

Topic 17: Metals – The Reactivity Series

Date:

For this topic, candidates should be able to:

- ☐ Describe the general properties of metals as solids having high melting and boiling points, malleable, good conductors of heat and electricity in terms of their structure.
 - ☐ Describe alloys as mixture of a metal with another element, e.g. brass; stainless steel
 - ☐ Identify representations of metals and alloys from diagrams of structures
 - ☐ Explain why alloys have different physical properties to their constituent elements
 - ☐ Place in order of reactivity calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to
 - the reactions, if any, of the metals with water, steam and dilute hydrochloric acid,
 - the reduction, if any, of their oxides by carbon and/or by hydrogen
 - ☐ Describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction with
 - the aqueous ions of the other listed metals
 - the oxides of the other listed metals
 - ☐ Deduce the order of reactivity from a given set of experimental results
 - ☐ Describe the action of heat on the carbonates of the listed metals and relate thermal stability to the reactivity series
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Multiple Choice Questions

- 1 Brass is an alloy of copper and zinc. Why is brass harder than pure copper?
- A The zinc atoms form strong covalent bonds with copper atoms.
 - B The zinc atoms prevent layers of copper atoms from slipping over each other easily.
 - C The zinc atoms prevent the 'sea of electrons' from moving freely in the lattice.
 - D Zinc atoms have more electrons than copper atoms. ()
- 2 Which of these combinations will not result in a displacement reaction?
- A magnesium and calcium nitrate solution.
 - B iron and lead(II) nitrate solution.
 - C tin and silver nitrate solution.
 - D zinc and copper(II) nitrate solution. ()
- 3 A student made the following observations in the laboratory:
- I Metal **X** did not react with aqueous nitrate solution of **Y**.
 - II Metal **Y** dissolved in the aqueous nitrate solution of **Z** and crystals of **Z** appeared.
 - III Metal **Z** did not react with the aqueous nitrate solution of **X**.

The order of increasing reactivity of the three metals would therefore appear to be

- A Y, X, Z B X, Z, Y C X, Y, Z D Z, X, Y ()

4 Carbon at red heat will remove the oxygen from the oxides of the metals **P**, **Q** and **R** but not from the oxide of metal **S**. Metal **R** will remove oxygen from the oxide of **P**, but not from the oxide of **Q**. The order of decreasing reactivity of the four metals would be

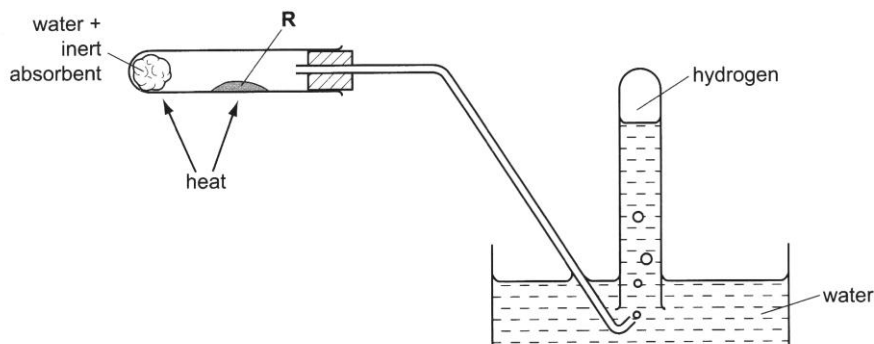
A **S, P, R, Q** **B** **P, Q, R, S** **C** **S, Q, R, P** **D** **P, R, Q, S** ()

5 Which statement about the metals iron, lead and copper is correct?

A They react with warm, dilute hydrochloric acid with evolution of hydrogen.
B Their sulfates are soluble in water.
C All their compounds are coloured.
D Their carbonates can all decompose upon heating.

()

6 The diagram shows an experiment to produce and collect hydrogen.



What is **R**?

A lead
C iron

B copper(II) oxide
D lead(II) oxide ()

7 On strong heating, which substance below will produce the highest amount of carbon dioxide in the first few seconds of the reaction?

A magnesium carbonate
B copper(II) carbonate
C potassium carbonate
D iron(II) carbonate ()

8 A white powder **Z** turns yellow when heated. When the product is cooled, it turns back to white. What is **Z**?

A magnesium carbonate
B lead(II) carbonate
C calcium carbonate
D zinc carbonate ()

9 When an alkali metal reacts with cold water, a colourless solution is formed with the evolution of a colourless gas. What is the pH of the eventual solution and what is the identity of the gas produced?

	pH of solution	gas evolved
A	1	hydrogen
B	1	hydrogen
C	13	carbon dioxide
D	13	carbon dioxide

()

10 Which one of the following oxides will be reduced by hydrogen?

A aluminium oxide
C zinc oxide

B copper(II) oxide
D calcium oxide

()

Structured Questions

1 Write balanced equations, with state symbols, for the following reactions:

(a) Action of heat on copper(II) carbonate.

.....[2]

(b) Reduction of zinc oxide by coke.

.....[2]

(c) Reaction of magnesium and steam.

.....[2]

(d) Addition of iron powder into an aqueous solution of copper(II) sulfate.

.....[2]

(e) Reaction between solid calcium oxide and water.

.....[2]

(f) Reaction between solid sodium with water.

.....[2]

2 Small pieces of each of the following metals were added to cold water and the volume of gas collected in the first two minutes was recorded.

metal	aluminium	barium	calcium	magnesium	potassium
volume/ cm ³	0	60	25	20	90

(a) (i) What is a metal?

.....
.....[1]

(ii) Use the data provided and arrange the metals in order of decreasing reactivity.

.....[1]

(b) Write an equation for the reaction between barium and water.

.....[1]

(c) Describe what you would expect to see when carbon dioxide is passed into the solution from the reaction in (b)? Give a reason for your answer.

.....
.....[2]

- (d) Explain why, although aluminium is a reactive metal, it does not produce any gas in the above reaction.

.....

[2]

- 3 You are provided with a list of substances:

solid copper(II) sulfate copper wire distilled water
 powdered zinc chloride zinc powder

Describe how you would carry out an experiment to show that zinc is more reactive than copper. Your answer should include the tests carried out and relevant observations made.

.....

[4]

- 4 In an experiment, small amounts of three metals were added to three aqueous metal nitrate solutions. The results are shown in the table.

	aqueous zinc nitrate	aqueous $X(NO_3)_2$	aqueous copper(II) nitrate
zinc		green solution fades to colourless and zinc coated with grey solid	
metal X	No reaction was observed		
copper		No reaction was observed	

- (a) Complete the table above. [3]

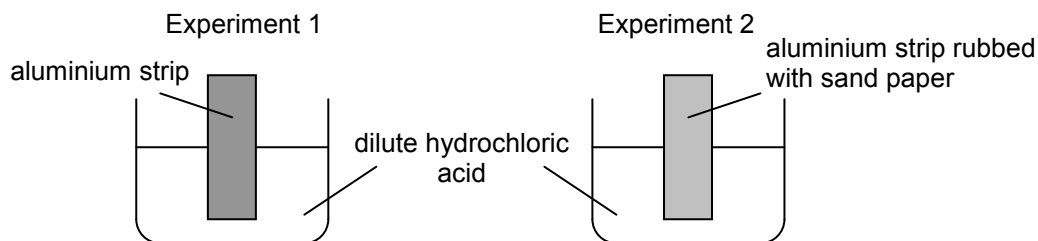
- (b) Write an ionic equation, with state symbols, for the reaction between zinc and nitrate of **X**.

.....[2]

(c) Arrange the zinc, metal X and copper in order of reactivity.

.....[1]

5 Aluminium is above hydrogen in the reactivity series. The following experiments were set up.



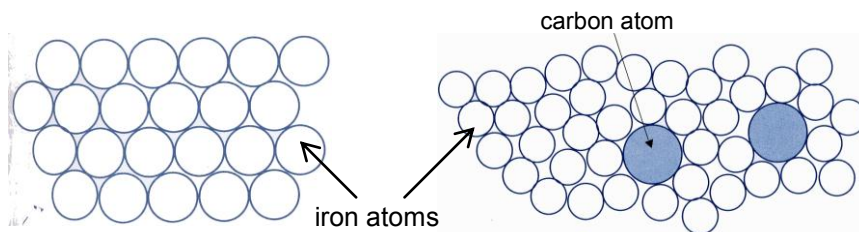
(a) Write down the observations you would see in each experiment.

.....
.....
.....[2]

(b) Explain why the two strips behave differently.

.....
.....
.....[2]

6 The diagram shows the structures of a metal and an alloy of the metal.



(a) What is an alloy?

.....
.....[1]

(b) Explain why the iron alloy has different physical properties to pure iron.

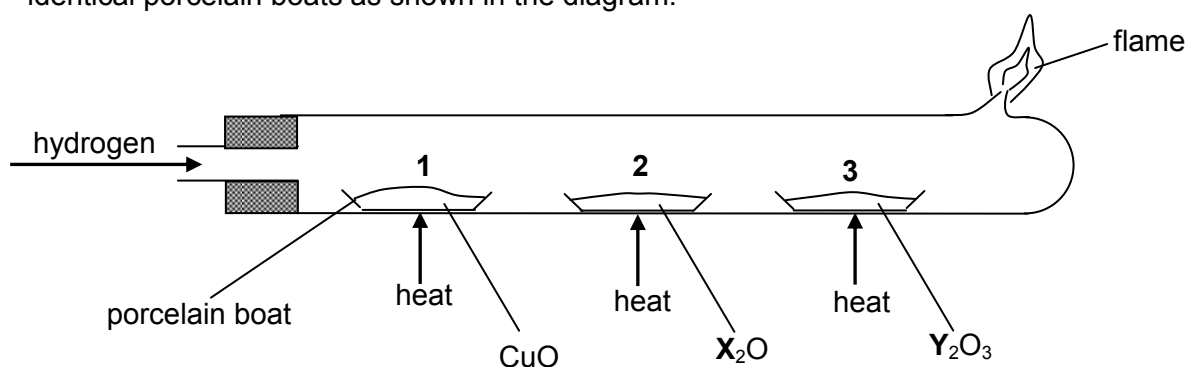
.....
.....
.....[3]

- (c) High carbon steel is much stronger but more brittle than mild steel.
Explain this observation.

.....

[3]

- 7 In an experiment, hydrogen gas was passed over equal masses of three heated metal oxides in identical porcelain boats as shown in the diagram.



- (a) The heat source is turned off when no more change is observed in the porcelain boats. However, the hydrogen is kept flowing until the tube is cold. What is the reason for this?

.....[1]

- (b) Describe a change you would see in porcelain boat 1.

.....[1]

- (c) The table shows some data from this experiment.

	start	end
mass of empty porcelain boat / g	16.35	16.35
mass of porcelain boat 2 and its contents / g	22.35	22.35
mass of porcelain boat 3 and its contents / g	22.35	20.55

- (i) Explain how data from the table shows that X is above Y in the reactivity series.

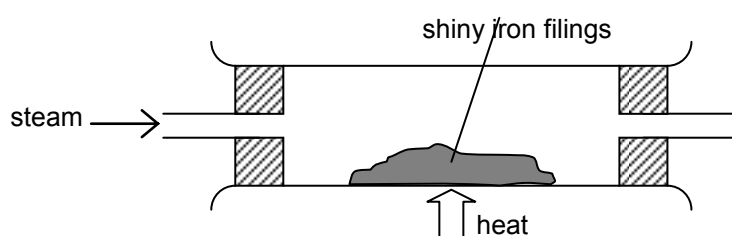
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[2]

- (ii) Using information from the diagram and the table, calculate the relative atomic mass of Y.

[3]

- 8 The diagram below shows an experiment in which steam was passed over hot iron fillings. The products of the reaction are iron oxide, Fe_3O_4 , and a gas which burns with a blue flame.



- (a) Write an equation, including state symbols, for the reaction and describe what you would see as the iron reacts with the steam.

.....
.....[3]

- (b) Describe how the observations would be different if the experiment was repeated using each of the following two metals in place of the iron filings.

(i) magnesium:
.....[2]

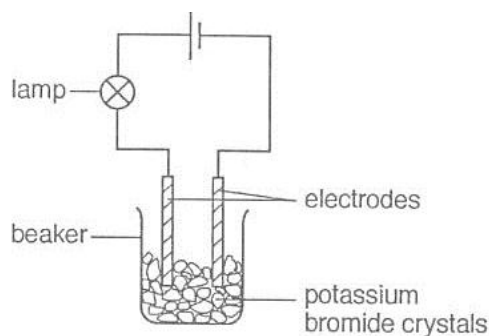
(ii) copper:[1]

For this topic, candidates should be able to:

- ☐ relate the physical properties (including electrical property) of ionic compounds to their lattice structure
- ☐ relate the physical properties (including electrical property) of covalent substances to their structure and bonding
- ☐ relate the electrical conductivity of metals to the mobility of the electrons in the structure

Multiple Choice Questions

- 1 Which one of the following substances does not conduct electricity?
- | | | |
|--|-----------------------------------|-----|
| A ammonia solution | B ethanol | |
| C dilute zinc chloride solution | D dilute hydrochloric acid | () |
- 2 What ions are present in aqueous potassium sulfate?
- | | | |
|---|---|-----|
| A K^+ , SO_4^{2-} | B K^+ , SO_4^{2-} , H_2^+ and OH^- | |
| C K^+ , SO_4^{2-} , H^+ and O^{2-} | D K^+ , SO_4^{2-} , H^+ and OH^- | () |
- 3 Which particles are responsible for the conduction of electricity through metals and electrolytes?
- | | | | |
|----------|---------------|---------------------------------|-----|
| | <u>metals</u> | <u>electrolytes</u> | |
| A | negative ions | positive ions | |
| B | electrons | electrons | |
| C | positive ions | electrons | |
| D | electrons | positive ions and negative ions | () |
- 4 The experiment shown is used to test potassium bromide crystals. The lamp does not light. Distilled water is then added to the beaker and the lamp lights.



Which experiment explains these results?

- | | | |
|----------|---|-----|
| A | Electrons are free to move in the solution when potassium bromide dissolves. | |
| B | Oppositely charged ions are free to move when potassium bromide dissolves in water. | |
| C | Metal ions are free to move when potassium bromide melts. | |
| D | Metal ions are free to move when potassium reacts with water. | () |
- 5 At first, the ammeter in an electrolysis setup showed that a current was flowing. Some dilute sulfuric acid was added to the original electrolyte and the ammeter showed that the current was greatly reduced.

What could the original electrolyte be?

- | | | | | |
|----------|---------------------------|----------|------------------------------|-----|
| A | barium hydroxide solution | B | potassium hydroxide solution | |
| C | sodium hydroxide solution | D | water | () |

6 An example of a strong electrolyte is

A vinegar
C aqueous ammonia

B dilute sulfuric acid
D graphite

()

Structured Questions

1 Question (a) to (c) refer to the following list of substances:

diamond	phosphorus	potassium chloride
sulfur	mercury	hydrogen chloride
zinc	sucrose	lead(II) bromide

(a) (i) Which of the listed substances conduct electricity in the solid state?

.....[1]

(ii) Why do these substances conduct electricity in the solid state?

.....
.....[1]

(b) (i) Which of the listed substances dissolve in water to produce a conducting solution?

.....[1]

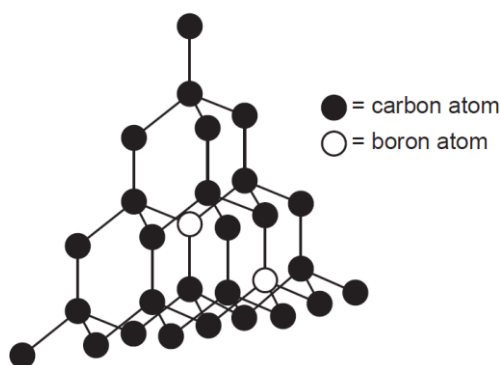
(ii) Explain why these solutions conduct electricity.

.....
.....[1]

(c) Which of the listed substances conduct electricity when molten?

.....[1]

(d) Blue diamonds are an impure form of carbon. Part of the structure of a blue diamond is shown below.



Suggest why blue diamonds can conduct electricity.

.....
.....[1]

2 The properties of five substances **A** - **E** are shown in the table below:

substance	solubility in water	properties of the aqueous solution	electrical conductivity of the pure substance at room temperature
A	soluble	neutral, conducts electricity	non-conductor
B	soluble	neutral, does not conduct electricity	non-conductor
C	insoluble	---	non-conductor
D	insoluble	---	conductor
E	soluble	acidic, conducts electricity	non-conductor

Identify the substances **A** - **E** from the following list of substances.
(You may choose the substance once, more than once or not at all.)

graphite	ammonia	diamond
glucose	zinc	dilute sulfuric acid
sodium chloride	lead(II) nitrate	hydrogen chloride

Identity of substance **A**:

B:

C:

D:

E:

[5]

For this topic, candidates should be able to:

Extraction of metals

- ☐ describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series

Recycling of metals

- ☐ describe metal ores as a finite resource and hence the need to recycle metals, e.g. recycling of iron
- ☐ discuss the social, economic and environmental issues of recycling metals

Iron

- ☐ describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace
- ☐ 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
- ☐ state the uses of mild steel, e.g. car bodies; machinery, and stainless steel, e.g. chemical plants; cutlery; surgical instruments
- ☐ 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; galvanizing
- ☐ 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

Multiple Choice Questions

1 Sodium can be obtained by

- A** electrolysis of molten sodium chloride
- B** electrolysis of sodium chloride solution
- C** heating sodium oxide with carbon
- D** electrolysis of sodium hydroxide solution ()

2 Steel is an alloy of

- A** iron and copper
- B** iron and carbon
- C** iron and carbon
- D** copper and carbon ()

3 **M** is a metal high in the reactivity series. It reacts with cold water and its oxide is stable to heating. Which of the following methods can **M** be best extracted?

- A** reduction of its oxide by carbon
- B** hydrolysis of its chloride
- C** electrolysis of an aqueous solution of its chloride
- D** electrolysis of its molten chloride ()

- 4 Which one of the following metals cannot be extracted from its ore by reduction method using coke?
A lead **B** copper **C** sodium **D** zinc ()
- 5 When a piece of aluminium is anodised, which of the following takes place?
A the surface layer of aluminum oxide is thickened
B the oxide of the surface layer is converted to the metal by reduction
C the surface layer of aluminium oxide is dissolved
D the surface is plated with aluminium ()
- 6 What is the reducing agent in the blast furnace for extracting iron from its ore?
A calcium carbonate **B** carbon dioxide
C carbon monoxide **D** silica ()
- 7 Steel differs in how much carbon they contain. Which are the properties of high carbon steel?
A soft and brittle **B** soft and easily shaped
C strong and brittle **D** strong and easily shaped ()
- 8 Each beaker contains two strips of metal fastened together and immersed in dilute hydrochloric acid. All the strips are of the same size. After 5 minutes, which beaker contains the **least** amount of zinc ions?

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

()

- 9 Scrap iron is often recycled. Which reason for recycling is not correct?
A it reduces the amount of pollution at the site of the ore extraction
B it reduces the amount of waste taken to landfill sites
C it reduces the need to collect the scrap iron
D it saves natural resources ()
- 10 Magnesium blocks are attached to boats made from iron. Why does magnesium stop the iron from rusting?
A magnesium reacts in preference to the iron
B magnesium reacts to form a protective coating
C the magnesium forms an alloy with the iron
D the magnesium stops oxygen in the water from getting to the iron ()

Structured Questions

1 (a) Draw diagrams to show the arrangement of atoms in

(i) low carbon steel alloy,

[1]

(ii) high carbon steel alloy.

[1]

(b) How do the properties of the two types of steel differ? Use your diagrams to explain why the properties are different.

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.....[2]

(c) Describe one use for each of the iron alloy above.

.....

.....[2]

2 Answer the following questions on the extraction of iron in the blast furnace.

(a) Give the name and formula of one mineral from which iron is extracted.

.....[1]

(b) Write two equations, with state symbols, to show how carbon monoxide is formed in the blast furnace, starting from coke.

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.....[2]

(c) Write the equation to show how metallic iron is formed in the blast furnace.

.....[1]

(d) Name a gaseous product that is liberated in large quantities from the blast furnace and can become a serious air pollutant.

.....[1]

- (e) Silica is one of the impurities present in iron ore. Explain how this impurity is removed in the blast furnace.

.....

[3]

- 3 Five steel nails were placed in water in separate test tubes. The test tubes were left open to the air. Before being placed in the test tubes, the nails were treated in different ways. After a period of time, the steel nails were examined for signs of rusting. The results are summarised in the table below:

nail	treatment before placing in water	what is seen in the test tube at the end of the experiment
A	nail was coated with oil	oily drops on the surface of the water and some brown substance around the nail
B	zinc foil was wound around the nail	white solid on the zinc and a little brown colour around the nail
C	no treatment	large amount of brown substance around the nail and throughout the water
D	magnesium ribbon was wound around the nail	large amount of white solid around the magnesium and nail; no brown colour
E	nail was sprayed with paint	some brown stains on the paint

- (a) (i) Which treatment was most effective at preventing rusting?

.....[1]

- (ii) Explain why this treatment was most effective.

.....
[2]

- (b) Suggest one reason why the oil was not effective in preventing rusting.

.....[1]

- (c) Suggest the chemical names for the two white solids and the brown substance formed in the above experiments.

.....
[3]

- 4 (a) Magnetite, Fe_3O_4 , is one form of iron oxide in iron ore. Calculate the percentage by mass of iron in magnetite.

[2]

- (b) When iron is extracted from magnetite, Fe_3O_4 , in the blast furnace, waste gases and solid waste products are formed.

- (i) Name two gaseous and one liquid waste products of this process.

.....[3]

- (ii) Write equations to show how they are formed.

.....
.....
.....[3]

- (c) State one advantage and one disadvantage of recycling iron.

.....
.....[2]

- (d) The Statue of Liberty in New York is made from an iron frame covered with copper plates. In 2004, work has to be carried out to stop the iron frame from rusting away. The iron frame was rusting much faster than normal where it was in contact with the copper.

- (i) Explain why the copper in contact with iron causes the iron to rust faster than normal.

.....
.....
.....[2]

- (ii) Would you expect the copper in contact with the iron to corrode faster or slower than normal? Explain your reasoning.

.....
.....[1]