Chapter 21: Further aspects of equilibria

Homework questions

1 A group of students was asked to find the pH of an unknown solution. They were provided with the following apparatus and chemicals:
* standard hydrogen electrode plus a supply of hydrogen
* standard Cu/Cu^{2+} half-cell electrode
* buffer solutions with pH values 4, 7, 9, plus solutions of 0.1 mol dm^{-3} hydrochloric acid and 0.1 mol dm^{-3} sodium hydroxide
* filter paper soaked in saturated potassium nitrate solution
* a high resistance voltmeter.

Giving essential experimental details, explain how you could use this apparatus to find the pH of the unknown solution. Your account should include the following:
* a diagram of the apparatus you would use
* any equations you would use and a description of the graphs you would draw
* a description of how the buffers, HCl and NaOH should be used.
  $[K_w = 1 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}]$

Total = 20

2 When bromine is added to water the following reaction takes place:
$$H_2O(l) + Br_2(l) \rightleftharpoons HOBr(aq) + HBr(aq)$$
a Explain why this is a disproportionation reaction. [3]
b The two acids formed are bromic(I) acid (HOBr) and hydrobromic acid (HBr). The pH values of their solutions are shown in the table below:

Acid	pH of 0.1 mol dm^{-3} solution
HOBr	4.83
HBr	1.0

   i Explain the terms **strong acid** and **weak acid**. [2]
   ii Using the pH value of its 0.1 mol dm^{-3} solution, explain why HBr is a strong acid. [2]
   iii Using the pH value of its 0.1 mol dm^{-3} solution, explain why HOBr may be considered a weak acid. [2]
   iv Calculate the acid dissociation constant, K_a, of HOBr. [3]
c **i** Draw a dot-and-cross diagram to show the bonding in HOBr. [1]
   ii Draw a molecule of HOBr and give the bond angle in the molecule. [2]
d When BrO^- ions are added to iodide ions in the presence of acid, iodine is formed along with bromide ions.
   i Write an equation for the reaction. [2]
   ii Describe what would be observed if the resulting solution was shaken with a nonpolar solvent, such as cyclohexane. [2]
   iii Explain why this happens. [2]

Total = 21

3 Dihydrogenphosphate ions ($H_2PO_4^-$) dissociate in aqueous solution to form hydrogenphosphate ions as follows:

$$H_2PO_4^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H^+(aq)$$

  a The pK_a of the dihydrogenphosphate ion is 7.2. Calculate the pH value for a 0.1 mol dm^{-3} solution of sodium dihydrogenphosphate. [5]

  b **i** Explain the term 'buffer solution' in terms of what it contains and what it does. [2]

     ii Explain why a mixture of dihydrogenphosphate and hydrogenphosphate ions would function as a buffer solution. [5]

    iii What is the pH of a solution consisting of 0.01 mol dm^{-3} dihydrogenphosphate ions and 0.06 mol dm^{-3} hydrogenphosphate ions? [4]

    iv Explain what would happen to the pH of the buffer if a small amount of solid sodium dihydrogenphosphate was added to the solution. [3]

  c Calcium phosphate, $Ca_3(PO_4)_2$, is a sparingly soluble salt of phosphoric acid.

    i Give the formulae of the **two** ions present in calcium phosphate. [2]

    ii Give the equation for the equilibrium between solid calcium phosphate and its constituent ions in solution. [1]

    iii Give the expression for the solubility product for calcium phosphate. [1]

    iv The solubility of calcium phosphate is 2.48×10^{-6} mol dm^{-3}. Use this information to calculate the solubility product of calcium phosphate. Remember to include the units. [5]

    v Explain why calcium phosphate has a very negative lattice energy. [2]

    vi Explain why calcium phosphate is sparingly soluble in water. [2]

Total = 32