1(a)(i)

Table 1.1

temperature of room temperature water, T_1 / °C	30.4
temperature of hot water, T_2 / °C	70.1
maximum temperature of combined water, T_3 / °C	48.2

1(a)(ii) Heat energy lost by the hot water
= mcΔT
= 50 × 4.18 × (T_2 – T_3)
= 50 × 4.18 × (70.1 – 48.2)
= 4577.1 J
= <u>4580 J</u> (3 s.f.)

Heat energy gained by the room temperature water = mcΔT
= 50 × 4.18 × (T_3 – T_1)
= 50 × 4.18 × (48.2 – 30.4)
= 3720.2 J
= <u>3720 J</u> (3 s.f.)

1(a)(iii) Heat energy absorbed by the calorimeter
= heat energy lost by hot water
– heat energy gained by room temp water
= 4577.1 – 3720.2
= 856.9 J
= <u>857 J</u> (3 s.f.)

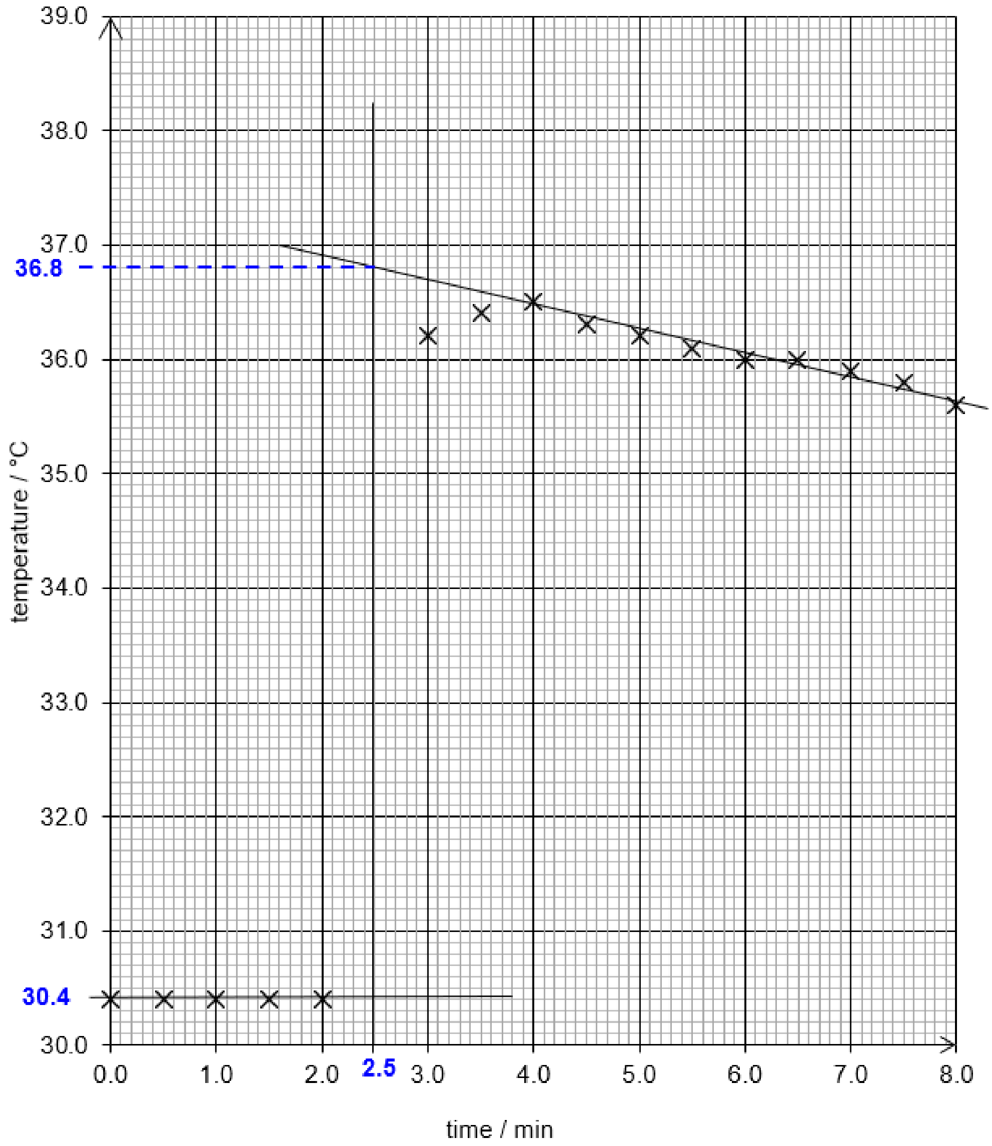
Heat capacity of calorimeter, C_{cal}
$= \frac{856.9}{T_3 - T_1} = \frac{856.9}{48.2 - 30.4}$
= 48.14 J °C^{-1}
= <u>48.1 J °C^{-1}</u> (3 s.f.)

1(b)(i)

mass of capped weighing bottle and **FA 1** / g	8.782
mass of capped weighing bottle after emptying **FA 1** / g	4.745
mass of **FA 1** used / g	4.037

time / min	temperature / °C
0.0	30.4
0.5	30.4
1.0	30.4
1.5	30.4
2.0	30.4
2.5	—
3.0	36.2
3.5	36.4
4.0	36.5
4.5	36.3
5.0	36.2
5.5	36.1
6.0	36.0
6.5	36.0
7.0	35.9
7.5	35.8
8.0	35.6

1(b)(ii)



1(b)(iii) T_{min} = 30.4 °C
T_{max} = 36.8 °C
ΔT = +6.4 °C

1(b)(iv) Total heat change, q
= heat absorbed by solution + heat absorbed by calorimeter
= $(mc\Delta T) + (C_{cal}\ \Delta T)$
= $(100 \times 4.18 \times 6.4) + (48.14 \times 6.4)$
= +2983 J
= +2980 J (3 s.f.)

1(b)(v) Amount of $MgSO_4$ used

$$= \frac{4.037}{24.3 + 32.1 + 4(16.0)}$$

= 0.03353 mol

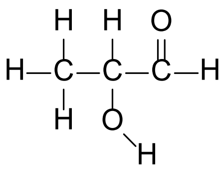
$$\Delta H_{sol} = -\frac{q}{n(MgSO_4)} = -\frac{+2983}{0.03353} = -89000 \text{ J mol}^{-1} \text{ (or } -89.0 \text{ kJ mol}^{-1}\text{) (3 s.f.)}$$

1(c) The heat energy absorbed by and heat capacity of calorimeter obtained in **(a)(iii)** is higher than expected. Hence, the ΔH_{sol} of **FA 1** obtained in **(b)(v)** is more exothermic than expected (or the magnitude of ΔH_{sol} of **FA 1** obtained in **(b)(v)** is higher than expected).

2(a)(i)

	tests	observations
1	Add 1 cm depth of **FA 2** into a clean test-tube. To this test-tube add 10 drops of sodium hydroxide followed by iodine solution, dropwise, until a permanent orange colour is present. Warm the test-tube in the beaker of hot water for 2 minutes.	**(pale) Yellow ppt** formed.
2	Add 1 cm depth of **FA 2** into a clean test-tube. Add 8 drops of Fehling's solution. Warm the test-tube in the beaker of hot water for 3 minutes.	**Brick-red ppt** formed.
3	Test solution **FA 2** with Universal Indicator paper.	Universal Indicator paper turned **dark yellow-green**. pH is **7**.

2(a)(ii)



2(b)(i)

	tests	observations
1	Using a 10 cm^3 measuring cylinder, add 2 cm^3 of **FA 3** into a clean boiling tube. Using another 10 cm^3 measuring cylinder, measure out 7 cm^3 of aqueous sodium hydroxide. Slowly with shaking, add this completely to **FA 3**. Stir the contents of the boiling tube with a glass rod. Filter the mixture into a clean test-tube. The filtrate will be used for test **4**. While waiting, proceed to test **2** and **3**.	**Off-white ppt. rapidly turned brown on contact with air.** Ppt. is insoluble in excess NaOH(aq). **Brown residue.** **Colourless filtrate**.

2(b)(i)

tests		observations
2	Add 1 cm depth of **FA 3** into a clean test-tube. Add 2 cm depth of aqueous sodium carbonate.	 **Off-white/ white ppt.** **Effervescence was observed.** **CO_2 gas evolved gave a white ppt. with limewater.**
3	Add 1 cm depth of **FA 3** into a clean test-tube. Add 1 cm depth of aqueous silver nitrate. Filter the mixture and discard the filtrate. Wash the residue by pouring deionised water through it. Discard the washings. Place the filter funnel containing the residue into a test-tube containing 1 cm depth of dilute nitric acid. Carefully add aqueous ammonia to the filter funnel until it covers the residue. The filtrate will collect in the test-tube containing the dilute nitric acid.	 **White ppt formed.** White residue obtained. Colourless filtrate. **White ppt formed.**
4	Add 1 cm depth of the filtrate from test 1 into a clean test-tube. Add dilute sulfuric acid drop-wise, until in excess.	 **White ppt.** formed, **soluble in excess dilute H_2SO_4** to give a colourless solution.

2(b)(ii)

cation	evidence
Mn^{2+}	In **test 1**, **FA 3** reacted with NaOH(aq) to give **an off-white ppt. of $Mn(OH)_2$** which was insoluble in excess NaOH(aq). On contact with air, $Mn(OH)_2$ was oxidised **to brown $Mn(OH)_3$**.
Al^{3+}	In **test 2**, **FA3** reacted with Na_2CO_3(aq) to give a **white ppt. of $Al(OH)_3$** together with the effervescence of **CO_2 gas**.
anion	evidence
Cl^-	In **test 3**, **FA 3** reacted with $AgNO_3$(aq) to form a **white ppt. of AgCl**. White ppt of AgCl soluble in excess ammonia to form colourless solution of $[Ag(NH_3)_2]^+$.

3(a)(i)

Titration number	1	2
Final burette reading / cm^3	21.90	41.80
Initial burette reading / cm^3	0.00	20.00
Volume of **FA 4** used / cm^3	21.90	21.80
Values used (✓)	✓	✓

3(a)(ii) Average volume of **FA 4** used = $\frac{21.90 + 21.80}{2}$ = <u>21.85 cm^3</u>

3(b)(i) Amount of $Na_2S_2O_3$ = $\frac{21.85}{1000} \times 0.100$
= 2.185×10^{-3} mol
Amount of I_2 produced = (½) (2.185×10^{-3})
= 1.093×10^{-3} mol
= <u>1.09×10^{-3} mol</u>

3(b)(ii) Amount of $KMnO_4$ reacted = (2/5) (1.093×10^{-3})
= 4.372×10^{-4} mol
= <u>4.37×10^{-4} mol</u>

3(b)(iii) Amount of $KMnO_4$ in 25.0 cm^3 **FA 7** = 4.372×10^{-4} mol

Amount of $KMnO_4$ in 250 cm^3 **FA 7**
= Amount of $KMnO_4$ in 34.50 cm^3 **P**
= $4.372 \times 10^{-4} \times 10 = 4.372 \times 10^{-3}$ mol
Conc. of $KMnO_4$ in **P** = $\frac{4.372 \times 10^{-3}}{34.5 \times 10^{-3}}$ = 0.1267 mol dm^{-3} = <u>0.127 mol dm^{-3}</u> (3sf)

3(b)(iv) Mass of $KMnO_4$ = 0.1267 × (39.1 + 54.9 + 4×16.0) = 20.02 g = <u>20.0 g</u> (3sf)

3(c)(i) Percentage = $\frac{21.0 - 20.0}{21.0} \times 100$ = <u>4.76%</u> (3sf)

3(c)(ii) I <u>do not agree</u> with the student, as <u>KI used was in excess</u>, hence the precision of the apparatus used is not relevant.

4(a) Excess $H_2NCH_2CH_2NH_2(aq)$ must be used so that <u>the equilibrium position of equation 4 lies to the right</u> and the reaction mixture contains mainly $[Ni(en)_3]^{2+}(aq)$.
OR
Excess $H_2NCH_2CH_2NH_2(aq)$ must be used to ensure <u>complete ligand exchange.</u>

4(b) Dilution of **FA 8**, 2.00×10^{-3} mol dm^{-3} $[Ni(H_2O)_6]^{2+}(aq)$

1. Using a burette, transfer 50.00 cm^3 of **FA 8** to a 100 cm^3 volumetric flask.
2. Top up to the mark with deionised water, stopper the volumetric flask and shake this solution to obtain a homogeneous solution. Label this solution as solution 1.
3. Repeat steps 1 to 2 using the volumes of **FA 8** shown in the table below to prepare solution 2 to solution 5.

Solution	Volume of **FA 8** / cm^3	$[Ni(H_2O)_6]^{2+}$ / mol dm^{-3}
1	50.00	1.00×10^{-3}
2	40.00	8.00×10^{-4}
3	30.00	6.00×10^{-4}
4	20.00	4.00×10^{-4}
5	10.00	2.00×10^{-4}

4(c) **Procedure**

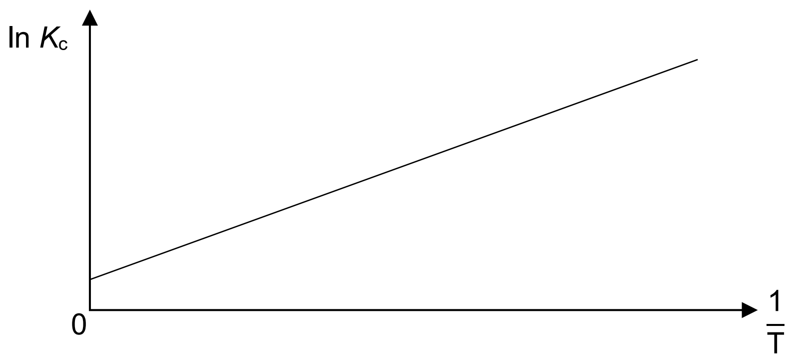
1. Using separate 25.0 cm^3 pipettes, transfer 25.0 cm^3 of 2.00 x 10^{-3} mol dm^{-3} **FA 8** and 25.0 cm^3 of 6.00 x 10^{-3} mol dm^{-3} **FA 9** into a 100 cm^3 conical flask/ beaker.
2. Shake/Swirl the conical flask/ beaker to ensure a homogeneous solution.
3. Place the conical flask/ beaker in a thermostatically controlled water bath maintained at 80 °C for about 5 min.
4. Measure and record the temperature of the solution using a thermometer.
5. Remove the solution in conical flask/ beaker from the water bath and use the spectrometer to immediately measure and record the absorbance.
6. Repeat steps 3 – 5 at 70 °C, 60 °C, 50 °C and 40 °C.
7. For each absorbance obtained, read off the calibration line to determine the corresponding concentration of $[Ni(en)_3]^{2+}(aq)$ at each temperature.
8. Calculate the K_c for each temperature according to the following method.

Let the concentration of $[Ni(en)_3]^{2+}(aq)$ obtained from the calibration line be x mol dm^{-3}

	$[Ni(H_2O)_6]^{2+}$	+ $3H_2NCH_2CH_2NH_2$	⇌ $[Ni(en)_3]^{2+}$	+ $6H_2O(l)$
initial / mol dm^{-3}	$\frac{2.00\times10^{-3}}{2}$ = 1.00×10^{-3}	$\frac{6.00\times10^{-3}}{2}$ = 3.00×10^{-3}	0	–
change / mol dm^{-3}	– x	– 3x	+ x	–
eqm / mol dm^{-3}	0.001 – x	0.003 – 3x	$[Ni(en)_3]^{2+}$ = x	–

$$K_c = \frac{x}{(0.001-x)(0.003-3x)^3}$$

4(d)(i)



Compare the equation given to y = mx + c, gradient = $-\Delta H / R$.
As $\Delta H < 0$ and $R > 0$, gradient is a positive constant

4(d)(ii)

$$\ln K_c = -\frac{\Delta H}{R}\left(\frac{1}{T}\right) + \frac{\Delta S}{R}$$

y = m x + c

gradient = $-\Delta H / R$
Hence, $\Delta H = -$ gradient × R

y-intercept = $\Delta S / R$
Hence, ΔS = y-intercept × R