Trinity College

Chemistry 3+4

Acids & Bases Test Solutions

TOTAL = 51 Marks

DO NOT MARK THIS PAPER

1. Consider the information in the table below regarding three different monoprotic acids.

Acid	K_a
Formic acid	1.82×10^{-4}
Hydrofluoric acid	6.76×10^{-4}
Propionic acid	1.35×10^{-5}

If separate 0.5 mol L^{-1} solutions of these three acids were tested with a pH meter, at the same temperature, which would have the highest pH?

(a) Formic acid.
(b) Hydrofluoric acid.
(c) Propionic acid.
(d) More information is required.

2. A student had five different 0.2 mol L^{-1} solutions on her lab bench. They were;

- nitric acid, $HNO_3(aq)$
- zinc chloride, $ZnCl_2(aq)$
- lithium hydrogencarbonate, $LiHCO_3(aq)$
- potassium hydroxide, $KOH(aq)$
- ammonium chloride, $NH_4Cl(aq)$

Rank these solutions in order of **increasing** pH (i.e. lowest to highest).

(a) HNO_3 < NH_4Cl < $ZnCl_2$ < $LiHCO_3$ < KOH
(b) KOH < NH_4Cl < $ZnCl_2$ < $LiHCO_3$ < HNO_3
(c) HNO_3 < $LiHCO_3$ < NH_4Cl < $ZnCl_2$ < KOH

(d) $KOH < ZnCl_2 < LiHCO_3 < NH_4Cl < HNO_3$

3. Calculate the pH of a solution formed by mixing 10.0 mL of 0.125 mol L^{-1} nitric acid, $HNO_3(aq)$, with 90.0 mL of water.

(a) 2.90
(b) 1.86
(c) 0.90
(d) 1.90

4. The endothermic auto-ionisation of water can be represented by the equation below.

$$H_2O(l) + H_2O(l) + \text{heat} \rightleftharpoons H_3O^+(aq) + OH^-(aq) \quad K_w = 1.0 \times 10^{-14} \text{ at } 25\ ^\circ C$$

If the temperature of pure water was raised to 50 °C, which of the following statements are **correct**?

(i) The concentration of $H_3O^+(aq)$ would be greater than 1.0×10^{-7} mol L^{-1}.
(ii) The concentration of $OH^-(aq)$ would be lower than 1.0×10^{-7} mol L^{-1}.
(iii) The value of K_w would increase.
(iv) The pH of the water would increase.

(a) (i) and (ii) only
(b) (iii) and (iv) only
(c) (i), (ii) and (iii) only
(d) (i) and (iii) only

Questions 5 and 6 refer to the following information.

Consider the following equilibrium which is formed between iron(III) ions and citrate ions, when 50 mL of iron(III) nitrate, $Fe(NO_3)_3(aq)$, is mixed with 50 mL of sodium citrate, $Na_3C_6H_5O_7(aq)$.

$$Fe^{3+}(aq) + C_6H_5O_7^{3-}(aq) \rightleftharpoons FeC_6H_5O_7(aq) \qquad K = 6.3 \times 10^{11} \text{ at } 25\ ^\circ C$$

very pale brown *colourless* *yellow*

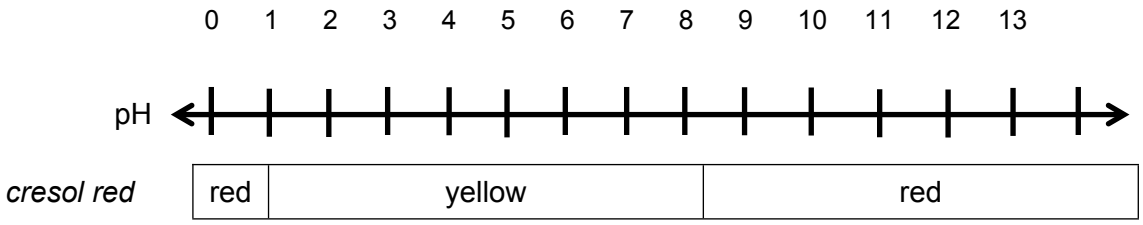
5. If this system was allowed to establish equilibrium at 25 °C, which of the following would be the **best prediction** of the appearance of the system?

(a) The solution would appear yellow.
(b) The solution would appear brown-yellow.
(c) The solution would appear very pale brown.
(d) The colour of the solution cannot be predicted.

6. If a few drops of citric acid ($C_6H_8O_7$) which is triprotic were added to this equilibrium system, which of the following gives the expected result?

	Favoured direction	**New concentration of $Fe^{3+}(aq)$**
(a)	forward	increased
(b)	forward	decreased
(c)	reverse	increased
(d)	reverse	decreased

7. Consider the diagram below, which shows the various colours of the indicator 'cresol red' under different pH conditions.



Which of the following pairs of solutions would **most easily** be distinguished by adding a few drops of cresol red indicator to each?

(a)	0.5 mol L^{-1} NaH_2PO_4	and	0.5 mol L^{-1} NaCl
(b)	2.0 mol L^{-1} H_2SO_4	and	2.0 mol L^{-1} NaOH
(c)	0.25 mol L^{-1} NH_3	and	water
(d)	0.7 mol L^{-1} H_2CO_3	and	0.7 mol L^{-1} NH_4NO_3

8. The conjugate base of the acid HPO_3^{2-} is:

(a) $H_2PO_3^-$
(b) PO_3^{2-}
(c) H_3PO_3
(d) PO_3^{3-}

Questions 9 and 10 refer to the information below.

Consider the following information for a 1.00 mol L^{-1} solution of Arsenous acid, (H_3AsO_4):

$$H_3AsO_4\,(aq) \quad \rightleftharpoons \quad H^+\,(aq) \quad + \quad H_2AsO_4^-\,(aq)$$

$$Ka \text{ (at } 25°C) \quad = \quad \frac{[H^+]\,[H_2AsO_4^-]}{[H_3AsO_4]} \quad = \quad 6.6 \times 10^{-10}$$

9. At equilibrium at 25°C, which of the following species will be present in the greatest concentration?

(a) $H^+\,(aq)$
(b) $H_2AsO_4^-\,(aq)$
(c) $H_3AsO_4\,(aq)$
(d) $OH^-\,(aq)$

10. Which of the following statements best describe the value of the equilibrium constant (K) for Arsenous acid at 25^o C?

(a) Arsenous acid is a strong acid existing essentially as molecules.
(b) Arsenous acid is a weak acid existing essentially as molecules.
(c) Arsenous acid is a weak acid existing essentially as ionic species.
(d) Arsenous acid is strong acid existing essentially as ionic species.

11. Which choice correctly describes the properties of aqueous solutions of the following salts?

Sodium ethanoate	Potassium nitrate	Ammonium chloride

	($NaCH_3COO$)	(KNO_3)	(NH_4Cl)
(a)	neutral	acidic	basic
(b)	basic	neutral	acidic
(c)	acidic	neutral	basic
(d)	basic	acidic	neutral

12. Consider the buffer solution represented by the chemical reaction below:

$$H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$$

Which of the following would be **true** after the addition of a small volume of 2.0 mol L^{-1} sodium hydroxide solution to the buffer solution?

(a) The forward reaction rate would be unaffected.
(b) The concentration of $H_2PO_4^-$ (aq) present in the system would increase.
(c) The pH of the system would decrease.
(d) The equilibrium would shift to the right.

13. A sample of barium sulfate powder is added to a beaker containing distilled water and stirred. The following chemical reactions occur;

$$\text{eq}^{\text{m}} \quad BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$$
$$\text{\&} \quad SO_4^{2-}(aq) + H_2O(l) \rightleftharpoons HSO_4^-(aq) + OH^-(aq)$$

If a few drops of HNO_3(aq) was added to the beaker, which of the following statements are **correct**?

(i) Equilibrium eqm shifts to the left.
(ii) Equilibrium & shifts to the right.
(iii) The pH of the solution would increase.
(iv) The amount of $BaSO_4$(s) present would decrease.
(v) The concentration of Ba^{2+}(aq) in the solution would increase.

(a) (i), (iii) and (v) only
(b) (ii), (iv), and (v) only
(c) (ii), (iii) and (iv) only
(d) (i), (ii) and (v) only

Questions 14 and 15 relate to the following information.

A chemist mixed 0.1 mol L^{-1} solutions of a weak, monoprotic acid and its sodium salt together in a beaker. The conjugate species formed a buffer as shown below;

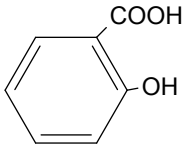
$$\text{weak acid(aq)} + H_2O(l) \rightleftharpoons \text{conjugate base(aq)} + H_3O^+(aq)$$

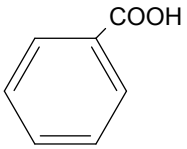
14. If a few drops of HCl(aq) are added to this system, which is **correct**?

(a) The pH falls quickly.
(b) The concentration of the weak acid equals the concentration of the conjugate base.
(c) The concentration of the weak acid increases.
(d) The concentration of the weak acid remains fairly constant until the buffering capacity is exceeded.

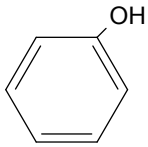
15. Which of the following pairs of substances, when dissolved in water, could produce a buffer matching the above description?

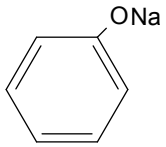
(a) $KHCO_3$ and K_2CO_3

(b) 

and 

(c) HNO_3 and $NaNO_3$

(d) 

and 

End of Section One

PART 2 : Short Answers (36 Marks)

Question 16 **(4 marks)**

Oxalic acid ($H_2C_2O_4$) is an organic acid, found in high levels in foods such as almonds, banana, rhubarb and spinach. It is a weak, diprotic acid which has many uses in the laboratory, such as in volumetric analysis where it can be used as a primary standard.

Explain what is meant when oxalic acid is referred to as a 'weak, diprotic acid'. Use relevant chemical equations to support your answer.

- **'weak' indicates ionisation of oxalic acid does not go to completion/only partially**
- **'diprotic' indicates each molecule of oxalic acid contains 2 ionisable/acidic hydrogen atoms**
- **$H_2C_2O_4 + H_2O \rightleftharpoons HC_2O_4^- + H_3O^+$ OR $H_2C_2O_4 \rightleftharpoons HC_2O_4^- + H^+$**

- $HC_2O_4^- + H_2O \rightleftharpoons C_2O_4^{2-} + H_3O^+$ OR $HC_2O_4^- \rightleftharpoons C_2O_4^{2-} + H^+$

Question 17 **(9 marks)**

Write observations for any reactions that occur in the following procedures. In each case describe in full what you would observe, including any:

- colours
- precipitates (give the colour)
- gases evolved (give the colour or describe as colourless).

If no change is observed, you should state this.

Also write full ionic equations and states

(a) Some hydrochloric acid solution is mixed with solid sodium carbonate.

(b) Some solid copper (II) hydroxide is mixed with a dilute nitric acid solution.

(c) Some acetic acid solution and magnesium ribbon.

(a) A white solid dissolves in a colourless solution, producing a colourless and odourless gas

$2H^+_{(aq)} + Na_2CO_{3(s)} \rightarrow 2Na^+_{(aq)} + H_2O_{(l)} + CO_{2(g)}$

(b) A blue solid dissolves in a colourless solution to produce a blue solution.

$Cu(OH)_{2(s)} + 2H^+_{(aq)} \rightarrow Cu^{2+}_{(aq)} + 2H_2O_{(l)}$

(c) A silvery metal dissolves in a colourless solution, producing a colourless and odourless gas

$2CH_3COOH_{(aq)} + Mg_{(s)} \rightarrow Mg^{2+}_{(aq)} + 2CH_3COO^-_{(aq)} + H_{2(g)}$

3 marks each question, 1 mark deducted for each error including states.

Question 18 **(6 marks)**

The Brønsted – Lowry theory can be used to account for the acidic and basic properties of a much wider array of substances whose properties cannot be easily explained using earlier theories.

Copy and complete the following table by stating the pH, and give a supporting balanced chemical equation to explain the pH for each of the substances listed.

Substance	pH (acidic, basic or neutral)	Equation
$NaCH_3COO$ (aq)	**Basic (1)**	$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$ **(1)**
NH_4Cl (aq)	**Acidic (1)**	$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ **(1)**
$NaHSO_4$ (aq)	**Acidic (1)**	$HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$ **(1)**

Question 19 **(6 marks)**

Calculate the pH of (assume 25^0C):

a) A solution of 0.320 grams of HCl in 250mL of water.

[3 marks]

HCl
1.008
+ 35.45
36.458 g.mol^{-1}

$$n(HCl) = \frac{m}{M} = \frac{0.320}{36.458} = 0.008777 \text{ mol}$$

$$[H^+] = [HCl] = \frac{n}{V}$$

$= \frac{0.008777}{0.250}$

$= 0.03511\ M$

$pH = -\log_{10}[H^+]$

$= -\log_{10} 0.03511$

$= 1.45$

b) 75ml of 0.15M $Ba(OH)_2$ aqueous solution.

[3 marks]

$Ba(OH)_2 = C = 0.15M$

But as there 2 OH x 2

$= 0.30\ M$

$[H^+] = \frac{1 \times 10^{-14}}{[OH^-]}$

$= \frac{1 \times 10^{-14}}{0.30}$

$= 3.333 \times 10^{-14}\ M$

$pH = -\log_{10}[H^+]$

$= -\log_{10}(1.862 \times 10^{-14})$

$= 13.477$ or 13.5 to 3SF

Question 20 **(4 marks)**

Hydrocyanic acid, HCN(aq), is an extremely poisonous acid with a

Ka value of **6.17×10^{-10}.**

It is made by dissolving liquid or gaseous hydrogen cyanide in water. Although small amounts of hydrogen cyanide can be extracted from the stones of some fruits

such as cherries, apricots and apples, it is generally manufactured on an industrial scale.

(a) What information does the value of Ka give us about hydrocyanic acid, HCN(aq)? Explain your answer.

(2 marks)

- **tells us that HCN is a weak acid i.e. ionisation of HCN does not occur to a large extent, molecular form favoured**
- **since K is equivalent to P/R, very low K value indicates that there is a much higher concentration of reactants present at equilibrium i.e. unionised HCN**

(b) Write out the ionization of HCN in water. On this Bronsted-Lowry equation, label the conjugate acid-base pairs. (2 marks)

Bronsted-Lowry	$HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$ A B CA CB

Question 21 **(7 marks)**

A 4.65g sample of pure $NaOH_{(s)}$ is dissolved in 200mL of distilled water and then added to 626mL of 0.15 $mol.L^{-1}$ $H_2SO_{4(aq)}$. Determine the pH of the mixture when the reaction is complete. Also state the limiting reagent.

n (NaOH) = m **n (H_2SO_4) = C x V**

$$M = \frac{4.65}{40} = 0.1163 \text{ mol} \qquad = 0.15 \times 0.626 = 0.0939 \text{ mol}$$ **1**

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$$

So $n(NaOH) = 2 \times H_2SO_4$ $\quad n(H_2SO_4) = 2 \times 0.0939 = 0.1878$ mol **2**

1

* We only have 0.1163 mol of NaOH

∴ NaOH is the LIMITING REACTANT!

∴ $n(H^+)$ remaining = TOTAL - n(NaOH neutralised

= 0.1878 - 0.1163 **1**

= 0.07155 mol

$$[H^+] = = \frac{n}{V}$$

$$= \frac{0.07155}{0.826}$$ **1**

$= 0.0866$ M

$pH = -\log_{10}[H^+]$

$= -\log_{10}(0.0866)$ **1**

$= 1.06$

END of PAPER

TOTAL MARKS = 51 Marks