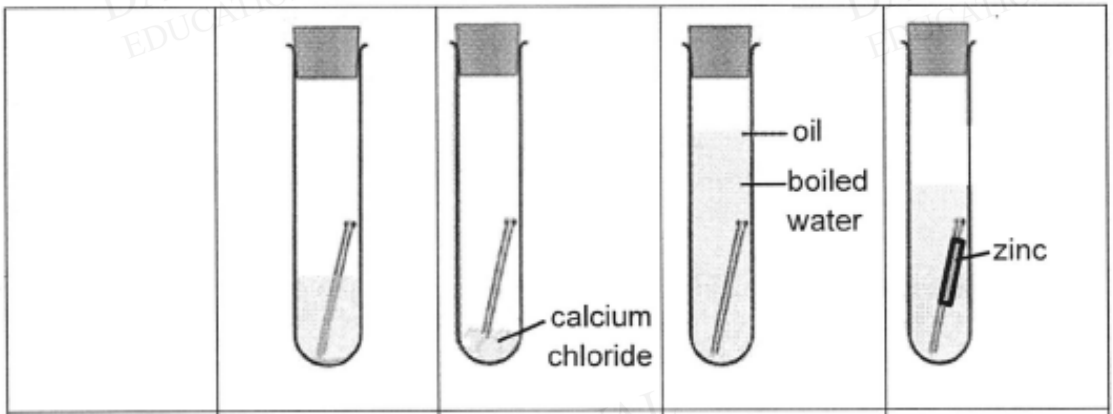
O Level Pure Chemistry Structured

Metals Test 3.0

Q1

(a) Iron is probably the most widely used and most important metal in the world today. One problem with using iron is that it rusts.

The diagram below shows an experiment carried out to investigate different rust prevention methods. An iron nail is placed in each of the four test tubes, A, B, C, and D. A ferroxyl indicator is used to indicate when rusting has taken place. When the colour of the ferroxyl indicator changes from yellow to blue, this indicates that rusting has taken place.



test tube	A	B	C	D
observation	indicator turns blue	indicator remains yellow	indicator remains yellow	

(i) Explain the observations seen in test tubes A, B and C.

.....

.....

.....

..... [3]

(ii) In test tube D, a piece of zinc metal is attached to the iron nail.

Suggest with a reason, the observation that would be made in the test tube after some time.

.....

.....

.....

..... [3]

(b) Iron alloys are widely used in the industry.

(i) Using a named example of an iron alloy, explain what is meant by the term *alloy*.

.....

.....

..... [2]

(ii) Using your example named in **(i)**, state and explain one advantage of the alloy over the pure metal(s).

.....

.....

..... [2]

Q2

Figure 1 shows the composition of elements in the Earth's crust.
Table 1 shows the year of discovery and cost per tonne of some metals.

Figure 1: Elemental composition of the Earth's crust by mass

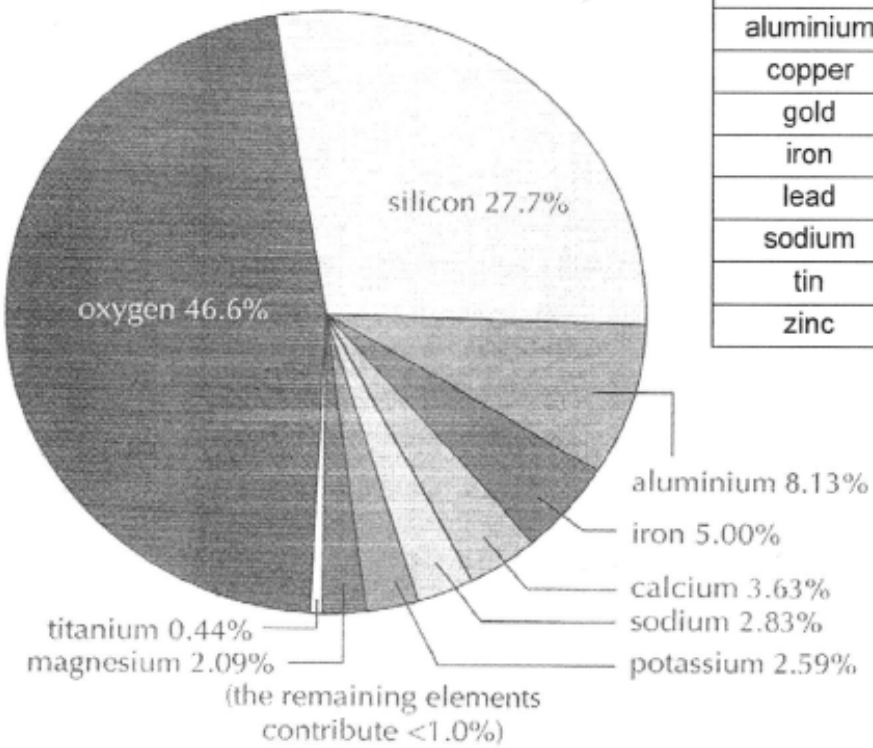


Table 1

Metal	Year of discovery	Cost per tonne / S$
aluminium	1827	2,500
copper	4200 BC	10,000
gold	6000 BC	50,000,000
iron	1500 BC	5,500
lead	3500 BC	2,500
sodium	1807	3,500
tin	1750 BC	25,000
zinc	1400	2,400

(a) Most metals are commonly found as ores. Using the information in Figure 1, which element is most likely to be found combined with metals?

..... [1]

(b) Using the information in Figure 1, suggest the most common compound found in the Earth's crust.

..... [1]

(c) Using your knowledge of the reactivity series, suggest the relationship between the year of discovery of the metals and the reactivity of the metals in Table 1.

..... [1]

(d) Using the information in Figure 1, suggest why it is costly to produce copper and tin.

..... [1]

(e) Which metals found in Table 1 were most likely isolated and discovered by electrolysis? Give a reason for your answer.

.....

..... [2]

(f) Suggest with a reason, why aluminium is discovered later than sodium despite sodium being more reactive than aluminium.

.....

..... [1]

Q3

Copper can be extracted by two different extraction processes involving low grade ore, chalcopyrite, $CuFeS_2$. The ore is first crushed in huge cylindrical ball mills.

The following show information about these processes.

process	roasting & smelting	leaching
main process	The concentrated ore is then heated in the furnace to about 700 °C in the presence of oxygen according to the following equation: $2CuFeS_2(s) + 3O_2(g) \rightarrow 2FeO(s) + 2CuS(s) + 2SO_2(g)$ The iron(II) oxide impurities are then removed by heating to over 1200 °C silica.	The ore is treated with dilute sulfuric acid and converts insoluble chalcopyrite into a solution containing Cu^{2+}, Fe^{2+}, Fe^{3+} and SO^{2-} ions.
conversion	Copper(II) sulfide is reduced to copper by further heating with oxygen.	Copper can also be extracted from solutions of copper(II) salts using scrap iron.

(a) Suggest **two** environmental reasons and why the extraction of copper by leaching is preferable to the roasting and smelting process.

_____

_____

_____ [2]

(b) The leaching process uses lesser energy than the roasting and smelting process. Use the information in the table to explain why.

_____

_____

_____ [2]

(c) **(i)** Give the ionic equation for the reaction involved in the recovery of solid copper from an aqueous solution using scrap iron.

_____ [1]

(ii) Can zinc or magnesium be used in place of iron?
Explain why.

_____

_____ [2]

(d) The copper obtained from these two processes is only 95% pure. This impure copper has to be further refined by electrolysis to obtain copper of 99% purity for use in electrical wiring.

Draw and label an electrolytic cell diagram to demonstrate the electrolytic refining of copper.

.

[2]

Q4

The reactivity of metals can be compared by their reactions with water, steam and displacement reactions. Some data of the experiments are recorded in table below.

metals	displacement reactions	reaction with water and steam	observations during reaction with steam
mercury	mercury does not displace any of the other metals	has no reaction with steam	silvery metal remains unchanged
magnesium	$Mg + Zn(NO_3)_2 \rightarrow Mg(NO_3)_2 + Zn$	reacts slowly with cold water but burns in steam	grey solid turns white
nickel	$Ni + Hg(NO_3)_2 \rightarrow Ni(NO_3)_2 + Hg$	has no reaction with water, reacts slowly with steam	silvery solid turns green
zinc	$Zn + Ni(NO_3)_2 \rightarrow Zn(NO_3)_2 + Ni$	has no reaction with water, reacts slowly with steam	grey solid turns yellow when hot

(a) From table above, arrange the metals in ascending order of their chemical reactivity. [1]

_____

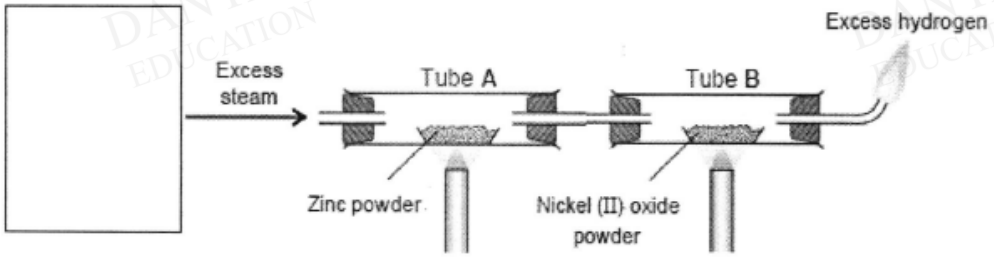
(b) **(i)** Solutions containing nickel(II) ions are usually green. What would you expect to see if magnesium is added to nickel(II) nitrate solution? [1]

_____

(ii) Write an ionic equation, with state symbols, for the reaction in **(b)(i)**. [2]

_____

(c) The figure below shows an apparatus set up where steam was first passed into tube A and zinc and the nickel(II) oxide were then heated.



(i) Write a balanced chemical equation with state symbols, for the reaction that occurs in tube **A**. [2]

_____

(ii) Nickel lies in between iron and lead in the reactivity series. What would you observe in tube **B**? Explain your answer. [2]

_____

_____

_____

Q5

Haematite is an iron ore which is mainly made up of iron(III) oxide. The process of extracting iron from haematite occurs in a blast furnace.

$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$

(a) 2000 g of haematite was used to produce 1300 g of iron. Find the percentage purity of iron(III) oxide in haematite. [2]

(b) There are a number of reactions occuring in the blast furnace. Write a balanced chemical equation with state symbols, for the reaction which is a thermal decomposition reaction. [2]

_____

(c) State the **chemical name** of the main molten waste product from the extraction of iron from haematite. [1]

_____

Answers

Metals Test 3.0

Q1

(a)	(i) test tube A – rusting takes place due to presence of oxygen (air) and water [1] test tube B – rusting does not take place due to absence of water (absorbed by calcium chloride) [1] test tube C – rusting does not take place due to absence of oxygen (air) in boiled water [1] (ii) indicator remains yellow [1] Zinc is more reactive than iron [1] and corrodes / reacts with oxygen (air) and water instead of iron [1]
(b)	(i) steel / stainless steel [1] mixture of iron with one or more other elements (carbon / carbon and chromium) [1] (ii) for steel: harder/stronger [1] than (pure) iron as the presence of atoms of different sizes make it more difficult for the layers of atoms to slide over one another [1] for stainless steel: more resistant to corrosion [1] than (pure) iron [1] due to the presence of more reactive metals (e.g. chromium) that react with oxygen and water instead of iron to form a protective layer [1]

Q2

(a)	oxygen [1]
(b)	Silicon dioxide / silica / SiO_2
(c)	The more reactive the metal is, the later the year of discovery. [1]
(d)	Both copper and tin are scarce (less than 1%) so the cost of production is higher.
(e)	Aluminium and sodium [1] Isolation of metals by electrolysis was only possible after 1800 when the voltaic cell was invented/ the two metals are too high in the reactivity series to be isolated by reduction with carbon or hydrogen. [1]
(f)	Aluminium requires a higher temperature to be melted / aluminium ores have a higher lattice energy due to the higher ionic charge, hence it is harder to be isolated.

Q3

(a) Lesser fossil fuels burnt (reduced energy requirements in leaching process) hence reducing CO_2 produced, a greenhouse gas which leads to reduced effect on global warming OR
conserves resources/fossil fuels [1]

No SO_2 gas produced, an air pollutant which causes acid rain [1] [2]

(b) The roasting and smelting required high energy demands such as

heating to a high temperature of 700 °C during the roasting of the ores, 1200 °C for the removal of iron(II) oxide impurities and additional heating of copper(II) oxide and oxygen during conversion (list any two) [1]

as compared to leaching where no heating is required.[1] [2]

(c) **(i)** $Cu^{2+}(aq) + Fe(s) \rightarrow Fe^{2+}(aq) + Cu(s)$ [1] [1]

(ii) No. Magnesium and zinc is more reactive than iron [1] [2]
and will displace iron from the aqueous solution as well. [1]
Copper obtained would be contaminated with iron.

(d) Electrolyte: any aqueous copper(II) solution[;]
Anode: impure copper[;] [2]
Cathode: pure copper[;]
Battery and wires [;]

Q4

a		Mercury, nickel, zinc, magnesium	1
b	i	Green solution turns colourless OR Silvery solid forms OR Grey magnesium dissolves	1
	ii	$Mg\ (s) + Ni^{2+}\ (aq) \rightarrow Mg^{2+}\ (aq) + Ni\ (s)$	2
c	i	$Zn(s) + H_2O\ (g) \rightarrow ZnO\ (s) + H_2\ (g)$	2
	ii	Silvery solid coated on green solid [1] Green nickel (II) oxide has been reduced by hydrogen to form silvery nickel metal. [1]	2

Q5

a		No of moles of Fe produced: 1300/56 = 23.2 mol moles of Fe : moles of Fe_2O_3 2 : 1 No of moles of Fe_2O_3= 23.2/2 = 11.6mol [1] % purity of Fe_2O_3=[(56 x 2 + 16 x 3) x 11.6]/2000 x 100% = 1856/2000 = 92.8% [1]	2
b		$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$	2
c		Calcium silicate *(NOT: slag)*	1