Methodist Ladies' College
Semester 1 Examination, 2016

CHEMISTRY
ATAR Year 12

Section One: Multiple-choice **25% (50 Marks)**

1	**d**	**6**	**a**	**11**	**b**	**16**	**a**	**21**	**b**
2	**a**	**7**	**c**	**12**	**b**	**17**	**d**	**22**	**d**
3	**d**	**8**	**d**	**13**	**a**	**18**	**a**	**23**	**c**
4	**c**	**9**	**d**	**14**	**c**	**19**	**d**	**24**	**b**
5	**b**	**10**	**c**	**15**	**b**	**20**	**d**	**25**	**a**

1. Solution **X** has a pH of 4.38. When it is diluted tenfold the pH changes to 4.88.

   X is likely to be:

   (a) an insoluble acid
   (b) a buffered acid
   (c) a strong acid
   (d) a weak acid

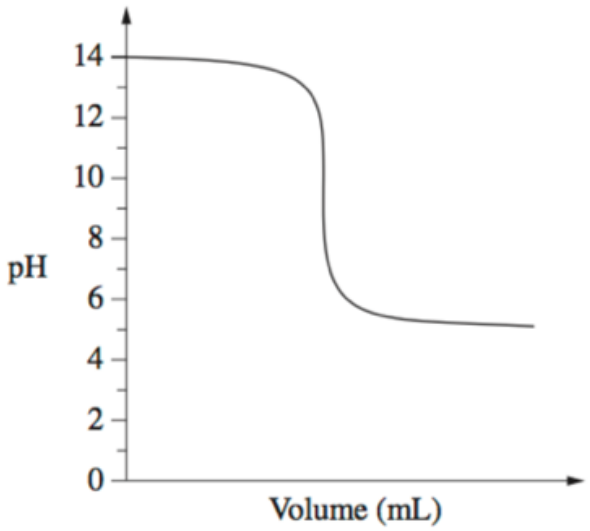
2. A lemon juice is found to have a pH of 3 and an apple juice a pH of 5. The concentration of hydrogen ions in the lemon juice compared with the apple juice are in the ratio:

   (a) 100 : 1
   (b) 1 : 100
   (c) 20 : 1
   (d) 3 : 5

3. A solution of sodium hydroxide is diluted with water. Which option shows the changes that occur?

	[H+]	[OH-]	electrical conductivity
(a)	decreases	increases	increases
(b)	decreases	increases	decreases
(c)	increases	decreases	increases
(d)	**increases**	**decreases**	**decreases**

4. The graph below shows the changes in pH during a titration.



Consider the following acid-base indicators.

Indicator	pH range of colour change	colour change
methyl red	4.4 – 6.2	red to yellow
bromothymol blue	6.0 – 7.6	yellow to blue
phenolphthalein	8.3 – 10.0	colourless to pink

Which of the following statements is correct?

(a) Bromothymol blue would be a good choice of indicator for this titration.

(b) With phenolphthalein the titration should be stopped when the solution in the conical flask shows the first permanent pink colour.

(c) With methyl red the endpoint would occur after the equivalence point.

(d) Methyl red is a good choice as the final pH lies between 4 and 6.

5. Which of the following could not be used to prepare a buffer solution?

(a) nitric acid and ammonia solutions

(b) nitric acid and potassium nitrate solutions

(c) ethanoic acid and potassium ethanoate solutions

(d) ethanoic acid and potassium hydroxide solutions

See next page

6. Which of the following shows the correct acid-base properties of the salts listed?

	NaF	$Fe(NO_3)_2$	K_2CO_3
(a)	**basic**	**neutral**	**basic**
(b)	basic	acidic	acidic
(c)	neutral	neutral	acidic
(d)	neutral	acidic	basic

7. $ClO_3^-(aq) + 6H^+(aq) + \mathbf{n}e^- \rightarrow Cl^-(aq) + 3H_2O(l)$

What is the value of **n**?

(a) 4

(b) 5

(c) 6

(d) 7

8. The reaction between hydrogen peroxide and ammonium ions is represented by the following equation.

$$3H_2O_2(aq) + 2NH_4^+(aq) \rightarrow N_2(g) + 2H^+(aq) + 6H_2O(l)$$

Which of the following statements is correct?

(a) NH_4^+ is the oxidant

(b) $H_2O_2(aq)$ is reduced to $H^+(aq)$

(c) $H_2O_2(aq)$ is oxidised to $H_2O(l)$

(d) $N_2(g)$ is the product of oxidation

9. Which of the following pairs of reactants **will not** undergo a spontaneous redox reaction?

(a) gold(III) nitrate solution and sodium bromide solution.

(b) potassium iodide solution and gaseous chlorine

(c) gaseous fluorine and metallic gold.

(d) tin(II) nitrate solution and metallic silver

See next page

10. Many crude oils contain H_2S. During refining, by the Claus process, the H_2S is converted into solid sulphur, which is then removed.

Reaction I $2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(l) + 2SO_2(g)$

Reaction II $2H_2S(g) + SO_2(g) \rightarrow 2H_2O(l) + 3S(s)$

Which statements about the Claus process are correct?

(i) H_2S is oxidised in reaction 1.

(ii) SO_2 oxidises H_2S in reaction II.

(iii) Hydrogen is oxidised in reaction II.

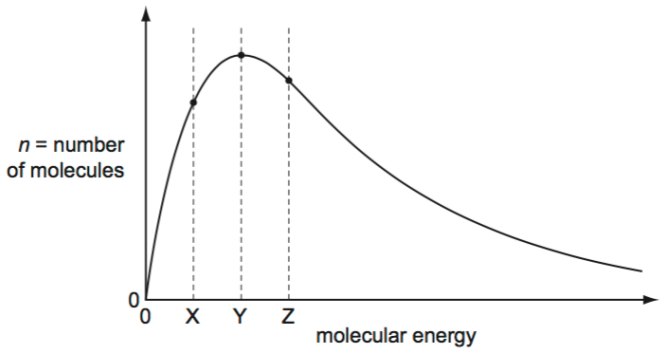
(a) (i), (ii) and (iii)

(b) (ii) and (iii)

(c) (i) and (ii)

(d) (i) only

11. The Boltzman (kinetic energy) distribution for a gas at constant temperature is shown below.



If the temperature is reduced by 10°C the graph changes shape. What happens to the values of n for the molecular energies X, Y and Z?

	X	Y	Z
(a)	higher	lower	higher
(b)	**higher**	**lower**	**lower**
(c)	lower	higher	lower
(d)	lower	lower	lower

See next page

12. Hydrazine, N_2H_4, is used as a rocket fuel because it reacts with oxygen as shown, producing 'environmentally friendly' gases.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2H_2O(g) \qquad \Delta H = -534 \text{ kJmol}^{-1}$$

Despite its use as a rocket fuel, hydrazine does not burn spontaneously in oxygen. Which statement best explains why hydrazine does not burn spontaneously?

(a) hydrazine is a liquid

(b) the activation energy is high

(c) there are more moles of product species than reactant species

(d) the reaction is exothermic

13. Which of the following processes is exothermic?

(a) water freezing

(b) $I_2(s) \rightarrow I_2(g)$

(c) $I_2(g) \rightarrow 2I(g)$

(d) $K \rightarrow K^+ + e^-$

14. The reaction shown below

$$H_2C_2O_4(aq) + Ba^{2+}(aq) + 2OH^-(aq) \rightarrow BaC_2O_4(s) + 2H_2O(l)$$

can be described as: 1. redox 2. acid-base 3. precipitation

(a) 1. only

(b) 1. and 2.

(c) 2. and 3.

(d) 1. and 3.

15. In which of the following would an increase in volume of the reacting system, at constant temperature, favour the forward reaction?

I $N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$

II $CH_3COO^-(aq) + H_2O(l) \rightleftarrows CH_3COOH(aq) + OH^-(aq)$

III $Cr_2O_7^{2-}(aq) + 2OH^-(aq) \rightleftarrows 2CrO_4^{2-}(aq) + H_2O(l)$

IV $Cl_2(g) + F_2(g) \rightleftarrows 2FCl(g)$

(a) I only

(b) II only

(c) I and III

(d) II and IV

16. NaOCl dissociates in water to form $Na^+(aq)$ and $OCl^-(aq)$. In solution $OCl^-(aq)$ undergoes slight hydrolysis:

$$OCl^-(aq) + H_2O(l) \rightleftarrows HOCl(aq) + OH^-(aq)$$

100mL of pure water at constant temperature is added to 100mL of 0.10 $molL^{-1}$ NaOCl. When the solution re-establishes equilibrium, the:

(a) pH of the solution has decreased

(b) $[OH^-]$ has increased

(c) value of the equilibrium constant has halved

(d) $[OCl^-]$ has increased

17. Q, R and S are three elements from period 3 of the Periodic Table. Given the information below:

i. the oxide of S dissolves in water to produce a solution that turns blue litmus paper red

ii. Q reacts vigorously with water forming a solution that turns red litmus paper blue

iii. R forms an oxide with a high melting point that is insoluble in both water and hydrochloric acid solution

If the elements are arranged in order of increasing atomic number, the correct order would be:

(a) QSR

(b) SRQ

(c) RQS

(d) QRS

18. For which conversion is an oxidising agent required?

(a) $H_2O_2(aq) \rightarrow O_2(l)$

(b) $F_2(g) \rightarrow 2F^-(aq)$

(c) $MnO_2(s) \rightarrow Mn_2O_3(s)$

(d) $Fe^{3+}(aq) \rightarrow Fe^{2+}(aq)$

See next page

19. A solution of lead(II) nitrate is to be stored in a metal container. Which one of the following metals would be best to use?

(a) Ni

(b) Zn

(c) Fe

(d) Cu

20. Consider the data below on the two allotropes of oxygen.

Name	Formula	colour of liquid/solid	Melting point °C	Boiling point °C	Density of liquid (g mL^{-1})	Polarity
oxygen	O_2	pale blue	-219	-183	1.1	non-polar
ozone	O_3	deep blue	-193	-111	1.6	polar

Equal masses of oxygen and ozone at -190°C are shaken together. When the system settles, what is observed?

(a) a homogeneous mid-blue liquid

(b) a deep blue solid below a pale blue liquid

(c) a pale blue liquid layer below a deep blue liquid layer

(d) a deep blue liquid layer below a pale blue liquid layer

21. Which of the following is likely to be least soluble in water?

(a) propan-1-ol

(b) propanal

(c) propanoic acid

(d) propan-2-ol

22. The following substances are mixed. In which one of these will there be no visible reaction?

(a) hydrogen peroxide solution and sodium iodide solution

(b) sulfuric acid and barium hydroxide solution

(c) carbonic acid solution and calcium nitrate solution

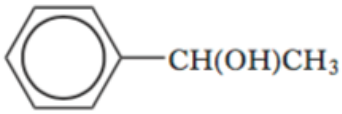
(d) calcium hydroxide solution and sodium nitrate solution

See next page

23. How many unsaturated isomers have the formula $C_3H_4F_2$?

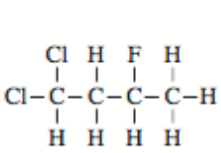
(a) 5
(b) 6
(c) 7
(d) 8

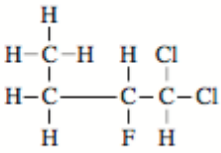
24. Which of the following statements about the compound below is correct?

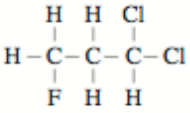


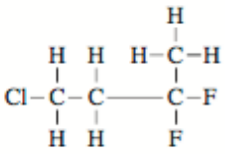
(a) It is likely to be basic in aqueous solution
(b) It can be oxidised to a ketone
(c) It reacts readily with bromine solution
(d) It can be oxidised to a carboxylic acid

25. Four compounds, W, X, Y and Z, are represented below.


Compound W


Compound X


Compound Y


Compound Z

Which of the following is a pair of isomers?

(a) W and X
(b) W and Y
(c) X and Y
(d) X and Z

END OF SECTION 1

See next page

Section Two: Short answer **35% (70 Marks)**

This section has eleven (11) questions. Answer all questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes

Question 26 **(5 marks)**

(a) The equilibrium constant expression for a reaction involving A, B, C and D is:

$$K = \frac{[C]^3[D]}{[A]\,[B]^2}$$

Write the chemical equation for this reaction (2 marks)

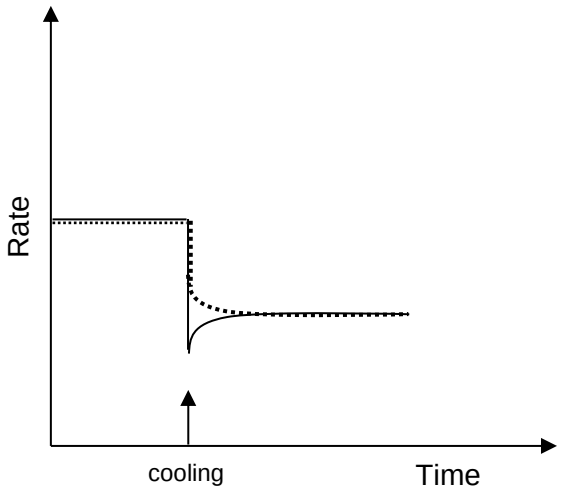
$A + 2B \rightleftarrows 3C + D$

(b) At 150°C the value of K is 25 and at 350°C the value of K is 73. Is the forward reaction endothermic or exothermic?

endothermic (1 mark)

(c) Using your answer to (b), complete the rates graph below, showing the effect of decreasing the temperature of an equilibrium mixture of A, B, C and D.

(2 marks)



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Question 27 **(6 marks)**

Complete the table by writing the name or formula for a substance that fits the description.

Description	Name or Formula
the conjugate base of $H_2AsO_4^-$	**$HAsO_4^{2-}$**
a strong monoprotic acid	**e.g HNO_3, HCl**
a white solid that dissolves in water to form a slightly basic solution	**e.g. Na_2CO_3, Na_3PO_4**
the halogen that is the best oxidant	**F_2**
a yellow malleable solid	**Au**
a green solid that decomposes on heating to form a black solid and a colourless gas	**$CuCO_3$**

Question 28 **(5 marks)**

When the green solid potassium manganate, K_2MnO_4, is sprinkled on water, it initially dissolves and then the manganate ion undergoes disproportionation (simultaneous oxidation and reduction), forming MnO_2 solid and the aqueous ion MnO_4^-.

(a) Write the oxidation and reduction half equations and the balanced redox equation for the disproportionation of the manganate ion.

(3 marks)

reduction **$MnO_4^{2-} + 4H^+ + 2e^- \rightarrow MnO_2 + 2H_2O$**
oxidation **$2MnO_4^{2-} \rightarrow 2MnO_4^- + 2e^-$** x 2
balanced redox **$3MnO_4^{2-} + 4H^+ \rightarrow MnO_2 + 2H_2O + 2MnO_4^-$**

(b) Give full observations for this reaction. (2 marks)

green solid dissolves in colourless liquid forming black solid and purple solution

See next page

Question 29 **(7 marks)**

Pure liquid ammonia, like water undergoes self-ionisation.

$NH_3(l) + NH_3(l) + \text{energy} \rightleftarrows NH_4^+(am) + NH_2^-(am)$ $K = 1.0 \times 10^{-30}$ at 25°C

$H_2O(l) + H_2O(l) + \text{energy} \rightleftarrows H_3O^+(aq) + OH^-(aq)$ $K = 1.0 \times 10^{-14}$ at 25°C

(am) represents dissolved in liquid ammonia

(a) At 25°C which liquid, water or ammonia, has the higher electrical conductivity? Explain your choice.

(2 marks)

Water as it has the larger K value indicating a higher concentration of product ions

(b) Predict the pH of a solution of sodium amide, $NaNH_2$. Circle the correct answer.

(2 marks)

Acidic **Basic** Neutral

Write an equation to justify your choice.

$NH_2^-(aq) + H_2O(l) \rightleftarrows NH_3(aq) + OH^-(aq)$

(c) At 90°C the pH of pure water is 6.2. The water is still described as neutral. Explain.

(3 marks)

At 90°C the concentration of both $H_3O^+(aq)$ and $OH^-(aq)$ will be higher as the forward reaction is endothermic. The concentrations are equal and so the solution is still described as neutral.

Question 30 **(9 marks)**

Calcium sulfate is slightly soluble in water. An equilibrium mixture of a saturated solution of calcium sulfate in contact with excess solid calcium sulfate is set up. The equilibrium is represented by the following equation.

$CaSO_4(s) \rightleftarrows Ca^{2+}(aq) + SO_4^{2-}(aq)$

Three test-tubes are set up, each containing the equilibrium mixture which appears as a small amount of white solid under a colourless solution.

(a) Complete the table below to show how the equilibrium responds when it is disturbed and give expected observations.

(6 marks)

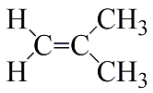
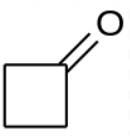
Test tube	What is done	equilibrium shift: write →, ← or no change	expected observation
1	a small quantity of solid calcium sulfate is added	**No change**	**amount of white solid increases**
2	a few drops of concentrated sulphuric acid is added	←	**a white precipitate forms increasing the amount of white solid**
3	a small quantity of solid sodium nitrate is added	**No change**	**white solid dissolves**

(b) Using collision theory and reaction rates, explain the equilibrium shift in test tube 2.
(3 marks)

The sulfate ion concentration increases resulting in a greater frequency of collisions between Ca^{2+} and SO_4^{2-} increasing the rate of the reverse reaction relative to the forward. This causes a build up of reactants as equilibrium is reestablished.

Question 31 **(6 marks)**

Complete the table below by giving the structural formulae or naming the following organic substances.

IUPAC Name	Structural formula
methylpropene	
cyclobutanone	

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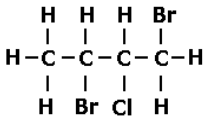
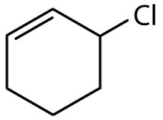
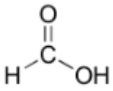
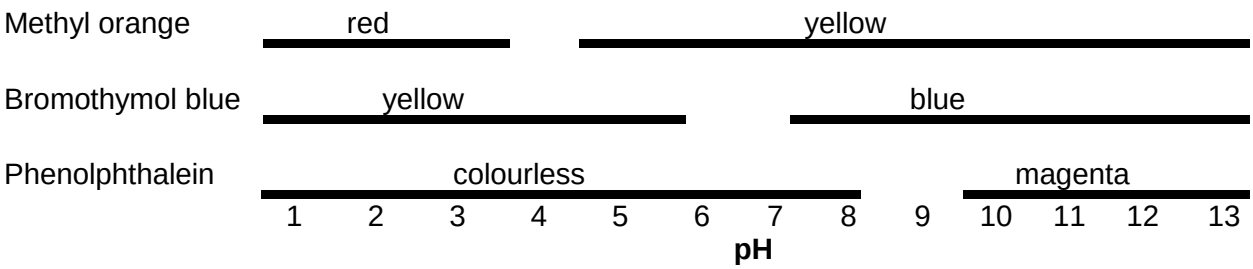
2,3-dichloropentanal	$CH_3CH_2CHClCHClCHO$
1,3-dibromo-2-chlorobutane	
3-chlorocyclohexene	
methanoic acid	

Question 32 **(6 marks)**

The following chart shows the colour ranges for the indicators methyl orange, bromothymol blue and phenolphthalein.



(a) Deduce the possible pH of a chemical that is yellow with methyl orange, blue with bromothymol blue and colourless with phenolphthalein. (1 mark)

pH = **>7 but < 8.2**

(b) Give the expected colour of the indicator in the following solutions. (2 marks)

methyl orange in a solution with $[OH^-(aq)]$ of 1.0×10^{-5} mol L^{-1} **yellow**

phenolphthalein in a 1.0×10^{-9} mol L^{-1} hydrochloric acid solution **colourless**

See next page

(c) Indicators are themselves weak acids. The indicator and its conjugate base have distinctly different colours.

$$HIn + H_2O \rightleftarrows In^- + H_3O^+$$

i) Identify the two conjugate acid/base pairs in the equilibrium. (2 marks)

HIn and In^-, H_2O and H_3O^+

ii) For bromothymol blue state the colour of HIn. **yellow**

(1 mark)

Question 33 **(2 marks)**

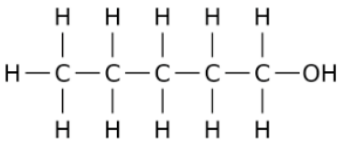
Write a balanced ionic equation for the reaction of sulfuric acid solution and barium hydroxide solution.

$2H^+(aq) + SO_4^{2-}(aq) + Ba^{2+}(aq) + 2OH^-(aq) \rightarrow BaSO_4(s) + 2H_2O(l)$

Question 34 **(6 marks)**

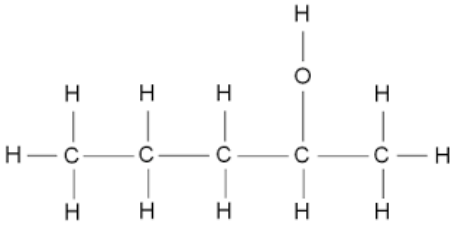
A number of alcohols have the molecular formula $C_5H_{11}OH$. Give the structural formulae and IUPAC name of a primary, secondary and tertiary alcohol with this molecular formula.

Primary



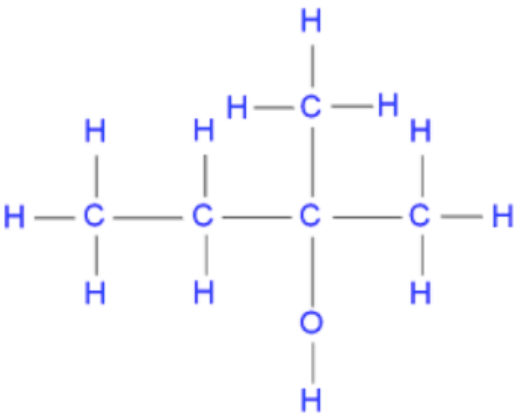
Name: **pentan-1-ol (or e.g. 2-methylbutan-1-ol)**

Secondary



Name: **e.g. pentan-2-ol**

Tertiary



Name: **2-methylbutan-2-ol**

See next page

Question 35 **(4 marks)**

1.35 g of aluminium chloride is dissolved in a little water and made up to 500.0 mL in a volumetric flask. Each mL of solution has a mass of 1.00 g. Determine the chloride ion concentration in parts per million (ppm).

$n(AlCl_3) = \frac{m}{M} = \frac{1.35}{133.33} = 0.01013$ mol

$n(Cl^-) = 3n(AlCl_3) = 3 \times 0.01013 = 0.03038$

$m(Cl^-) = nM = 0.03038 \times 35.45 = 1.077$ g $= 1077$ mg

$ppm = \frac{m\ solute\ in\ mg}{m\ solution\ kg} = \frac{1077}{0.500} = 2154$ ppm $= 2.15 \times 10^3$ ppm

Question 36 **(14 marks)**

Consider the following five 0.10 mol L^{-1} aqueous solutions at 25°C.

Sulfuric acid	Sodium hydroxide	Ethanoic acid
Ammonia	Nitric acid	

(a) Explain which solution has the highest electrical conductivity. (2 marks)

sulfuric acid has the greatest conductivity as it is a strong acid and ionises 100% in its first ionisation and produces more ions in its second partial ionisation giving it the highest overall ion concentration and therefore the highest conductivity.

(b) Explain which solution has the lowest hydrogen ion concentration. (2 marks)

sodium hydroxide as it is the most basic solution with the highest hydroxide ion concentration, as $[H^+][OH^-] = 1.0 \times 10^{-14}$, the higher the hydroxide ion concentration the lower the hydrogen ion concentration.

(c) The ammonia solution has a pH of 10.2. Write an equation for the ionisation of ammonia and determine the percentage ionisation at 25°C. **(**4 marks)

$NH_3(aq) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$

$[OH^-] = 10^{-3.8} = 0.0001584$ mol L^{-1}

(or $[H^+] = 10^{-10.2} = 6.31 \times 10^{-11}$ so $[OH^-] = Kw/[H^+] = 0.0001584$**)**

% ionisation $= \frac{0.0001584}{0.10} \times 100 = 0.16\%$

(d) i) Choose two solutions from the list and describe how you could prepare 300 mL of a buffer solution using only your chosen solutions. (3 marks)

e.g. add 200 mL of ethanoic acid and 100 mL of sodium hydroxide to produce an equimolar solution of ethanoic acid and ethanoate ion (weak acid and conjugate base)

(or 200 mL ammonia and 100 mL nitric acid equimolar weak base and conjugate acid)

See next page

ii) Write an equation representing your buffer system (1 mark)

$CH_3COOH(aq) + H_2O(l) \rightleftarrows CH_3COO^-(aq) + H_3O^+(aq)$

(or $NH_3(aq) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$)

iii) Explain how your buffer system responds to the addition of a strong acid. (2 marks)

addition of a strong acid increases the [H_3O^+] increasing the rate of the reverse reaction relative to the forward and so most of the added hydrogen ions are consumed as they react with the ethanoate ion to form ethanoic acid molecules as the system reestablishes equilibrium.

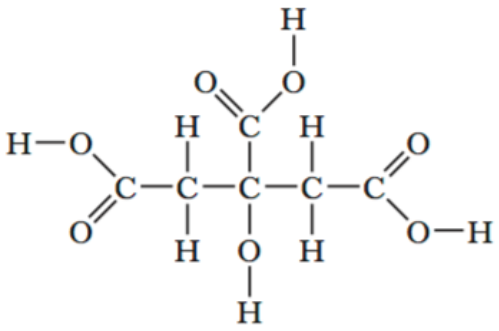
End of Section Two

Section Three: Extended answer **40% (80 Marks)**

Question 37 **(14 marks)**

Sherbet is a sweet powder that fizzes on the tongue.

(a) Sherbet contains the weak triprotic acid, citric acid.



Circle and name the two types of functional group in the citric acid molecule. (2 marks)

1. **alcohol (tertiary)** 2. **carboxylic acid (carboxyl)**

Another triprotic acid is phosphoric acid. Consider the following information.

Acid	pH 0.10 $molL^{-1}$ solution
Citric, $C_6H_8O_7$	3.9
Phosphoric, H_3PO_4	2.6

(b) Explain which acid would have the smallest value equilibrium constant for its first ionisation. (2 marks)

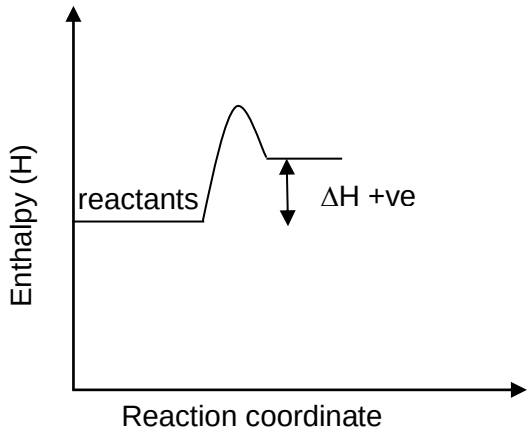
Citric acid since the higher pH indicates a lower hydrogen ion concentration and therefore a lower K value.

(c) When sherbet fizzes on the tongue a cold sensation is felt.

See next page

(i) Complete the reaction profile diagram to show the energy pathway for the reaction. Label the enthalpy change, ΔH.

(2 marks)



(ii) If the energy term was included in the equation for this reaction, would it be a reactant or product?

(1 mark)

Reactant

(d) A sherbet is made by mixing 15.0 g of sodium hydrogen carbonate with 15.0 g of citric acid, which react according to the equation below.

$$C_6H_8O_7 + 3NaHCO_3 \rightarrow C_6H_5O_7Na_3 + 3H_2O + 3CO_2$$

(i) Which reactant is the limiting reagent? (4 marks)

n($NaHCO_3$) = $\frac{15.0}{84.008}$ = 0.1786

n($C_6H_8O_7$) = $\frac{15.0}{192.124}$ = 0.07807

from equation n($NaHCO_3$) = 3n($C_6H_8O_7$) = 3 x 0.07807 = 0.2342 mol, don't have enough therefore n($NaHCO_3$) is LR

(ii) Calculate the maximum volume of carbon dioxide that could be released from this sherbet at 37°C and 101 kPa.

(3 marks)

n(CO_2) = n($NaHCO_3$) = 0.1786

v = $\frac{nRT}{P}$ = $\frac{0.1786 \times 8.314 \times 310.15}{101}$ = 4.56 L

Question 38 **(11 marks)**

Hydrogen cyanide, HCN, is a toxic gas that dissolves in water to produce the weak acid hydrocyanic acid.

$$HCN(aq) \rightleftarrows H^+(aq) + CN^-(aq)$$

(a) Hydrocyanic acid reacts with sodium hydroxide solution.

(i) Write an ionic equation for this reaction. (2 marks)

$HCN(aq) + OH^-(aq) \rightarrow CN^-(aq) + H_2O(l)$

(ii) If the reactants are mixed in stoichiometric quantities, suggest and explain, including relevant equations, the likely pH value of the resultant solution. (2 marks)

Basic as the cyanide ion (conjugate base of weak acid) undergoes slight hydrolysis.

$CN^-(aq) + H_2O(l) \rightleftarrows HCN(aq) + OH^-(aq)$

(b) One of the main uses for sodium cyanide is in the extraction of precious metals, such as gold, from ores. In the presence of oxygen and water, trace amounts of gold in the ore react with the sodium cyanide and dissolve out of the rock.

(i) Use oxidation numbers to identify the: (2 marks)

$$\underset{\mathbf{0}}{Au(s)} + CN^-(aq) + \underset{\mathbf{0}}{O_2(g)} + H_2O(l) \rightarrow \underset{\mathbf{+1}}{Au(CN)_2^-(aq)} + \underset{\mathbf{-2}}{OH^-(aq)}$$

oxidising agent **oxygen (0 to -2 a decrease therefore reduced)**

reducing agent **gold (0 to +1an increase therefore oxidised)**

(ii) Balance the equation (2 marks)

$$\mathbf{4}Au(s) + \mathbf{8}CN^-(aq) + O_2(g) + \mathbf{2}H_2O(l) \rightarrow \mathbf{4}Au(CN)_2^-(aq) + \mathbf{4}OH^-(aq)$$

See next page

(c) If the pH of the extraction process is too low, toxic hydrogen cyanide gas is produced. To prevent this, the reaction mixture is maintained at pH 10.2 by addition of calcium hydroxide. Calculate the concentration in, mol L^{-1}, of calcium hydroxide in a pH 10.2 solution.

(3 marks)

pH = 10.2 pOH = 3.8

$[OH^-] = 10^{-3.8} = 1.585 \times 10^{-4}$

$[Ca(OH)_2] = ½ \times 1.585 \times 10^{-4} = 7.92 \times 10^{-5}$ mol L^{-1}

(or $[H^+] = 10^{-10.2} = 6.310 \times 10^{-11}$ $[OH^-] = Kw/[H^+] = 1.585 \times 10^{-4}$)

Question 39 **(9 marks)**

7.65 L of hydrogen chloride gas at 102 K Pa and 27°C was dissolved in water and made up to 500 mL in a volumetric flask. A 20.0 mL sample of this solution was pipetted into a beaker and 30.0 mL of 1.20 mol L^{-1} barium hydroxide was added to the beaker.

Calculate the pH of the final solution.

n(HCl) = $\frac{PV}{RT}$ = $\frac{102 \, x \, 7.65}{8.314 \, x \, 300.15}$ = 0.3127 mol

n(HCl or H^+) in 20mL = $\frac{20}{500}$ x 0.3127 = 0.01251 mol

$n(OH^-) = 2n(Ba(OH)_2) = 2cv = 2 \times 1.20 \times 0.0300 = 0.0720$ mol

OH^- is in excess by 0.0720 – 0.01251 = 0.05949 mol

[OH^-] in resultant solution = $\frac{0.05949}{0.0500}$ = 1.190 mol L^{-1}

pOH = –0.07555 pH = 14 – (–0.07555) = 14.1

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Question 40 **(23 marks)**

Four separate organic liquids with similar molar masses are known to be:

3-methylbutan-1-ol	butanoic acid	pentan-2-one	3-methylpent-2-ene
88g mol^{-1}	88g mol^{-1}	86g mol^{-1}	84g mol^{-1}

(a) To identify the liquids a student decided to observing the boiling points of each liquid. The results are tabulated below.

(i) Complete the table by matching each liquid to its boiling point (2 marks)

Liquid	**Boiling Point (°C)**	**Liquid is:**
1.	164	**butanoic acid**
2.	132	**3-methylbutan-1-ol**
3.	102	**pentan-2-one**
4.	68	**3-methylpent-2-ene**

(ii) Explain your choices in terms of intermolecular forces. Diagrams may support your answer.

(4 marks)

Boiling point depends on strength of intermolecular forces. The stronger the forces the more energy is required to overcome hence the higher the boiling point. All substances have similar molar masses and therefore similar strength dispersion forces. Any difference in boiling point is due to the presence of dipole-dipole or hydrogen bonds in addition to dispersion.

3-methylpent-2-ene is nonpolar so only exhibits dispersion forces. the weakest, between its molecules and has the lowest boiling point.

Pentan-2-one has dipole-dipole intermolecular forces as well as dispersion and so has a higher boiling point.

Butanoic acid and 3-methylbutan-1-ol both exhibit the strongest type of intermolecular forces, hydrogen-bonds and have the highest boiling points. Butanoic acid is the highest as it has two oxygen's with non-bonding pairs that can accept hydrogen bonds and due to extra oxygen has greater polarity overall.

See next page

(b) Another student decided to identify each liquid by carrying out a series of chemical tests as outlined in the table below. Complete the table.

(9 marks)

Chemical test	Name of liquid expected to give a positive test	Expected observations (positive test)	Structural formula of the organic product
add $Br_2(aq)$ to a sample of each organic liquid and shake	**3-methylpent-2-ene**	**orange solution immediately turns colourless**	**correct structure of 2,3 dibromo-2-methylpentane**
warm a sample of the remaining liquids with acidified $K_2Cr_2O_7(aq)$	**3-methylbutan-1-ol**	**orange solution turns deep green**	**correct structure of 3-methylbutanoic acid (or –al)**
add $NaHCO_3(aq)$ to a sample of the remaining liquids	**butanoic acid**	**fizzing occurs and a colourless gas is evolved**	**correct structure of butanoate ion** $CH_3CH_2CH_2COO^-$

(c) Write the oxidation and reduction half equations and the balanced redox equation for the reaction between the organic liquid and acidified potassium dichromate solution, as mentioned in the second chemical test of the table above. Assume the chemical oxidation is complete.

(3 marks)

$C_5H_{11}OH + H_2O \rightarrow C_4H_9COOH + 4H^+ + 4e^-$ X 3

$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ X 2

$3C_5H_{11}OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3C_4H_9COOH + 4Cr^{3+} + 11H_2O$

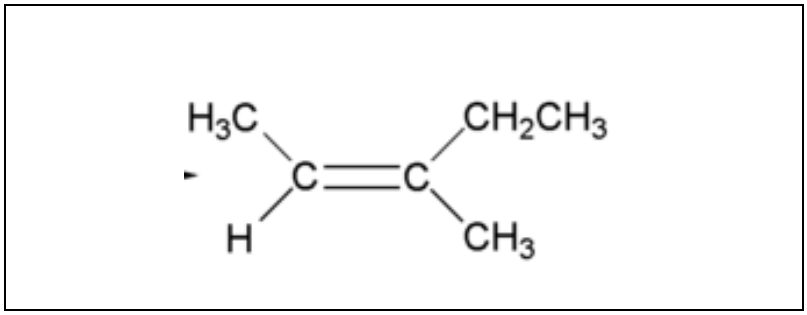
See next page

(d) Draw and name two structural isomers of pentan-2-one. (4 marks)

name **e.g. pentanal**	name e.g. **pentan-3-one** **or, 2-methylbutanal etc..**

(e) 3-methylpent-2-ene exhibits geometric isomerism. Give the structural formula of the 'cis' isomer.

(1 mark)



Question 41 **(13 marks)**

Many important industrial chemical reactions are reversible and reach equilibrium and this often results in low yields of the desired product.

Consider the information below on five important industrial processes.

(a) Balance the equations (in the table) for the Contact, Ostwald and Deacon processes. (3 marks)

(b) (i) In the Ostwald Process, how is yield affected by an increase in temperature? (1 mark)

Yield decreases

(ii) How is the value of the equilibrium constant, K, related to rate of reaction? (1 mark)

No relationship

See next page

Process	equation	ΔH	Equilibrium constant, K at 373K	Equilibrium constant, K at 773K
Contact	**2** $SO_2(g)$ + __$O_2(g)$ ⇄ **2** $SO_3(g)$	–196	1×10^{23}	2×10^{13}
Birkeland-Eyde	$N_2(g)$ + $O_2(g)$ ⇄ $2NO(g)$	+180	3×10^{-23}	4×10^{-11}
Ostwald	**4** $NH_3(g)$ + **5** $O_2(g)$ ⇄ **4** $NO(g)$ + **6** $H_2O(g)$	–905	$>1 \times 10^{99}$	9×10^{68}
Deacon	**4** $HCl(g)$ + __ $O_2(g)$ ⇄ **2** $Cl_2(g)$ + **2** $H_2O(g)$	–117	2×10^{14}	1×10^{9}
Cativa	$CO(g)$ + $CH_3OH(g)$ ⇄ $CH_3COOH(g)$	–135	5×10^{28}	7×10^{13}

Process	Actual conditions		
	Temp °C	Pressure kPa	catalyst
Contact	450	200	V_2O_5
Birkeland-Eyde	3000	100	none
Ostwald	200	1000	Pt
Deacon	450	100	RuO_2
Cativa	140	3000	$IrCl_4$

(c) Four of the five processes use a catalyst. Suggest why catalysts are particularly useful in these processes.

(2 marks)

The processes are all exothermic and so use lower temperatures to minimise effect on yield. A catalyst gives a faster rate at the lower temperature.

(d) Often the 'actual' conditions of temperature and pressure chosen for important industrial processes are not the same as those that 'in theory' would produce maximum yield. Discuss, two examples of this, with reference to the industrial processes described.

(4 marks)

e.g. Ostwald Process, high pressure favours reverse reaction since this reduces the moles of gas. The high pressure together with the catalyst ensure a good rate at the low temperature

Deacon Process, high pressure favours forward but atmospheric pressure is used, the yield must be good enough at that pressure and 450°C to not require the cost of a higher pressure.

Contact process doesn't use very high pressure although in theory high pressure would favour yield and rate, suggests yield and rate must be good enough with conditions used so no need for added expense.

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(e) Hydrogen gas is produced industrially by treating natural gas (methane) with steam.

$$CH_4(g) + H_2O(g) \rightleftarrows 3H_2(g) + CO(g)$$

3.50×10^3 L of methane is reacted with excess steam at 400°C and 112 KPa. Under the same conditions of temperature and pressure 9.27×10^3 L of hydrogen is produced. Determine the efficiency of the process.

(2 marks)

expected $V(H_2) = 3V(CH_4) = 3 \times 3.50 \times 10^3 = 1.05 \times 10^4$ L

% efficiency = $\frac{9270}{10500}$ x 100 = 88.3%

Question 42 **(10 marks)**

A 1.481 g sample of an ammonium sulfate fertiliser was dissolved in water, filtered and made up to 250 mL in a volumetric flask. 20.0 mL of this solution was pipetted into a conical flask containing 20.0 mL of 0.1124 mol L^{-1} (an excess) of sodium hydroxide solution. The flask was heated to convert all the ammonium ions to ammonia and drive of the ammonia gas from the solution.

$$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$$

When all the ammonia gas was driven off the inner walls of the conical flask were washed down with distilled water and then titrated with 0.1189 mol L^{-1} hydrochloric acid using phenolphthalein as the indicator. The average titre was found to be 9.55 mL.

(a) Calculate the moles of sodium hydroxide remaining, unreacted, after all the ammonia had been driven off.

(2 marks)

$n(HCl) = cv = 0.1189 \times 0.00955 = 1.135 \times 10^{-3}$

$n(NaOH)$ remaining $= n(HCl) = 1.135 \times 10^{-3}$

(b) Calculate the moles of hydroxide ions in the conical flask before the 20.0 mL of fertiliser solution was added.

(1 mark)

$n(NaOH)$ original $= cv = 0.1124 \times 0.0200 = 2.248 \times 10^{-3}$

(c) Determine the % by mass of ammonium sulfate present in the 1.481 g sample of fertiliser.

(4 marks)

$n(OH^-)$ reacting with NH_4^+ = original – remaining
$= 2.248 \times 10^{-3} - 1.135 \times 10^{-3} = 1.113 \times 10^{-3}$

$n(NH_4^+) = 1.113 \times 10^{-3}$

$n((NH_4)_2SO_4) = \frac{1}{2}\, n(NH_4^+) = 5.565 \times 10^{-4}$

$m((NH_4)_2SO_4)$ in 20mL $= nM = 5.565 \times 10^{-4} \times 132.154 = 0.07354$ g

$m((NH_4)_2SO_4)$ in 250mL $= \frac{250}{20} \times 0.07354 = 0.9193$ g

% = $\frac{0.9193}{1.481}$ x 100 = 62.1%

See next page

(d) During the analysis, why did the student wash the inner walls of the conical flask with distilled water?

(1 mark)

to ensure that and NaOH that had splashed or come out of solution on the sides of the flask was washed back into the solution.

(e) Phenolphthalein was a good choice of indicator for this titration. What must be considered when choosing an indicator for an acid-base titration.

(2 marks)

The endpoint of the indicator (pH range of colour change) must lie within the rapid pH change that occurs around the equivalence point.

END OF QUESTIONS

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