Christ Church
Grammar School

Year 12 Chemistry

Acids and bases test
2018

Time allowed: 45 minutes

Name: SOLUTIONS

Mark = .../46

Teacher:

KLW CEM JPT NMO

Section 1 Multiple Choice **10 marks**

1. Which of these is not an acid-base reaction?

   A. $H_3O^+(aq) + OH^-(aq) \rightarrow 2\ H_2O\ (l)$
   B. $H_2O(l) + HCl\ (aq) \rightarrow H_3O^+(aq) + Cl^-(aq)$
   C. $OH^-(aq) + H_3O_2^+(aq) \rightarrow H_2O\ (l) + H_2O_2\ (aq)$
   D. $2\ H_2O\ (aq) \rightarrow 2\ H_2\ (l) + O_2\ (g)$

2. The conjugate base of HCO_3^- is

   A. $H_2CO_3^-$
   B. CO_3^{2-}
   C. H_2CO_3
   D. CO_2

3. Which of the following solutions will have a pH greater than 7?

   A. 0.01 $molL^{-1}$ NH_4Cl
   B 0.01 $molL^{-1}$ $NaHSO_4$
   C. 0.01 $molL^{-1}$ CH_3COOH
   D. 0.01 $molL^{-1}$ KCH_3COO

4. Which of the following pairs of solutions **can not** be used to prepare an effective buffer?

   A. $NaHCO_3$ and HCl
   B. HNO_3 and $NaNO_3$
   C. CH_3COOH and KOH
   D. NH_3 and HCl

5. Which of the following best describes the reaction that occurs when ethanoic acid reacts with magnesium carbonate?

   A. $2\ H^+(aq) + MgCO_3\ (s) \rightarrow CO_2\ (g) + H_2O\ (l) + Mg^{2+}\ (aq)$
   B. $2\ CH_3COOH\ (aq) + MgCO_3\ (s) \rightarrow CO_2\ (g) + H_2O\ (l) + Mg(CH_3COO)_2\ (aq)$
   C. $2\ CH_3COOH\ (aq) + MgCO_3\ (s) \rightarrow CO_2\ (g) + H_2O\ (l) + Mg^{2+}\ (aq) + 2CH_3COO^-\ (aq)$
   D. $2\ H^+(aq) + CO_3^{2-}\ (aq) \rightarrow CO_2\ (g) + H_2O\ (l)$

6. Sulfurous acid (H_2SO_3) is an acid which ionises in water according to the following equation.

$$H_2SO_3\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + HSO_3^-\ (aq) \qquad K_a = 1.54 \times 10^{-2}$$

Which of the following statements is true about 100 mL of a 0.1 $molL^{-1}$ H_2SO_3 solution?

A. If water is added, the pH will decrease.
B. $[H_3O^+] > [H_2SO_3]$
C. $[H_3O^+] > [OH^-]$
D. The pH is 1.0

7. Equal volumes of HF (a weak acid with Ka = 7.2×10^{-4}) and a solution of nitric acid of equal concentration are mixed together. Which of the following correctly indicates the various ions in the resulting solution in descending order of concentration?

A. $H_3O^+ > NO_3^- > HF > F^-$
B. $H_3O^+ > NO_3^- > F^- > HF$
C. $HF > H_3O^+ > NO_3^- > F^-$
D. $NO_3^- > H_3O^+ > F^- > HF$

8. A buffer is prepared consisting of equal concentrations of ethanoic acid and potassium ethanoate. A small volume of concentrated sodium hydroxide solution is added to this buffer and equilibrium is re-established. Which of the following is true?

A. The pH will remain unchanged
B. The value of the equilibrium constant for the reaction will increase.
C. The concentration of hydrogen ions will increase.
D. The concentration of ethanoate ions will increase.

9. The pH of an unknown aqueous solution is found to be 13.00. Which of the following is most likely to be the unknown solution?

A. 1.00×10^{-13} $molL^{-1}$ sodium hydroxide
B. 5.00×10^{-2} $molL^{-1}$ barium hydroxide
C. 1.00×10^{-13} $molL^{-1}$ nitric acid
D. 1.00×10^{-2} $molL^{-1}$ potassium hydroxide

10. The Ka values of a number of acids are listed below:

Acid	Ka value
CH_3COOH	1.76×10^{-5}
HF	7.2×10^{-4}
HS^-	6.2×10^{-8}
HCO_3^-	4.7×10^{-11}

Based on the above information, which of the following 1 $molL^{-1}$ solutions would you expect to have the highest pH?

A. $NaCH_3COO$ (aq)
B. NaF (aq)
C. Na_2S (aq)
D. Na_2CO_3 (aq)

Section 2 Written questions **36 marks**

Question 1 **(2 marks)**

Water is amphiprotic, meaning that it can act as both an acid and a base according to the Bronstëd-Lowry Theory. Using its reaction with HCl and NH_3 as examples, write balanced equations to show the amphiprotic nature of water.

Acting as an acid

Equation: $H_2O_{(l)} + NH_{3(aq)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

Acting as a base

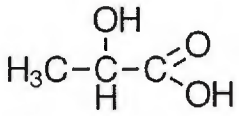
Equation: $H_2O_{(l)} + HCl_{(aq)} \rightleftharpoons H_3O^+{}_{(aq)} + Cl^-{}_{(aq)}$

-1 if the two equations are in the wrong place

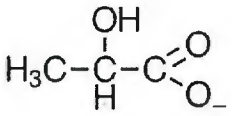
Question 2 **(11 marks)**

A buffer was formed by the addition of 100 mL of 1 $molL^{-1}$ lactic acid ($CH_3CHOHCOOH$) (aq) to 100 mL of 1 $molL^{-1}$ sodium lactate ($NaCH_3CHOHCOO$) (aq). At this point, the pH was 3.9.

Lactic acid is a monoprotic acid and its structure and that of the lactate ion are shown below.



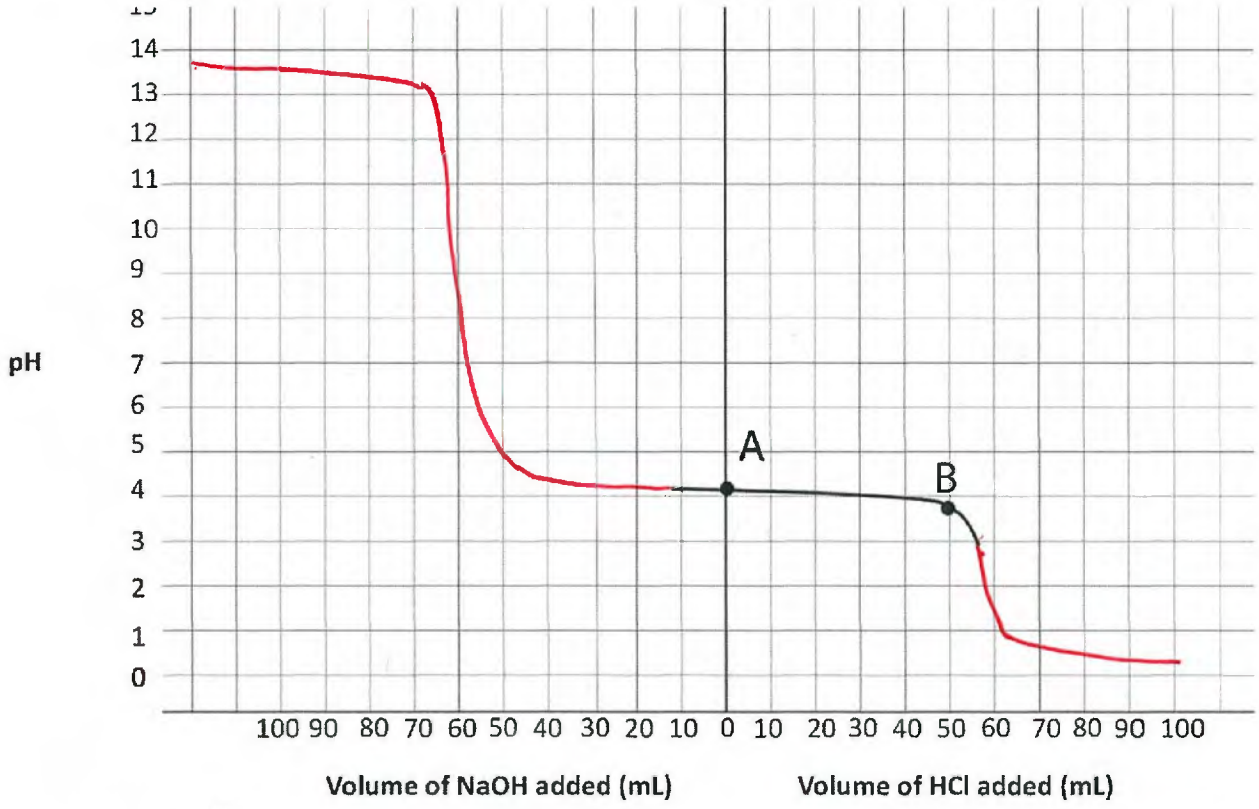
lactic acid



lactate ion

100 mL aliquots of the lactic acid/lactate buffer solution were added to two different beakers.

1 $molL^{-1}$ HCl (aq) and 1 $molL^{-1}$ NaOH (aq) were added to each beaker respectively, and the pH measured. A section of the resulting graph has been completed for you.



a) Write an equation to represent the equilibrium between the species present in the lactic acid/lactate buffer mixture.

$CH_3CHOHCOOH_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + CH_3CHOHCOO^-_{(aq)}$

(1 mark)

b) Explain why the pH drops significantly at point B. Use a calculation to support your answer.

- the buffer capacity is exceeded (1)
- there is no more $CH_3CHOHCOO^-_{(aq)}$ for the H^+ to react with (1)
- relevant calculation or mathematic reasoning (1)

eg. $n(\text{lactate}) = C \times V = 1 \times 0.05 = 0.05$ moles

$V(HCl)$ containing 0.05 moles $= \frac{n}{C} = \frac{0.05}{1} = 50$ mL.

(3 marks)

c) Complete the graph between the addition of 100 mL of NaOH **and** 100 mL of HCl.

(1) pH rise ~ 50 mL of NaOH
(1) for ending between (13 ∝ 14) & (0 ∝ 1)

(2 marks)

d) Using an equation, explain why the buffer maintains a fairly constant pH when HCl (aq) is added between points A and B, but when the same amount of HCl is added to water, the pH drops by a significant amount.

When HCl is added to the buffer, it reacts with the lactate ion. (1)

$CH_3CHOHCOO^-_{(aq)} + H_3O^+_{(aq)} \longrightarrow CH_3CHOHCOOH + H_2O_{(l)}$ (1)

- Most of the added H_3O^+ is consumed, so its concentration increases by a small amount, and the pH only drops slightly (1)

- In water, the concentration of OH^- is 10^{-7} (1)
there is very little OH^- present to react with added H^+, so the concentration of H^+ increases greatly, and the pH drops (1)

(5 marks)

(3) for buffer explanation
(2) for water

d) However, despite the difference in rates of reaction, both the propanoic acid and HCl solutions will react with the same mass of nickel hydroxide over time. Explain this observation.

$CH_3CH_2COOH + H_2O \rightleftharpoons H_3O^+ + CH_3CH_2COO^-$ (not required)

- Although less H_3O^+ is present initially, propanoic acid continues to ionise, as it reacts with $Ni(OH)_2$ (1)
- The total amount of H_3O^+ available to react is the same (1)

(2 marks)

Question 4 **(5 marks)**

a) Rank the following 1 $molL^{-1}$ solutions in order of increasing pH: KNO_3, Na_2CO_3, CH_3COOH, HNO_3

Lowest $HNO_3 < CH_3COOH < KNO_3 < Na_2CO_3$ Highest

- (1) if in reverse order

(2 marks)

b) Using an equation, account for the predicted pH of Na_2CO_3

The CO_3^{2-} ion is weakly basic

It hydrolyses in water to form OH^- ions (1)

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$ (1)

$[OH^-] > [H_3O^+]$, so the solution is basic (1)

(3 marks)

Question 3 **(9 marks)**

Propanoic acid is a weak acid that ionises in water according to the following equation.

$CH_3CH_2COOH\ (aq) + H_2O\ (l) \rightleftharpoons CH_3CH_2COO^-\ (aq) + H_3O^+\ (aq)$ $K_a = 1.34 \times 10^{-5}$

a) Circle the two species acting as Bronstëd-Lowry bases in the above equation.
(1 mark)

b) Write a balanced ionic equation and observation for the reaction between solid nickel hydroxide and a solution of propanoic acid.

Equation: $Ni(OH)_{2\,(s)} + 2CH_3CH_2COOH_{(aq)} \longrightarrow 2H_2O_{(l)} + Ni^{2+}_{(aq)} + 2CH_3CH_2COO^-_{(aq)}$

(2 marks)

Observation:

Green solid dissolves in colourless solution (1)
to form a green solution (1)

(2 marks)

c) Compared to a solution of HCl of the same volume and concentration, propanoic acid will react more slowly with the nickel hydroxide. Explain this observation.

- propanoic acid is weak
- therefore the concentration of H^+ is lower (1)
- the frequency of collisions between H^+ & $Ni(OH)_{2\,(s)}$ is lower (1)

(2 marks)

Question 5 **(9 marks)**

Determine the resultant pH of the following mixtures:

a) 200 mL of 1.5 $molL^{-1}$ NaOH solution is diluted with 100 mL of water.

$n(OH^-) = C \times V$

$= 1.5 \times 0.2$

$= 0.3$ moles (1)

new $[OH^-] = \frac{n}{V} = \frac{0.3}{0.3} = 1\ molL^{-1}$ (1)

$[H^+] = \frac{10^{-14}}{[OH^-]} = 10^{-14}$ $pH = 14.$ (1) (3 marks)

b) 100 mL of an unknown solution of pH 2 is mixed with 200 mL of a 0.001 $molL^{-1}$ KOH solution.

$H^+ + OH^- \longrightarrow H_2O$

$[H^+] = 10^{-2}$

$= 0.01\ molL^{-1}$

$n(H^+) = C \times V$

$= 0.01 \times 0.1$

$= 0.001$ moles (1)

$n(OH^-) = C \times V$

$= 0.001 \times 0.2$

$= 0.0002$ moles (1)

H^+ & OH^- react in 1:1 ratio.

$n(H^+) > n(OH^-)$. $\therefore$ OH^- is the LR (1)

H^+ is in excess

$n(H^+)$ left over $= 0.001 - 0.0002$

$= 0.0008$ moles (1)

$[H^+] = \frac{n}{V} = \frac{0.0008}{0.3} = 0.002667\ molL^{-1}$ (1)

(6 marks)

final $pH = 2.57$ (1)

END OF TEST