Christ Church Grammar School

Year 12 Chemistry

Acids and Bases Test 2019 SOLUTIONS

Time allowed: 45 minutes

Name:_____

Mark = ……/ 45

Teacher:

CEM DGM JJF JPT

Section 1 Multiple Choice **10 marks**

1. Consider the following Brønsted- Lowry equation:

$$HS^-(aq) + CO_3^{2-}(aq) \rightleftharpoons S^{2-}(aq) + HCO_3^-(aq)$$

Which of the following is **not** true of this equation?

A. HCO_3^- is acting as an acid.

B. CO_3^{2-} is acting as a base.

C. HS^- is acting as a base.

D. CO_3^{2-} accepts a proton from HS^-

2. What is the conjugate base of $[Al(H_2O)_6]^{3+}$?

A. $[Al(HO)_6]^{2+}$

B. $[Al(H_2O)_5(OH)]^{4+}$

C. $[Al(H_2O)_5(OH)]^{2+}$

D. $[Al(OH)_6]^{3+}$

3. Which of the following combinations of substances would **not** result in a visible reaction?

A. Hydrochloric acid and sodium carbonate solution

B. Sulfuric acid and barium hydroxide solution

C. Ethanoic acid and magnesium

D. Nitric acid and potassium hydroxide solution

4. Which of these solutions would be the most effective buffer solution?

A. 100 mL of 1.0 $molL^{-1}$ NaOH (aq) mixed with 100 mL of 1.0 $molL^{-1}$ CH_3COOH (aq)

B. 100 mL of 1.0 $molL^{-1}$ HCl (aq) mixed with 50 mL of 1.0 $molL^{-1}$ $NaCH_3COO$ (aq)

C. 100 mL of 1.0 $molL^{-1}$ NaOH (aq) mixed with 200 mL of 1.0 $molL^{-1}$ CH_3COOH (aq)

D. 50 mL of 1.0 $molL^{-1}$ NaOH (aq) mixed with 100 mL of 1.0 $molL^{-1}$ $NaCH_3COO$ (aq)

5. Which of the following best describes the change taking place when ethanoic acid reacts with potassium hydroxide solution?

A. $KOH\ (aq) + CH_3COOH\ (aq) \rightarrow H_2O\ (\ell) + KCH_3COO\ (aq)$

B. $OH^-\ (aq) + CH_3COOH\ (aq) \rightarrow H_2O\ (\ell) + CH_3COO^-\ (aq)$

C. $OH^-\ (aq) + H_3O^+\ (aq) \rightarrow 2H_2O\ (\ell)$

D. $K^+\ (aq) + CH_3COO^-\ (aq) \rightarrow KCH_3COO\ (aq)$

6. Which of the following statements is true about equal volumes of hydrochloric acid and ethanoic acid of the same concentration?

A. Each contains the same number of H_3O^+ ions in solution.

B. When added to magnesium metal, each will produce hydrogen gas at the same rate.

C. Each will require the same amount of sodium hydroxide in order to react completely.

D. When each is reacted to completion with sodium hydroxide, the pH of the resulting solutions are the same.

7. Which of the following solutions has a pH less than 7?

A. 0.001 mol L^{-1} potassium carbonate

B. 0.001 mol L^{-1} magnesium nitrate

C. 0.001 mol L^{-1} sodium hydrogensulfate

D. 0.001 mol L^{-1} sodium ethanoate (acetate)

8. When carbonic acid is added to water, it ionises according to the following series of reactions:

$$H_2CO_3\ (aq) + H_2O\ (\ell) \rightleftharpoons H_3O^+\ (aq) + HCO_3^-\ (aq) \qquad K_1 = 2.5 \times 10^{-4}$$

$$HCO_3^-\ (aq) + H_2O\ (\ell) \rightleftharpoons H_3O^+\ (aq) + CO_3^{2-}\ (aq) \qquad K_2 = 4.7 \times 10^{-11}$$

Which of the following lists correctly ranks the species present in order of decreasing abundance.

A. $CO_3^{2-}\ (aq),\ HCO_3^-\ (aq),\ H_3O^+\ (aq),\ H_2CO_3\ (aq)$

B. $H_2CO_3\ (aq),\ HCO_3^-\ (aq),\ H_3O^+\ (aq),\ CO_3^{2-}\ (aq)$

C. $H_3O^+\ (aq),\ H_2CO_3\ (aq),\ CO_3^{2-}\ (aq),\ HCO_3^-\ (aq)$

D. $H_2CO_3\ (aq),\ H_3O^+\ (aq),\ HCO_3^-\ (aq),\ CO_3^{2-}\ (aq)$

9. Several drops of concentrated NaOH are added to the following buffer system, containing equimolar amounts of $H_2PO_4^-$ and HPO_4^{2-} ions.

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

Which of the followings statements about the effect of adding NaOH is true?

A. The concentration of H_3O^+ increases

B. The concentration of OH^- decreases

C. The concentration of $H_2PO_4^-$ increases

D. The concentration of HPO_4^{2-} increases

10. Which of the following correctly assigns pH values to the four 0.01 $molL^{-1}$ solutions listed in the table below.

	H_2SO_4	$NH_4C\ell$	$NaNO_3$
A.	1.6	5.6	9
B.	1.6	5.6	7
C.	1.9	7	9
D.	**1.9**	**5.6**	**7**

Section 2 Short answer **35 marks**

11. a) Identify the acid/base conjugate pairs in the following Brønsted- Lowry equation.

$$NH_3\,(aq) + CH_3CH_2NH_2\,(aq) \rightleftharpoons NH_2^-\,(aq) + CH_3CH_2NH_3^+\,(aq)$$

Pair 1: Acid NH_3 Conjugate Base NH_2^-

Pair 2: Acid $CH_3CH_2NH_3^+$ Conjugate Base $CH_3CH_2NH_2$

b) Given the K_c value of the reaction in part a) is greater than 1, identify the strongest base present in the reaction.

Strongest base: $CH_3CH_2NH_2$

(3 marks)

12. Write an equation and an observation to describe the reaction between solid ammonium nitrate and potassium hydroxide solution.

Equation:

$NH_4NO_3\,(s) + OH^-\,(aq) \rightarrow NH_3\,(aq) + H_2O\,(\ell) + NO_3^-\,(aq)$

2 marks, state symbols not required

Observations:

A white solid is added to a colourless solution. The white solid dissolves to form a colourless solution. A pungent smell is evolved.

(4 marks)

13. Determine the pH of the following:

a) The solution formed when 12.3 g of barium hydroxide is dissolved in 200 mL of water.

$n\ (Ba(OH)_2) = m/M$
$n\ (Ba(OH)_2) = 12.3 / 171.316$
$n\ (Ba(OH)_2) = 0.07179$ moles
$n(OH^-) = 2 \times n\ (Ba(OH)_2 = 0.1436$ moles (1)
$[OH^-] = n/V = 0.1436 / 0.2$
$[OH^-] = 0.718\ molL^{-1}$ (1)
$[H^+] = Kw / 0.718$
$[H^+] = 1.393 \times 10^{-14}$ (1)
$pH = -log([H^+]) = 13.86$ (1)

(4 marks)

b) The solution formed when 0.54 g of magnesium is added to 50.0 mL of a 1.04 $molL^{-1}$ nitric acid solution. Note the reaction proceeds according to the following equation. You may also assume that there is no change in volume during the reaction.

$$Mg\ (s) + 2H^+\ (aq) \rightarrow H_2(g) + Mg^{2+}\ (aq)$$

$n\ (Mg) = m/M$
$n\ (Mg) = 0.54 / 24.31$
$n\ (Mg) = 0.0222$ moles (1)

$n(HCl) = C \times V$
$n(HCl) = 0.05 \times 1.04$
$n(HCl) = n(H^+) = 0.052$ moles (1)

n (Mg) needed to react completely with the HCl is 0.026 moles.
The n(Mg) present is less than the n(Mg) needed,
Therefore, Mg is the limiting reagent and H^+ is in excess. (1)

$n\ (H^+)$ in excess = initial n(H+) – reacted n(H+)
$n\ (H^+)$ in excess = 0.052 – 0.0444
$n\ (H^+)$ in excess = 0.0076 moles (1)
$[H^+] = n /V$
$[H^+] = 0.0076 / 0.05 = 0.152\ molL^{-1}$ (1)
$pH = -log([H^+]) = 0.818$ (1)

(6 marks)

14. Information about several weak acids and their Ka values are listed in the table below:

Acid	Ka value
Methanoic acid (CHOOH)	1.8×10^{-4}
Hydrocyanic acid (HCN)	6.2×10^{-10}
Hypochlorous acid (HCℓO)	3.5×10^{-8}
Oxalic acid ($H_2C_2O_4$)	5.8×10^{-2}

a) Write an ionic equation to show the ionisation of hydrocyanic acid in water. Include state symbols.

$$HCN\ (aq) + H_2O\ (\ell) \rightleftharpoons CN^-\ (aq) + H_3O^+\ (aq)$$

(2 marks)

b) Complete the following table, indicating whether the following statements are true or false.

Statement	True/False
Methanoic acid is a stronger acid than oxalic acid	False
0.1 $molL^{-1}$ NaCℓO (aq) has a higher pH than 0.1 $molL^{-1}$ KCN (aq)	False
In a hypochlorous acid solution, [HCℓO] > [$C\ell O^-$]	True
The conjugate base of oxalic acid ($H_2C_2O_4$) is $C_2O_4^{2-}$	False

(4 marks)

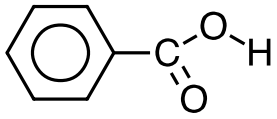
c) Explain why a solution of potassium methanoate (KCHOO) is basic. Use equations to illustrate your answer.

The methanoate ion is the conjugate base of a weak acid.
It hydrolyses in water to produce OH^- ions (1)
$CHOO^-\ (aq) + H_2O\ (\ell) \rightleftharpoons OH^-\ (aq) + CHOOH\ (aq)$ (1)
The $[OH^-]$ concentration increases
$[OH^-] > [H^+]$, therefore is basic (1)

(3 marks)

15. Benzoic acid, drawn below, is a monoprotic weak acid.

Benzoic acid (C_6H_5COOH)



A buffer was produced by mixing 100 mL of 0.5 $molL^{-1}$ benzoic acid with 100 mL of 0.5 $molL^{-1}$ sodium benzoate (NaC_6H_5COO) solution.

a) Write an equation to show the equilibrium system that is established in this buffer solution.

$$C_6H_5COOH\ (aq)\ +\ H_2O\ (\ell)\ \rightleftharpoons\ H_3O^+\ (aq) + C_6H_5COO^-\ (aq)$$

The benzoate reacting with water to form OH^- is also ok

(1 mark)

b) When a single drop of concentrated sodium hydroxide is added to the benzoic acid buffer solution, the pH increases only minimally. Account for this observation, using an equation(s) to illustrate your answer. Note, a detailed collision theory response is not required.

When OH- is added to the buffer, it reacts with the benzoic acid, and reacts as shown below.

$$C_6H_5COOH\ (aq)\ +\ OH^-\ (aq)\ \rightleftharpoons\ H_2O\ (\ell) + C_6H_5COO^-\ (aq) \qquad (2)$$

Most of the additional OH^- is consumed, therefore its concentration only increases slightly (1)

(3 marks)

c) When the same drop of concentrated sodium hydroxide is added to water, the pH increases significantly. Account for this observation.

H^+ is only present in water at very low concentrations (10^{-7} $molL^{-1}$) (1)

Therefore, the buffer capacity is very low and quickly exceeded when sodium hydroxide is added (1)

Therefore, the concentration of OH^- increases significantly, increasing the pH.

(2 marks)

16. The acidification of the world's oceans as a result of increased atmospheric carbon is causing damage to marine ecosystems.

When CO_2 (g) dissolves in water, it produces carbonic acid (H_2CO_3), which then ionises in water to produce H_3O^+ ions, decreasing the pH of the water as shown below.

$H_2CO_3\,(aq) + H_2O\,(\ell) \rightleftharpoons HCO_3^-\,(aq) + H_3O^+\,(aq)$

One major concern due to the increased acidity of the oceans its effect on calcification, the process by which marine organisms build their shells using carbonate ions.

Calcification: $Ca^{2+}\,(aq) + CO_3^{2-}\,(aq) \rightleftharpoons CaCO_3\,(s)$

Carbonate ions can also react with hydronium ions present in the ocean.

$H_3O^+\,(aq) + CO_3^{2-}\,(aq) \rightleftharpoons HCO_3^-\,(aq) + H_2O\,(\ell)$

a) Hence, or otherwise, complete the following table, describing the effects on the concentration or mass of various species in the oceans due to the increased levels of atmospheric CO_2.

Species	Effect (increase/decrease/no change)
$[HCO_3^-]$	increase
$[CO_3^{-2}]$	decrease
Mass of $CaCO_3$	decrease

(3 marks)

End of test