CH1011 Tutorial 9 Answers

1. Calculate the hydrogen ion concentration, pH and pOH for a 0.100 M solution of hypochlorous acid (HClO, $pK_a = 7.52$).

 $HClO + H_2O \stackrel{\Longrightarrow}{\leftarrow} H_3O^+ + Cl^-$

 $\begin{array}{ll} pKa = -\log_{10}K_{a} & K_{a} = 10^{(\text{-pKa})} = 10^{-7.52} = 3.00 \text{ x } 10^{-8} \\ [\text{H}^{+}] = (K_{a}C_{acid})^{1/2} = (3.00 \text{ x } 10^{8} \text{ x } 0.10 \text{ mol } \text{dm}^{-3})^{1/2} = \textbf{5.48 x } 10^{-5} \text{ M} \\ \textbf{pH} = -\log_{10}[\text{H}^{+}] = -\log_{10}(5.48 \text{ x } 10^{-5}) = \textbf{4.26} \\ pK_{w} = \text{pOH} + \text{pH} = 14 \\ \textbf{pOH} = 14 - \text{pH} = 14 - 4.26 = \textbf{9.74} \\ \text{Alternatives: pH} = 0.5(\text{pKa } -\log_{10}[\text{HA}]) \qquad [\text{OH}] = K_w/[\text{H}^{+}] \end{array}$

2. Define the working range of an indicator and the equivalence point of a titration. How should a suitable indicator for a titration between an acid and a base be chosen?

The *working range* of an indicator is the pH range where an indicator changes colour, generally this is centered at a value specific for the indicator and takes around 2 pH units (pK_{In} +/- 1). The *equivalence point of a titration* is the point in a titration of an acid and a base where

 $n_{\text{base}} = n_{\text{acid}}$

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A *suitable indicator* for a acid / base titration is one which has a working range that occurs in the region of the equivalence point where the pH is changing rapidly. Ideally the working range and equivalence point will occur within one drop of the titrant and thereby indicate the endpoint of the titration.

3. What is the function of a **buffer solution** and how do the various components of a buffer contribute to this function. Illustrate your answer using carbonic acid (H_2CO_3 ; $pK_{a1} = 6.36$).

The function of a buffer solution is to moderate pH changes in solution – effectively a "pH shock absorber".

When small amounts of either an acid or base are added to a buffer the pH changes only very slightly. A buffer is composed of two components 1) a weak acid in moderate/high concentration and 2) the conjugate base of the weak acid (salt of the weak acid) also in moderate/high concentration.

 $H_2CO_3 + H_2O \implies HCO_3^- + H_3O^+$ Weak acid Conjugate Base

When an acid is added to the buffer then the bicarbonate base reacts with it. As there is a large amount of this base the pH of the solution changes only slightly as the pH is primarily determined by the H_2CO_3/HCO_3^- equilibrium which remains essentially the same (only a small amount of HCO_3^- converted into H_2CO_3 .

4. Acid rain is a minor problem in some regions of Australia but a major problem in several countries internationally.

- What are the major components of acid rain?
- How does acid rain form?

When the pH of rain falls below 4.9 it is referred to as acid rain. The main components are the mineral acids: H_2SO_4 (70%) and HNO_3 (30%) Overall components of acidity: H_2SO_4 , HNO_3 , H_2CO_3 , HCl and organic acids including CH₃SO₃H.

Acid rain forms when the emissions from coal fired power stations or smelters react in the atmosphere to form the acids:

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$
 $SO_3 + H_2O \leftrightarrows H_2SO_4$

There are also heterogeneously catalysed reactions which form H_2SO_4 using metal particles from dust on the inside of fog, cloud or rain drops.

$$2SO_2 + 2H_2O + O_2 \implies 2H_2SO_4$$
 (aqueous, Mn catalyst)

Another gas that is an important contributor to acid formation is NO_x formed from high temperature combustion, either in furnaces or internal combustion engines. The hydroxyl radical is always present at a background level due to the photo-reaction of water.

$$NO_2 + OH \Leftrightarrow HNO_3$$
 (aqueous, Mn catalyst)

The chemical reactions that form H_2SO_4 and HNO_3 are not instantaneous and so this is a form of regional pollution as the harmful acids form a distance away from the source of the gases and may contribute to acidity in rainfall up to 3500km away from the source.

5. Reverse osmosis is widely used in obtaining freshwater from saline waters.

• Explain what you understand by the terms osmosis, osmotic pressure and reverse osmosis.

<u>Osmosis</u> is the diffusion of a solvent through a semi-permeable membrane from a region of high solvent concentration to one of lower solvent concentration.

Osmotic Pressure (π) is the pressure associated with the process of osmosis π = [solute]RT. It can be defined as the magnitude of the pressure that must be applied to the system (on the side of the membrane containing the lowest solvent concentration) which just prevents osmosis from occurring.

In <u>**Reverse Osmosis**</u> the solvent passes through a membrane from a region of low solvent concentration to one of higher concentration (e.g. from salt solution to pure water). This is achieved by applying a pressure on the low solvent concentration side of the membrane which is greater than the natural osmotic pressure of the system. $p_{ext} > \pi$