Section Four : Acids (酸) and Alkalis (鹼)

Unit Fourteen: Acids

II. Properties of Dilute Acids (稀酸)

(d) ***Action on metals***: salt and hydrogen gas are formed.

e.g.2 $2HCl(aq) + Zn(s) \longrightarrow ZnCl_2(aq) + H_2(g)$

Ionic equation:

$2H^+(aq) + \cancel{2Cl^-(aq)} + Zn(s) \longrightarrow Zn^{2+}(aq) + \cancel{2Cl^-(aq)} + H_2(g)$

$2H^+(aq) + Zn(s) \longrightarrow Zn^{2+}(aq) + H_2(g)$

e.g.3 $2CH_3COOH(aq) + 2Na(s) \longrightarrow 2CH_3COO^-Na^+(aq) + H_2(g)$

Ionic equation:

$\cancel{2CH_3COO^-(aq)} + 2H^+(aq) + 2Na(s) \longrightarrow \cancel{2CH_3COO^-(aq)} + 2Na^+(aq) + H_2(g)$

$2H^+(aq) + 2Na(s) \longrightarrow 2Na^+(aq) + H_2(g)$

(e) ***Action on carbonate and hydrogencarbonate***:

e.g.1 $2HNO_3(aq) + Na_2CO_3(aq) \longrightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$

Ionic equation:

$2H^+(aq) + \cancel{2NO_3^-(aq)} + \cancel{2Na^+(aq)} + CO_3^{2-}(aq) \longrightarrow \cancel{2Na^+(aq)} + \cancel{2NO_3^-(aq)} + H_2O(l) + CO_2(g)$

$2H^+(aq) + CO_3^{2-}(aq) \longrightarrow H_2O(l) + CO_2(g)$

e.g.2 $HCl(aq) + KHCO_3(aq) \longrightarrow KCl(aq) + H_2O(l) + CO_2(g)$

Ionic equation:

$H^+(aq) + \cancel{Cl^-(aq)} + \cancel{K^+(aq)} + HCO_3^-(aq) \longrightarrow \cancel{K^+(aq)} + \cancel{Cl^-(aq)} + H_2O(l) + CO_2(g)$

$H^+(aq) + HCO_3^-(aq) \longrightarrow H_2O(l) + CO_2(g)$

(f) ***Action on metal oxides and hydroxide (Neutralisation)***:

e.g.1 $H_2SO_4(aq) + Na_2O(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l)$

Ionic equation:

$2H^+(aq) + \cancel{SO_4^{2-}(aq)} + \cancel{2Na^+(aq)} + O^{2-}(aq) \longrightarrow \cancel{2Na^+(aq)} + \cancel{SO_4^{2-}(aq)} + H_2O(l)$

$2H^+(aq) + O^{2-}(aq) \longrightarrow H_2O(l)$

e.g.2 $HCl(aq) + KOH(aq) \longrightarrow KCl(aq) + H_2O(l)$

Ionic equation:

$H^+(aq) + \cancel{Cl^-(aq)} + \cancel{K^+(aq)} + OH^-(aq) \longrightarrow \cancel{K^+(aq)} + \cancel{Cl^-(aq)} + H_2O(l)$

$H^+(aq) + OH^-(aq) \longrightarrow + H_2O(l)$

IV. Basicity (鹽基度) of an Acid

Acid	Ionization in water	Basicity
Sulphuric acid	$H_2SO_4(aq) \longrightarrow H^+(aq) + HSO_4^-(aq)$ $HSO_4^-(aq) \longrightarrow H^+(aq) + SO_4^{2-}(aq)$ Overall: $H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$	2 or dibasic (二鹽基度)
Sulphurous acid	$H_2SO_3(aq) \longrightarrow H^+(aq) + HSO_3^-(aq)$ $HSO_3^-(aq) \longrightarrow H^+(aq) + SO_3^{2-}(aq)$ Overall: $H_2SO_3(aq) \longrightarrow 2H^+(aq) + SO_3^{2-}(aq)$	
Carbonic acid	$H_2CO_3(aq) \longrightarrow H^+(aq) + HCO_3^-(aq)$ $HCO_3^-(aq) \longrightarrow H^+(aq) + CO_3^{2-}(aq)$ Overall: $H_2CO_3(aq) \longrightarrow 2H^+(aq) + CO_3^{2-}(aq)$	
Phosphoric acid	$H_3PO_4(aq) \longrightarrow H^+(aq) + H_2PO_4^-(aq)$ $H_2PO_4^{2-}(aq) \longrightarrow H^+(aq) + HPO_4^{2-}(aq)$ $HPO_4^{2-}(aq) \longrightarrow H^+(aq) + PO_4^{3-}(aq)$ Overall: $H_3PO_4(aq) \longrightarrow 3H^+(aq) + PO_4^{3-}(aq)$	3 or tribasic (三鹽基度)

VI. General Characteristics of Concentrated Acids (濃酸)

A. Hydrochloric Acid

Compare the behaviour of dilute and concentrated hydrochloric acid:

Test	Action of dil. HCl (2M)	Action of conc. HCl (11M)
Adding zinc granule	The gas bubbles burn with a pop sound in burning splint test. ***Equation:*** $Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$	
Adding calcium carbonate	The gas turns limewater milky. ***Equation:*** $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$	
Adding copper(II) oxide	***Equation:*** $CuO(s) + 2HCl(aq) \longrightarrow CuCl_2(aq) + H_2O(l)$	

B. *Nitric Acid*

1. *Acid properties of nitric acid*

Example:

$$Zn(s) + HNO_3(aq) \longrightarrow Zn(NO_3)_2(aq) + H_2(g)$$

$$Cu(s) + HNO_3(aq) \longrightarrow \text{no reaction}$$

2. *Oxidizing properties of nitric acid (Refer to Section Five)*

(i) Oxidizing action of ***dilute nitric acid*** *(2M)*

(b) Copper (Below hydrogen in E.C.S.)

Equations:

$$HNO_3(aq) + 3H^+(aq) + 3e^- \longrightarrow NO(g) + 2H_2O(l)$$
$$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$$
$$2HNO_3(aq) + 6H^+(aq) + 3Cu(s) \longrightarrow 2NO(g) + 4H_2O(l) + 3Cu^{2+}(aq)$$

(ii) Oxidizing action of ***concentrated nitric acid***

(a) Magnesium

Equations:

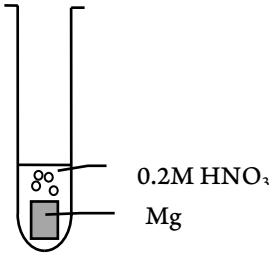
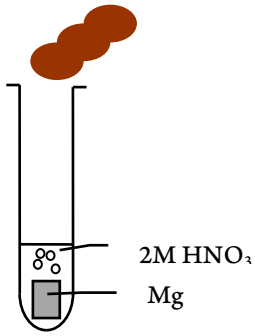
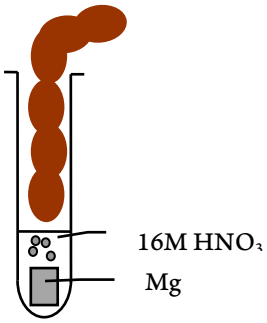
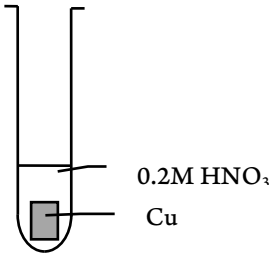
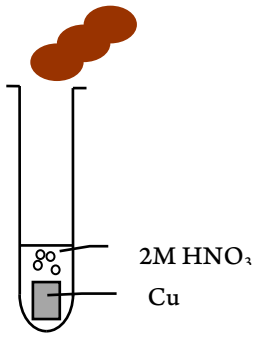
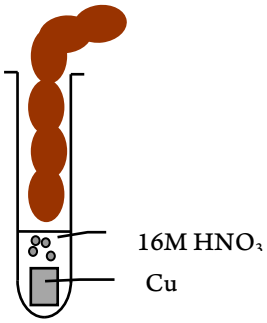
$$HNO_3(aq) + H^+(aq) + e^- \longrightarrow NO_2(g) + H_2O(l)$$
$$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^-$$
$$2HNO_3(aq) + 2H^+(aq) + Mg(s) \longrightarrow 2NO_2(g) + 2H_2O(l) + Mg^{2+}(aq)$$

(b) Copper

Equations:

$$HNO_3(aq) + H^+(aq) + e^- \longrightarrow NO_2(g) + H_2O(l)$$
$$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$$
$$2HNO_3(aq) + 2H^+(aq) + Cu(s) \longrightarrow 2NO_2(g) + 2H_2O(l) + Cu^{2+}(aq)$$

Compare the behaviour of very dilute, dilute and concentrated nitric acid

<table>
<tr><th rowspan="2">Tests</th><th colspan="3">Observations of reactions with nitric acid</th></tr>
<tr><th>Very dilute (0.2M)</th><th>Dilute (2M)</th><th>Concentrated (16M)</th></tr>
<tr><td rowspan="2">Adding magnesium</td><td> 
</td><td> 
</td><td> 
</td></tr>
<tr><td>ACID behaviour</td><td colspan="2">O.A. beahviour</td></tr>
<tr><td rowspan="2">Adding copper</td><td> 
</td><td> 
</td><td> 
</td></tr>
<tr><td>ACID behaviour</td><td colspan="2">O.A. beahviour</td></tr>
<tr><td rowspan="2">Adding calcium carbonate</td><td colspan="3">$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$</td></tr>
<tr><td colspan="3">ACID behaviour</td></tr>
<tr><td rowspan="2">Adding copper(II) oxide</td><td colspan="3">$CuO(s) + 2HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + H_2O(l)$</td></tr>
<tr><td colspan="3">ACID behaviour</td></tr>
</table>

C. Sulphuric acid

Compare the behaviour of dilute and concentrated sulphuric acid

Test	Action of dil.H_2SO_4 (2M)	Action of conc. H_2SO_4 (18M)
Adding zinc granule	$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$	$Zn(s) + H_2SO_4(aq) + 2H^+(aq) \longrightarrow Zn^{2+}(aq) + SO_2(g) + 2H_2O(l)$
Adding copper granule	No reaction	$Cu(s) + H_2SO_4(aq) + 2H^+(aq) \longrightarrow Cu^{2+}(aq) + SO_2(g) + 2H_2O(l)$
Adding calcium carbonate	$CaCO_3(s) + H_2SO_4(aq) \longrightarrow CaSO_4(s) + H_2O(l) + CO_2(g)$	

Adding copper(II) oxide	$CuO(s) + H_2SO_4(aq) \xrightarrow{heat} CuSO_4(aq) + H_2O(l)$	
Adding Sucrose	No reaction	$C_{12}H_{22}O_{11}(s) \longrightarrow 12C(s) + 11H_2O(l)$
Adding Cellulose		$[C_6H_{10}O_5]_n(s) \longrightarrow 6nC(s) + 5nH_2O(l)$
Adding Sulphur		$S(s) + 2H_2SO_4(l) \longrightarrow 3SO_2(g) + 2H_2O(l)$
Adding Carbon		$C(s) + 2H_2SO_4(l) \longrightarrow CO_2(g) + 2SO_2(g) + 2H_2O(l)$

Revision 1: Reaction of acid with carbonate and hydrogencarbonate

	K_2CO_3 / Na_2CO_3 ($M^+ CO_3^{2-}$)	**$CaCO_3$ / $MgCO_3$ / $ZnCO_3$ / $FeCO_3$ ($M^{2+} CO_3^{2-}$)**	**$Al_2(CO_3)_3$ ($M^{3+} CO_3^{2-}$)**	**$KHCO_3$ / $NaHCO_3$ ($M^+ HCO_3^-$)**	**$Ca(HCO_3)_2$ / $Mg(HCO_3)_2$ ($M^{2+} HCO_3^-$)**
HCl	$M_2CO_3 + 2HCl \longrightarrow 2MCl + H_2O + CO_2$	$MCO_3 + 2HCl \longrightarrow MCl_2 + H_2O + CO_2$	$M_2(CO_3)_3 + 6HCl \longrightarrow 2MCl_3 + 3H_2O + 3CO_2$	$MHCO_3 + HCl \longrightarrow MCl + H_2O + CO_2$	$M(HCO_3)_2 + 2HCl \longrightarrow MCl_2 + 2H_2O + 2CO_2$
HNO_3	$M_2CO_3 + 2HNO_3 \longrightarrow 2MNO_3 + H_2O + CO_2$	$MCO_3 + 2HNO_3 \longrightarrow M(NO_3)_2 + H_2O + CO_2$	$M_2(CO_3)_3 + 6HNO_3 \longrightarrow 2M(NO_3)_3 + 3H_2O + 3CO_2$	$MHCO_3 + HNO_3 \longrightarrow MNO_3 + H_2O + CO_2$	$M(HCO_3)_2 + 2HNO_3 \longrightarrow M(NO_3)_2 + 2H_2O + 2CO_2$
H_2SO_4	$M_2CO_3 + H_2SO_4 \longrightarrow M_2SO_4 + H_2O + CO_2$	$MCO_3 + H_2SO_4 \longrightarrow MSO_4 + H_2O + CO_2$	$M_2(CO_3)_3 + 3H_2SO_4 \longrightarrow M_2(SO_4)_3 + 3H_2O + 3CO_2$	$2MHCO_3 + H_2SO_4 \longrightarrow M_2SO_4 + 2H_2O + 2CO_2$	$M(HCO_3)_2 + H_2SO_4 \longrightarrow MSO_4 + 2H_2O + 2CO_2$

Revision 2: Reaction of acid with oxide and hydroxide

	Na_2O / K_2O ($M^+ O^{2-}$)	**CaO / MgO / ZnO / FeO ($M^{2+} O^{2-}$)**	**Al_2O_3 ($M^{3+} O^{2-}$)**	**KOH / $NaOH$ ($M^+ OH^-$)**	**$Ca(OH)_2$ / $Mg(OH)_2$/ $Zn(OH)_2$ ($M^{2+} OH^-$)**
HCl	$M_2O + 2HCl \longrightarrow 2MCl + H_2O$	$MO + 2HCl \longrightarrow MCl_2 + H_2O$	$M_2O_3 + 6HCl \longrightarrow 2MCl_3 + 3H_2O$	$MOH + HCl \longrightarrow MCl + H_2O$	$M(OH)_2 + 2HCl \longrightarrow MCl_2 + 2H_2O$
HNO_3	$M_2O + 2HNO_3 \longrightarrow 2M(NO_3)_2 + H_2O$	$MO + 2HNO_3 \longrightarrow M(NO_3)_2 + H_2O$	$M_2O_3 + 6HNO_3 \longrightarrow 2M(NO_3)_3 + 3H_2O$	$MOH + HNO_3 \longrightarrow MNO_3 + H_2O$	$M(OH)_2 + 2HNO_3 \longrightarrow M(NO_3)_2 + 2H_2O$
H_2SO_4	$M_2O + H_2SO_4 \longrightarrow M_2SO_4 + H_2O$	$MO + H_2SO_4 \longrightarrow MSO_4 + H_2O$	$M_2O_3 + 3H_2SO_4 \longrightarrow M_2(SO_4)_3 + 3H_2O$	$2MOH + H_2SO_4 \longrightarrow M_2SO_4 + 2H_2O$	$M(OH)_2 + H_2SO_4 \longrightarrow MSO_4 + 2H_2O$

Revision 3: Reaction of metals with dilute and concentrated acids

	K / Na	Ca/ Mg/ Zn/ Fe	Al	Cu	Ag
dil. and conc. HCl	$2M + 2HCl \longrightarrow 2MCl + H_2$	$M + 2HCl \longrightarrow MCl_2 + H_2$	$2M + 6HCl \longrightarrow 2MCl_3 + 3H_2$	No reaction	No reaction
dil. HNO_3	$2M + 2HNO_3 \longrightarrow 2MNO_3 + H_2$	$2M + 2HNO_3 \longrightarrow M(NO_3)_2 + H_2$	$2M + 6HNO_3 \longrightarrow 2M(NO_3)_3 + 3H_2$	No reaction	No reaction
bench HNO_3	$3M + HNO_3 + 3H^+ \rightarrow 3M^+ + NO + 2H_2O$	$3M + 2HNO_3 + 6H^+ \rightarrow 3M^{2+} + 2NO + 4H_2O$	$M + HNO_3 + 3H^+ \rightarrow M^{3+} + NO + 2H_2O$	$3M + 2HNO_3 + 6H^+ \rightarrow 3M^{2+} + 2NO + 4H_2O$	$3M + HNO_3 + 3H^+ \rightarrow 3M^+ + NO + 2H_2O$
conc. HNO_3	$M + HNO_3 + H^+ \rightarrow M^+ + NO_2 + H_2O$	$M + 2HNO_3 + 2H^+ \rightarrow M^{2+} + 2NO_2 + 2H_2O$	$M + 3HNO_3 + 3H^+ \rightarrow M^{3+} + 3NO_2 + 3H_2O$	$M + 2HNO_3 + 2H^+ \rightarrow M^{2+} + 2NO_2 + 2H_2O$	$M + HNO_3 + H^+ \rightarrow M^+ + NO_2 + H_2O$
dil. H_2SO_4	$2M + H_2SO_4 \longrightarrow M_2SO_4 + H_2$	$M + H_2SO_4 \longrightarrow MSO_4 + H_2$	$2M + 3H_2SO_4 \longrightarrow M_2(SO_4)_3 + 3H_2$	No reaction	No reaction
conc. H_2SO_4	$2M + H_2SO_4 + 2H^+ \rightarrow 2M^+ + SO_2 + 2H_2O$	$M + H_2SO_4 + 2H^+ \rightarrow M^{2+} + SO_2 + 2H_2O$	$2M + 3H_2SO_4 + 6H^+ \rightarrow 2M^{3+} + 3SO_2 + 6H_2O$	$M + H_2SO_4 + 2H^+ \rightarrow M^{2+} + SO_2 + 2H_2O$	$2M + H_2SO_4 + 2H^+ \rightarrow 2M^+ + SO_2 + 2H_2O$

Supplementary Exercise

A1. (a) $2Al(s) + 6HNO_3(aq) \longrightarrow 2Al(NO_3)_3(aq) + 3H_2(g)$

(b) Hold a burning splint to the gas. The gas burns with a "pop" sound.

(c) Mole of Al = 0.2; moles of aluminium nitrate formed = 0.2; mass of aluminium nitrate = 42.6g

A2. (a) (i) Moist acid reacts with the sodium hydrogencarbonate.

(ii) $NaHCO_3(s) + HA(aq) \longrightarrow NaA(aq) + H_2O(l) + CO_2(g)$

(iii) The reaction with acid forms carbon dioxide.

The gas makes the cake "rise".

(b) To neutralize the acid spilt on skin after first washing to dilute the acid.

A3. (a) (i) $50cm^3$

(ii) measuring cylinder

(b) To control factors that may affect the speed of reaction.

If volume affects speed, equal volumes keep this factor the same in each experiment.

(c) Compare the speed at which bubbles are produced.

(d) Solution of pH 1. Magnesium reacts fastest with a strong acid.

(e) Hydrogen