



## GENERAL COMMENTS

Students' overall performance on this examination was generally consistent with the performance in previous years. Below are some general comments, while comments on specific questions are included with the answers/solutions in the Specific Information section.

### Section A

Section A included several 'calculation' questions, which once again challenged a significant proportion of the students.

Responses to Question 6, a type of question that has appeared in a variety of forms over the years, indicated that students need to pay more attention to 'reacting' mole ratios when determining the amount of excess reactant. A balanced equation is the key to accurate reacting mole ratios, and incorporating this may have assisted the students who answered Question 5 incorrectly. Question 13 also referred to reaction between an acid and a base, but the required calculation focused on the non-reacting  $K^+$  ions. At the simplest level, students needed to recognise that doubling the volume of a solution will halve the concentration of a non-reacting species. The question emphasised the importance of accurate question interpretation – a skill that requires continued practice.

Questions relating to pH once again proved challenging. Students should be advised to check that their answers make sense; over 40 per cent of students chose a response to Question 12 that incorrectly implied that diluting an aqueous solution of NaOH will increase the pH. This suggests that students focused on the pH calculation without considering the impact of the dilution on  $OH^-$  concentration. Question 7 in Section B also showed that there is room for improvement in both qualitative and quantitative understanding of pH, especially in relation to weak acids.

Students were generally adept at calculations using the general gas equation. However, Question 15 showed that reflecting on the relationships between the variables in that equation was more challenging.

The overall performance in Section A of this examination suggests that an increased emphasis on techniques for answering multiple-choice questions that involve calculations is needed. Students should have access to a wide variety of multiple-choice questions (including past VCE examinations) during their examination preparation. They should be wary of falling into the trap of thinking that because alternatives are provided, there is little work associated with identifying the correct response. Students should be encouraged to use the space around questions that involve calculations to jot down key steps. The lack of working out on many examination scripts is probably indicative of the use of graphics calculators. This will be particularly pertinent in 2006 when only scientific calculators will be permitted in the chemistry examination.

### Section B

Section B inevitably provided more direct evidence of students' strengths and weaknesses. The role of the light in Atomic Absorption Spectroscopy (AAS) was not well understood, with many students seeming to confuse AAS with flame tests. Part d of Question 1 was a good example of the need to answer the question which is asked. Students continued to struggle with ppm and mg, which has been an issue for the last three examinations.

Questions 2a, 5c, 7a and 8a all tested students' equation writing skills. Students should be reminded of the need to balance equations for both atoms and charge. Question 2c showed that students knew the correct rinsing techniques for laboratory glassware. The majority of students handled the structural formula requirements in Question 3 well, although systematic nomenclature could be an area for improvement.

Parts of Questions 4, 5 and 7 emphasised that 'explanation' type questions reveal both real understanding and students' quality of preparation. Students should be encouraged to provide sufficient detail in their answers; for example, writing the single word 'fertiliser' when asked to 'give a major industrial use of sulphuric acid' (Question 5d) was not enough. On the basis of score, Question 7cii. proved to be the 'hardest' question on the paper. It suggests there is scope for drawing links between different areas of study and/or practical activities.

Question 6c showed that the skill of manipulating equilibrium constants, which had been tested via multiple-choice questions in previous examinations, proved more challenging in the environment of Section B.

Students are encouraged to attempt as many examination-type questions as possible in their examination preparation. While the answers to questions on past and practice examinations are very helpful, discussion that focuses on the interpretation of these questions, both amongst students and/or with teachers, would also be of benefit.



SPECIFIC INFORMATION

Section A – Multiple-choice questions

The table below indicates the percentage of students who chose each option. The correct answer is indicated by shading.

Question	% A	% B	% C	% D	% No Answer	Comments
1	84	8	4	4	0	Chromatographs and spectrophotometers all have a 'detector' and a 'recorder', so option A was the correct answer. Light sources and monochromators are components of spectrophotometers only.
2	86	7	5	2	0	Of the techniques listed, only chromatography (option A) can be used to separate components of the mixture. Since sugars are heat sensitive, and likely thermally decompose in a GC, HPLC is the most appropriate technique.
3	9	86	2	3	0	A catalyst <b>increases</b> the rate of reaction, hence gets the reaction to equilibrium faster, and it has <b>no effect</b> on the equilibrium yield.
4	12	58	17	13	1	$[D^+][OD^-] = 1.82 \times 10^{-16}$ In a neutral solution; $[D^+] = [OD^-]$ So $[D^+]^2 = 1.82 \times 10^{-16} \rightarrow [D^+] = \sqrt{(1.82 \times 10^{-16})}$ $= 1.35 \times 10^{-8} \text{ mol L}^{-1}$ Students who chose option A probably did not see past $K_w = 10^{-14}$ at 25°C. The popularity of option C suggests that, although students understood that $[D^+] = [OD^-]$ , many struggled with the mathematical operation required to get to the $[D^+]$ and divided by 2 rather than taking the square root.
5	20	11	52	14	2	The products of the combustion of $C_4H_9OH$ are $CO_2$ and $H_2O$ . $C_4H_9OH \rightarrow 4CO_2 + 5H_2O$ 1 'O' on the reactant side ; 13 'O' on the product side 12 'O' i.e. 6 $O_2$ required on the reactant side $C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$ So, 0.10 mol $C_4H_9OH$ reacts with 0.60 mol $O_2$ (option C). This question proved more challenging than might have been expected. Students at this level are expected to know that the reacting mole ratio for reactants is shown in a balanced equation.
6	34	25	19	21	1	$\begin{array}{r} Ba(OH)_2(aq) + 2HNO_3(aq) \rightarrow Ba(NO_3)_2(aq) + 2H_2O(l) \\ 50.00 \text{ mL} \quad 50.00 \text{ mL} \\ 0.020 \text{ M} \quad 0.060 \text{ M} \\ \downarrow \quad \downarrow \\ \text{Initially (mol)} \quad 1.0 \times 10^{-3} \quad 3.0 \times 10^{-3} \\ \text{Reacting (mol)} \quad 1.0 \times 10^{-3} \quad 2.0 \times 10^{-3} \\ \text{Finally (mol)} \quad - \quad 1.0 \times 10^{-3} \end{array}$ $n(H^+) \text{ in resultant solution} = n(HNO_3) \text{ in excess}$ $= 1.0 \times 10^{-3} \text{ mol (in 100 mL of solution)}$ $[H^+] \text{ in resultant solution} = 1.0 \times 10^{-3} \text{ mol} / 0.10 \text{ L}$ $= 0.010 \text{ mol L}^{-1}$ Alternatively: $n(H^+) \text{ initially} = n(HNO_3)$ $= 0.0030 \text{ mol}$ $n(OH^-) \text{ initially} = 2 \times n[Ba(OH)_2]$ $= 2 \times 0.0010$ $= 0.0020 \text{ mol}$ Since the reaction is $OH^-(aq) + H^+(aq) \rightarrow H_2O(l)$ $n(H^+) \text{ in resultant solution} = 0.0030 - 0.0020$ $= 0.0010 \text{ mol}$ $[H^+] \text{ in resultant solution} = 1.0 \times 10^{-3} \text{ mol} / 0.10 \text{ L}$ $= 0.010 \text{ mol L}^{-1}$



						<p>When provided with the amounts of both reactants, a recommended starting point is to identify the limiting (or excess) reactant. Also, when working the concentration of a species after mixing two solutions, students should divide by the <b>total</b> volume.</p> <p>This was a similar question to Question 10 on the 2004 examination. Given that 'division by total volume' was emphasised in the 2004 Assessment Report, the popularity of option B may also have been due to students not establishing the correct mole ratio for the reaction between Ba(OH)<sub>2</sub> and HNO<sub>3</sub>. Assuming a 1:1 mole ratio leads to the calculation of 2.0 x 10<sup>-3</sup> mol HNO<sub>3</sub> in excess, and a [H<sup>+</sup>] of 0.020 M.</p>
7	14	34	42	10	0	<p>Applying oxidation numbers shows that this is a redox reaction:</p> $\overset{+1}{\text{Na}}\text{H}(\text{s}) + \overset{-1}{\text{H}}\overset{+1}{\text{H}}\overset{-2}{\text{O}}(\text{l}) \rightarrow \overset{+1}{\text{Na}}^+(\text{aq}) + \overset{-2}{\text{O}}\overset{+1}{\text{H}}(\text{aq}) + \overset{0}{\text{H}_2}(\text{g})$ <p>The oxidation number of H decreases from +1 in H<sub>2</sub>O to 0 in H<sub>2</sub>. The oxidation number of H increases from -1 in H<sup>-</sup> (NaH) to 0 in H<sub>2</sub>. H<sup>-</sup> reduces H<sub>2</sub>O to H<sub>2</sub>, and is itself oxidised to H<sub>2</sub>. H<sub>2</sub>O oxidises H<sup>-</sup> to H<sub>2</sub>, and is itself reduced to H<sub>2</sub>.</p> <p>This can also be verified by half-equations. Reduction: 2H<sub>2</sub>O(l) + 2e<sup>-</sup> → H<sub>2</sub>(g) + 2OH<sup>-</sup> Oxidation: 2H<sup>-</sup>(aq) → H<sub>2</sub>(g) + 2e<sup>-</sup></p> <p>The ionic equation shows that the reaction is also an acid-base reaction: H<sup>-</sup>(aq) + H<sub>2</sub>O(l) → OH<sup>-</sup>(aq) + H<sub>2</sub>(g) H<sub>2</sub>O is the acid. It donates H<sup>+</sup>, to the base H<sup>-</sup>, and forms OH<sup>-</sup>. H<sup>-</sup> is the base. It accepts H<sup>+</sup>, from the acid H<sub>2</sub>O, and forms H<sub>2</sub>.</p> <p>This proved to be one of the most challenging questions on the paper. Over one-third of the students were able to identify the reaction as a redox reaction but not as an acid-base reaction. In answering such questions, students are advised to check if the reaction types mentioned in the alternatives can be identified in the equation.</p>
8	10	31	10	47	2	<p><math>n(\text{CaCO}_3)</math> in dolomite = <math>n(\text{CaO})</math> produced = 1.24 g / 56.1 g mol<sup>-1</sup> = 0.0221 mol</p> <p><math>m(\text{CaCO}_3)</math> in dolomite = 0.0221 mol x 100.1 g mol<sup>-1</sup> = 2.21 g</p> <p>% CaCO<sub>3</sub> in dolomite = <math>[m(\text{CaCO}_3) / m(\text{dolomite})] \times 100</math> = (2.21 / 3.72) x 100 = 59.5 % (option D)</p> <p>The popularity of option B suggests that many students simply divided the mass of CaO by the mass of dolomite. This may have been because students focused on the data in the actual question without integrating it with the information that preceded the question.</p>
9	16	24	55	5	0	<p>If the CaO precipitate is not rinsed with water, acid soluble components of the ore may be trapped in and collected with the precipitate, hence increasing the total mass of the precipitate. If the precipitate is not heated to constant mass, some water will remain and the weighed mass of the precipitate will be higher than the mass of CaO.</p> <p>In both instances the calculated <math>m(\text{CaCO}_3)</math> will be higher and the calculated percentage CaCO<sub>3</sub> in the dolomite will be higher, so option C was the correct answer.</p> <p>Students should be able to deduce the effect of 'not fully drying the precipitate' on the calculated percentage, by mass, of CaCO<sub>3</sub> in the sample. The popularity of option B suggests that the impact of not rinsing the precipitate with water was more challenging.</p>



10	12	6	11	70	0	$\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{HCl}(\text{g})$ <p>Initially (mol)    3        2            Reacting (mol)   2        2    →    4            Finally (mol)    1        -        4</p> <p>When reaction is complete, 1 mol of <math>\text{H}_2</math> and 4 mol of <math>\text{HCl}</math> are present (option D).</p> <p>When given the amounts of both reactants, it is essential that a check for 'excess' reactant is carried out. The molar amounts of reactants reacting will always be in the ratio indicated by the equation.</p>																																																													
11	20	13	59	8	0	<p>Assume a 100 g sample  <math>m(\text{C}) = 39.1 \text{ g}</math>; <math>m(\text{H}) = 8.7 \text{ g}</math>; <math>m(\text{O}) = 100 - (39.1 + 8.7) = 52.2 \text{ g}</math></p> <table style="margin-left: 40px;"> <tr> <td>C</td> <td>:</td> <td>H</td> <td>:</td> <td>O</td> </tr> <tr> <td>mass ratio</td> <td></td> <td>39.1</td> <td>:</td> <td>8.7</td> <td>:</td> <td>52.2</td> </tr> <tr> <td>mole ratio</td> <td></td> <td>39.1/12.0</td> <td>:</td> <td>8.7/1.0</td> <td>:</td> <td>52.2/16.0</td> </tr> <tr> <td></td> <td></td> <td>3.26</td> <td>:</td> <td>8.7</td> <td>:</td> <td>3.26</td> </tr> <tr> <td>simplest ratio</td> <td></td> <td>3.26/3.26</td> <td>:</td> <td>8.7/3.26</td> <td>:</td> <td>3.26/3.26</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>:</td> <td>2.67</td> <td>:</td> <td>1</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>:</td> <td>2<sup>2</sup>/3</td> <td>:</td> <td>1</td> </tr> <tr> <td></td> <td></td> <td>1</td> <td>:</td> <td>8/3</td> <td>:</td> <td>1</td> </tr> <tr> <td></td> <td></td> <td>3</td> <td>:</td> <td>8</td> <td>:</td> <td>3</td> </tr> </table> <p>Empirical formula <math>\text{C}_3\text{H}_8\text{O}_3</math></p> <p>This was a straightforward empirical formula calculation; however, the fact that 1 in 5 students chose option A suggests that in the empirical formula calculation 2.67 was rounded off to 3 to give the ratio 1:3:1. Students should be discouraged from such severe rounding off in empirical formula calculations.</p>	C	:	H	:	O	mass ratio		39.1	:	8.7	:	52.2	mole ratio		39.1/12.0	:	8.7/1.0	:	52.2/16.0			3.26	:	8.7	:	3.26	simplest ratio		3.26/3.26	:	8.7/3.26	:	3.26/3.26			1	:	2.67	:	1			1	:	2 <sup>2</sup> /3	:	1			1	:	8/3	:	1			3	:	8	:	3
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12	39	18	12	30	1	<p>The solution of <math>\text{NaOH}(\text{aq})</math> is basic, so dilution is a decrease in the <math>[\text{OH}^-]</math>  <math>\text{pH } 10 \rightarrow [\text{H}_3\text{O}^+] = 10^{-10}</math>            Assuming the solution is at <math>25^\circ\text{C}</math>; <math>[\text{H}_3\text{O}^+][\text{OH}^-]</math>  <math>[\text{OH}^-] = 10^{-14} / 10^{-10} = 10^{-4} \text{ M}</math>            Volume is increased by a factor of 100 (from 10 mL to 1000 mL).            Concentration is therefore decreased by a factor of 100.</p> <table style="margin-left: 40px;"> <tr> <td><math>[\text{OH}^-]</math></td> <td><math>= 10^{-4} / 100 = 10^{-6} \text{ M}</math></td> </tr> <tr> <td><math>[\text{H}_3\text{O}^+]</math></td> <td><math>= 10^{-14} / 10^{-6}</math></td> </tr> <tr> <td></td> <td><math>= 10^{-8} \text{ M}</math></td> </tr> <tr> <td>pH</td> <td><math>= 8</math> (option A)</td> </tr> </table> <p>The popularity of option D suggests that students applied the principle that a tenfold decrease in concentration of <math>\text{H}_3\text{O}^+</math> causes a 1 unit increase in pH. However, the solution – <math>\text{NaOH}(\text{aq})</math> – was basic, not acidic, so D is an illogical answer. If the pH increases it suggests that a more dilute solution of <math>\text{NaOH}(\text{aq})</math> is more strongly basic, i.e. has a higher concentration of <math>\text{OH}^-(\text{aq})</math>.</p> <p>For a base, if the concentration decreases by a factor of 10, the pH decreases by 1 unit. For an acid, if the concentration decreases by a factor of 10, the pH increases by 1 unit. Since <math>[\text{H}_3\text{O}^+][\text{OH}^-] = 10^{-14}</math> at <math>25^\circ\text{C}</math>, if the <math>[\text{OH}^-]</math> decreases, due to dilution, then the <math>[\text{H}_3\text{O}^+]</math> must increase and the pH decrease.</p>	$[\text{OH}^-]$	$= 10^{-4} / 100 = 10^{-6} \text{ M}$	$[\text{H}_3\text{O}^+]$	$= 10^{-14} / 10^{-6}$		$= 10^{-8} \text{ M}$	pH	$= 8$ (option A)																																																					
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13	34	36	18	11	1	<p><math>\text{HCl}(\text{aq}) + \text{KOH}(\text{aq}) \rightarrow \text{KCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})</math>; <math>\text{K}^+(\text{aq})</math> is a spectator ion  <math>\text{KOH}(\text{aq}) \rightarrow \text{K}^+(\text{aq}) + \text{OH}^-(\text{aq})</math>  <math>n(\text{K}^+) = n(\text{KOH}) = 0.30 \times 20.0 \times 10^{-3}</math>  <math>= 6.0 \times 10^{-3} \text{ mol}</math></p> <p>Total volume = 40.0 mL  <math>c(\text{K}^+) = 6.0 \times 10^{-3} / 40.0 \times 10^{-3}</math>  <math>= 0.15 \text{ mol L}^{-1}</math> (option B)</p> <p>Alternatively:</p>																																																													



						<p>Initial <math>c(\text{K}^+) = c(\text{KHO}) = 0.30 \text{ M}</math>            Since volume is doubled, from 20 mL to 40 mL, the <math>c(\text{K}^+)</math> will be halved.</p> <p>To arrive at option A, students probably worked out the <math>n(\text{KOH})</math> in excess – <math>4.0 \times 10^{-3} \text{ mol}</math> in a total volume of 40 mL – and then calculated the <math>c(\text{K}^+) = 4.0 \times 10^{-3} / 40 \times 10^{-3} = 0.10 \text{ M}</math>. This may be due to exposure to similar questions where the focus was on the amount of excess reactant/pH of resultant solution. This emphasises the importance of reading the question and answering the <b>actual</b> question that is asked.</p>
14	8	10	61	21	1	<p>For a fixed amount of gas:</p> $\frac{p_2 V_2}{T_2} = \frac{p_1 V_1}{T_1}$ $\frac{p_2 \times 50}{293} = \frac{1 \times 100}{283}$ $p_2 = \frac{1 \times 100}{283} \times \frac{293}{50}$ $= 2.07 \text{ atm}$ $= 2 \text{ atm}$ <p>With over 1 in 5 students choosing option D, there appears to be some issues with understanding the relationships between pressure and volume (pressure increases as volume decreases) and pressure and temperature (an increase in pressure is proportional to an increase in absolute, Kelvin, temperature).</p>
15	6	33	34	26	1	<p><math>M(\text{SO}_2) = 64.1 \text{ g mol}^{-1}</math>; <math>M(\text{O}_2) = 32.0 \text{ g mol}^{-1}</math>            Since the <math>M(\text{SO}_2)</math> is twice the <math>M(\text{O}_2)</math>, and there are equal masses of both gases, <math>n(\text{SO}_2) = \frac{1}{2} n(\text{O}_2)</math>. If both gases are at the same temperature and occupy the same volume then the pressure exerted by each gas depends on the number of mol present. Since <math>n(\text{SO}_2) = \frac{1}{2} n(\text{O}_2)</math> at the same volume and temperature, then:</p> $p(\text{SO}_2) = \frac{1}{2} \times p(\text{O}_2)$ $= \frac{1}{2} \times 100$ $= 50 \text{ kPa}$ <p>The high proportion of students who selected options C and D suggests that there was significant confusion between ‘mass’ and ‘number of moles’ of the two gases as far as the impact on pressure is concerned. While students are familiar with the general gas equation <math>pV = nRT</math>, there is scope for improved understanding of the relationships between the four variables: <math>p</math>, <math>V</math>, <math>n</math> and <math>T</math>.</p>
16	9	14	69	7	1	<p>This question was very similar to Question 2c from Section B of the 2004 examination.</p>
17	6	12	11	69	1	$n(\text{O}_2) = pV / RT$ $= 20.4 \times 1 / (8.31 \times 298)$ $= 8.2 \times 10^{-3} \text{ mol}$ $c(\text{O}_2) = n(\text{O}_2) / V$ $= 8.2 \times 10^{-3} / 1$ $= 0.0082 \text{ mol L}^{-1}$



18	4	12	5	79	0	<p>Applying an oxidation number of -2 for O and +1 for H:  <math>\text{H}_2\text{S}_2\text{O}_7: 2(+1) + 2x + 7(-2) = 0 \rightarrow 2x = 12 \rightarrow x = +6</math>                      The oxidation number of S is +6  <math>\text{N}_2\text{O}_5: 2x + 5(-2) = 0 \rightarrow 2x = 10 \rightarrow x = +5</math>                      The oxidation number of N is +5  <math>\text{HIO}_3: +1 + x + 3(-2) \rightarrow x = +5</math>                      The oxidation number of I is +5  <math>\text{Cl}_2\text{O}_7: 2x + 7(-2) = 0 \rightarrow 2x = 14 \rightarrow x = +7</math>                      The oxidation number of Cl is +7</p>
19	55	13	19	12	2	<p>Identify the repeating units in the polymer chain, each of which has a carbon-carbon double bond C=C.</p> <p>The two monomers are <math>\text{CH}_2=\text{CF}_2</math> and <math>\text{CF}_2=\text{CF}(\text{CF}_3)</math> (option A).</p> <p>The ability to deduce the monomers from a given polymer chain is as important as showing a section of a polymer chain formed from given monomers.</p>
20	13	10	61	16	0	<p>During the further 30 minutes, the two pigments and the solvent front would each move approximately twice the distance that they had moved from the origin in the first 15 minutes. So, after a further 30 minutes, the chromatogram would show the pigments having moved approximately three times as far as they moved in the first 15 minutes. Both pigments would have moved further and would be further apart. Only option C is consistent with this outcome.</p> <p>This question emphasised the importance of being able to interpret and apply given information/data.</p>

## Section B – Short-answer questions

Asterisks (\*) are used in some questions to show where marks were awarded.

### Question 1

1a

Marks	0	1	Average
%	47	53	0.6

Any of:

- the lamp must emit wavelengths of light that will be absorbed by Ca atoms
- the lamp must emit an emission spectrum of calcium
- the lamp must emit wavelengths absorbed by the element being analysed
- it must be a Ca lamp.

The characteristics of lamps used in AAS should be emphasised by teachers in the study of the instrument.

1b

Marks	0	1	2	Average
%	50	32	19	0.7

Two marks were awarded if the response included two of the following three points:

- the sample is dehydrated in the flame and the  $\text{Ca}^{2+}$  ions are converted to an atomic vapour

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- Ca atoms absorb some of the wavelengths of light coming from the lamp
- electrons in Ca atoms are excited to higher energy levels by the light.

In AAS the flame dehydrates the ions in the solution, forming anhydrous salts. These salts are then dissociated into atoms. It is the Ca atoms which absorb the light from the calcium lamp.

Many students referred to electrons being excited to higher energy levels due to the heat of the flame. This was generally combined with the emission of light as electrons returned to lower energy levels. Such responses suggested that many students were well aware of the impact of spraying a sample into a flame as part of a flame test, but that they could not distinguish between the functions of the flame and the light in atomic absorption spectroscopy.

1c

Marks	0	1	Average
%	53	47	<b>0.5</b>

A particular wavelength/emission line/colour is selected\* by the monochromator.

An implication of wavelength separation was required here. A significant number of students identified the involvement of the monochromator, but did not then explain what happens to the light as it passes through the monochromator.

1d

Marks	0	1	Average
%	57	43	<b>0.5</b>

The instrument is calibrated by measuring the absorbances of a series of Ca<sup>2+</sup>(aq) standards.

Many students mentioned a 'calibration curve' with little or no reference to how the curve is established experimentally. This emphasises the importance of answering the question which is asked, in this case: 'What **additional experiments** does the analyst carry out...?'

1e

Marks	0	1	2	Average
%	48	22	29	<b>0.9</b>

As a result of an error on the exam, either 1 mg L<sup>-1</sup> or 1 x 10<sup>-6</sup> mg L<sup>-1</sup> was accepted for ppm.

$$\begin{aligned}
 0.025 \text{ ppm} &\rightarrow 0.025 \text{ mg L}^{-1} \\
 &\rightarrow 2.5 \times 10^{-5} \text{ g L}^{-1} \\
 &\rightarrow \frac{2.5 \times 10^{-5}}{40.1 \text{ mol L}^{-1}} \\
 &= 6.2 \times 10^{-7} \text{ mol L}^{-1}
 \end{aligned}$$

$$\begin{aligned}
 0.025 \text{ ppm} &\rightarrow 0.025 \times 10^{-6} \text{ mg L}^{-1} \\
 &\rightarrow 2.5 \times 10^{-11} \text{ g L}^{-1} \\
 &\rightarrow \frac{2.5 \times 10^{-11}}{40.1 \text{ mol L}^{-1}} \\
 &= 6.2 \times 10^{-13} \text{ mol L}^{-1}
 \end{aligned}$$

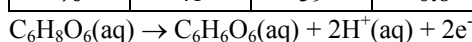
The first mark was given for the correct conversion of mg to g. The second mark was for accurate division by 40.1

The overall performance on this question indicates that the use of mg, and particularly converting mg to mol, continues to prove challenging for many chemistry students.

## Question 2

2a

Marks	0	1	Average
%	41	59	<b>0.6</b>



The most common error on this question was incorrectly locating the electrons. Students are advised to always check that half-equations are balanced for charge as well as atoms.

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**2b**

Marks	0	1	2	3	4	Average
%	16	13	15	22	34	2.6

**2bi.**

$$n(\text{I}_3^-) = 2.00 \times 10^{-4} \times 15.65 \times 10^{-3}$$

$$= 3.13 \times 10^{-6} \text{ mol}$$

**2bii.**

$$n(\text{C}_6\text{H}_8\text{O}_6) \text{ in } 25.00 \text{ mL diluted fruit juice} = n(\text{I}_3^-)$$

$$= 3.13 \times 10^{-6} \text{ mol}$$

**2biii.**

$$n(\text{C}_6\text{H}_8\text{O}_6) \text{ in undiluted fruit juice} = \frac{3.13 \times 10^{-6}}{25} \times 250$$

$$= 3.13 \times 10^{-5} \text{ mol}$$

$$c(\text{C}_6\text{H}_8\text{O}_6) = \frac{3.13 \times 10^{-5}}{20 \times 10^{-3}}$$

$$= 1.57 \times 10^{-3} \text{ mol L}^{-1}$$

Alternatively:

$$c(\text{C}_6\text{H}_8\text{O}_6) \text{ in diluted juice} = \frac{3.13 \times 10^{-6}}{25.0 \times 10^{-3}}$$

$$= 1.25 \times 10^{-4} \text{ mol L}^{-1}$$

$$c(\text{C}_6\text{H}_8\text{O}_6) \text{ in original sample} = 1.25 \times 10^{-4} \times \frac{250}{20}$$

$$= 1.57 \times 10^{-3} \text{ mol L}^{-1}$$

Significant figures were checked on this question. Acceptable answers included  $1.565 \times 10^{-3}$  and  $1.6 \times 10^{-3}$ , which was consistent with past practice of allowing one more or one less than the actual number of significant figures.

**2c**

Marks	0	1	2	3	4	Average
%	5	4	12	28	52	3.3

i. 20 mL pipette

ii. 250 mL volumetric flask

iii. 25 mL pipette

iv. conical flask

	pure water	original fruit juice	diluted juice	standard $\text{I}_3^-$ solution
		✓		
	✓			
			✓	
	✓			

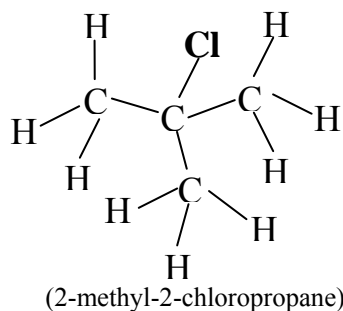
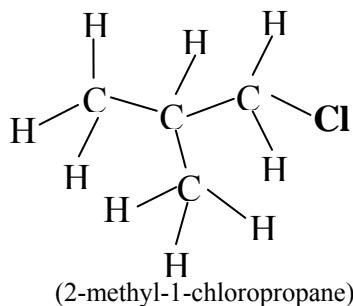
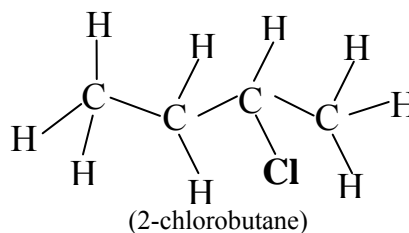
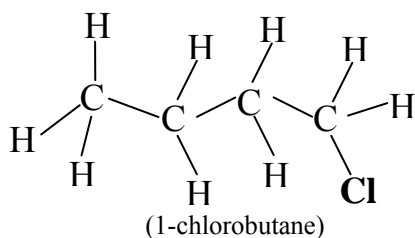
Students generally knew the rinsing procedures associated with titration.

## Question 3

**3a**

Marks	0	1	2	3	4	Average
%	3	6	18	20	53	3.2





This question was generally well done, although some students struggled to identify a 'fourth' isomer. Repetition of 2-chlorobutane or 2-methyl-1-chloropropane was relatively common.

**3b**

Marks	0	1	2	Average
%	29	31	40	1.2

**3bi.**

Any of:

- potassium dichromate
- acidified potassium dichromate
- $K_2Cr_2O_7$
- $Cr_2O_7^{2-}$ .

There were occasional mentions of acidified potassium permanganate,  $KMnO_4$ , or  $O_2$  in the presence of a silver catalyst, which were also accepted.

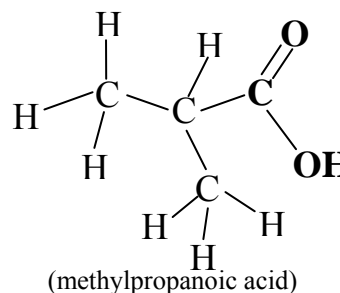
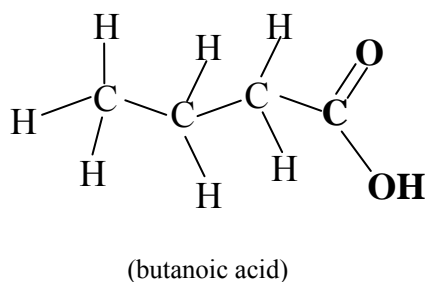
**3bii.**

Butanoic acid

A common answer was 1-butanoic acid. While this was accepted, it should be emphasised to students that since 2-butanoic acid does not exist, the 1- is not necessary in the systematic name.

**3c**

Marks	0	1	2	Average
%	27	25	48	1.3



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The number of students who did not score on this question was surprisingly high given that the key knowledge in the Industrial Chemistry Area of Study is so specific: structural isomers of compounds containing one chloro, hydroxy or carboxyl functional group (up to four-carbon compounds).

### 3d

Marks	0	1	2	3	Average
%	21	22	28	30	1.8

### 3di.

Methyl propanoate

### 3dii.

1-octanol

### 3diii.

2-chloropentane

Part iii. was generally well answered. In part ii., 2-octanol was a frequent incorrect response, which suggests that many students presumed that the hydroxy group was bonded to the second carbon atom. The identification of esters continues to prove challenging.

## Question 4

### 4a

Marks	0	1	Average
%	43	57	0.6

$$\begin{aligned}\Delta H &= -400 - (-170) \\ &= -230 \text{ kJ mol}^{-1}\end{aligned}$$

Allowance was made for variations in reading the energy profile, and answers between  $-225$  and  $-240$  were accepted.

### 4b

Marks	0	1	Average
%	56	44	0.5

$$\begin{aligned}E_a &= -40 - (-400) \\ &= 360 \text{ kJ mol}^{-1}\end{aligned}$$

Allowance was made for variations in reading the energy profile, and answers between  $355$  and  $370$  were accepted.

### 4c

Marks	0	1	2	Average
%	26	44	30	1.1

- The fraction (or number) of fruitful collisions (collisions with energy greater than  $E_a$ ) increases.\*
- The particles are moving faster (have higher kinetic energy), so there will be more collisions per second.\*

Many students struggled to give two distinct points. Students should be aware that the key to increasing the rate of reaction is increasing the proportion of fruitful or successful collisions; that is, collisions with energy greater than the activation energy. Qualitative explanations of factors that increase the rate of reaction inevitably include reference, either direct or indirect, to the activation energy.

Common misconceptions included 'rate increasing because the reaction was exothermic' and 'increasing temperature changing the activation energy'.

Given the similarity of this question to Question 1bii. on the 2004 examination, more students might have been expected to score at least one mark.

### 4d

Marks	0	1	2	Average
%	23	25	52	1.4

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## 4di.

A catalyst decreases the activation energy by providing an alternative reaction path.\*

## 4dii.

A catalyst has no effect on the  $\Delta H$ , because it does not alter the extent of reaction *or* total amount of reactants reacting *or* energy difference between reactants and products *or* position of equilibrium.

Only one mark was awarded across parts i. and ii. if the student correctly identified both effects but did not provide explanations.

## Question 5

### 5a

Marks	0	1	Average
%	42	58	0.6

Spraying the molten sulphur produces droplets which provide a greater surface area\* for contact with  $O_2$  and hence speed up the reaction.

Students generally either identified the link between 'greater surface area' and 'increased reaction rate' or missed the point altogether.

### 5b

Marks	0	1	2	3	4	Average
%	18	11	15	19	37	2.6

#### 5bi.

Because the forward reaction is exothermic, the yield of  $SO_3$  is greater at lower temperatures. However, the rate of reaction is faster at higher temperatures.\* This rate/yield conflict is resolved by using a temperature which provides a balance (compromise) between the conflicting effects\* *or* the combination of a moderate temperature and a catalyst gives a good yield at a good rate.

#### 5bii.

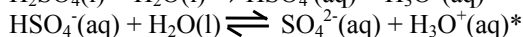
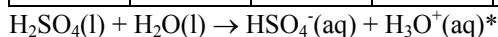
The amount of  $SO_3$  will increase\* as the equilibrium responds to the pressure increase by moving to the side with fewer particles\* *or* to decrease pressure *or* to compensate for pressure increase.

The 'rate/yield' conflict is a common aspect in questions relating to the production of sulphuric acid. Many responses showed a good understanding of the conflict and its resolution; however, many students did not identify what the conflict was, while others did not refer to the role of temperature in resolving the conflict.

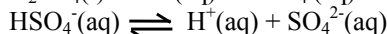
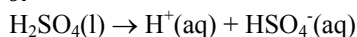
Part ii. proved more challenging than might have been expected. There were indications that some students, having learned that high pressures are not used in the Contact process, were confused by having to explain the impact of increased pressure.

### 5c

Marks	0	1	2	Average
%	33	28	39	1.1



*or*



The range of mistakes in this part of the question was extensive, particularly the use of incorrect chemical formulae, including incorrect charges. Equations involving  $H_2S_2O_7$  were not uncommon, which suggests that some students simply defaulted to learned material. Students needed to include  $\rightleftharpoons$  in the second equation to get both marks.

### 5d

Marks	0	1	Average
%	50	50	0.5

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Some of the accepted answers are listed below:

- production of fertilisers\* such as superphosphate
- electrolyte in car batteries
- metallurgy
- drug manufacture (sulphonating agent).

The responses 'in fertilisers', 'fertiliser', or 'as fertiliser' were common; however, no marks were awarded for these responses. Responses which simply mentioned a property of sulphuric acid such as acid, oxidant or dehydrating agent were also not accepted.

## Question 6

6a

Marks	0	1	Average
%	11	89	<b>0.9</b>

$$K = \frac{[\text{NO}_2]^2}{[\text{N}_2\text{O}_4]} (= 5.5 \times 10^{-3})$$

6b

Marks	0	1	2	3	Average
%	12	13	62	12	<b>1.8</b>

6bi.

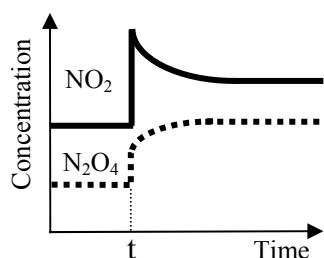
Endothermic\*

The position of equilibrium has moved to the right (more NO<sub>2</sub> is produced) at the higher temperature.\*

6bii.

More intense

When the volume of the syringe is halved, the [NO<sub>2</sub>] doubles. As the system responds by the position of equilibrium moving to the side with fewer particles the [NO<sub>2</sub>] decreases, but not back to its original concentration, so the brown colour is more intense at the new equilibrium.

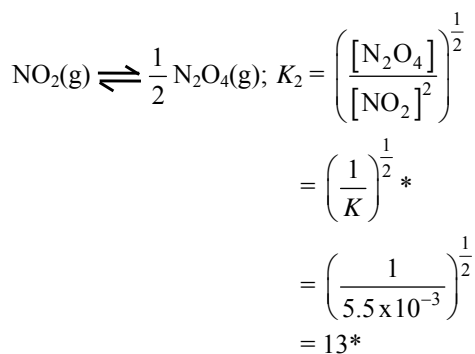
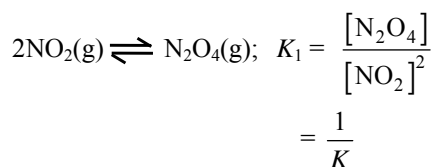
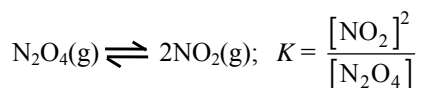


The most common response to part ii. was 'less intense'. This would suggest that students identified the equilibrium adjustment in response to the volume change, but not the overall effect on NO<sub>2</sub> concentration.

6c

Marks	0	1	2	Average
%	47	15	38	<b>1.0</b>

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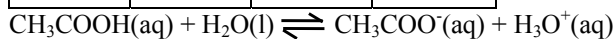
The manipulation of equilibrium constants appeared in the multiple-choice section of the previous three examinations. Students seemed to find it more difficult to calculate the value of the equilibrium constant than identify the correct answer in a multiple-choice question.

Students seemed to recognise that the equilibrium constant for the 'reverse' of the original equilibrium is the reciprocal of the original equilibrium constant; however, recognition of the impact of halving the stoichiometric coefficients was less common. Dividing by two rather than raising to the power of  $\frac{1}{2}$  (taking the square root) was common in the equilibrium constant calculation.

## Question 7

7a

Marks	0	1	Average
%	32	68	<b>0.7</b>



or



States were checked in this question.

7b

Marks	0	1	2	3	Average
%	38	11	13	38	<b>1.6</b>

7bi.

$$[\text{H}^+] = 10^{-2.88} = 1.32 \times 10^{-3} \text{ M}*$$

7bii.

$$K_a = \frac{[\text{CH}_3\text{COO}^-][\text{H}^+]}{[\text{CH}_3\text{COOH}]}$$

$$= \frac{[\text{H}^+]^2}{[\text{CH}_3\text{COOH}]}$$

$$= \frac{(1.32 \times 10^{-3})^2}{0.100} *$$

$$= 1.74 \times 10^{-5}*$$

$$\text{or } \frac{(1.32 \times 10^{-3})^2}{0.100 - 0.00132}$$

$$\text{or } 1.77 \times 10^{-5}$$

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A significant number of students used the concentration of  $\text{CH}_3\text{COOH}$ , rather than the pH, to determine the  $[\text{H}^+]$ . When asked to calculate the  $[\text{H}^+]$ ,  $1.32 \times 10^{-3} \text{ M}$  is a more appropriate answer than  $10^{-2.88}$ . If students incorrectly calculated  $[\text{H}^+]$  in part i. but used this value correctly in part ii., they received both marks for ii.

Calculations associated with acidity constants continue to prove challenging for a significant proportion of students.

7c

Marks	0	1	2	3	Average
%	48	41	3	8	<b>0.8</b>

7ci.

Ethanoic acid, because:

- lower  $K_a \rightarrow$  weaker acid, hence less ionisation
- fewer  $\text{H}^+$  ions in solution
- $[\text{H}^+]$  is lower  $\rightarrow$  higher pH.\*

7cii.

- They would both require the same amount\* of NaOH.
- The  $n(\text{NaOH})$  required depends on the  $n(\text{acid})$  present. Both acids are monoprotic and there are equal numbers of moles of both acids present.\*

Providing a qualitative explanation of why ethanoic acid had the higher pH challenged most students. In part ii. most answers related the required volume of NaOH to acid strength rather than to concentration.

Most students probably encounter stoichiometry questions related to the analysis of the ethanoic acid content of vinegar by titration with NaOH(aq); some useful links might be made with this question.

## Question 8

8a

Marks	0	1	Average
%	21	79	<b>0.8</b>

Any of:

- $\text{Hb} + \text{O}_2 \rightleftharpoons \text{HbO}_2$
- $\text{Hb}_4 + 4\text{O}_2 \rightleftharpoons \text{Hb}_4\text{O}_8$
- haemoglobin +  $\text{O}_2 \rightleftharpoons$  oxyhaemoglobin.

A 'sensible equation' indicating the formation of oxyhaemoglobin was required.

8b

Marks	0	1	Average
%	46	54	<b>0.6</b>

If the oxygen concentration drops, the position of equilibrium moves left\* and less oxygen is carried to the cells/less oxyhaemoglobin is formed.

8c

Marks	0	1	Average
%	60	40	<b>0.4</b>

A high blood count means there is a higher concentration of haemoglobin in the blood, so the position of equilibrium moves right\*/more oxyhaemoglobin is formed.

In parts b and c some explanation of the impact on the reaction between oxygen and haemoglobin was required. Responses suggested that some students did not see the link between the information in part c and the information in the question stem.