Christ Church Grammar School

Year 12 Chemistry

Acids and Bases Test 2021

Time allowed: **45 minutes**

Name: ANSWERS

Mark = .../48

SECTION 1 MULTIPLE CHOICE 10 marks

1. In which group would all three oxides be classified as basic oxides?

   A. CO_2, SiO_2, CuO

   B. P_4O_{10}, SO_2, CO_2

   C. CaO, Na_2O, K_2O.

   D. ZnO, SO_2, Na_2O

2. In which of the following reactions is water behaving as an acid?

   A. $H_2O(g) + Mg(s) \rightleftharpoons MgO(s) + H_2(g)$

   B. $H_2O(\ell) + CH_3NH_2(aq) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

   C. $2H_2O(\ell) \rightleftharpoons 2H_2(g) + O_2(g)$

   D. $H_2O(l) + H_2S(g) \rightleftharpoons HS^-(aq) + H_3O^+(aq)$

3. Consider the following information regarding weak acids.

   Solution 1: 20.0 mL of 0.100 mol L^{-1} $HC\ell O$ has a pH of 4.27
   Solution 2: 20.0 mL of 0.100 mol L^{-1} HCN has a pH of 5.11

   The two solutions are combined. Which of the following would be present in the mixture at the highest concentration?

   A. H_3O^+

   B. HCN

   C. $HC\ell O$

   D. $C\ell O^-$

4. Which of the following equations shows the hydrogen sulfide ion, HS^- acting as a base ?

   A. $HS^-(aq) + NH_4^+(aq) \rightleftharpoons H_2S(aq) + NH_3(aq)$

   B. $2HS^-(aq) + Cu^{2+}(aq) \rightleftharpoons Cu(HS)_2(s)$

   C. $HS^-(aq) + F_2(g) \rightleftharpoons S(s) + H^+(aq) + 2F^-(aq)$

   D. $HS^-(aq) + O^{2-}(aq) \rightleftharpoons OH^-(aq) + S^{2-}(aq)$

5. Which of the following statements is incorrect ?

A. The higher the pH of a solution, the higher its $[OH^-]$.

B. The higher the pH of a solution, the more acidic it is.

C. The lower the alkalinity of a solution, the lower its pH.

D. The higher the concentration of OH^- in a solution, the lower its $[H^+]$.

6. 'Milk of magnesia' consists of a saturated solution of magnesium hydroxide, and is used to treat acid indigestion. If the pH of milk of magnesia is 10, the concentration of $Mg(OH)_2$ in the solution is :

A. 1.0×10^{-10} mol L^{-1}

B. 5×10^{-11} mol L^{-1}

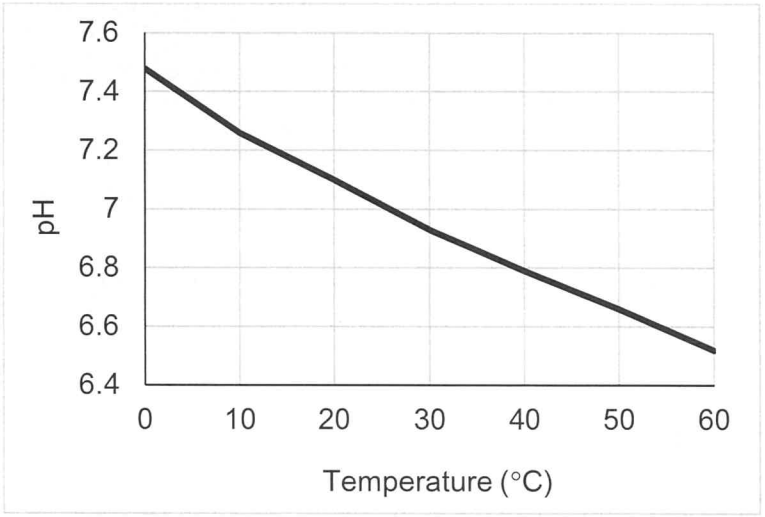
C. 1.0×10^{-4} mol L^{-1}

D. 5.0×10^{-5} mol L^{-1}

7. A chemist carried out an experiment to investigate the self-ionisation of water.

$$\mathbf{H_2O(\ell) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OH^-(aq)}$$

The data collected by the chemist is shown in the graph below.



Which of the following is **not** a conclusion that can be made from the data collected in this experiment?

A. An increase in water temperature will favour the forward reaction.

B. An increase in water temperature will increase the forward reaction rate.

C. The self-ionisation of water is exothermic.

D. The concentration of $H_3O^+(aq)$ in water is temperature-dependant.

8. A chemist prepares solutions of nitrous acid and hydrocyanic acid that have the same concentration

The Ka values of these acids are:

- Nitrous acid (HNO_2) Ka = 4.6×10^{-4}
- Hydrocyanic acid (HCN) Ka = 6.17×10^{-10}

Which acid is stronger and which has the highest pH

	STRONGER ACID	**HIGHER pH**
A.	Nitrous acid	Hydrocyanic acid
B.	Nitrous acid	Nitrous acid
C.	Hydrocyanic acid	Hydrocyanic acid
D.	Hydrocyanic acid	Nitrous acid

9. The following three reactions all have K values > 1.

$$\mathbf{HSO_4^-(aq) + NO_2^-(aq) \rightleftharpoons HNO_2(aq) + SO_4^{2-}(aq)}$$

$$\mathbf{HNO_2(aq) + CN^-(aq) \rightleftharpoons HCN(aq) + NO_2^-(aq)}$$

$$\mathbf{HC\ell O_4(aq) + SO_4^{2-}(aq) \rightleftharpoons HSO_4^-(aq) + C\ell O_4^-(aq)}$$

Rank the bases above in order from strongest to weakest

A. $C\ell O_4^- > SO_4^{2-} > NO_2^- > CN^-$

B. $CN^- > NO_2^- > SO_4^{2-} > C\ell O_4^-$

C. $C\ell O_4^- > NO_2^- > SO_4^{2-} > CN^-$

D. $CN^- > NO_2^- > C\ell O_4^- > SO_4^{2-}$

10. Which of the following solutions describes the buffer with the highest buffering capacity?

A. Equal volumes of 0.5 $molL^{-1}$ Na_2HPO_4 and 0.5 $molL^{-1}$ K_3PO_4

B. Equal volumes of 2.0 $molL^{-1}$ Na_3PO_4 and 2.0 $molL^{-1}$ K_3PO_4

C. Equal volumes of 2.0 $molL^{-1}$ Na_3PO_4 and 1.0 $molL^{-1}$ KOH

D. Equal volumes of 2.0 $molL^{-1}$ Na_2HPO_4 and 1.0 $molL^{-1}$ KOH

SECTION 2 **SHORT ANSWER** **(38 marks)**

Question 1 **(8 marks)**

Write ionic equations for the following:

(a) The hydrogencarbonate ion acting as Bronsted-Lowry base.

$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$

(2 marks)

(b) ~~The~~ hydrocyanic acid (HCN) acting as a Bronsted-Lowry acid.

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

(2 marks)

For the equation you wrote in (b) identify the conjugate acid-base pairs

Acid-base pair 1	Acid- base pair 2
Acid: HCN	Acid: H_3O^+
Base: CN^-	Base: H_2O

(2 marks)

(d) A 0.1 molL^{-1} solution of HCN has a pH = 5.2 . Calculate the % ionisation of the HCN.

$$\%\text{ ionisation} = [H_3O^+]/[HCN] \times 100$$
$$= 10^{-5.2}/10^{-1} \times 100$$
$$= 6.31 \times 10^{-3}\ \%$$

(2 marks)

Question 2 **(8 marks)**

(a) The following ionic salts were all dissolved separately in equal volumes of water at 25°C. Complete the table below indicating whether the solutions would be acidic, basic or neutral.

Salt	Acid, base or neutral
Potassium nitrate	Neutral
Ammonium chloride	acidic
sodium ethanoate	basic
Potassium hydrogensulfate	acidic

(4 marks)

(b) Another salt, ammonium phosphate was dissolved in water and found to have a pH of 8.1. Use your knowledge of acid/base chemistry to account for this observation. Use equations to support your answer.

① $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+$

② $PO_4^{3-} + H_2O \rightleftharpoons HPO_4^- + OH^-$ or $PO_4^{3-} + 3H_2O \rightleftharpoons H_3PO_4 + 3OH^-$

② proceeds to a greater extent than ①

$[OH^-] > [H_3O^+]$ $pH > 7$

(4 marks)

Question 3 **(9 marks)**

The pH within the human body is tightly controlled by a series of buffer systems. One of the major buffers present is the phosphate buffering system, as shown below:

Reaction1: $H_3PO_4\,(aq) + H_2O \rightleftharpoons H_3O^+\,(aq) + H_2PO_4^-\,(aq)$

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

Reaction 3: $HPO_4^{2-}\,(aq) + H_2O \rightleftharpoons H_3O^+\,(aq) + PO_4^{3-}\,(aq)$

(b) The value for the equilibrium constant (Ka) for Reaction 2 is 6.23×10^{-8} at 25°C. This value changes to 7.82×10^{-8} at 40°C. Is it an endothermic or exothermic reaction? Circle the correct alternative below and explain your answer.

Endothermic **Exothermic** (1 mark)

Explanation:

As T increases K increases.
This means Σproducts increase.
Increase in T favours the endothermic process ∴ forward reaction is endothermic

(3 marks)

(d) Using collision theory explain how Reaction 2 acts as a buffer if the $[OH^-]$ increases. Use appropriate equations in your answer.

- $OH^- + H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H_2O$ $(H_3O^+ + OH^- \rightleftharpoons 2H_2O)$
- When OH^- is added the frequency of collisions increases.
- The rate of the forward reaction increases, rate of the reverse reaction stays the same initially.
- Equilibrium shifts right consuming the OH^- that has been added
- Change in pH is minimised.

(5 marks)

Question 4 **(9 marks)**

100.0 mL of a NaOH solution with a pH = 13 has the same volume of 0.01mol L^{-1} H_2SO_4 added to it. Calculate the pH of the combined solution.

$[OH^-] = 10^{-1}$ mol L^{-1}

$n(OH^-) = 0.1 \times 0.1$

$= 0.01$ mole

$n(H^+) = .1 \times .01 \times 2$

$= .002$ mole

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

$n(OH^-)$ in x.s. $= 0.008$ mole

$[OH^-] = n/V = .008/0.2 = 0.04$ mol L^{-1}

$[H^+] = 10^{-14}/0.04 = 2.5 \times 10^{-13}$ mol L^{-1}

$pH = 12.6$

Question 5 **(4 marks)**

There is evidence to suggest that the increase in ocean acidification is caused carbon dioxide produced as a result of human activity such as the burning of fossil fuels. The chemistry of carbon dioxide dissolving in seawater is summarized in the equations below.

Equation 1 $CO_2(g) \rightleftharpoons CO_2(aq)$

Equation 2 $CO_2(aq) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq)$

Equation 3 $H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$

Equation 4 $HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$

(a) How does an increase in atmospheric carbon dioxide can lead to an increase in acidity in seawater?

If $[CO_2(g)]$ increases all equilibria shift right

$[H_3O^+]$ in Equations 3 + 4 increases

(2 marks)

(b) There is also evidence that the increased acidity is causing thinning of seashells. Write an ionic equation for this process.

$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$

(2 marks)