NYJC J2 Prelim Exam 2020 Paper 4 Suggested Mark Scheme

1(c) Results

	1	2
initial burette reading / cm^3	0.00	10.25
final burette reading / cm^3	10.25	20.50
volume of **FA 1** added / cm^3	10.25	10.25

[2]

- correct headers, units and results recorded in a single table
- results recorded to 2dp and no 50.00 in the table and results recorded under the correct header
- correct evaluation of volume of **FA 1** added
- 3 pts – 2m, 2pts – 1m

(d)

volume of **FA 1** = $\frac{10.25+10.25}{2}$ = 10.25 cm^3

volume of **FA 1** = 10.25 …….. cm^3 [1]

Student obtains appropriate "average", to 2 d.p., from any experiments with uncorrected end-point titre values within 0.10 cm^3.
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.

(e) (i)

Volume of **FA 1** = 10.25 × $\frac{50.0}{10.0}$ (or × 5) = 51.25 cm^3

volume of **FA 1** = 51.25…….. cm^3 [1]

(ii)

Equilibrium amount of $C_2H_5CO_2H(aq)$ = amount of NaOH that reacts with the acid remaining in 50 cm^3 of the aqueous layer = $\frac{51.25}{1000}\times 0.050$ = 0.002562 ≈ 0.00256 mol [1]

	$C_2H_5CO_2H(aq)$	Ý	$C_2H_5CO_2H(org)$
initial amount / mol	$\frac{50}{1000}\times 0.200 = 0.01000$ (1)		0
change in amount / mol	– 0.007437 (3)		+ 0.007437 (4)
equilibrium amount / mol	0.002562 (2)		0.007437 ≈ 0.00744 [1]

Equilibrium amount of $C_2H_5CO_2H(aq)$ = 0.00256…… mol [1]
Equilibrium amount of $C_2H_5CO_2H(org)$ = 0.00744…… mol [1]

(iii)

$$K_c = \frac{0.007437 / 40/1000}{0.002562 / 50/1000} = 3.628 \approx 3.63$$

K_c = 3.63..... [2]

finding conc. – 1m, substituting the values into the K_c expression correctly – 1m

(f) Increases [1]

Solubility of propanoic acid in 2-methylpropane decreases [1] [because energy released when propanoic acid forms instantaneous dipole-induced dipole forces of attraction with 2-methylpropane is not really enough to overcome the hydrogen bond between the propanoic acid molecules]. So more **FA 1** is required to neutralise the propanoic acid that remains in the aqueous phase.

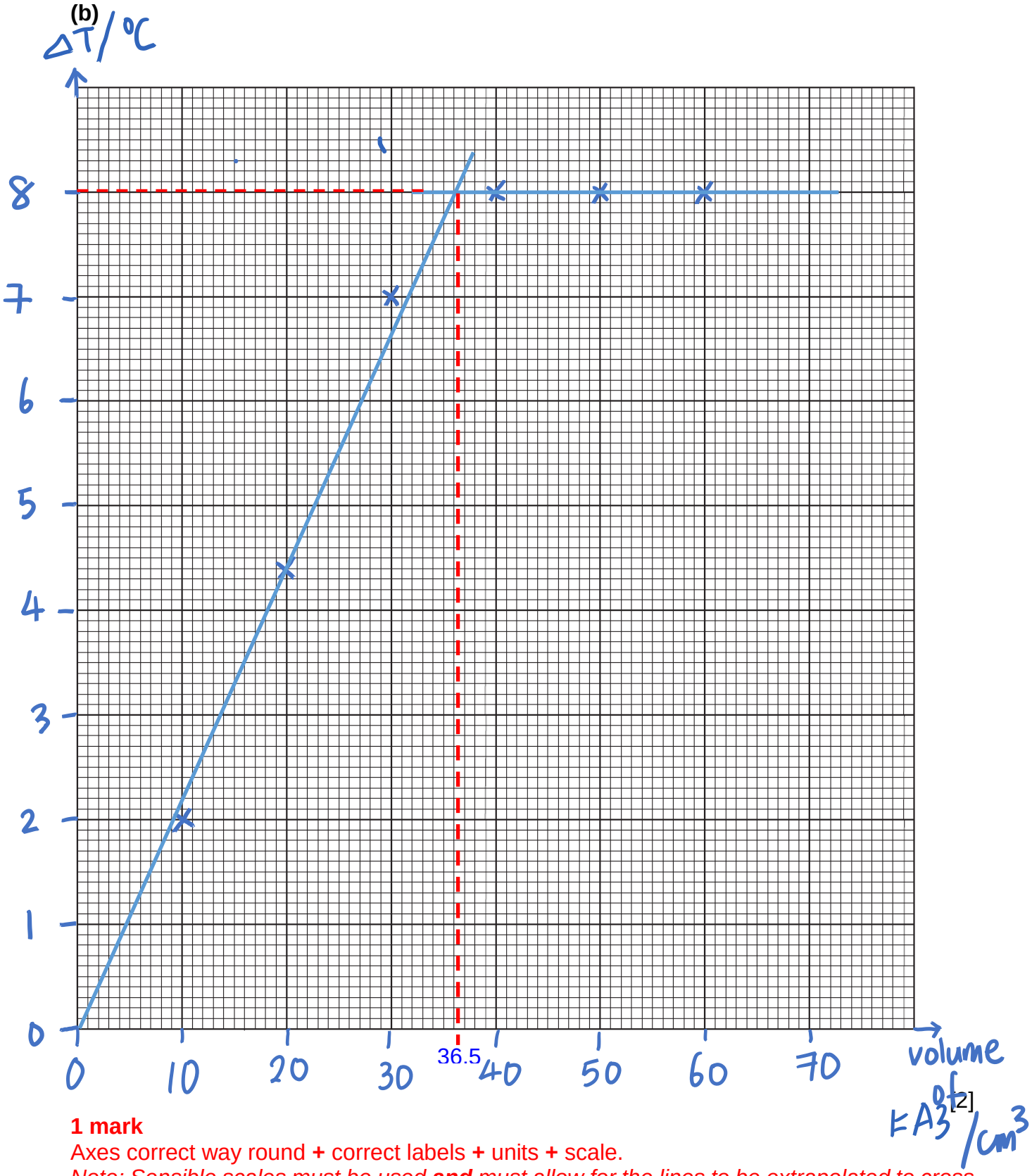
2(a) Results

Experiment	**1**	**2**	**3**	**4**	**5**	**6**
Volume of **FA 4** (or H_2SO_4) / cm^3	25	25	25	25	25	25
Volume of water (or H_2O) / cm^3	**65**	**45**	55	35	25	15
Volume of **FA 3** (or NaOH) / cm^3	**10**	**30**	20	40	50	60
Initial temperature of **FA 4** and water / °C	30.0	30.0	30.0	30.0	30.0	30.0
Initial temperature of **FA 3** (or NaOH) / °C	30.0	30.0	30.0	30.0	30.0	30.0
Average initial temperature / °C	30.0	30.0	30.0	30.0	30.0	30.0
Maximum temperature obtained / °C	32.0	37.0	34.4	38.0	38.0	38.0
ΔT / °C	2.0	7.0	4.4	8.0	8.0	8.0

[7]

1 mark: headers and units
1 mark: All temperature recorded to 1 decimal place and all volumes recorded to whole number or 1 decimal place
1 mark: volumes of water added is correct
1 mark: correctly calculate average initial temperature and ΔT for all expts to 1 decimal place.
1 mark: Selected four additional volumes of **FA 3** and the selected volumes must be sequential and well-spaced i.e. 5 cm^3 or more from any other volume.
1 mark: Student selects **one** **FA 3** volume **less than** 35 cm^3, except 0 cm^3 and 30 cm^3
1 mark: Student selects **three** **FA 3** volumes **more than** 35 cm^3 and **less than or equal** 60 cm^3

(b)



[2]

1 mark

Axes correct way round **+** correct labels **+** units **+** scale.

*Note: Sensible scales must be used **and** must allow for the lines to be extrapolated to cross each other. Awkward scales (e.g. 3:10) are not allowed. The plotted points must occupy at least half of the graph grid in both x and y directions.*

1 mark

Plotting – all points correctly plotted within ±½ small square.

(c) z, the volume of **FA 3** = 36.5 cm^3.....

maximum temperature change, ΔT_{max} = 8 ^oC.....

1 mark
Graph lines must be best-fit lines, drawn so as to best reflect the distribution of points **before** and **after** the equivalence point. The line **before** and **after** the equivalence point should be extrapolated until it **crosses.**
*Markers **must not** alter or adjust a poorly drawn student's line.*

1 mark for the followings:
- Correctly read V(**FA 3**) at ΔT_{max} and ΔT_{max} from graph

2 marks on Accuracy
Accuracy based on V(**FA 3**) at ΔT_{max} and on value of ΔT_{max}
If a student has incorrectly read either/both of the values of V(**FA 3**) and ΔT_{max}, the teacher will read the correct values from the student's graph and use these values in awarding accuracy marks. However, if the student's line is not best-fit, teacher will not re-draw the best-fit line and re-read V(**FA 3**) and ΔT_{max}.

Comparison of student's V(**FA 3**) at ΔT_{max} with teacher's **FA 3** at ΔT_{max}: if within 2 cm^3, award 1 mark, otherwise 0 mark

Comparison of student's ΔT_{max} with teacher's ΔT_{max}: if within or equal to 1 ^oC, award 1 mark, otherwise 0 mark

(d) **(i)** $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

$$n(NaOH) = \frac{36.5}{1000} \times 1.50$$
$$= 0.05475 \text{ mol}$$
$$n(H_2SO_4) = 0.05475 / 2$$
$$= 0.02737 \text{ mol}$$
$$[H_2SO_4] = \frac{0.02737}{25/1000}$$
$$= 1.095$$
$$\approx 1.10 \text{ mol dm}^{-3}$$

concentration of H_2SO_4 in the **FA 4** solution = 1.10 mol dm^{-3}..... [1]

(ii) $$\Delta H_1 = -\frac{100 \times 4.18 \times 10^{-3} \times 8}{0.02737}$$
$$= -122 \text{ kJ mol}^{-1}$$

ΔH_1 = – 122 kJ mol^{-1} ..... [2]

1 mark
Calculate $[H_2SO_4]$ correctly
1 mark
Calculate ΔH_1 correctly, including giving the correct sign
1 mark
Shows appropriate significant figures and units

(e) **(i)** Before the equivalence point, NaOH is the limiting reactant. The amount of water produced is equal to the amount of NaOH. As the total volume of the reaction mixture is kept constant (100 cm^3), the volume of NaOH (**FA 3**) is proportional to ΔT. As volume of NaOH increases, ΔT increases proportionally. [1]

$\Delta H = -\frac{mc\Delta T}{n(H_2O)} = -\frac{Vc\Delta T}{n(H_2O)}$, where V is the total volume of the solution.

(Assuming 1 cm^3 of solution ≡ 1 g.)

When NaOH is the limiting reagent,

$\Delta H = -\frac{Vc\Delta T}{n(H_2O)} = -\frac{Vc\Delta T}{n(NaOH)} = -\frac{Vc\Delta T}{[NaOH] \times \frac{V(NaOH)}{1000}}$

$\therefore V(NaOH) = -\frac{1000Vc\Delta T}{[NaOH] \times \Delta H}$

Since V, c, [NaOH] and ΔH are constants, V(NaOH) is proportional to ΔT.

(ii) After the equivalence point, H_2SO_4 is the limiting reactant. The amount of water produced is constant as volume of H_2SO_4(**FA 4**) is constant at 25 cm^3. As the total volume of the reaction mixture is kept constant (100 cm^3), no matter how much volume of NaOH increases, ΔT is constant/will not change. [1]

When H_2SO_4 is the limiting reagent,

$\Delta H = -\frac{Vc\Delta T}{n(H_2O)} = -\frac{Vc\Delta T}{2n(H_2SO_4)} = -\frac{Vc\Delta T}{2 \times [H_2SO_4] \times \frac{V(H_2SO_4)}{1000}}$

$\therefore V(H_2SO_4) = -\frac{1000Vc\Delta T}{2 \times [H_2SO_4] \times \Delta H}$

Since $V(H_2SO_4)$ is constant, ΔT will be constant.

3(a)

1. Weigh the mass of a clean, **dry** and empty 250 cm^3 conical flask on an electronic balance.
2. Using a clean and **dry** 250 cm^3 conical flask/beaker, weigh the mass of the 100 cm^3 of water on an electronic balance. **Or** Use a 50 cm^3 burette to measure 100.00 cm^3 of distilled water and transfer the water into a clean and **dry** 250 cm^3 conical flask/beaker.
3. Place the beaker in the tub containing the ice cubes and controlled the temperature in the tub using the thermometer, ensuring that the temperature is roughly maintained at 10 ^oC.
4. (Using a spatula, add a large spatula of) Add (solid) $Ca(OH)_2$ into the flask/beaker and **stir with a glass rod**. **OR**
   Using a dry, empty weighing bottle, weight accurately 5.00g of $Ca(OH)_2$. Add (solid) $Ca(OH)_2$ into the flask/beaker and **stir with a glass rod.**
   Continue to add more solid and stir, **until some $Ca(OH)_2$ remains undissolved** to ensure a saturated solution is obtained. **Allow the mixture to stand in the ice-bath for 30 minutes to establish equilibrium.**
5. Weigh the mass of the mixture obtained from step 4 **OR**
   Reweigh the weighing bottle with the residual $Ca(OH)_2$ to find out the mass of $Ca(OH)_2$ added to the beaker.
6. Weigh the mass of a piece of **dry** filter paper. Filter the mixture using the **dry** filter paper and a **dry** filter funnel into another **dry** 250 cm^3 conical flask/beaker.
7. **Dry the filter paper and residue under an IR lamp.** (After 10 minutes, **allow the filter** paper **to cool down** in a desiccator.)
8. Using an electronic balance, **weigh the residue with the filter paper**.
9. **Repeat the process of heating, cooling and weighing** (steps 7–8) until a **constant mass** is obtained.
10. The mass of calcium hydroxide in the saturated solution = mass of the mixture obtained from step 5 – mass of 100 cm^3 water – mass of undissolved $Ca(OH)_2$ in step 9 – mass of empty 250 cm^3 conical flask. **OR**
    mass of calcium hydroxide in the saturated solution = mass of $Ca(OH)_2$ in weighing bottle in step 4– mass of weighing bottle with the residual $Ca(OH)_2$ in step 5 – mass of undissolved $Ca(OH)_2$ in step 9
11. Using the following equation, the solubility of $Ca(OH)_2$ can be obtained.

    $$\text{Solubility} = \frac{\text{mass of solid (g)}}{\text{mass of 100 cm}^3\text{ of water}} \text{ or } \frac{\text{mass of solid (g)}}{\text{100 cm}^3\text{ of water} \times \rho_{H_2O}}$$ depending on whether the volume of the water or the mass of the water was measured.

2 marks for step 1, 2, 5, 6 (weigh the mass of a piece of filter paper), 10
1 mark for step 11
1 mark for step 3
2 marks for step 4
2 marks for 6 (filter the mixt., 7, 8, 9)

(b)

1. Using a **burette (measuring cylinder not accepted)**, measure **50.00 cm^3** of the 0.5 mol dm^{-3} sample of NaOH into a **100 cm^3 volumetric flask**.
2. **Top up to the mark with distilled water.**
3. Insert the stopper and **shake to obtain a homogenous solution**
4. This will give a solution of 0.25 mol dm^{-3} NaOH.
5. Repeat steps 1 to 3 using 70.00 cm^3 of 1.5 mol dm^{-3} sample of NaOH to obtain a solution of 1.05 mol dm^3 NaOH (accept other variations of concentration, as long as conc is within stated limit of qn)

(i) 1 mark for correct calculation of V(NaOH) to be diluted
Students are expected to prepare another 2 solutions of NaOH of the following concentrations: $[NaOH]_{diluted}$ < 0.5 mol dm^{-3} and 0.5 mol dm^{-3} < $[NaOH]_{diluted}$ < 1.5 mol dm^{-3}

Do NOT allow any preparation of concentrations that requires volumes of NaOH that cannot be measured accurately. E.g. a preparation of conc. 1.0 mol dm^{-3} is not accepted as V(1.5 mol dm^{-3} NaOH) required is 66.67 cm^3 which cannot be measured accurately.

(ii) 1 mark for Procedure
Correct apparatus used for measuring the V(NaOH) to be diluted and use of volumetric flask for dilution

4

	test	observations
(a)	Test the **FA 5** solution using Universal Indicator paper.	Obs 1. pH 2–4 Yellow universal indicator paper changes to orange
(b)	1. Using a measuring cylinder, transfer 10 cm^3 of **FA 5** to a clean boiling tube. 2. Using another measuring cylinder, measure out 10 cm^3 of **FA 6**. 3. Use a dropping pipette to transfer 1.0 cm^3 of **FA 6** from the measuring cylinder to the boiling tube. 4. Mix the contents of the boiling tube thoroughly. 5. Repeat points 3 and 4 until the measuring cylinder is empty. 6. Swirl and leave the mixture to stand for 5 minutes.	Obs 2. (slight) white ppt formed Obs 3. effervescence/bubbles but **not** 'gas evolved' Obs 4. gas evolved gives a white ppt with limewater Obs 5. green/grey-green/blue-green/grey-blue precipitate (indicates initial precipitate becomes darker) Obs 6. then turns brown
(c)(i)	Place about 2 cm depth of **FA 5** into a test-tube. Carefully add sodium hydroxide, dropwise with shaking, until no further changes are seen. Swirl and filter the mixture, collecting the filtrate in a test-tube. The filtrate is **FA 7** which should be put to one side for use in **(ii)**. Wash the residue thoroughly with deionised water. Discard the washings. The residue is **FA 8**. Retain the residue for use in **(iii)**.	Obs 7. white ppt formed (soluble in excess NaOH) Obs 8. then green/grey-green/blue-green/dirty green/light blue ppt formed Obs 9. insoluble in excess NaOH Obs 10. green residue/ppt then turns brown Obs 11. colourless/pale yellow filtrate
(ii)	To the filtrate, **FA 7** from **(c)(i)**, carefully add hydrochloric acid, dropwise *(do not shake the mixture while adding the **HCl**)*, until no further change is seen.	Obs 12. white ppt forms Obs 13. that dissolves in excess HCl
	Note: When aqueous potassium manganate(VII) is added in **(c)(iii)**, the endpoint is a permanent **pale** pink colour. Use the same dropping pipette and record the number of drops of aqueous potassium manganate(VII) you added to reach the endpoint.	

(iii)	Transfer **FA 8** into a clean test-tube. Carefully add hydrochloric acid, a few drops at a time with shaking, until no further changes are seen. Add aqueous potassium manganate(VII), dropwise with shaking, until the endpoint is reached.	Obs 14. solid dissolves in acid Obs 15. to form an orange/orange-brown/brown/yellow solution Obs 16. after equal or > 3 drops, it turns pink/endpoint is reached

Observation points

See the responses listed below. There are 16 observational points identified in **1(a)** to **(d)**. Record the total number of observational points awarded in the "Obs points" box at the end of question 4. Use the scaling grid below to determine the number of marks awarded. Write this number in the "marks" box at the end of question 1.

14 – 16 obs pts = **6**; 12 – 13 = **5**; 9 – 11 = **4**; 6 – 8 = **3**; 4 – 5 = **2**; 2 – 3 = **1**

(d) **A**, +2 and **B**, +3 [1]

(e) acidic [1] Al^{3+} [1]

(f)

- The acidic cation in **FA 5** (which is Al^{3+}) has high charge density, hence hydrolyse in water to produce acidic solution.
- Na_2CO_3 reacts with the acidic solution to produce CO_2.
- White ppt is $Al(OH)_3$, green ppt is $FeCO_3/Fe(OH)_2$
- (The white ppt appeared first as it has a lower Ksp.) Optional

3pts – 2m, 2pts – 1m

(g) $[Al(OH)_4]^-$ [1]

(h)

- precipitate forms due to removal of OH^- by HCl, causing the position of equilibrium of reaction **(1)** to shift to the left.
  $Al(OH)_3 + OH^- \rightleftharpoons [Al(OH)_4]^-$ ————(1) [1]
- precipitate dissolves due to <u>further</u> removal of OH^- by the <u>excess</u> HCl, causing the position of equilibrium of reaction **(2)** to shift to the left
  $Al^{3+} + 3OH^- \rightleftharpoons Al(OH)_3$ —(2)
  OR
  Precipitate dissolves due to <u>acid-base reaction</u> with the <u>excess</u> HCl [1]

(i) acid-base reaction [1]
$Fe(OH)_2(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + 2H_2O(l)$ [1] for balanced equation with state symbols
Accepts $Fe(OH)_3(s) + 3HCl(aq) \rightarrow FeCl_3 + 3H_2O(l)$

(j) hercynite formula = $FeAl_2O_4$ [1]