

GENERAL COMMENTS:

The overall performance profile on this examination was consistent with previous years. Comments on specific questions are included with the answers/solutions in the Section A and B information sections, however, some general comments are appropriate.

Section A included a significant number of 'calculation' questions, some of which may have seemed different to some students. In Question 4 the calculation of a relative atomic mass from the supplied data may have been unfamiliar, but the overall performance on this question was stronger than on Questions 5, 13 and 17, all of which were associated with pH. This suggests that pH is an area which continues to prove challenging, especially when the question involves more than simple conversion from the $[H^+]$.

Performance on equilibrium questions in Section A – notably Questions 12, 14 and 16 – may have been expected to be better overall. At times it seems that numbers of students struggle with question interpretation or perhaps do not read the question enough times prior to deciding on the correct response. Question 14, in particular, is a style of equilibrium question that makes an occasional appearance, but which inevitably seems to be misinterpreted. Students may benefit from underlining or highlighting key terms/data in the stem of a question. Whilst students would be expected to be exposed to a wide variety of questions during their examination preparation, they may benefit from enhanced emphasis on appropriate techniques in handling multiple-choice questions. Perhaps there are situations where, because the answer is provided, there is a reluctance to work towards identifying the correct answer. Questions 8, 9 and 10 are good examples of questions where the correct answer could not be identified without a significant amount of work.

In Section B, misinterpretation of questions is inevitably more obvious than in Section A. In Question 1 many students struggled to identify the inherent differences in (b) i, ii and iii, which focussed on the qualitative explanation of factors that affect the rate of reaction. Questions 2 and 3 had a different 'feel' about them with so much focus on systematic names, structural formulae and semi-structural formulae. Errors in extracting monomer structures from representations of polymer chains suggest that many students are not comfortable with working back from the polymer structure. The question interpretation focus arises again when we consider Question 3. The responses of some students suggest that the significance of the information in the first three lines of the question was not fully taken on board.

Answers to Question 4 in Section B suggested that difficulties with units, evident on the 2003 examination, were still prevalent. A surprising number of students treated 0.90 mg L^{-1} as if it was 0.90 mol L^{-1} . Many students seem to find dealing with mg, and to some extent kg, difficult. It is as if it is outside their stoichiometry comfort zone. On the issue of taking on board information in a question, it was evident that the first three lines of part (b) did not provide the insight into answering b (ii) that might have been expected.

Question 5 approached sulfuric acid chemistry in a slightly different manner than previously, but the fundamentals were still being tested. Question 6 seemed to be either done well, or not done at all.

Students are encouraged to attempt as many examination type questions as possible in their examination preparation. Whilst solutions and answers to questions on past and practice examinations are very helpful, discussion focussed on the **interpretation** of these questions will also be of benefit.

SPECIFIC INFORMATION

Section A – Multiple Choice

This table indicates the approximate percentage of students choosing each distractor. The correct answer is the shaded alternative.

Question	A	B	C	D	Selected comments
1	5	7	11	77	Atomic absorption spectroscopy is commonly used for determining the amount of metal ion present in a solution/sample.
2	76	10	4	10	Ethanol and the other components of petrol are volatile and most readily separated and identified by gas chromatography. <i>The popularity of alternative D was surprising given the association of AAS with metals.</i>
3	10	9	68	13	In paper chromatography the species more strongly attracted to the stationary phase moves the shorter distance up the paper and so has the lower R_f value. In HPLC the species more strongly attracted to the stationary phase remains in the column longer and has the higher R_f .
4.	15	17	58	7	$m(X) = 3.27 \text{ g}$ $n(X) = 3.27 / M(X)$ $m(O) = 4.07 - 3.27 = 0.80 \text{ g}$ $n(O) = 0.80 / 16.0 = 0.050 \text{ mol}$ Since $n(X) = n(O) \rightarrow 3.27 / M(X) = 0.050$ $3.27 = 0.050 \times M(X)$ $M(X) = 3.27 / 0.050$ $= 65.4 \text{ g mol}^{-1}$ $A_r(X) = 65.4$ <i>Over 3 per cent of students did not record a response for this question. This is unusual for a multiple-choice question.</i>
5.	6	43	47	3	pH of pure water at $25^\circ\text{C} = 7$ Since HCl(aq) is a strong acid, $10^{-2} \text{ mol HCl} \rightarrow 10^{-2} \text{ mol H}^+$ Assuming the addition of HCl does not change the total volume $[\text{H}^+] = n(\text{H}^+) / V = 10^{-2} / 1.00 = 10^{-2} \text{ M}$ $[\text{H}^+] = 10^{-2} \text{ M} \rightarrow pH = 2$ So pH has decreased from 7 to 2, i.e. by 5 <i>The popularity of alternative B suggests that many students did not read the question as carefully as would be hoped. At this level students should be aware that the pH of pure water at 25°C is 7</i>
6	8	71	11	10	$\overset{+4}{\text{Mn}}\overset{-2}{\text{O}_2}(\text{s}) + 4\overset{+1}{\text{H}}\overset{-1}{\text{Cl}}(\text{aq}) \rightarrow \overset{0}{\text{Cl}_2}(\text{g}) + 2\overset{+1}{\text{H}}\overset{-2}{\text{O}}(\text{l}) + \overset{+2}{\text{Mn}}\overset{-1}{\text{Cl}_2}(\text{aq})$ Oxidation number of Mn decreases from +4 to +2 Oxidation number of Cl increases from -1 to 0
7	4	25	58	11	Since all gases are measured at the same temperature and pressure, the volumes of C_xH_y , CO_2 and H_2O are in the same ratio as the mole ratio. $\text{C}_x\text{H}_y \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ $2 \text{ L} \quad 8 \text{ L} \quad 10 \text{ L}$ $2 \text{ mol} \quad 8 \text{ mol} \quad 10 \text{ mol}$ $1 \text{ mol} \quad 4 \text{ mol} \quad 5 \text{ mol}$ So 1 mol $\text{C}_x\text{H}_y \rightarrow 4 \text{ mol CO}_2$ (4 mol C) and 5 mol H_2O (10 mol H) Molecular formula is C_4H_{10} <i>The popularity of B was surprising. The equation for the combustion of ethene $\text{C}_2\text{H}_4(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{g})$ does not suggest a 4 : 5 volume ratio of products. Perhaps student familiarity with ethene was an overriding factor.</i>

Question	A	B	C	D	Selected comments
8	10	14	64	11	$m(\text{NH}_4\text{NO}_3) = (80/100) \times 1000 \text{ g} = 800 \text{ g}$ $n(\text{NH}_4\text{NO}_3) = 800 / 80.0 = 10.0 \text{ mol}$ $n(\text{N}) = 2 \times n(\text{NH}_4\text{NO}_3) = 20.0 \text{ mol}$ $m(\text{N}) = n(\text{N}) \times M(\text{N})$ $= 20.0 \text{ mol} \times 14.0 \text{ g mol}^{-1}$ $= \mathbf{280 \text{ g}}$ <p>The 25 per cent of students who chose B and D effectively overlooked the 80 % data and were considering the mass of nitrogen in 1.0 kg of ammonium nitrate. This again emphasises the need for students to read the question carefully and perhaps underline or highlight key data before attempting the question.</p>
9	23	9	63	4	$n(\text{MnO}_4^-) \text{ reacting} = n(\text{KMnO}_4) = c(\text{KMnO}_4) \times V(\text{KMnO}_4)$ $= 0.0240 \times 15.60 \times 10^{-3}$ $= 3.74 \times 10^{-4} \text{ mol}$ $n(\text{Fe}^{2+}) \text{ reacting} = 5 \times n(\text{MnO}_4^-) = 5 \times 3.74 \times 10^{-4}$ $= 1.87 \times 10^{-3} \text{ mol}$ $c(\text{FeSO}_4) = c(\text{Fe}^{2+}) = n(\text{Fe}^{2+}) / V(\text{FeSO}_4)$ $= 1.87 \times 10^{-3} / 20.00 \times 10^{-3}$ $= \mathbf{0.0936 \text{ M}}$ <p>The popularity of alternative A reflects a form of blind adherence to $c_1V_1 = c_2V_2$ without considering the information supplied by the equation. This was unfortunate because it was a relatively straightforward question.</p>
10	55	13	25	5	$\text{HCl(aq)} + \text{NaOH(aq)} \rightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}$ $n(\text{HCl}) = c(\text{HCl})V(\text{HCl}) = 0.100 \times 25.00 \times 10^{-3} = 2.50 \times 10^{-3} \text{ mol}$ $n(\text{NaOH}) = c(\text{NaOH})V(\text{NaOH}) = 0.180 \times 25.00 \times 10^{-3} = 4.50 \times 10^{-3} \text{ mol}$ $n(\text{NaOH}) \text{ reacting} = n(\text{HCl}) = 2.50 \times 10^{-3} \text{ mol}$ $n(\text{NaOH}) \text{ remaining} = 4.50 \times 10^{-3} - 2.50 \times 10^{-3} = 2.00 \times 10^{-3} \text{ mol}$ $[\text{OH}^-] \text{ remaining} = n(\text{OH}^-) \text{ remaining} / V(\text{mixture})$ $= 2.00 \times 10^{-3} / 50.00 \times 10^{-3}$ $= \mathbf{0.0400 \text{ M}}$ <p>The students who chose alternative C seemingly divided the $n(\text{OH}^-)$ by 0.025, i.e. the original volume of the NaOH(aq), rather than the total volume of the mixture in which the OH^- was in excess.</p>
11	15	14	5	65	<p>When sulfuric acid acts as an oxidant it causes oxidation and is itself reduced. Consequently the oxidation number of S must decrease from +6.</p> <p>Oxidation numbers of sulfur in the alternatives.</p> <p>$\text{S}(0)$; $\text{H}_2\text{S} - \text{H}(+1)_2\text{S}(-2)$; $\text{SO}_2 - \text{S}(+4)\text{O}(-2)_2$; $\text{H}_2\text{SO}_4 - \text{H}(+1)_2\text{S}(+6)_2\text{O}(-2)_7$ Hence $\text{H}_2\text{S}_2\text{O}_7$ could not be a product.</p> <p>In conjunction with Q6, the performance on this question suggests that many students struggled with the application of oxidation numbers.</p>
12	19	43	8	30	<p>The sleepiness of the traffic warden is consistent with the behaviour of the equilibrium $\text{HbO}_2 + \text{CO(g)} \rightleftharpoons \text{HbCO} + \text{O}_2(\text{g})$ which, because of the greater affinity of CO for haemoglobin, has a high equilibrium constant.</p> <p>The choice of D suggests lack of recognition of 'the effect of carbon monoxide on the oxygen carrying capacity of haemoglobin'.</p> <p>Perhaps some students took the words 'this information' too literally and did not apply their knowledge of the effects of CO. Certainly they could be expected to know that 'several parts per million of CO' has a significant impact on the equilibrium.</p>

Question	A	B	C	D	Selected comments
13	41	17	22	20	<p>The reaction $H^+(aq) + OH^-(aq) \rightarrow H_2O$ is exothermic. So the equilibrium $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$ is endothermic At $25^\circ C$; $K_w = 10^{-14}$, $pH = 7$ At $80^\circ C$ the position of equilibrium will lie further to the right, so $[H^+]$ and $[OH^-]$ will be greater. Hence $K_w = \{[H^+][OH^-]\}$ will be $> 10^{-14}$ and $pH = \{-\log_{10}[H^+]\}$ will be < 7 <i>The key to successfully answering this question was correctly identifying the direction of the equilibrium shift as the temperature of water increases from $20^\circ C$ to $80^\circ C$. The popularity of alternatives C and D suggest that over 40 % of students struggled to do this. Many, perhaps, did not realise the significance of the exothermic nature of the reaction between $H^+(aq)$ and $OH^-(aq)$. The fact that pH decreases as $[H^+]$ increases and vice versa continues to prove challenging in contexts such as that provided by this question.</i></p>
14	22	24	47	5	<p>The addition of 100 mL of water to 100 mL of 0.10 M NaOCl doubles the volume and instantaneously halves the concentrations of $OCl^-(aq)$, $HOCl(aq)$ and $OH^-(aq)$. This halves the value of the concentration fraction, i.e. $[HOCl][OH^-] / [OCl^-]$, so the value of the concentration fraction becomes less than K_c. To restore equilibrium the concentration fraction must increase so the forward reaction is favoured. So the addition of water also pushes the equilibrium $OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$ to the right. Whilst this shift in equilibrium position increases the $n(HOCl)$ and $n(OH^-)$ the increase is not enough to fully compensate for the impact of the volume increase on the $[HOCl]$ and $[OH^-]$. The overall effect of the addition of 100 mL of pure water is that the $[HOCl]$ decreases and $[OH^-]$ decreases. The decrease in $[OH^-]$ causes an increase in $[H^+]$ and the pH to decrease. <i>The impact of volume increases on aqueous solution equilibrium systems continues to prove challenging for most students. The impact is emphasised in an arbitrary concentration-time graph for the equilibrium.</i></p> <p>The concentrations of $HOCl$ and OCl^- when equilibrium is reached after the addition of water are less than the equilibrium concentrations prior to the addition of water, even though the amounts of $HOCl$ and OCl^- have increased.</p>
15	13	15	2	69	$K_1 = \frac{[HOCl][OH^-]}{[OCl^-]}$ $K_2 = \frac{[HOCl]^2[OH^-]^2}{[OCl^-]^2}$ $= \frac{([HOCl][OH^-])^2}{[OCl^-]^2}$ $= K_1^2$ <p><i>Manipulation of equilibrium constants has now appeared on the last three Unit 3 examinations. The performance of students continues to improve.</i></p>

Question	A	B	C	D	Selected comments
16	5	59	31	4	<p>An increase in the $[\text{Cl}_2]$ results from the position of equilibrium moving to the right. Consider the alternatives</p> <p>A. Adding NaCl, increases $[\text{Cl}^-]$ and position of equilibrium moves right.</p> <p>B. Adding NaOH, reduces $[\text{H}^+]$ – as it reacts with OH^- – so the position of equilibrium moves left.</p> <p>C. Adding $\text{H}_2\text{SO}_4(\text{aq})$, increases $[\text{H}^+]$ and position of equilibrium moves right.</p> <p>D. Adding HOCl pushes the position of equilibrium to the right.</p> <p>So the addition of NaOH will not raise the $[\text{Cl}_2]$.</p> <p><i>The popularity of alternative C raises some questions. Was it a case of 'misreading' the question, despite the emphasis on 'not', and familiarity with H_2SO_4?</i></p> <p><i>The implication that a significant number of students decided that the addition of H_2SO_4 would not push the equilibrium to the right but the addition of NaOH would do so suggests uncertainty in dealing with changes imposed on equilibrium systems.</i></p>
17	22	49	16	12	<p>$\text{HF}(\text{aq}) \rightleftharpoons \text{H}^+(\text{aq}) + \text{F}^-(\text{aq})$</p> <p>$K_a = \frac{[\text{H}^+][\text{F}^-]}{[\text{HF}]}$</p> <p>Since HF is a weak acid $[\text{H}^+]_e = [\text{F}^-]_e$ and $[\text{HF}]_e = 0.10$</p> <p>$6.8 \times 10^{-4} = \frac{[\text{H}^+]^2}{0.10} \rightarrow [\text{H}^+]^2 = 0.10 \times 6.8 \times 10^{-4}$</p> <p>$[\text{H}^+] = \sqrt{(6.8 \times 10^{-5})}$</p> <p>$= 8.2 \times 10^{-3}$</p> <p>pH $= -\log_{10}(8.2 \times 10^{-3})$</p> <p>$= 2.1$</p> <p><i>This is a relatively common type of K_a question. It is an area where students may benefit from more practice.</i></p>
18	66	7	19	6	<p>Alternatives B, C and D all refer to factors that increase the rate of reaction, namely increase in concentration, increase in temperature and increase in surface area.</p> <p><i>The popularity of alternative C was perhaps another instance of students not fully taking on board the emphasis on 'not' in the question.</i></p>
19	2	77	8	12	<p>A catalyst increases the rate of a reaction by lowering the activation energy, and hence increasing the number of collisions with energy greater than the activation energy, i.e. fruitful or successful collisions. It provides an alternative reaction pathway.</p>
20	19	15	16	50	<p>According to the energy profile for the reaction</p> <p>$2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{NOCl}(\text{g})$</p> <p>the activation energy for the reaction</p> <p>$2\text{NOCl}(\text{g}) \rightarrow 2\text{NO}(\text{g}) + \text{Cl}_2(\text{g})$</p> <p>is $62 - (-38) = 100 \text{ kJ mol}^{-1}$.</p> <div style="display: flex; align-items: center;"> </div> <p><i>Overall performance on this question suggests that students may benefit from quickly sketching an energy profile as a means of arriving at the correct answer.</i></p>

Section B – Short Answers

Question 1. (7)

(a)

Marks	0	1	Average
%	18	82	0.81

$$\begin{aligned}
 1. \% \text{ Mg} &= M(\text{Mg}) / M(\text{MgCO}_3) \times 100 \\
 &= (24.3 / 84.3) \times 100 \\
 &= 28.8 \%
 \end{aligned}$$

NB if expressed to 2 significant figures the answer must be 29

It was expected that students would use relative atomic mass data as provided on the data sheet.

(b) i.

Marks	0	1	Average
%	42	58	0.58

1. Exothermic. The temperature increase – final temperature higher than the initial temperature – in each experiment shows that energy is released as reaction proceeds.

(b) ii.

Marks	0	1	Average
%	66	34	0.33

1. Increased temperature increases the number of collisions with energy greater than the activation energy* / fruitful collisions / collisions that lead to reaction / energetic collisions / successful collisions.

Some reference to the quality or nature of the collisions was required.

(b) iii.

Marks	0	1	Average
%	65	35	0.34

1. Increased amount of MgCO_3 provides a greater surface area* for reaction.

(b) iv.

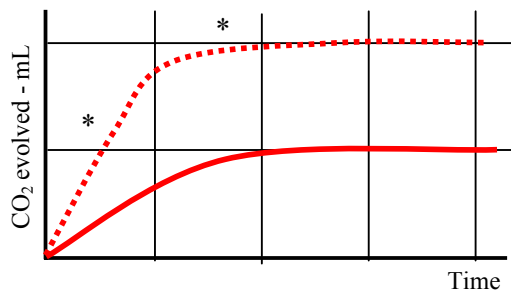
Marks	0	1	Average
%	36	64	0.64

1. Higher $c(\text{HCl})$, and hence higher $c(\text{H}^+)$, means more frequent collisions between $\text{H}^+(\text{aq})$ and MgCO_3^* .

(b) v.

Marks	0	1	2	Average
%	6	26	68	1.61

2.



*the two marks are for showing (for experiment 3)
- a higher gradient, even a moderately small increase
- the graph levelling on (or very close to) twice the volume of CO_2 evolved.*

A large number of students identified the reaction between MgCO_3 and HCl as endothermic. This was perhaps due to misinterpretation of the data, seeing the temperature increase as the cause of the reaction rather than the effect. Explanation of changes that affect the rate of a reaction proved challenging for many students, with quite a number giving the same response for all three parts of the question. In part (ii) many presumed that mention of increased kinetic energy was sufficient explanation, but indication of the impact of the temperature increase on the nature or outcome of the collisions between reacting particles was expected. In part (iii) the significance of the MgCO_3 being a solid and present in small lumps – hence the surface area factor – was overlooked more often than it was identified.

The graph in part (v) was generally well handled.

Overall Question 1(b) indicated that 'qualitative explanations of changes that increase the rate of reaction' is an area which students find challenging.

Question 2. (10)

(a) i.

Marks	0	1	Average
%	27	73	0.72

1. 2-propanol or propan-2-ol

(a) ii.

Marks	0	1	Average
%	21	79	0.79

1. methanoic acid

(a) iii.

Marks	0	1	Average
%	25	75	0.75

1. 2-chlorobutane

(a) iv.

Marks	0	1	Average
%	48	52	0.51

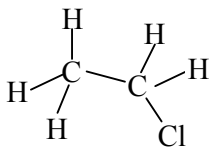
1. ethyl propanoate

This part of the question was generally well handled with part (iv) – naming the ester proving the most challenging.

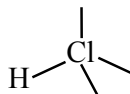
(b)

Marks	0	1	2	Average
%	16	31	52	1.36

2.



or $\text{CH}_3\text{CH}_2\text{Cl}$;



or HCl or $\text{H} - \text{Cl}$

$\text{C}_2\text{H}_5\text{Cl}$ was not acceptable as a structural formula.

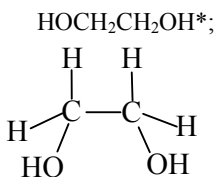
CH_3CHCl_2 , $\text{CH}_2\text{ClCH}_2\text{Cl}$ or similar chlorosubstituted ethanes were accepted instead of $\text{CH}_3\text{CH}_2\text{Cl}$.

Just over 50 per cent of students obtained both marks for this part of the question. However, well over 80 per cent obtained at least one mark. The most common source of one mark was HCl with an incorrect chloroethane or a correct chloroethane but with H_2 as the other product.

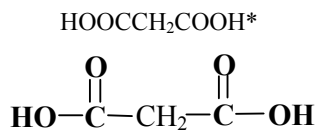
(c) i.

Marks	0	1	2	Average
%	67	8	25	0.57

2.



or $\text{CH}_2\text{OHCH}_2\text{OH}$



(c) ii.

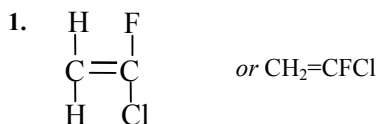
Marks	0	1	Average
%	39	61	0.6

1. H₂O

Even with a fair degree of flexibility in acceptable representations of the structures, the majority of students struggled to accurately identify the monomers from which the polyester chain was formed. It was also evident that there was some confusion as to which atom in the hydroxy functional group is actually bonded to carbon.

(d)

Marks	0	1	Average
%	48	52	0.52



Any clear representation of CH₂=CFCl was acceptable as long as the C=C double bond was evident.
The number of students who struggled with this part of the question was surprisingly high. Parts (c) and (d) together suggest that working back from polymer structures to monomer structures is an area for improvement.

Question 3. (5)

Marks	0	1	2	3	4	5	Average
%	23	11	12	14	13	25	2.58

(i) 1. CH₃CH=CHCH₃ or CH₃CHCHCH₃ or CH₃(CH)₂CH₃

(ii) 1. H₂

(iii) 1. CH₃CH₂CH=CH₂ [CH₂=CHCH₂CH₃] or CH₃CH₂CHCH₂ or (CH₃)₂C=CH₂ or (CH₃)₂CCH₂

(iv) 1. CH₃CH=CH₂ [CH₂=CHCH₃] or CH₃CHCH₂

(v) 1. CH₄

NB If students swapped the correct responses for (i) and (iii), i.e. gave CH₃CH₂CH=CH₂ for part (i) and then CH₃CH=CHCH₃ for part (iii) they received 1 of the 2 marks.

Whilst it was not necessary to show the C=C double bonds in the semi-structural formulae, the sequencing of atom groups had to be correct.

This question proved to be quite challenging. Just over 50 per cent of students obtained 3 or more marks whilst approximately 23 per cent did not score any marks.

Many students may have found the 'style' of question unfamiliar. In such situations they should be encouraged to focus on key words and **apply** acquired knowledge.

The keys to the question were recalling that:

- cracking of an alkane produces an alkene and a smaller alkane or an alkene and hydrogen.
- alkenes undergo addition reactions.
- structural isomers have the same molecular formula but different structures.

When writing semi-structural formulae for alkenes students should be encouraged to keep the location of the C=C double bond in mind. Whilst CH₃CHCH₂ is an acceptable semi-structural formula for propene, CH₃CH₂CH is **not**.

Question 4. (10)

(a) i.

Marks	0	1	2	Average
%	52	17	31	0.79

2.
$$\begin{aligned} n(\text{NaF}) &= n(\text{F}) = 0.90 \times 10^{-3} / 19 * \\ &= (4.74 \times 10^{-5} \text{ mol}) \\ m(\text{NaF}) &= (4.74 \times 10^{-5}) \times 42.0 \\ &= 2.0 \times 10^{-3} \text{ g} \\ &= \mathbf{2.0 \text{ mg} *} \end{aligned}$$

Alternatively

$$\begin{aligned}\% \text{ F in NaF} &= [M(\text{F}) / M(\text{NaF})] \times 100 \\ &= (19.0 / 42.0) \times 100 \\ &= 45.2 \% \\ \text{So } 0.90 \text{ mg} &= 45.2 \% \text{ of } m(\text{NaF}) \\ &= 0.452 \times m(\text{NaF}) \\ m(\text{NaF}) &= 0.90 / 0.452 \\ &= \mathbf{2.0 \text{ mg}}\end{aligned}$$

A number of students interpreted 0.90 mg L⁻¹ as 0.90 mol L⁻¹.

Students who then calculated m(NaF) as 0.90 x 42 = 37.8 g = 3.8x10⁴ mg received one mark for multiplying n(NaF) by 42 and correctly converting to mg.

(a) ii.

Marks	0	1	Average
%	61	39	0.39

$$\begin{aligned}1. m(\text{NaF}) &= 2.0 \text{ mg L}^{-1} \times 750 \times 10^6 \text{ L} \\ &= 1.5 \times 10^9 \text{ mg} = 1.5 \times 10^6 \text{ g} \\ &= \mathbf{1.5 \times 10^3 \text{ kg}^*}\end{aligned}$$

The mark was awarded for the correct use of the answer to (i)

(a) iii.

Marks	0	1	2	Average
%	46	18	37	0.91

$$\begin{aligned}2. n(\text{F}^-) \text{ in } 1 \text{ L} &= 4.74 \times 10^{-5} \text{ mol}^* \dots \text{ from (i)} \\ N(\text{F}^-) \text{ in } 1 \text{ L} &= 4.74 \times 10^{-5} \times 6.02 \times 10^{23}^* \\ &= \mathbf{2.9 \times 10^{19}}\end{aligned}$$

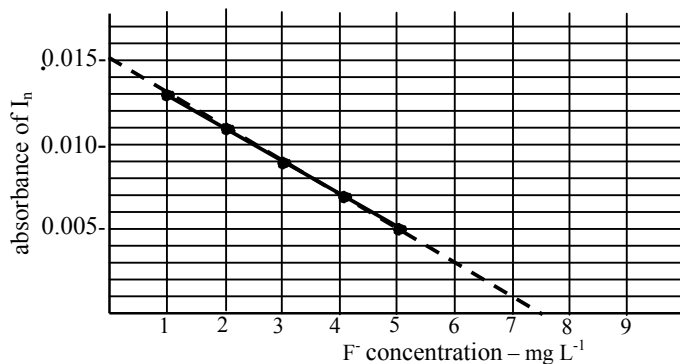
Overall this question caused significant problems for many students. Correct use and conversion of units proved challenging in parts (i) and (ii). There is a tendency for some students to try to get directly from the mass of one substance to the mass of another without paying heed to the 'mole' link.

The application of Avogadro's number in part (iii) was not handled as well as might be expected. Interestingly a number of students who could not work out the n(F⁻) in part (i) were able to do so correctly in part (iii).

(b) i.

Marks	0	1	Average
%	8	92	0.91

1.



All points should be correctly plotted or, if student had only plotted 2 or 3 points, the connecting line must take in all 5 points. The graph does **not** have to extend to the axes.

(b) ii.

Marks	0	1	Average
%	61	39	0.39

1. As the [F⁻] increases more I_n (absorbing species) reacts or [I_n] decreases*.

An acceptable answer requires clear recognition that the more F⁻ present in the solution, the less I_n present.

(b) iii.

Marks	0	1	Average
%	14	86	0.86

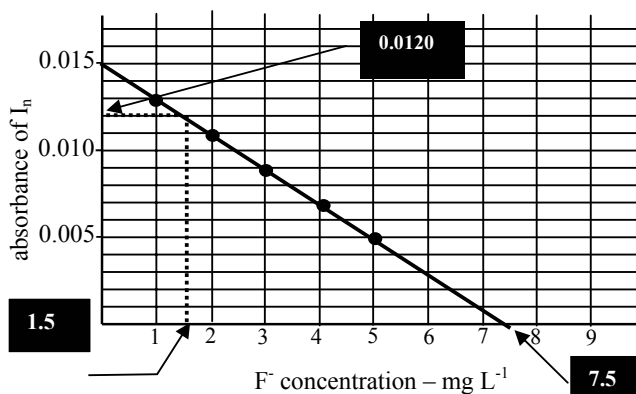
1. 1.5 mg L^{-1} * (accept 1.4-1.6 mg L^{-1})

(b) iv.

Marks	0	1	2	Average
%	84	13	3	0.18

2. Q mol I_n was used up at the point the absorbance reached zero.

$$\begin{aligned} Q &= n(I_n) = n(F^-) \text{ at zero absorbance} \\ c(F^-) \text{ at zero absorbance} &= 7.5 \text{ mg L}^{-1} * \\ m(F^-) &= (25 / 1000) \times 7.5 \\ &= 0.1875 \text{ mg} \\ n(F^-) &= 0.1875 \times 10^{-3} / 19 \\ &= 9.9 \times 10^{-6} \text{ mol} \\ Q &= 9.9 \times 10^{-6} * \end{aligned}$$



Use of the answer from (iii) and calculating $n(F^-) = (25 / 1000) \times 1.5 \times 10^{-3} / 19 = 2.0 \times 10^{-6}$ was awarded 1 mark.

In part (ii) clear explanations of why the absorbance falls with increasing $[F^-]$ were in the minority (60 per cent of students did not obtain the available mark). It was almost as if the first three lines of the question - part(b) - had been overlooked.

Part (iv) proved very challenging. Students generally did not recognise that the $n(I_n)$ present (which is the same as Q) would be equal to the $n(F^-)$ needed react with all the indicator and hence register zero absorbance.

Question 5.

(a)

Marks	0	1	Average
%	9	91	0.9

1. $S(l) + O_2(g) \rightarrow SO_2(g)$

(b) i.

Marks	0	1	Average
%	40	60	0.6

1. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

To obtain the mark on this part of the question, all (correct) states had to be included.

(b) ii.

Marks	0	1	2	Average
%	28	14	58	1.29

2. Yield of SO_3 decreases* because the forward reaction is exothermic*

Implications of yield decrease such as 'reverse reaction favoured', 'K decreases', etc were acceptable

(b) iii.

Marks	0	1	Average
%	28	72	0.72

1. Rate of reaction decreases* / is too low.

(c) i.

Marks	0	1	Average
%	29	71	0.71



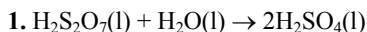
(c) ii.

Marks	0	1	Average
%	47	53	0.52

1. an acid fog (or mist) is created when SO_3 is added to water under these conditions.

(d)

Marks	0	1	Average
%	36	64	0.63



Given the focus on sulfuric acid in the course, students would be expected to come to the examination with a reasonable handle on the associated chemistry, particularly the key equations.

However, the use of correct states and, for $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{SO}_3(\text{g})$, accurately balancing equations is an area for improvement.

Explanation of the impact of temperature changes on the equilibrium $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$ was generally well handled but some confusion about rate and yield was evident.

Question 6.

(a)

Marks	0	1	2	Average
%	35	35	31	0.96

2. $n(\text{CO}_2) = 5.00/44 = 0.1136 \text{ mol}$
 Since $V = 1.00 \text{ L}$, $[\text{CO}_2] = 0.1136 \text{ M}$ *
 $K_n = p(\text{CO}_2) / [\text{CO}_2(\text{aq})]$
 $= 3.00 / 0.1136$
 $= 26.4$ *

There were some surprising interpretations of how to approach this question, with a number of attempts confusing the $\text{CO}_2(\text{g})$ in the space above the water and $\text{CO}_2(\text{aq})$ dissolved in the 1.00 L of water. Some students may have been deterred by the unfamiliar equilibrium expression, however, 65 per cent obtained at least one mark for the question.

(b)

Marks	0	1	2	3	4	Average
%	26	6	15	26	27	2.22

4. $n(\text{CO}_2) \text{ evolved} = n(\text{CO}_2) \text{ in } 0.500 \text{ L of the solution}$
 $= 0.1136/2$
 $= 0.0568 \text{ mol}^*$

$p(\text{CO}_2) = 101.325 \text{ kPa}$ *
 $V(\text{CO}_2) = nRT/p$
 $= 0.0568 \times 8.31 \times (30+273)^* / 101.325$
 $= 1.41 \text{ L}^*$

One mark for correct $n(\text{CO}_2)$, one for pressure conversion, one for temperature conversion, one for answer consistent with use of $V = nRT/p$

(c)

Marks	0	1	2	Average
%	32	20	49	1.17

2. $[\text{H}^+] = K_a \times [\text{CO}_2] / [\text{HCO}_3^-]$
 $= 4.5 \times 10^{-7} \times 0.0020 / 0.050$ *
 $= 1.8 \times 10^{-8}$
 $\text{pH} = -\log_{10}(1.8 \times 10^{-8})$ *
 $= 7.7$

The second mark was available for accurately calculating pH for whatever answers was obtained for $[\text{H}^+]$.