Topic 12: **Answers** Metals

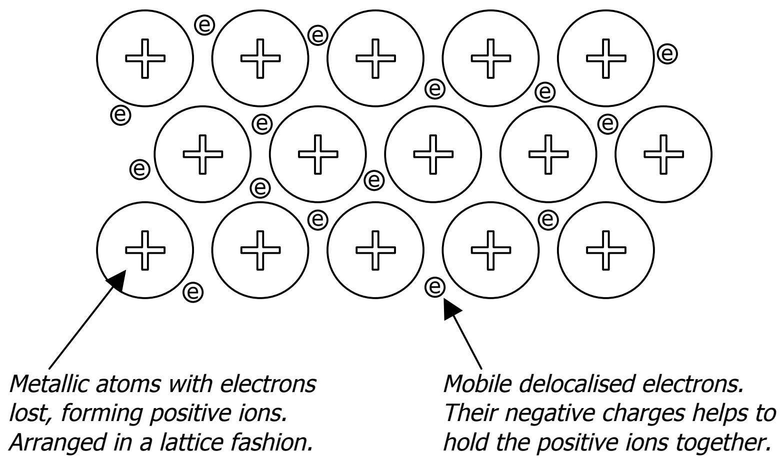
SYLLABUS RELEVANCE & TEXTBOOK CHAPTERS		
O-LEVEL PURE (5072)	✓	Chapter 14
O-LEVEL SCIENCE (5116)	✓	Chapter 13
N-LEVEL SCIENCE (5155)	✓	Chapter 11

Lesson Package & Accompanying Slides Designed by Alex Lee (2008)
Last Modified by Alex Lee (2011)

1. Structure & Physical Properties of Pure Metals

In Chemistry, a metal is defined as an element which tends to ......lose...... electrons, to form a ......positively...... charged ion. As an element, the atoms undergo **metallic bonding** and delocalize their electrons to form positive ions.

The **structure of a metal** is a ......lattice of positive ions, in a 'sea' of delocalized electrons......



Below lists four physical properties of metals. Match these four properties with their corresponding explanations by connecting them with straight lines.

Malleable & ductile texture •	• Strong electrostatic forces of attraction between positive ions and delocalised electrons, requiring a lot of energy to overcome.
High melting & boiling points •	• Presence of mobile electrons between the positive ions allow charges to flow along the metal.
Good electrical conductivity •	• Atoms arranged in an orderly manner, allowing layers of atoms to slide over each other easily.
Good heat conductivity •	• Presence of mobile electrons allow rapid transfer of thermal energy by free electron diffusion.

2. Structure & Physical Properties of Alloys

The term 'alloys' are used to refer to metals with other elements mixed into them. These other elements **may be either metals or non-metals** themselves. Since the chemical properties of the constituents remain the same, **alloys are mixtures**, not compounds.

Some Common Alloys:

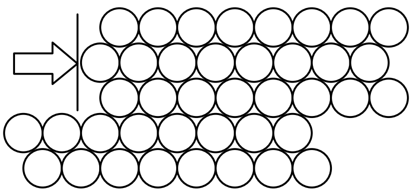
Brass – mixture of ......copper...... and zinc

Bronze – mixture of ......copper...... and tin

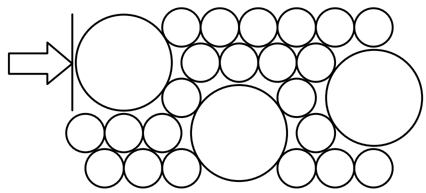
Nichrome – mixture of ......nickel...... and ......chromium......

Steel – mixture of ......iron...... and carbon

Stainless Steel – mixture of ......iron......, chromium, carbon and nickel



a pure metal



an alloy

Unlike a pure metal, **alloys are far less malleable and ductile**, as it the presence of 'foreign atoms' prevent the metallic atoms from sliding past each other so easily. In daily life, we tend to use alloys more often than pure metals. Below lists several reason as to why, industrially, alloys are more useful.

ADVANTAGES OF ALLOYS

Harder, Stronger Texture

e.g. ......steel......

Unlike pure metals which are malleable and ductile, alloys tend to be stronger due to the presence of foreign atoms which disrupt the regular arrangement of the metal. This prevents the atoms from sliding past each other so easily.

More Resistant to Corrosion

e.g. ......stainless steel......

Alloys can be more resistant to corrosion. For example, pure iron corrodes if exposed to air for a long period of time. In comparison, stainless steel (an alloy of iron) is able with withstand corrosion despite contact with air and water.

Alter Melting & Boiling Points

e.g. ......solder......

Sometimes we may desire alloys with low melting points; e.g. solder, a mixture of tin and lead, is often melted to join other metals together. Conversely, we may also desire alloys which can withstand greater temperatures than their constituents.

Aesthetic Appeal

e.g. ......white gold......

By mixing several metals, we are able to obtain alloys of varying colours. In addition, due to the increased resistance to corrosion, alloys also tend to have a shiny appearance (a better 'luster') which enhances its aesthetic appeal.

3. **Review Questions**

(a) In the table below, compare and contrast between alkali metals and transition metals.

	Alkali Metals	Transition Metals
Texture	softer	harder
Melting Points	lower m.p.	higher m.p.
Density	less dense	more dense
Reactivity	more reactive	less reactive
Oxidation State	always +1	multiple oxidation states
Colour of Salts	white when solid colourless when aqueous	forms coloured salts

(b) Sodium, magnesium and aluminium are in the same period of the Periodic Table. Which of these three metals has the highest melting point? Explain your answer.

Aluminium, as it has the most valence electrons (i.e. three), leading to a larger number of delocalised electrons to hold the positive ions together.

(c) Explain why pure metals are malleable and ductile, while alloys have a harder texture.

In a pure metal, the atoms are arranged in an orderly manner and hence layers of atoms are able to slide over each other easily.

In an alloy, the presence of foreign atoms disrupt the regular arrangement, and hence the atoms are no longer able to slide over each other easily.

(d) (i) Are alloys able to conduct electricity? Explain why they are able or not able to do so.

Yes; this is because alloys contain delocalised electrons in their structure which are mobile and hence able to carry an electric current.

(ii) State two reasons why steel, and not iron, is often used for making kitchen utensils.

Steel has a harder, stronger texture, i.e. less malleable and ductile.

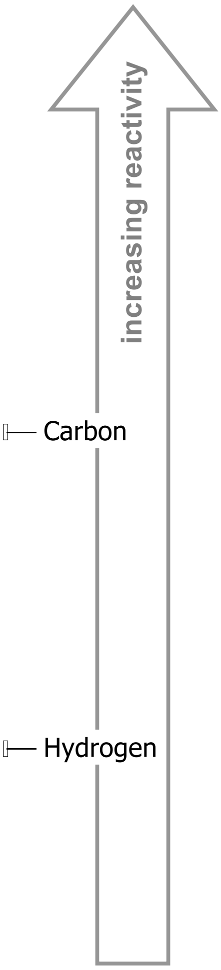
Kitchen utensils often use stainless steel, which does not rust.

(e) Name the only two pure metals which are **not** grey in appearance, and state their colours.

copper (pink) and gold (yellow)

4. **<u>Metal Oxidation Reactions 1 & 2: Reactions with Cold Water and Steam</u>**

Some metals are more reactive than others, i.e. they form compounds more readily. In general, the alkali metals (Group I) are the most reactive, followed by the alkali earth metals (Group II). Below lists the reactivity series for nine common metals.



<table>
<tr><th></th><th>Cold Water (4)</th><th>Hot Steam (6)</th></tr>
<tr><td>Potassium</td><td rowspan="3">Reacts with cold water to produce <u>hydroxides</u> and hydrogen gas.

$Ca\ (s) + 2\ H_2O\ (l) \rightarrow Ca(OH)_2\ (aq) + H_2\ (g)$</td><td rowspan="3">Explosive reaction, dangerous to conduct.</td></tr>
<tr><td>Sodium</td></tr>
<tr><td>Calcium</td></tr>
<tr><td>Magnesium</td><td colspan="2">Reacts slowly with water, vigorously with steam.</td></tr>
<tr><td>Zinc</td><td rowspan="5">No reaction occurs.</td><td rowspan="2">Reacts with steam to produce <u>oxides</u> and hydrogen gas.

$Zn\ (s) + H_2O\ (g) \rightarrow ZnO\ (s) + H_2\ (g)$</td></tr>
<tr><td>Iron</td></tr>
<tr><td>Lead</td><td rowspan="3">No reaction occurs.</td></tr>
<tr><td>Copper</td></tr>
<tr><td>Silver</td></tr>
</table>

(a) (i) Where in the above reactivity series would caesium be located?

Above potassium

(ii) Where in the above reactivity series would barium be located?

Above calcium but below sodium

(b) Construct chemical equations for the reaction

(i) between sodium and cold water,

$2\ Na + 2\ H_2O \longrightarrow 2\ NaOH + H_2$

(ii) between magnesium and steam.

$Mg + H_2O \longrightarrow MgO + H_2$

5. **<u>Metal Oxidation Reactions 3 & 4: Reactions with Dilute Acid and Oxygen</u>**

Apart from reactions with water and steam, the reactivity series can also predict other oxidation reactions of metals; namely with acid (as learnt in the chapter on acids and bases) and when heated in the presence of oxygen.

increasing reactivity

<table>
<tr><th></th><th>Reaction with HCl (7)</th><th>Heating with O_2 (8)</th></tr>
<tr><td>Potassium</td><td rowspan="3">Explosive reaction, dangerous to conduct.</td><td rowspan="3">Violent reaction, dangerous to conduct.</td></tr>
<tr><td>Sodium</td></tr>
<tr><td>Calcium</td></tr>
<tr><td>Magnesium</td><td rowspan="4">Reacts with dilute acids to produce salts and hydrogen gas.

$Mg\ (s) + 2\ HCl \rightarrow MgCl_2\ (aq) + H_2\ (g)$</td><td>Burns in oxygen with a bright white flame.</td></tr>
<tr><td>Carbon</td><td rowspan="6">Reacts with oxygen (in the presence of heat) to produce <u>oxides</u>.

$2\ Cu\ (s) + O_2\ (g) \rightarrow 2\ CuO\ (s)$</td></tr>
<tr><td>Zinc</td></tr>
<tr><td>Iron</td></tr>
<tr><td>Lead</td><td>Only reacts, slowly, with an acid when heated.</td></tr>
<tr><td>Hydrogen</td><td rowspan="3">No reaction occurs.</td></tr>
<tr><td>Copper</td></tr>
<tr><td>Silver</td><td>No reaction occurs.</td></tr>
</table>

(a) Name a metal which is able to react with dilute acids but not with steam.

Lead

(b) Construct chemical equations, including state symbols for

(i) the reaction between zinc and sulfuric acid,

$Zn\ (s) + H_2SO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + H_2\ (g)$

(ii) the reaction when lead is heated in air,

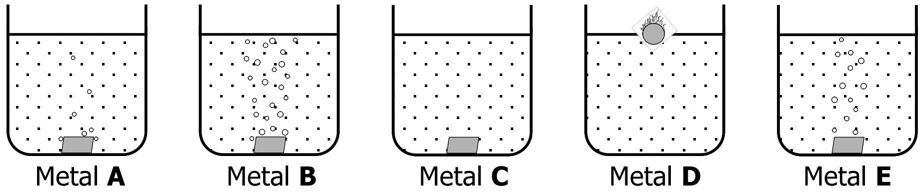
$2\ Pb\ (s) + O_2\ (g) \longrightarrow 2\ PbO\ (s)$

(iii) the reaction between iron and hydrochloric acid.

$Fe\ (s) + 2\ HCl\ (aq) \longrightarrow FeCl_2\ (aq) + H_2\ (g)$

6. **Review Questions**

(a) Samples of five unknown metals were placed into separate beakers of cold water as shown.



(i) Arrange the five metals in order of increasing reactivity.

C, A, E, B, D

(ii) Suggest the identity for metal **D**, citing the main reason for your choice.

Potassium, as it gives off a (lilac) flame when reacting.

(iii) Metals **A**, **B** and **C** were found to be calcium, iron and magnesium, not in any particular order. Suggest the identities of metals **A**, **B** and **C**.

A: magnesium **B**: calcium **C**: iron

(iv) A student makes a hypothesis that metal **E** is actually lithium. State **two** reasons why this hypothesis is wrong.

Lithium is less dense than water and will float, not sink.

Lithium, an alkali metal, would react more vigorously than metal B (calcium).

(b) A student carried out an experiment to investigate the reactivity of five metals, **A** – **E**. The results obtained are given below.

Metal	Reaction With H_2O	Reaction With H_2SO_4
A	Reacts very slowly with cold water, but very vigorously with steam	Reacts vigorously and gives off hydrogen gas
B	Does not react with cold water, but moderately with steam	Reacts moderately and gives off hydrogen
C	Does not react with water or steam	Does not react even when heated
D	Reacts vigorously with cold water	Reacts explosively and gives off hydrogen gas that burns
E	Does not react with water or steam	Only reacts when heated, few bubbles of hydrogen produced

(i) Arrange the five metals in increasing order of their reactivity.

C, E, B, A, D

(ii) Suggest which metal could be

copper: C sodium: D magnesium: A

7. **<u>Relating Thermal Stability of Salts to the Reactivity Series</u>**

Some salts are able the decompose upon heating. Such salts are referred to as being **thermally unstable**. On the other hand, salts which do not decompose upon heating are referred to as being thermally stable.

The thermal stability of a salt can be predicted from the reactivity series:

> The more reactive the metal, the ..... more stable ..... a compound it forms. Therefore, it is more difficult / requires more energy to ..... thermally decompose .....

This can be illustrated by observing the ease of thermal decomposition of metal carbonates, metal hydroxides, metal nitrates and metal sulfates. As you would observe, the lower the metal in the reactivity series, the easier to decompose its compound.

<table>
<tr><th></th><th>Metal Carbonates
CO_3^{2-}</th><th>Metal Hydroxides
OH^-</th><th>Metal Nitrates
NO_3^-</th><th>Metal Sulfates
SO_4^{2-}</th></tr>
<tr><td>K^+</td><td rowspan="2">may not thermally decompose</td><td rowspan="2">may not thermally decompose</td><td rowspan="2">thermally decomposes to form nitrites and O_2</td><td rowspan="5">may not thermally decompose</td></tr>
<tr><td>Na^+</td></tr>
<tr><td>Ca^{2+}</td><td rowspan="7">thermally decomposes to form oxides and CO_2</td><td rowspan="7">thermally decomposes to form oxides and H_2O</td><td rowspan="7">thermally decomposes to form oxides, NO_2 and O_2</td></tr>
<tr><td>Mg^{2+}</td></tr>
<tr><td>Zn^{2+}</td></tr>
<tr><td>Fe^{2+}</td><td rowspan="4">thermally decomposes to form oxides and SO_2/SO_3</td></tr>
<tr><td>Pb^{2+}</td></tr>
<tr><td>Cu^{2+}</td></tr>
<tr><td>Ag^+</td></tr>
</table>

(a) Solid samples of calcium carbonate and lead(II) carbonate are heated strongly over an open flame. Which compound would you expect to take a longer time to decompose? Explain how you arrived at your answer.

Calcium carbonate. This is because calcium is a more reactive metal than lead, and hence will form more stable compounds. Thus calcium carbonate is more difficult to decompose than lead(II) carbonate.

(b) From the above table, what conclusion can you draw about Group I carbonates and their ease of thermal decomposition?

Group I carbonates are unable to undergo thermal decomposition.

8. **<u>Obtaining Metals from Ores</u>**

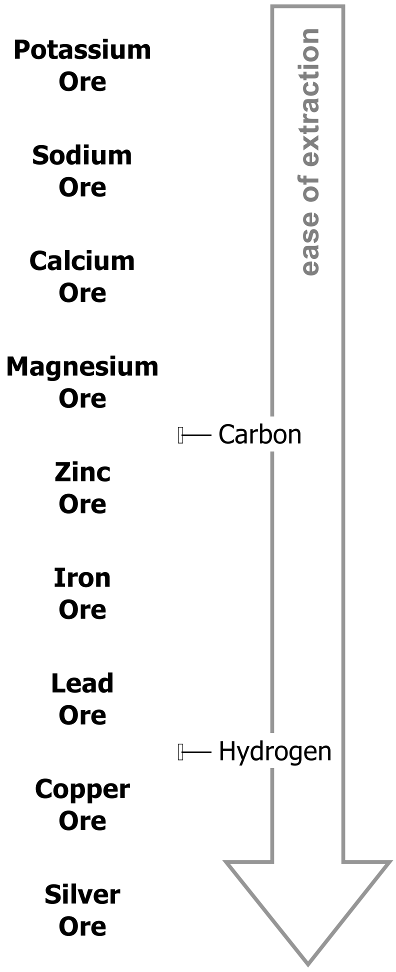
Many metals do not exist naturally as elements. Most of them **occur naturally as compounds such as oxides and sulfides**, e.g. iron(III) oxide and calcium carbonate. These compounds are obviously not pure either, and they often contain other rocks and particles within them. We refer to these materials are **ores** (e.g. impure zinc sulfide).

After refining, the purified compound is known as **minerals** (e.g. pure zinc sulfide). These minerals then undergo various reduction processes to obtain the **pure metal**.

Rocks	mining →	ores	refining →	minerals	reduction →	metals
		impure compound		*purified compound*		*element*

We can observe a relationship between reactivity and the ease of reduction of a metal ore:

> The more reactive the metal, the ......more stable...... a compound it forms. Therefore, it is more difficult / requires more energy to ......reduce the ore to become a metal.......



Method of Extraction	
Method: electrolysis *Electricity is passed through the ore to reduce it into element form. Performed at high temperatures in order to maintain the ore in a molten state.* *Less reactive metals, such as copper, can be extracted from aqueous solutions instead to save cost.* *Example:* **$Na^+ + e^- \rightarrow Na$**	*(more reactive metals form extremely stable ores, and hence may not be extracted through carbon reduction)*
	Method: carbon reduction *Metal ore is heated with coke (carbon). The more reactive the metal, the higher the temperature required for reaction.* *Example:* **$2\ ZnO + C \rightarrow 2\ Zn + CO_2$**

9. **Review Questions**

(a) Zinc ore and iron ore can both be obtained reduced by heating with carbon. Which of these two ores will require a higher temperature for extraction? Explain your answer.

Zinc ore. Zinc is a more reactive metal than iron, and hence zinc ore is more stable than iron ore and requires a greater amount of energy for reduction.

(b) Small samples of three metal ores, **X**, **Y** and **Z**, are heated strongly with carbon until globules of liquid metal were formed. The time taken for the ore to be completely reduced is shown:

Ore	Time Taken for Reduction (min)
X	Completely reduced in 25 min
Y	Completely reduced in 10 min
Z	No reduction at all after an hour.

(i) Arrange the three ores in decreasing order of stability.

Z, X, Y

(ii) Suggest a possible identity for ore **Z**.

potassium/sodium/calcium/magnesium ore

(c) Calcium metal is industrially obtained from electrolysis of its molten ore, gypsum.

(i) In terms of structure and bonding, explain why the ore needs to be molten, and not solid, in order to be extracted by electrolysis.

The minerals in gypsum are ionic compounds. When solid, the ions are held in fixed positions and hence unable to conduct an electric current. When molten, the ions are free to move and hence can conduct an electric current.

(ii) Zinc metal can also be obtained by electrolysis of its molten ore, sphalerite. However, industrially, this is done by reduction by carbon instead. Explain why this is so.

Electrolysis is a far more expensive process as a large amount of energy is required, not only in terms of electricity, but also to keep the ore molten.

(d) Gold is a precious metal which is below silver in the reactivity series. Suggest why, in the extraction of gold from its ore, there is no need for reduction.

Gold is highly unreactive and already occurs naturally as an element, hence only purification of the ore is necessary, and not reduction.

(e) Under bright sunlight, silver chloride can decompose into its elements as shown:

$$2\ AgCl\ (s) \longrightarrow 2\ Ag\ (s) + Cl_2\ (g)$$

Do you expect sodium chloride to behave the same way under sunlight? Why or why not?

No. Sodium is a very reactive metal and hence forms very stable compounds. Thus sodium chloride is unlikely to be decomposed by light.

(f) The carbonates of three metals, **P**, **Q** and **R**, are heated strongly over a bunsen burner. The products of the decomposition are shown below.

Carbonate	Products of Decomposition
$\mathbf{P}_2CO_3$	decomposes to become $\mathbf{P}_2O$ and CO_2
$\mathbf{Q}_2CO_3$	does not decompose
$\mathbf{R}_2CO_3$	decomposes to become **R**, CO_2 and O_2

(i) Arrange the three metals in increasing order of reactivity.

R, P, Q

(ii) Suggest a possible identity for metal **Q**.

potassium or sodium

(g) The table below shows the results of heating the sulfates of three metals and the reaction of the same metal oxides with hot carbon.

Metal	Effect of Placing Metal in Dilute Hydrochloric Acid	Effect of Heating Metal Oxide with Carbon
S	moderate effervescence	reduced to the metal
T	vigorous effervescence	no reaction
U	no visible change	reduced to the metal

(i) Hence arrange the three metals, **S**, **T** and **U**, in increasing order of reactivity.

U, S, T

(ii) Suggest the identity of metal **S**, citing your reasons clearly.

Zinc/iron/lead. The metal can react with dilute hydrochloric acid, showing it is above copper in the reactivity series; while the metal oxide may be reduced by heating with carbon, showing it is below magnesium in the reactivity series.

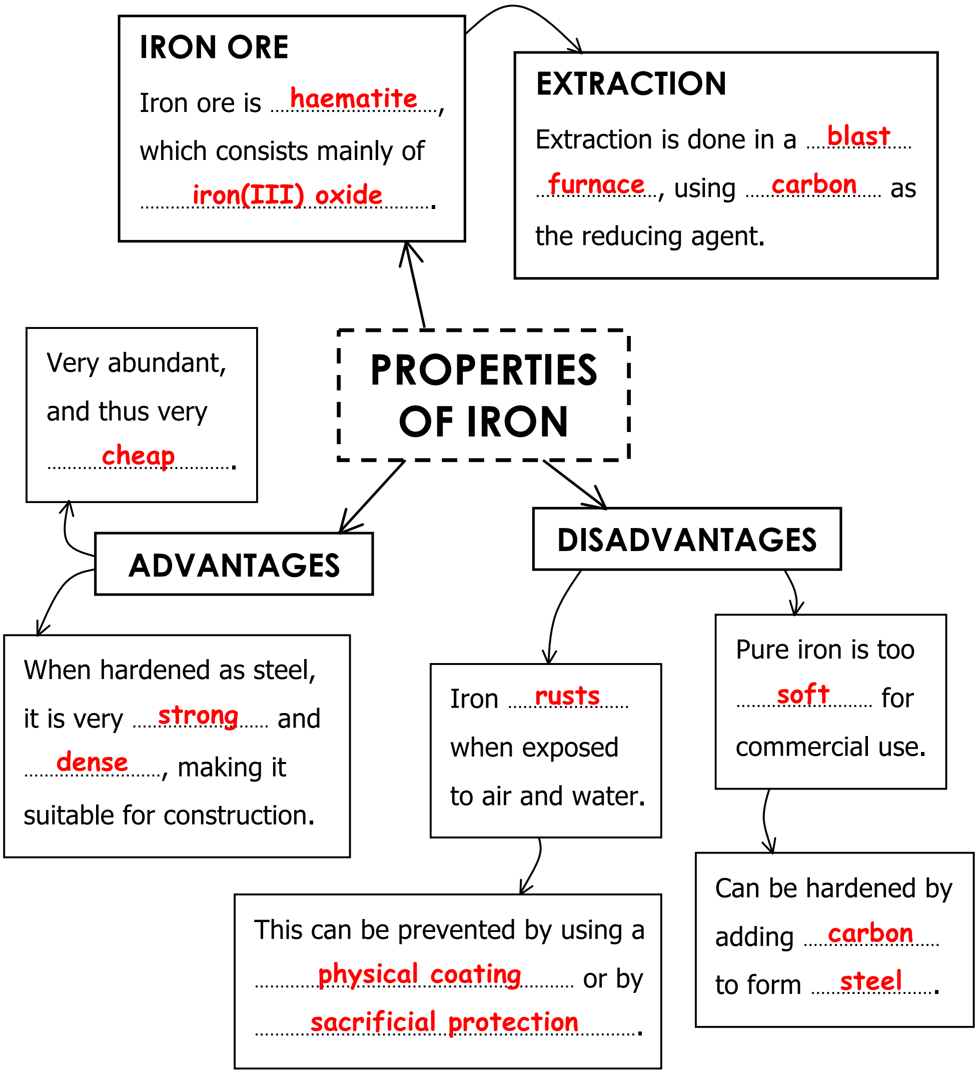
(iii) State how, industrially, **T** should be obtained from its ore.

By electrolysis of the molten ore

10. **Iron: An Overview**

Iron is the most abundant metal in the world. As it also has a high density and high strength, iron is industrially very useful in building construction and the manufacture of many tools and equipment.

The concept map below explores the various properties of iron:



(a) Explain, in terms of its structure, why iron is soft when it is pure.

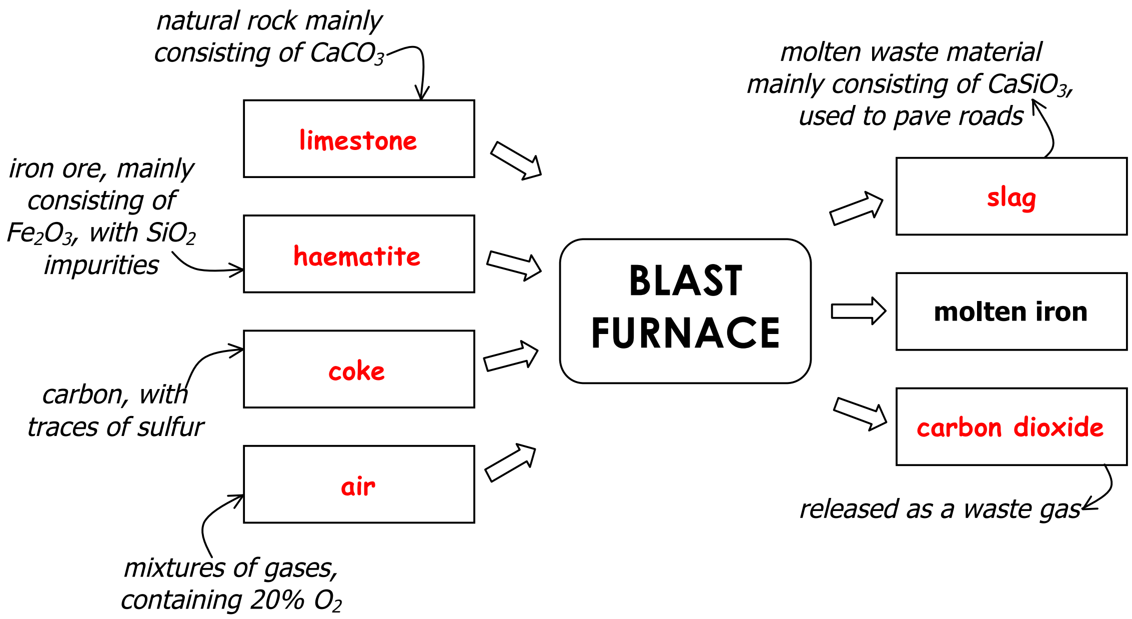
In pure iron, the atoms are arranged in an orderly manner. Hence when a force is applied, layers of iron atoms are able to slide over each other easily.

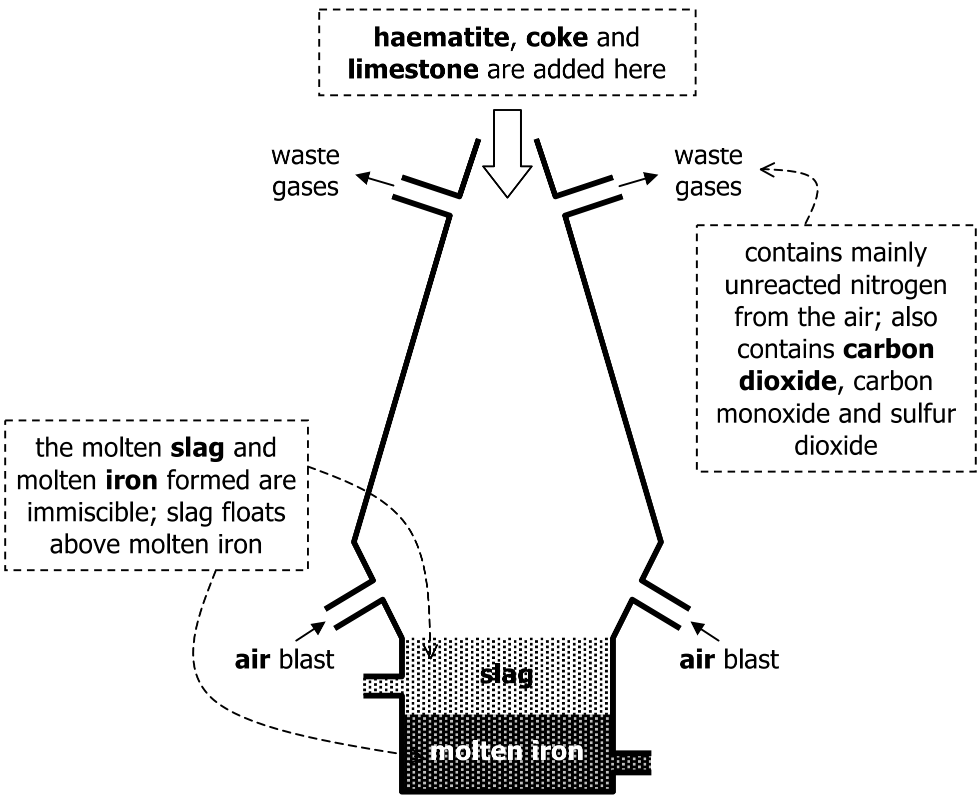
(b) Suggest how the addition of carbon helps to strengthen the iron.

The presence of foreign carbon atoms disrupts the orderly arrangement of iron atoms, hence inhibiting the iron atoms from sliding over each other as easily.

11. **<u>Iron: Extraction in Blast Furnace</u>**

Iron metal is extracted industrially from its ore, **haematite**. This process is carried out in a large chimney-like structure known as a **blast furnace**. The blast furnace is made up of refractory brick in order to withstand high temperatures.





The reactions that occur in the blast furnace can be categorised into three parts – the production of carbon monoxide, the reduction of iron(III) oxide and the removal of the sand impurities.

PRODUCTION OF CARBON MONOXIDE
Coke, which consists of carbon, is allowed to combust in air to form carbon dioxide. This combustion provides the heat which is necessary for the subsequent steps to occur. *Equation:* $C\ (s) + O_2\ (g) \longrightarrow CO_2\ (g)$ The carbon dioxide then reacts with more coke to form carbon monoxide. This reaction can only take place if coke is in excess, causing incomplete combustion to occur. *Equation:* $CO_2\ (s) + C\ (s) \longrightarrow 2\ CO\ (g)$ Due to the sulfur impurities in coke, traces of sulfur dioxide may be produced and released as a waste gas, leading to air pollution.

REDUCTION OF IRON(III) OXIDE
The carbon monoxide produced above reacts with iron(III) oxide in haematite, hence reducing the ore to form molten iron, which settles as a liquid at the bottom of blast furnace *Equation:* $Fe_2O_3\ (s) + 3\ CO\ (g) \longrightarrow 2\ Fe\ (l) + 3\ CO_2\ (g)$ The molten iron formed contains impurities such as carbon and sulfur. However, it is good enough for industrial use and may be tapped off from the blast furnace to manufacture alloys.

REMOVAL OF SAND IMPURITIES
Due to the heat in the blast furnace, limestone ($CaCO_3$) undergoes thermal decomposition to form quicklime (CaO). Carbon dioxide gas is evolved. *Equation:* $CaCO_3\ (s) \longrightarrow CaO\ (s) + CO_2\ (g)$ The quicklime then reacts with acidic impurities such as sand (SiO_2) to form molten calcium silicate, otherwise known as slag. Slag may be used to make roads. *Equation:* $CaO\ (s) + SiO_2\ (s) \longrightarrow CaSiO_3\ (l)$

12. **Review Questions**

(a) Indicate if the following statements describing the blast furnace are **true** or **false**.

The combustion of coke produces carbon dioxide and a lot of heat.	true
Excess air must be present to allow the formation of carbon monoxide.	false
Traces of sulfur dioxide are present in the waste gases.	true
The main component of the waste gases is carbon dioxide.	false
Iron(III) oxide is directly reduced by carbon in the blast furnace.	false
The iron formed in the blast furnace is in the liquid state.	true
The iron formed in the blast furnace is still impure.	true
One mole of iron is produced for every mole of carbon monoxide.	false
Limestone is added to the blast furnace to act as a reducing agent.	false
Limestone is added to the blast furnace to remove basic impurities.	false

(b) The formation of slag can be represented by the chemical equation below:

$$CaO\ (s) + SiO_2\ (s) \longrightarrow CaSiO_3\ (l)$$

(i) Briefly explain why this reaction can be considered to be 'neutralisation'.

It can be considered to be neutralisation because a basic oxide, CaO, and an acidic oxide, SiO_2, to form a salt.

(ii) Has the silicon atom in silicon dioxide been oxidised, reduced or neither? Explain.

Neither. Its oxidation state remains the same: +4 in SiO_2 and +4 in $CaSiO_3$.

(iii) State one way in which the slag produced can be used.

Used to make roads.

(c) At the bottom of the blast furnace, two molten substances are obtained – slag and iron.

(i) Briefly explain why these two substances are easily separated.

The two liquids are immiscible, and hence settle at the bottom of the blast furnace in different layers.

(ii) Which substance will be found at the bottom – slag or iron?

Iron

13. <u>**Iron: Conditions for Rusting**</u>

The term 'rusting' is used to refer to the **corrosion of iron**. Rust, the reddish-brown deposits coating the corroded metal, is hydrated iron(III) oxide. Its striking colour and uneven texture gives the corroded iron a very unsightly appearance.

Rusting may only occur when iron is exposed to ....both oxygen and water........:

$$\mathbf{2\,Fe\,(s) + 3\,O_2\,(g) + 2n\,H_2O\,(l) \rightarrow 2\,Fe_2O_3.nH_2O\,(s)}$$

iron *oxygen* *water* *rust*

Do note that the term 'rusting' may **not** be used to describe the corrosion or oxidation of any other metals – it is used for iron and its alloys only.

(a) One method to prevent an iron object from rusting is by painting it.

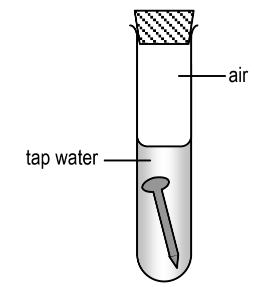
(i) Explain how this method prevents an iron object from rusting.

It prevents the iron object from coming in contact with oxygen and water, which are the conditions necessary for rusting to occur.

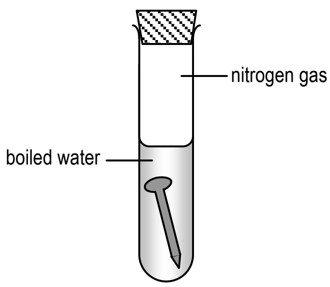
(ii) Suggest other similar ways in which an iron object can be protected against rusting.

Greasing, plastic-coating, tin-plating, gold-plating

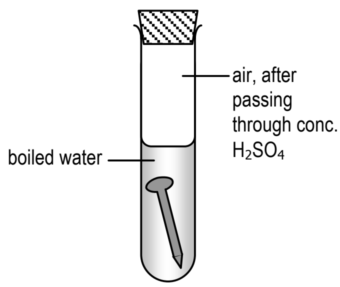
(b) In an experiment, iron nails were placed in various conditions as shown below. For each of the diagrams, indicate whether they "<u>will rust</u>" or "<u>will not rust</u>".



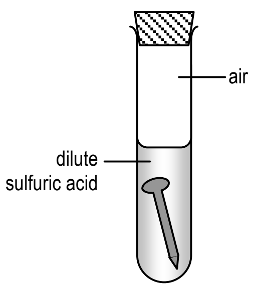
will rust



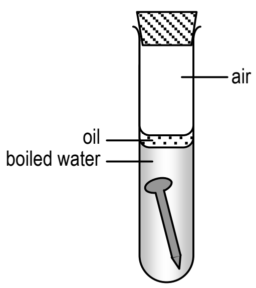
will not rust



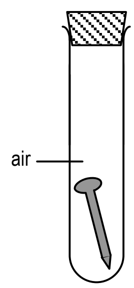
will rust



will rust (quickly)



will not rust



will rust (slowly)

14. **<u>Recycling of Metals</u>**

Besides mining for ores, another way to obtain metals for industrial use is by recycling scrap metal. This has both its advantages and its disadvantages.

Recycling of metals refers to the collecting, sorting and melting down of scrap metal and putting them to new uses.

The **most important reason** why we should recycle metals is because metals are a finite resource, and recycling enables us to conserve this finite resource for future use.

In the table below, discuss the various advantages and disadvantages of recycling, as compared to mining for new metals.

	Advantages of Recycling Metals	**Disadvantages of Recycling Metals**
Resources	Recycling increases the availability of metals, which are a finite resource.	
Costs	Recycling saves costs and time required to mine for new metals.	Recycling requires costs and time to collect/sort scrap metal.
Usage of Fuels & Air Pollution	Extraction of new metals from their ores requires large amounts of fossil fuels, straining the availability of fossil fuels. Extraction of new metals also produces air pollution, due to either intentional or unintentional combustion, e.g. blast furnace.	Recycling involves melting down of scrap metal, using a large amount of fossil fuels, straining the availability of fossil fuels. The melting down of scrap metals during recycling may also cause air pollution due to poisonous gases released.
Land Use	Recycling reduces the land required for disposal of scrap metal by dumping, hence reducing land pollution. Recycling also reduces the land required for mining, increasing availability of land for other uses such as agriculture.	

Self-Designed Summary

Supplementary Questions

1. For each of the following reactions, construct a balanced chemical equation including state symbols. If there is no reaction, write "no reaction".
   (a) potassium + cold water
   (b) sodium + cold water
   (c) calcium + cold water
   (d) magnesium + cold water
   (e) zinc + cold water
   (f) iron + cold water
   (g) lead + cold water
   (h) copper + cold water
   (i) silver + cold water

2. For each of the following reactions, construct a balanced chemical equation including state symbols. If there is no reaction, write "no reaction".
   (a) potassium + steam
   (b) sodium + steam
   (c) calcium + steam
   (d) magnesium + steam
   (e) zinc + steam
   (f) iron + steam
   (g) lead + steam
   (h) copper + steam
   (i) silver + steam

3. For each of the following reactions, construct a balanced chemical equation including state symbols. If there is no reaction, write "no reaction".
   (a) potassium + nitric acid
   (b) sodium + nitric acid
   (c) calcium + nitric acid
   (d) magnesium + nitric acid
   (e) zinc + nitric acid
   (f) iron + nitric acid
   (g) lead + nitric acid
   (h) copper + nitric acid
   (i) silver + nitric acid

4. For each of the following reactions, construct a balanced chemical equation including state symbols. If there is no reaction, write "no reaction".
   (a) potassium + sulfuric acid
   (b) sodium + sulfuric acid
   (c) calcium + sulfuric acid
   (d) magnesium + sulfuric acid
   (e) zinc + sulfuric acid
   (f) iron + sulfuric acid
   (g) lead + sulfuric acid
   (h) copper + sulfuric acid
   (i) silver + sulfuric acid

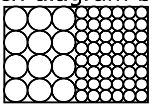
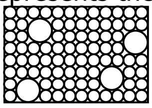
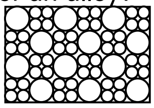
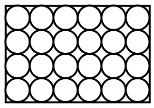
5. Below shows several metals. Use this list to answer the following questions. Each metal may be used once, more than once, or not at all.

Aluminium	**Copper**	**Iron**	**Magnesium**	**Sodium**	**Zinc**

   (a) Which metal reacts quickly with cold water?
   (b) Which metal reacts slowly with cold water, but decomposes with steam at red heat?
   (c) Which metal does not react with steam?
   (d) Name one metal that forms an ion with an oxidation state of +1.
   (e) Name two metals that form coloured ions.
   (f) Name two metals that form amphoteric oxides.
   (g) Which two metals form oxides which can be reduced by carbon?

6. The questions below refer to the extraction of iron in the blast furnace.
   (a) Name the reducing agent that reacts with haematite. Construct a chemical equation, including state symbols, for the reduction of haematite by this reducing agent.
   (b) What is the main impurity in haematite? Describe in detail how this impurity is removed. Write down two chemical equations, including state symbols, for the removal of the impurity.
   (c) What is the chemical formula of slag? State one use of the slag formed.
   (d) Suggest why air, and not pure oxygen, is used in the blast furnace.
   (e) Name two gases, other than nitrogen, present in large proportions in the waste gases.

7. Which diagram below best represents the structure of an alloy?

A  **B**  **C**  **D** 

8. Which of the following metals will not produce hydrogen when added to dilute hydrochloric acid?
A magnesium **B** copper **C** iron **D** calcium

9. Which of the following does not react with cold water but will react with steam?
A sodium **B** copper **C** magnesium **D** calcium

10. A metal water storage tank is ideal for storing cold water but dissolves away rapidly if used to store dilute acid. The tank is made of
A aluminium. **B** copper. **C** lead. **D** zinc.

12. Which of the following elements has a melting point of 98 °C and a density of 0.97 g/dm^3?
A sodium **B** iron **C** zinc **D** calcium

13. An alloy consists of
A a mixture of two or more metals
B a special type of metal
C a compound of two or more metals
D metals joined together chemically

14. Which of the following has the *least* tendency to form positive ions?
A calcium **B** aluminium **C** iron **D** sodium

15. A metal **M** with a proton number 11 reacts with water to form a hydroxide of formula
A $\mathbf{M}OH$ **B** $\mathbf{M}_2(OH)_3$ **C** $\mathbf{M}_2OH$ **D** $\mathbf{M}(OH)_2$

16. Which statement best indicates that lithium is a metal?
A It is a good conductor of electricity.
B It floats on water.
C It burns readily in air.
D It is soft.

17. Information comparing elements **X**, **Y** and **Z** is given in the table below. All three elements are in the same group of the Periodic Table.

Element	*Reaction with dilute acid*	*Formula of chloride*
X	hydrogen forms slowly	$\mathbf{X}Cl_2$
Y	hydrogen forms quickly	$\mathbf{Y}Cl_2$
Z	hydrogen forms very quickly	$\mathbf{Z}Cl_2$

Which statement about the elements could be correct?
A **X** is above **Z** in Group II.
B **Z** is below **X** in Group III.
C **Y** is at the top of Group II.
D **X**, **Y** and **Z** are non-metals.

18. The table shows the results of some reactions of three metals.

Metal	*Reaction with HCl (aq)*	*Reaction with ZnO (s)*
X	slow	violent
Y	slow	none
Z	none	none

Arrange the three metals in decreasing order of reactivity.
A **X, Y, Z** **B** **Y, Z, X** **C** **Y, X, Z** **D** **X, Z, Y**

19. What are the conditions necessary for rusting to occur?
A Only water needs to be present.
B Only oxygen needs to be present.
C Both water and oxygen need to be present.
D Either water or oxygen needs to be present.

Supplementary Questions (Answers)

Question 1

(a) $2\ K\ (s) + 2\ H_2O\ (l) \longrightarrow 2\ KOH\ (aq) + H_2\ (g)$
(b) $2\ Na\ (s) + 2\ H_2O\ (l) \longrightarrow 2\ NaOH\ (aq) + H_2\ (g)$
(c) $Ca\ (s) + 2\ H_2O\ (l) \longrightarrow Ca(OH)_2\ (s) + H_2\ (g)$
(d) $Mg\ (s) + 2\ H_2O\ (l) \longrightarrow Mg(OH)_2\ (s) + H_2\ (g)$
(e) to (i) – no reaction

Question 2

(a) $2\ K\ (s) + H_2O\ (g) \longrightarrow K_2O\ (s) + H_2\ (g)$ [explosive]
(b) $2\ Na\ (s) + H_2O\ (g) \longrightarrow Na_2O\ (s) + H_2\ (g)$ [explosive]
(c) $Ca\ (s) + H_2O\ (g) \longrightarrow CaO\ (s) + H_2\ (g)$ [explosive]
(d) $Mg\ (s) + H_2O\ (g) \longrightarrow MgO\ (s) + H_2\ (g)$
(e) $Zn\ (s) + H_2O\ (g) \longrightarrow ZnO\ (s) + H_2\ (g)$
(f) $Fe\ (s) + H_2O\ (g) \longrightarrow FeO\ (s) + H_2\ (g)$
(g) to (i) – no reaction

Question 3

(a) $2\ K\ (s) + 2\ HNO_3\ (aq) \longrightarrow 2\ KNO_3\ (aq) + H_2\ (g)$ [explosive]
(b) $2\ Na\ (s) + 2\ HNO_3\ (aq) \longrightarrow 2\ NaNO_3\ (aq) + H_2\ (g)$ [explosive]
(c) $Ca\ (s) + 2\ HNO_3\ (aq) \longrightarrow Ca(NO_3)_2\ (aq) + H_2\ (g)$ [explosive]
(d) $Mg\ (s) + 2\ HNO_3\ (aq) \longrightarrow Mg(NO_3)_2\ (aq) + H_2\ (g)$
(e) $Zn\ (s) + 2\ HNO_3\ (aq) \longrightarrow Zn(NO_3)_2\ (aq) + H_2\ (g)$
(f) $Fe\ (s) + 2\ HNO_3\ (aq) \longrightarrow Fe(NO_3)_2\ (aq) + H_2\ (g)$
(g) $Pb\ (s) + 2\ HNO_3\ (aq) \longrightarrow Pb(NO_3)_2\ (aq) + H_2\ (g)$
(h) to (i) – no reaction

Question 4

(a) $2\ K\ (s) + H_2SO_4\ (aq) \longrightarrow K_2SO_4\ (aq) + H_2\ (g)$ [explosive]
(b) $2\ Na\ (s) + H_2SO_4\ (aq) \longrightarrow Na_2SO_4\ (aq) + H_2\ (g)$ [explosive]
(c) $Ca\ (s) + H_2SO_4\ (aq) \longrightarrow CaSO_4\ (s) + H_2\ (g)$ [explosive]
(d) $Mg\ (s) + H_2SO_4\ (aq) \longrightarrow MgSO_4\ (aq) + H_2\ (g)$
(e) $Zn\ (s) + H_2SO_4\ (aq) \longrightarrow ZnSO_4\ (aq) + H_2\ (g)$
(f) $Fe\ (s) + H_2SO_4\ (aq) \longrightarrow FeSO_4\ (aq) + H_2\ (g)$
(g) $Pb\ (s) + H_2SO_4\ (aq) \longrightarrow PbSO_4\ (s) + H_2\ (g)$
(h) to (i) – no reaction

Question 5

(a) sodium
(b) magnesium
(c) copper
(d) sodium (copper)
(e) copper, iron
(f) aluminium, zinc
(g) zinc, iron (copper)

Question 6

(a) carbon monoxide; $Fe_2O_3\ (s) + 3\ CO\ (g) \longrightarrow 2\ Fe\ (l) + 3\ CO_2\ (g)$
(b) silica/silicon dioxide/sand; It is removed by adding limestone to the blast furnace.
First, the limestone decomposes under heat to form quicklime; $CaCO_3\ (s) \longrightarrow CaO\ (s) + CO_2\ (g)$
Next, the quicklime reactions with the silica to form slag; $CaO\ (s) + SiO_2\ (s) \longrightarrow CaSiO_3\ (l)$
The slag settles at the bottom of the blast furnace and is subsequently tapped off.
(c) $CaSiO_3$; Used to make roads.
(d) Pure oxygen will cause an explosive reaction; air is cheaper; excess oxygen will inhibit the formation of carbon monoxide necessary as a reducing agent.
(e) carbon dioxide, carbon monoxide

Multiple-Choice Questions

7 B 8 B 9 C 10 D 11 A 12 A 13 C 14 A

15 A 16 A 17 A 18 C 19 B

Lecture Slides

Metals

Anglo-Chinese School (Barker Road)

CHEMISTRY
Prepared by Alex Lee

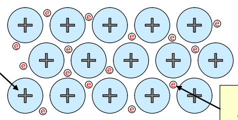
Chapter Overview

In This Chapter, We Will Learn …

1. Structure & Properties of Metals
2. Alloys: Examples, Properties and Uses
3. Reactivity Series of Metals
4. Relating Stability of Salts to the Reactivity Series
5. Extraction of Metals
6. Iron: Extraction in a Blast Furnace
7. Iron: Rusting
8. Recycling of Metals

Metallic Bonding

- A **metallic** atom has a tendency to **lose** electrons, to form a **positively charged ion**.



Metallic atoms with electrons lost, forming positive ions. Arranged in a lattice fashion.

Mobile delocalised electrons. Negative charges hold the positive ions together.

- Hence the structure of a metal is a **lattice of positive ions, in a 'sea' of delocalised electrons**.

Metallic Bonding

This metallic structure gives rise to a few properties:

- **Malleable & ductile texture**
- **High melting & boiling points**
- **Good electrical conductivity**
- **Good heat conductivity**

Atoms arranged in an orderly manner, allowing layers of atoms to slide over each other easily.

Strong electrostatic forces of attraction between positive ions and delocalised electrons, requiring a lot of energy to overcome.

Presence of mobile electrons between positive ions allow charges to flow along the metal.

Presence of mobile electrons allow rapid transfer of thermal energy by free electron diffusion.

Alloys: A Mixture

- An **alloy** is a **mixture of a metal and another element**, *e.g. bronze is a mixture of copper and tin.*
- It is not necessary for the other element to be a metal, *e.g. steel is a mixture of iron and* ***carbon***.
- Since the chemical properties of the constituents remain the same, and that the composition of an alloy may vary, alloys are considered to be mixtures.

Alloys: A Mixture

Some common alloys:

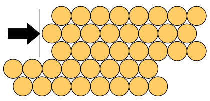
- **Brass** – a mixture of copper and zinc
- **Bronze** – a mixture of copper and tin
- **Nichrome** – a mixture of nickel and chromium
- **Steel** – mixture of iron and carbon
- **Stainless Steel** – mixture of iron, chromium, carbon and nickel

Alloys: A Mixture

- Alloys share many similar properties with pure metals – high melting points, high boiling points, good electrical conductivity, good heat conductivity.
- However, one key difference is that **alloys are less malleable and ductile** than pure metals.
- We can hence describe alloys as being relatively **'brittle'**, i.e. more likely to shatter/break upon impact.

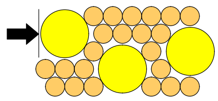
Alloys: A Mixture

Pure Metal



Atoms **can slide** over each other easily due to the **regular arrangement.**

Alloy



Atoms **may not slide** over each other as easily due to **irregular arrangement.**

Alloys: A Mixture

Some advantages of using alloys:

- **Harder, stronger texture** — e.g. Steel, Cast Aluminium
- **More resistant to corrosion** — e.g. Stainless Steel, Nichrome
- **Alter melting and boiling points** — e.g. Solder, Superalloys
- **Aesthetic appeal** — e.g. Bronze, White Gold

Reactivity Series of Metals

- Metals may lose electrons (i.e. get oxidised) to form metal compounds such as salts or bases.
- The ease in which a metal is oxidised / loses electrons is known as the **reactivity** of the metal.
- Different metals have different reactivity!

Reactivity Series of Metals

- You must **memorize** the order of reactivity:

most reactive

Potassium
Sodium
Calcium
Magnesium
Zinc
Iron
Lead
Copper
Silver

least reactive

Generally, Group I metals are the most reactive.

Group II metals are the next most reactive.

Memory Tip:
"Perhaps Someone Could Make Zombies Infiltrate London Carrying Shotguns."

Reactivity Series of Metals

- What you learn is just nine metals – many more exist!

most reactive

Rubidium
Potassium
Sodium
Strontium
Calcium
Magnesium
Aluminium
Zinc
Chromium
Iron
Tin
Lead
Copper
Silver
Gold

least reactive

Reactivity Series of Metals

- We shall study the reactivity series of these nine metals in relation of their oxidation reactions with
  - cold water
  - hot steam
  - dilute hydrochloric acid
  - oxygen

Reactivity Series of Metals

	Cold Water (4)	Hot Steam (6)
Potassium	Reacts to form a **hydroxide** and **hydrogen**. $2 K + 2 H_2O \rightarrow 2 KOH + H_2$ (Magnesium reacts very slowly.)	(However, it is dangerous to conduct this experiment with potassium, sodium or calcium.)
Sodium		
Calcium		
Magnesium		Reacts to form an **oxide** and **hydrogen**. $Zn + H_2O \rightarrow ZnO + H_2$
Zinc	Unable to react.	
Iron		
Lead		Unable to react.
Copper		
Silver		

Reactivity Series of Metals

	Dilute Acid (7)	Heat in Oxygen (8)
Potassium	(However, it is dangerous to conduct this experiment with potassium, sodium or calcium.)	(However, it is dangerous to conduct this experiment with potassium, sodium or calcium.)
Sodium		
Calcium		
Magnesium	Reacts to form a **salt** and **hydrogen**. $Mg + 2 HCl \rightarrow MgCl_2 + H_2$	Reacts to form an **oxide**. $2 Cu + O_2 \rightarrow 2 CuO$
Zinc		
Iron		
Lead	(Lead may require heating.)	
Copper	Unable to react.	
Silver		Unable to react.

Reactivity Series Summary

Oxidation Reactions

	4	6	7	8
	Can react with cold water.	Can react with hot steam.	Can react with dilute acids.	Can react with oxygen (heat).
Potassium	✓	✓	✓	✓
Sodium	✓	✓	✓	✓
Calcium	✓	✓	✓	✓
Magnesium	✓	✓	✓	✓
Zinc		✓	✓	✓
Iron		✓	✓	✓
Lead			✓	✓
Copper				✓
Silver				

Thermal Stability of Metal Compounds

- The thermal stability of a metallic compound can also be determined by the reactivity series.
- The more reactive the metal, the more **stable a compound** it forms. Therefore, it is more difficult / requires more energy to **thermally decompose**.

Thermal Stability of Metal Compounds

- More **reactive metals** form more **stable compounds**.

most reactive element	Potassium	most stable compound
↓	Sodium	↑
	Calcium	
	Magnesium	
	Zinc	
	Iron	
	Lead	
	Copper	
least reactive element	Silver	least stable compound

Thermal Stability of Metal Compounds

- The thermal stability of a salt affects whether it can be prepared by evaporation to dryness.
- **Thermally stable salts**, such as sodium chloride, can be obtained from its solution by **evaporation till dryness**. This is because it is unlikely to be decomposed by heat.
- **Thermally unstable salts**, such as copper(II) sulfate, should be obtained from its solution by **crystallisation**.

Thermal Stability of Metal Compounds

- For example, the thermal stability of metal carbonates.

will not decompose

Potassium Carbonate
Sodium Carbonate

These are the most stable carbonates and hence will not decompose under any circumstance.

difficult to decompose

Calcium Carbonate
Magnesium Carbonate
Zinc Carbonate
Iron(II) Carbonate
Lead(II) Carbonate
Copper(II) Carbonate
Silver Carbonate

easy to decompose

These are the least stable carbonates and hence decompose easily.

Obtaining Metals from Ores

- Many metals do not exist naturally in element form. Instead, they exist as a variety of compounds such as oxides and sulfides.
- Mining helps us obtain **impure samples** of these metal compounds, known are **ores**.
- The ores may be further **purified** to form **minerals**.

Rocks $\xrightarrow{\text{mining}}$ Ores $\xrightarrow{\text{refining}}$ Minerals $\xrightarrow{\text{extraction}}$ Metals

Obtaining Metals from Ores

Some common ores …

Name of Ore	Main Constituent
Haematite	Iron Ore, Fe_2O_3
Sphalerite	Zinc Ore, ZnS
Barite	Barium Ore, $BaSO_4$
Gypsum	Calcium Ore, $CaSO_4$
Galena	Lead Ore, PbS
Bauxite	Aluminium Ore, Al_2O_3

Obtaining Metals from Ores

- The more reactive a metal, the **more stable** an ore / a compound it forms. Thus it is more difficult / requires more energy to **reduce the ore to become a metal**.
- Industrially, there are two main methods used to reduce a metal ore:
  - **electrolysis** of the molten ore
  - **heating with coke** (carbon)

Obtaining Metals from Ores

	Electrolysis	Carbon Reduction
Potassium Sodium Calcium Magnesium	May be extracted by electrolysis of the molten ore. Expensive process which involves passing an electric current through a liquid ore, forcing the positive metal ions to gain an electron. $Na^+ (l) + e^- \longrightarrow Na (l)$	Unable To Be Extracted by Carbon Reduction
Zinc Iron Lead Copper Silver		May be extracted by carbon reduction, i.e. heat with coke. $2\ ZnO + C \longrightarrow 2\ Zn + CO_2$

Obtaining Metals from Ores

- However, **electrolysis is a very expensive process as a large amount of energy is needed**, not only in terms of electricity, but also to keep the ore molten.
- Hence, whenever possible, carbon reduction is the preferred method of extracting a metal from its ore.
- Only reactive metals, such as potassium, sodium, calcium and magnesium, are extracted by electrolysis of its molten ore.

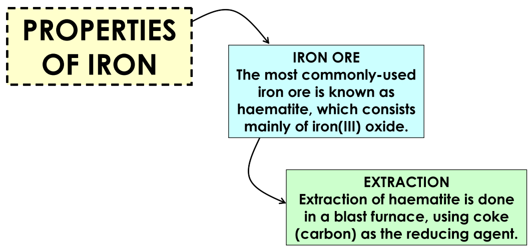
Obtaining Metals from Ores

- Highly **unreactive metals** do not require extraction as they occur naturally as an element already.
- For example, **gold ore** already contains **gold metal** within it. Hence only purification, and not reduction, is necessary to obtain the metal.

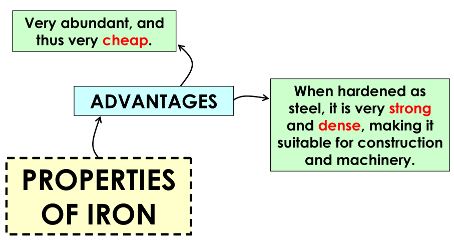
Iron: An Overview

- Iron is the **most commonly used metal** (often in the form of steel) due to its low cost and high strength (compared to other metals).
- Iron is **cheaper** than most other metals because of its abundance and ease of extraction from its ore.
- Iron and steel are hence used to manufacture a wide variety of equipment, and also heavily used in the construction of buildings.

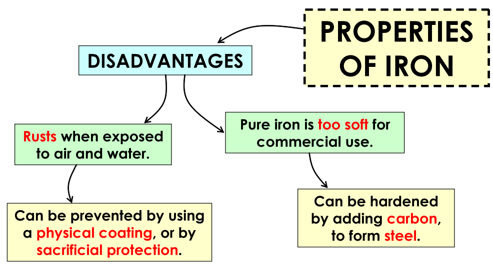
Iron: An Overview



Iron: An Overview

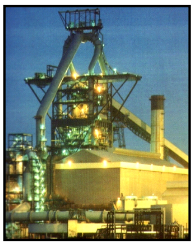


Iron: An Overview



Iron: Blast Furnace Extraction

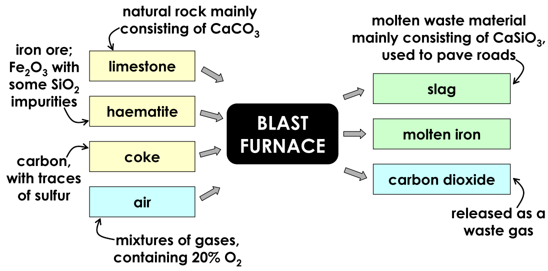
- Iron is extracted from its ore, **haematite**, which largely consists of iron(III) oxide, $\mathbf{Fe_2O_3}$.
- This is done by reduction with carbon monoxide, in a large chimney-like structure known as a **blast furnace**.
- The raw materials are used in the blast furnace are **haematite**, **limestone** and **coke**.



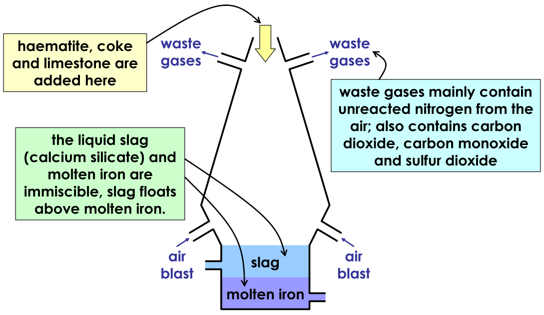
Images: http://www.corusgroup.com/en/responsibility/education/picture_gallery/ironmaking/

Iron: Blast Furnace Extraction

- An overview of the reactants and products:



Iron: Blast Furnace Extraction



Iron: Blast Furnace Extraction

- The reactions that occur in the blast furnace can be categorised into three parts:
  - production of carbon monoxide
  - reduction of iron(III) oxide
  - removal of sand (SiO_2) impurities

Iron: Blast Furnace Extraction

Production of Carbon Monoxide (1)

- **Coke**, which consists of **carbon**, is allowed to **combust in air** form carbon dioxide.

$$\mathbf{C\,(s) + O_2\,(g) \longrightarrow CO_2\,(g)}$$

- This combustion provides the **heat** which is necessary for the subsequent steps to occur.

Iron: Blast Furnace Extraction

Production of Carbon Monoxide (2)

- Carbon dioxide then reacts with **more coke** to form carbon monoxide.
- This reaction can only take place if **coke is in excess**, causing **incomplete combustion** to occur.

$$\mathbf{CO_2\,(g) + C\,(s) \longrightarrow 2\,CO\,(g)}$$

- Due to the sulfur impurities in coke, traces of **sulfur dioxide** may be produced, leading to air pollution.

Iron: Blast Furnace Extraction

Reduction of Iron(III) Oxide

- The **carbon monoxide** produced in the previous stage reacts with **iron(III) oxide in haematite**, hence reducing the ore to form **molten iron**.

$$Fe_2O_3\ (s) + 3\ CO\ (g) \longrightarrow 2\ Fe\ (l) + 3\ CO_2\ (g)$$

- Molten iron settles at the bottom of the blast furnace.
- The iron **still contains impurities** such as carbon and sulfur, but is good enough for industrial use.

Iron: Blast Furnace Extraction

Removal of Sand Impurities (1)

- Due to heat in the blast furnace, limestone (calcium carbonate) undergoes **thermal decomposition**.
- The products are quicklime (calcium oxide) and **carbon dioxide** gas.

$$CaCO_3\ (s) \longrightarrow CaO\ (s) + CO_2\ (g)$$

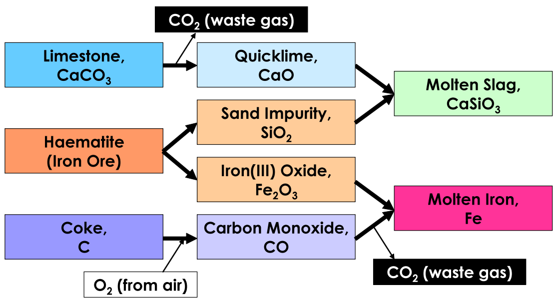
Iron: Blast Furnace Extraction

Removal of Sand Impurities (2)

- The quicklime then **reacts with acidic impurities such as sand** to form **molten calcium silicate ($CaSiO_3$)**, otherwise known as **slag**.
- Slag may be used to **make roads**.

$$CaO\ (s) + SiO_2\ (s) \longrightarrow CaSiO_3\ (l)$$

Iron: Blast Furnace Extraction



Iron: Rusting

- When iron is exposed to **both oxygen and water**, the following reaction takes place:

$$2\ Fe\ (s) + 3\ O_2\ (g) + 2n\ H_2O\ (l) \rightarrow 2\ Fe_2O_3.nH_2O\ (s)$$

Oxygen (either from air or dissolved in water)

Water (includes water vapour in air)

Rust (reddish-brown solid)

- This process is known as **rusting**.
- The iron(III) oxide formed is known as **rust**, and coats the corroded metal. Its striking colour and uneven texture gives a very unsightly appearance.

Iron: Rusting

Rusting Occurs Everywhere …

- An iron object kept indoors, away from water, will still rust after a long period of time, due to **water vapour present in the air**.
- An iron object sunken in the sea, away from air, will still rust due to **dissolved oxygen in the water**.

Iron: Rusting

Rate In Which Rusting Occurs ...

- Affected by the availability of oxygen and water; e.g. an iron object in a humid atmosphere (more water vapour) will rust faster.
- Presence of dissolved salts will also accelerate the rate in which rusting occurs.
- A lower pH (acidic medium) increases the rate of rusting, a higher pH (alkaline medium) slows down the rate of rusting.

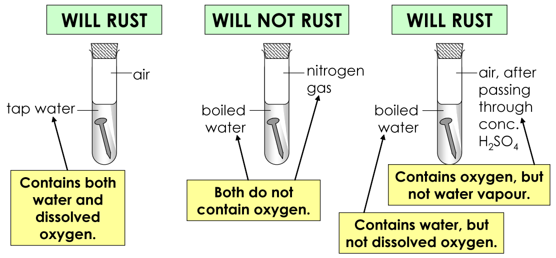
Iron: Rusting

Prevention By Coating ...

- One method to protect an iron or steel object from rusting is by **painting** it.
- This protects the iron by **preventing the object from coming in contact with oxygen and water, which are the conditions necessary for rusting to occur**.
- Other similar methods of rust-prevention include **greasing**, **plastic-coating** and **tin-plating**.

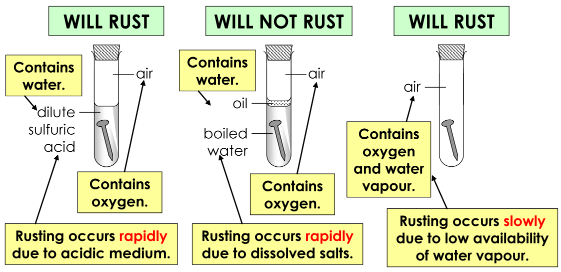
Iron: Rusting

Which of the following nails will rust?



Iron: Rusting

Which of the following nails will rust?



Recycling of Metals

- There are two main ways to obtain metal for use:
  - **mine** for new ores
  - **recycling** existing scrap metal
- We shall examine the advantages and disadvantages of each of the above two methods.

Recycling of Metals

- **Recycling** of metals refers to the **collecting**, **sorting** and **melting down** of scrap metal, and **putting them to new uses**.
- The most important reason why we should recycle metals is because **metals are a finite resource**, and recycling enables us to **conserve this finite resource for future use**.

Recycling of Metals

	Advantages of Recycling Metals	Disadvantages of Recycling Metals
Resources	Recycling increases the availability of metals, which are a finite resource.	
Costs	Recycling saves costs and time required to mine for new metals.	Recycling requires costs and time to collect/sort scrap metal.

Recycling of Metals

	Advantages of Recycling Metals	Disadvantages of Recycling Metals
Usage of Fuels & Air Pollution	Extraction of metals from their ores requires large amounts of fossil fuels, straining the availability of fossil fuels. Extraction of metals causes air pollution, due to combustion, e.g. blast furnace.	Recycling uses a large amount of fossil fuels, straining availability of already-scarce fossil fuels. The melting down of scrap metals during recycling may also cause air pollution due to poisonous gases released.

Recycling of Metals

	Advantages of Recycling Metals	Disadvantages of Recycling Metals
Land Use	Recycling reduces the land required for disposal of scrap metal by dumping, hence reducing land pollution. Recycling also reduces the land required for mining, increasing availability of land for other uses such as agriculture.	