HWA CHONG INSTITUTION
2018 C2 H2 CHEMISTRY PRELIMINARY EXAM
SUGGESTED SOLUTIONS

Paper 4

1 (a) Tabulates initial and final burette readings and volume added in each of the tables.
(b) (i) Tables have correct headers and units. **[1]**
Mark is lost if any final and initial burette readings are inverted.

All the burette readings are recorded to the nearest 0.05 cm^3. **[1]**

Has at least two uncorrected titres (refers to student's computed titres) for end-point within 0.10 cm^3. **[1]**

(b) (ii) Student correctly obtains appropriate 'average' from any experiments with uncorrected end-point titre values within 0.10 cm^3. **[1]**
Mark is lost if the titres used are not identified either in the table (by, for example, a tick) or in a calculation or identified wrongly or no titre within 0.10 cm³. Mark is lost if there are arithmetic errors in the titration results table. Mark is lost if the candidate made an arithmetic error in the calculation of the mean titre.

Calculate the Supervisor's and the student's scaled mean titre values using the following expression:

$$\text{Scaled mean titre} = \frac{49.25 \times \text{mean titre}}{\text{volume of FA 1 diluted}}$$

Calculate the difference between the student's scaled mean titre value and the Supervisor's scaled mean titre value.

Give 3 marks if this difference is ≤ 0.2
Give 2 marks if this difference is > 0.2 but ≤ 0.3
Give 1 mark if this difference is > 0.3 but ≤ 0.5
Give 0 marks if this difference is > 0.5 **[3]**

(c) (i) nO_2 produced by $1cm^3$ of $H_2O_2 = 0.75 \div 24000$
nH_2O_2 in $1\ cm^3 = 0.75 \div 24000 \times 2 = 6.25 \times 10^{-5}$ mol **[1]**

$[H_2O_2] = \text{ans} \div 1/1000 = 0.0625\ \text{mol dm}^{-3}$ **[1]**

(ii) nH_2O_2 in $25.0\ cm^3 = 0.0625 \times 25/1000 = 1.56 \times 10^{-3}$ mol $= nI_2$

$nS_2O_3^{2-} = 1.56 \times 10^{-3} \times 2 = 3.125 \times 10^{-3}$ mol
$[S_2O_3^{2-}] = 3.125 \times 10^{-3} \div 31.50/1000 = 0.0992\ \text{mol dm}^{-3}$ **[1]**

(iii)
1. $nS_2O_3^{2-} = 0.0992$(or ecf) × (titre in (b) ÷ 1000)
2. $nKIO_3$ = ANS ÷ 6
3. $[KIO_3]$ in **FA 5** = ANS ÷ 25/1000

Award 1 mark for the correct use of the mole ratio in step 2 and 1 mark for steps 1 and 3 if both correct (allow ecf for step 3 if step 2 is wrong). **[2]**

(iv) [KIO_3] in **FA 1** = ANS(c(iii)) x (250 ÷ volume of **FA1** used) **[1]**

(d) The transition metal would cause the hydrogen peroxide to decompose leading to less hydrogen peroxide reacting with the iodide. **[1]**
Less iodine would be produced, so volume of sodium thiosulfate used will be lower than expected.

Hence, it would give the false impression that the concentration of thiosulfate is higher than what it actually is. So the concentration of potassium iodate calculated will be higher than expected. **[1]**

2 (a) Axes correct way round **+** correct labels **+** units **+** scale (must be chosen so that plotted points occupy at least half the graph grid in both *x* and *y* directions).
Sensible scales must be chosen. Awkward scales (e.g. 3:10) are not allowed. **[1]**

Plotting – <u>all points</u> within ± ½ small square. Check all points and put ticks if correct. **[1]**

Draws <u>best fit straight line</u> through plotted points. **[1]**

(c) **From 2(c)**
Correctly extrapolates ΔT for M g of potassium iodide, ΔT_M, from plotted graph at the point

$$M = \frac{\text{mass } \textbf{FA 6} \text{ dissolved}}{2}$$

Or correctly calculates using ΔT per gram of potassium iodide by finding gradient

Working on the graph, e.g. dotted lines or otherwise, must be shown. **[1]**

(b) Record mass of empty weighing bottle, mass of weighing bottle + **FA 6**, mass of weighing bottle + residual solid, mass of **FA 6** used.
and
Table has correct headers and units. **[1]**

Follows instructions – weighs 5.95 g to 6.04 g of **FA 6**
*Final mass of **FA 6** dissolved may be out of range, but initially weighed mass must be within range.* **[1]**

Records initial water temperature and final temperature of solution, **and**
Table has correct headers and units. **[1]**

All temperature recorded and calculated ΔT_x value are to 0.5 ^{o}C, **and** all mass recorded calculated mass of FA 6 used are to 2 d.p. **[1]**

Correctly calculates ΔT_x. **[1]**

(c) **Method 1:**

Correctly calculates change in temperature due to lithium chloride,
$\Delta T_x + \Delta T_M = \Delta T_{LiCl}$ **[1]**

Correctly calculates the value of change in temperature of water per gram of lithium chloride =

$\frac{\Delta T_{LiCl}}{M}$ where M = mass of **FA 6** dissolved ÷ 2

[1]

Method 2:

Calculates the value of change in temperature of water per gram of FA 6,

$\frac{\Delta T_x}{\text{mass of FA 6 dissolved, m}}$

Since **FA 6** contains equal masses of lithium chloride and potassium iodide, ΔT_x/m gives the total temperature change for 0.5 g of lithium chloride and 0.5 g of potassium iodide. Therefore, to obtain the total temperature change for 1 g of each compound, ΔT_x/m needs to be multiplied by two.

The temperature change per gram of lithium chloride
= $2(\Delta T_x/m) - (-\Delta T$ per gram of potassium iodide)
[1 mark for addition; 1 mark for correct computation]

3 (a) Magnesium **[1]**

(b)

$$\begin{tikzcd}
Mg(s) + Cu(s) + 2HCl\,(aq) \arrow[rr, "\Delta H_r"] \arrow[dr, "\Delta H_2"'] & & CuCl_2(aq) + H_2(g) + Mg(s) \arrow[dl, "\Delta H_1"] \\
& MgCl_2(aq) + Cu(s) + H_2(g) &
\end{tikzcd}$$

OR

$$\begin{tikzcd}
MgCl_2(aq) + Cu(s) + 2HCl\,(aq) \arrow[rr, "\Delta H_r"'] & & CuCl_2(aq) + H_2(g) + MgCl_2(aq) \\
& 2HCl(aq) + CuCl_2(aq) + Mg(s) \arrow[ul, "\Delta H_1"] \arrow[ur, "\Delta H_2"'] &
\end{tikzcd}$$

Correct energy cycle **[1]**

From correct energy cycle, $\Delta H_r = \Delta H_2 - \Delta H_1$ **[1]**

(c) **M1**: [Justification of quantities]
Either choose a suitable mass of metal powder or suitable volume of HC*l*, and show calculations to obtain the minimum quantity of the other reagent needed, and state chosen quantities of reagents.

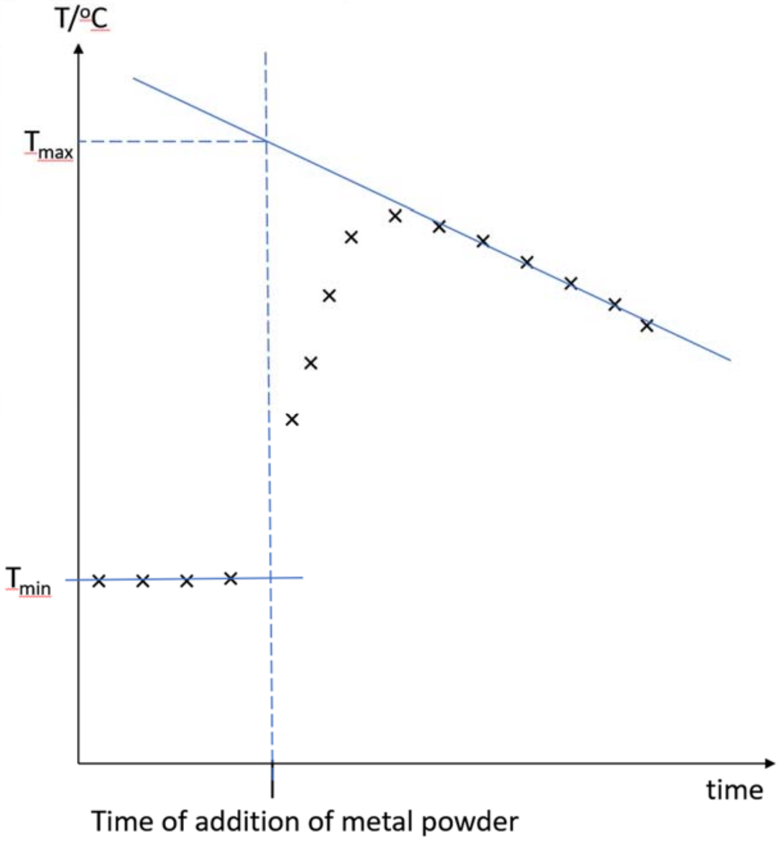
[1]

M2: [Data to be collected]
CORRECT temperature taking procedure. Describes taking temperature readings over time from before addition of metal until at least 6 extra readings after maximum temperature is reached.

[1]

M3: [Sketch of graph]
Sketch of cooling curve and show correctly how to extrapolate min/max or ΔT temperatures from sketch. Axes must be temperature against time.

[1]



M4 & M5: [Details in procedure] – dot-tick marking, up to 2m, no half marks

- <u>weighing balance</u> for weighing metal powder
- <u>suitable apparatus (burette/pipette/measuring cylinder)</u> for measuring volume of $HCl(aq)$
- <u>thermometer</u> for measuring temperature
- measures taken to ensure accuracy of expt / minimise hazards, e.g. stirring/ use lid/ double styrofoam cup / beaker for support

[2]

M6: [Processing of results]
Correct sample calculation for obtaining ΔH_2. Answer may differ depending on whether metal or acid chosen as limiting reactant, and students' chosen metal.

$$Q = 1.0 \times V_{HCl} \times 4.18 \times (T_{max} - T_{min}) = a \text{ J}$$

[if metal is limiting]

$$\Delta H_2 = -\frac{a}{m_M \div A_r} \div 1000 \text{ kJ mol}^{-1}$$

[if acid is limiting]

$$\Delta H_2 = -\frac{a}{V_{HCl} \div 1000 \times 1.0} \times 2 \div 1000 \text{ kJ mol}^{-1}$$

[1]

Sample procedure:

Amount of Mg in 1 g of magnesium = 1 ÷ 24.3 = 0.0412 mol
Volume of HCl required for complete reaction = (0.0412 × 2) × 1.0 × 1000 = 82.3 cm^3
Volume of HCl to be used = 100 cm^3 (excess)

Using a weighing balance and weighing bottle, weigh accurately about 1.0 g of Mg metal.
Using a measuring cylinder, transfer 100 cm^3 of $HCl(aq)$ into a Styrofoam cup.
Place the Styrofoam cup into another Styrofoam cup and place both into a 250 cm^3 beaker for stability.
Cover with a lid and insert a thermometer through the lid.
Record the temperature of the solution, and start the stopwatch.
Take the temperature every 30 seconds until 2.5 min.
At 3 min, add the magnesium from the weighing bottle to the $HCl(aq)$ in the Styrofoam cup.
From 3.5 min, take temperature readings every 30 seconds until there are at least 6 readings after the temperature starts decreasing linearly.
Reweigh the weighing bottle to obtain the mass of magnesium used, $\mathbf{m_M}$.
Plot a graph of temperature /°C against time /min.

(graph sketch)

$Q = 1.0 \times 100 \times 4.18 \times (T_{max} - T_{min}) = \mathbf{a}$ J

$$\Delta H_2 = -\frac{\mathbf{a}}{\mathbf{m_M}/24.3} \div 1000 \text{ kJ mol}^{-1}$$

(d) $H_2(g)$ / metal powder is flammable. Avoid naked flames. **[1]**

4 (a)
1. White solid ($K_2C_2O_4$) dissolves
2. Effervescence/bubbles after each addition (REJECT: gas evolved)
3. Gas gives white ppt with limewater. Gas is CO_2.
4. Temperature of mixture increases
5. Black/grey residue obtained.
6. Colorless / pale yellow filtrate.

(b) (i)
7. Filtrate from **(a)** forms light brown ppts with both $NaOH(aq)$ and $NH_3(aq)$.
8. **FA 9** forms off-white/ very light brown ppts with both $NaOH(aq)$ and $NH_3(aq)$ (Note: the colour of these ppts must be lighter than those in point 7.)
9. **All** 4 ppts insoluble in excess.
10. Ppts darken on standing (mentioned at least twice)

(c) (i)
11. Yellow bromine water decolourised (test 1).
12. Purple $KMnO_4$ decolourises (test 2).
13. Colourless solution turns progressively darker brown (test 2).
14. Solution turns green (test 3).
15. Colour deepens/turns darker green as more drops added (test 2).

Observation points
14 – 15 = 7 marks
12 – 13 = 6 marks
10 – 11 = 5 marks
8 – 9 = 4 marks
6 – 7 = 3 marks
4 – 5 = 2 marks
2 – 3 = 1 mark
0 – 1 = 0 mark **[7]**

(a) **(i)** Either a convincing explanation based on the cessation of effervescence/bubbles (on addition of more **FA 7**)
Or
a convincing explanation based on the temperature starting to fall on addition of more **FA 7**) **[1]**

(ii) Conclusion: the reaction is exothermic
Evidence: the temperature increased as more **FA 7** was added (even without further heating) **[1]**

Conclusion: redox reaction
Evidence: effervescence of CO_2 shows that ethanedioate ions are oxidised (while **FA 7** is reduced). **[1]**

(b) **(i)** Procedure should describe the <u>addition of a small volume/ dropwise addition</u>, and the addition of an <u>excess</u>, of NaOH(aq) and NH_3(aq), both with shaking, to separate samples. **[1]**

(ii) Ion present is Mn^{2+}.

The darker colour of the precipitates is due to incomplete reduction of **FA 7**/ some Mn^{3+} present. **[1]**

(c) **(ii)** Molecular formula is C_5H_8. **[1]**

- Br_2(aq) decolourised so C=C present
- Cold alkaline $KMnO_4$ oxidised alkene to a diol <u>OR</u> $C_5H_{10}O_2 - 2 \times OH = C_5H_8$

[1]

(iii) Clear structure of cyclopentene **[1]**

(d) Tests include warming with Fehling's solution; warming with potassium dichromate(VI) $K_2Cr_2O_7$ in the presence of dilute H_2SO_4; adding neutral iron(III) chloride $FeCl_3$; warming with Tollens' reagent.

Selects reagents and conditions that would unambiguously identify all 3 compounds with positive tests for each [2] **or**
Selects reagents and conditions that would unambiguously identify 2 compounds with positive tests for each [1]

[2]

Outlines a logical sequence/order of testing; doesn't test compounds already identified.

[1]

Clearly and unambiguously links the testing sequence with the compounds to be identified.

[1]

An example of the plan is as follow:

All tests should be carried out in a separate test-tubes, and fresh samples of the organic compound should be used each time.

1. To 1 cm^3 of each organic compound, add 1 cm^3 of Tollens' reagent and warm in a water bath. The test-tubes showing the formation of silver mirror would be either 3-hydroxybenzaldehyde or 2-phenylethanal. The test-tube that does not give the silver mirror would contain phenol.

2. To 1 cm^3 of the compound that does not give a positive test in step 1, add a few drops of neutral $FeCl_3$. The formation of violet colouration would confirm the identity of phenol.

3. To 1 cm^3 of separate samples of the organic compounds that give silver mirror in step 1, add 1 cm^3 of Fehling's solution and heat in a water bath. The test-tube that shows the formation of brick-red ppt would contain 2-phenylethanal while the one with no brick-red ppt would contain 3-hydroxybenzaldehyde.