Answers to 2024 Preliminary Examination 6092/3:

No.	Answers	Marks	Comments
1ai	*[1] Records initial (burette) readings, final (burette) readings and volume of P added with correct headings and units in the titration table.* ***[NO MARK if there are repeat units within each reading in table]*** *[1] All burette readings for all titres in titration table are recorded to nearest 0.05 cm^3 (2 d.p.).* *[1] Determine concordance with at least two UNCORRECTED titres within ±0.20 cm^3.* *[2] Determine accuracy of candidate average titre using CORRECTED values…* • *2 marks: (±0.20 cm^3) within 23.20 – 23.60 cm^3* • *1 mark: (±0.30 cm^3) within 23.10 – 23.70 cm^3*	**[5]**	
1aii	Average volume of P = (Reading 1 + Reading 2) / 2 = 23.40 cm^3 [1] ** Note that appropriate average volume of ___ from closest titre values (titres should be identified either in the table by a tick or in a calculation AND within 0.20 cm^3 of each other).* *REJECT if answer is not in 2 d.p. or rounding error **OR** ticked values and calculations mismatch from student's selected titre values.*	**[1]**	
1aiii	No. of moles of P reacted = 1.50 x (23.40/1000) = 0.0351 mol [1] Based on mole ratio, no. of moles of Na_2CO_3 in Q reacted = 0.0351 / 2 = 0.01755 mol Molar concentration of Q = 0.01755 / (25.0/1000) = 0.702 mol/dm^3 [1] *(if final answer is not in 3.s.f., deduct one mark)*	**[2]**	
1aiv	M_r of $Na_2CO_3 \cdot xH_2O$ = 200 / 0.702 = 284.900 = 283.9 [1] M_r of $Na_2CO_3 \cdot xH_2O$ = 106 + x (18) = 284.900 x = 9.94 ≈ 10 (nearest whole number) [1]	**[2]**	

1av	After rinsing, some of Q would have reacted with (residual) P (HCl) **OR** Q is neutralised with P, hence the number of moles of Q transferred to the conical flask would be less (than expected) [1]. The M_r of $Na_2CO_3 \cdot xH_2O$ will therefore be larger (than expected), and the (value of x OR) amount of water of crystallisation would also be larger (than expected) [1]. ** Note that student must show understanding of "water of crystallisation", otherwise award [0].*	**[2]**	
1b	1. Prepare a recording table as follows: | Mass of empty boiling tube / g | a | | Mass of boiling tube and Na_2CO_3 crystals (before heating) / g | b | | Mass of boiling tube and content (after 1st heating) / g | c | | Mass of boiling tube and content (after 2nd heating) / g | d | | Mass of boiling tube and content (after 3rd heating) / g | d | 2. Using an electronic mass balance, measure and record the mass of an empty boiling tube. 3. Transfer the Na_2CO_3 crystals to the boiling tube. Measure and record the total mass of boiling tube and Na_2CO_3 crystals. 4. Heat the boiling tube for approximately 2-3 minutes (max. of 5 mins) and leave the boiling tube to cool to room temperature [1]. 5. Reweigh the boiling tube and its content and record the mass (after 1st heating). 6. Repeat Steps 4 and 5 until a constant mass is obtained [1]. 7. Calculate the mass of water of crystallisation lost: *mass of water of crystalliation = (b-d) g* 8. Calculate the value of x: $nNa_2CO_3 : nH_2O = 1: x = [(d-a)/(106$ which is M_r of $Na_2CO_3)] : [(b-d)/(18$ which is M_r of $H_2O)]$ *[1] Apparatus – Boiling tube (or suitable apparatus, e.g. crucible/evaporating dish) AND electronic (mass) balance (REJECT: test-tube/beaker/conical flask…)* *[1] Recording of "mass of empty boiling tube/g" AND "mass of boiling tube and Na_2CO_3 crystals (before heating)/g"* *[1] Recording of "mass of boiling tube and content (after heating)/g"* *[1] Calculation of Steps 7 & 8 to determine the value of x*	**[6]**	

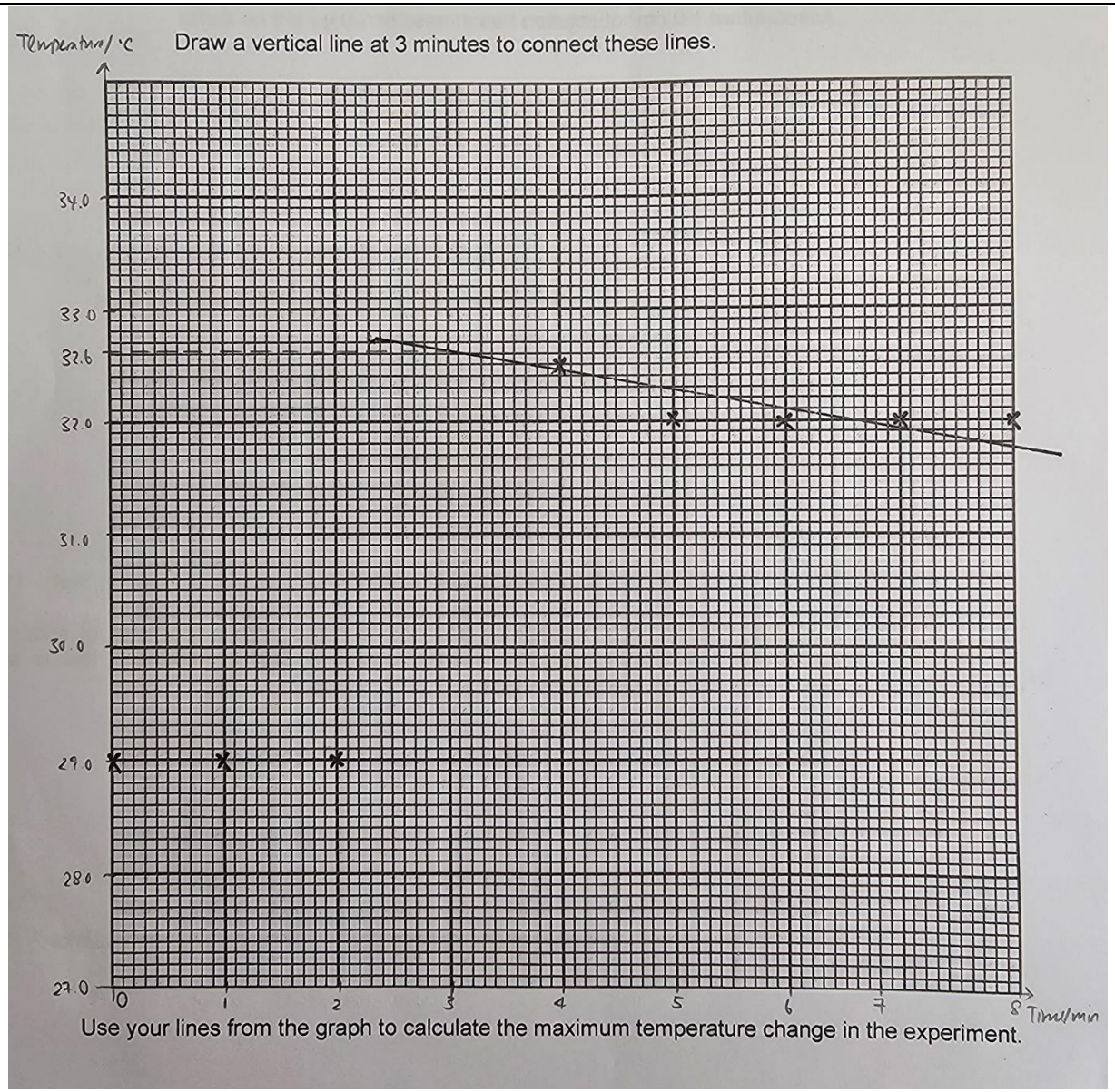
2ai mass of sodium carbonate added = 5.12 g (acceptable range of 4.80g – 5.25g)

[2]

time / min	0	1	2	3	4	5	6	7	8
temperature / ^{o}C	29.0	29.0	29.0		32.5	32.0	32.0	32.0	32.0

[1] Values of <u>BOTH</u> mass measurements to 2 decimal places and mass of Na_2CO_3 added is within range

[1] Values of <u>ALL</u> temperature measurements to nearest 0.5 ^{o}C

2aii	 Temperature/°C Draw a vertical line at 3 minutes to connect these lines. 34.0 33.0 32.6 32.0 31.0 30.0 29.0 28.0 27.0 0 1 2 3 4 5 6 7 8 Time/min Use your lines from the graph to calculate the maximum temperature change in the experiment.	**[5]**	

	[1] All plotted points must be present (but allow for one error) *[1] Axis labels AND units* *[1] Appropriate scales of both axes (e.g. in 2/5/10)* *[1] Best-fit straight lines (i.e. no curve, connect-the-dots, crooked/thick lines and MUST include straight line at 3rd min with connections to 2 straight lines before and after addition)* Maximum temperature change = 32.6 - 29.0 = + 3.6 ^{o}C [1] *(MUST be (i) based on graph drawn, (ii) dotted lines, (iii) 1.d.p and (iv) workings)*		
2aiii	Amount of heat change = (100)(3.6)(4.2) = 1512 J = 1510 J	**[1]**	
2aiv	No. of moles of Na_2CO_3 used = 5.12 / 106 = 0.048302 mol = 0.0483 mol	**[1]**	
2av	Enthalpy change of reaction = - (1512 / 0.048302) = - 32945 J/mol = - 31.3 kJ/mol *[1] Numerical answer and sign for enthalpy change of reaction* *[1] Answers to 3 significant figures for (a)(iii), (a)(iv) AND (a)(v).*	**[2]**	
2avi	error: Acid spray resulting in loss of volume of solution [1] in the Styrofoam cup. **OR** Heat loss to the surrounding effect on the value of enthalpy change of reaction calculated: Since the volume of solution in the Styrofoam cup is less, the amount of heat change calculated will be less than expected **OR** the highest temperature recorded is lower than expected AND the value of the enthalpy change of reaction will be smaller (than expected) [1]. improvement: Cover the Styrofoam cup with a (plastic) lid [1] with a hole for the thermometer, immediately after adding sodium carbonate.	**[3]**	
2b	Add (excess) aqueous sulfuric acid (or H_2SO_4 (aq)) [1] to a sample of sodium carbonate. If barium carbonate is present, a white precipitate [1] (of barium sulfate) will be observed. Otherwise, if barium carbonate is not present, there will be no precipitate formed.	**[2]**	

<table>
<tr>
<td>3a</td>
<td>
<table>
<tr><th>test</th><th>observations</th></tr>
<tr><td>1</td><td>The solid <u>dissolves</u> to form a <u>green solution</u> [1].</td></tr>
<tr><td>2</td><td>A <u>green precipitate</u> is formed, which is <u>insoluble in excess NaOH (aq)</u> [1].</td></tr>
<tr><td></td><td><u>No observable change</u> [1]</td></tr>
<tr><td>3</td><td>A <u>white precipitate</u> is formed in a green solution[1].</td></tr>
</table>

* Note that any contradictory observations in above table (e.g. mentioning “effervescence”, when no effervescence evolved), student will be awarded [0]. For subsequent questions in (b) and (c), answers cannot contradict the observations seen, otherwise be awarded [0].
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<td>[4]</td>
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<td>3b</td>
<td>Although a green precipitate is formed when NaOH (aq) is added, <u>the green precipitate did not turn reddish-brown when the test-tube is left to stand</u> [1]. This confirms that Fe^{2+} (aq) is absent.

* Note that this mark can only be awarded if student did not write contradictory observation based on Test 2.</td>
<td>[1]</td>
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<td>3c</td>
<td><u>When HNO_3 (aq) is added to the Y, there was no effervescence observed</u>, thus confirming that CO_3^{2-} (aq) is absent.

* Note that this mark can only be awarded if student did not write contradictory observation based on Test 1.</td>
<td>[1]</td>
<td></td>
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End of Paper