2009
Assessment
Report

VICTORIAN CURRICULUM AND ASSESSMENT AUTHORITY

2009 Chemistry GA 3: Examination 2

GENERAL COMMENTS

The November examination proved less challenging for students than the June examination. Most students appeared to finish the examination comfortably.

Overall performance on Section A of the exam was strong, with only four questions with less than 50 per cent correct responses. The emphasis in the 2008 Assessment Report that multiple-choice questions are very much about **application** of understandings rather than mere factual recall seems to have been well heeded.

In Section A, Question 2 showed that the distinction between the relative effects on the reaction rate of ‘particles having more energy’ and ‘more particles having energy greater than the activation energy’ at a higher temperature remains challenging for students. Question 10 proved to be the most challenging question in this section with nearly 70 per cent of students selecting a response consistent with not converting J to kJ and/or using an incorrect total volume of solution or number of mole in the calculations. Question 12 was surprisingly poorly handled given that ‘positive to positive’ and ‘negative to negative’ is a fundamental rule of recharging. Question 16 was particularly revealing. While it is expected that most students know that fuel cells are more efficient in converting chemical energy to electrical energy than fossil fuel power stations, less than 50 per cent of students seemed to realise that fuel cells are not 100 per cent efficient in that conversion.

Section B was generally well handled but particular aspects of some questions proved challenging. Question 1 tested students’ ability to use, and their understanding of the limitations of, the electrochemical series. Students were asked to use the series to write a balanced **overall** equation showing H_2O_2 acting as a reductant. Many students simply transcribed a half equation, almost as if they had not previously used the electrochemical series to develop overall equations. Students are expected to know that a key limitation of the electrochemical series is that it gives no indication of reaction rate. A commonly expressed reason why a predicted reaction may not be observed was ‘non-standard’ conditions. Students should be encouraged to be more specific in such responses since higher than standard temperatures, concentrations or pressures may make it more likely that the predicted reaction may be observed since they will increase the rate of reaction. Students should consider the context of questions when providing descriptive answers, and not simply restate learned generalisations.

Question 2, and to some extent Question 3, emphasised the need for students to be able to make connections between concepts, process information and apply understandings to familiar and new concepts. Interpretation of a rate-time graph challenged most students. Students should be able to write a balanced equilibrium equation for the hydrolysis of any weak acid, although the variety of different formulae given for the ammonium ion suggested that many students did not refer to the data book. Most students missed the link between writing the K_a expression for the hydrolysis of $NH_4^+(aq)$ in Question 2ci. and determining the mass of NH_4NO_3 in Question 2ciii., perhaps again suggesting that they were not drawn to the data book. Equilibrium calculations also proved challenging for many students in Question 3c.

The calculations in Question 4 were generally well done, although units proved a source of confusion for some students. Responses to Question 4e. suggested that a significant proportion of students were not expecting a question on biofuels, perhaps because they had also covered biofuels in Unit 3. However, renewable fuels are part of the key knowledge in Unit 4. In Question 4f., the simple response ‘more energy’ was given as an advantage of nuclear fission. Students must realise that such superficial answers are unlikely to be awarded any marks.

In Question 5, students needed to apply their understandings to new or different examples. All students should come to the examination well versed in the principles of electrochemistry. However, the electrochemical cell to which they had to apply this knowledge was different to the examples they would have encountered in class and textbooks.

Responses to Question 6a. indicated that the majority of students had a good understanding of the fundamentals of rates and equilibrium.

Students were generally very familiar with the properties and uses of the selected chemical they had studied in Unit 4. However, careless responses deny students relatively easy marks. To suggest that a use of sulfuric acid is as a fertiliser does not suggest full awareness of its properties. It is important that students be able to distinguish between a chemical property and the use of a chemical. Question 6ciii. on this exam and Question 6d. on the November 2008 exam may provide useful preparation for future students.

Question 7a. was poorly done and it appeared that some students did not read the question carefully. Question 7b. was well done, which is an indication of good competence in calculations associated with Faraday's laws.

Question 7b. stated that the answer should be expressed to an appropriate number of significant figures and in general this was done very well. However, it is important that students do not round off too much during a multi-step calculation. Some students gave the answer to three significant figures but rounded off so severely that their final answer was not within a reasonable range. Significant figures were not always as well handled in other calculations throughout the examination. It appeared that some students may have assumed that unless significant figures are specifically mentioned in a question they are not important. Students should take note of the first dot point in the Instructions for Section B on the examination: 'give simplified answers with an appropriate number of significant figures to all numerical questions ... '

Overall, student performance showed that the examination was very accessible but contained enough challenging questions to accurately rank student performance. The data book should have been more effectively used by more students. Even if students feel confident of a value, for example, the specific heat of water, a quick check can reinforce the units. Terms such as 'weak acid', 'electrochemical series' and 'enthalpy of combustion' should prompt students to access the data book.

Students are reminded that they must read questions carefully and ensure they answer them as asked.

Teachers are encouraged to use the discussion throughout this report and statistical data provided to schools on how individual classes performed on each question on the examination in evaluating how their students performed, and use this in planning for the next cohort of students.

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	97	1	1	2	
2	20	3	28	49	As the temperature increases, so does the kinetic energy of the particles and hence the faster-moving particles collide more frequently. However, 'more frequent collisions' is not the determining factor in increasing the rate of reaction. Rather it is an increase in 'fruitful collisions', that is, collisions involving particles with energy greater than the activation energy. The increase in the number of particles with energy greater than the activation energy is more significant than the increase in the frequency of collisions between faster-moving particles. Students who chose options A and C did not make this subtle distinction. While more frequent collisions will occur as the temperature is raised, the rate increase is mainly due to the increased proportion of 'fruitful collisions'. Future students may benefit from a comparison of this question with Question 4 in Section A of the November 2008 Chemistry examination.
3	7	7	79	7	
4	88	7	4	1	

Question	% A	% B	% C	% D	Comments
5	6	9	26	59	To check the direction the reaction is moving in heading towards equilibrium, compare the reaction quotient (*Q*) with the equilibrium constant. $Q = [HF]^2 / \{[H_2][F_2]\}$ $= 0.400^2 / \{0.0200 \times 0.0100\}$ $= 800$ Since $Q > K$ (313), the reverse reaction dominates as *Q* decreases on the way to equilibrium. Hence, [HF] will be < 0.400 M at equilibrium. The selection of option B or C assumes that the forward reaction is dominating as the system moves to equilibrium.
6	3	21	10	66	Since K is lower at the higher temperature, the forward reaction is exothermic. The popularity of option B was unexpected given that the K values suggest that if an equilibrium mixture at 25°C is heated to 40°C, the position of equilibrium will shift to the left, giving a higher equilibrium concentration of N_2O at 40°C.
7	63	16	13	7	When an acidic solution is diluted the pH increases, and when a basic solution is diluted the pH decreases. When 10.0 mL of 0.100 M HCl(aq) is diluted to 1.00 L at 25°C, the pH increases from 1 to 3. When 10.0 mL of 0.100 M KOH(aq) is diluted to 1.00 L at 25°C, the pH decreases from 13 to 11.
8	8	55	23	14	The graph showed that K_w increases as the temperature increases. This is consistent with the self ionisation of water equilibrium, that is, $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ moving to the right as temperature increases and the $[H_3O^+]$ and $[OH^-]$ increase. The water remains neutral but the pH decreases. Students should be aware that 'pure' water has a pH of 7 at 25°C but is neutral at all temperatures.
9	11	62	12	15	Energy required to heat water to its boiling temperature is determined using the specific heat of water. This was given in the data book. $E = 4.18\ J\ g^{-1}\ °C^{-1} \times m(H_2O) \times \Delta T$ Using the density of water, also given in the data book, 1.00 L of water has a mass of 1.00×10^3 g. $E = 4.18 \times 1.00 \times 10^3 \times (100 - 20)$ $= 3.34 \times 10^5$ J = 334 kJ. From Table 13 of the data book it could be deduced that 0.10 mol $C_4H_{10} \rightarrow$ 287 kJ 0.10 mol $C_5H_{12} \rightarrow$ 351 kJ 0.10 mol $C_6H_{14} \rightarrow$ 416 kJ Hence, both 0.10 mol C_5H_{12} and 0.10 mol C_6H_{14} release enough energy to heat the water to its boiling temperature if all of the energy released is transferred to the water.

10	19	31	32	18	Energy released during the reaction raises the temperature of **100 mL** of solution: E = 4.18 J g^{-1} °C^{-1} x m(solution) x ΔT = 4.18 x 100 x 3.5 = 1463 J = 1.463 x 10^3 kJ. ΔH is determined from the energy released by one mole of KOH or HCl. Energy per mole = 1.463x10^3 kJ/0.025 mol = 59 kJ mol^{-1} Since the reaction is exothermic, ΔH = -59 kJ mol^{-1}. Possible errors leading to the choice of options A, C or D could have included: • calculating energy released for 50 mL of solution rather than 100 mL – options A and C • dividing the energy released by 0.050 mol rather than 0.025 mol – options A and C • not converting the energy from J to kJ – options C and D.
11	9	13	20	58	Since electrons move spontaneously from the strongest reductant to the strongest oxidant, then, according to the electrode signs, Co^{2+}(aq) is a stronger oxidant than Cd^{2+}(aq) and Mn3+(aq) is a stronger oxidant than Co^{2+}(aq). Hence, on the electrochemical series Mn^{3+}(aq) is above Co^{2+}(aq), which is above Cd^{2+}(aq). $Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$ $Co^{2+}(aq) + 2e^- \rightleftharpoons Co(s)$ $Cd^{2+}(aq) + 2e^- \rightleftharpoons Cd(s)$ Mn^{2+}(aq) will not react spontaneously with Co^{2+}(aq) because the reductant Mn^{2+}(aq) is higher on the electrochemical series than the oxidant Co^{2+}(aq). Option C described the reaction between the strongest oxidant, Mn^{3+}(aq), and strongest reductant, Cd(s). Students who chose option C may have overlooked the word ‘not’ in the question.
12	7	13	42	38	The fundamental rule of recharging is that the positive terminal of the power supply is connected to the positive electrode of the cell (and negative terminal to negative electrode) and a voltage greater than the discharge voltage of the cell is applied. It was surprising that many students did not choose a (+) to (+) and (-) to (-) option.
13	65	10	9	16	X: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ Oxidation at the anode. Y: $O_2(g) + 2H_2O(l) + 2e^- \rightarrow 4OH^-(aq)$ Reduction at the cathode.
14	52	25	18	5	$Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ $Q = It$ = 2.0x10^{-6} x 1 = 2.0x10^{-6} C $n(e^-) = Q / F$ = 2.0x10^{-6} / 96500 = 2.07x10^{-11} mol n(Mg) = ½ x 2.07x10^{-11} = **1.0x10^{-11}** mol Options B and C are consistent with mole ratio errors in determining the n(Mg) from the n(e^-).

15	56	20	12	12	CH_3OH is the fuel and O_2 is the oxidant. The fuel is oxidised at the negative electrode, according to the half equation $CH_3OH(l) + H_2O(l) \rightarrow CO_2(g) + 6H+(aq) + 6e-$. O_2 is reduced at the (+) electrode. The selection of option B suggests many students did not correctly link the sites of oxidation and reduction with electrode polarity.
16	15	18	43	24	Fuel cells are not 100 per cent efficient in the conversion of chemical energy to electrical energy. Some chemical energy is converted into thermal energy. This question proved more challenging for students than expected. Students should be aware that, while fuel cells are more efficient in the conversion of chemical energy to thermal energy than using the same fuel in a power station, they are not 100 per cent efficient.
17	70	19	6	5	The half equation can be deduced from the overall equation. Oxidation: $NADH(aq) \rightarrow NAD^+(aq) + H^+(aq) + 2e^-$ Reduction: $O_2(g) + 2H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ Some students referred back to the content of this question in Question 4e. of Section B, but tended to incorrectly identify NAD^+ rather than NADH as a biochemical fuel.
18	2	86	4	8	
19	12	21	14	54	Species present in the mixture: $K^+(aq)$, $I^-(aq)$, $Ca^{2+}(aq)$, $Br^-(aq)$, $H_2O(l)$ On the basis of the electrochemical species $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ $Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$ $I_2(aq) + 2e^- \rightarrow 2I^-(aq)$ $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ $Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$ $K^+(aq) + e^- \rightarrow K(s)$ The strongest reductant present in the mixture, I-(aq), is oxidised at the anode according to $2I^-(aq) \rightarrow I_2(aq) + 2e^-$. It was concerning that 21 per cent of students selected a reduction half equation for the reaction occurring at the anode (option B).
20	7	12	19	61	$Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$ $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2\mathbf{H_2O}(l)$ $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$ $2\mathbf{H_2O}(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ $\mathbf{Li^+}(aq) + e^- \rightarrow Li(s)$ The electrochemical series indicates that an aqueous solution cannot be used because H_2O is a stronger oxidant than Li^+ and would be preferentially reduced at the cathode. An Fe rod cannot be used as the anode because Fe is a stronger reductant than Cl^- and would be preferentially oxidised.

Section B – Short-answer questions

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

Question 1a.

Marks	0	1	2	Average
%	65	5	30	0.7

One of the following full equations was required:

- $\mathbf{F_2(g)} + H_2O_2(aq) \rightarrow \mathbf{2F^-(aq)} + O_2(g) + 2H^+(aq)$
- $2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$
- $\mathbf{2Au^+(aq)} + H_2O_2(aq) \rightarrow \mathbf{2Au(s)} + O_2(g) + 2H^+(aq)$
- $\mathbf{Cl_2(g)} + H_2O_2(aq) \rightarrow \mathbf{2Cl^-(aq)} + O_2(g) + 2H^+(aq)$
- $\mathbf{Br_2(l)} + H_2O_2(aq) \rightarrow \mathbf{2Br^-(aq)} + O_2(g) + 2H^+(aq)$
- $\mathbf{2Ag^+(aq)} + H_2O_2(aq) \rightarrow \mathbf{2Ag(s)} + O_2(g) + 2H^+(aq)$
- $\mathbf{2Fe^{3+}(aq)} + H_2O_2(aq) \rightarrow \mathbf{2Fe^{2+}(aq)} + O_2(g) + 2H^+(aq)$.

That is, the oxidant had be higher on the electrochemical series than $O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O_2(aq)$.

Many students simply wrote a half equation showing either the oxidation or reduction of $H_2O_2(aq)$.

Question 1b.

Marks	0	1	Average
%	50	50	0.5

Acceptable reponses included:

- the rate of reaction was too slow
- the electrochemical series gives no indication of reaction rate.

Many responses to this question included statements such as 'non-standard conditions' or 'not at SLC', as if **any** conditions other than the 25°C, 1M and 101.3 kPa associated with the electrochemical series could be the reason for reaction not being observed. These answers do not show understanding. Better reponses referred to temperature less than 25°C, c($CuSO_4$) less than 1 M or p(H_2) less than 101.3 kPa.

Question 2ai–ii.

Marks	0	1	2	3	Average
%	6	21	21	52	2.2

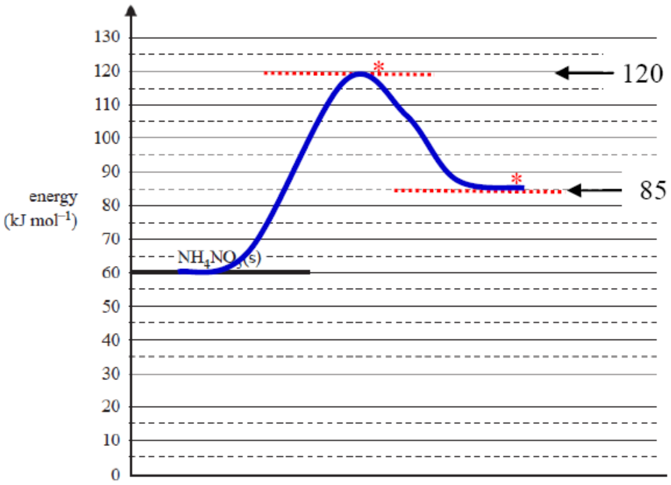
2ai.

Acceptable responses included:

- minimum amount of energy needed for reaction to occur
- minimum amount of energy colliding particles must have for reaction
- minimum amount of energy needed to break bonds in reactants.

Most students were able to define activation energy.

2aii.



In this question the accurate use of the activation energy proved challenging for students, with the most common error being using 35 kJ mol^{-1} as the activation energy of the forward reaction. Endothermic profiles were relatively common, suggesting that students focused on the ‘reverse’ reaction, despite NH_4NO_3(s) being the reactant on the profile.

Question 2bi-iii.

Marks	0	1	2	3	4	Average
%	19	33	28	12	7	1.6

2bi.

$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$*

A surprising number of students did not include equilibrium arrows. Incorrect formulae for the ammonium ion indicated that many students did not automatically link weak acids with the data book.

2bii.

The most likely change at t_2 was a decrease in product concentration. Removal of NH_3 or removal of H_3O^+ was also acceptable.

The rate of reverse reaction decreases due to a drop in product concentration/number of collisions, and then increases (and the rate of the forward reaction decreases) as the system returns to equilibrium*.

This question proved particularly challenging for many students. While a reasonable proportion of students suggested a sensible ‘change’, most struggled to give a coherent explanation of why the rate of the back reaction is affected. It appeared that many students read the graph as a ‘concentration-time’ graph and attempted to explain the changes in terms of Le Chatelier’s principle rather than factors that affect reaction rate.

A significant number of students suggested ‘dilution’ as the cause of the change. This was accepted on the basis that the graph did not show the units for rate. On the basis of rate expressed in mol L^{-1} s^{-1} , this response is not correct but it does have credence in this situation if the rate is expressed in terms of number of collisions per second.

2biii.

Equal to*

A significant number of students suggested that the equilibrium constant would change, seemingly ignoring the constant temperature highlighted in the question.

Question 2ci–iii.

Marks	0	1	2	3	4	5	Average
%	22	17	18	13	9	21	2.3

2ci.
Any one of:

- $K_a = [H_3O^+][NH_3] / [NH_4^+]$
- $K_a = [H^+][NH_3] / [NH_4^+]$
- $[H_3O^+][NH_3] / [NH_4^+] = 5.6\text{x}10^{-10}$.

Student performance in this question indicated that most students were not automatically directed to the data book by the reference to the acidity constant of NH_4^+. Students should realise that the data book is more than an optional extra; realising when to refer to it is an integral part of the examination.

2cii.
$[H_3O^+] = 10^{-5.04}$
$= \mathbf{9.1\text{x}10^{-6}*}$ mol L^{-1}

If students are asked to calculate the $[H_3O^+]$ from the pH, stating the answer as 10^{-pH} is not enough.

2ciii.
$5.6\text{x}10^{-10} = (9.1\text{x}10^{-6})^2 / [NH_4^+]*$
$[NH_4^+] = (9.1\text{x}10^{-6})^2 / 5.6\text{x}10^{-10}$
$= 0.148 * \text{M}$
$n(NH_4NO_3) = n(NH_4^+)$
$= 0.148 \text{ x } 300\text{x}10^{-3}$
$= 0.0444$ mol
$m(NH_4NO_3) = 0.0444 \text{ x } 80.0$
$= \mathbf{3.6*}$ g

Most students seemed to incorrectly assume that the $[NH_4^+]$ was the same as the $[H_3O^+]$ calculated in Question 2cii. and used it to calculate the $n(NH_4NO_3)$. Many of these students ended up with an answer of $2.2\text{x}10^{-4}$ g of NH_4NO_3. The fact that the pack contained a bag of water inside a ‘larger’ bag of NH_4NO_3 should have indicated that this answer was unrealistic.

Question 3a.

Marks	0	1	Average
%	21	79	0.8

Any one of:

- $K = [CH_3OCH_3][H_2O] / [CH_3OH]^2$
- $5.74 = [CH_3OCH_3][H_2O] / [CH_3OH]^2$
- $[CH_3OCH_3][H_2O] / [CH_3OH]^2$.

The most common error was leaving $[H_2O]$ out of the equilibrium expression.

Question 3b.

Marks	0	1	Average
%	31	69	0.7

$2CH_3OH(g) \rightleftharpoons CH_3OCH_3(g) + H_2O(g); K = 5.74$
$CH_3OCH_3(g) + H_2O(g) \rightleftharpoons 2CH_3OH(g);$
$K = 1 / 5.74$
$= \mathbf{0.174} *$

A surprising number of students left the answer as 1/5.74 and did not calculate it out.

Question 3ci–iii.

Marks	0	1	2	3	4	5	Average
%	12	31	15	15	14	13	2.3

3ci.

$[CH_3OH] = 0.340 / 20.0$
$= \mathbf{0.0170}$ * (M)

3cii.

$[CH_3OCH_3] = [H_2O]$
$5.74 = [CH_3OCH_3]^2 / (0.0170)^2$
$[CH_3OCH_3]^2 = 5.74 \times (0.0170)^2$
$[CH_3OCH_3] = \sqrt{[5.74 \times (0.0170)^2]}$*
$= 0.0407$ M
$n(CH_3OCH_3) = 0.0407 \times 20.0$
$= \mathbf{0.815}$* (mol)

Many students struggled with the mathematics in this question, mainly through not squaring the $[CH_3OH]$ or not realising that since the equilibrium $[CH_3OCH_3]$ is the same as the equilibrium $[H_2O]$ it was necessary to take the square root.

3ciii.

$n(CH_3OH)$ reacted $= 2 \times n(CH_3OCH_3)$
$= 2 \times 0.815$*
$= 1.630$ (mol)
$n(CH_3OH)$ at eqm = 0.340 mol
$n(CH_3OH)$ initially = 1.630 + 0.340*
$= \mathbf{1.970}$ (mol)

This question was well done, with a good proportion of students recognising that they simply needed to double their answer to Question 3cii. and add the $n(CH_3OH)$ at equilibrium – this was given in the stem of the question.

Question 4a.

Marks	0	1	2	3	Average
%	11	5	22	62	**2.4**

$CF = VIt/\Delta T$
$= 5.61 \times 4.40 \times 240$*$/1.75$
$= \mathbf{3.39 \times 10^3\ J°C^{-1}}$** or 3.39×10^3 J K^{-1} or 3.39 kJ°C^{-1} or 3.39 kJ K^{-1}

The third mark in this question was awarded for the correct units. Most students who scored two marks gave incorrect units.

Question 4b.

Marks	0	1	Average
%	44	56	**0.6**

$E = 3.39 \times 6.19$*
$= \mathbf{21.0}$ (kJ)

Many students calculated, and tried to use, the n(methyl palmitate). Others seemed to confuse joules and kilojoules.

Question 4c.

Marks	0	1	2	Average
%	38	12	50	**1.2**

n(methyl palmitate) = 0.529 / 270
$= 1.96 \times 10^{-3}$* (mol)
Energy per mol = $21.0 / 1.96 \times 10^{-3}$
$= \mathbf{1.07 \times 10^4}$* (kJ)

Poor use of significant figures in this question suggested that students had difficulties with scientific notation.

Question 4d.

Marks	0	1	2	Average
%	35	32	33	1

ΔH = (-) 1.07x10^4 x 2
= **-2.14x10^4** * (kJ mol^{-1})

Students simply had to double their answer to Question 4c. and include a negative sign. Many students did not include a negative sign.

Question 4ei–ii.

Marks	0	1	2	3	Average
%	32	29	23	17	1.3

In Question 4ei., one mark was awarded for a recognised biofuel and one mark for its source. In Question 4eii., the mark was awarded for a 'common-sense' answer. However, CO_2 production was not accepted as this disadvantage is common to both fossil fuels and biochemical fuels.

A number of students referred to Question 17 in Section A, in which the oxidation of NADH in a biochemical fuel cell was described. Hence, NADH was accepted as a biochemical fuel. Unfortunately most students who sought recourse in that question identified NAD^+, which is the product of the oxidation of the fuel. There was also acceptance of glucose as a biochemical fuel because of the development, albeit limited, of glucose-powered fuel cells. However, glucose was not accepted as raw material for biochemical fuel production.

4ei.
Acceptable responses included:

- ethanol* – from plant material*, for example, sugar cane, corn, bagasse or biomass
- methane/biogas – from plant and animal waste
- biodiesel – from plant and animal fats, algae
- methanol/wood gas – from wood, sawmill offcuts, biomass.

4eii.
Acceptable responses included:

- use of land normally used for crops (food production)
- clearing forests
- availability of water.

A number of students suggested that a disadvantage of biochemical fuels is that they have lower energy content than fossil fuels. While there is validity in this argument when comparing methanol with methane (natural gas), it does not necessarily hold when comparing a biochemical fuel with brown coal.

Question 4fi–ii.

Marks	0	1	2	Average
%	23	34	44	1.2

Many students did not access marks on this question because of lack of detail. Statements such as 'more energy' or 'greater efficiency' in Question 4fi. and 'cost' in 4fii. lacked required detail. Responses were expected to indicate that students realised that nuclear fuels release large amounts of energy from a small mass of fuel, or nuclear reactors are very expensive to build and operate.

4fi.
Acceptable responses included:

- large amounts of energy released from a small mass [of nuclear fuel (uranium)]
- high energy density of nuclear fuel
- limited greenhouse gas emissions.

4fii.
Acceptable responses included:

- disposal of radioactive waste*
- potential use in nuclear weapons/terrorism

- environmental concerns in case of reactor failure
- non-renewable fuel
- cost and time required to set up nuclear reactor.

Question 5a.

Marks	0	1	Average
%	34	66	0.7

Electrode A – positive/(+)
Electrode B – negative/(-)*

Question 5b.

Marks	0	1	Average
%	42	58	0.6

[✓ VO_2^+] * VO^{2+} V^{3+} [✓ V^{2+}]

It was decided that ‘when the cell is fully charged’ could be interpreted as either ‘at the end of recharging’, in which case electrode A would be the anode and VO_2^{2+} would have the highest concentration, or ‘at the start of discharging’, in which case electrode B would be the anode and V^{2+} would have the highest concentration.

Question 5c.

Marks	0	1	Average
%	54	46	0.5

$VO^{2+}(aq) + H_2O(l) + V^{3+}(aq) \rightarrow VO_2^+(aq) + V^{2+}(aq) + 2H^+(aq)$*

The discharge equation was prevalent in responses to this question.

Question 5d.

Marks	0	1	Average
%	43	57	0.6

Acceptable responses included:

- fuel cells are not rechargeable
- fuel cells needs continuous supply of reactants
- fuels in fuel cells are molecular, not ionic
- products of fuel cells are not recycled
- some fuel cells produce CO_2
- fuel cell electrodes are porous.

Students could have also taken the opposite approach, that is, a vanadium-redox cell is rechargeable and vanadium-redox cell contains reactants.

Students should be able to make comparisons between a previously unseen electrochemical cell and the general principles of operation of electrochemical cells that they have studied.

Question 5e.

Marks	0	1	Average
%	70	30	0.3

One of:

- $2V^{3+}(aq) + Fe(s) \rightarrow 2V^{2+}(aq) + Fe^{2+}(aq)$
- $2VO_2^+(aq) + 4H^+(aq) + Fe(s) \rightarrow 2VO^{2+}(aq) + 2H_2O(l) + Fe^{2+}(aq)$
- $Fe(s) + 2H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$.

The three equations accepted were based on the possibilities of:

- $Fe(s)$ being oxidised by $V^{3+}(aq)$ in the $V^{3+}(aq)/V^{2+}(aq)$ half-cell
- $Fe(s)$ being oxidised by $H^+(aq)$ in the half-cell

- Fe(s) being the strongest reductant at electrode B being oxidised in the galvanic cell by VO_2^+(aq).

As the reductant Fe(s) is lower on the electrochemical series than any of the three oxidants VO_2^+(aq), H^+(aq) and V^{3+}(aq), more students might have been expected to write a correct equation.

Question 6a.

Marks	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**Average**
%	2	1	5	11	17	21	43	**4.8**

	Would the rate of reaction 2 become **higher, lower or remain unchanged?**	Would the **equilibrium** yield of reaction 2 become **higher, lower** or **remain unchanged?**	Would the **value of the equilibrium constant,** *K*, of reaction 2 become **higher, lower or remain unchanged?**
The temperature of reaction 2 is lowered to 150°C.	lower*	higher*	higher*
The pressure of reaction 2 is increased to 5 atm by pumping more B(g) and C(g) into the reaction vessel, at constant temperature.	higher*	higher*	unchanged*

Question 6b.

Marks	**0**	**1**	**Average**
%	29	71	**0.7**

Acceptable responses included:

- provide energy for reaction 1
- increase the rate and/or yield of reaction 1
- heat the incoming reactants
- generate electricity.

With regards to using released heat energy to generate electricity, students should also be aware of how the electricity might be used in such a process, for example, powering the pumps used to move the gases.

Question 6ci–iii.

Marks	**0**	**1**	**2**	**3**	**4**	**Average**
%	4	16	26	31	23	**2.5**

Ammonia

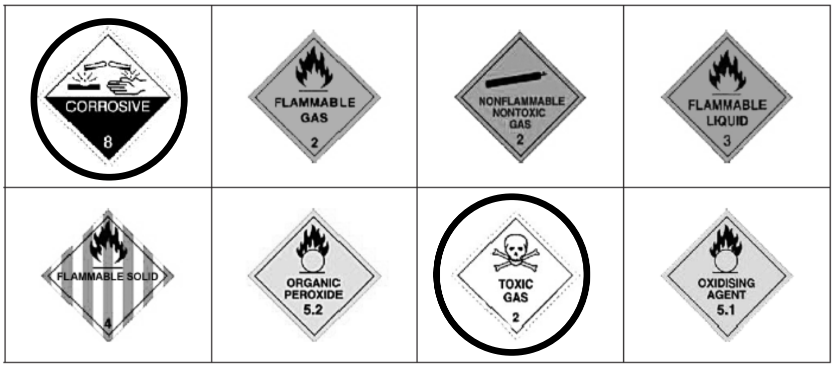
6ci.

Acceptable responses included:

- recycling unreacted N_2 and H_2
- monitoring/using by-products associated with H2 production.

6cii.

*



6ciii.

Acceptable responses included:

- as a fertiliser
- in the production of fertilisers, for example, NH_4NO_3
- production of nitric acid
- production of ammonium compounds
- industrial refrigeration
- manufacture of pharmaceuticals/vitamins
- production of nylon and other polymers
- in cleaning products.

Sulfuric acid

6ci.

Acceptable responses included:

- recycling unreacted SO_2 and O_2
- use of the double absorption process
- monitoring emissions for SO_2
- minimising H_2SO_4 mist emissions.

6cii.

*

6ciii.

Acceptable responses included:

- in the production of superphosphate
- in the production of fertilisers, for example, $(NH_4)_2SO_4$
- in the production of nitric acid
- in the production of sulfate salts
- drying non-reactive gases
- dehydrating carbohydrates
- processing metals
- in the production of rayon
- in the production of paints, pigments and dyes
- the manufacture of drugs/pharmaceuticals
- the manufacture of synthetic detergents
- as an electrolyte in lead-acid batteries
- in the production of oleum
- oil refining.

Nitric acid

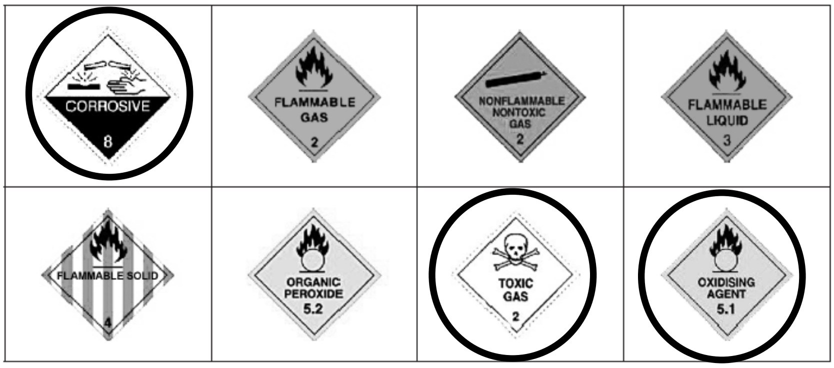
6ci.

Acceptable responses included:

- recycling unreacted NO and NO_2
- filtering the gas mixture entering the converter

- monitoring emissions for NO_x and trace HNO_3.

6cii.



6ciii.

Acceptable responses included:

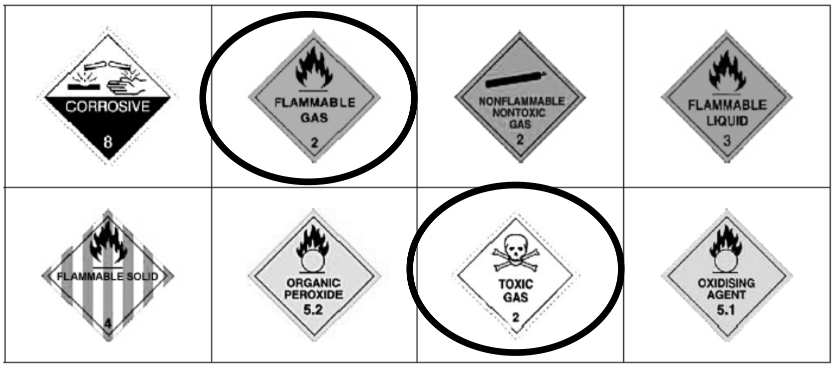
- in the production of fertilisers, for example, NH_4NO_3
- in the production of explosives
- in the production of nitrate salts
- in the purification of precious metals
- in the production of dyes and perfumes
- in the production of paints, pigments, dyes
- as a nitrating agent in organic synthesis.

Ethene
6ci.

Acceptable responses included:

- recycling unreacted feedstock
- the removal of sulfur from feedstock
- the use of coke from cracking furnace as a fuel
- to extract by-products, for example, propene
- H_2 and CH_4 used as fuels.

6cii.



6ciii.

Acceptable responses included:

- in the production of polymers, for example, polyethene, PVC and polystyrene
- in the manufacture of containers and plastic film
- controlled ripening of fruit
- in the production of ethylene for detergent manufacture
- in the production of ethanol.

Generally this question was well handled. H_2SO_4 and NH_3 were the two most commonly selected chemicals. Students were aware of associated waste management strategies; the on-sale of CO_2 for food and drink production was a common answer for NH_3.

Some students tended to state properties as uses, for example, an oxidising agent or strong acid for sulfuric acid or base for ammonia. It is expected that students be aware of the uses of the chemical dependent on such properties; for example, sulfuric acts as an acid when it is used to dissolve the oxide layer on steel.

Students should be reminded that answers should be rational and considered, and that single-word responses may not be sufficient for some questions. It is correct to say that H_2SO_4 is used in the production of fertilisers; for example, it acts as an acid and NH_3 as a base in the production of ammonium sulfate. To give 'fertiliser' as a use of sulfuric acid, that is, to imply that sulfuric acid acts as a fertiliser, is **not** a rational response. To give 'fertiliser' as a use of NH_3 was acceptable but 'explosive' was not. Responding that NH_3 is used in the production of explosives was acceptable.

Future students are advised to consider the differences in expectation between Question 6ciii. from this exam and Question 6d. from the November 2008 exam.

Question 7a.

Marks	**0**	**1**	**Average**
%	61	39	**0.4**

$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

This question was poorly done with the majority of students focusing on the oxidation of Zn, seemingly not recognising that Zn is the product of the reduction of $Zn^{2+}(aq)$.

Question 7b.

Marks	**0**	**1**	**2**	**3**	**4**	**Average**
%	21	5	8	20	47	**2.7**

$n(Zn) = 0.900 / 65.4$
$= 0.01376$ mol
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$
$n(e^-) = 2 \times 0.01376$
$= 0.02752$ mol*****
$Q = 0.02752 \times 96500$*****
$= 2656$ C
$I = Q / t$
$= 2656 / (30.0 \times 60)$
= **1.48** A***** - 3 sig figs*****

One mark was awarded for correctly calculating the $n(e^-)$ and one mark for the inclusion of three significant figures.

This question was generally well done and showed that, when reminded, students pay particular attention to significant figures. Students should ensure that they pay attention to significant figures in all calculation questions.