



eduresourceza.com

METALS

[UNIT 9]

MST_CREATOR

Table of Contents

Note From Author.....	3
Properties of Metals.....	4
Physical Properties of Metals & Non-Metals.....	4
Reactions of Metals.....	4
Reaction With Air/Oxygen.....	5
Reaction With Water.....	5
Reaction With Steam.....	6
Reaction With Dilute HCl.....	6
Uses of Metals.....	7
Alloys & Their Properties.....	8
Examples & Uses.....	8
Structure.....	9
Reactivity of Metals.....	10
Reactions With Water & Steam.....	10
Reactions With Dilute HCl.....	11
Using The Reactions to Make the Reactivity Series.....	12
Aluminium & Its Oxide Layer.....	12
Metal Displacement Reactions.....	13
Examples.....	13
Displacement As a Redox Reaction.....	14

Extraction of Metals	15
Extraction of Iron	15
Why Carbon?	15
The Blast Furnace	16
The Process	16
Extraction of Aluminium	17
The Process (Hall–Hérout process)	17
More Info About the Electrolytic Cell	18
Corrosion of Metals	19
What is Rust?	19
Causes of Rust	19
How Does Iron Rust?	19
Aluminium: The Strange One	20
Rust Prevention	20
Painting	20
Oiling & Greasing	20
Plastic Coatings	21
Electroplating	21
Galvanizing	21
Sacrificial Protection	22
Definitions	23

Note From Author

Hello reader!

Hope you are doing well, I just wanted to tell you that this unit is unit 9 from the syllabus (topic 9: metals)

In the book, this unit covers chapters 14, 15, and 16.

Anyway, that's it for this segment, you can start with the actual content now!

MST_CREATOR

Properties of Metals

Physical Properties of Metals & Non-Metals

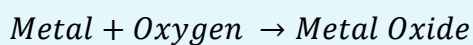
Metals	Non-Metals
High melting & boiling points	Low melting & boiling points
Good conductors of electricity	Poor conductors of electricity (except graphite)
Good conductors of heat	Poor conductors of heat (except diamond)
High densities	Low densities
Strong	Brittle
Sonorous	Not sonorous
Generally grey (except copper & gold) and can be polished	Vary in colour and have dull surface when solid.

Reactions of Metals

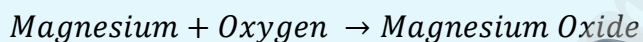
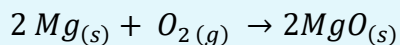
Metal	Reaction With...		
	Air	Water	Dilute HCl
Sodium	Burn strongly to form Metal Oxide	React with cold water to give Hydrogen	React strongly to give Hydrogen
Calcium			
Magnesium			
Aluminium	Burn less strongly to form Metal Oxide	React with steam (when heated) to give Hydrogen	React less strongly to give Hydrogen
Zinc			
Iron			
Lead	React to form oxide layer when heated	Do not react	
Copper			
Silver	Do not react		
Gold			

Reaction With Air/Oxygen

When a metal reacts with Oxygen, it forms a Metal Oxide:



Example



Note

This only happens with the reactive metals (like Sodium) and for metals that are less reactive (like Iron), a layer of Metal Oxide forms (rust) which flakes off and for Aluminium, the layer of Metal Oxide sticks and hides the reactivity of the metal.

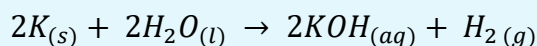
Metals that are not reactive (like gold) won't react as they are unreactive.

Reaction With Water

Reactive metals (like potassium) react with water to form metal hydroxide & hydrogen gas:



Example

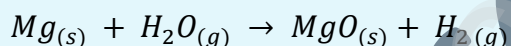


Reaction With Steam

Metals that are less reactive react with steam rather than water to give Metal Oxide & Hydrogen:



Example



Magnesium + Steam → Magnesium Oxide + Hydrogen

Magnesium reacts with steam more than it does with water.

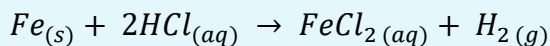
(Magnesium reacts very slowly with water)

Reaction With Dilute HCl

Metals that are moderately reactive can be reacted safely with dilute hydrochloric acid to give metal chloride and hydrogen gas:



Example



Iron + Hydrochloric Acid → Iron Chloride + Hydrogen

Uses of Metals

Aluminium is used to make aircrafts as it is light (due to the low density) and strong.

Aluminium is also used to manufacture overhead power lines as it has low density and is a good conductor of electricity.

Aluminium is also used for food packaging and containers as it is resistant to corrosion and is light.

Copper is used in electrical wiring as it is ductile and a good conductor of electricity.

Alloys & Their Properties

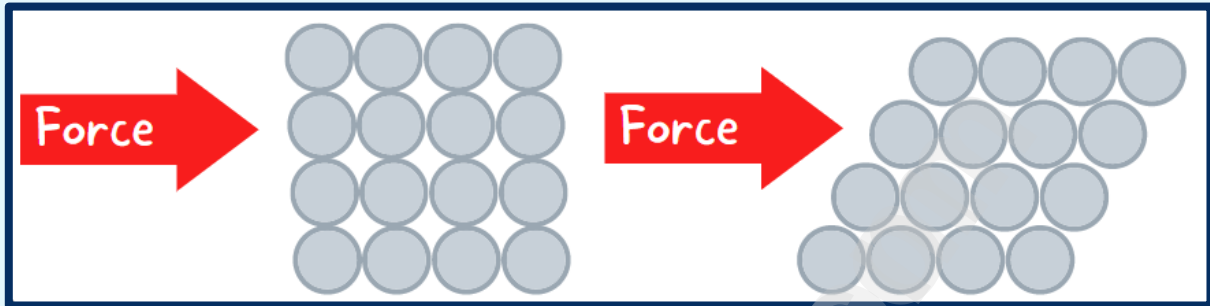
Alloys are mixtures of elements (generally metals) that are designed to have properties useful for a particular purpose.

Examples & Uses

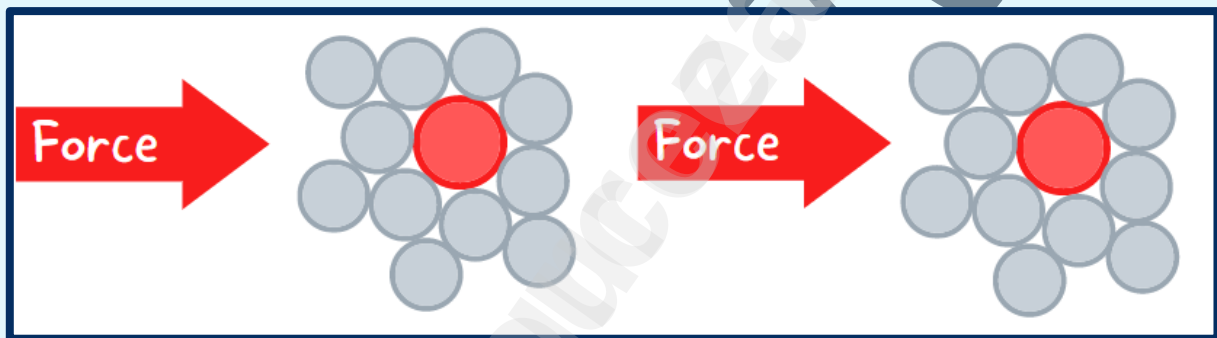
Alloy Name	Contents	Uses
Brass	Copper & Zinc	Brass is used to make the gold-coloured musical instruments, ornaments, and electrical connections mainly because it is harder than pure copper.
Stainless Steel	Iron, Chromium & Nickel	Stainless steel is used in cutlery and surgical equipment as it does not rust and is strong.
Solder	Tin & Lead	Solder is used for electrical connections as it has a low melting point.
Mild Steel	Iron & Carbon	Mild steel is used to manufacture car bodies as it is stronger and harder than pure iron.

Structure

For a normal metal, they slide easily when force is applied:



For alloys, they don't slide easily as there are other molecules that vary in size:



When force is applied, it is hard to make them slide as the big molecules prevent it from sliding.

Alloys is a regular lattice of atoms.

Reactivity of Metals

The reactivity series is a series of elements that arranges elements in order of their reactivity, you need to memorize this:

Potassium (K)	
Sodium (Na)	R
Calcium (Ca)	E
Magnesium (Mg)	A
Aluminium (Al)	C
Carbon (C)	T
Zinc (Zn)	I
Iron (Fe)	V
Hydrogen (H)	I
Copper (Cu)	T
Silver (Ag)	Y
Gold (Au)	

Reactions With Water & Steam

Reagents	Reaction
Lithium & Water	Reacts Steadily: $2\text{Li} + 2\text{H}_2\text{O} \rightarrow 2\text{LiOH} + \text{H}_2$
Sodium & Water	Reacts Strongly: $2\text{Na} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$
Potassium & Water	Reacts Violently: $2\text{K} + 2\text{H}_2\text{O} \rightarrow 2\text{KOH} + \text{H}_2$
Calcium & Water	Reacts Strongly: $\text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2$
Magnesium & Steam	Glows Brightly When Reacting: $\text{Mg} + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{H}_2$

Reactions With Dilute HCl

Metal	Observation with HCl or H ₂ SO ₄	Equations
Magnesium	1. Reacts strongly. 2. Produces bubbles of gas. 3. Disappears and forms colourless solution.	$\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2$ $\text{Mg} + \text{H}_2\text{SO}_4 \rightarrow \text{MgSO}_4 + \text{H}_2$
Aluminium	1. Slow reaction in cold acid. 2. Bubbles form when heated. 3. Forms colourless solution.	$4\text{Al} + 6\text{HCl} \rightarrow 2\text{Al}_2\text{Cl}_3 + 3\text{H}_2$ $2\text{Al} + 3\text{H}_2\text{SO}_4 \rightarrow \text{Al}_2(\text{SO}_4)_3 + 3\text{H}_2$
Zinc	1. Produces bubbles of gas. 2. Disappears and forms colourless solution.	$\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$ $\text{Zn} + \text{H}_2\text{SO}_4 \rightarrow \text{ZnSO}_4 + \text{H}_2$
Iron	1. Produces bubbles of gas. 2. Disappears and forms pale green solution.	$\text{Fe} + 2\text{HCl} \rightarrow \text{FeCl}_2 + \text{H}_2$ $\text{Fe} + \text{H}_2\text{SO}_4 \rightarrow \text{FeSO}_4 + \text{H}_2$
Copper	No Reaction	
Silver	No Reaction	
Gold	No Reaction	

Using The Reactions to Make the Reactivity Series

We can use all the data from the tables to arrange the elements from most to least reactive.

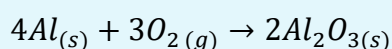
This is how it would go (most reactive to least reactive):

Metal	Reaction With...	
	Water	Acid
Potassium	Reacts vigorously	Reacts vigorously
Sodium	Reacts strongly	Reacts strongly
Calcium	Reacts strongly	Reacts strongly
Magnesium	Reacts slowly	Reacts strongly
Aluminium	No Reaction	Reacts slowly
Zinc		Reacts slowly (slower than Aluminium)
Iron		Reacts very slowly
Copper		Reacts extremely slowly
Silver		Barely reacts
Gold	Does not react	

Aluminium & Its Oxide Layer

If you look at the table with the reaction of metals with dilute acid, you will see that aluminium doesn't really react fast with the acid despite being a very reactive metal.

The reason is that aluminium reacts with air to form an oxide layer:



The oxide layer decreases the reactivity of aluminium which is why it reacted slowly with dilute acid.

Metal Displacement Reactions

The oxide layer decreases the reactivity of aluminium which is why it reacted slowly with dilute acid.

Examples

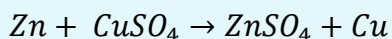
Reagents	Symbolic Equation	Word Equation	Reason
Copper Sulphate And Zinc	$\text{Zn} + \text{CuSO}_4 \rightarrow \text{ZnSO}_4 + \text{Cu}$	Zinc + Copper Sulphate → Zinc Sulphate + Copper	Zinc is more reactive than Copper
Silver Nitrate And Copper	$2\text{AgNO}_3 + \text{Cu} \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{Ag}$	Silver Nitrate + Copper → Copper Nitrate + Silver	Copper is more reactive than Silver
Sodium Chloride And Zinc	No Reaction		Sodium is more reactive than Zinc

Displacement As a Redox Reaction

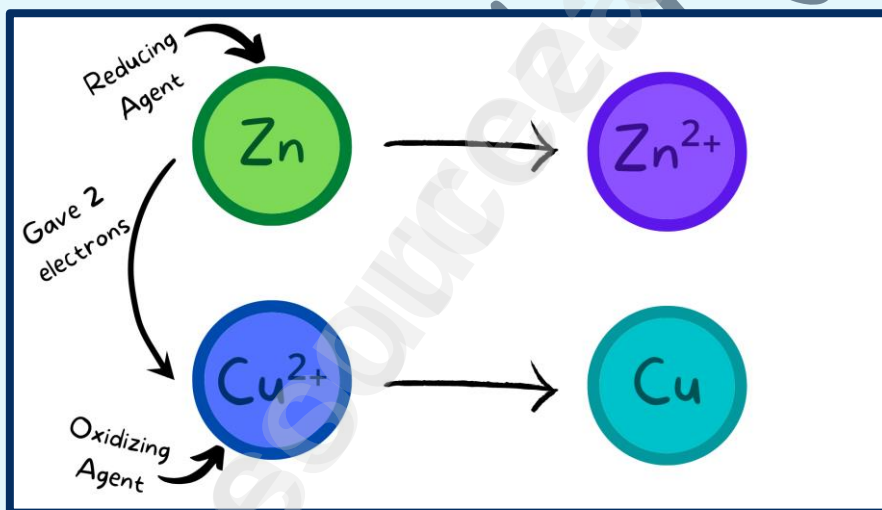
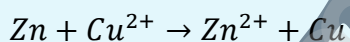
Reactive metals are good reducing agents, this means that they can lose electrons easily.

Example

We can take the example of Copper Sulphate & Zinc:

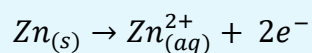


We can remove SO_4 as it doesn't really take part in the reaction:

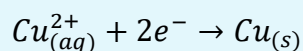


We can write 2 half-equations for this:

Oxidising Half-Equation:



Reduction Half-Equation



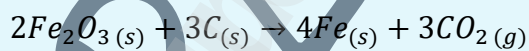
Extraction of Metals

How we decide on the method of extraction

Position In the Reactivity Series	Method
Under Hydrogen	Exist as pure metals, no extraction needed.
Above Hydrogen & Under Carbon	Metal Oxide is heated with Carbon
Above Carbon	Electrolysis

Extraction of Iron

The main ore of iron is Hematite (Fe_2O_3), we make Hematite react with Carbon, so it gives us:



Why Carbon?

That's because Carbon is cheap.

We can use other elements that are more reactive than Iron like Magnesium or Lithium (We use electrolysis for that).

The Blast Furnace

This is what we use to extract iron from hematite.

The blast furnace is a tower, lined up with heat-resistant bricks of Magnesium Oxide that are cooled with water.

The extracted iron is known as "Pig Iron" or "Cast Iron".

The Process

The Extraction Bit	
Step	What Happens
1	Furnace is loaded with "charge" which is made up of Iron ore, Coke (form of carbon), and Limestone (Calcium Carbonate).
2	The charge is then heated with Coke & Limestone to make sure that solids mix well.
3	The charge is then mixed with more Coke.
4	Blasts of hot air are sent through the holes near the bottom of the blast furnace.
5	Oxygen reacts with Coke to form CO_2
6	The CO_2 that forms reacts again with Coke to form CO
7	CO reduces Iron Oxide to Iron as it is a reducing agent: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
8	Some of the Carbon will also reduce the Iron Oxide to Iron.

The Removal of Silica (SiO ₂)	
Step	What Happens
1	We add limestone and it decomposes to lime in the furnace: $\text{CaCO}_{3(s)} \rightarrow \text{CaO}_{(s)} + \text{CO}_{2(g)}$ Limestone → Lime + Carbon Dioxide
2	The Lime then reacts with the sand (or silica) to give us Calcium Silicate: $\text{CaO}_{(s)} + \text{SiO}_{2(s)} \rightarrow \text{CaSiO}_{3(l)}$ Lime + Silica → Calcium Silicate
3	The Calcium Silicate that form is liquid and flows down the furnace to form a molten layer of slag on top of the iron: ▪ The slag does not mix with the Iron as it is less dense. ▪ The slag is used by builders for various things like roadbuilding.

Extraction of Aluminium

Aluminium is an extremely reactive metal and is extracted using electrolysis.

The main or of Aluminium is Bauxite which is a red brown in colour.

The Process (Hall–Héroult process)

Step	What Happens
1	Bauxite is treated with Sodium Hydroxide in a refinery to obtain pure Aluminium Oxide (alumina) and is shipped to the electrolysis plant.
2	The alumina is dissolved in molten cryolite (Sodium Aluminium Fluoride), this lowers the melting point of the oxide and therefore, the working temperature of the cell. Cryolite reduces cost greatly
3	Molten mixture of aluminium oxide & cryolite is electrolyzed in a cell fitted with graphite electrodes.

More Info About the Electrolytic Cell

The electrolyte in the cell in step 3 is a solution of alumina & cryolite.

The process is run continuously as liquid aluminium is pumped out and more alumina is added as necessary.

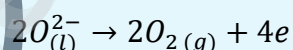
The mixture is kept molten due to the large current being supplied constantly.

Aluminium ions are attracted to the cathode which is the Carbon lining of the cell.

The aluminium is then discharged as a liquid which sinks to the bottom of the cell:



The Oxide ions are attracted to the Carbon anode where they are discharged as Oxygen gas:



Under high temperatures, the Oxygen reacts with the Carbon anode giving Carbon Dioxide, this means that the Carbon anode is changed frequently.

Corrosion of Metals

When metals are attacked by water, air, or other substances, it is said that it “corrodes”.

Corrosion of Iron or Steel is called “rusting”.

What is Rust?

Rust is a red-brown powder that consists of Hydrated Iron (III) Oxide
($\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$)

Causes of Rust

Water and Oxygen are essential to make something rust.

Acid rain increases the rate of rust.

Salt in seawater makes iron rust faster.

How Does Iron Rust?

When Iron rusts, the rust forms in flakes.

The attack continues as these flakes keep falling off until the Iron corrodes completely.

Aluminium: The Strange One

Aluminium is more reactive than Iron however, it does not corrode as much as Iron.

The reason for this is that when Oxygen reacts with Aluminium, a layer of Aluminium Oxide (Al_2O_3) forms on the top.

This layer protects the Aluminium from corroding.

This layer can be made thicker using electrolysis.

Rust Prevention

Painting

Some paints react with Iron to form very strong protective layer.

Generally, painting only protects Iron if the paint layer is unscratched which means we need to repaint every now and then.

Oiling & Greasing

Oiling or greasing moving parts of machines forms a protective film which prevents rusting.

Same as painting, we must do this every now and then as the oil wears off over time.

Plastic Coatings

Used to form a protective layer on items like refrigerators.

The Plastic Poly (Vinyl Chloride) PVC pipes is used often for this.

Electroplating

Iron or Steel objects can be electroplated with a layer of Chromium or Tin to prevent rusting.

Tin is used because it is unreactive and non-toxic.

The problem with this is that if some of the coating is damage or broken off, the steel or iron under it will start to rust.

Galvanizing

This is when we an object is covered with a layer of Zinc (more reactive than Iron).

Its advantage over other methods is that the Iron will not rust even if the layer is scratched or damaged.

There are many ways we can coat the object in Zinc, one way is using electroplating, another could be to dip the object in Zinc.

Sacrificial Protection

This is when we attach blocks of metals more reactive to the Iron surface.

A common use of this technique is at the hull of ships or oil rigs (we use Zinc and Magnesium blocks).

These metals are more reactive than Iron and will react first.

An electrochemical cell is set up.

The metal blocks lose electrons in preference to iron to prevent it from forming Iron (III) Oxide.

Definitions

Keyword	Definition
Electrical Conductivity	The ability to conduct electricity.
Malleable	Used to describe a substance that can be bent or beaten into shape.
Ductile	Used to describe a substance that can be drawn out into a wire.
Thermal Conductivity	The ability to conduct heat.
Sonorous	Used to describe a metal substance that rings like a bell when struck.
Alloys	Mixture of metals (usually metals) designed to have properties that are useful for a particular purpose.
Brass	A hard alloy made of Copper & Zinc.
Stainless Steel	Steel that consist of a lot of Chromium which causes it to be rust resistant.
Reactivity	The ease with which a chemical substance to take part in a chemical reaction.
Reactivity Series	Order of reactivity, with the most reactive metal first, based on the results of many experiments with air, water, HCl, and metal salt solutions.
Displacement Reaction	Reaction in which a more reactive element displaces a less reactive element from a solution of its salt.
Ore	Naturally occurring mineral from which a metal can be extracted.
Electrolysis	The breakdown of an ionic compound using electricity.
Hematite	Major ore of Iron (Fe_2O_3)
Blast Furnace	Furnace for extracting metals (specifically iron) by reduction with Carbon that uses hot air blasted in the base of the furnace to raise temperature.
Limestone	A form of Calcium Carbonate (CaCO_3).
Mineral	Naturally occurring rock containing a particular compound.

Keyword	Definition
Slag	Molten mixture of impurities, mainly Calcium Silicate which is formed in the blast furnace.
Corrosion	Process that takes place in metals & alloys are chemically attacked by Oxygen, water, or other substances found in their immediate environment.
Bauxite	Major ore of aluminium which, a form of aluminium oxide (Al_2O_3).
Electrolyte	Ionic compound that conducts electricity when molten or dissolved in water but not when solid.
Cryolite	Sodium Aluminium Fluoride (Na_3AlF_6) which is another ore of aluminium and is used to decrease the operating temperature of the electrolytic cell.
Electrolytic Cell	Cell which contains an electrolyte and 2 electrodes (cathode & anode) which are connected an external DC power source where positive & negative ions in the electrolyte are separated & discharged.
Rusting	The corrosion of Iron & Steel to form Hydrated Iron (III) Oxide.
Galvanizing	Protection of Iron/Steel objects by coating with a Zinc layer.
Sacrificial Protection	Method or rust prevention involving attachment of blocks made of metals more reactive than iron. These blocks are corroded in place of the Iron/Steel structure.

The End

If these notes helped you out in any way...

I am happy for you 😊