

## Further aspects of Equilibria - 2021

### 1. Nov/2020/Paper\_41/No.4

(a) (i) Give the mathematical expression for each of the terms pH and  $K_w$ .

pH = .....

$K_w$  = .....

[2]

(ii) Calculate the pH of  $0.027 \text{ mol dm}^{-3} \text{ NaOH(aq)}$ .

pH = ..... [1]

(b) The  $K_a$  value of chloric(I) acid,  $\text{HClO}$ , is  $3.72 \times 10^{-8} \text{ mol dm}^{-3}$ .

Calculate the pH of  $0.010 \text{ mol dm}^{-3} \text{ HClO(aq)}$ .

pH = ..... [1]

(c) Water and octan-1-ol form two layers when mixed.

Ethanamide is more soluble in water than it is in octan-1-ol. When  $1.00 \text{ g}$  of ethanamide is added to  $50.0 \text{ cm}^3$  of water and this is then shaken with  $50.0 \text{ cm}^3$  of octan-1-ol, it is found that the water layer contains  $0.935 \text{ g}$  of ethanamide at equilibrium.

(i) Calculate the partition coefficient,  $K_{pc}$ , for ethanamide in water and octan-1-ol.

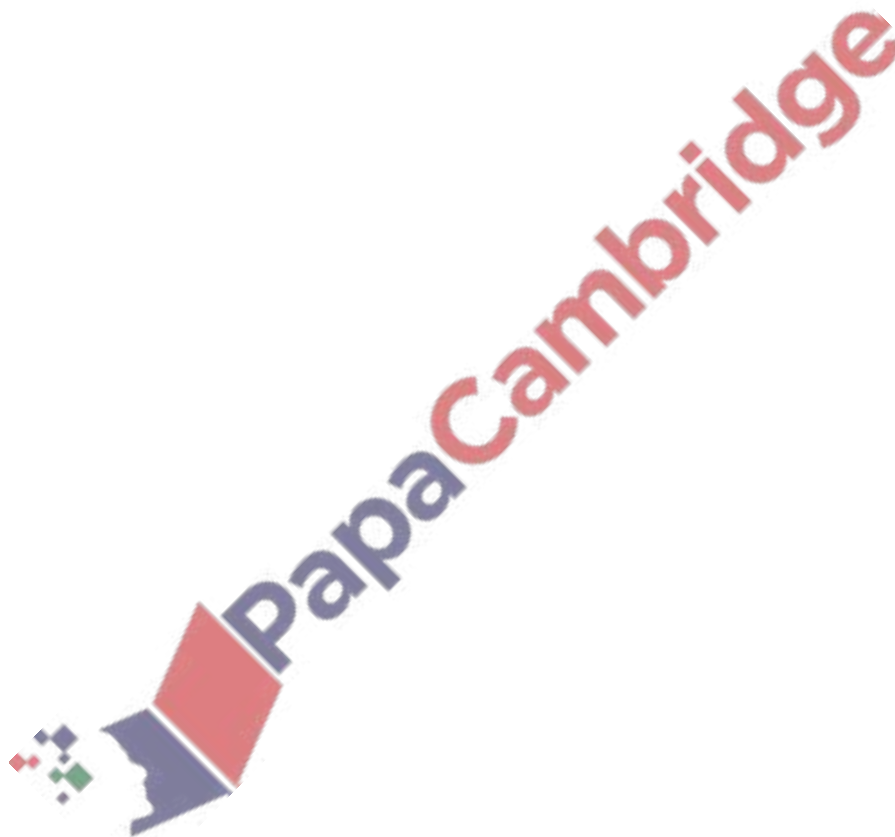
$K_{pc}$  = ..... [1]

- (ii) The  $50.0\text{ cm}^3$  of water containing  $0.935\text{ g}$  of ethanamide is then shaken with  $100.0\text{ cm}^3$  of pure octan-1-ol under the same conditions.

Calculate the mass of ethanamide that is dissolved in the  $100.0\text{ cm}^3$  of octan-1-ol at equilibrium.

mass of ethanamide = ..... g  
[2]

[Total: 7]



2. Nov/2020/Paper\_42/No.2

- (a) Write an expression for the  $K_a$  of the weak acid HA in terms of the concentrations of the species involved.

$$K_a =$$

[1]

- (b) The hydroxylammonium ion,  $\text{HONH}_3^+$ , is a weak acid. A  $1.00 \times 10^{-3} \text{ mol dm}^{-3}$  solution of hydroxylammonium ions has a pH of 4.41.

- (i) Calculate the  $K_a$  of  $\text{HONH}_3^+$ .

$$K_a = \dots\dots\dots [2]$$

- (ii) Calculate the  $\text{p}K_a$  of  $\text{HONH}_3^+$ .

$$\text{p}K_a = \dots\dots\dots [1]$$

- (c) The solubility product of manganese(II) hydroxide,  $\text{Mn}(\text{OH})_2$ , in water is  $1.1 \times 10^{-11} \text{ mol}^3 \text{ dm}^{-9}$  at 298 K.

Calculate the solubility of  $\text{Mn}(\text{OH})_2$  in water at 298 K.

$$\text{solubility} = \dots\dots\dots \text{ mol dm}^{-3} [2]$$

[Total: 6]

3. March/2020/Paper\_42/No.5b

(b) A buffer solution was prepared by dissolving 2.04 g of gallic acid in 250 cm<sup>3</sup> of a solution containing 0.0600 mol dm<sup>-3</sup> of gallate ions, C<sub>7</sub>H<sub>5</sub>O<sub>5</sub><sup>-</sup>.



(i) Define the term *buffer solution*.

.....  
.....  
..... [2]

(ii) Calculate the pH of this buffer solution.

pH = ..... [3]

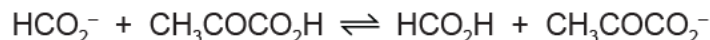
(iii) Write **two** equations to show how a solution containing gallic acid, C<sub>7</sub>H<sub>6</sub>O<sub>5</sub>, and gallate ions, C<sub>7</sub>H<sub>5</sub>O<sub>5</sub><sup>-</sup>, acts as a buffer.

.....  
.....  
.....  
..... [2]

- (b) (i) The numerical values of  $K_a$  for methanoic acid,  $\text{HCO}_2\text{H}$ , and pyruvic acid,  $\text{CH}_3\text{COCO}_2\text{H}$ , are given.

acid	$K_a$
$\text{HCO}_2\text{H}$	$1.78 \times 10^{-4}$
$\text{CH}_3\text{COCO}_2\text{H}$	$4.07 \times 10^{-3}$

An equilibrium mixture containing the two acid-base pairs is formed.



Use the  $K_a$  values to calculate the equilibrium constant,  $K_{\text{eq}}$ , for this equilibrium.

$$K_{\text{eq}} = \dots\dots\dots [1]$$

- (ii) Use your value of  $K_{\text{eq}}$  to predict the position of this equilibrium. Indicate this by placing a tick ( $\checkmark$ ) in the appropriate box in the table. Explain your answer.

equilibrium lies to the left	equilibrium lies in the middle	equilibrium lies to the right

[1]

- (iii) Ethanedioic acid,  $\text{HO}_2\text{CCO}_2\text{H}$ , has two dissociation constants,  $K_{a1}$  and  $K_{a2}$ , whose  $\text{p}K_a$  values are 1.23 and 4.19.

Suggest equations to show the two dissociations that give rise to these  $\text{p}K_a$  values.

$\text{p}K_{a1}$  1.23 .....

$\text{p}K_{a2}$  4.19 .....

[2]

- (iv) State the mathematical relationship between  $\text{p}K_a$  and the acid dissociation constant  $K_a$ .

..... [1]

(g) The ionic product,  $K_w$ , for  $D_2O$  has a value of  $1.35 \times 10^{-15} \text{ mol}^2 \text{ dm}^{-6}$  at 298 K.

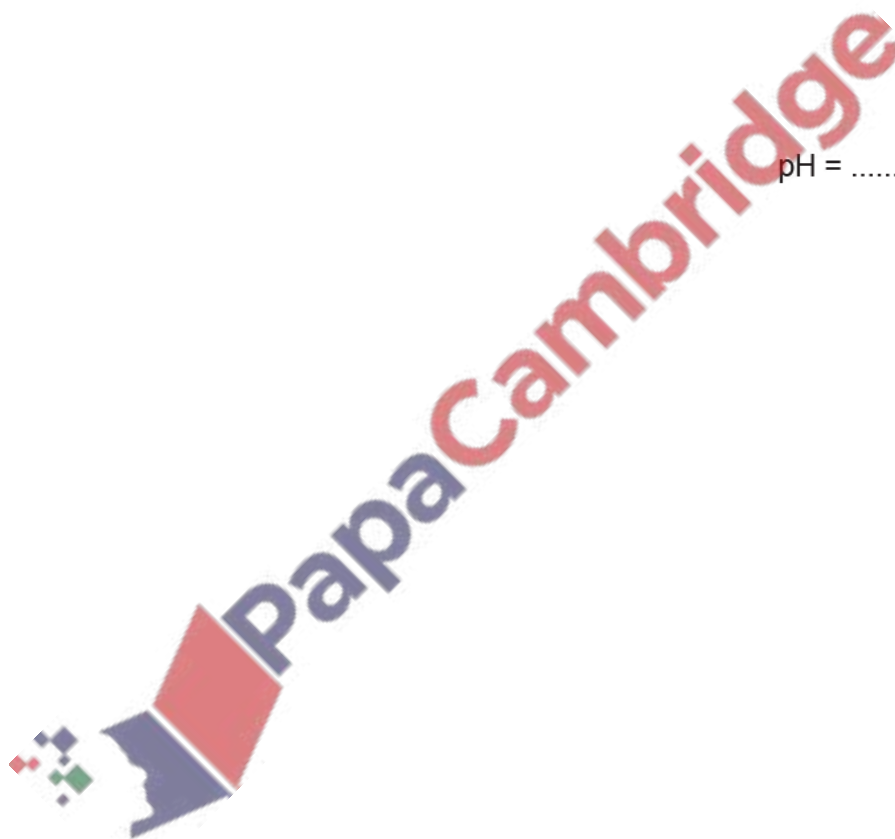
(i) Write the expression for the  $K_w$  of  $D_2O$ .

$$K_w =$$

[1]

(ii) Calculate the pH of pure, neutral  $D_2O$  at 298 K.  
Assume  $[D^+]$  is equivalent to  $[H^+]$  for pH calculations.

pH = ..... [2]



(a) Explain what is meant by the term *buffer solution*.

.....  
.....  
..... [2]

(b) (i) Write an expression for the acid dissociation constant,  $K_a$ , for ammonium ions,  $\text{NH}_4^+(\text{aq})$ .

$$K_a =$$

[1]

(ii) Write **two** equations to describe how a solution containing ammonium ions,  $\text{NH}_4^+(\text{aq})$ , and ammonia,  $\text{NH}_3(\text{aq})$ , can act as a buffer.

.....  
..... [2]

(iii) The numerical value of  $K_a$  for  $\text{NH}_4^+(\text{aq})$  is  $5.6 \times 10^{-10}$  at 298 K.  
A buffer solution was prepared by adding  $0.80 \text{ dm}^3$  of  $0.25 \text{ mol dm}^{-3}$  ammonia, an excess, to  $0.20 \text{ dm}^3$  of  $0.20 \text{ mol dm}^{-3}$  hydrochloric acid.

Calculate the pH of the buffer solution formed at 298 K.

pH = ..... [3]

[Total: 8]

