5072 CHEMISTRY (NEW PAPERS WITH SPA)
TOPIC 9: METALS

5067 CHEMISTRY (NEW PAPERS WITH PRACTICAL EXAM)
TOPIC 9: METALS

SUB-TOPIC 9.3 TO 5
EXTRACTION OF METALS; RECYLING OF METALS; IRON

LEARNING OUTCOMES
SUB-TOPIC 9.3: EXTRACTION OF METALS a) Describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series. SUB-TOPIC 9.4: RECYCLING OF METALS a) Describe metal ores as a finite resource and hence the need to recycle metals; e.g. recycling of iron. b) Discuss the social, economic and environmental advantages and disadvantages of recycling metals SUB-TOPIC 9.5: IRON a) Describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace b) Describe steels as alloys which are a mixture of iron with carbon or other metals and how controlled use of these additives changes the properties of the iron, e.g. high carbon steels are strong but brittle whereas low carbon steels are softer and more easily shaped c) State the uses of mild steel, e.g. car bodies; machinery, and stainless steel, e.g. chemical plants; cutlery; surgical instruments d) Describe the essential conditions for the corrosion (rusting) of iron as the presence of oxygen and water; prevention of rusting can be achieved by placing a barrier around the metal, e.g. painting; greasing; plastic coating; galvanising e) Describe the sacrificial protection of iron by a more reactive metal in terms of the reactivity series where the more reactive metal corrodes preferentially, e.g. underwater pipes have a piece of magnesium attached to them

A Extraction of Metals

- Reactive metals do not exist in their free state in nature. They exist, combined with other elements, in the form of compounds called metal ores.
- Metal ores are normally in the form of oxides, sulphides or carbonates.

Metal	Ore	Chemical Compound in Ore
Aluminium	Bauxite	Aluminium Oxide
Iron	Haematite	Iron (III) Oxide
Tin	Cassiterite	Tin (IV) Oxide
Zinc	Zinc Blende	Zinc Sulphide

- To obtain pure metals, we must extract them from their ores. The three methods of extraction are:
  - Electrolysis of the Molten Ore
  - Reduction of Ore using Carbon
  - Heating alone
- Which method is chosen depends on the position of the metal in the reactivity series.
- Potassium, Sodium, Calcium, Magnesium and Aluminium are extracted by electrolysis.
  - E.g. Sodium
    - Sodium is extracted by electrolysis of molten sodium chloride.
    - Sodium ion is reduced at the cathode to sodium metal:
    - $Na^+ (l) + e^- \rightarrow Na (l)$
- Zinc, Iron, Tin, Lead and other metals below them are extracted by reducing the metal oxides using Carbon or Carbon Monoxide in a blast furnace.
  - E.g. Lead
    - Lead is extracted by reducing Lead (II) Oxide with Coke.
    - $2PbO (s) + C (s) \rightarrow 2Pb (s) + CO_2 (g)$
- Copper can usually be extracted from its oxide alone by heating with charcoal as it is not that reactive.
- The last 2 metals on the reactivity series, Gold and Silver usually exist as a free element as they are very unreactive.

B Metals – A Finite Resource

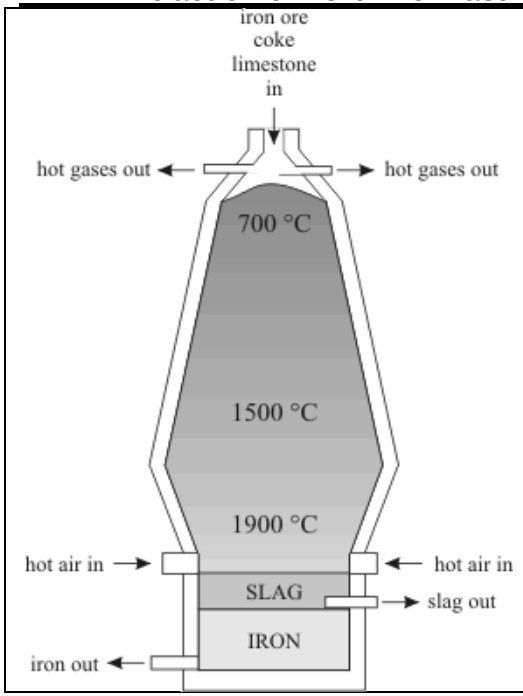
- The following table shows the distribution of some metals in the Earth's crust and oceans.
- From the table, it can be said that metal ore resources are finite and limited. If we go one extracting metals from their ores, we will run out of metal ores.
- Hence, we must recycle metals.

Metal	% Abundance
Aluminium	7.50
Iron	4.71
Titanium	0.58

C Problems from Recycling

	Advantages	Disadvantages
Social	- Recycling helps to conserve metals, especially valuable ones such as gold & platinum. - Recycling promotes new business and job opportunities.	- Difficult to separate the metals into alloys
Economic	- Recycling saves the cost of extracting newer metals. - The cost of recycling is a fraction of the cost of extracting more aluminium from the Earth's crust.	- Recycling iron is more expensive than extracting newer iron from the Earth. - Transportation costs for collecting scrap metal is high.
Environmental	- Recycling can be beneficial to the environment by preventing land pollution. - Used Aluminium cans are not biodegradable	- Land used as landfill to bury the articles is wasted. - Recycling can cause air pollution - Discarded old aluminium cans or articles presents an ugly sight and spoils the environment.

D Extraction of Iron/ The Blast Furnace



Stage 1
Coke is fed into the Blast Furnace and oxidises to form Carbon Dioxide.
$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$

Stage 2
The Carbon Dioxide rises in the furnace and comes into contact with more coke. Here, it reacts endothermically (temperature falls to 1500^0C) to form Carbon Monoxide.
$CO_2\ (g) + C\ (s) \rightarrow 2CO\ (g)$

Stage 3
The Carbon Monoxide reduces the iron ore at the top of the furnace, to molten iron metal (pig metal) which falls to the bottom of the furnace, and Carbon Dioxide gas escapes from the top as a waste gas.
$Fe_2O_3\ (s) + 3CO\ (g) \rightarrow 2Fe\ (l) + 3CO_2\ (g)$

Limestone is present in the furnace to remove impurities. Inside the furnace, the Limestone is decomposed to form Lime and Carbon Dioxide.
$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$

The Carbon Dioxide produced reacts with the hot coke to produce more Carbon Monoxide, but the lime combines with the sand (Silicon Dioxide) impurities to form a molten slag called Calcium Silicate.

Source http://www.ktf-split.hr/glossary/en_o.php?def=blast%20furnace	$CaO\ (s) + SiO_2\ (s) \rightarrow CaSiO_3\ (l)$ This slag, because it is molten, runs to the bottom of the furnace, and as it is lighter than molten iron, it floats on the surface and can be tapped off. It is used in the building of road foundations.

E Steel

- Steel is an alloy of Iron and Carbon.
- By varying the amount of Carbon, different types of Carbon steels are produced.

Carbon Steel Name	% of Carbon	Properties	Uses
Mild Steel	< 0.2	Malleable, Ductile	Car Bodies, Machinery, Cables, Nails, Chains
Medium Steel	0.2-0.6	Tougher and Harder than Mild Steel	Steel Girders, Rails
High Carbon Steel	0.6-1.5	Tough and hard, but brittle	Cutlery, Tools, Spring

- Alloy steels contain not only Carbon, but also controlled amounts of other metals such as Chromium, Nickel, Vanadium and Tungsten.

Alloy Steel Name	Metals Added	Properties	Uses
Stainless Steel	Chromium, Nickel	Corrosion Resistant, Acid Resistant	Cutlery, Chemical Plants, Surgical instruments
Chromium Steel	Chromium	Corrosion Resistant, Hard	Ball Bearings
High-Speed Steel	Tungsten, Vanadium	Very Hard, Heat Resistant	High Speed Drills
Manganese Steel	Manganese	Very high tensile strength	Rock-breaking machinery, railway cross-overs

F Rusting

- Iron rusts when it comes into contact with Oxygen and water
- In the anodic region each Iron atom loses 2 electrons to form an Fe^{2+} ion.
  $Fe\ (s) \rightarrow Fe^{2+}\ (aq) + 2e^-$
- The electrons that are released flow through the iron to the cathode region.
- The electrons that react with Oxygen and water to form Hydroxide ions.
  $O_2\ (g) + 2H_2O\ (l) + 4e^- \rightarrow 4OH^-\ (aq)$
- The Fe^{2+} ions migrate through the moisture to the cathodic region to react with Oxygen to form rust.
  $4Fe^{2+} + O_2\ (g) + (4 + 2n)H_2O\ (l) \rightarrow 2Fe_2O_3.nH_2O\ (s) + 8H^+\ (aq)$
- Rust is hydrated Iron(III) Oxide, $Fe_2O_3.nH_2O$
- To stop rusting, water and air must be prevented from coming into contact with the surface of iron:

Method	Where	Comment
Painting	Large objects, e.g. ships, cars, bridges	If the paint is scratched, rusting will take place under the painted surface.
Oiling and Greasing	Tools and machine parts	The protective film gathers dust and must be renewed.

Galvanising (Zinc Plating)	Buckets, dustbins, roofs, sinks	The metal does not rust even if the zinc layer is damaged.
Tin Plating	Food cans	If the tin coating is scratched, the iron beneath it rusts.
Chrome Plating	Taps, kettles, bicycle handlebars	This gives a bright shiny finish as well as rust prevention.
Sacrificial Protection (Metal Block of Zinc/ Magnesium)	Underground pipes, legs of steel piers, ships	Magnesium and Zinc corrode in preference to Iron because they are more reactive metals.
Stainless Steel	Cutlery, surgical equipment	Stainless steel contains Chromium and Nickel which does not rust.