SACE Stage 1 Chemistry 2015

Topic Test: Metals and Metal Extraction

NAME: Suggested solutions Mark: /58

1. Define 4 properties to classify mineral.

1. Naturally occuring
2. Inorganic
3. Have a definite chemical composition
4. Solid with a crystalline structure

(4 marks-A2)

2. Name one common example of a mineral and the metal that can be extracted from its ore.

Iron oxide (mineral) Iron (metal)
Bauxite (mineral) Aluminium (metal)

(1 mark-AE1)

3. Complete the following table of common metals in our everyday life, an example of where they are used and a property which makes them useful. (3 marks-AE1)

Metal	Use	Property
Aluminium	Packaging, cookware	light, corrosion resistant
Iron	Buildings, stainless steel	strong, cheap
copper	electrical wires	Good conductor of electricity
Nickel	coins	corrosion resistant

4. Alloys are often used instead of a pure metal. Explain why this is, with the aid of a diagram.

Alloys are a mixture of metals or another element ✓
Pure metal is soft as layers can slide over each other ✓
Alloy makes a metal stronger/harder than a pure metal as it stops layers sliding over each other ✓

Pure metal

Alloy

(3 marks-AE1)

Use the metal reactivity series below to answer the following questions.
Carbon and hydrogen have been added for comparison.

Most reactive	**Potassium**	K
↓	**Sodium**	Na
	Calcium	Ca
	Magnesium	Mg
	Aluminium	Al
	Carbon	C
	Zinc	Zn
	Iron	Fe
	Nickel	Ni
	Tin	Sn
	Lead	Pb
	Hydrogen	H
	Copper	Cu
	Silver	Ag
Least reactive	**Gold**	Au

5. Two iron nails were placed into a solution of magnesium chloride and silver nitrate respectively. Use the metal reactivity series and *balanced, relevant equations where applicable* to explain any reaction that took place.

- Iron nail in magnesium chloride:

$Fe + MgCl \rightarrow$ no reaction

As iron is less reactive than magnesium, Fe will not displace Mg ∴ no reaction

- Iron nail in silver nitrate:

Iron is more reactive than silver, Fe will displace Ag ions from solution

$Fe + 2AgNO_3 \rightarrow Fe(NO_3)_2 + 2Ag$

(4 Marks-A2)

6. State how metals low on the reactivity series are found.

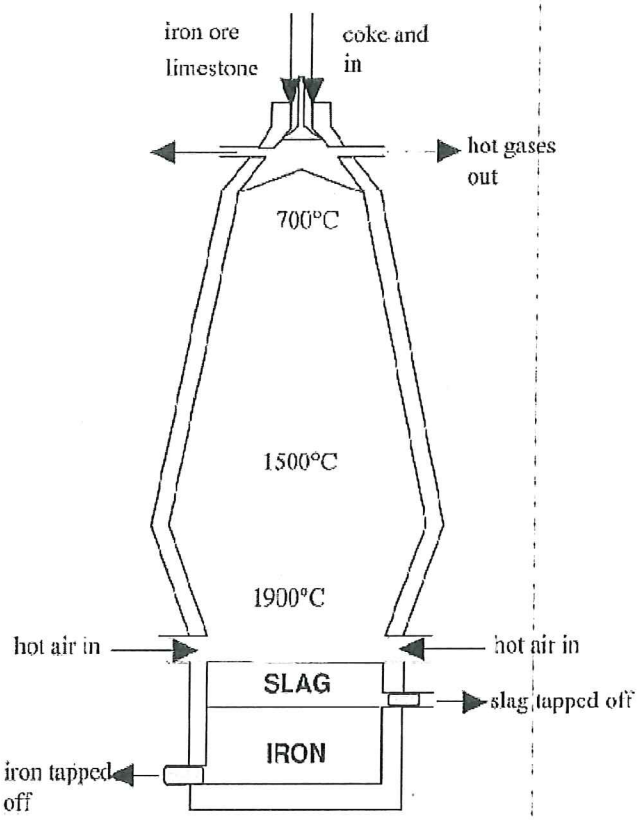
Metals with low reactivity can be found as native metals and not combined with other elements

(1 mark-KU2)

7. Iron is the second most abundant metal after aluminium in the Earth's crust.

One method of obtaining a metal in the middle of the reactivity series from its ore is reduction of the metal ore with coke in a blast furnace.

The following diagram shows a simple outline of the blast furnace.



a) Complete the following table outlining the raw materials added to the furnace and their uses.

Raw Material	Function	Formula
Hematite	Iron ore raw material	Fe_2O_3
Limestone	Remove impurities to form slag (byproduct)	$CaCO_3$
Coke	Reduction of Iron Oxide	C

(3 marks-A2)

b) Suggest why the temperature at the bottom of the blast furnace should not drop below 1550°C.

The Iron oxide / Fe_2O_3 may solidify

(1 mark-AE1)

c) The iron oxide in the iron ore reacts with carbon monoxide.
Using equations, show how coke (a form of carbon) is converted into carbon monoxide.

Reaction 1 $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ (1 mark-A2)

Reaction 2 $CO_2 + C \rightarrow 2CO$ (1 mark-A2)

d) Name the main impurity found in iron ore.

silicon dioxide/sand (1 mark-KU2)

e) Write the reaction equation when limestone reacts with this impurity.

$CaCO_3 \rightarrow CaO + CO_2$

$CaO + SiO_2 \rightarrow CaSiO_3$ (1 mark-A2)

f) Iron can then be obtained by reduction in the blast furnace. Write a balanced equation for the reduction of iron (III) oxide using carbon monoxide.

$Fe_2O_{3(s)} + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$ (2 marks-A2)

g) Describe the Basic Oxygen Steelmaking (BOS) Process and why it is a necessary step in the production of iron from iron ore.

Iron produced from blast furnace called 'pig iron' and has high percentage of carbon impurities resulting in it being too hard/brittle for use.
BOS process necessary to lower carbon content and remove impurities such as C, S, P, Si by injecting high purity oxygen to convert impurities into their o
(3 marks-AE1)

h) Iron is in the middle of the reactivity series and iron oxide can be reduced by reaction with carbon in a blast furnace. Explain why aluminium cannot be extracted in same way with reference to the reactivity series of metals.

Iron can be reduced with carbon as carbon is highe than iron on the reactivity series
Aluminium oxide is more reactive than carbon and therefore cannot be extracted in the same w as carbon is not a strong a strong enough (CO) reducing agent
(3 marks-AE1)

8. Alcoa, the world's leading aluminium supplier, produces alumina from bauxite ore at refineries in Western Australia.

After mining the ore, the main impurities in bauxite, silicon dioxide and iron oxide, are removed in the Bayer process.
First the bauxite is crushed and then mixed with hot, concentrated sodium hydroxide before being filtered.

Step 1: Bauxite is crushed and mixed with sodium hydroxide	→	Step 2: Water and seed crystals are added	→	Step 3: Alumina is separated off and dried ready for electrolysis

a) Explain why the bauxite is mixed with sodium hydroxide in step 1.

Mixed with NaOH to 'dissolve' Alumina and silicon dioxide (silica)

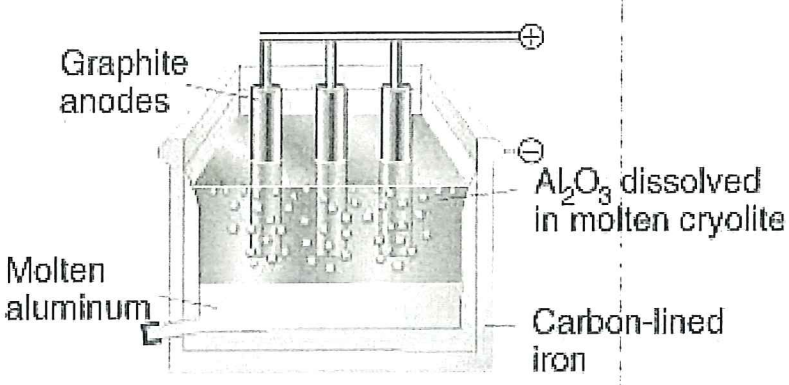
(2 marks-AE2)

b) What is filtered off after step 1?

the solid / undissolved (Fe_2O_3) Ironoxide as red mud. ✓

(1 mark-AE2)

9. The following is a diagram of the Hall-Heroult cell which is used for the electrolysis of alumina.



a) The final extraction of aluminium from alumina is done by electrolysis of the alumina in molten cryolite. State the function of cryolite in this process and explain an economic reason it is used.

Cryolite is used as a catalyst to reduce melting point of alumina ✓ to conserve energy and lower the production cost. ✓

(2 marks-KU2)

b) Explain why molten alumina is used and not an aqueous solution of an aluminium salt.

Aluminium is high on the reactivity series so any water molecules present will be reduced in preference to aluminium ions because they are more easily reduced and the aluminium ions will remain in solution (2 marks-AE1)

c) Write an equation for the reaction that takes place at the cathode.

$Al^{3+}_{(l)} + 3e^- \longrightarrow Al_{(s)}$

(2 marks-A2)

d) With the aid of an equation(s), explain the product that is released at the anode.

Anode: $2O^{2-} \longrightarrow O_2 + 4e^-$ rather than $O_2 + C \longrightarrow CO_2$

the carbon electrodes 'burn away' releasing carbon dioxide

(2 marks-A2)

e) The product from part d) reacts with the electrode itself.
State an environmental issue that this could pose.

Enhanced greenhouse effect (→ global warming)

(1 mark-KU2)

f) Suggest 2 benefits for recycling aluminium. - any 2

- less mining → loss of landscape
- reduce cost (recycle vs extract)
- conserve natural resources
- less CO_2 emission/waste products

(2 marks-KU2)

g) Compare and contrast iron and aluminium extraction referring to:

i) Cost and energy consumption

Iron: energy required to run blast furnace = cost

Al: high energy required for aqueous electrolysis

ii) Environmental concerns

Iron: Produces CO_2 in blast furnace

Al: Produces CO_2 at anode where oxygen reacts with carbon anode

(4 Marks-KU2)

10. Precipitation reactions are sometimes used in metal extraction.

a) Write balanced chemical equations the following reactions:

A- Iron sulfate + sodium carbonate.

$FeSO_{4(aq)} + Na_2CO_{3(aq)} \rightarrow FeCO_{3(s)} + Na_2SO_{4(aq)}$

(2 marks– A2)

B- Silver nitrate + sodium chloride.

$AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$

(2 marks– A2)

b) Consider the following table:

Anion	*Cations forming soluble compounds*	*Cations forming insoluble compounds*
Nitrates	*All*	-
Chlorides *Bromides* *Iodides*	*Most*	Ag^+, Pb^{2+}
Sulfates	*Most*	Ba^{2+}, Pb^{2+}
Carbonates	Na^+, K^+, NH_4^+	*Most*
Phosphates	Na^+, K^+, NH_4^+	*Most*
Sulfides	Na^+, K^+	*Most*
Hydroxides and oxides	Na^+, K^+, Ba^{2+}	*Most*

(i) State which reaction(s) A, B or BOTH produced a precipitate.

Both A & B produced a precipitate

(1 mark – A2)

(ii) State the compound(s) that were responsible for the precipitate(s).

$FeCO_{3(s)}$ + $AgCl_{(s)}$

Iron carbonate, Silver chloride

(1 mark – A2)

c) Precipitate reactions are important to our environment and our drinking water supply.
Minerals such as Mg^{2+} and Ca^{2+} leach into our water supply and cause 'water hardness.'
'Hard' water means soap doesn't lather well and leaves your skin feeling sticky and filmy because soaps and oils do not come off as easily.

To remove these mineral ions, water treatment plants add special compounds that precipitate out some of the Mg^{2+} and Ca^{2+} ions.
Using the above solubility table, suggest a way these ions could be precipitated out and consequently filtered out of our water supply.

By adding any of the following: Hydroxides / oxides
Sulfides
Phosphates
Carbonates
which will result in a solid precipitate
eg. adding a carbonate resulting in calcium carbonate or magnesium carbonate

(2 marks– A&E1)