EXTRACTION OF METALS

Occurrence
- ores of some metals are very common (iron, aluminium)
- others occur only in limited quantities in selected areas
- ores need to be purified before being reduced to the metal - this adds to the expense
- high grade ores are therefore cheaper to process.

Theory The method used depends on the . . .
- purity required
- energy requirements
- cost of the reducing agent
- position of the metal in the reactivity series

Reactivity Series

K Na Ca Mg Al **C** *Zn Fe* **H** *Cu Ag*

- Lists metals in descending reactivity
- Hydrogen and carbon are often added
- The more reactive a metal the less likely it will be found in its pure, or native state.
- Consequently it will be harder to convert it back to the metal.

Methods

General	Low in series	occur native or extracted by roasting an ore	e.g. Cu, Ag
	Middle of series	metals below carbon are extracted by reduction of the oxide with carbon or carbon monoxide	e.g. Zn, Fe
	High in series	reactive metals are extracted using electrolysis - an expensive method due to energy costs	e.g. Na, Al

Variations can occur due to special properties of the metal.

Specific
- reduction of metal oxides with carbon — IRON
- reduction of metal halides with a metal — TITANIUM
- reduction of metal oxides by electrolysis — ALUMINIUM
- reduction of metal oxides with a metal — CHROMIUM

Metal	*Ore(s)*	*O.N. in ore*	*Use / importance*	*Method*	*Process*
Aluminium					
Copper					
Sodium					
Tungsten					
Zinc					

EXTRACTION OF IRON

Process

- high temperature
- continuous
- reduction of iron ores by carbon / carbon monoxide in the Blast Furnace
- possible because iron is below carbon in the reactivity series

Raw materials

iron ore	Fe_2O_3 - *haematite*
coke	fuel / reducing agent - *cheap and plentiful*
air	for combustion of fuel
limestone	for conversion of silica into slag (calcium silicate) which is used in the construction industry

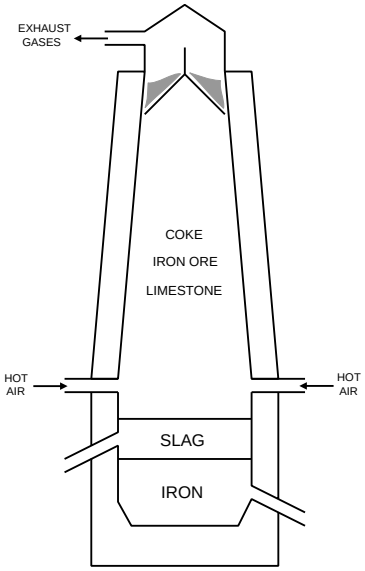
Reactions

$$\mathbf{C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}}$$

$$\mathbf{C_{(s)} + CO_{2(g)} \longrightarrow 2CO_{(g)}}$$

$$\mathbf{Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2}$$

or $\mathbf{Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO}$



Slag production

- silica is found with the iron ore
- it is removed by reacting it with limestone
- calcium silicate (SLAG) is produced
- molten slag is run off and cooled
- it is used for building materials

limestone decomposes on heating $\mathbf{CaCO_3 \longrightarrow CaO + CO_2}$

calcium oxide combines with silica $\mathbf{CaO + SiO_2 \longrightarrow CaSiO_3}$

overall $\mathbf{CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2}$

Pollution

- SO_2 from sulphur in the fuel and sulphides in the ore gives rise to acid rain

$$\mathbf{S + O_2 \longrightarrow SO_2}$$

$\mathbf{SO_2 + H_2O \longrightarrow H_2SO_3}$ *sulphurous acid*

- CO_2 burning fossil fuels increases the amount of this greenhouse gas

Limitations Theoretically, several other important metals can be extracted this way but are not because they **combine with the carbon to form a carbide**

e.g. Molybdenum, Titanium, Vanadium, Tungsten

Usefulness Iron produced from the Blast Furnace contains a lot of carbon which makes it brittle. To make it more useful, most iron is made into steel.

STEEL MAKING

Process In the **Basic Oxygen Process**, excess carbon is burnt off in a converter and the correct amount of carbon added to make steel. Other metals (e.g. chromium) can be added to make specialist steels.

Removal of impurities

SILICA	*add calcium oxide*	**$CaO + SiO_2 \longrightarrow CaSiO_3$**
CARBON	*burnt off using oxygen*	**$C + O_2 \longrightarrow CO_2$**
PHOSPHORUS	*burnt off using oxygen*	**$2P + 5O_2 \longrightarrow P_4O_{10}$**
SULPHUR	*magnesium is added*	**$Mg + S \longrightarrow MgS$**

Q.1 *Give a use and reason for using the following metals in specialist steels.*

a) chromium

b) manganese

c) cobalt

What is pig iron ? How did it get its name ?

Titanium

- ores **e.g. titanium(IV) oxide TiO_2**, are relatively common yet it is not used extensively
- extraction is difficult using conventional methods and is ultimately very expensive
- the oxide can be reduced by carbon but the titanium reacts to give titanium carbide
- the oxide is converted to the chloride which is then reduced with sodium.

$$TiO_{2(s)} + 2C_{(s)} + 2Cl_{2(g)} \longrightarrow TiCl_{4(l)} + 2CO_{(g)}$$

$$TiCl_{4(l)} + 4Na_{(s)} \longrightarrow Ti_{(s)} + 4NaCl_{(s)}$$

The reduction of $TiCl_4$ is carried out in an **atmosphere of argon** because the titanium **reacts with oxygen** at high temperatures.

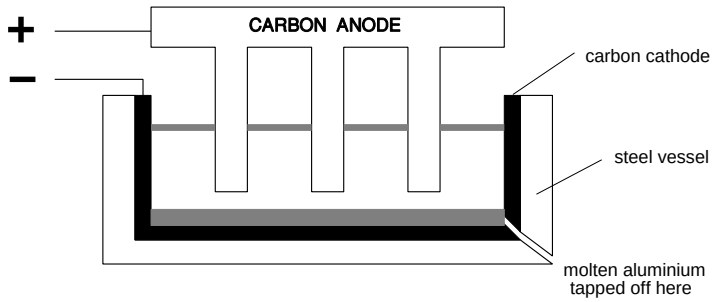
Q.2 *Give some uses of titanium and state why it must be very pure*

a) uses

b) reason for high purity

Aluminium Electrolysis of alumina (impure in bauxite) ... aluminium is above carbon in the series.

- Cryolite (Na_3AlF_6) is mixed with the alumina to lower the (very high) melting point.
- Consumes vast amounts of electricity so H.E.P. is needed *(e.g. Scottish Highlands)*
- Aluminium is discharged at the **cathode** $Al^{3+} + 3e^- \longrightarrow Al$
  Oxygen is discharged at the **anode** $O^{2-} \longrightarrow \frac{1}{2}O_2 + 2e^-$



Q.3 *Why do the carbon anodes need to be replaced at regular intervals ?*

Q.4 *State the difference between, and the advantages/disadvantages of,*

- *batch processes*

- *continuous processes*

Q.5 *List other factors taken into consideration when metals are extracted*

RECYCLING

Problems

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-
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Social benefits

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-
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Economic benefits

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