1. (a) Explain what is meant by the terms:

i. Bronsted-Lowry acid,
ii. Bronsted-Lowry base.

(b) Identify any Bronsted-Lowry acids and bases in the following systems:

i. $HCl(aq) + NaOH(aq) \text{ ---> } NaCl(aq) + H_2O(l)$

ii. $CH_3COOH(aq) + H_2O(l) \text{ ---> } CH_3COO^-(aq) + H_3O^+(aq)$

iii. $CH_3COOH(aq) + HCl(aq) \text{ ---> } CH_3COOH_2^+(aq) + Cl^-(aq)$

iv. $2H_2SO_4(l) \text{ ---> } H_3SO_4^+(l) + HSO_4^-(l)$

v. $NH_3(aq) + H_2O(l) \text{ ---> } NH_4^+(aq) + OH^-(aq)$

2. The ionisation of phenol in water can be represented by the equation.

$$C_6H_5OH + H_2O \rightleftharpoons C_6H_5O^- + H_3O^+$$

(a) Identify the Bronsted lowry acid and base in the above equilibrium.
(b) Name the H_3O^+ ion.
(c) Write an expression for the equilibrium constant for the above reaction.

3. For each of the following equilibria identify the conjugate base and conjugate acid.

(a) $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$

(b) $HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$

(c) $HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$

(d) $2H_2SO_4(l) \rightleftharpoons H_3SO_4^+(l) + HSO_4^-(l)$

4. Water has a small but measurable electrical conductivity, due to reversible self ionisation.

$$2H_2O \rightleftharpoons H_3O^+ + OH^- \quad \Delta H \text{ (forward) } = -57\text{kJ mol}^{-1}$$

(a) Write an expression for the ionic product of water, Kw.
(b) What is the value of Kw at 25°C?
(c) What is the concentration of hydroxonium ions in water at 25°C?
(d) What effect does increasing the temperature of water have on the hydroxonium ion concentration?

H_2O Ex 2.9

1. (a) (i) An acid is a substance that can donate a proton

(ii) A base is a substance that can accept a proton

(b) (i) Acid - $H_3O^+(aq)$ base - $OH^-(aq)$

(ii) Acid - $CH_3COOH(aq)$ base - $H_2O(l)$

(iii) Acid - $H_3O^+(aq)$ base $CH_3COOH(aq)$

(iv) Acid - $H_2SO_4(l)$ base $H_2SO_4(l)$

(v) Acid - $H_2O(l)$ base $NH_3(aq)$

2. (a) Acid C_6H_5OH base H_2O.

(b) hydronium or oxonium or hydroxonium

(c) $K = \frac{[C_6H_5O^-][H_3O^+]}{[C_6H_5OH][H_2O]}$ or $\frac{[C_6H_5O^-][H_3O^+]}{[C_6H_5OH]}$

3 (a) NH_4^+ conjugate acid of NH_3

OH^- " base of H_2O

(b) H_3O^+ " acid of H_2O

Cl^- " base of HCl

(c) H_3O^+ " acid of H_2O

$HCOO^-$ " base of $HCOOH$

(d) $H_3SO_4^+$ " acid of $H_2SO_4(l)$

HSO_4^- " base of $H_2SO_4(l)$

4. (a) $[H^+][OH^-] = K_w$ or $[H_3O^+][OH^-] = K_w$

(b) 1×10^{-14} mol^2/l^2

(c) $[H_3O^+]^2 = \sqrt{1 \times 10^{-14}}$ $= 1 \times 10^{-7}$ mol/l

(d) Increase since K_w increases with temp.

Hydrogen ion concentration & pH 2.10

1. Calculate the concentration of hydrogen ions in the following solutions. In each case assume that the acid is fully ionised.

(*a*) 0·1 mol l^{-1} hydrochloric acid (HCl) (*b*) 0·02 mol l^{-1} sulphuric acid (H_2SO_4)

(*c*) 0·3 mol l^{-1} nitric acid (HNO_3) (*d*) 0·05 mol l^{-1} phosphoric acid (H_3PO_4)

2. Calculate (i) the hydrogen ion concentration and (ii) the pH , of the following solutions.

(a) 0·5 mol l^{-1} hydrochloric acid (b) 0·05 mol l^{-1} sulphuric acid

(c) 0·8 mol l^{-1} sodium hydroxide (d) 2 mol l^{-1} nitric acid

(e) 0·05 mol l^{-1} calcium hydroxide (f) 2 x 10^{-3} mol l^{-1} potassium hydroxide

3. Comparing solutions of sulphuric and sulphurous acid of equal concentrations.

(*a*) Which has the higher conductivity? Explain your answer.
(*b*) Which has the higher pH? Explain your answer.
(*c*) Which gives the slower reaction with metals? Explain your answer.

4. Nitrous acid (HNO_2) acid is a weak acid, while nitric acid (HNO_3) is a strong acid. In each case the equilibria in aqueous solution are

Nitrous acid $HNO_2 \rightleftharpoons H^+ + NO_2^-$

Nitric acid $HNO_3 \rightleftharpoons H^+ + NO_3^-$

(a) In the case of nitric acid does the equlibrium lie towards the right or left?
(b) Use the equilibrium for nitrous acid to explain why 100 cm^3 of 0·1 mol l^{-1} nitrous acid requires the same amount of acid for neutralisation as 100 cm^3 of 0·1 mol l^{-1} nitric acid, although the nitrous acid solution contains many fewer hydrogen ions.

5. For each of the following solutions calculate the concentration of

(i) hydrogen ions (ii) hydroxide ions

(a) hydrochloric acid pH 4·5 (b) sulphuric acid pH 3·6

(c) sodium hydroxide solution pH 10·7 (d) ammonia solution pH 9·8

2.10

1\. (a) $[H^+] = 0.1$ mol/l (b) $[H^+] = 2 \times 0.02 = 0.04$ mol/l

c) $[H^+] = 0.3$ mol/l (d) $[H^+] = 3 \times 0.05 = 0.15$ mol/l

2\. (a)(i) $[H^+] = 0.5$ mol/l

(ii) $pH - \log[0.5] = 0.30$

(b) $[H^+] = 2 \times 0.05 = 0.1$ mol/l

$pH = -\log[0.1] = 1$

(c)(i) $[OH^-] = 0.8$ mol/l

$[H^+] = \frac{1 \times 10^{-14}}{0.8} = 1.25 \times 10^{-14}$ mol/l

$pH = -\log[1.25 \times 10^{-14}]$

$= 13.9$

(d) $[H^+] = 2$ mol/l

$pH = -\log[H^+] = -\log[2]$

$= -0.3$

(e) $[OH^-] = 2 \times 0.05 = 0.1$ mol/l

$[H^+] = \frac{1 \times 10^{-14}}{0.1} = 1 \times 10^{-13}$ mol/l

$pH = -\log[1 \times 10^{-13}] = 13$

(f) $[OH^-] = 2 \times 10^{-3}$

$[H^+] = \frac{1 \times 10^{-14}}{2 \times 10^{-3}} = 5 \times 10^{-12}$

$pH = -\log[5 \times 10^{-12}]$

$= 11.3$

3\.

(a) Sulphuric has the higher conductivity because it is a stronger acid therefore will ionise more in water and more ions will result in a high conductivity

(b) Sulphurous has the high pH because it is a weaker acid therefore it will be less ionised in water than H_2SO_4 therefore will have a lower concentration of H^+ ions

(c) Sulphurous will have slower rate of reactn with metals as rate of a reactn will proportional to $[H^+]$

4 (a) Right

(b) Although Nitrous acid has a low concentration of H^+ ions, when they are removed by OH^- ions from the alkali that is added, the equilibrium shifts to right and more H^+ ions are produced. This process continues untill all Nitrous acid molecules have ionized therefore 100 cm^3 of 0.1 Mol/l Nitrous acid will require same amount of alkali to neutralise as 0.1 mol/l Nitric acid.

5.

(a)

$[H^+] = \text{antilog}(-4.5)$

$= 3.16 \times 10^{-5}$ mol/l

$[OH^-] = \frac{1 \times 10^{-14}}{3.16 \times 10^{-5}}$

$= 3.16 \times 10^{-10}$ mol/l

(b)

$[H^+] = \text{antilog}(-3.6)$

$= 2.51 \times 10^{-4}$ mol/l

$[OH^-] = \frac{1 \times 10^{-14}}{2.51 \times 10^{-4}}$

$= 3.98 \times 10^{-11}$ mol/l

(c)

$[H^+] = \text{antilog}(-10.7)$

$= 1.99 \times 10^{-11}$ mol/l

$[OH^-] = \frac{1 \times 10^{-14}}{1.99 \times 10^{-11}}$

$= 5.02 \times 10^{-4}$ mol/l

(d)

$[H^+] = \text{antilog}(-9.8)$

$= 1.58 \times 10^{-10}$ mol/l

$[OH^-] = \frac{1 \times 10^{-14}}{1.58 \times 10^{-10}}$

$= 6.33 \times 10^{-5}$ mol/l