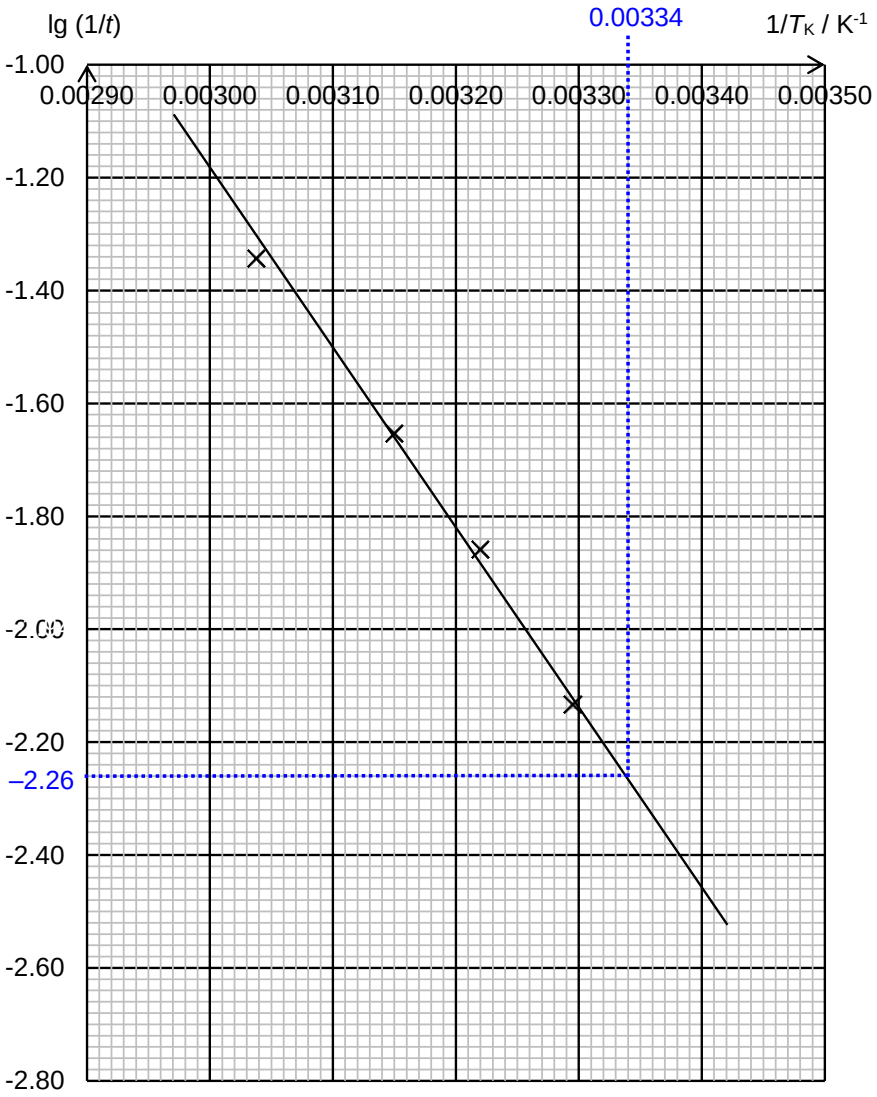
1(a)

Expt	$T_{initial}$ / ^oC	T_{final} / ^oC	t / s	$1/t$ / s^{-1}	lg ($1/t$)	T_{ave} / ^oC	T_K / K	$1/T_K$ / K^{-1}
1	30.4	30.6	136	0.00735	-2.13	30.5	304	0.00329
2	62.4	50.0	22	0.0455	-1.34	56.2	329	0.00304
3	39.2	36.0	72	0.0139	-1.86	37.6	311	0.00322
4	48.2	40.8	45	0.0222	-1.65	44.5	318	0.00315

1(b)(i)



(b)(ii) $t = 3 \times 60 = 180$ s
lg ($1/t$) = lg (1/180) = –2.26

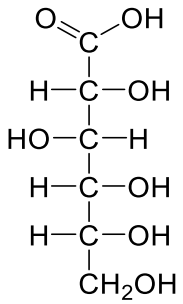
From the graph, $1/T_K = 0.00334\ K^{-1}$
T_{ave} = <u>26.4 ^oC</u>

(c)(i) Mole ratio of MnO_4^- : D-glucose : e^- = 1 : 2.5 : 5

Hence, mole ratio of D-glucose : e^- = 1 : 2

1 mol of D-glucose loses <u>2 mol of e^-</u>.

(c)(ii) Structure of **P**:



Since 1 mol of D-glucose loses 2 mol of e^- and only one carbon atom in each glucose molecule is oxidised, the oxidation state of this carbon must have increased by 2. Hence, the aldehyde group of D-glucose is oxidised to carboxylic acid as the <u>oxidation state of carbon increases from +1 in aldehyde to +3 in carboxylic acid</u>.

(d)(i) Maximum total percentage uncertainty = $\left(\frac{2(\pm 0.05)+(\pm 0.5)+(\pm 0.5)}{60}\right) \times 100\% = \underline{\pm 1.83\%}$

(d)(ii) Although T_{ave} was calculated, the <u>difference between $T_{initial}$ and T_{final} was quite significant</u>, especially for experiments conducted at temperatures above room temperature. This in turn resulted in <u>inaccuracy in the measurement of the temperature of the reaction/measurement of the time required</u> for the reaction to complete at T_{ave}.

A modification to the experimental procedure would be to use a <u>water bath maintained at a fixed temperature for each experiment</u>, to equilibrate the reactants at the same fixed temperature before starting the reaction, and to ensure that the temperature of the reaction mixture stayed constant throughout the reaction.

OR

The <u>human perception of when the reaction mixture turned colourless may be inconsistent/vary across different experiments</u>, hence resulting in <u>inaccuracy in the measurement of the time required</u> for the reaction to complete at T_{ave}.

A modification to the experimental procedure would be to <u>use a colorimeter to monitor the absorbance of the reaction mixture</u>, and stopping the stopwatch only when there was no more absorbance (i.e. reaction mixture had turned colourless).

2(a)(i)

Mass of capped weighing bottle and **FA 4** / g	9.135
Mass of capped weighing bottle after emptying **FA 4** / g	5.211
Mass of **FA 4** used / g	3.924

Titration number	**1**	**2**
Final burette reading / cm^3	19.90	39.80
Initial burette reading / cm^3	0.00	19.90
Volume of **FA 1** used / cm^3	19.90	19.90
Values used	✓	✓

2(a)(ii) Average volume of **FA 1** used = (19.90 + 19.90) / 2 = <u>19.90 cm^3</u>

2(b)(i) $n(MnO_4^-) = \frac{19.90}{1000} \times 0.0100 = 0.0001990$ mol

$n(Fe^{2+})$ in 25.0 cm^3 of **FA 5** $= 5(MnO_4^-) = 5 \times 0.0001990 = 0.0009950$ mol

$[Fe^{2+}] = \frac{0.0009950}{0.025} = \underline{0.0398 \text{ mol dm}^{-3}}$

2b(ii) $n(Fe^{2+})$ in 250 cm^3 of **FA 5** $= 0.25 \times 0.0398 = 0.009950$ mol

n(**FA 4**) in 250 cm^3 of **FA 5** $= n(Fe^{2+}) = 0.009950$ mol

M_r of **FA 4** $= \frac{3.924}{0.00995} = \underline{394}$

2(b)(iii) Total number of positive charge = total number of negative charge

$(+1)a + 2 = 2b$

$\underline{a = 2b - 2}$

2(b)(iv) Using the formula $(NH_4)_aFe(SO_4)_b.6H_2O$,

M_r of **FA 4** $= a(14.0 + 4 \times 1.0) + 55.8 + b(32.1 + 16.0 \times 4) + 6(2 \times 1.0 + 16.0)$

$= 18.0a + 96.1b + 163.8$

From **(b)(ii)**, $M_r = 394.4 \Rightarrow 18.0a + 96.1b + 163.8 = 394.4$ ----------(1)

Substitute $a = 2b-2$ in (1),

$18.0(2b - 2) + 96.1b + 163.8 = 394.4$

$36.0b - 36.0 + 96.1b + 163.8 = 394.4$

$132.1b = 266.6 \Rightarrow b = 2.018 = \underline{2}$ (whole number)

$a = 2(2) - 2 = \underline{2}$

2(c) The student's titre value would be <u>higher</u>.

Due to insufficient amount of H_2SO_4, <u>MnO_4^- is reduced to MnO_2</u> instead of Mn^{2+}. As MnO_4^- <u>accepts 3 e^-</u> when it is reduced to MnO_2 compared to <u>accepting 5 e^-</u> when it is reduced to Mn^{2+}, more MnO_4^- is needed to oxidise the same amount of Fe^{2+}, so titre value to reach end-point is higher.

3(a)

test	observations
Using a 10 cm^3 measuring cylinder, add 5.0 cm^3 of **FA 3** to a boiling tube.	
To this boiling tube, add 5.0 cm^3 of **FA 8** using the same 10 cm^3 measuring cylinder.	No observable change.
Leave this boiling tube in the hot water bath for about 3 minutes.	Red/brown ppt formed.
Filter the reaction mixture into another boiling tube.	
Wash the residue with some deionised water.	Red/brown residue.
The residue is **FA 9**.	Brown filtrate.
Retain the filter funnel containing **FA 9** for **3(c)(iii)**.	

3(b)

	test	observations with **FA 6**	observations with **FA 7**
(i)	Add about 2 cm depth of **FA 6** to a test-tube. To this test-tube, add 2 cm depth of dilute sulfuric acid, followed by 1 drop of potassium manganate(VII) solution and shake well. Leave the test-tube to stand in a beaker of hot water for about 5 minutes.	Decolourisation of purple $KMnO_4$	no observable change
(ii)	Add 1 cm depth of aqueous silver nitrate to a test-tube. Then slowly add 1 cm depth of aqueous sodium hydroxide. Add aqueous ammonia slowly, with shaking, until the precipitate just dissolves. You may use a clean glass rod to stir the mixture and help dissolve the precipitate. Add 1 cm depth of **FA 6** to this mixture, shake the tube and place it in the test-tube rack to stand.	Silver mirror formed.	no observable change
(iii)	Add about 1 cm depth of **FA 7** to a test-tube. To this test-tube, add 4 drops of sodium hydroxide solution followed by iodine solution, dropwise, until a permanent orange/red colour is present. Warm the mixture in a beaker of hot water for about 2 minutes.	solution **FA 6** turns orange	Yellow ppt formed in orange / red solution.
	Add sodium hydroxide solution using a teat pipette until no further change is seen.	solution **FA 6** turns colourless	Solution turns colourless. Yellow ppt remained.

3(b)(iv)

	functional group	evidence
FA 6	aldehyde	In test **(b)(ii)**, **FA 6** gives a silver mirror with Tollens' reagent.
FA 7	ketone	In test **(b)(i)**, **FA 7** did not decolourise purple acidified $KMnO_4$. In test **(b)(iii)**, **FA 7** gave yellow ppt, CHI_3, with alkaline aq iodine.

3(c)

	test	observations
(i)	Test solution **FA 8** with Universal Indicator paper.	Universal indicator turns dark blue. pH is 12.
(ii)	Add about 1 cm depth of **FA 8** to a test-tube. Then add 1 cm depth of dilute nitric acid. To this test-tube, add about 1 cm depth of aqueous barium nitrate slowly, with shaking, until no further change is seen.	Solution **FA 8** turns from dark blue to light blue. No effervescence. White ppt formed in light blue solution.
(iii)	Place the filter funnel containing **FA 9** into a clean test-tube. Using a 10 cm^3 measuring cylinder, carefully add 2.0 cm^3 of dilute sulfuric acid to the filter funnel. The filtrate will collect in the test-tube. The residue is **FA 10**. The filtrate is **FA 11**.	 The residue turned from red/brown to red-brown/dark brown/black . Red-brown/dark brown/black residue. Blue filtrate.
(iv)	Add 1 cm depth of **FA 11** to a test-tube. Add aqueous ammonia slowly, with shaking, until no further change is seen.	 Blue ppt formed, soluble in excess $NH_3(aq)$ to form a dark blue solution.

3(c)(v) Cu^{2+}

3(c)(vi) Oxidation state of element **X**: +1

Type of reaction: Disproportionation

3(c)(vii) SO_4^{2-} is present. In test **(c)(ii)**, **FA 8** reacted with $Ba(NO_3)_2$ in the presence of $HNO_3(aq)$ to form white ppt of $BaSO_4$.

4(a)(i) Let V_{neut} cm^3 be the volume of barium hydroxide and (100 - V_{neut}) cm^3 be the volume of hydrochloric acid used at which stoichiometric amount of barium hydroxide and hydrochloric acid react.

Assuming $[Ba(OH)_2] = 0.080$ mol dm^{-3},

mole ratio of HC*l* : $Ba(OH)_2$ = 2 : 1

$n(HCl) = 2 \times n(Ba(OH)_2)$

$$\frac{100 - V_{neut}}{1000} \times 0.200 = 2 \times \frac{V_{neut}}{1000} \times 0.080$$

$20 - 0.2V_{neut} = 0.16V_{neut}$

$0.36V_{neut} = 20$

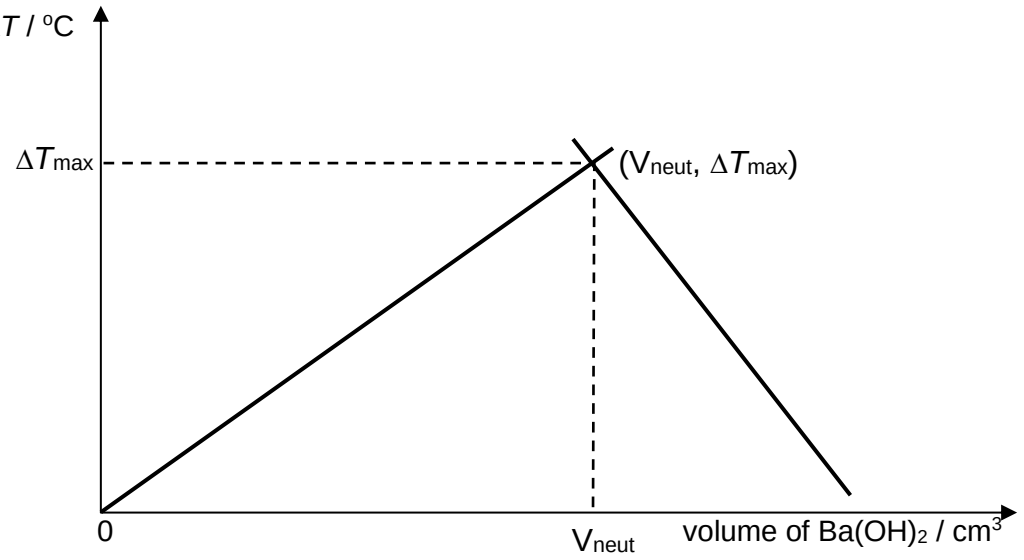
$V_{neut} = 55.6\ cm^3$

4(a)(ii) Procedure

1. Using a 100 cm^3 measuring cylinder, transfer 10.0 cm^3 of $Ba(OH)_2$ into a clean and dry Styrofoam cup supported in a 250 cm^3 beaker.
2. Use a thermometer to measure and record the steady initial temperature of $Ba(OH)_2$.
3. Using another 100 cm^3 measuring cylinder, measure 90.0 cm^3 of 0.200 mol dm^{-3} HC*l*. Ensure that both $Ba(OH)_2$ and HC*l* have the same initial temperature.
4. Add HC*l* from the measuring cylinder into the Styrofoam cup containing $Ba(OH)_2$ and cover the Styrofoam cup with a lid. Use the thermometer to stir the mixture gently. Measure and record the highest temperature of the mixture.
5. Empty, wash and carefully dry the Styrofoam cup.
6. Repeat steps 1 to 5 using volumes of HC*l* and $Ba(OH)_2$ in the table below so that the total volume of the mixture is 100 cm^3.
7. Record all measurements of volume, highest temperature after mixing and temperature change, ΔT, in the table below.

volume of $Ba(OH)_2$ / cm^3	volume of HC*l* / cm^3	initial temperature of $Ba(OH)_2$ / ^oC	highest temperature after mixing / ^oC	ΔT / ^oC
10	90			
20	80			
30	70			
40	60			
50	50			
60	40			
65	35			
70	30			
75	25			
80	20			

4(b)(i)



4(b)(ii)

$$\frac{[Ba(OH)_2] \times V_{neut}}{0.200 \times (100 - V_{neut})} = \frac{1}{2}$$

$$[Ba(OH)_2] \times V_{neut} = \frac{1}{2} \times 0.200 \times (100 - V_{neut})$$

$$[Ba(OH)_2] = \frac{0.100 \times (100 - V_{neut})}{V_{neut}} \text{ mol dm}^{-3}$$

$$\text{Heat released} = \frac{100 \times 4.18 \times \Delta T_{max}}{1000} \text{ kJ} \quad \left(\text{accept } q = + \frac{100 \times 4.18 \times \Delta T_{max}}{1000} \text{ kJ}\right)$$

$$n(H_2O) \text{ produced} = n(HCl) \text{ reacted} = 0.200 \times \frac{(100 - V_{neut})}{1000} = 0.0002 \times (100 - V_{neut})$$

$$\Delta H_{neut} = - \frac{\frac{100 \times 4.18 \times \Delta T_{max}}{1000}}{0.0002 \times (100 - V_{neut})} = - \frac{2090 \times \Delta T_{max}}{100 - V_{neut}} \text{ kJ mol}^{-1}$$

4(c) When a bottle of barium hydroxide solution is left standing in the air for some time, barium hydroxide reacts with carbon dioxide in the air to form barium carbonate. The enthalpy change of neutralisation of barium hydroxide and hydrochloric acid is different from that of barium carbonate and hydrochloric acid, this results in an inaccurate determination of ΔH_{neut} of barium hydroxide and hydrochloric acid.