

Unit 11: Reactivity of metals



HKDSE Syllabus

Reactivity of metals

Students should learn

- reactions of some common metals(sodium, calcium, magnesium, zinc, iron, lead, copper, etc.) with oxygen/air, water, dilute hydrochloric acid and dilute sulphuric acid
- metal reactivity series and the tendency of metals to form positive ions
- displacement reactions and their interpretations based on the reactivity series
- prediction of the occurrence of reactions involving metals using the reactivity series
- relation between the extraction method of a metal and its position in the metal reactivity series

Students should be able to

- describe and compare the reactions of some common metals with oxygen/air, water and dilute acids
- write the word equations for the reactions of metals with oxygen/air, water and dilute acids
- construct a metal reactivity series with reference to their reactions, if any, with oxygen/air, water and dilute acids
- write balanced chemical equations to describe various reactions
- use the state symbols (*s*), (*l*), (*g*) and (*aq*) to write chemical equations
- relate the reactivity of metals to the tendency of metals to form positive ions
- describe and explain the displacement reactions involving various metals and metal compounds in aqueous solutions
- deduce the order of reactivity of metals from given information
- write balanced ionic equations
- predict the feasibility of metal reactions based on the metal reactivity series
- relate the extraction method of a metal to its position in the metal reactivity series

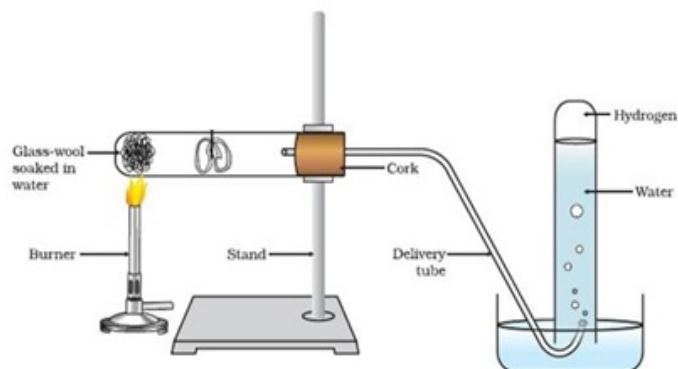
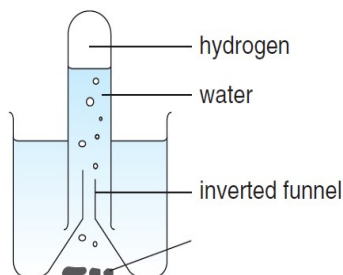
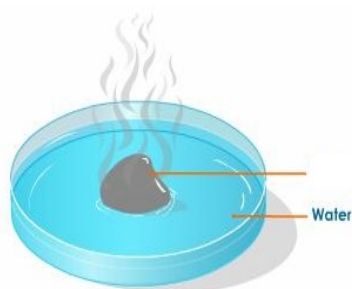
Points for this unit

1. Reactions between metals with: a) _____ b) _____ c) _____
2. Explaining _____ (M.R.S.)
3. _____ reaction (置換反應) and writing _____ equation
4. _____ of metal oxide (Extraction)

A. Reactions with Oxygen, Water and acid

1. Metal + Oxygen \longrightarrow _____

Metal	Heat needed to start reaction	Observation	Word and chemical equations (General: Metal + Oxygen \rightarrow Metal oxide)
		1. Burns vigorously with a _____ flame. 2. _____ powder formed.	_____ + _____ \rightarrow _____ $K_{(s)} + O_{2(g)} \longrightarrow$
	Medium	1. Burns vigorously with a _____ flame. 2. _____ powder formed	Sodium + oxygen \rightarrow Sodium oxide $Na_{(s)} + O_{2(g)} \longrightarrow$
		1. _____ flame 2. _____ powder	Calcium + Oxygen \rightarrow Calcium oxide $Ca_{(s)} + O_{2(g)} \longrightarrow$
		1. _____ white flame 2. White powder formed	Magnesium + Oxygen \rightarrow Magnesium oxide $Mg_{(s)} + O_{2(g)} \longrightarrow$
		White powder formed	Aluminium + Oxygen \rightarrow Aluminium oxide $Al_{(s)} + O_{2(g)} \longrightarrow$
	Strong	_____ powder when hot, _____ powder when cold	Zinc + Oxygen \rightarrow Zinc oxide $Zn_{(s)} + O_{2(g)} \longrightarrow$
		Black powder formed	Iron + Oxygen \rightarrow Iron(III) oxide $Fe_{(s)} + O_{2(g)} \longrightarrow$
		_____ powder when hot, _____ powder when cold	Lead + Oxygen \rightarrow Lead oxide $Pb_{(s)} + O_{2(g)} \longrightarrow PbO$
		Black powder formed	Copper + Oxygen \rightarrow Copper(II) oxide $Cu_{(s)} + O_{2(g)} \longrightarrow CuO$
	Very strong	Red powder formed	Mercury + Oxygen \rightarrow <u>Mercury(II)</u> oxide $Hg_{(s)} + O_{2(g)} \longrightarrow HgO$
		Do NOT burn	NO reaction

2. Metal + Water \longrightarrow _____ / _____ + _____


Metal	Observation	Word and chemical equations (General: Metal + Oxygen \rightarrow Metal oxide)
Metal + Water \longrightarrow Metal hydroxide + hydrogen gas		
	1. _____, _____ into a silvery ball and darts around. 2. Burns with a _____ flame	Potassium + water \rightarrow _____ + _____ $\text{K}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow$
	1. _____, _____ into a silvery ball and darts around. 2. _____ flame can be seen.	Sodium + water \rightarrow _____ + _____ $\text{Na}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow$
	1. _____ 2. Colourless gas bubbles 3. _____ suspension	Calcium + Water \rightarrow Calcium hydroxide + hydrogen $\text{Ca}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow \text{Ca}(\text{OH})_{2(aq)} + \text{H}_{2(g)}$
Metal + Steam \longrightarrow Metal oxide + hydrogen gas		
	Cold water : _____ Hot water : react very slowly	$\text{Mg}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow$
	Steam: reacts much faster.	$\text{Mg}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow$
	Same as _____ but less vigorous	$\text{Al}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow \text{Al}_2\text{O}_{3(s)} + \text{H}_{2(g)}$
	Same as _____ but less vigorous (Remark: colour of oxide: _____ when hot, _____ when cold)	$\text{Zn}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow \text{ZnO}_{(s)} + \text{H}_{2(g)}$
	Same as _____ but less vigorous	$\text{Fe}_{(s)} + \text{H}_2\text{O}_{(l)} \longrightarrow \text{Fe}_2\text{O}_{3(s)} + \text{H}_{2(g)}$

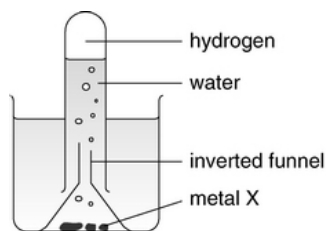
3. Metals + Acid \longrightarrow _____ + _____

Metal	Observation	Word and chemical equations
	1. Metal dissolves and give out a lot of heat. (_____放熱的)	$\text{Ca}_{(s)} + \text{HCl}_{(aq)} \longrightarrow$
	2. Colourless gas bubbles evolved. (_____冒泡)	$\text{Mg}_{(s)} + \text{HCl}_{(aq)} \longrightarrow$
		$\text{Al}_{(s)} + \text{HCl}_{(aq)} \longrightarrow \text{AlCl}_{3(aq)} + \text{H}_{2(g)}$
		$\text{Zn}_{(s)} + \text{HCl}_{(aq)} \longrightarrow \text{ZnCl}_{2(aq)} + \text{H}_{2(g)}$
		$\text{Fe}_{(s)} + \text{HCl}_{(aq)} \longrightarrow \text{FeCl}_{3(aq)} + \text{H}_{2(g)}$
	Reacts very _____	$\text{Pb}_{(s)} + \text{HCl}_{(aq)} \longrightarrow \text{PbCl}_{2(aq)} + \text{H}_{2(g)}$

1. The oxide of a metal is orange when it is hot but yellow when it is cold. The metal is

- A calcium. B lead. C potassium. D zinc.

2. Hydrogen is produced when metal X reacts with water in the set-up shown below:



X could be

- A lead.
B magnesium.
C potassium.
D strontium.

3. Which of the following metals can react with cold water readily to give hydrogen?

- (1) Calcium (2) Magnesium (3) Zinc

- A (1) only B (2) only C (1) and (3) only D (2) and (3) only

B. Explaining the Metal reactivity Series

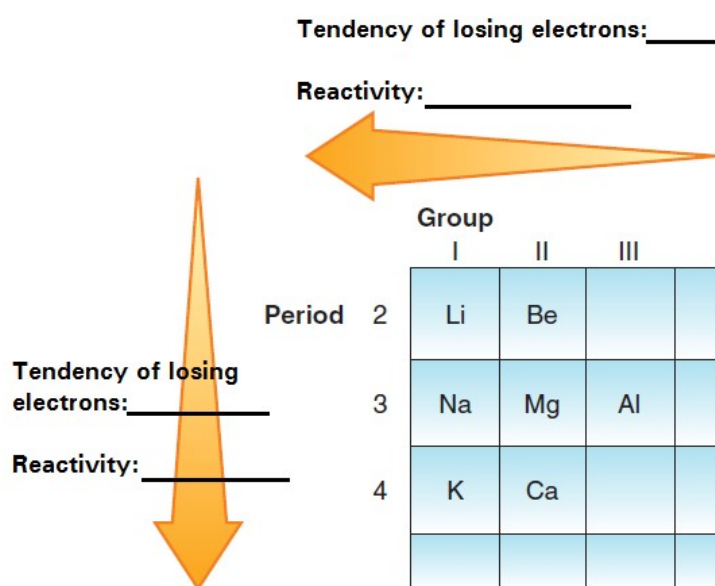
All metals _____ electrons to form positive ions (_____) during reaction.

Metal atom \longrightarrow Metal ion + electron

Atoms of _____ reactive metals lose outermost shell electrons to form cations _____ readily.

Metal reactivity series	Reactivity	Tendency of losing electron
	<u>Most/least</u> reactive	<u>Highest/lowest</u> tendency
	<u>Most/least</u> reactive	<u>Highest/lowest</u> tendency

Conclusion: More reactive metal is more/less readily to lose electrons.



Factor affecting the tendency of losing outermost shell electrons

1. _____
2. _____

The reactivity of the Group I metals increases in the order

_____ < _____ < _____

while that of Group II metals increases in the order

_____ < _____ < _____

Across the third period, reactivity decreases in the order

_____ > _____ > _____

C. Displacement reaction(置換作用) and ionic equation

A more reactive metal A (Higher in M.R.S.) will displace a less reactive metal B (Lower in M.R.S.) from a solution of a compound of metal B.

Experiment 1

Add copper to an aqueous solution of silver nitrate.

Chemical equation:

An ionic equation is the equation which **ONLY** includes the **ions formed** or **changed** in the reaction

Ionic equation

- Observations: 1. Copper _____
 2. _____ deposits on the _____ surface
 3. The colour of solution turns from _____ to _____

Experiment 2

Add iron to an aqueous solution of copper(II) nitrate.

Chemical equation:

Ionic equation

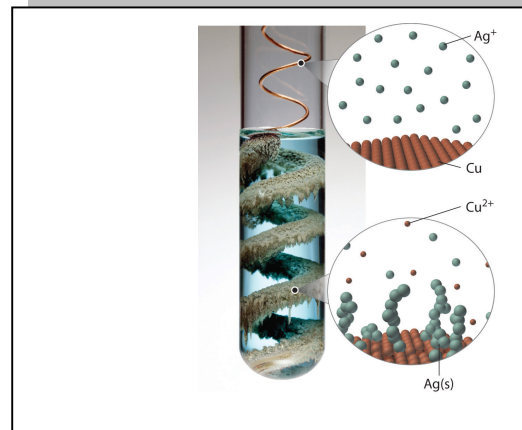
- Observations: 1. Iron _____
 2. _____ deposit on the _____ surface
 3. The colour of solution turns from _____ to _____

Experiment 3

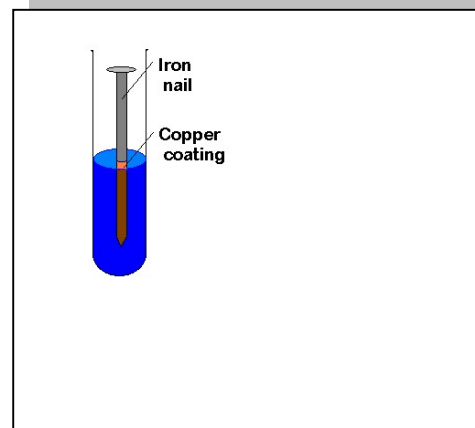
Add potassium to an aqueous solution of copper (II) nitrate.

Experiment 4

Add lead to an aqueous solution of magnesium nitrate.



Tips for writing ionic equation:
 Delete the chemical species which does **NOT** change in _____ or _____ after the reaction.



D. Reduction of metal oxide

_____ (氧化作用): Gain of oxygen to a substance

Metal $\xrightarrow{\hspace{10em}}$ **Metal oxide**

_____ (还原作用): Loss of oxygen from a substance



Metal	Reactivity of metal	Stability of their compounds (in Ore)	Extraction method	Chemical equations involved
	<u>Most/least</u> reactive	<u>Most/least</u> stable		Example: $\text{NaCl}(_) \longrightarrow$ $\text{Al}_2\text{O}_3(_) \longrightarrow$
			Heating with _____	Step1: $\text{ZnS} + _ \longrightarrow _ + _$ Step2: $_ + \text{C} \longrightarrow _ + _$
			Examples of reducing agent (R.A.): _____	$\text{FeO} + _ \longrightarrow _ + _$ $\text{Fe}_2\text{O}_3 + _ \longrightarrow _ + _$
			_____	Step1: $\text{PbS} + _ \longrightarrow _ + _$ Step2: $_ + \text{C} \longrightarrow _ + _$
			R.A. can take up _____ and _____ the metal oxide back to _____	$\text{CuO} + \text{C} \longrightarrow _ + _$
				$\text{CuS} + \text{O}_2 \longrightarrow _ + _$ $\text{HgS} + \text{O}_2 \longrightarrow _ + _$
				$\text{Ag}_2\text{O} \longrightarrow _ + _$
	<u>Most/least</u> reactive	<u>Most/least</u> stable		

Conclusion:

Compounds of a metal _____ in the reactivity series have _____ stability.
Thus, the reduction of the oxide of the metal is harder.

Exercises

91 MC 08

X, Y and Z are metals. Y can displace X from a solution of the nitrate of X. Oxides of X and Y can be reduced by hydrogen but not the oxide of Z. Which of the following arrangements represents the correct descending order of reactivity of the metals?

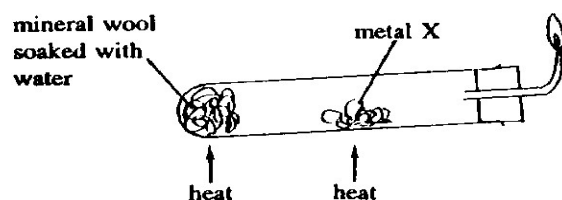
- A. $Z > Y > X$ B. $X > Y > Z$ C. $Z > X > Y$ D. $X > Z > Y$

91 MC 02

Rubidium (Rb) is a group I element below potassium in the Periodic Table. Which of the following statements about rubidium is correct?

- A. Rubidium forms an acidic oxide.
 B. Rubidium is more reactive than potassium.
 C. Rubidium can be obtained from its oxide by reduction with carbon.
 D. The formula for rubidium chloride is $RbCl_2$.

92 MC 31



In the above experiment, a gas is evolved and burns at the jet. Metal X is probably

- A. zinc. B. aluminium C. magnesium D. copper

95 MC 18

Metal X reacts with dilute hydrochloric acid to liberate hydrogen, but metal Y and metal Z have no reaction with the dilute acid. The oxide of metal Y decomposes on heating but the oxide of metal Z does not. Which of the following arrangements represents the order of increasing reactivity of the three metals?

- A. $X < Y < Z$ B. $Y < Z < X$ C. $X < Z < Y$ D. $Z < Y < X$

89 3(b) The results of experiments with iron and three other metals X, Y, Z and their oxides are summarized in the following tables:

Experiment \ Metal	Iron	X	Y	Z
Action of metal on iron(II) sulphate solution	No immediate reaction	Iron is deposited	A gas is evolved	No reaction

Experiment \ Metal oxide	Fe_2O_3	XO	Y_2O	Z_2O
Action of heat on metal oxide	No reaction	No reaction	No reaction	Metal Z is formed

- (i) What was the gas evolved in the reaction of Y with iron(II) sulphate solution? Write an equation for the reaction involved. (State symbols should be given.)
 (ii) Arrange the four metals in descending order of activity, and briefly explain your answer.

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2. Which of the following processes would NOT give oxygen ?

- A. heating mercury(II) oxide strongly
- B. electrolysis of dilute sulphuric acid
- C. fractional distillation of liquefied air
- D. passing steam over heated magnesium

2016 DSE

3. Consider the following information concerning metal Y :

- (1) Y reacts vigorously with water.
- (2) Y forms an oxide with chemical formula Y_2O .
- (3) An atom of Y has five occupied electron shells.

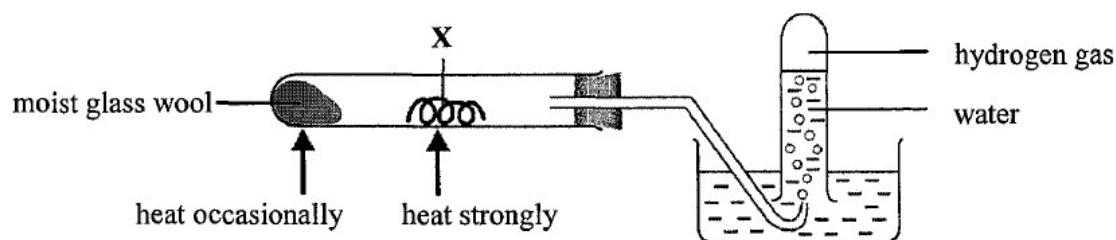
Y may be

- A. silver (Ag).
- B. caesium (Cs).
- C. strontium (Sr).
- D. rubidium (Rb).

9. Which of the following processes would NOT produce metal ?

- A. heating zinc oxide
- B. heating copper(II) oxide with carbon
- C. electrolysis of molten lithium chloride
- D. heating iron(III) oxide with carbon monoxide

4. Consider the following experimental set-up :



Which of the following would NOT be X ?

- A. iron
- B. zinc
- C. copper
- D. magnesium

2. Water pipes used to carry drinking water are commonly made of copper instead of iron. Although lead-containing solder can be used to join these water pipes, such use is prohibited.

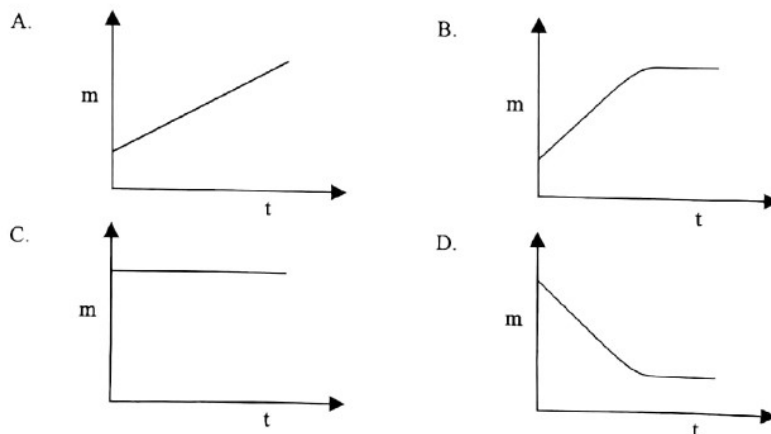
(a) Suggest one chemical property of copper that makes it more suitable than iron for making water pipes. Explain your answer.

(2 marks)

- (b) (i) Suggest one reason of adding lead to soldering materials.
- (ii) Explain why lead-containing solder is prohibited in joining these water pipes.

2018 DSE

3. A certain mass of a sample of $\text{Ag}_2\text{O}(\text{s})$ is strongly heated in a test tube. Which of the following shows the relationship of the mass of the contents (m) in the test tube with time (t) from the start of heating?



7. Which of the following statements concerning iron and magnesium is correct?
- A. Iron is ductile but magnesium is not.
 B. Iron corrodes less readily than magnesium.
 C. The abundance of magnesium is higher than that of iron in the earth crust.
 D. Both magnesium and iron can have more than one oxidation number in their oxides.
9. X, Y and Z are different metals. When they are placed separately in $\text{NaCl}(\text{aq})$, only Y gives colourless gas bubbles. When each of their oxides is heated strongly, only the oxide of X gives a colourless gas. Which of the following shows the decreasing order of reactivity of these three metals?
- A. $\text{Y} > \text{Z} > \text{X}$
 B. $\text{X} > \text{Y} > \text{Z}$
 C. $\text{Y} > \text{X} > \text{Z}$
 D. $\text{Z} > \text{Y} > \text{X}$

Reactivity series of metal

Metals	Metals	Metals	Metals
K 鉀			
Na 鈉			
Ca 鈣			
Mg 鎂			
Al 鋁			
Zn 鋅			
Fe 鐵			
Pb 鉛			
Cu 銅			
Hg 汞			
Ag 銀			
Au 金			