Christ Church Grammar School

MODEL ANSWERS

YEAR 12 CHEMISTRY

Mid-year Examination 2017

TIME ALLOWED FOR THIS PAPER

READING TIME BEFORE COMMENCING WORK: TEN MINUTES

Working time for the paper: Three hours

MATERIAL REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the candidate

Pens, pencils, calculator satisfying the conditions set by the School Curriculum & Standards Authority

To be provided by the supervisor

This Question/Answer Booklet; Multiple-choice Answer Sheet; Chemistry Data Sheet.

Section 1		**Section 2**			**Section 3**			**Totals**		
No. Correct	Out of	Q	Mark	Out of	Q	Mark	Out of		Mark	Out of
	25	26		4	37		12	Section 1		50
		27		6	38		12	Section 2		70
		28		3	39		12	Section 3		80
		29		3	40		9	Total		200
		30		3	41		14			
		31		7	42		21	**Total**		**%**
		32		7						
		33		4						
		34		15						
		35		9						
		36		9						
		Total		70	Total		80			

STRUCTURE OF THE PAPER

Section	Format	No. of questions set	No. of questions to be attempted	Recommend time (minutes)	Marks Allocated	% of Exam
1	Multiple Choice	25	ALL	50	25	25%
2	Short Answer	11	ALL	60	70	35%
3	Extended Response	6	ALL	70	80	40%

Instructions to candidates

1. Answer the questions according to the following instructions.

Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through the square and shade a new answer. Do not erase or use correction fluid. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any one question.

Sections Two and Three: Write answers in the Question/ Answer Booklet.

2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to three significant figures and include appropriate units where applicable.

3. You must be careful to confine your answers to the specific question asked and to follow instructions that are specific to a particular question.

4. Spare pages are included at the end of the 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 an answer is to be 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.

Section One: Multiple Choice **25 marks (25% of paper)**

This section contains 25 questions. Answer all questions on the Multiple–choice Answer Sheet provided. Use blue or black pen only. If you make a mistake, place a cross through that square. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is given for any question.

Suggested working time for this section is 50 minutes.

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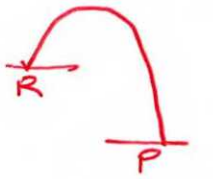
1. For a reversible chemical reaction that is exothermic in the forwards direction, which of the following statements is FALSE?

   A. The enthalpy of the transition state (activated complex) of the forwards reaction is lower than that of the backwards reaction. F

   B. The activation energy of the forwards reaction is smaller than that of the backwards reaction. T

   C. The enthalpy of the reactants is greater than that of the products. T

   D. If the temperature is increased, the value of K will decrease. T



R ⇌ P

2. What is the correct equilibrium expression for K for the following reaction?

$$PC\ell_3(l) + C\ell_2(g) \rightleftharpoons PC\ell_5(s)$$

   A. $K = [PC\ell_5]/[PC\ell_3][C\ell_2]$

   B. $K = 1/[PC\ell_3][C\ell_2]$

   C. $K = [C\ell_2]$

   D. $K = 1/[C\ell_2]$

3. Consider the following four reactions

   I. $H_2(g) + O_2(g) \rightleftharpoons H_2O_2(l)$
   II. $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(l)$
   III. $H_2O_2(l) \rightleftharpoons H_2(g) + O_2(g)$
   IV. $2H_2O(l) \rightleftharpoons 2H_2(g) + O_2(g)$

   Which of the following pairs of reactions share the same equilibrium constant expression?

   A. I and II.

   B. I and III.

   C. III and IV.

   D. None of them.

I. $K = \frac{1}{[H_2][O_2]}$

II. $K = \frac{1}{[H_2]^2[O_2]}$

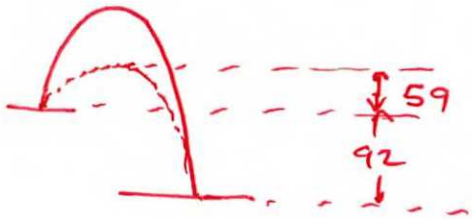
III. $K = [H_2][O_2]$

IV. $K = [H_2]^2[O_2]$

Questions 4, 5 and 6 all refer to the Haber Process, which is the industrial manufacture of ammonia, whose details are given below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ}$$

4. If the activation energy of the uncatalysed forward reaction was decreased from 160kJ to 59kJ by addition of a catalyst, what would be the activation energy of the catalyzed backwards reaction?



(A.) +151 kJ

B. -59 kJ

C. +59 kJ

D. +252 kJ

5. What would be the approximate energy change if 10.1 g of hydrogen was completely reacted with an excess of nitrogen?

$n = \frac{10.1}{2.016} = 5.01$

$\Rightarrow \Delta H = (-92) \times \frac{5.01}{3} = -154 \text{ kJ}$

A. 4.61×10^2 kJ of energy given out to the surroundings.

B. 4.6×10^2 kJ of energy taken in from the surroundings.

C. 1.38×10^3 kJ of energy given out to the surroundings.

(D.) 154 kJ of energy given out to the surroundings.

6. A very high pressure of approximately 20,000 kPa is often chosen in the Haber Process. Which of the following are factors that contribute to this choice of pressure?

I. To achieve a compromise between yield and rate of reaction.

II. To increase the frequency of collisions between nitrogen and hydrogen molecules.

III. To decrease the activation energy.

IV. To save money.

A. I and II only.

B. I, II and III only.

C. I and IV only.

(D.) II only.

Questions 7 and 8 refer to the following equilibrium

$$F_2(g) + I_2(g) \rightleftharpoons 2FI(g) \qquad K = 0.02 \text{ at } 400^0C$$

7. In two separate vessels, an inert gas is added. In one vessel it is added at constant pressure and in the other it is added at constant volume. In each case, predict the effect that the inert gas addition will have on the value of K.

	Effect on K when inert gas is added at constant volume	Effect on K when inert gas is added at constant pressure
(A)	No change	No change
B	K increases	No change
C	No change	K increases
D	K increases	K increases

8. Given that F-I covalent bonds are stronger than either F-F or I-I covalent bonds, if the temperature of the system was increased, the value of K would

A. Increase.

(B.) Decrease.

C. Remain unchanged because there are equal numbers of moles of gas on each side of the equation.

D. It is not possible to determine the effect on K without further information.

9. Consider the equilibrium

$$Co(H_2O)_6^{2+}(aq) + 4C\ell^-(aq) \rightleftharpoons CoC\ell_4^{2-}(aq) + 6H_2O(l)$$

Which of the following would result in a decrease in the rate of the forwards reaction, once equilibrium is re-established?

I. Addition of silver nitrate solution.

II. Decrease in temperature.

III. Addition of a small volume of concentrated potassium chloride solution.

IV. Addition of water.

(A.) I, II and IV.

B. II and IV.

C. I and II.

D. all of them.

10. Consider the equilibrium between oxygen and ozone (O_3)

$$2O_3(g) \rightleftharpoons 3O_2(g) \qquad K = 1 \times 10^{54} \text{ at } 25^0C$$

$$= \frac{[O_2]^3}{[O_3]^2}$$

Given that a sample of air has an oxygen concentration of approximately 0.01 $molL^{-1}$, what would be the approximate concentration of ozone in the sample?

A. 1×10^{-52} $molL^{-1}$

B. 1×10^{-30} $molL^{-1}$

C. 1×10^{-27} $molL^{-1}$

D. 1×10^{-24} $molL^{-1}$

$$[O_3] = \sqrt{\frac{[O_2]^3}{K}}$$

$$= \sqrt{\frac{(0.01)^3}{1 \times 10^{54}}}$$

$$= 1 \times 10^{-30} \text{ mol } L^{-1}$$

11. Which of the following is not a conjugate acid/base pair?

A. H^+ and OH^-.

B. N^{3-} and HN^{2-}.

C. Nitric acid and $H_2NO_3^{+}$.

D. Phenol (C_6H_5OH) and the phenoxide ion ($C_6H_5O^-$).

12. Ethanoic acid is a weak acid with an equilibrium constant of 1.74×10^{-5}

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

Which of the following statements is **true**?

A. The concentration of ethanoate ions is greater than the concentration of ethanoic acid.

B. The ethanoate ion is a stronger base than water.

C. The ethanoate ion can also act as an acid donating a further proton.

D. The pH of the solution will be greater than 7.

13. What would be the pH of 45mL of a 0.01$molL^{-1}$ hydrochloric acid solution?

irrelevant

A. 3.35

B. 2.0

C. 0.35

D. 0.01

$$[H^+] = 0.01$$

$$pH = -\log(0.01)$$

$$= 2.0$$

14. Which of the following is not an acid/base reaction?

A. $O^{2-} + H_2O \rightarrow 2OH^-$

B. $HO_2^- + H_3O^+ \rightarrow H_2O_2 + H_2O$

C. $2HSO_4^- \rightarrow H_2SO_4 + SO_4^{2-}$

D. $2H_2O_2 \rightarrow H_2O + O_2$

15. Two indicators M and N have the following properties

Indicator	Colour in acid	Colour in alkali	End point range
M	yellow	colourless	8-9
N	colourless	blue	4-5

If 50 mL of 0.1 $molL^{-1}$ sodium hydroxide is added from a burette to 25 mL of 0.1 $molL^{-1}$ hydrochloric acid containing both M and N, what sequence of colour changes would you expect to see?

A. Colourless, yellow, blue, colourless.

B. Yellow, blue.

C. Yellow, green, blue.

D. Yellow, colourless, blue.

16. Which of the following is a possible pH of 0.050 $molL^{-1}$ sulfuric acid?

A. 0.8

B. 1.0

C. 1.2

D. 1.4

$0.05 < [H^+] < 0.10$

$1.3 > pH > 1$

17. A student prepared 0.100 $molL^{-1}$ solutions of various salts and measured their pH. Which of the following is an expected set of results?

	Sodium ethanoate B	Potassium nitrate N	Sodium hydrogensulfate A	Potassium phosphate B
A	9	7	5	9
B	7	5	7	7
C	9	7	7	9
D	7	7	5	5

A = acidic ion

B = basic ion

N = neutral ion

18. A correct method for determining the concentration of ammonia is to pipette ammonia into a conical flask and to titrate with hydrochloric acid using a methyl orange indicator, which changes colour in the pH range 4-6. If phenolphthalein (pH range 8-10) was used instead, what would be the effect on the volume of acid required to reach both the equivalence point and the end point?

HCl

NH3

	Effect on end point	Effect on equivalence point
A	unchanged	decreased
B	unchanged	increased
C	decreased	unchanged
D	increased	unchanged

see below

19. A mixture of which of the following pairs of substances could be used to make an effective buffer solution?

A. Nitric acid and potassium nitrate.

B. Sodium hydrogensulfate ($NaHSO_4$) and sodium sulfate.

C. Sodium hydroxide and sodium ethanoate.

D. Sulfuric acid and sodium hydrogensulfate ($NaHSO_4$).

20. In which of the following substances is arsenic in the highest oxidation state?

A. As_2O_3 +3

B. Na_3AsO_4 +5

C. AsO_2^- +3

D. AsH_4^+ -3

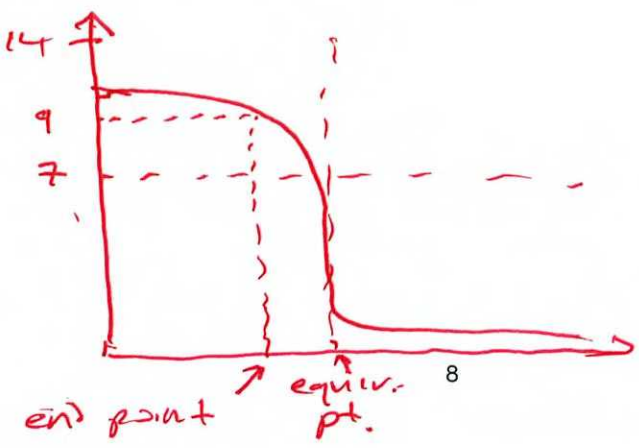
21. In which of the following reactions is chlorine oxidised?

A. $\overset{0}{Cl_2} + 2Br^- \rightarrow 2\overset{-1}{Cl^-} + Br_2$

B. $H\overset{+1}{O}\overset{}{Cl} + H^+ + 2I^- \rightarrow \overset{-1}{Cl^-} + I_2 + H_2O$

C. $2S_2O_8^{2-} + \overset{+1}{Cl}O^- + 2H_2O \rightarrow 4SO_4^{2-} + \overset{+5}{Cl}O_3^- + 4H^+$

D. $\overset{+7}{Cl}O_4^- + 2Fe^{2+} + 2H^+ \rightarrow \overset{+5}{Cl}O_3^- + 2Fe^{3+} + H_2O$



Q18

22. Which of the following are redox reactions?

I. $Ca + 2H_2O \rightarrow Ca^{2+} + H_2 + 2OH^-$

II. $CaO + H_2O \rightarrow Ca^{2+} + 2OH^-$

III. $Ca(OH)_2 + 2H^+ \rightarrow Ca^{2+} + 2H_2O$

IV. $CaO + 2H^+ \rightarrow Ca^{2+} + H_2O$

Ca = +2
H = +1
O = -2
throughout.

A. All of them
B. II and IV only
C. I only
D. II, III and IV only

23. The addition of which of the following could result in aqueous iron (II) nitrate turning from green to brown in colour?

A. potassium metal
B. 1.0molL^{-1} copper (II) sulfate
C. 1.0molL^{-1} acidified hydrogen peroxide, H_2O_2
D. 1.0molL^{-1} hydrochloric acid

$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$

$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$

24. Which of the following metals would you expect to fizz when added to both water and 1.0 mol^{-1} hydrochloric acid?

A. Lead
B. Calcium
C. Iron
D. Nickel

$2H^+ + 2e^- \rightleftharpoons H_2$

$2H_2O + 2e^- \rightleftharpoons H_2 + 2OH^-$

$Ca^{2+} + 2e^- \rightleftharpoons Ca$

25. How many moles of electrons are released when 3 moles of hydrazine (N_2H_4) are oxidized to nitrite (NO_2^-) ions?

A. 5
B. 10
C. 15
D. 30

$N_2H_4 + 4H_2O \rightarrow 2NO_2^- + 12H^+ + 10e^-$

1 mol of N_2H_4 releases $10e^-$

$\Rightarrow$ 3 " " " " $30e^-$

END OF SECTION ONE

END OF SECTION ONE

Section Two: Short Answer **70 marks (35% of paper)**

This section has **eleven** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to appropriate number of significant figures and include appropriate units where applicable.

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

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Suggested time for working for this section is 60 minutes.

Question 26 **(4 marks)**

Identify the oxidation numbers of the underlined element in each of the following species

Species	Oxidation number
$\underline{Mn}O_4^{2-}$	+6
$\underline{S}_2O_3^{2-}$	+2
$\underline{N}H_4NO_3$	−3
$H_2\underline{O}_2$	−1

Question 27 **(6 marks)**

The persulfate ($S_2O_8^{2-}$) reacts with dinitrogen monoxide, with nitrate and sulfate ions being formed as products. Us this information to produce the following equations in the boxes below.

.....

.....

Oxidation half equation	$N_2O + 5H_2O \rightarrow 2NO_3^- + 10H^+ + 8e^-$
Reduction half equation	$S_2O_8^{2-} + 2e^- \rightarrow 2SO_4^{2-}$ (x4)
Full redox equation	$N_2O + 4S_2O_8^{2-} + 5H_2O \rightarrow 2NO_3^- + 8SO_4^{2-} + 10H^+$

Use the table of Standard Reduction Potentials in your Data Book to answer Questions 28 and 29.

Question 28 **(3 marks)**

Write ionic equations below for the reaction between $F_2(g)$ and $C\ell_2(g)$ in the presence of water.

oxidation half equation any of these	$Cl_2 + 2H_2O \rightarrow 2HClO + 2H^+ + 2e^-$ $2H_2O \rightarrow H_2O_2 + 2H^+ + 2e^-$ $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
reduction half equation	$F_2 + 2e^- \rightarrow 2F^-$
full equation any of these	$F_2 + Cl_2 + 2H_2O \rightarrow 2HClO + 2F^- + 2H^+$ $F_2 + 2H_2O \rightarrow H_2O_2 + 2F^- + 2H^+$ $2F_2 + 2H_2O \rightarrow O_2 + 4H^+ + 4F^-$

Question 29 **(3 marks)**

A pink solution is added to a colourless solution, resulting in the formation of a grey solid and a colourless gas that, when bubbled through lime water, turned the lime water milky. Write equations below that are consistent with these observations.

oxidation half equation	$H_2C_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-$
reduction half equation	$Co^{2+} + 2e^- \rightarrow Co$
full equation	$Co^{2+} + H_2C_2O_4 \rightarrow Co + 2CO_2 + 2H^+$

Question 30 **(3 marks)**

If the pH of 0.1 $molL^{-1}$ nitrous acid (HNO_2) is 2.18, calculate the % of nitrous acid molecules that are ionised. Use an appropriate number of significant figures in your answer.

$[H^+] = 10^{-2.18}$

$= 0.00661$ ✓

$\Rightarrow$ % ionisation $= \frac{0.00661}{0.1} \times 100$

$= 6.61\%$ ✓

$= 7\%$ to 1 sig. fig. ✓

Question 31 **(7 marks)**

Calculate the pH of the solution formed when 28.5 mL of 0.100 $molL^{-1}$ sodium hydroxide is added to 25.0 mL of 0.100 $molL^{-1}$ nitric acid.

$n(H^+) = (0.100)(0.0250)$

$= 0.00250$ ✓

$n(OH^-) = (0.100)(0.0285)$

$= 0.00285$ ✓

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

$\Rightarrow OH^- = XS, \quad H^+ = LR$ ✓ either of these

$n(OH^-)_{XS} = n_{init} - n_{reac}$

$= 0.00285 - 0.00250$

$= 0.00035$ ✓

$\Rightarrow [OH^-] = \dfrac{0.00035}{0.0535}$

$= 0.00654 \; molL^{-1}$ ✓

$\Rightarrow [H^+] = \dfrac{1 \times 10^{-14}}{0.00654}$

$= 1.529 \times 10^{-12}$ ✓

$pH = -\log(1.529 \times 10^{-12})$

$= 11.8$ ✓

Question 32 **(7 marks)**

(a) When ionic salts dissolve in water, the resultant solution might be acidic, basic or neutral. Circle the correct answer for each of the following salts, together with Bronsted-Lowry equations to support your answer, if the solution is not neutral.

(i) potassium phosphate acidic neutral (basic) ✓

equation $PO_4^{3-} + H_2O \rightleftharpoons HPO_4^{2-} + OH^-$ ✓✓

(ii) lithium nitrate acidic (neutral) basic ✓

equation NR

(iii) sodium hydrogensulfate (acidic) neutral basic ✓

equation $HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$ ✓✓

Question 33 **(4 marks)**

Hydrazinium ethanoate ($N_2H_5CH_3COO$) is an ionic salt which is soluble in water. When hydrazinium ethanoate is dissolved in water with a few drops of methyl orange in it, the solution turned red, showing that the solution is acidic. Suggest reasons, using relevant equation(s), for this observation.

- it dissolves to form $N_2H_5^+{}_{(aq)}$ and $CH_3COO^-{}_{(aq)}$

- $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$

  ethanoate ions are basic, ✓

- so as pH < 7, hydrazinium ions must be acidic.

  $N_2H_5^+ + H_2O \rightleftharpoons N_2H_4 + H_3O^+$ (or $N_2H_5^+ \rightleftharpoons N_2H_4 + H^+$) ✓

- $N_2H_5^+$ eqm must be further over to the r.h.s. than CH_3COO^- eqm (or similar) ✓

- $\Rightarrow [H_3O^+] > [OH^-]$ ✓

maximum 3 if correct but no equations

Question 34 **(15 marks)**

A common aqueous equilibrium is that between dichromate and chromate ions, whose equation is given below

$$Cr_2O_7^{2-}(aq) + H_2O(l) \rightleftharpoons 2CrO_4^{2-}(aq) + 2H^+(aq)$$

A series of test tubes were set up containing 20 mL of a mixture of the two ions and then a series of changes made to each tube. Use your knowledge of factors affecting equilibrium to complete the table below, once equilibrium has been re-established. In all apart from the 'observation' column, write 'increase', 'decrease' and 'no change'.

Change	Observation	Effect on $[CrO_4^{2-}]$	Effect on rate of forwards reaction	Effect on pH
Add a few drops of concentrated sodium hydroxide	more yellow	increase	decrease	increase
* Add 20m mL of distilled water	more yellow (+ paler)	decrease	decrease	increase
Add a few crystals of sodium chromate	more yellow (+ more intense)	increase	increase	increase

(12 marks)

In a further experiment, another tube containing the mixture was heated and it was observed that the tube turned more orange in colour. What inference could you make about the reaction, as written above, from this observation? Explain your answer.

• eqm. shifted to the l.h.s.
• ↑ in temp favours endothermic reaction (LCP)
• backwards reaction is endothermic
• forwards reaction is exothermic.
* – 1 if no mention of paler, only if F/T marks otherwise,

(3 marks)

N.B. In WACE exam (and your mock) the use of "→" or "←" will get you 0 marks (out of 12). OUCH !!

Question 35 **(9 marks)**

Iron (III) , thiocyanate, (SCN^-) and thiocyanatoiron(III), ($FeNCS^{2+}$) ions exist in the following equilibrium.

$$Fe^{3+}(aq) + NCS^-(aq) \rightleftharpoons FeSCN^{2+}(aq)$$

When sodium hydroxide is added to this equilibrium mixture (at time t_1), the blood red colour of the thiocyanatoiron(III) ion fades and the solution appears more brown, once equilibrium is established(at time t_2).

(a) Explain the above observation, using relevant equation(s) where relevant.

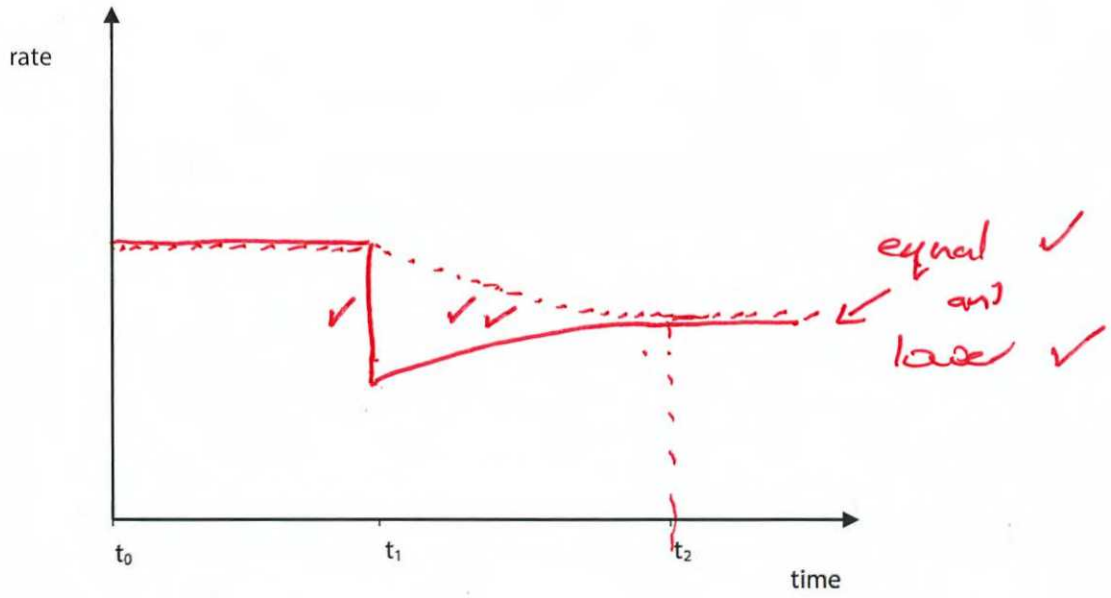
• $Fe^{3+} + 3OH^- \rightarrow Fe(OH)_3(s)$ or $Fe(OH)_3$ precipitates ✓

• ✓ $[Fe^{3+}]$ decreases, so frequency of collisions between Fe^{3+} and NCS^- decreases, rate of forwards reaction ↓ ✓

• eqm shifts to l.h.s. ... more brown etc. ✓

(4 marks)

(b) Draw a rate/time graph to show how the rates of both the forward (—) and backwards (---) reactions vary from t_0 to beyond t_2.



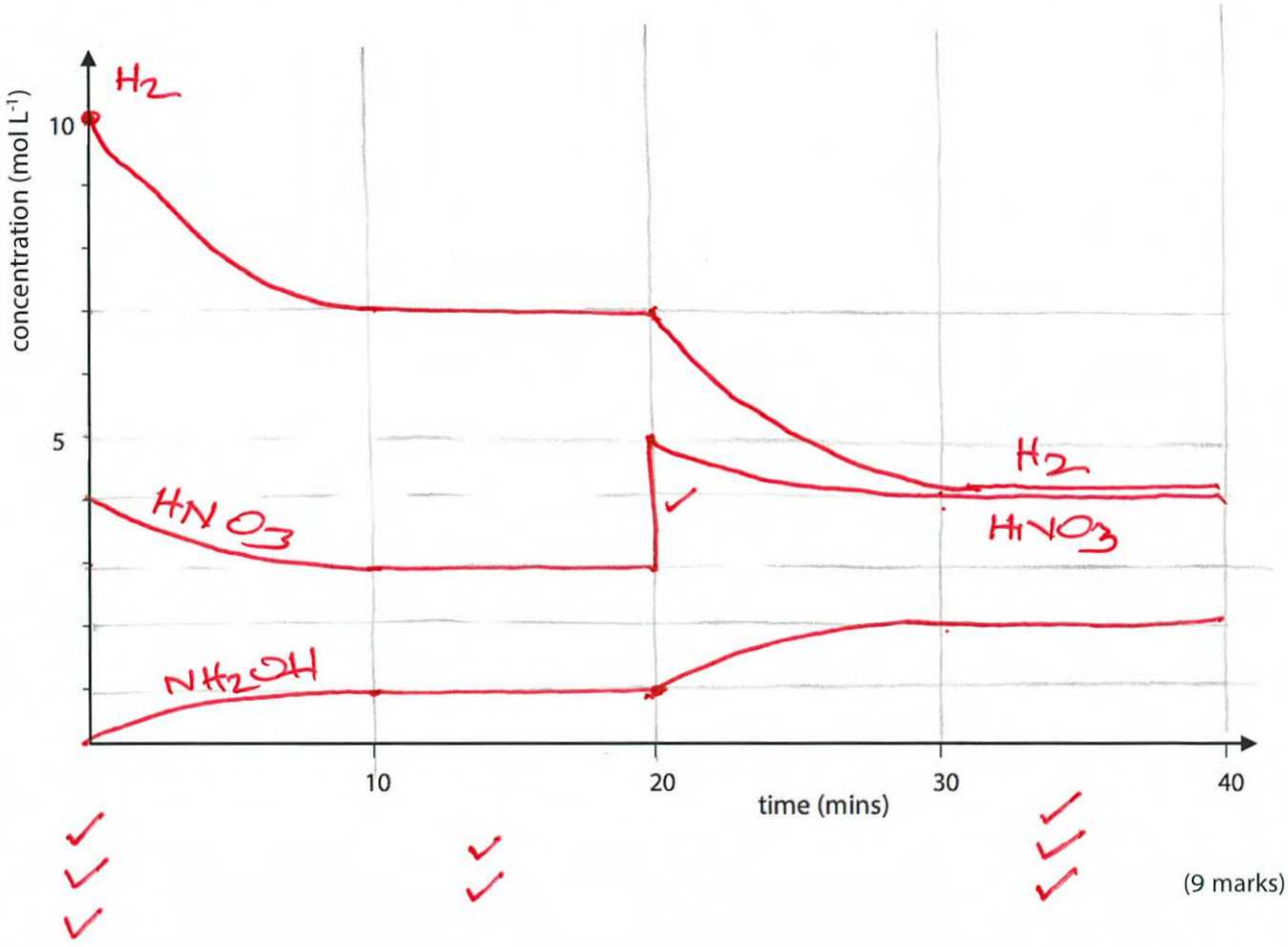
(5 marks)

Question 36 **(9 marks)**

Hydroxylamine (NH_2OH) is an important chemical, one of whose uses is in biochemistry to modify the nature of strands of DNA in genes to deliberately introduce mutations. A possible method of production involves the reaction of nitric acid with hydrogen gas at an elevated temperature.

$$HNO_3(g) + 3H_2(g) \rightleftharpoons NH_2OH(g) + 2H_2O(l)$$

In a particular process, 40 moles of gaseous nitric acid were injected into a 10L chamber, along with 100 moles of hydrogen gas. After 10 minutes, equilibrium was reached and it was found that 10 moles of hydroxylamine had formed. The equilibrium mixture was then left until 20 minutes, at which point a further 20 moles of nitric acid gas were added. When equilibrium was re-established after 30 minutes, it was found that the concentrations of HNO_3 and H_2 in the reaction mixture were equal. The mixture was then left unchanged until 40 minutes. Use this information to draw a graph below of how the concentrations of HNO_3, H_2 and NH_2OH vary with time.



(9 marks)

Section Three: Extended answer **80 marks (40% of paper)**

This section contains **six** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to appropriate number of significant figures.

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Suggested working time for this section is 70 minutes.

Question 37 **(12 marks)**

Acid and bases react together in neutralisation reactions. In the absence of a suitable indicator, the temperature change can be used to monitor the reaction.

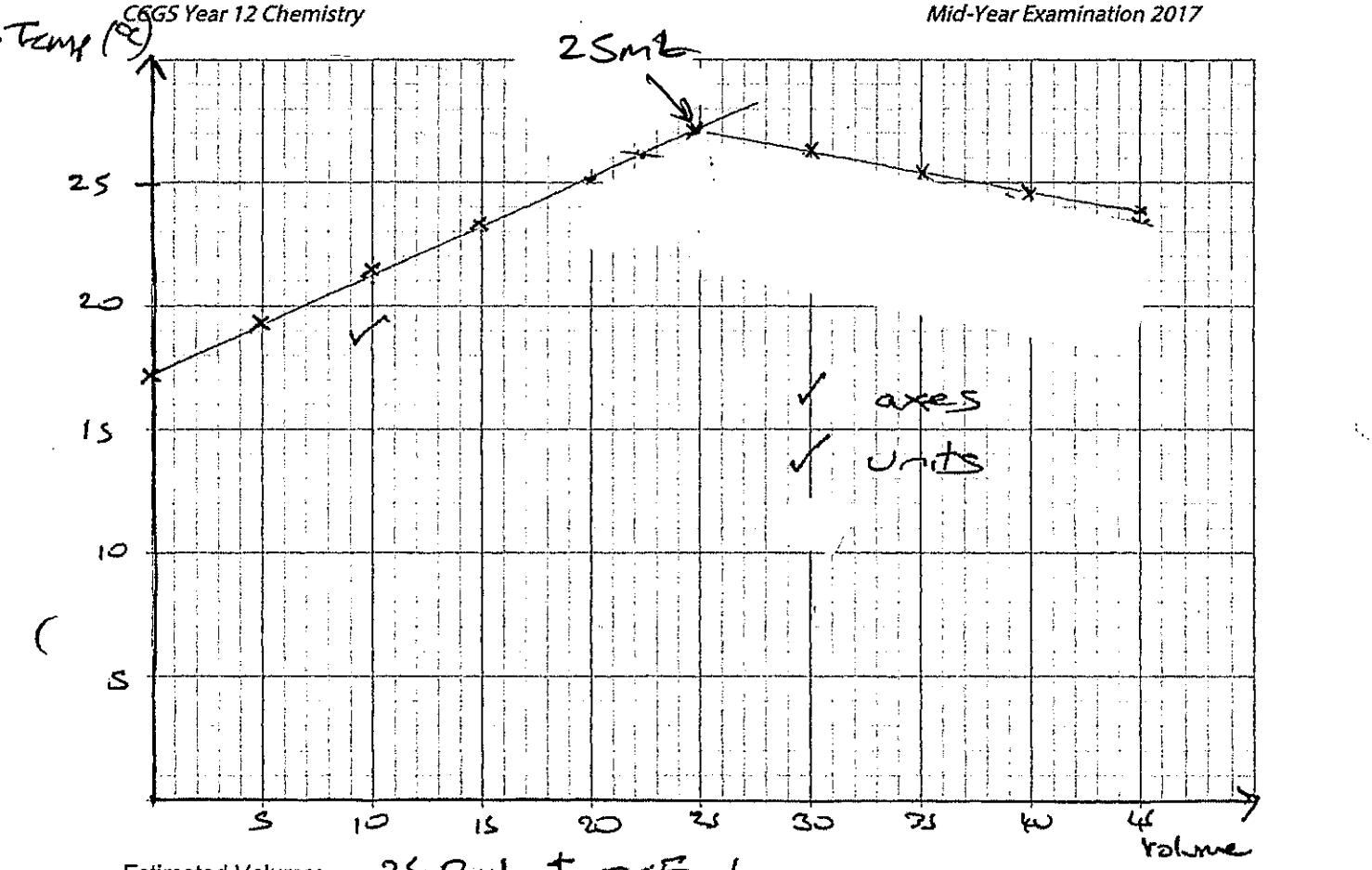
In a particular experiment, the following procedure was undertaken to identify the identity of element X in a sample of $HC\ell O_x$, a strong monoprotic acid

1. 3.945 g of $HClO_x$ was dissolved in water and made up to 250 mL.
2. 10.0mL samples of this solution were pipetted into each of ten insulated beakers.
3. Ten different quantities of 0.0703 $molL^{-1}$ sodium hydroxide was added to each of the beakers and the temperature of the solution after addition was measured.

The results of the above procedure are in the table below

Volume of NaOH (mL) added	0	5	10	15	20	25	30	35	40	45
Temperature (°C)	17.1	19.4	21.4	23.1	25.0	25.6	25.1	24.5	23.9	23.3

(a) Plot the results from the experiment and use your graph to estimate the volume of barium hydroxide needed to neutralise the acid. (5 marks)



Estimated Volume: 25.0 mL ± 0.5mL

(b) Is the neutralization reaction endothermic or exothermic? Suggest a reason for your answer.

(2 marks)

- exothermic ✓
- temperature increases ✓

(c) Use the information given and your value of the volume of sodium hydroxide to calculate the value of x in $HClO_x$.

$$HClO_x + OH^- \rightarrow ClO_x^- + H_2O$$

$n(OH^-) = (0.0703)(0.0250)$

$= 0.001758$ ✓

$\Rightarrow n(HClO_x)_{10mL} = 0.001758$ ✓

$\Rightarrow n(HClO_x)_{25} = 0.001758 \times \frac{25}{10}$

$= 0.04394$ ✓

$\Rightarrow M(HClO_x) = \frac{m}{n}$

$= \frac{4.388}{0.04394}$

$= 99.85$ ✓

(5 marks)

$$\Rightarrow \quad 1.008 + 35.45 + (16.00x) = 99.86$$

$$\Rightarrow \quad x = \frac{63.4}{16}$$

$$= 3.96 \quad \checkmark$$

$$HClO_4$$

Question 38 **(12 marks)**

Aluminium reacts with nitric acid according to the following equation

$$2A\ell\,(s) + 6HNO_3(aq) \rightarrow 2A\ell\,(NO_3)_3(aq) + 3H_2(g)$$

0.389 g of aluminium is added to 250 mL of 0.207 $molL^{-1}$ nitric acid and the reaction is allowed to go to completion.

(i) Identify the limiting reactant

(ii) Calculate the volume of hydrogen gas evolved, measured at 21 °C and 101 kPa.

(iii) Calculate the concentrations of $A\ell^{3+}$, NO_3^- and OH^- ions in the resultant solution, as well as the final pH, entering their values in the table below.

$n(Al) = \frac{0.389}{26.98}$

$= 0.0144$ ✓

$n(HNO_3) = (0.207)(0.250)$

$= 0.0518$ ✓

req? $\frac{n(HNO_3)}{n(Al)} = \frac{6}{2} = 3$

actual $\frac{n(HNO_3)}{n(Al)} = \frac{0.0518}{0.0144}$

$= 3.60$

$\Rightarrow HNO_3$ = XS, Al = LR ✓✓

$\Rightarrow n(H_2) = n(Al) \times \frac{3}{2}$

$= 0.0144 \times \frac{3}{2}$

$= 0.0216$ ✓

$\Rightarrow V(H_2) = \frac{(0.0216)(8.314)(294.15)}{(101)}$

$= 0.524\ L$ ✓

$n(H^+)_{XS} = n_{init} - n_{react}$

$= 0.0518 - 0.0432$

$= 0.0086$ ✓

$\Rightarrow [H^+] = \frac{0.0086}{0.250}$

$= 0.0344\ molL^{-1}$ ✓

$\Rightarrow [OH^-] = \frac{1 \times 10^{-14}}{0.0344}$

$= 2.91 \times 10^{-13}$ ✓

Ion	Concentration ($molL^{-1}$)
$A\ell^{3+}$	0.0576
NO_3^-	0.207
pH^-	1.46
OH^-	2.91×10^{-13}

$n(Al^{3+}) = 0.0144$ ✓

$n(NO_3^-) = 0.0518$ ✓

$pH = -\log(0.0344)$

$= 1.46$ ✓

Question 39 **(12 marks)**

A student aimed to standardise a solution of approximately 0.1 $molL^{-1}$ sodium hydroxide by titrating it with oxalic acid, HOOCCOOH, a weak diprotic acid. Oxalic acid is a solid at room temperature and is commonly used as a primary standard.

(a) Apart from being a solid, suggest two other properties that might make it a useful primary standard.

Property 1 high purity, high M, does not react with components of air,

Property 2 does not absorb H_2O.

+ "stable", "unreactive" = no mark. (2 marks)

The student adopted the following correct procedure, during which he rinsed out items of glassware with the appropriate substance prior to using them.

1. Weigh out a known mass of oxalic acid.
2. Dissolve the oxalic acid in water.
3. Make this solution up to 250 mL in a volumetric flask.
4. Use this oxalic acid solution to fill the burette.
5. Pipette a 20.0 mL aliquot of the sodium hydroxide solution into a conical flask.
6. Add a few drops of phenolphthalein indicator to the conical flask.
7. Titrate the oxalic acid into the conical flask until and the end point is observed
8. Repeat steps 5-7 until three concordant titre values are achieved.

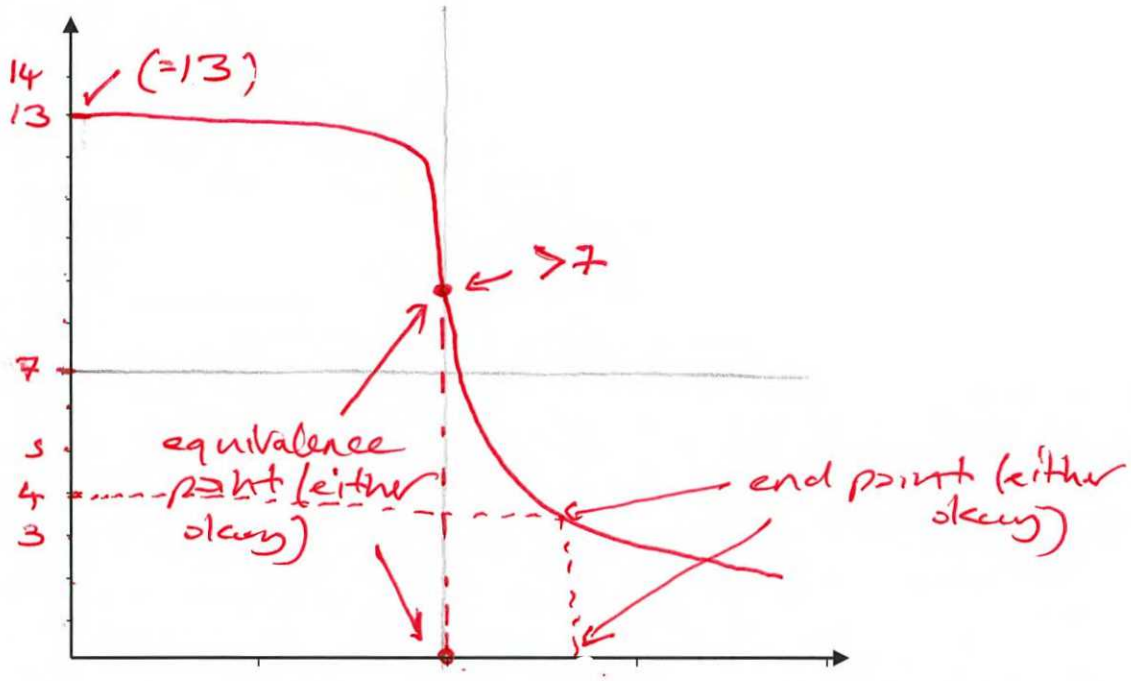
(b) Other students attempted the same practical but their methods differed in the following ways. Use your knowledge of acid/base titrations to fill in the gaps in the following table, writing 'increase', 'decrease' and 'no change'. Do not fill the shaded boxes.

Difference in method	Effect on end point titre value	Effect on calculated concentration of sodium hydroxide
Rinsing the pipette with distilled water		decrease
Rinsing the conical flask with sodium hydroxide	increase	
Accidentally 'overshooting' the 250mL mark when filling the volumetric flask.		increase
Using thymol blue (end point range 3.0-4.5) instead of phenolphthalein	increase.	

see previous note on the use of "↑" and "↓"

(4 marks)

(c) On the graph below, draw a pH (y-axis) against volume of oxalic acid added (x-axis), showing how you obtained your answer to the thymol blue question in part (b).



(4 marks)

(d) Describe a source of each of these errors in the above procedure

Random error	pipette volume judgment burette volume judgement volumetric flask judgement end point judgement
Systematic error	equipment manufacturers uncertainty

(2 marks)

N.B. human errors/mistakes = no marks.

Question 40 **(9 marks)**

Phosphorus can be extracted from 'rock phosphate', which is an impure form of calcium phosphate, $Ca_3(PO_4)_2$. The process can be summarised by these two steps, both of which take place in an electric furnace at about 1500°C.

Step 1. Reaction with silicon dioxide

$$Ca_3(PO_4)_2 + 6SiO_2 \rightarrow 6CaSiO_3 + P_4O_{10} \qquad (62\% \text{ efficient})$$

Step 2. Reduction with carbon

$$P_4O_{10} + 10C \rightarrow 4P + 10CO \qquad (98\% \text{ efficient})$$

In a particular process, the manufacturer had rock phosphate containing 42% $Ca_3(PO_4)_2$.

(i) If the manufacturer wanted to produce 5.00 tonnes of phosphorus, calculate the mass of 'rock phosphate' that would be needed.

$n(P) = \frac{5,000,000}{30.97}$

$= 161,447$ ✓

$\Rightarrow n(P_4O_{10}) = 161,447 \times \frac{1}{4}$

$= 40,361$ ✓

$\Rightarrow n(Ca_3(PO_4)_2) = 40,361 \times \frac{3}{1} \times \frac{100}{62}$

$= 130,199$ ✓✓

$\Rightarrow M(Ca_3(PO_4)_2) = (130,199)(310.18)$

$= 40,385,000$ g ✓

$\Rightarrow M(\text{rock phosphate}) = 40,385,000 \times \frac{100}{42}$

$= 96,155,000$

$= 96,200,000$ g

$= 96,200$ kg

$= 96.2$ tonnes (3sf) ✓

(6 marks)

The carbon monoxide formed in step 2 is extremely toxic. One useful process that can utilize the carbon monoxide is in the manufacture of methanol.

$$CO + 2H_2 \rightarrow CH_3OH \qquad (100\% \text{ efficient})$$

(ii) Calculate the volume of pure liquid methanol that could be formed from the carbon monoxide, given that the density of methanol is 0.791 gmL^{-1}.

$n(CO) = n(P) \times \frac{10}{4}$

$= 161,447 \times \frac{10}{4}$

$= 403,616$ ✓

$\Rightarrow n(CH_3OH) = 403,616$

$\Rightarrow m(CH_3OH) = (403,616)(32.042)$

$= 12,933,000$ g ✓

$\Rightarrow V(CH_3OH) = \frac{12,933,000}{0.791}$

$= 16,350,000$ mL

$= 16,500$ L ✓

$= 16.5 m^3$ (3sf)

(3 marks)

Question 41 **(14 marks)**

Lactic acid (2-hydroxypropanoic acid), $CH_3CH(OH)COOH$ is a monoprotic weak acid. Its conjugate base is the lactate ion, $CH_3CH(OH)COO^-$.

(a) Write a Bronsted-Lowry equation for the reaction between lactic acid and water.

$CH_3CH(OH)CO_2H + H_2O \rightleftharpoons CH_3CH(OH)CO_2^- + H_3O^+$

(1 mark)

A combination of lactic acid and the lactate ion are partly responsible for controlling the pH of muscle tissue. Respiration in muscles produces carbon dioxide, which dissolves to form carbonic acid (H_2CO_3).

(b) Explain, with the use of appropriate equations, how this buffer solution can protect the cells against large changes in pH when respiration occurs.

✓ $CO_2 + H_2O \rightleftharpoons H_2CO_3$

$H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$

✓ As $[H^+]$ increase frequency of collisions between

✓ H^+ and Lact increases, backwards reaction increases,

✓ $[H^+]$ decreases, minimising drop in pH,

(4 marks)

In order to investigate the action of this buffer in the laboratory, two students prepared buffer solutions using different methods. They both aimed to produce a solution that was equimolar in both lactic acid and lactate ions.

Student 1 took 4.50 g of lactic acid and a mass of sodium lactate, dissolved them both in water and made the resultant solution up to 500 mL in a volumetric flask.

(c) Calculate the mass of sodium lactate that Student 1 would need to use, and the concentrations of both lactic acid and sodium lactate in the resultant solution.

$n(HLact) = \frac{4.50}{90.048}$

$= 0.0500$ ✓

$\Rightarrow [HLact] = \frac{0.0500}{0.5}$

$= 0.100$ mol/L ✓

$\Rightarrow m(NaLact) = (0.0500)(112.52)$

$= 5.60$ g ✓

(3 marks)

Student 2 took 250 mL of 0.100 $molL^{-1}$ lactic acid solution and added 0.500 g of solid sodium hydroxide.

(d) Calculate the concentration of both lactic acid and lactate ions in the resultant solution.

$HLact + OH^- \rightarrow Lact^- + H_2O$

$n(HLact) = (0.10)(0.25)$ ✓

$= 0.025$ ✓

$n(NaOH) = \frac{0.500}{39.998}$

$= 0.0125$ ✓

$\Rightarrow OH^-$ = LR

$\Rightarrow n(HLact)_{final} = 0.0250 - 0.0125$

$= 0.0125$

$n(Lact^-) = 0.0125$ ✓

$\Rightarrow [HLact] = 0.050\ molL^{-1}$

$= [Lact^-] = 0.050\ molL^{-1}$ } ✓

(4 marks)

(e) Briefly describe the difference between the two buffer solutions.

- [HLact] and [Lact$^-$] both 10 x higher in student 1 ✓
- Student 1 has greater buffering capacity ✓

(2 marks)

Question 42 **(21 marks)**

Porphyrin rings are extremely common and important structures in many biological systems. The simplest of these is called porphin. Porphin is known to contain carbon, hydrogen and nitrogen, with the possibility that it might also contain oxygen.

In order to establish establish the formula of porphin, the following analysis was undertaken.

Firstly, 2.841 g of porphin was completely burnt in excess oxygen, producing 8.057 g of carbon dioxide and 1.154 of water.

(a) Calculate the percentage by mass of carbon and hydrogen in porphin

$n(CO_2) = \frac{8.057}{44.01}$

$= 0.183$

$\Rightarrow n(C) = 0.183$

$\Rightarrow m(C) = (0.183)(12.01)$

$= 2.20\ g$

$\Rightarrow \%C = \frac{2.20}{2.841} \times 100$

$= 77.4\%$

$n(H_2O) = \frac{1.154}{18.016}$

$= 0.0641$

$\Rightarrow n(H) = (0.0641) \times 2$

$= 0.128$

$\Rightarrow m(H) = (0.128)(1.008)$

$= 0.129\ g$

$\Rightarrow \%H = \frac{0.129}{2.841} \times 100\%$

$= 4.5\%$

(6 marks)

Secondly, 1.477 g of porphin was treated to convert all the nitrogen into ammonia. This ammonia was dissolved in water and made up to 250mL in a volumetric flask. 20.0mL samples of this solution were titrated with 0.108 molL-1 hydrochloric acid and an average titre of 14.10 mL was obtained.

(b) Calculate the percentage by mass of nitrogen in porphin

$n(H^+) = (0.108)(0.01410)$

$= 0.00152$

$\Rightarrow n(NH_3)_{20} = 0.00152$

$\Rightarrow n(NH_3)_{250} = 0.00152 \times \frac{250}{20}$

$= 0.0190$

$\Rightarrow m(N) = 0.0190$

$\Rightarrow m(N) = (0.0190)(14.01)$

$= 0.267\ g$

$\Rightarrow \%N = \frac{0.267}{1.477} \times 100$

$= 18.1\%$

(5 marks)

(c) Does porphin contain oxygen (circle your answer below)

Yes (No)

Give your reasoning below

%O = 100 − 77.4 − 4.5 − 18.1

%O = 0%

(bonus mark for palindromic statement?)

(2 marks)

(d) Calculate the empirical formula of porphin

C	H	N
77.4 / 12.01	4.5 / 1.008	18.1 / 14.01
6.44 :	4.46 :	1.29
5 :	3.5 :	1
10 :	7 :	2

(3 marks0

It is known that porphyrin rings can combine with metallic elements such as iron to form substances called hemes. When they do this, they react in a 1:1 molar ratio. When 4.672g of porphin was reacted with an excess of iron, the mass of the final product was 5.513g. Use this information to determine the molecular formula of porphin.

m(Fe) = 5.513 − 4.672

= 0.841 g ✓

⇒ n(Fe) = 0.841 / 55.85

= 0.0151 ✓

⇒ n(porph) = 0.0151

⇒ M(porph) = 4.672 / 0.0151

= 310.3 ✓

M($C_{10}H_7N_2$) = 155.2 ✓

M(MF) / M(EF) = 310.3 / 155.2 = 2.00

(5 marks)

⇒ MF = $C_{20}H_{14}N_4$ ✓

END OF EXAMINATION