | **2 O2-** | **Each** **oxygen molecule (O2) gains 4 electrons to produce 2 oxide ions (O2-)** |

A reaction where a reactant **gains** an **electron** (or **electrons**) is called a **REDUCTION REACTION**. The **oxygen molecule (O2)** is **REDUCED** as it has **gained** **4 electrons**.

**2** **magnesium atoms** each lose **2 electrons** forming **2** **magnesium ions**. In total, **4 electrons** are transferred to the **oxygen molecule**.

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| --- | --- | --- | --- | --- | --- |
| **2 Mg** |  | **2 Mg2+** | **+** | **4 e-** | **The magnesium atoms are OXIDISED.** |

**Reduction** and **oxidation** reactions **ALWAYS** occur together. Reactions where electrons are transferred from one reactant to another are called **REDOX REACTIONS**.

When a **metal** reacts with an **acid** the **electrons lost** by the **metal** are transferred to the **hydrogen ions** in the **acid**. This converts the **hydrogen ions (H+)** into **hydrogen molecules (H2)**.

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| **Zn** | **+** | **2H+(aq) + SO42-(aq)** |  | **Zn2+(aq) + SO42-(aq)** | **+** | **H2(g)** |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **2H+(aq)** | **+** | **2 e-** |  | **H2(g)** | **The hydrogen ions (H+) are REDUCED.** |

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|  | To practise recognising oxidation and reduction reactions do the **OXIDATION & REDUCTION** examples on **page 2** of the **Practice Examples Booklet**. |

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| **N4** | **OBTAINING METALS** | **N5** |

The metals we use are obtained from rocks in the Earth’s crust.

Most metals are too reactive to exist in a pure uncombined form in the Earth’s crust. Metals are found in rocks as metal compounds. The usual metal compounds found in rocks are **OXIDES, SULPHIDES** and **CARBONATES.**

**NATIVE METALS**

A few metals are found uncombined, as they are very unreactive. Metals, which are found uncombined, are called **NATIVE METALS.**

The native metals are:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| http://www.trinityminerals.com/denver2007/100_3760.JPG |  | http://www.minresco.com/display/rjpg/mi1289.jpg |  | http://www.minclassics.com/rk47a.jpg |  | http://www.aamineralspecimens.com/Portals/0/Product%20Images/native-copper-720218B.jpg |
| **Gold (Au)** |  | **Platinum (Pt)** |  | **Silver (Ag)** |  | **Copper (Cu)** |

**METAL ORES**

Rocks, which contain metals or compounds of metals, are called **ORES**.

As man’s knowledge of chemistry increased more metals were discovered, as ways of extracting metals were found.

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| **REACTIVITY SERIES OF METALS** | |  | Using the **N5 Chemistry Data Booklet**; complete the **REACTIVITY SERIES OF METALS** with the **Date of Discovery.** |
|  | |  |
| **METAL** | **DATE OF DISCOVERY** |  |
| potassium **(K)** |  |  |  |
| sodium **(Na)** |  |  | **CONCLUSION**  The least reactive metals were discovered the earliest. |
| lithium **(Li)** |  |  |
| calcium **(Ca)** |  |  |
| magnesium **(Mg)** |  |  |
| aluminium **(Al)** |  |  |
| zinc **(Zn)** |  |  |
| iron **(Fe)** |  |  |
| tin **(Sn)** |  |  |
| lead **(Pb)** |  |  |
| copper **(Cu)** |  |  |
| mercury **(Hg)** |  |  |
| silver **(Ag)** |  |  |
| gold **(Au)** |  |  |

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| **EXAMPLES OF METAL ORES** | | |
| **NAME OF ORE** | **NAME OF METAL COMPOUND IN ORE** | **METAL IN ORE** |
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**METAL OXIDES**

A large number of ores contain **metal oxides**.

To extract a metal from an ore requires **heat**. Some metal oxides break down by heat alone.

**HEATING SILVER(I) OXIDE AND COPPER(II) OXIDE**

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| **COPPER(II) OXIDE** |  | **SILVER(I) OXIDE** |  | **RESULTS** |
| **copper(II) oxide**  **HEAT** |  | **silver(I) oxide**  **HEAT** |  | **Silver(I) oxide breaks down on heating** to form **silver** and **oxygen**.  **Heating has no effect on** **copper(II) oxide.** |

Breaking down a compound into its elements from which it is made is called a **DECOMPOSITION REACTION**.

**Silver(I) oxide** **decomposes** on heating to form silver and oxygen.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **silver(I) oxide** | **heat** | **silver** | **+** | **oxygen** |
|  | **heat** |  |  |  |
| **2 Ag2O** |  | **4 Ag** | **+** | **O2** |

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| **Ionic equation:** |  |  |  |  |
|  | **heat** |  |  |  |
| **2 (Ag+)2O2-** |  | **4 Ag** | **+** | **O2** |

The **silver(I) ion** is changed to a **silver atom**. To do this each **silver(I) ion** has to **gain 1 electron**. This change is **reduction**.

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| **Ag+** | **+** | **e-** |  | **Ag** |

**METAL OXIDES WITH CARBON**

**Metals** with **very low reactivity** can be extracted by just heating their compounds. **Copper** is **too reactive** to be extracted by **HEAT ALONE**.

**Metals** with **low to middle reactivity** can be extracted by heating their compounds with **carbon**.

**HEATING COPPER(II) OXIDE WITH CARBON**

|  |  |  |
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| **cold water**  **Drop hot test tube into cold water.**  **copper(II) oxide**  **HEAT** |  | **RESULTS**  After the reaction some **orange / brown copper** can be seen in the beaker.  The products of the reaction are **COPPER** and **CARBON DIOXIDE** |

**Carbon** helps remove the **oxygen** from the **copper(II) oxide**. The **oxygen** transfers to the **carbon** forming **carbon** **dioxide**.

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| copper(II) **oxide** | **+** | carbon | **heat** | copper | **+** | carbon **dioxide** |
|  |  |  | **heat** |  |  |  |
| **2** Cu**O** | **+** | C |  | **2** Cu | **+** | C**O2** |

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| --- | --- | --- | --- | --- | --- | --- |
| **Ionic equation:** |  |  | **heat** |  |  |  |
| **2** Cu2+**O2-** | **+** | C |  | **2** Cu | **+** | C**O2** |

The **copper(II) ion** is changed to a **copper atom**. To do this each **copper(II) ion** has to **gain 2 electrons**. This change is **reduction**.

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| --- | --- | --- | --- | --- |
| **Cu2+** | **+** | **2 e-** |  | **Cu** |

**EXTRACTING IRON – THE BLAST FURNACE**

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| Iron is extracted from its ore using carbon. The reaction requires a lot of heat. To provide the necessary heat the reaction is carried out in a **BLAST FURNACE**.  The extraction of the iron happens in **3 stages**.  **STAGE 1:** The coke (carbon) burns to produce carbon dioxide **CO2**.  **C**(s) **+** **O2(g)** C**O2(g)**  **STAGE 2:** The **CO2** from stage 1 reacts with more carbon to form carbon monoxide **CO.**  C**O2(g) +** **C**(s) **2** C**O(g)**  **STAGE 3:** The **CO** from stage 2 reacts with iron(III) oxide **Fe2O3** in the iron ore removing the oxygen.  Fe2O3**(s) +** **3** C**O(g)**  2 Fe + **3** C**O2(g)** | Iron ore, coke (carbon) and limestone enter the furnace from the top of the furnace.  Molten iron flows to the bottom of the furnace.  **STAGE 2**  **STAGE 3**  **STAGE 1**  **HOT AIR BLAST**  **HOT AIR BLAST**  **Fe(*l*)** |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| iron(III) **oxide** | **+** | carbon **monoxide** | **heat** | iron | **+** | carbon **dioxide** |
|  |  |  | **heat** |  |  |  |
| Fe2**O3** | **+** | **3** C**O** |  | **2** Fe | **+** | **3** C**O2** |

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| --- | --- | --- | --- | --- | --- | --- |
| **Ionic equation:** |  |  | **heat** |  |  |  |
| (Fe3+)2 (**O2-**)**3** | **+** | **3** C**O** |  | **2** Fe | **+** | **3** C**O2** |

The **iron(III) ion** is changed to an **iron atom**. To do this each **iron(III) ion** has to **gain 3 electrons**. This change is **reduction**.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Fe3+** | **+** | **3 e-** |  | **Fe** |

**EXTRACTING ALUMINIUM**

**N5**

**CHEMISTRY**

Aluminium is too reactive to extract by heating with carbon or carbon monoxide.

All reactive metals from aluminium upwards on the reactivity series are extracted using **ELECTROLYSIS**.

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| The bauxite ore is purified to produce pure **aluminium oxide** **Al2O3**. This is called **ALUMINA**. |  |  |  |

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| Solid ionic compound do not conduct electricity as their ions are not free to move.  **Alumina** is dissolved in **molten cryolite (Na3AlF6)**, as it has a lower melting point than **aluminium oxide, which** reduces the energy needed for the extraction.  This solution is electrolysed and molten aluminium metal forms at the **negative electrode**. |  |  |



Carbon lining as the negative electrode.

Carbon positive electrode.

Solution of aluminium oxide in molten cryolite.

Molten aluminium collects at the bottom.

The **aluminium ion (Al3+)** moves to the negative electrode where it **gains** **3 electrons** and changes to an **aluminium atom (Al)**. This change is **reduction**.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Al3+** | **+** | **3 e-** |  | **Al** |

**ALLOYS**

Often the properties of a pure metal makes it unsuitable for the purposes we wish to use it. Iron, for example, rusts easily and is quite brittle.

The properties of metals can be altered, by adding small quantities of other metals, or non-metals, to make a new metal called an **ALLOY**.

|  |
| --- |
| **An ALLOY is a metal made by mixing different metals, or metals with non-metals.** |

Alloys improve the properties of metals by making them **harder**, **stronger** and more **resistant to corrosion**



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| --- | --- | --- | --- |
| **ALLOY** | **MAIN METAL** | **OTHER ELEMENTS PRESENT** | **USES** |
| Mild steel |  |  |  |
| Stainless steel |  |  |  |
| 12-carat gold |  |  |  |
| Duralumin |  |  |  |
| Bronze |  |  |  |
| Brass |  |  |  |
| Cupro-nickel |  |  |  |