GENERAL COMMENTS

The overall performance on the 2006 Chemistry examination 1 was similar to other recent Chemistry 1 examinations, although performance at the top end of the mark range was stronger than in 2005 (see statistics on the VCAA website).

When considering what factors influence student performance on an examination such as this, it is often the mistakes that were made which provide the greatest insight. An important part of examination preparation should be learning from the mistakes of those who have gone before. Therefore, as well as discussing correct responses, this report will deal with some of the common errors that were shown in students' answers.

An example where students could have learnt from past mistakes was Question 9 in Section A. Just under half of the 2006 students correctly recognised that there are two structural isomers that are carboxylic acids with the formula $C_4H_8O_2$. This question was similar to Question 3c. in Section B of the 2005 examination where students were required to 'draw full structural formulas of all carboxylic acids with the empirical formula $C_4H_8O_2$'.

Similarly, Question 5 in Section A, which proved to be amongst the most challenging questions, had links to Question 7c. on the 2005 examination. Question 5 elicited almost equal numbers for each alternative, suggesting that, despite the similarity to the 2005 exam, most students did not realise that the amount of strong base needed to neutralise an acid depends on the $n(H^+)$ available from the acid (that is, that the base can take from the acid), irrespective of acid strength.

Some students appeared to struggle with components of the key knowledge associated with the Industrial Chemistry area of study (Question 10 in Section A and parts of Question 7 in Section B). The results for Questions 9 and 10 in Section A suggest that functional groups and organic reaction sequences continue to prove challenging to a significant proportion of students.

In order to perform well on the calculation questions, Questions 3 and 4 in Section B, students needed to interpret data, understand chemical formulae and appreciate the relationships between units. In Question 3a. many students did not recognise that $n(P) = 2 \times n(Mg_2P_2O_7)$. It was also of concern that nearly one-third of students received no marks for part d. of this question. Students should be encouraged to proceed through successive parts of such questions even if their answer to an earlier part seems unrealistic, as consequential marks may possibly be available.

Question 4 of Section B highlighted the need for students to carefully read the question. In part a. few students took note of the fact that 'bright blue' also absorbs significantly at the wavelength where curcumin shows maximum absorbance. The focus of many incorrect answers was clearly more on the maximum absorbance of curcumin rather than the wavelength at which it strongly absorbs but other species in the mixture do not. Many students appeared totally confused with changing units in part b., which has been a common theme in recent assessment reports. Although the principles involved had probably been practised many times using the $c_1V_1 = c_2V_2$ relationship, most students struggled to use the data correctly.

It is important for students to try to gain as many marks as possible on any examination. Therefore, if a question is particularly difficult or causes problems, the student should move on to other questions and return later to the 'problem' question. Occasionally there was evidence of students who had become so bogged down that it affected their performance on subsequent questions.

The quality of 'descriptive' responses was an issue for some questions. Students should be aware that if three marks are available for a descriptive question, three distinct, relevant and accurate points are generally required in the answer. In Question 3eii. many students struggled to give a coherent explanation of why washing the conical flask with water would have no effect on the calculated result. Similarly, many students were not able to give a clear explanation of how the boiling points of alkanes are dependent on the bonding 'between' the molecules for Question 7b. Descriptions of fractional distillation in Question 7c. varied significantly in quality.

The general performance on equation writing – Questions 5a., 7dii. and 8d. – was similar to previous years. Marks continued to be lost through inaccurate balancing and the use of incorrect formulae; for example, CO_3^- for CO_3^{2-} and $NaCO_3$ for Na_2CO_3 were surprisingly common.

Students should be reminded that practising as many examination type questions as possible is an essential part of their examination preparation. Although Assessment Reports and solutions to questions on past and practice examinations

are very helpful, the underlying issue for many students is accurate interpretation of the questions and identifying the relevant key knowledge and skills. Many students would also benefit from more experience in the effective use of reading time, particularly with respect to gaining some feel for the relative difficulty of questions in Section B.

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	Comments
1	4	3	73	21	Flame tests are a simple form of qualitative analysis used to test metallic compounds for the presence of particular metals. They provide a quick means of distinguishing the presence of different metals.
2	63	16	13	7	Molar volume = volume occupied by 1 mol. $V = \dfrac{nRT}{p}$ $= \dfrac{1 \times 8.31 \times 373}{101.3}$ $= 30.6$ L Students who selected alternatives B or C possibly used STP or SLC facts rather that carrying out the calculation.
3	3	2	86	9	The reaction rate increases when the number of fruitful collisions (collisions with energy greater than the activation energy) per second increases. Powdered Zn provides a greater surface area for reaction, leading to more fruitful collisions.
4	4	18	71	7	The greater affinity of CO for haemoglobin forces the equilibrium haemoglobin + oxygen $\rightleftharpoons$ oxyhaemoglobin to the left as the equilibrium haemoglobin + carbon monoxide $\rightleftharpoons$ carboxyhaemoglobin is established.
5	25	22	24	28	The $n(NaOH)$ required to neutralise an acid depends on the $n(H^+)$ available from the acid rather than the acid strength. So, the fact that CH_3COOH is a weak acid was not a key factor in this question. Since the same number of mole of each acid was used, the $n(NaOH)$ required would depend on whether the acid was monoprotic or diprotic. $CH_3COOH(aq)$ and $HNO_3(aq)$ are both monoprotic and would require the same $n(NaOH)$, hence the same volume of NaOH. $CH_3COOH(aq) + NaOH(aq) \rightarrow CH_3COONa(aq) + H_2O(l)$ $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$ H_2SO_4 is diprotic so requires double the $n(NaOH)$, hence double the volume of NaOH, compared to CH_3COOH and HNO_3. $H_2SO_4(aq) + 2NaOH(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$ Hence, alternative D is correct. Students who selected alternatives B and C were probably focused on the fact that CH_3COOH is a weak acid. The popularity of alternative A was surprising, as students should know that H_2SO_4 is a diprotic acid, whereas HNO_3 and CH_3COOH are monoprotic acids.
6	7	78	7	9	Since the solvent front moves the same distance for both components, $\dfrac{R_f(II)}{R_f(I)} = \dfrac{d(II)}{d(I)}$ $\dfrac{R_f(II)}{0.50} = \dfrac{3.0}{4.0}$ $R_f(II) = \dfrac{0.50 \times 3.0}{4}$ $= 0.38$

7	7	90	1	2	
8	13	6	69	12	Butyl methanoate, $HCOOCH_2CH_2CH_2CH_3$, is produced by reaction between 1-butanol ($CH_3CH_2CH_2CH_2OH$) and methanoic acid ($HCOOH$).
9	10	45	19	25	There are two (alternative B) carboxylic acids with molecular formula $C_4H_8O_2$, $CH_3CH_2CH_2COOH$ – butanoic acid $(CH_3)_2CHCOOH$ – methylpropanoic acid. This question was a simpler version of Question 3c. on the 2005 examination. It refers to the key knowledge point 'structural isomers of compounds containing one chloro, hydroxyl or carboxyl functional group (up to four-carbon compounds)'.
10	18	50	15	17	$CH_2 = CHCH_2CH_2CH_3 + HCl \rightarrow CH_3CHClCH_2CH_2CH_3$ $CH_3CHClCH_2CH_2CH_3 + OH^- \rightarrow CH_3CHOHCH_2CH_2CH_3 + Cl^-$ 2-chloropentane 2-pentanol
11	71	5	10	14	Reverse the equation and take reciprocal of K value. $2Cl(g) \rightleftharpoons Cl_2(g); K = \dfrac{1}{1.13 \times 10^{-6}}$ $= 8.85 \times 10^{-5} M^{-1}$
12	16	32	14	37	$K_2CO_3(aq) \rightarrow 2K^+(aq) + CO_3^{2-}(aq)$ $\begin{aligned} c(K^+) &= 2 \times 0.0500 \\ &= 0.100 \text{ mol L}^{-1} \\ &= 0.100 \text{ mol L}^{-1} \times 39.1 \text{ g L}^{-1} \\ &= 3.91 \text{ g L}^{-1} \end{aligned}$ Alternatively $\begin{aligned} n(K^+) \text{ in 100 mL} &= 2 \times n(K_2CO_3) \\ &= 2 \times 0.0500 \times 100 \times 10^{-3} \\ &= 1.00 \times 10^{-2} \text{ mol} \end{aligned}$ $\begin{aligned} m(K^+) \text{ in 100 mL} &= 1.00 \times 10^{-2} \times 39.1 \\ &= 0.391 \text{ g} \end{aligned}$ $m(K^+) \text{ in 1000 mL} = 3.91 \text{ g}$ $c(K^+) = 3.91 \text{ g L}^{-1}$ Alternative B reflects the calculation of the $m(K^+)$ in 100 mL of the solution rather than 1 L. Alternatives A and C both suggest an oversight of the fact that 1 mol K_2CO_3 contains 2 mol K^+ ions. Students who calculated the $n(K^+)$, but not the $c(K^+)$ as required, might almost have been on automatic pilot as soon as they read 100 mL of 0.0500 M K_2CO_3.
13	16	11	18	55	$\quad\quad\quad\quad 2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ Initially 3 mol 2 mol Reacting 3 mol 1.5 mol $\rightarrow$ 3 mol Finally 0 mol 0.5 mol 3 mol Students should be encouraged to ensure that they always check for excess when amounts of two reactants are supplied.
14	62	7	26	5	$\overset{+3\ -2}{Fe_2O_3}(s) + 3\overset{+2\ -2}{CO}(g) \rightarrow 2\overset{0}{Fe}(l) + 3\overset{+4\ -2}{CO_2}(g)$ Fe_2O_3 is reduced to Fe by CO; therefore, CO is the reductant. It is possible that the students who chose alternative C assumed that CO was the oxidant because it was oxidised.
15	3	6	5	86	
16	9	4	78	8	

17	39	14	24	32	$HCOOH(aq) \rightleftharpoons H^+(aq) + HCOO^-(aq)$; $K_a = 1.82 \times 10^{-4}$ $CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$; $K_a = 1.74 \times 10^{-5}$ Since both are weak acids (have low K_as) $[CH_3COO^-] < [CH_3COOH]$ and $[HCOO^-] < [HCOOH]$. Since the K_a for methanoic acid is greater than the K_a for ethanoic acid, more of the methanoic ionises in aqueous solution. Consequently, $[HCOO^-] > [CH_3COO^-]$ and $[HCOOH] < [CH_3COOH]$ Therefore, CH_3COOH is the species with the highest concentration. This was similar to Question 7c. on the 2005 examination. Students who chose alternative D picked up on methanoic acid being stronger but not the significance of the acidity constant values as far as the extent of reaction or position of equilibrium was concerned.
18	7	10	23	59	$A + B \to C$ $E_A = 200$ kJ mol^{-1} $A + B \to C$ $\Delta H = -120$ kJ mol^{-1} $C \to A + B$ $E_A = 200 - (-120)$ $= 320$ kJ mol^{-1} Students could be encouraged to do a quick sketch of the energy profile when supplied with ΔH and activation energy data.
19	64	17	9	9	Students should identify the repeating units in the polymer chain, each of which has a carbon–carbon double bond C=C. $-CH_2CF_2 \vert CF_2CH_2 \vert CF_2CH_2 \vert CH_2CF_2 \vert CH_2-$ $CH_2{=}CF_2$ $CF_2{=}CH_2$ $CF_2{=}CH_2$ $CH_2{=}CF_2$
20	4	35	7	54	During the polymerisation, the carboxyl (–COOH) group on one molecule may react with the hydroxyl (–OH) group on an adjacent molecule in a condensation reaction. For each n monomers that react to form the polymer chain, (n–1) ester groups are formed and (n–1) H_2O molecules are condensed out. The relative molecular mass of the polymer chain will be $1000 \times M_r(HOCH_2CH_2CH_2COOH) - 999 \times M_r(H_2O)$ $= 1000 \times 104 - 999 \times 18$ $= 104\,000 - 17\,982$ $= 86\,018$ So the approximate molar mass of the polymer is 86 000 g mol^{-1}. Over half of the students did not recognise that polymerisation involving $HOCH_2CH_2CH_2COOH$ would have to be condensation polymerisation and incorrectly treated this question as addition polymerisation.

Section B – Short-answer questions

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

Question 1

Marks	0	1	2	3	4	Average
%	16	14	28	1	42	**2.5**

	Name of liquid
A	hexene
B	ethanoic acid
C	ethanol
D	pentane

There was a good correlation between performance on this question and overall examination performance.

Question 2a.

Marks	0	1	2	Average
%	10	29	61	**1.6**

2ai.
band A

2aii.
Acceptable answers included:
- change/modify the stationary phase; for example, make the column longer or use more finely divided Al_2O_3
- change the mobile phase
- change the temperature.

Question 2b.

Marks	0	1	Average
%	30	70	**0.7**

Band A because:
- it is the band most strongly attracted/adsorbed to the stationary phase
- it moves the least distance from the origin relative to the solvent front.

The mark was awarded for the correct band with a valid explanation.

Question 2c.

Marks	0	1	Average
%	32	68	**0.7**

Band C because:
- it is the band that passes through the column fastest
- it is least strongly attracted/adsorbed to the stationary phase.

The mark was awarded for the correct band with a valid explanation.

Question 3a.

Marks	0	1	Average
%	16	84	**0.9**

$$n(Mg_2P_2O_7) = \frac{0.0352}{222.6}$$
$$= 1.58 \times 10^{-4} \text{ mol}$$

Most errors in this question involved the incorrect calculation of the molar mass.

Question 3b.

Marks	0	1	Average
%	66	34	**0.4**

$$n(P) = 2 \times n(Mg_2P_2O_7)$$
$$= 2 \times 1.58 \times 10^{-4}$$
$$= 3.16 \times 10^{-4} \text{ mol}$$

This question was not well answered as most students did not establish the link between P and $Mg_2P_2O_7$. This may have been because students struggled to interpret the data and procedures given in the question.

Question 3c.

Marks	0	1	Average
%	46	54	**0.6**

$$n(P) \text{ in fertiliser sample } = n(P) \text{ in 250 mL of solution}$$
$$= \left(\frac{3.16 \times 10^{-4}}{20}\right) \times 250$$
$$= 3.95 \times 10^{-3} \text{ mol}$$

Dividing the mass of fertiliser by the molar mass of phosphorus or phosphate was a common mistake.

Question 3d.

Marks	0	1	2	3	Average
%	32	10	16	42	**1.8**

$$n(PO_4^{3-}) = n(P)$$
$$= 3.95 \times 10^{-3} \text{ mol}$$
$$m(PO_4^{3-}) = 3.95 \times 10^{-3} \times 95.0 *$$
$$= 0.376 \text{ g}$$
$$\%PO_4^{3-} = \left(\frac{0.376}{5.97}\right) \times 100$$
$$= 6.29\% *$$

The third mark was awarded for answers that were correct to three significant figures.

A common error was to use the molar mass of P rather than PO_4^{3-}. This is an example of a question where consequential marks were available even if an earlier part of the calculation was incorrect. The large number of students who received no marks for Question 3d. suggests that the idea of 'consequential' marks should be emphasised during examination preparation. Answers such as 1.57% and 3.15% could receive three marks for Question 3d. because the error leading to these answers had occurred earlier in Question 3.

Question 3e.

Marks	0	1	2	3	4	5	Average
%	5	12	20	21	22	20	**3.1**

3ei.

Action	Calculated result would be too low	No effect on calculated result	Calculated result would be too high
A. The MgNH$_4$PO$_4$ precipitate was not washed with water.			✓
B. The conical flask had been previously washed with water but not dried.		✓	
C. A 25.00 mL pipette was unknowingly used instead of a 20.00 mL pipette.			✓
D. The mass of the fertiliser was recorded incorrectly. The recorded mass was 0.2 g higher than the actual mass.	✓		

An important part of practical exercises is for students to be able to identify the effect of possible errors on calculated results.

3eii.

The presence of water does not affect the $n(PO_4^{3-})$ or the $n(P)$ in the conical flask or the amount of fertiliser (solution) added to the flask; hence, the $m(Mg_2P_2O_7)$ or m(precipitate) is not affected.

A more detailed explanation than 'water does not react' was required to gain the mark for this question.

Question 4a.

Marks	0	1	Average
%	94	6	**0.1**

400 nm

The absorbance used for the analysis of the curcumin content should be one at which curcumin absorbs strongly but the other colouring agent present, bright blue, does not. Curcumin absorbs most strongly between 400 nm and 500 nm. Of the wavelengths suggested within this span, bright blue would absorb least, and have less impact, at 400 nm.

Most students focused on the wavelength at which curcumin displays maximum absorbance, without considering the absorbance of bright blue at that wavelength. The data provided probably looked different to most previous experiences with UV-visible spectroscopy, perhaps leading to the selection of the maximum wavelength at which curcumin absorbs, rather than a wavelength at which 'only' curcumin absorbs strongly.

Question 4b.

Marks	0	1	2	3	4	5	6	7	Average
%	18	10	25	12	11	8	7	8	**2.9**

4bi.

$$n(\text{curcumin}) \text{ in stock solution} = \frac{0.100}{368}$$
$$= 2.72 \times 10^{-4} \text{ mol } *$$

$$c(\text{curcumin}) \text{ in stock solution} = \frac{2.72 \times 10^{-4}}{250.0 \times 10^{-3}}$$
$$= 1.09 \times 10^{-3} \text{ mol L}^{-1}*$$

Alternatively:

$$m(\text{curcumin}) \text{ in 1 L} = 0.400 \text{ g } *$$

$$n(\text{curcumin}) \text{ in 1 L} = \frac{0.400}{368}$$
$$= 1.09 \times 10^{-3} \text{ mol } *$$
$$c(\text{curcumin}) = 1.09 \times 10^{-3} \text{ mol L}^{-1}$$

Although part bi. was generally well-handled, a number of students were unable to calculate the molar concentration of curcumin in the stock solution from the supplied data.

4bii.
m(curcumin) in standard 3 $= m$(curcumin) in 10 mL stock solution

$$= \left(\frac{0.400}{1000}\right) \times 10 \; or \; \left(\frac{0.100}{250}\right) \times 10$$

$$= 4.00 \times 10^{-3} \text{ g}$$

c(curcumin) in standard 3 $= 1.00 \times 10^{-2}$ g L^{-1}

$$V\text{(stock solution)} = \frac{m(\text{curcumin})}{c(\text{curcumin})}$$

$$= \frac{4.00 \times 10^{-3} \text{ g}}{1.00 \times 10^{-2} \text{ g L}^{-1}}$$

$$= 0.400 \text{ L}$$
$$= 400 \text{ mL *}$$
$$V\text{(water)} = 400 - 10$$
$$= 390 \text{ mL *}$$

Alternatively; using $c_2V_2 = c_1V_1$:

$$c\text{(curcumin) in standard 3} = \frac{1.00 \times 10^{-2} \text{ g L}^{-1}}{368 \text{ g mol}^{-1}}$$

$$= 2.72 \times 10^{-5} \text{ mol L}^{-1}$$

n(curcumin) in 'y' L of standard 3 $= n$(curcumin) in 10.0 mL of stock

$$2.72 \times 10^{-5} \times \text{'y'} = 1.09 \times 10^{-3} \times 10.0 \times 10^{-3}$$

$$\text{'y'} = \left(\frac{1.09 \times 10^{-3} \times 10.0 \times 10^{-3}}{2.72 \times 10^{-5}}\right)$$

$$= 0.401 \text{ L}$$
$$= 401 \text{ mL *}$$
$$V\text{(water)} = 391 \text{ mL *}$$

One mark was awarded for the volume of solution and the second mark for subtracting 10 to get the volume of water.

Many students who used $c_2V_2 = c_1V_1$, which was applicable because the amount of curcumin present does not change as a result of the dilution, ran into difficulty because they mixed the g L^{-1} concentration of standard 3 with the mol L^{-1} concentration calculated for the stock solution in part bi. Many who did calculate a volume by this method seemed to presume they had calculated the volume of water rather than the volume of solution.

4biii.
From the graph, an absorbance of 0.170 corresponds to c(curcumin) = 9.00×10^{-3} g L^{-1} *
Since the curcumin from the peas was extracted into 100 mL of solution,
m(curcumin) in peas sample $= 0.100$ L * $\times 9.00 \times 10^{-3}$ g L^{-1}

$$= 9.00 \times 10^{-4} \text{ g}$$
$$= (0.900 \text{ mg})$$

$$\text{curcumin content} = \frac{m(\text{curcumin}) \text{ in mg}}{m(\text{peas}) \text{ in g}}$$

$$= \frac{0.900}{9.780}$$

$$= 0.0920 \text{ * mg/g}$$

Alternatively:

9.780 g peas in 100 mL is equivalent to 97.80 g peas in 1 L

m(curcumin) in 1 L = 9.00×10^{-3} g $\rightarrow$ 9.00 mg

$$\text{curcumin content} = \frac{9.00}{97.80} \, *$$
$$= 0.0920 \, * \text{ mg/g}$$

The first mark was awarded for correctly reading the data off the graph. Consequential marks were awarded to students who read the calibration curve incorrectly, but used this reading correctly through the rest of the question.
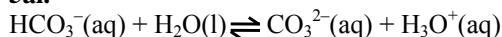
The calibration graph was challenging for many students. 'Unusual' graph readings suggested that students had issues with linking the information on the horizontal axis to the supplied concentration data. An associated error was giving the graph reading in mol L^{-1}.

Question 4 proved to be the most challenging question in Section B, with students finding parts bii. and biii. particularly difficult.

Question 5a.

Marks	0	1	2	Average
%	22	14	63	**1.5**

5ai.

$HCO_3^-(aq) + H_2O(l) \rightleftharpoons CO_3^{2-}(aq) + H_3O^+(aq)$

or

$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq)$

5aii.

$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^-(aq)$

or

$HCO_3^-(aq) \rightleftharpoons CO_2(g \text{ or } aq) + OH^-(aq)$
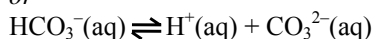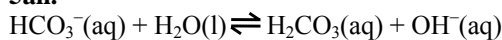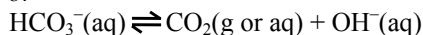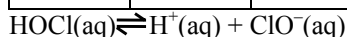
Although the majority of students handled this fundamental question well, many marks were lost due to the use of incorrect chemical formulae.

Question 5b.

Marks	0	1	2	3	Average
%	37	7	6	50	**1.8**

$HOCl(aq) \rightleftharpoons H^+(aq) + ClO^-(aq)$

$$K_a = \frac{\left[H^+\right]\left[ClO^-\right]}{\left[HOCl\right]} \, or \, \frac{\left[H_3O^+\right]\left[ClO^-\right]}{\left[HOCl\right]}$$

$$= \frac{\left[H^+\right]^2}{\left[HOCl\right]}$$

$$3.0 \times 10^{-8} = \frac{\left[H^+\right]^2}{0.50} \, *$$

$$[H^+]^2 = 0.50 \times 3.0 \times 10^{-8}$$

$$[H^+] = \sqrt{\left(0.50 \times 3.0 \times 10^{-8}\right)}$$

$$= 1.2 \times 10^{-4} \text{ M } *$$

$$pH = -\log(1.2 \times 10^{-4})$$

$$= 3.9*$$

A common error was to attempt to calculate the pH directly from the [HOCl] or the K_a value.

Question 5c.

Marks	0	1	2	Average
%	31	15	54	**1.3**

5ci.

$[OH^-] = 10^{-pOH}$

$\qquad = 10^{-3}$ M

5cii.

$[H^+] = \dfrac{10^{-14}}{10^{-3}}$

$\qquad = 10^{-11}$ M

The mark was awarded for the correct use of $[H^+][OH^-] = 10^{14}$.

Question 6a.

Marks	0	1	2	3	4	5	6	7	8	Average
%	2	0	1	4	7	14	18	22	33	**6.4**

Change to the equilibrium	I. Colour at new equilibrium compared with initial equilibrium		II. $[Fe^{3+}]$ at new equilibrium compared with initial equilibrium	
	less red	more red	decreased	increased
Sample 1: 1 drop of a concentrated solution of $Ag^+(aq)$ is added, which forms a AgSCN precipitate	✓			✓
Sample 2: 1 drop of a concentrated solution of $Fe^{3+}(aq)$ is added		✓		✓
Sample 3: 1 drop of a concentrated solution of $HPO_4^{2-}(aq)$ is added, which forms colourless $FeHPO_4^+(aq)$	✓		✓	
Sample 4: Addition of a large volume of water	✓		✓	

This question was well handled, which was expected as many students would probably have investigated this system during their equilibrium-related practical exercises.

Question 6b.

Marks	0	1	Average
%	0	62	**0.7**
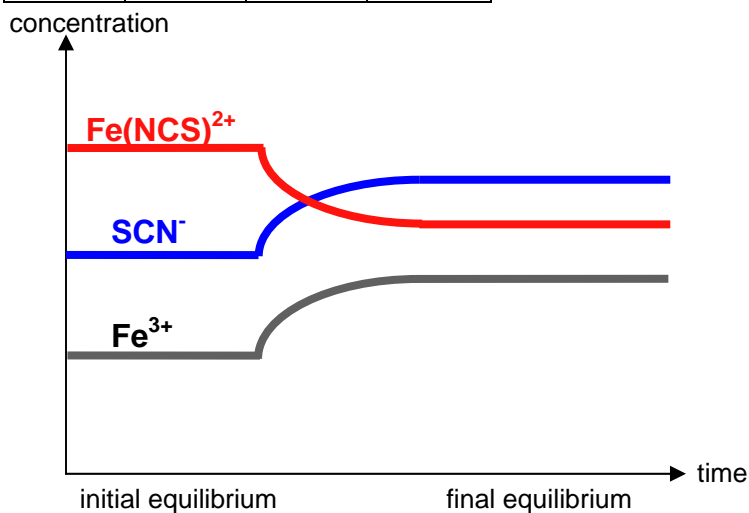
To receive the mark, students had to show the gradual concentration changes levelling off at the 'final equilibrium'. The lines did not have to cross over.

Question 7a.

Marks	0	1	Average
%	15	85	**0.9**

Nonane, C_9H_{20}

Question 7b.

Marks	0	1	Average
%	58	42	**0.5**

Shorter chain (smaller) alkanes have weaker bonding/dispersion forces between the molecules.

This question was not well answered. A lack of understanding of the bonding that directly influences boiling temperature was evident. Many students did not explain that it is the bonding **between** the molecules which is the issue. Statements such as 'the longer chain alkanes have more bonds or stronger bonds' were insufficient. A number of students incorrectly considered the number of bonds in the molecules of the long chain alkanes to be the key factor rather the relative strength of the bonding between the molecules.

Question 7c.

Marks	0	1	2	3	Average
%	24	20	29	27	**1.7**

Acceptable points included the following.
- The temperature decreases up the tower/there is a temperature gradient in the tower.
- Lighter (lower boiling temperature) fractions are collected near the top of the tower and heavier (higher boiling temperature) fractions near the bottom.
- Crude oil is separated into fractions. Each fraction consists of molecules within a specific mass range, with similar boiling temperatures.
- Fractions condense on strategically placed trays. Trays contain bubble caps which force the vapour to travel through condensed liquid.
- A mixture of vapour and liquid from heated crude oil is added near the bottom of the tower.
- The compounds in the vapour rise up until they condense at temperatures below their boiling temperatures.

To be awarded full marks, students had to make **three** distinct points and refer to fractions (by mentioning or showing where different fractions are collected) and the temperature profile in the tower; that is, that it decreases up the tower. If a diagram was used, it needed to include annotations consistent with 'fractions', 'temperature decrease up the tower' and one other distinct point.

The majority of students demonstrated a good understanding of the process; however, there was evidence of confusion between cracking and fractional distillation.

Question 7d.

Marks	0	1	2	3	4	Average
%	19	17	14	24	26	**2.3**

7di.
Acceptable responses included
- C_3H_6 / $CH_3CH=CH_2$
- H_2
- C_2H_4 / $CH_2=CH_2$
- CH_4
- C_2H_2
- C_3H_4

The combination of C_2H_6 and CH_2 was surprisingly common. Students should be aware that the products of cracking may include an alkene, a smaller alkane and, sometimes, H_2. The mark allocation was two marks for four correct formulas, or one mark for two or three correct formulas.

7dii.
Acceptable responses included the following.
- $CH_2 = CH_2(g) + H_2(g) \rightarrow CH_3CH_3(g)$ *or* $C_2H_4 + H_2 \rightarrow C_2H_6$
- $CH_2 = CH_2(g) + Br_2(g) \rightarrow CH_2BrCH_2Br(g)$ *or* $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$
  (or with Cl_2, I_2, or F_2 instead of Br_2)
- $CH_2=CH_2(g) + HCl(g) \rightarrow CH_3CH_2Cl(g)$ *or* $C_2H_4 + HCl \rightarrow C_2H_5Cl$
  (or with HF, HI, or HBr instead of HCC)
- $CH_2=CH_2(g) + H_2O(g) \rightarrow CH_3CH_2OH(g)$ *or* $C_2H_4 + H_2O \rightarrow C_2H_6O$
- $nCH_2=CH_2 \rightarrow (CH_2-CH_2)_n$ *or* $nC_2H_4 \rightarrow (C_2H_4)_n$
- $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$
- $C_2H_4(g) + 2O_2(g) \rightarrow 2CO(g) + 2H_2O(g)$

There was evidence of some confusion between addition reactions characteristic of ethene and substitution reactions characteristic of ethane.

Question 8a.

Marks	0	1	Average
%	39	61	**0.7**

Either of:
- vanadium pentoxide
- vanadium (V) oxide
- V_2O_5.

Question 8b.

Marks	0	1	Average
%	28	72	**0.8**

Either of:
- at 300° the rate of reaction is too slow
- at 450° a good yield is obtained but with a faster rate of reaction.

Question 8c.

Marks	0	1	2	Average
%	21	27	52	**1.4**

8ci.
Le Chatelier's principle suggests that higher pressures will cause the equilibrium to adjust by moving to lower the pressure by favouring the side with fewer particles/moles so the amount of SO_3 present at equilibrium is greater.

8cii.
The yield is very good/economical at low pressures so the expense of high pressures is not necessary.

Question 8d.

| Marks	0	1	2	3	4	5	Average
%	20	15	16	18	18	13	**2.5**

8di.
- $H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + CO_2(g \text{ or } aq) + H_2O(l)$
- $H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow Na_2SO_4(aq) + H_2CO_3(aq)$
- $2H^+(aq) + CO_3^{2-}(aq) \rightarrow CO_2(g \text{ or } aq) + H_2O(l)$
- $2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2CO_3(aq)$
- $H_2SO_4(aq) + Na_2CO_3(aq) \rightarrow NaHSO_4(aq) + NaHCO_3(aq)$
- $H^+(aq) + CO_3^{2-}(aq) \rightarrow HCO_3^-(aq)$

The incorrect formulae $NaCO_3$ and $NaSO_4$ were surprisingly common. Students at this level should be familiar with the charge on common ions such as Na^+, CO_3^{2-} and SO_4^{2-}.

8dii.
$SO_3(g) + H_2SO_4(l) \rightarrow H_2S_2O_7(l)$
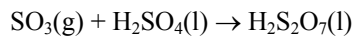
8diii.
- $Zn(s) + SO_4^{2-}(aq) + 4H^+(aq) \rightarrow Zn^{2+}(aq) + SO_2(g) + 2H_2O(l)$
- $Zn(s) + H_2SO_4(aq) + 2H^+(aq) \rightarrow Zn^{2+}(aq) + SO_2(g) + 2H_2O(l)$
- $Zn(s) + 2H_2SO_4(aq) \rightarrow ZnSO_4(aq) + SO_2(g) + 2H_2O(l)$

One mark was awarded for correctly identifying SO_2 as a product and one mark for giving a correctly balanced equation.

Students who struggled to balance the equation would have benefited from first writing the two half-equations; that is, $Zn \rightarrow Zn^{2+}(aq) + 2e^-$ and $SO_4^{2-} + 4H^+(aq) + 4e^- \rightarrow SO_2(g) + 2H_2O(l)$.

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