Topic 18 – Metals

Subject content

Content

9.1 Properties of metals
9.2 Reactivity series
9.3 Extraction of metals
9.4 Recycling of metals
9.5 Iron

Learning outcomes:

9.1 Properties of metals

(a) describe the general physical properties of metals as solids having high melting and boiling points, malleable, good conductors of heat and electricity in terms of their structure
(b) describe alloys as a mixture of a metal with another element, e.g. brass; stainless steel
(c) identify representations of metals and alloys from diagrams of structures
(d) explain why alloys have different physical properties to their constituent elements.

9.2 Reactivity series

(a) place in order of reactivity calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to
 (i) the reactions, if any, of the metals with water, steam and dilute hydrochloric acid,
 (ii) the reduction, if any, of their oxides by carbon and/or by hydrogen
(b) describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction with
 (i) the aqueous ions of the other listed metals
 (ii) the oxides of the other listed metals
(c) deduce the order of reactivity from a given set of experimental results
(d) describe the action of heat on the carbonates of the listed metals and relate thermal stability to the reactivity series.

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.

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 issues of recycling metals.

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

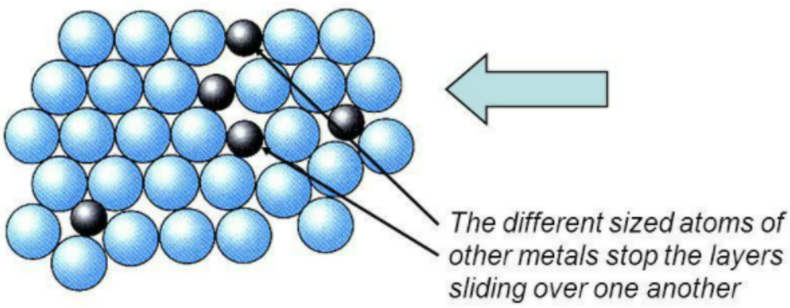
(e) describe the sacrificial protection of iron by a more reactive metal in terms of the reactivity series where the more reactive metal corrodes preferentially, e.g. underwater pipes have a piece of magnesium attached to them.

18.1 Physical Properties of Metals

Alloys: mixture of metal + other elements (metal / non-metal)

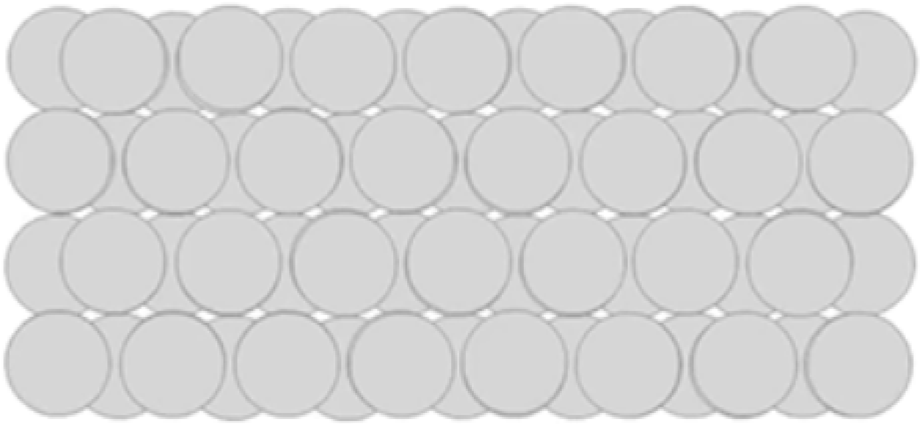
- Harder and stronger
  - Atoms of added elements are of different size
  - DIsrupt regularly arranged layers of metal atoms
  - Layers of metal atoms cannot slide over each other easily when force is applied
- Common alloys:

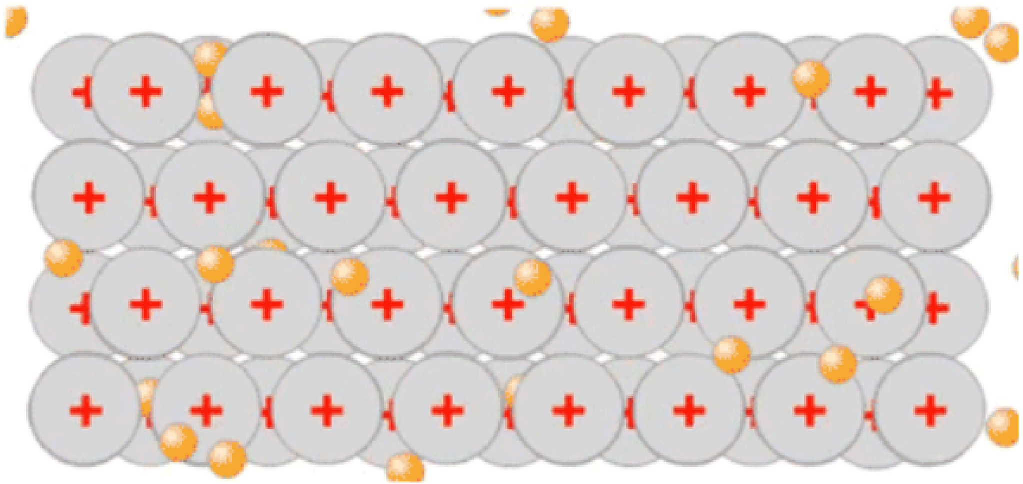
Alloy	Components	Properties	Usages
Low carbon steel	○ iron ○ 0.25% carbon	○ Hard ○ Strong ○ Malleable	car bodies, machinery
High carbon steel	○ iron ○ 0.45% ~ 1.5% carbon	○ Strong ○ Brittle	cutting and boring tools
Stainless steel	○ iron ○ carbon ○ chromium ○ nickel	○ Durable ○ Corrosion resistant	cutlery, surgical instruments, equipment in chemical plants
Brass	○ copper ○ zinc	○ Hard ○ Does not corrode	electric plug



Physical properties of metals:

Property	Explanation	Usages	Exceptions
1. **Good conductor of electricity & heat**	● Delocalised electrons move freely around metallic structure → carry electrical charges through metal ● Delocalised electrons move freely around metallic structure → transfer energy (thermal) quickly	Electrical components Cooking pots and pans	
2. **Malleable + ductile**	● Hammered into thin sheets, bent into shapes without breaking ● Drawn into long thin wire ● Pure: atoms arranged orderly in regular layers → slide over easily when force applied	Car, statue, ornaments Electrical wires	Magnesium, zinc
3. **High melting + boiling points**	● Strong electrostatic attraction between positive metal ions & 'sea of electrons' is strong ● Large amount of energy required to overcome electrostatic attraction → change state		Group I metals, mercury





18.2 Reactivity Series of Metals

Reactivity series

Reactivity: tendency for metal atom to lose valence electrons → cations

The more reactive a metal is, the greater the tendency for it to lose its valence electrons to form cations

Reactivity series:

Most reactive							→							Least reactive
K	**Na**	**Ca**	**Mg**	***Al***	(C)	**Zn**	**Fe**	**Sn**	**Pb**	(H)	**Cu**	**Hg**	**Ag**	**Au**

Chemical properties of metals:

1. Metal + cold water → soluble metal hydroxide (alkali) + hydrogen
   Metal + steam → insoluble metal oxide (base) + hydrogen
2. Metal + dilute acid → salt + hydrogen

Hydrogen (non-metal) included in reactivity series

- Compare position of metals to that of hydrogen → determine whether <u>metal react with dilute acids → salt + hydrogen gas</u>
- Metals above hydrogen are 'more reactive' → displace hydrogen from acid to form hydrogen gas; metals below hydrogen will not
- Reaction of metal + dilute acids to form hydrogen gas is displacement reaction

Reaction with cold water / steam

Metal	Reaction	
	Cold water	Steam
K	React **violently** $2\,K\,(s) + 2\,H_2O\,(l) \rightarrow 2\,KOH\,(aq) + H_2\,(g)$ • a lot of heat given off • hydrogen burns in air	
Na	React **vigorously** $2\,Na\,(s) + 2\,H_2O\,(l) \rightarrow 2\,NaOH\,(aq) + H_2\,(g)$ • hydrogen burns in air	
Ca	React **readily** $Ca\,(s) + 2\,H_2O\,(l) \rightarrow Ca(OH)_2 + H_2\,(g)$ • rapid effervescence of hydrogen	
Mg	React **very slowly** $Mg\,(s) + 2\,H_2O\,(l) \rightarrow Mg(OH)_2\,(s) + H_2\,(g)$	React **violently** $Mg\,(s) + H_2O\,(g) \rightarrow MgO\,(s) + H_2\,(g)$
Zn	**No** observable reaction	React **readily** $Zn\,(s) + H_2O\,(g) \rightarrow ZnO\,(s) + H_2\,(g)$
Fe	**No** observable reaction	React **slowly** $3\,Fe\,(s) + 4\,H_2O\,(g) \rightarrow Fe_3O_4\,(s) + 4\,H_2\,(g)$
Cu	**No** reaction	**No** reaction

Reaction with dilute hydrochloric acid

Reactions:

Metal	Reaction
K	React **explosively** $2\,K\,(s) + 2\,HCl\,(aq) \rightarrow 2\,KCl\,(aq) + H_2\,(g)$
Na	React **explosively** $2\,Na\,(s) + 2\,HCl\,(aq) \rightarrow 2\,NaCl\,(aq) + H_2\,(g)$
Ca	React **violently** $Ca\,(s) + 2\,HCl\,(aq) \rightarrow CaCl_2\,(aq) + H_2\,(g)$ ● rapid effervescence of hydrogen
Mg	React **rapidly** $Mg\,(s) + 2\,HCl\,(aq) \rightarrow MgCl_2\,(aq) + H_2\,(g)$ ● rapid effervescence of hydrogen
Al	React **very slowly** $Al_2O_3\,(s) + 6\,HCl\,(aq) \rightarrow 2\,AlCl_3\,(aq) + 3\,H_2O\,(l)$ ● Al_2O_3 coating on surface of Al (corrosion → protective oxide layer)
Zn	React **moderately fast** $Zn\,(s) + 2\,HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$ ● effervescence of hydrogen
Fe	React **slowly** $Fe\,(s) + 2\,HCl\,(aq) \rightarrow FeCl_2\,(aq)$ [pale green] $+ H_2\,(g)$ ● effervescence of hydrogen
Cu	**No** reaction

Most reactive

<table>
<tr><th>Metal</th><th>Reaction with cold water and steam</th><th>Reaction with dilute hydrochloric acid</th></tr>
<tr><td>Potassium (K)</td><td rowspan="2">react violently with cold water; explode with steam</td><td rowspan="2">explode with dilute hydrochloric acid</td></tr>
<tr><td>Sodium (Na)</td></tr>
<tr><td>Calcium (Ca)</td><td>reacts readily with cold water; explodes with steam</td><td>reacts violently with dilute hydrochloric acid</td></tr>
<tr><td>Magnesium (Mg)</td><td>reacts slowly with cold water; reacts violently with steam</td><td rowspan="2">react readily with dilute hydrochloric acid</td></tr>
<tr><td>Zinc (Zn)</td><td>no reaction with cold water; reacts readily with steam</td></tr>
<tr><td>Iron (Fe)</td><td>no reaction with cold water; reacts slowly with steam</td><td>reacts slowly with dilute hydrochloric acid</td></tr>
<tr><td>Lead (Pb)</td><td>no reaction with cold water and steam</td><td>*reacts very slowly with dilute hydrochloric acid</td></tr>
<tr><td>(Hydrogen) (H)</td><td></td><td></td></tr>
<tr><td>Copper (Cu)</td><td rowspan="2">no reaction with cold water and steam</td><td rowspan="2">no reaction with dilute hydrochloric acid</td></tr>
<tr><td>Silver (Ag)</td></tr>
</table>

Least reactive

*Note: The reaction between lead and hydrochloric acid forms lead(II) chloride, which is an insoluble salt. Once formed, this salt coats the surface of the lead and prevents further reaction between the lead and the dilute hydrochloric acid. Hence, in addition to being slow, the reaction is also hardly visible.

Displacement reactions

<table>
<tr><th>Aqueous solution</th><th>Metal oxides</th></tr>
<tr><td>A more reactive metal displaces a less reactive metal from its salt solution</td><td>A more reactive metal removes oxygen from the metal oxide of a less reactive metal</td></tr>
<tr><td>Colours
<table>
<tr><th>Grp I, II, III metals</th><th>Transition metals</th></tr>
<tr><td>metals: grey / silver
metal compounds: white solids
solutions: colourless</td><td>most metals: grey / silver
copper: reddish-brown / pink (raw copper)
form coloured compounds
Fe^{2+}: green / pale green
Cu^{2+}: blue (ex. $CuCl_2$ dark green, CuO black solid / powder)
Fe^{3+}: reddish brown / brown / orange / yellow (depend on conc of solution)</td></tr>
</table></td><td>Thermit reaction
Equation:
$Al\ (s) + Fe_2O_3\ (s)$
$\rightarrow Al_2O_3\ (s) + Fe\ (l)$
$Al > Fe \rightarrow$ remove oxygen from Fe_2O_3
Highly exothermic → iron in liquid (molten) state
<u>Redox</u> reaction
Oxidation: Al is oxidised (gain oxygen to form Al_2O_3)
Reduction: Fe_2O_3 is reduced
(lose oxygen to form Fe)</td></tr>
</table>

<u>Reduction of metal oxides</u>

Reducing agents: <u>more reactive</u> than metals in metal oxide to reduce it

Metal oxide	Reducing agent	
	hydrogen	carbon
K	not reduced	not reduced
Na		
Ca		
Mg		
Al		
(carbon)		
Zn	not reduced	$ZnO + C \rightarrow Zn + CO$ $2\ ZnO + C \rightarrow Zn + CO_2$
Fe(III)	$Fe_2O_3 + 3\ H_2 \rightarrow 2\ Fe + 3\ H_2O$	$Fe_2O_3 + 3\ C \rightarrow 2\ Fe + 3\ CO$ $2\ Fe_2O_3 + 3\ C \rightarrow 4\ Fe + 3\ CO_2$
Pb(II)	$PbO + H_2 \rightarrow Pb + H_2O$	$PbO + C \rightarrow Pb + CO$ $2\ PbO + C \rightarrow 2\ Pb + CO_2$
(hydrogen)		

Cu(II)	$CuO + H_2 \rightarrow Cu + H_2O$	$CuO + C \rightarrow Cu + CO$ $2\ CuO + C \rightarrow 2\ Pb + CO_2$
Ag	$Ag_2O + H_2 \rightarrow 2\ Ag + H_2O$	$Ag_2O + C \rightarrow 2\ Ag + CO$ $2\ Ag_2O + C \rightarrow 4\ Ag + CO_2$

Displacement: more reactive metal displaces less reactive metal from its compound
- Reaction of the more reactive metal with:
  - aqueous ions of other metals → formation of solid deposits on metal's surface + change in the colour of the solution
  - oxides of other metals → energy released (heat and/or light)
- The more reactive the metal is, the more readily it forms compounds
  Less reactive metal has higher tendency to stay uncombined & more readily displaced from its compounds

Thermal stability of metal carbonates

The more reactive the metal,
the more thermally stable the carbonate is,
the harder it is for carbonate to decompose (take more time)

Metal carbonate	Observation
K	Stable to heat, do not decompose easily
Na	
Ca	Decompose → metal oxide + carbon dioxide
Mg	
Al	
Zn	
Fe(II)	
Pb(II)	
Ag	Decompose → silver + oxygen + carbon dioxide

18.3 Extraction of Metals

Ore: compound of metal + impurities
Extraction: decompose ore to give metal

Examples of ores

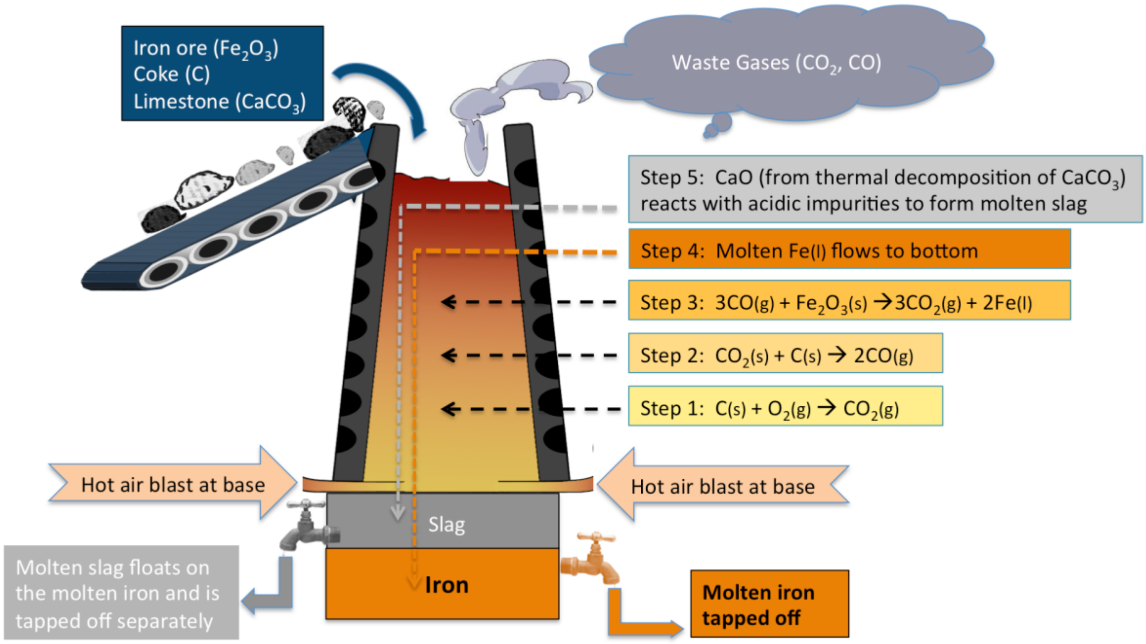
Ore	Metal extracted
haematite	iron
chalcocite	copper
cassiterite	tin
sphalerite	zinc

Extraction:

<table>
<tr><th>Metal</th><th>Extraction</th><th>Explanation</th></tr>
<tr><td>K</td><td rowspan="5">Electrolysis of molten compound</td><td rowspan="5">more reactive metals form stable compounds (strong ionic bonds)
pass electricity through molten compound to break it down into metal</td></tr>
<tr><td>Na</td></tr>
<tr><td>Ca</td></tr>
<tr><td>Mg</td></tr>
<tr><td>Al</td></tr>
<tr><td>Zn</td><td rowspan="4">Reduction of metal oxides to metal by reducing agent (C, CO, H_2)</td><td rowspan="4">found as oxides / sulfides
heat sulfides in air → oxides
heat oxides + reducing agent
carbon → all metals
hydrogen → only iron and below</td></tr>
<tr><td>Fe</td></tr>
<tr><td>Pb</td></tr>
<tr><td>Cu</td></tr>
<tr><td>Ag</td><td rowspan="2"></td><td rowspan="2">exist as element</td></tr>
<tr><td>Au</td></tr>
</table>

18.4 Iron

Extraction of iron in blast furnace



Extraction of iron:

- **Haematite**: main ore from which iron is extracted (contains mainly iron(III) oxide)
- Substances involved

Raw materials added	Waste gases
1. coke (C) 2. limestone ($CaCO_3$) 3. air	1. carbon monoxide (CO) 2. carbon dioxide (CO_2) 3. nitrogen (N_2)

- Extraction process

Step	Equation
1. Haematite + raw materials added, hot air enter blast from bottom	
2. Hot air reacts with coke when rising to the top	$C (s) + O_2 (g) \rightarrow CO_2 (g)$
3. Carbon dioxide formed reacts with coke to form carbon monoxide (reducing agent)	$CO_2 (g) + C (s) \rightarrow 2 CO (g)$
4. Limestone decomposes to form calcium oxide and carbon dioxide	$CaCO_3 (s) \rightarrow CaO (s) + CO_2 (g)$
5. Iron ore reduced to molten iron by carbon monoxide, flow down furnace	$Fe_2O_3 (s) + 3 CO (g) \rightarrow 2 Fe (l) + 3 CO_2 (g)$
6. Acidic impurities in haematite (mainly silicon dioxide) reacts with calcium oxide to form slag → removed	$CaO (s) + SiO_2 (s) \rightarrow CaSiO_3 (l)$

- **Pig iron**: high percentage of carbon
  - hard + brittle
  - not strong enough for everyday purposes
  - very difficult to shape (not malleable)
  - corrode / rust easily

Corrosion

Corrosion: destruction of metal due to reaction with air, water, chemicals
Metals in presence of **oxygen** **AND** **air**: react and change → metal ions (dissolve into solution) → metal gradually disappear

Rusting: corrosion of **iron**

- Conditions that speed up rusting:
  1. dissolved ionic particles
     1) carbon dioxide in water
     2) sulfur dioxide in water
     3) droplets of dissolved sodium chloride in air
  2. Iron / steel in contact with less reactive metal
- Formation of rust
  - Fe loses electrons to water + oxygen → Fe^{2+}
  - Fe^{2+} ions oxidised by oxygen → $Fe_2O_3 \cdot 5\,H_2O$ (hydrated)

$$4\,Fe\,(s) + 3\,O_2\,(g) + 2x\,H_2O\,(l) \rightarrow 2\,Fe_2O_3 \cdot x\,H_2O\,(s)$$

Prevention of rusting: (SUGGEST + EXPLAIN)

Prevention	Method	Application	Note
1. **Coat with layer of substance**	Painting	Large objects (cars, door frames)	● Physical protective barrier → iron not exposed to oxygen + water ● If paint is scratched, rusting occurs under painted surface
	Oiling / greasing	Tools, machine parts	● Protective film gathers dust → frequent re-application of oil / grease
2. **Electro-plating**	Tin-plating	Food cans	● If tin is scratched, iron underneath rusts ● Broken tin-plated iron surface rust faster than pure iron (iron more reactive, loses electrons in preference to tin)
	Chrome-plating	Taps, handlebars	● Provide bright shiny finish
	Silver/gold-plating	Jewellry	● Provide bright shiny finish
3. **Sacrificial protection**	Zinc-plating (galvanising)	Roof, kitchen sink, dustbins	● If surface is broken, zinc gives electrons more readily (more reactive), corrode in place of iron → protect iron from rusting
	Attaching metal blocks (Zn, Mg)	Underground pipes, ship hull, legs of steel piers	● Zn, Mg corrode in place of iron (more reactive)
4. **Stainless steel**		Cutlery, surgical instruments	● Corrosion resistant

18.5 Recycling Metals

Advantage	Disadvantage
1. Conserve natural resources ● save limited amount of non-renewable metal ores 2. Environmental issues ● reduce environmental problems caused by metal extraction ● prevent dumping of rusty metals ● prevent abandoned metal from being slowly corroded by air + rain → leech into soil & river water (water pollution) 3. Cheaper costs ● require less energy than extracting new metal from ores	1. Pollution ● smelting process: produce harmful metal fumes (air pollution) ● recycle lead from car batteries → release harmful gases (air pollution) 2. Social issues ● invest effort + time in education 3. High costs ● collecting ● sorting ● separating ● cleaning ● transporting

Typical questions

Multiple choice questions

1 Which metal is least likely to form positive cations?

A Aluminium
B Zinc
C Copper
D Sodium

2 Steel is used to make

A bridges
B drink cans
C carrier bags
D bodies of aircraft

3 Which metal can be used to displace Cr in Cr2O3?

A Magnesium
B Nickel
C Copper
D Gold

4 Which of the reactions does not produce any gas?

A Addition of gold metal to acid
B Addition of sodium metal to water
C Reaction of metal carbonate with acid
D Electrolysis of molten sodium chloride

5 An aqueous solution contains both calcium sulfate and copper(II) sulfate. When a strip of tin is added into it, which of the elements will be displaced?

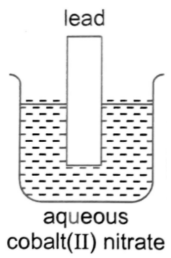
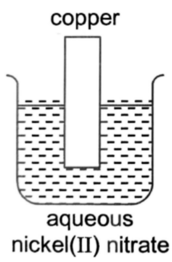
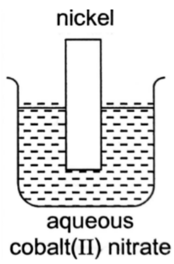
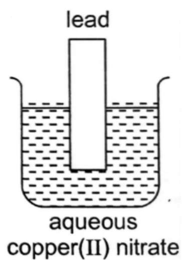
A Copper
B Calcium
C Hydrogen
D Oxygen

6 Which metal is most suitable for the sacrificial protection of iron?

A Copper
B Lead
C Magnesium
D Tin

Structured questions

1 A student carried out a series of experiments to determine the order of reactivity of four metals.

Experiment		1	2	3	4
Figure					
Colour of metal	start	grey	reddish-brown	silver	grey
	end	grey	reddish-brown	silver-grey	reddish-brown
Colour of solution	start	red	green	red	blue
	end	red	green	green	colourless

From the above results, answer the following questions:

(a) Arrange the metals in decreasing reactivity.

nickel → cobalt → lead → copper

(b) Describe what is observed when a piece of cobalt is placed in a solution of copper(II) nitrate solution.

Equation: $Co\ (s) + Cu\ (NO_3)_2\ (aq) \rightarrow Co(NO_3)_2\ (aq) + Cu\ (s)$

Blue solution turns red.

Reddish-brown solid is formed on silver-grey metal.

2 A series of experiments were carried out to determine the relationship between the position of the metal in the reactivity series and the stability of its carbonates. The procedure for the experiment is as follows:

1) Place the 0.5 g of the metal carbonate in a test tube.
2) Heat the metal carbonate strongly and start the stopwatch.
3) Bubble the gas produced through 5 cm^3 of limewater.
4) When a white precipitate forms in limewater, stop the stopwatch and record the time taken for the precipitate to form.

The results and observations were recorded in the table below:

Metal carbonate	Observation	
	Colour change of solid	Time taken for precipitate to form / s
copper(II) carbonate	green solid turns black	45
calcium carbonate	white solid remains white	127
magnesium carbonate	white solid remains white	96
sodium carbonate	white solid remains white	no precipitate formed
zinc carbonate	white solid turns yellow yellow solid turns white when cool	62

Based on the above results, answer the following questions:

(a) List the order of the ease of decomposition of the four carbonates, from the carbonate that takes the shortest time to decompose to the one that takes the longest time.

copper(II) carbonate → zinc carbonate → magnesium carbonate → calcium carbonate → sodium carbonate

(b) What is the relationship between the position of the metal in the reactivity series and the ease of decomposition of its metal carbonate?

The more reactive the metal,
the more thermally stable its metal carbonate,
the harder it is for the carbonate to decompose.

3 What is the purpose of adding calcium carbonate to the blast furnace during the extraction of iron?

To produce CaO, a basic oxide used to neutralise and thus remove acidic impurities, mainly SiO_2 from the molten iron produced.

4 The iron produced (known as pig iron) in the blast furnace contains a high percentage of carbon (3% ~ 4%). Where does this carbon come from?

As molten iron flows down the furnace, some carbon from coke will be mixed into molten iron.

5 Explain the following.

(a) Duralumin is used to make the bodies of aircraft and train coaches instead of pure aluminium.

The bodies of aircrafts and trains have to be light and strong. Aluminium is light but it is not strong enough. Duralumin is an alloy of aluminium and copper. By adding copper to aluminium, the metal becomes stronger, harder and has low density.

(b) Ornamental wrought gates are made from pure iron instead of steel.

Pure iron is soft. It is malleable and ductile. It can be easily moulded into various patterns, designs and shapes. Steel is an alloy of iron and carbon. Steel is hard, making it difficult to mould.

(c) Cutlery and utensils are made from stainless steel instead of pure iron.

Cutlery and utensils must be hard, strong and resistant to corrosion. Pure iron is soft and corrodes easily. Stainless steel is an alloy of iron, chromium and nickel. It is hard, strong and does not rust easily.

(d) Solder is used to join electrical wires instead of tin or lead.

Solder is an alloy of tin and lead. Adding impurities, in this case another metal, to a pure metal, lowers the melting point of the metal. Solder has low melting point and it solidifies quickly, making it a good metal to join electrical wires.

6 Answer the following questions regarding rusting and recycled metals.

(a) What are the necessary conditions required for iron to rust?

Air and water are needed for iron to rust.

(b) State three different methods of rust prevention. Explain how each method works.

Three methods of rust prevention are painting the iron, plating it with corrosion resistant metals and sacrificial protection. Painting the iron ensures that the surface is not exposed to air and moisture. Plating it with corrosion resistant metals prevents air and water from reaching the surface of the easily corroded metals. Sacrificial protection involved sacrificing a more reactive metal in place of the metal.

(c) Give two reasons why metals need to be recycled. State two problems faced when recycling metals.

Two reasons for recycling metals are to conserve the limited resources of minerals on Earth and to reduce the cost of extracting new metals from their ores.
Two problems faced when recycling are the high cost of recycling and the pollution that might happen if it is not done carefully.

(d) Aluminium and steel are the most commonly recycled metals in the world. Explain.

Recycling aluminium and steel is more economical than extracting them from their ores as it saves cost and energy. By recycling these metals, 95% of the production cost is saved. Steel is the most widely used metal, hence, it forms a large portion of the metals recycled.

7 Apart from colour changes, state two other observations that would indicate that a displacement reaction between metals has taken place.

- A precipitate is formed on the surface of the metal added.
- The reaction mixture becomes warmer (due to increase in temperature during reaction).
- The metal added becomes smaller in size. (metal strip)
- Metal powder reacts and “dissolves” to form a solution.

8 What will happen if the paint on a galvanised car body is scratched off? Explain your answer.

The car body does not rust.
Since zinc is more reactive than iron, zinc corrodes preferentially in place of iron.

9 The table below gives the densities and melting points of substances used in the blast furnace, at normal atmospheric pressure.

Substance	Density / g/cm^3	Melting point / °C
calcium carbonate	2.71	decomposes at 850°C
calcium oxide	3.35	2600
calcium silicate	2.50	1530
carbon	2.25	4000
iron	7.80	1539
iron(III) oxide	5.24	1566
magnesium oxide	3.58	2900

Some elements, including those used in the blast furnace, are shown below in decreasing order of reactivity.

$$Ca > Mg > Fe > C > H > Ti$$

(a) Name the substances that are fed into the furnace at A.

carbon, calcium carbonate, iron(III) oxide

(b) This reaction takes place at the base of the furnace:

$$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$$

How is the carbon dioxide formed immediately reduced to carbon monoxide?

Carbon dioxide formed is reduced by excess carbon to form carbon monoxide.

(c) Why is the temperature of the slag coming out of B much lower than 1530°C?

It contains impurities that lower its melting point.

(d) Why is it useful for slag to float on top of the molten iron?

Slag protects the molten iron from oxidation by the hot air.

(e) The furnace is lined with magnesium oxide bricks. Suggest one physical property and one chemical property of magnesium oxide that makes it a suitable material.

Physical property	High melting point. It acts as a refractory substance to withstand high temperatures.
Chemical property	It does not react with any of the substances in the furnace.

(f) Why might the furnace explode if damp substances were added at A?

Iron and carbon reduce water to hydrogen. Hydrogen gas and air from an explosive mixture.

$Fe + H_2O \rightarrow H_2 + FeO$

$C + H_2O \rightarrow H_2 + CO$ **OR** CO_2

10 Steel is an alloy of iron with carbon and/or other metals. It is made from cast iron extracted from the blast furnace. Steel has many uses and properties.

(a) Carbon steel is a main category of steel. There are two types of carbon steel – high-carbon steel and mild steel. State how the compositions of high-carbon steel and mild steel account for their properties and uses.

High-carbon steel	Contains a higher percentage composition of carbon, making it strong but brittle. It is used to manufacture cutting and boring tools.
Mild steel	Has low carbon content, so it is relatively soft and malleable. It is used to make car bodies and machinery.

(b) Recycling metals helps to conserve natural resources and has many advantages. Discuss some problems faced in metal recycling.

- Recycling metals can be extremely costly. It is more expensive than extracting metal from metal ore on earth.
- Recycling metals pollutes the environment. Air pollutants are produced when recycling lead-acid batteries.
- It takes time and effort to educate communities to adopt recycling as a lifestyle, making it not immediately effective.