YIJC 2025 Prelim Paper 4 Mark Scheme

Hierarchy to be used in calculating mean titres in question 1(b)(i):

- Value of 2 identical titres
- Average of titres within 0.05 cm^3
- Average of titres within 0.10 cm^3

Use the selected titres to determine the mean titre for the end-point.

1. For calculations, the principle of no double penalty (error carried forward) applies. For connecting parts, marking from point of first penalty onwards will be based on correct method only.
2. Examiners should consider the context and scientific use of any keywords when awarding marks. Although keywords may be present, marks should not be awarded if the keywords are used incorrectly.
3. The examiner should not choose between contradictory statements given in the same question part, and credit should not be awarded for any correct statement that is contradicted within the same question part. Wrong science that is irrelevant to that question should be ignored.
4. Although spellings do not have to be correct, spelling of syllabus terms must allow for clear and unambiguous separation from other syllabus terms with which they may be confused. (e.g., ethane/ethene)

Question	Answer	Marks
1(b)(i)	**M1 (MMO Quality)**	**1**

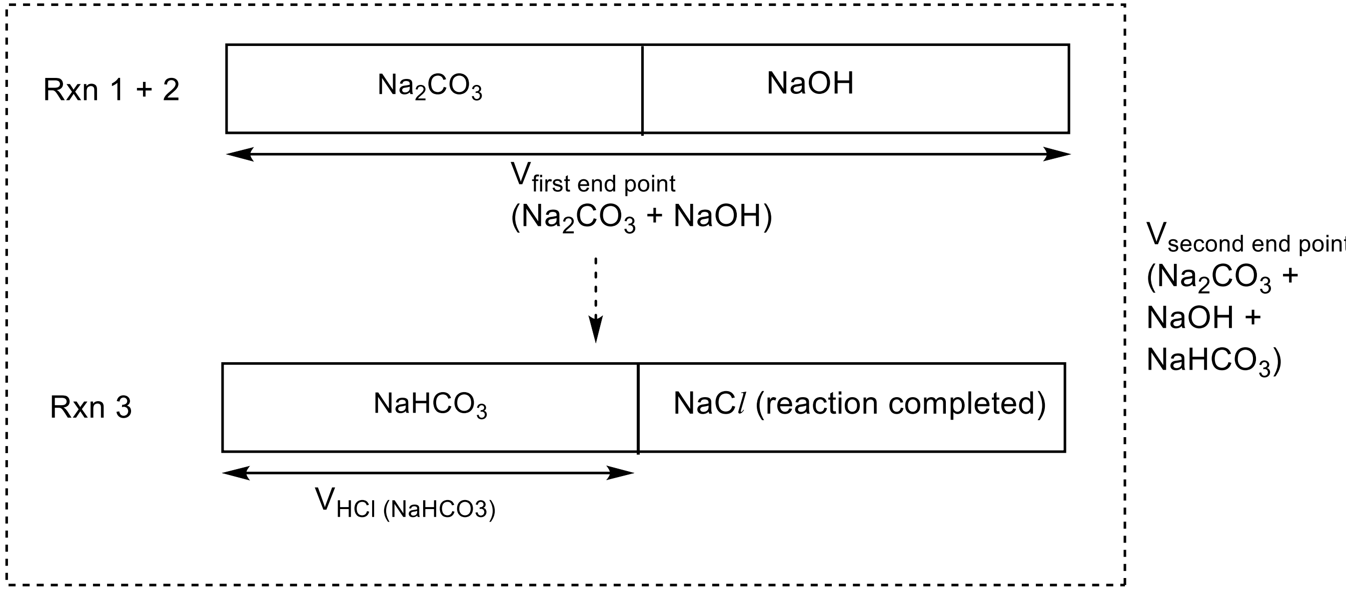
SAMPLE DATA		
Initial burette reading / cm^3	4.10	2.20
Burette reading at first end-point / cm^3	26.10	24.20
Burette reading at second end-point / cm^3	37.20	35.20
Volume of **FA 3** used to complete reactions 1 and 2 / cm^3	22.00	22.00
Volume of **FA 3** used to complete reaction 3 / cm^3	11.10	11.00
Total volume of **FA 3** used for titration / cm^3	33.10	33.00

Has at least two **uncorrected** titres for end point within 0.10 cm^3 for **total volume of FA 3** required for the titration.

*A student's "rough"/"trial" titre value can be considered by the examiner when selecting titre values for the mean titre calculation if the student has "validated" this value either by ticking it or by using it in an expression in **(b)(ii)**. (By doing either of these, the student has declared it to be no longer a "rough"/"trial" value)*

Question	Answer	Marks
	M2 (PDO Record) All the burette readings, for all accurate titres in the titration table, are recorded to the nearest 0.05 cm^3. *Treat all titres as 'accurate' unless labelled 'rough' or first titre is recorded to a lower precision than subsequent titres. [For arithmetic errors in calculations in table, deduct M5.]*	**1**
	M3, M4 (MMO Quality, MMO Accuracy) **Calculate** the student's mean titre (based on **total** volume of **FA 3** required for the titration) as described on page 1. Award M2 and M3 based on the difference, Δ titre, between Student's and Supervisor's mean titre.	**2**

	Give 2 marks if this difference is ≤ 0.30cm^3 Give 1 marks if this difference is > 0.30cm^3 but ≤ 0.50cm^3 Give 0 marks for a difference > 0.50cm^3	
1(b)(ii)	**M5 (MMO Decision)** • (For total volume of **FA 3** used for the titration): Student obtains appropriate "average" to 2 d.p., from any experiments with uncorrected end-point titre values within 0.10 cm^3. • (For volume of **FA 3** used to complete reactions 1 and 2): Student obtains appropriate "average" to 2 d.p., **from the same set of experiments selected in first bullet point above**. *Do not award this mark if the titres used are not identified either in the table (by, for example, a tick) or in a calculation.* *Do not award this mark if there are arithmetic errors in the table.*	**1**
1(c)(i)	**M6 (ACE Interpret)** [HC*l*] in **FA 3** = 20.00/250 x 1.5 = 0.120 mol dm^{-3} **M6**	**1**
1(c)(ii)	**M7, M8 (ACE Interpret)** Let the volume of **FA 3** required to reach first end-point be $V_{first\ end\ point}$, and total volume of **FA 3** required for the titration be $V_{second\ end\ point}$. Vol of **FA 3** required to react with $NaHCO_3$ = $V_{second\ end\ point} – V_{first\ end\ point} = V_{HCl(NaHCO3)}$ **M7** Amount of Na_2CO_3 in 25.0 cm^3 of **FA 1** = Amount of $NaHCO_3$ formed = Amount of HC*l* that reacted with $NaHCO_3$ = 0.120 x V/1000 = n_{Na2CO3} **M8**	**2**

	 $V_{second\ end\ point}$ (Na_2CO_3 + NaOH + $NaHCO_3$) = $V_{first\ end\ point}$ (Na_2CO_3 + NaOH) + $V_{HCl\ (NaHCO3)}$	
1(c)(iii)	**M9, M10 (ACE Interpret)** Amount of HC*l* to react with both Na_2CO_3 and NaOH = 0.120 x $V_{first\ end\ point}$ /1000 = $n_{(Na2CO3\ +\ NaOH)}$ **M9** From **(c)(ii)**, we found n_{Na2CO3} $n_{NaOH} = n_{(Na2CO3\ +\ NaOH)} - n_{Na2CO3}$ **M10** **OR** Volume of **FA 3** reacted with NaOH = $V_{first\ end\ point} – V_{HCl(NaHCO3)} = V_{HCl(NaOH)}$ **M9** Amount of NaOH in 25.0 cm^3 of **FA 1** = 0.120 x $V_{HCl(NaOH)}$/1000 = n_{NaOH} **M10**	**2**

1(c)(iv)	**M11, M12 (ACE Interpret)** [Na_2CO_3] in **FA 1** = n_{Na2CO3} x 1000/25 = c1 **M11** [NaOH] in **FA 1** = n_{NaOH} x 1000/25 = c2 **M12** *If student cannot obtain* n_{Na2CO3} *or* n_{NaOH}*, they can use 0.00120 mol and 0.00100 mol in place of* n_{Na2CO3} *and* n_{NaOH} *respectively.*	 **1** **1**
1(d)(i)	**M13 (ACE interpret)** Thymolphthalein colour change from blue to colourless is preferable because **it does not obscure or confuse the detection of the second indicator's colour change.**	**1**
1(d)(ii)	**M14 (ACE interpret)** Since methyl orange is a weak base, it **will also react with HC*l*.** **More HC*l* (higher volume of FA 3) is thus required** for end-point to be reached. *Simply stating more hydrochloric acid is required without any justification warrants no marks at all.*	 **1**
1(e)	**M15 (ACE interpret)** Effect: **No effect** Explanation: If left uncapped, some NaOH in **FA 1** will react with CO_2 to form Na_2CO_3 **(n(NaOH) : n(Na_2CO_3) = 2 : 1).** However, **n(Na_2CO_3) : n(HC*l*) = 1 : 2,** so the amount of HC*l* required does not change even though there is less NaOH and more Na_2CO_3 in uncapped **FA 1**.	**1**

1(f)	**M16 (ACE interpret)** Discontinuous method requires two separate samples of the $NaOH/Na_2CO_3$ mixture. **If the samples are not exactly the same, then the titre volumes obtained from both titrations will result in the calculated composition to be inaccurate.** **OR** Performing **two separate titrations** increases the **overall percentage uncertainty**, which in turn increases the error in the calculated composition.	**1**

2(a)(i)	**M17 (PDO layout)** Tabulates weighed masses, *t* and *T*. Students should record these data in a table or tables. Given the large amount of data to be recorded, students should be allowed to record *t* and *T* data in multiple tables. All tables should contain correct headers and units. Missing “capped” – BOD If units have been penalised here, it will not be penalised for M21.		**1**
	M18 (PDO record) Record all masses to 3 d.p. Record temperatures to 0.1 °C Record time to 1 d.p. (0.5 min) Only based on data students presented on page 8.		**1**
	M19 (MMO Collect) Complete set of *t* and *T* readings. T readings required at: T= 0.0, 0.5, 1.0, 1.5, 2.0, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0 min AND Complete set of masses • Capped weighing bottle and **FA 4** • Emptied weighing bottle plus cap • Mass of **FA 4** used (check for arithmetic error)		**1**
	M20 (MMO Quality) Read the Supervisor’s and the student’s temperature at 2.0 min and at 3.0 min. Calculate the ΔT for Supervisor and student. Calculate mass of **FA 4** used by student (do not use uncorrected) and also calculate mass of **FA 4** used by Supervisor. Then, calculate (ΔT / mass of **FA 4**) for both the supervisor and the student to 2 d.p. and calculate the difference in these two values. Give 1 mark if the difference is ≤ 1		**1**

2(a)(ii)	**M21 (PDO Layout)** Axes correct way round + correct labels + units + scale Scales chosen so that plotted points occupy at least half graph grid in both x and y directions. The scale **must** start at zero on the x-axis. The scale on the y-axis must allow for both straight lines to be extrapolated to *t* = 2.5 min.	**1**
	M22 (PDO Layout) All points correctly plotted within ± ½ small squares.	**1**
	M23 (PDO Manipulate) Both lines are best fit straight lines and are correctly extrapolated to 2.5 min.	**1**
2(a)(iii)	**M24 (PDO Manipulate)** Min temp and max temp correctly read to ± ½ small squares (dp: readings from graph can be given to a precision allowed by half small square, OR to 1 dp, which is the precision of the thermometer) **And** ΔT_2 correctly calculated (ignore sign)	**1**
2(a)(iv)	**M25 (ACE Interpret)** $q_2 = 30 \times 4.18 \times \Delta T_2$ **M25** (ignore sign)	**1**
2(a)(v)	**M26, M27 (ACE Interpret)** Let the mass of **FA 4** used be m1 Amount of $NaHCO_3$ = m1 / 84 = n3 **M26** ΔH_2 = **+** (q_2 / 1000) / n3 **M27** (must include sign)	 **1** **1**

2(b)	**M28 (ACE Interpret)** ΔH_1 = (–24.0) – $2\Delta H_2$ **M28**	**1**
	M29 (PDO Manipulate) Appropriate significant figures in **1(c)(i) – (iv), 2(a)(iv), (a)(v)** and **2(b)**	**1**
	M30 (PDO Manipulate) Relevant working shown in all calculations in **1(c)(i) – (iv), 2(a)(iv), (a)(v)** and **2(b)**	**1**
	M31 (PDO Manipulate) Appropriate units in **1(c)(i) – (iv), 2(a)(iv), (a)(v)** and **2(b)**	**1**
2(c)	**M32 (ACE Interpret)** **ΔT_2 will be halved** as the same amount of heat is absorbed by double the mass (volume). **ΔH_2 will be the same** as **heat change, *q*, and amount of $NaHCO_3$ used are the same**.	**1**
2(d)	**M33 (ACE Interpret)** The graphical method / extrapolation **compensates for / takes into consideration heat gained from surroundings** to give a more accurate minimum temperature reached, resulting in a more accurate ΔT_2.	**1**

3(a)	**M34, M35, M36, M37, M38 (Plan)**	**5**

Obtain mass of empty boiling tube Obtain mass of boiling tube + solid before heating Obtain mass of boiling tube + solid after heating	**1**
Cooling of boiling tube before weighing	**1**
Repeat heat cool weigh process until consistent mass	**1**
Amount of (CO_2 + H_2O) = (mass loss) ÷ (44.0 + 18.0)	**1**
% by mass of $NaHCO_3$ = [2 × amount of (CO_2 + H_2O) × 84.0] ÷ (mass of solid before heating) × 100	**1**

<u>Sample Answer 1</u>

1. Weigh, using a weighing balance, an empty boiling tube.
2. Place the sample in boiling tube and weigh boiling tube with solid with a weighing balance. Record the mass.
3. Calculate the mass of solid before heating by (mass in Step 2) – (mass in Step 1).
4. Using a holder, gently heat the boiling tube with the sample using a Bunsen burner (for about 1 minutes) before strongly heating (for about 2-3 minutes).
5. Cool, and then weigh the boiling tube and residue. Record the mass.
6. Repeat the heat-cool-weigh process till consistent mass is obtained.
7. Mass lost = mass of CO_2 + mass of H_2O
8. Amount of (CO_2 + H_2O) = (mass lost) ÷ (44.0 + 18.0)
9. Since **2**$NaHCO_3$: 1(CO_2 + H_2O) **OR** since **2**$NaHCO_3$: 1CO_2
   % by mass of $NaHCO_3$
   = [**2** × amount of (CO_2 + H_2O) × 84.0] ÷ (mass of solid before heating) × 100%
   = [**2** × [(mass lost) ÷ (44.0 + 18.0)] × 84.0] ÷ (mass of solid before heating) × 100%

OR

8. Amt of CO_2
= mass of CO_2 ÷ 44.0
= [percentage by mass of CO_2 x (mass lost)] ÷ 44.0
= [44.0/(44.0 + 18.0) x (mass lost)] ÷ 44.0

	= (mass lost) ÷ (44.0 + 18.0) 9. Since **2**$NaHCO_3$: **1**CO_2 % by mass of $NaHCO_3$ = [**2** × amount of CO_2 × 84.0] ÷ (mass of solid before heating) × 100% = [**2** × [(mass lost) ÷ (44.0 + 18.0)] × 84.0] ÷ (mass of solid before heating) × 100% **<u>Sample Answer 2</u>** 1. Weigh, using a weighing balance, an empty boiling tube. 2. Place the sample in boiling tube and weigh boiling tube with solid with a weighing balance. Record the mass. 3. Calculate the mass of solid before heating by (mass in Step 2) – (mass in Step 1). 4. Using a holder, gently heat the boiling tube with the sample using a Bunsen burner (for about 1 minutes) before strongly heating (for about 2-3 minutes). 5. Cool, and then weigh the boiling tube and residue. Record the mass. 6. Repeat the heat-cool-weigh process till consistent mass is obtained. 7. Mass lost = mass of CO_2 + mass of H_2O 8. Based on balanced equation, every 1 mol of $NaHCO_3$ decomposed produces 0.5 mol of CO_2 and 0.5 mol of H_2O, i.e., every 84.0 g of $NaHCO_3$ decomposed produces 22.0 g of CO_2 and 9.0 g of H_2O, i.e., every 84.0 g of $NaHCO_3$ decomposed results in mass loss of 31.0 g. 9. Using simple ratio, mass of $NaHCO_3$ decomposed = (mass lost ÷ 31.0) x 84.0 10. % by mass of $NaHCO_3$ = [(mass lost ÷ 31.0) x 84.0] ÷ (mass of solid before heating) × 100%	
3(b)	**M39 (Plan)** The water formed condenses at the mouth of the boiling tube and give inaccurate mass readings whereas the use of a **crucible has a wide opening that enables the water to evaporate more readily**.	**1**

4(a)(i)

	test	observations
1	Add 1 cm depth of **FA 5** solution to a boiling tube. Add 1 cm depth of aqueous sodium hydroxide. Add a piece of aluminium foil to the reaction mixture. Warm the mixture.	White ppt formed* White ppt soluble in excess* Moist red litmus paper turn blue* Ammonia gas evolved*
2	Add 1 cm depth of **FA 5** solution to a test-tube. Add a 1 cm depth of dilute nitric acid, then add a few drops of aqueous silver nitrate. Add aqueous ammonia to the reaction mixture until the aqueous ammonia is in excess.	White ppt formed* Soluble in aqueous ammonia*
3	Add 1 cm depth of **FA 5** solution to a test-tube. Add a 1 cm depth of aqueous barium nitrate. Add dilute nitric acid.	White ppt formed* No observable change*

M40. M41, M42, M43 (MMO Collecting)

Total 8*
2*: 1 mark

4

4(a)(ii)	**M44, M45 (ACE Conclusion)** Chloride / Cl^- Sulfate / SO_4^{2-}	**2**
4(a)(iii)	**M46, M47, M48, M49 (Plan)** <table><tr><td>Test</td><td>Observation</td></tr><tr><td>To 1 cm depth of **FA 5**, add ammonia slowly, with shaking, until no further change is seen. **M46**</td><td>White ppt* soluble in excess*</td></tr><tr><td>To 1 cm depth of **FA 5**, add 1 cm depth of NaOH and warm the solution. **M47**</td><td>White ppt formed* White ppt soluble in excess* Gas evolved turns moist red litmus blue.* Ammonia is produced* **6* - 2 marks** **3 to 5* - 1 mark** **M48, M49**</td></tr></table>	**4**
4(a)(iv)	**M50, M51 (Plan)** Deduction of Zn^{2+} and NH_4^+	**2**

4(b)(i)	**M52, M53, M54 (MMO Collecting)**	**3**

	test	observations
1	To a 1 cm depth of aqueous silver nitrate in a test-tube add a few drops of aqueous sodium hydroxide and then add aqueous ammonia slowly until the grey precipitate that forms just dissolves. To this solution add a 1 cm depth of **FA 6** and leave to stand in the water bath.	Silver mirror formed.
2	To a 1 cm depth of **FA 6** in a test-tube, add a 2 cm depth of dilute sulfuric acid. Place the test-tube in the water bath. Then add two or three drops of aqueous potassium manganate(VII). Leave to stand in the water bath.	Purple solution decolorises/ Purple solution turns colourless (accept pale yellow)*
3	To a 1 cm depth of **FA 6** in a test-tube add a small spatula of sodium carbonate.	Effervescence observed.* Gas gives white ppt with limewater.* Carbon dioxide gas evolved*

4* : 3 marks
2 – 3* : 2 marks
1*: 1 mark

4(b)(ii)	**M55 (ACE Conclusion)** HCOOH, allow ecf of methanal if test 3 was negative.	**1**