

Section Three : Metals

Unit Ten : Reactivity of Metals

II. Reactions of Metals with Air / oxygen (O₂)

Metals	Equations
Potassium (K)	$4\text{K(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{K}_2\text{O(s)}$
Sodium (Na)	$4\text{Na(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{Na}_2\text{O(s)}$
Calcium (Ca)	$2\text{Ca(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{CaO(s)}$
Magnesium (Mg)	$2\text{Mg(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{MgO(s)}$
Aluminium (Al)	$4\text{Al(s)} + 3\text{O}_2\text{(g)} \longrightarrow 2\text{Al}_2\text{O}_3\text{(s)}$
Zinc (Zn)	$2\text{Zn(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{ZnO(s)}$
Iron (Fe)	$2\text{Fe(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{FeO(s)}$
Lead (Pb)	$2\text{Pb(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{PbO(s)}$
Copper (Cu)	$2\text{Cu(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{CuO(s)}$
Mercury (Hg)	$2\text{Hg(s)} + \text{O}_2\text{(g)} \longrightarrow 2\text{HgO(s)}$

III. Reactions of Metals with Water / Steam (H₂O)


Metals react with water

Potassium	$2\text{K(s)} + 2\text{H}_2\text{O(l)} \longrightarrow 2\text{KOH(aq)} + \text{H}_2\text{(g)}$
Sodium	$2\text{Na(s)} + 2\text{H}_2\text{O(l)} \longrightarrow 2\text{NaOH(aq)} + \text{H}_2\text{(g)}$
Calcium	$\text{Ca(s)} + 2\text{H}_2\text{O(l)} \longrightarrow \text{Ca(OH)}_2\text{(aq)} + \text{H}_2\text{(g)}$

Heated metals react with steam

Magnesium	$\text{Mg(s)} + \text{H}_2\text{O(g)} \longrightarrow \text{MgO(s)} + \text{H}_2\text{(g)}$
Zinc	$\text{Zn(s)} + \text{H}_2\text{O(g)} \longrightarrow \text{ZnO(s)} + \text{H}_2\text{(g)}$
Iron	$\text{Fe(s)} + \text{H}_2\text{O(g)} \longrightarrow \text{FeO(s)} + \text{H}_2\text{(g)}$
(No reaction for Al)*	$2\text{Al(s)} + 3\text{H}_2\text{O(g)} \longrightarrow \text{Al}_2\text{O}_3\text{(s)} + 3\text{H}_2\text{(g)}$

***IV. Reactions of Metals with Dilute Hydrochloric Acid**

Reactivity	Metal	Equation
<p>Most reactive</p>  <p>Less reactive</p>	K	$2\text{K}(\text{s}) + 2\text{HCl}(\text{aq}) \longrightarrow 2\text{KCl}(\text{aq}) + \text{H}_2(\text{g})$
	Na	$2\text{Na}(\text{s}) + 2\text{HCl}(\text{aq}) \longrightarrow 2\text{NaCl}(\text{aq}) + \text{H}_2(\text{g})$
	Ca	$\text{Ca}(\text{s}) + 2\text{HCl}(\text{aq}) \longrightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2(\text{g})$
	Mg	$\text{Mg}(\text{s}) + 2\text{HCl}(\text{aq}) \longrightarrow \text{MgCl}_2(\text{aq}) + \text{H}_2(\text{g})$
	Al	$2\text{Al}(\text{s}) + 6\text{HCl}(\text{aq}) \longrightarrow 2\text{AlCl}_3(\text{aq}) + 3\text{H}_2(\text{g})$
	Zn	$\text{Zn}(\text{s}) + 2\text{HCl}(\text{aq}) \longrightarrow \text{ZnCl}_2(\text{aq}) + \text{H}_2(\text{g})$
	Fe	$\text{Fe}(\text{s}) + 2\text{HCl}(\text{aq}) \longrightarrow \text{FeCl}_2(\text{aq}) + \text{H}_2(\text{g})$
	Pb	$\text{Pb}(\text{s}) + 2\text{HCl}(\text{aq}) \longrightarrow \text{PbCl}_2(\text{aq}) + \text{H}_2(\text{g})$
	Cu	No reaction
	Hg	
Ag		
Au		

VI. Ionic Equations**Example:**

- $\text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) \longrightarrow \text{H}_2\text{O}(\text{l})$
- $2\text{I}^-(\text{aq}) + \text{Cl}_2(\text{g}) \longrightarrow 2\text{Cl}^-(\text{aq}) + \text{I}_2(\text{aq})$
- $\text{SnO}(\text{s}) + 2\text{H}^+(\text{aq}) \longrightarrow \text{Sn}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- $2\text{Na}(\text{s}) + 2\text{H}^+(\text{aq}) \longrightarrow 2\text{Na}^+(\text{aq}) + \text{H}_2(\text{g})$
- $\text{Fe}^{3+}(\text{aq}) + 3\text{OH}^-(\text{aq}) \longrightarrow \text{Fe}(\text{OH})_3(\text{s})$
- $2\text{Ag}^+(\text{aq}) + 2\text{OH}^-(\text{aq}) \longrightarrow \text{Ag}_2\text{O}(\text{s}) + \text{H}_2\text{O}(\text{l})$
- $\text{Cu}(\text{s}) + 4\text{H}^+(\text{aq}) + 2\text{NO}_3^-(\text{aq}) \longrightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{NO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$
- $\text{CaCO}_3(\text{s}) + 2\text{H}^+(\text{aq}) \longrightarrow \text{Ca}^{2+}(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$
- $2\text{MnO}_4^-(\text{aq}) + 16\text{H}^+(\text{aq}) + 10\text{Cl}^-(\text{aq}) \longrightarrow 2\text{Mn}^{2+}(\text{aq}) + 5\text{Cl}_2(\text{g}) + 8\text{H}_2\text{O}(\text{l})$
- $\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{Fe}^{2+}(\text{aq}) \longrightarrow 6\text{Fe}^{3+}(\text{aq}) + 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$

VII. Displacement Reactions 置換反應

Write Full and Ionic equations for the following reactions.

Metal	$\text{Cu}^{2+} (\text{aq})$	$\text{Mg}^{2+} (\text{aq})$	$\text{Zn}^{2+} (\text{aq})$	$\text{Fe}^{2+} (\text{aq})$	$\text{Ag}^{+} (\text{aq})$
Copper		No change	No change	No change	$\text{Cu} + 2\text{AgNO}_3 \rightarrow \text{Cu}(\text{NO}_3)_2 + 2\text{Ag}$ $\text{Cu} + 2\text{Ag}^{+} \rightarrow \text{Cu}^{2+} + 2\text{Ag}$
Magnesium	$\text{Mg} + \text{Cu}(\text{NO}_3)_2 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{Cu}$ $\text{Mg} + \text{Cu}^{2+} \rightarrow \text{Mg}^{2+} + \text{Cu}$		$\text{Mg} + \text{Zn}(\text{NO}_3)_2 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{Zn}$ $\text{Mg} + \text{Zn}^{2+} \rightarrow \text{Mg}^{2+} + \text{Zn}$	$\text{Mg} + \text{Fe}(\text{NO}_3)_2 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{Fe}$ $\text{Mg} + \text{Fe}^{2+} \rightarrow \text{Mg}^{2+} + \text{Fe}$	$\text{Mg} + 2\text{AgNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + 2\text{Ag}$ $\text{Mg} + 2\text{Ag}^{+} \rightarrow \text{Mg}^{2+} + 2\text{Ag}$
Zinc	$\text{Zn} + \text{Cu}(\text{NO}_3)_2 \rightarrow \text{Zn}(\text{NO}_3)_2 + \text{Cu}$ $\text{Zn} + \text{Cu}^{2+} \rightarrow \text{Zn}^{2+} + \text{Cu}$	No change		$\text{Zn} + \text{Fe}(\text{NO}_3)_2 \rightarrow \text{Zn}(\text{NO}_3)_2 + \text{Fe}$ $\text{Zn} + \text{Fe}^{2+} \rightarrow \text{Zn}^{2+} + \text{Fe}$	$\text{Zn} + 2\text{AgNO}_3 \rightarrow \text{Zn}(\text{NO}_3)_2 + 2\text{Ag}$ $\text{Zn} + 2\text{Ag}^{+} \rightarrow \text{Zn}^{2+} + 2\text{Ag}$
Iron	$\text{Fe} + \text{Cu}(\text{NO}_3)_2 \rightarrow \text{Fe}(\text{NO}_3)_2 + \text{Cu}$ $\text{Fe} + \text{Cu}^{2+} \rightarrow \text{Fe}^{2+} + \text{Cu}$	No change	No change		$\text{Fe} + 2\text{AgNO}_3 \rightarrow \text{Fe}(\text{NO}_3)_2 + 2\text{Ag}$ $\text{Fe} + 2\text{Ag}^{+} \rightarrow \text{Fe}^{2+} + 2\text{Ag}$
Silver	No change	No change	No change	No change	

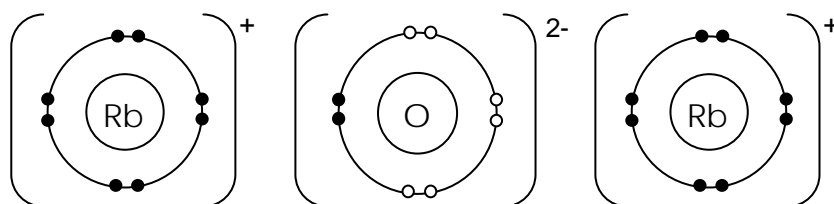
Supplementary Exercise

- A1. (a) sodium (b) copper, iron
 (c) copper, zinc (and iron) (d) aluminium, sodium
 (e) sodium (f) copper

- A2. (a) P : zinc
 Q : silver (or copper)
 (b) magnesium, zinc, silver (or copper)
 (c) $\text{Zn(s)} + 2\text{H}^+(\text{aq}) \longrightarrow \text{Zn}^{2+}(\text{aq}) + \text{H}_2(\text{g})$

- A3. (a) Rb_2O

The melting point of Rb_2O is higher than that of SO_3 because Rb_2O is an ionic compound, the ions are held together by strong electrostatic force while SO_3 is a covalent compound, the molecules are held together by weak van der Waal's force.



- (b) Rb is more reactive than K because the size of Rb atom is larger, its outermost electron is held less strongly and is thus easier to be lost.
 (c) Electrolysis of molten RbCl , Rb is liberated at the cathode.
 (d) Rb melts to a silvery ball and darts about on the water surface with a hissing sound, becoming smaller and smaller in size. Hydrogen gas is given off, and it burns spontaneously.

$$2\text{Rb(s)} + 2\text{H}_2\text{O(l)} \longrightarrow 2\text{RbOH(aq)} + \text{H}_2(\text{g})$$

 (e) Rb has two isotopes ^{85}Rb and ^{87}Rb .
 85.5 is the weighted average.
 (f) (i) flammable and corrosive.
 (ii) keep out of water.
- A4. (a) A layer of inert oxide of aluminium (Al_2O_3) prevents the metal from further oxidation.
 (b) Aluminium is lighter than steel.
 (c) Since soft-drink may contain acids that may dissolve the Al_2O_3 layer, the plastic film is used to protect the oxide from contact with the soft-drink.
 (d) hydrochloric acid
 (e) $3\text{HCl(aq)} + \text{Al(OH)}_3(\text{s}) \longrightarrow \text{AlCl}_3(\text{aq}) + 3\text{H}_2\text{O(l)}$
- A5. (a) (1) $2\text{H}^+(\text{aq}) + 2\text{Z(s)} \longrightarrow 2\text{Z}^+(\text{aq}) + \text{H}_2(\text{g})$
 (2) $\text{Y(s)} + \text{Fe}^{2+}(\text{aq}) \longrightarrow \text{Fe(s)} + \text{Y}^{2+}(\text{aq})$
 (b) $\text{Z} > \text{Y} > \text{Fe} > \text{X}$
 From experiment I and II, Z is the most reactive metal because it displaces hydrogen from water.
 From experiment II, Y must be more reactive than Fe because it displaces iron from FeSO_4 solution.
 From experiment III, X must be the least reactive metal (e.g. Ag) because its oxide X_2O decomposes to give the metal on heating.
 (c) Y. Because it is more reactive than iron / higher than iron in the electrochemical series (or reactivity series) and does not react readily with water.

- A6. (a) hydrogen
(b) Copper does not react with dilute HCl.
Copper forms a black powder.
Copper does not give a flame when heated.
(c) (i) magnesium / calcium / zinc.
(ii) e.g. magnesium oxide.
(iii) e.g. $\text{Mg(s)} + 2\text{HCl(aq)} \longrightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)}$
- A7. (a) Lithium and sodium (density $< 1.00 \text{ g/cm}^3$).
(b) copper
(c) (i) Lithium. It floats on water but is less active than sodium.
(ii) $2\text{Li(s)} + 2\text{H}_2\text{O(l)} \longrightarrow 2\text{LiOH(aq)} + \text{H}_2\text{(g)}$
- A8 (a) $2\text{Al(s)} + 3\text{CuSO}_4\text{(aq)} \longrightarrow \text{Al}_2\text{(SO}_4\text{)}_3\text{(aq)} + 3\text{Cu(s)}$
(b) Becomes covered with a brown deposit.
(c) Aluminium takes the place of copper in copper(II) sulphate.
(d) e.g. calcium ions. Al is lower than Ca in the reactivity series.
(e) Do it again after finishing Section 3.
6g of Al \longrightarrow 0.22 moles of Al;
from equation, 0.22 moles Al \longrightarrow 0.33 moles Cu \longrightarrow 21.12g Cu.
- A9 (a) B, C, D, A
(b) B: silver is displaced. D: no reaction.
(c) Iron or lead.
The metal must be above copper (as it reacts with CuSO_4 solution) and below zinc (no reaction with ZnSO_4 solution).
- A10 (a) $\text{Mg(s)} + \text{CuSO}_4\text{(aq)} \longrightarrow \text{MgSO}_4\text{(aq)} + \text{Cu(s)}$
(b) No reaction.
(c) $\text{Zn(s)} + 2\text{AgNO}_3\text{(aq)} \longrightarrow \text{Zn(NO}_3\text{)}_2\text{(aq)} + 2\text{Ag(s)}$
(d) $\text{Ca(s)} + 2\text{H}_2\text{O(l)} \longrightarrow \text{Ca(OH)}_2\text{(aq)} + \text{H}_2\text{(g)}$
(e) No reaction.
(f) $2\text{PbO(s)} + \text{C(s)} \longrightarrow 2\text{Pb(s)} + \text{CO}_2\text{(g)}$
- A11 (a) D but not A can react with cold water. Therefore D is more reactive.
(b) C more reactive. As oxide of B is reduced by heat alone, B is low in the reactivity series and will not react with dilute acid.
(c) B, A, C, D.
(d) (i) The order of reactivity is the order in which the metals were discovered.
(ii) More reactive metals discovered recently. It was more difficult to separate the metals from their compounds.
(e) B is silver or gold (oxide reduced by heat alone).
D is a very reactive metal, e.g. sodium.
A and C are between Ca and Pb in the reactivity series, with C above A.