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CHEMISTRY
PHYSICAL CHEMISTRY

Level & Board	CIE (A-LEVEL)
TOPIC:	EQUILIBRIA
PAPER TYPE:	QUESTION PAPER - 1
TOTAL QUESTIONS	10
TOTAL MARKS	75

Equilibria - 1

1)

(a) Ethanoic acid is a weak acid. What do you understand by the term in italics? [1]

(b) The dissociation constant for ethanoic acid, $K_c = 1.74 \times 10^{-5}$ mol dm^{-3}.

(i) Calculate the pH of a 0.100 mol dm^{-3} solution of ethanoic acid.

(ii) Sketch the titration curve for the titration of a 20.0 cm^3 sample of this solution with 0.200 mol dm^{-3} sodium hydroxide. Label the end – point and suggest a suitable indicator from the following list.

indicator	pH at which colour changes
methyl violet	0 – 1
methyl orange	3 – 4
bromothymol blue	6 – 7
phenolphthalein	9 – 10

[6]

(c) The nitrogen content of a urea – based fertilizer can be measured by boiling a sample of known mass of the fertilizer with an excess of NaOH(aq). Hydrochloric acid of known concentration.

$$NH_2CONH_2 + 2OH^- \longrightarrow 2NH3 + CO_3^{2-}$$

$$NH_3 + HCl \longrightarrow NH_4Cl$$

When 0.100 g of a fertilizer was subjected to this procedure, the resulting solution of ammonia require 14.0 cm3 of 0.200 mol dm-3 HCl / for neutralization.

Calculate the percentage of nitrogen in the fertilizer. [3]

2)

The main buffering agent in blood plasma is the carbon dioxide/hydrogen carbonate system.

$$H_2O + CO_2 \rightleftharpoons HCO_3^- + H^+ \quad K_a = 7.90 \times 10^{-7} \text{ mol } dm^{-3}$$

(a) What is meant by the term buffer? [2]

(b) Explain how the system above acts as a buffer when OH^- ions are added to the blood plasma. [1]

(c) Use the data above to calculate the pH of normal blood plasma, if the $[HCO3^-]/[CO_2]$ ratio is 20:1. [2]

(c) The total $CO_2 + HCO_3^-$ content of blood plasma can be found by boiling a plasma sample with an excess of dilute sulphuric acid and absorbing the carbon dioxide evolved in a solution of barium hydroxide. The precipitated barium carbonate can be filtered off, dried and weighed.

When a 100 cm^3 sample of plasma was treated in this way, 0.600 g of barium carbonate was produced.

(i) Write a balanced equation for the reaction between carbon dioxide and barium hydroxide.

(ii) Use the data given to calculate the total number of moles of $CO_2 + HCO_3^-$ in the blood plasma sample, and use the ration given in (c) to calculate the $[CO_2(aq)]$

[5]

3)

(b) Although most chlorates are very soluble in water, iodates are much less so. The numerical value of the solubility products, K_{sp}, for strontium iodate(V), $Sr(1O_3)_2$, is 1.1 10^{-9}.

(i) Write an expression for Ksp and state its unite.

(ii) Calculate [Sr2+] in a saturated solution of $Sr(1O_3)_2$, [4]

4)

(d) Dilute solutions of HF behave as weak acids. Aqueous HF of concentration 0.1 mol dm^{-3} is only 8% dissociated into ions.

(i) Calculate the pH of 0.1 mol dm^{-3} HF,

(ii) By using data from the table, suggest why dilute solutions of HF behave as weak acids. [3]

I am Sorry !!!!

5)

There are few natural occurring organic compounds that contain fluoride. The South African plant Diichapetalum cymosum contais fluoroethanoic acid, FCH2CO2H. Data about ethanoic, fluoroethanioc and chloroethanioc acids are given below.

	CH_2CO_2H	FCH_2CO_2H	C/CH_2CO_2H
pK_a	4.76	2.57	2.87

(a) (i) Define the term pK_a.

(ii) Define the term K_a.

(iii) Calculate K_a for fluoroethanoic acid. [3]

(b) (i) State which is the strongest and which is the weakest of the three acids.

(ii) Suggest an explanation for the differences in acid strengths of the three acids in terms of their structures and bonding. [4]

6)

When the gases dinitrogen tetroxide and nitrogen monoxide are mixed in a 1:2 ratio, the two gases slowly react to form the blue compound dinitrogen trioxide according to the following equilibrium.

$$N_2O_4(g) + 2NO(g) \rightleftharpoons 2N_2O_3(g) \qquad \Delta H^{\ominus} = -26 \text{ KJ mol}^{-1}$$

(c) A mixture containing a 1:2 ratio of N2O4 and NO at an initial total pressure of 3 atm was allowed to reach equilibrium. At equilibrium the following partial pressures were measured.

Compound	Partial pressure /atm
N2O4	0.75
NO	1.50
N2O3	0.25

(i) Write the expression for K_p, including its units.

(c) Suggest with an explanation, how the position of equilibrium might alter when

(i) the temperature is increased.

(ii) the pressure is increased. [4]

7)

Alcohols and esters are important organic compounds which are widely used as solvents.

Esters such as ethyl ethanoate can be formed by reacting carboxylic acids with alcohols.

$$CH_3CO_2H + C_2H_5OH \rightleftharpoons CH_3CO_2C_2H_5 + H_2O$$

This reaction is an example of a dynamic equilibrium.

(a) Explain what is meant by the term *dynamic equilibrium*. [1]

(b) Write the expression for the equilibrium constant for this reaction, k_c. [1]

(c) For this equilibrium, the value of K_c is 4.0 at 298 K. A mixture containing 0.5 mol of ethanoic acid, 0.5 mol ethanol, 0.1 mol ethyl ethanoate and 0.1 mol water was set up and allowed to come to equilibrium at 298 K. the final volume of solution was V dm3.
Calculate the amount, in moles, of each substance present at equilibrium. [4]

Alcolhols may be classified into primary, secondary and tertiary. Some reactions are common to all three types of alcohol. In other cases, the same reagent gives different products depending on the nature of the alcohol.

(d) In the empty squares below give the structural formula of the organic compound formed in each of the reaction occurs, write 'no reaction' in the space.

alcohol / Reagent(s)and conditions	$CH_3CH_2CH_2OH$	$CH_3CH_2CH(OH)CH_3$	$(CH_3)_3COH$
Red phosphorus and iodine heat under reflux			
Concentrated H_2SO_4 heat			
$Cr_2O_7^{2-}/H^+$ Heat under reflux			

[5]

8)

(a) Use the general formula of a carboxylic acid, RCO2H, to write equations to explain the following terms.

(i) K_a

(ii) pK_a [2]

(b) The pKa values of four carboxylic acids are listed in the table below.

acid	Formula of acid	pK_a
1	$CH_3CH_2CO_2H$	4.9
2	$CH_3CCHClCO_2H$	2.8
3	$CH_3CC_2CO_2H$	1.4
4	$CH_2ClCH_2CO_2H$	4.1

(i) Describe and explain the trend in acid strength shown by acids 1,2 and 3.
(ii) Suggest an explanation for the difference in the pK_a values for acids 2 and 4.
(iii) Calculate the pH of a 0.010 mol dm-3 solution of propanoic acid (acid 1). [6]

9)

Potassium manganite (VII) can be used to estimate the percentage of hydrogen peroxide in household bleach. The following unbalanced equation represents the reaction between them.

….. MnO_4^- + ….. H_2O_2 + ….. H^- → …… Mn^{2+} + …… H_2O + …… O_2

(a) Balanced this equation by putting the appropriate numbers in the spaces above. [1]
(b) Use data from the Data Booklet to calculate the $E^{\ominus}_{cell}$ for the reaction. [1]
(c) When 0.020 mol dm^{-3} KMnO4 (aq) was added from a burette into an acidified 25.0 cm^{-3} sample of H_2O_2, 15.0 cm^3 of $KMnO^4$ was required to reach the end – point.
(i) Describe what you would see during this titration, and also at the end - point.
(ii) Calculate the concentration of H_2O_2 in the sample. [4]

10)

When hydrocarbons such as patrol or paraffin was are burned in an excess of air in a laboratory, carbon dioxide and water are the only products. When petrol is burned in a car engine, nitrogen monoxide, NO, is also formed.

(a) Explain how NO is formed in an internal combustion engine but not formed when a small sample of petrol is burnt in an evaporating basin. [2]

The engines of modern motor cars have exhaust systems which are fitted with catalytic converters in order to reduce atmospheric pollution from substances such as NO.

(b) (i) State **three more** pollutions, other than CO_2 and H_2O, that are present in the exhaust gases of a car engine.
(ii) What is the active material present in the catalytic converter?

(iii) Write one balanced equation to show how NO is removed from the exhaust gases of a car engine by a catalytic converter. [4]

NO is also formed when nitrosyl chloride, NOCl, dissociates according to the following equation.

$$2NOCl(g) \rightleftharpoons 2NO(g) + Cl_2(g)$$

Different amounts of the three gases were placed in a closed container and allowed to come to equilibrium at 230^0C. The experiment was repeated at 465^0C.

The equilibrium concentrations of the three gases at each temperature are given in the table below.

	Concentration / mol dm^{-3}		
temperature / ^{0}C	NOCl	NO	Cl_2
230	2.33×10^{-3}	$1.46\times\times10^{-3}$	1.15×10^{-2}
465	3.68×10^{-4}	7.63×10^{-3}	2.14×10^{-4}

(c) (i) Write the expression for the equilibrium, K_c, for this reaction. Give the units.

(ii) Calculate the value of Kc at each of the temperatures given.
230 ^{0}C
465 ^{0}C

(iii) Is the forward reaction endothermic or exothermic? Explain your answer. [5]

(d) The temperature of the equilibrium was then altered so that the equilibrium concentration of NOCl and NO were the same as each other.
What will be the effect on the equilibrium concentration of NOCl when the following changes are carried out on this new equilibrium? In each case, explain your answer.

(i) The pressure of the system is halved at constant temperature.

(ii) A mixture of NOCl(g) and NO(g) containing equal numbers of moles of each gas is introduced into the container at constant temperature.

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