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91392







Mana Tohu Mātauranga o Aotearoa New Zealand Qualifications Authority

Level 3 Chemistry 2024

91392 Demonstrate understanding of equilibrium principles in aqueous systems

Credits: Five

| Achievement | Achievement with Merit | Achievement with Excellence |
|---|--|---|
| Demonstrate understanding of equilibrium principles in aqueous systems. | Demonstrate in-depth understanding of equilibrium principles in aqueous systems. | Demonstrate comprehensive understanding of equilibrium principles in aqueous systems. |

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

A periodic table and other reference material are provided in the Resource Booklet L3–CHEMR.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–12 in the correct order and that none of these pages is blank.

Do not write in any cross-hatched area (1/1/2). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

QUESTION ONE

Write the equation for the equilibrium occurring in a saturated solution of silver sulfate, (i) (a) Ag,SO4.



Write the expression for $K_{e}(Ag_{3}SO_{4})$. (ii)



(iii) Calculate the solubility of Ag_2SO_4 in water at 25 °C, and give $[Ag^+]$ and $[SO_4^{-2}]$.

 $K_{\rm s}({\rm Ag}_{2}{\rm SO}_{4}) = 1.20 \times 10^{-5}$ $[Ag^{+}] = 2X \ [SO_{4}^{2-}] = X$ $K_{5} = (2X)^{2} \times X = 4 \ X^{3} = [.20 \times 10^{-5}]$ =) X= 0.0144 0.044

Below is a list of solutions of the same concentration available for a student to add to a saturated (b) solution of Ag₂SO₄:

$$HNO_3(aq), Na_2SO_4(aq), (NH_3(aq)), KNO_3(aq)$$

of Ag2S04

Select and justify, including any relevant equations, an appropriate solution the student could add

to: (i) increase the solubility of Ag₂SO₄. They add NAI zaging Solution to in crease the solubility of Ag₂SO₄. As NHz(ag) will react with Ag⁺ ions to produce the complex ion [Ag (NHz)2]t. Thus, this removes some Ag⁺ ions, leading the equilibrium to tavour the forward teaction, speeding up of reaction, & replenishing the Agt 00955

3 Hence, more Ag2SO4 solid will dissolve and so the solubility of Aq2 SO4 increases which is a common ion, They Kan add Naz SO4 (ags (ii) decrease the solubility of Ag_2SO_4 solution to decrease the solubility of Ag 2 SO4 As extra SO42 ions are added from Naz SO4(ag), the equilibrium of Ag 2564 will favour the remove the extra 5042reverse/reaction to ions, spelding up the rate of reverse reaction Thus, more Ag2 SO4 solid will form and hence the solubility of Agr SOG mendecreases. [SO42-] increases and so Predict, by calculation, whether a precipitate of silver sulfate, Ag₂SO₄, will form when <u>20.0 mL</u> (c) of 0.0188 mol L⁻¹ silver nitrate, AgNO₃, is added to 30.0 mL of 0.0146 mol L⁻¹ aluminium sulfate, Al₂(SO₄)₃. $K_{\rm s}({\rm Ag}_{2}{\rm SO}_{4}) = 1.20 \times 10^{-5}$ [Ag+] = 0.0188 x 20 = 7.52 × 10-3 molt $[S0_4^{2-7}] = 0.0146 \times \frac{30}{50} = 0.02628$ $= [Ag^{+}]^{-}[SO4^{-}] = 1.486 \times 10^{-6} \text{mol} L^{-1}$ IP < Ks(Ag2 SO4) (1.486a×10-6<1.20×10-5) As the solution is unsaturated and so a precipitate of silver sulfate, Ag2SO4, does not form. Chemistry 91392, 2024 00955

QUESTION TWO

CH3COO- +H2O = CH3COOH+ 0H-

(a) (i) List all the species present in a solution of sodium ethanoate, CH₃COONa, in order of decreasing concentration. Do not include water.



(ii) Sodium ethanoate can be mixed with ethanoic acid, CH₃COOH, to form a buffer solution.

Explain how this buffer solution would react upon the addition of a small volume of hydrobromic acid (HBr,) including a balanced equation(s) to support your answer. Beltter solution is a solution that can resist pl change when a Small volume of strong acid (or base) CH3COONA -> CH3COO + (Nat, CH3COO + H2O = CH3COOH+OH-CH3COONA -> CH3COO + (Nat, CH3COO + H2O = CH3COOH+OH-CH3COON + H2O = CH3COO + H3O+. When the solution gains H3O+ ions from HBr, the baseiccomponent (basconingate base) of the baffer solution will react with it and neuthalise the solution. CH3COO + H3O+ = CH3COOH + H2O. By producing weaker acid than HBr, the baffer solution mitigates the change in pH, (HBr + H2O -) H3O+ + B7)

(iii) Calculate the mass of sodium ethanoate that must be added to 250 mL of 0.354 mol L⁻¹ CH₃COOH to give a buffer solution with a pH of 4.11.

Assume there is no change in volume when the solid is added.

 $K_{a}(CH_{3}COOH) = 1.74 \times 10^{-5}$ p $K_{a}(CH_{3}COOH) = 4.76$ $M(CH_{3}COONa) = 82.0$ g mol⁻¹ CH3CODH+H20 = CH3CO0-H130+ $M(CH_3COONa) C$ $K_a = \frac{(CH_3COO^{-}](H_3O^{-})}{(CH_3COOH)}$ $\mathcal{K} \times 10^{-4.11} = 1.74 \times 10^{-5}$ 0.354 =) x = 0.07935 moll-1 $N((H_3(OON)a) = 0.07935 \times 0.25$ $m = nM = 0.0198 \times 82 = 1.6279$

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(b) Three colourless 0.110 mol L⁻¹ solutions of (H_3NH_2, H_3COOH) , and (NH_4Cl) have lost their labels. The solutions are randomly labelled A, B, and C. The electrical conductivity of each solution, and the colour of the solution when the acid-base indicator bromothymol blue $(pK_a = 7.2)$ was added, are shown in the table below.

| Solution | Electrical conductivity | Colour with bromothymol blue |
|----------|-------------------------|---------------------------------|
| А | Poor | Yellow |
| В | Poor | Blue |
| С | Good | Yellow |

Identify the three solutions.

No calculations are necessary.

Justify your identification in terms of the degree of dissociation and the relative concentration of ions in each solution, including relevant equations.

Electrical conductivity depends on the number of free imobile charged photicles (ions) in the solution. is an acidic salt, it will & completely 5 NHUC dissociate , & creating high (NH4] and [[] here high lions] Clag-NH4 Clus NH4 Clags This & contrasts with the other two solution - CH3 NH2 (weak base) and CH3 COOH (weak NH4Clus-

acid). The Each of them both partially dissociates CH3NH2 PH20 = CH2NH3 + OH @ 2 CH3000 + H30+ . Hence, NH4 CI CH3LOOH + H2O solution is the only good electrical conductor, while CH3NH2 and CH3 COOK Solutions are both pour electrical having low Cions]. Thus, sotution (will Solution. Moreover, as solution Bis CB CH2 1 be. e only solution with blue colour with bromothymo, (no colomychange) OHZ Solution is only basic solution be CH3 NH2 solution. Lastin BJII be CH3COOH - Which is not weak WIII Solution acid - making the bromothymal blue to change its colour to gelbow - chemistry 91392, 2024 00955

QUESTION THREE

A titration was carried out by adding 0.169 mol L^{-1} sodium hydroxide, NaOH, to 25.0 mL of 0.135 mol L^{-1} hydrofluoric acid, HF.

The equation for the reaction is:



(ii) Sketch the missing portion of the titration curve between 0 and 17.5 mL to complete the curve provided above.

Consider the initial pH after 10.0 mI of NaOH has been added, and the shape of the curve. $\mu_1 \rho H = \rho K \alpha$.

If you need to redraw your curve, use the graph on page 9.

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Constant Press, Constant Constant South and Constant South and Constant

7 After a certain volume of NaOH has been added, the HF and NaF are present in a 1:9 ratio (b) (i) in the solution. Calculate the pH of this solution, and evaluate its buffering ability. pH=pKa+log Cacid] =pKa+log [F] + 109 = 4.124 E  $H_a = \frac{\left[F^{-}\right]\left[H_{30}^{\dagger}\right]}{\left[H_{F}\right]}$ = 4.124 =) 6.076×10-4 = 9[H30+] => [H3()+ ]= 7.511×10-5 (ii) Justify why the pH increases rapidly between 18.0 mL and 22.0 mL. No calculations are necessary. acidic compound (HF) of the buffer the 45 mostly neutralised and Solution 15 50 the ratio F-1 to CHF1 greater than 10 (10:1), the Solution between 18.0mL and 22.0mL a effective. Thus, there is not become butter Solution. is not effective. Thus, there is longer enough acidle compound (HF-1H30+) to the added OH- ion's from NaOH 15 Hence, the pH increases rapidly between 18.0ml and 22.0ml Question Three continues on the next page. Chemistry 91392, 2024 00955

(a) (b) Calculate the pH at the equivalence point 
$$[HF] = [OH] = \frac{h}{(Hsol)}$$
  
 $F + H_2O = HF + OH$   
 $F + H_2O = HF + OH$   
 $A_{a}(HF) = \frac{(F - ](H_2 of)}{(HF)} = \frac{(F - ](H_3 of)^{2}}{(HF)} = \frac{(F - ](H_3 of)^{2}}{(H^{O})} = \frac{(F - ](H_3 of)^{2}}{(H^$ 

### SPARE DIAGRAM

If you need to redraw your response to Question Three (a)(ii), use the graph below. Make sure it is clear which answer you want marked.



10 Extra space if required. Write the question number(s) if applicable. QUESTION Q2(w)(ii) Also, as there is only a small change in the ratio of CCH2(00-] to (CH3(00H), there is only a small change in pH = pKatlog[base] =) pH = pKa + log <u>CCH3600-]</u> for CH3COOH Solution than that for Q3(()(ii) ME solution. Hence pl at the equivalence point of this titration will be higher than the previous one. 1.1.1.1. Chemistry 91392, 2024 00955

## Merit

### Subject: Chemistry

### **Standard:** 91392

### Total score: 15

| Q     | Grade<br>score | Marker commentary                                                                                                                                                                                                                                                                                                    |  |
|-------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|
| One   | M5             | The candidate was awarded M5 for the following reasons:                                                                                                                                                                                                                                                              |  |
|       |                | In part (a), the candidate gave the equilibrium equation and $K_s$ expression, and calculated the solubility, but did not determine [Ag <sup>+</sup> ] and [SO <sub>4</sub> <sup>2-</sup> ], and has therefore not gained a Merit for this part.                                                                     |  |
|       |                | In part (b), the candidate selected and justified the correct<br>solutions to both increase and decrease the solubility of silver<br>sulfate but did not give the equation to show the formation of the<br>complex ion between silver ions and ammonia. This has prevented<br>the candidate from gaining Excellence. |  |
|       |                | In part (c), the candidate correctly calculated the ionic product and compared it to the solubility product to predict that a precipitate of silver sulfate will not form.                                                                                                                                           |  |
| Two   | M5             | The candidate was awarded M5 for the following reasons:                                                                                                                                                                                                                                                              |  |
|       |                | In part (a), the candidate listed the correct remaining species<br>present in the solution of sodium ethanoate, explained how the<br>buffer would react upon addition of HBr, with support from a<br>relevant equation, and calculated the mass of sodium ethanoate<br>required to prepare a buffer.                 |  |
|       |                | In part (b), the candidate explained the electrical conductivity of the three different solutions in terms of the degree of dissociation and [ions]. To gain M6, the candidate needed to link the colour of the indicator to the $[H_3O^+]$ or $[OH^-]$ for two of the solutions.                                    |  |
| Three | M5             | The candidate was awarded M5 for the following reasons:                                                                                                                                                                                                                                                              |  |
|       |                | In part (a), the candidate showed by calculation that the initial pH of the HF solution was 2.02, but the shape of the sketched portion of the curve did not meet the requirements for Merit.                                                                                                                        |  |
|       |                | In part (b), the candidate calculated the pH of the buffer, but did<br>not evaluate its effectiveness. This has prevented the candidate<br>from gaining Excellence. The candidate explained how the buffer is<br>no longer functioning after 18mL and how the pH therefore<br>changes upon addition of NaOH.         |  |
|       |                | In part (c), the candidate calculated the pH at the equivalence<br>point and explained how the pH at the equivalence point would<br>change if the HF were replaced with CH <sub>3</sub> COOH in the titration. The<br>candidate has gained Excellence for part (c).                                                  |  |