Section Three: Extended answer **40% (83 Marks)**

This section contains **five (5)** 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 the appropriate number of significant figures.

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 that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 38 **(22 marks)**

A student set out to compare the effectiveness of a given quantity of two antacid preparations, one containing $Mg(OH)_2$ and the other $A\ell(OH)_3$, purchased from his local pharmacy.

He titrated each preparation against a hydrochloric acid solution to determine how much acid each could neutralise and to determine the concentration of active ingredient in each preparation. He first standardised the hydrochloric acid solution available in the laboratory against a primary standard, and chose anhydrous sodium carbonate as the primary standard.

(a) Give **two** reasons why anhydrous sodium carbonate is an appropriate standard. (2 marks)

- It has a large molar mass (therefore there will be a smaller percentage error in its mass)
- It is cheap
- It is available in high purity
- It is stable in the presence of air
- It does not have any water of hydration
- It dissolves readily in water.

Any 2; 1 mark each.

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The student prepared 1.00 L of a 0.0248 mol L^{-1} Na_2CO_3 solution. He titrated three 25.0 mL aliquots of this solution against the HCℓ and found an average titre of 24.35 mL.

(b) Calculate the concentration of the standardised HCℓ solution. (4 marks)

$2HCl_{(aq)} + Na_2CO_{3(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

0.02435 L, C = ? | 0.025 L, 0.0248 M

$n(Na_2CO_3) = CV = 0.0248 \times 0.025 = 6.200 \times 10^{-4}$ mol

$SR = \frac{n(HCl)}{n(Na_2CO_3)} = \frac{2}{1} = 2$

$n(HCl) = 2 \times 6.2 \times 10^{-4} = 1.240 \times 10^{-3}$ mol

$C(HCl) = \frac{n}{V} = \frac{1.240 \times 10^{-3}}{0.02435} = 5.0924 \times 10^{-2}$ M

$= 5.09 \times 10^{-2}$ M (3 s.f.)

(c) Below is a list of common errors that can occur in titrations. From this list select **one** source of random error and **one** source of systematic error and explain your choice in the tables below. (4 marks)

Some can be random or systematic. That's OK as long as explanation matches.

- reading of burette R/S
- bubbles in the pipette S
- not drying Na_2CO_3 in an oven prior to its use as a primary standard S
- rinsing all glassware with distilled water S
- incorrect indicator S
- perception of colour change at the end point R/S

Random error	Why error is classified as random
Reading of burette	Reading is equally likely to be over or under true value.

Systematic error	Why error is classified as systematic
Not drying Na_2CO_3 in an oven prior to its use	Na_2CO_3 is likely to contain water which means mass of pure Na_2CO_3 and concentration of primary standards will also always be lower than expected.

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Question 38 (continued)

The antacid suspensions were thoroughly shaken and 20.0 mL of each transferred to separate 250.0 mL volumetric flasks. Both were made up to the mark with distilled water and shaken vigorously. 10.0 mL aliquots of the diluted suspensions were transferred to conical flasks for titration and an appropriate indicator added.

The titre values obtained for the $A\ell(OH)_3$ suspension are shown in the table below:

Titre volume HCℓ (mL)				Average titre volume (mL)
Trials				
1	2	3	4	
22.62	21.98	21.94	21.90	21.94

(d) Account for the need for four trials in the titration. (1 mark)

OR: To reduce random error. *

The first trial was used to determine the approximate volume of the titre and was not concordant with the others and was therefore discarded. Three more trials were performed and averaged.

(e) (i) Calculate the concentration, in moles per litre (mol L^{-1}), of $A\ell(OH)_3$, in the original $A\ell(OH)_3$ suspension. (5 marks)

$Al(OH)_{3(aq)} + 3HCl \rightarrow AlCl_{3(aq)} + 3H_2O_{(l)}$

10 mL, c = ? | 21.94 mL, 5.09×10^{-2} M

$SR = \frac{\text{unknown}}{\text{known}} = \frac{1}{3}$

$n(HCl) = cV = 5.09 \times 10^{-2} \times 0.02194 = 0.0011167$ mol

$n(Al(OH)_3$ in 10 mL aliquot of diluted sol^n) $= \frac{1}{3} \times 0.0011167 = 0.00037224$

$n(Al(OH)_3$ in 250 mL vol. fl.) $= \frac{250}{10} \times 0.00037224 = 0.0093062$ mol

V (original suspension of $Al(OH)_3$) $= 20$ mL

c (original suspension of $Al(OH)_3$) $= \frac{n}{V} = \frac{0.0093062}{0.02}$

$= 0.4653108$ mol L^{-1}

$= 0.465$ mol L^{-1} (3sf)

(ii) From his titration of the $Mg(OH)_2$ diluted suspension, the student found the mass of $Mg(OH)_2$ in the 250 mL **diluted** suspension to be 1.13 g. Determine the concentration of $Mg(OH)_2$ in the original **undiluted** suspension and express your answer in moles per litre (mol L^{-1}). (2 marks)

$c(Mg(OH)_2 - \text{undiluted}) = m/V = \frac{1.13}{0.02} = 56.5\ g/L$

$n = \frac{m}{M} = \frac{56.5}{(24.31+32.00+2.016)} = 0.96869\ mol$

$\therefore c(Mg(OH)_2; \text{undiluted}) = 0.969\ mol\ L^{-1}\ (3sf)$

(f) Which of the preparations would be more effective (neutralise more HCℓ) for a given volume? Show your workings. (4 marks)

$n(Mg(OH)_2 \text{ in } 20mL \text{ antacid}) = 0.0193739\ mol$

$Mg(OH)_2$ neutralises 2 mol of HCl per mol $= 2 \times 0.0193739$

$= 3.87 \times 10^{-2}$ mol HCl neutralised

$n(Al(OH)_3 \text{ in } 20mL \text{ antacid}) = 9.3098733 \times 10^{-3}\ mol$

$Al(OH)_3$ neutralises 3 mol of HCl per mol $= 3 \times 9.3098733 \times 10^{-3}$

$= 2.79 \times 10^{-2}$ mol

$\therefore Mg(OH)_2$ is more effective

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Question 39 **(19 marks)**

Qualitative analysis of an organic compound showed that it contained only carbon, hydrogen and oxygen. A quantitative study of the same compound was performed, in which a 0.5096 g sample was burnt in excess oxygen to produce 0.4160 g of water and 700.7 mL of carbon dioxide, collected at 100.0 °C and 102.8 kPa.

(a) Determine the empirical formula of the compound. (10 marks)

$C_xH_yO_z + O_2 \rightarrow H_2O + CO_2$

0.5096 g 0.4160 g 700.7 mL at 100°C; 102.8 kPa

$PV = nRT$

$n(C) = n(CO_2) = \frac{PV}{RT} = \frac{102.8 \times 0.7007}{8.314 \times 373}$

$= 0.0232277$ mol

$m(C) = nM = 0.0232277 \times 12.01$

$= 0.278964$ g

$n(H) = 2 \times n(H_2O) = 2 \times \frac{0.4160}{18.016} = 0.0461811$ mol

$m(H) = nM = 0.0461811 \times 1.008$

$= 0.04655$ g

$m(O) = 0.5096 - 0.04655 - 0.278964$

$= 0.184086$ g

$n(O) = \frac{m}{M} = \frac{0.184086}{16} = 0.011505$

	C	H	O
mol	0.02322	0.04618	0.011505
÷ 0.011505	2.01	4.01	1
Round	2	4	1

Empirical formula is C_2H_4O

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