



GENERAL COMMENTS

The 2008 Chemistry November examination was generally well received by students. While student performance was below that of the June examination, it should be noted that the percentage of students at each grade was similar on both examinations. A score of approximately 81 per cent was needed to achieve an A⁺ and approximately 72 per cent was needed to receive an A. The mean score for this examination was 51.6 per cent compared to 55.4 per cent in 2007, which was the final year of the previous study design. The mean score corresponded to a grade of a high C⁺.

The results of the examination suggest that many students may benefit from greater emphasis on the first dot point of the 'Apply chemical understandings' key skill in the *VCE Chemistry Study Design* – to make connections between concepts; process information; and apply understandings to familiar and new contexts (page 12). Responses to many questions in Section A supported this contention. Questions 15–20 focussed on energy, electrochemical cells and the electrochemical series and proved to be, as a group, quite challenging. This may indicate that, in the latter part of the semester, some students struggled to come to terms with the content of the 'Supplying and using energy' area of study.

There were other questions in Section A in which an alternative other than the correct one proved attractive. For example, Question 2, relating to 'how' a catalyst increases reaction rate, and Question 4, on why increasing temperature increases reaction rate. Responses to Questions 3 and 8, both involving the interpretation of concentration-time graphs, suggested that the subtleties of these graphs need attention. In Question 3, few students selected the alternative in which the starting concentration of one species was not consistent with the question. Question 8 emphasised that applying understanding of a familiar reaction, in a perhaps unfamiliar situation, is an area that requires improvement. Students should be well aware that the position of an equilibrium system which has the same number of particles on both sides is not affected by a volume change. However, all concentrations increase when the volume is decreased. The subtle difference in the extent of the concentration increases on the very similar concentration-time graphs was missed by most students.

In Section B, Question 2a., the requirement to express the answer to an appropriate number of significant figures was generally well done. However, it also suggested that reinforcing the 'rules' for significant figures, particularly when the addition or subtraction of amounts is involved, would be appropriate.

Question 3 provided some interesting insights into the students' understanding of pH, acid strength and the behaviour of weak acids. Question 3e. indicated that most students assume that if the concentration of an acid is changed by a factor of 10 then the pH changes by 1, irrespective of whether the acid is a weak acid or a strong acid. This is not the case for weak acids and can be shown to students by asking them to calculate, for example, the pH of 0.10 M and 0.010 M ethanoic acid. When a weak acid is diluted by a factor of 10, all concentrations instantly decrease by a factor of 10. This decreases the value of the concentration fraction (reaction quotient) relative to the K_a value, and so the position of equilibrium then shifts right, producing more $H^+(aq)$. The overall effect is that the concentration of H^+ decreases by a factor less than 10 and the pH increases by less than 1.

In Question 5 the majority of students selected 'sulfuric acid'. However, most of these students ignored the 'different' sulfur source offered in Question 5a. Question 5d. reinforced the need for effective question interpretation. Students were required to name a useful product formed 'from' sulfuric acid, for example, $(NH_4)_2SO_4$, but many instead identified chemicals produced 'using' sulfuric acid.

Student performance on Questions 6, 7 and 8 dealing with aspects of energy and electrochemical cells was similar to student performance on the Section A questions on this area of the study. Interpretation of the question was an issue in Questions 6biii. and 6c. Question 8c. was not well handled; most students were unable to link $E = QV$ (from $E = VIt$ and $Q = It$) and $Q = n(e^-) \times F$ and identify the correct units.

Overall, student performance showed that the examination was challenging and students seemed to use the data book well.



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 | 57 | 6 | 32 | 5 | 0 | More particles on the product side suggests that increased conversion of reactants to products will be favoured by decreased pressure/increased volume. Since the forward reaction is endothermic it is favoured by a temperature increase. |
| 2 | 3 | 52 | 41 | 4 | 0 | Solid catalysts decrease the activation energy for a reaction by providing a surface onto which reactant molecules are adsorbed and from which product molecules are desorbed. A 'finely divided' catalyst provides a greater surface area. Students who chose option C perhaps mistakenly assumed that the lowering of the activation energy characteristic of a catalyst was the same as increasing the energy of reactant molecules. These students may not have been familiar with the significance of the interaction between reactant molecules and the catalyst surface. |
| 3 | 48 | 16 | 4 | 31 | 0 | The number of students who chose option D may suggest that many did not link the mole ratios in the equation to the extent of the relative changes in the concentrations of CH ₄ and H ₂ . However, the fact that [H ₂] did not start at zero should have negated its selection. |
| 4 | 2 | 4 | 41 | 53 | 0 | The factor with the ' biggest effect ' is the one that is most likely to increase the proportion of collisions with energy greater than the activation energy. This occurs because an increase in temperature increases the kinetic energy of the particles. It appeared that many students who chose option C were attracted by the mention of more 'collisions'. There is a subtlety here that requires emphasis. More frequent collisions will occur as the temperature is raised, however the rate increase is mostly due to the increased 'proportion of collisions that are fruitful', which is a consequence of the increase in 'kinetic energy' of the particles. |
| 5 | 3 | 9 | 3 | 85 | 0 | |
| 6 | 25 | 2 | 70 | 4 | 0 | The fact that the catalyst lowers the activation of both forward and reverse reactions was overlooked by some students. |
| 7 | 55 | 20 | 15 | 10 | 0 | There were three steps in obtaining the required ΔH 1. $\text{Cu}_2\text{O}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}) \rightarrow 2\text{CuO}(\text{s}); \Delta H = -312 - (-170) = -142 \text{ kJ mol}^{-1}$. 2. $2\text{CuO}(\text{s}) \rightarrow \text{Cu}_2\text{O}(\text{s}) + \frac{1}{2}\text{O}_2(\text{g}); \Delta H = +142 \text{ kJ mol}^{-1}$ 3. $4\text{CuO}(\text{s}) \rightarrow 2\text{Cu}_2\text{O}(\text{s}) + \text{O}_2(\text{g}); \Delta H = +284 \text{ kJ mol}^{-1}$ Aside from the 'sign' errors associated with options C and D, the students who selected options B and C overlooked the impact of changing equation stoichiometry on the ΔH value. |



| Question | % A | % B | % C | % D | % No Answer | Comments |
|----------|-----|-----|-----|-----|-------------|--|
| 8 | 18 | 26 | 31 | 25 | 0 | <p>As there are the same number of molecules on both sides of the equilibrium, the decrease in volume (increase in pressure) has no impact on the position of equilibrium. However, because of the volume decrease, all concentrations increase by the same factor (2.0/1.3). This means that the higher the initial concentration (in mol L⁻¹), the greater the actual change in concentration (in mol L⁻¹). Hence the change in concentration is greatest for HI and least for I₂.</p> <p>Options A and D missed the significance of the impact of the decrease in volume on concentration, and the fact that position of this equilibrium is not affected by a volume change respectively. Options B and C looked very similar. Ideally this would have encouraged students to think, 'Why are the volume changes the same in option C but different in option B?'</p> <p>This proved to be the most challenging question in Section A.</p> |
| 9 | 6 | 60 | 12 | 22 | 0 | <p>A. $K = 0.40$. B. $K = 0.11$, C. $K = 0.40$, D $K = 0.40$ Assuming recognition of $K = [\text{PCl}_3]x[\text{Cl}_2] / [\text{PCl}_5]$, incorrect choices may be attributed to mathematical error and lack of practice with a scientific calculator.</p> |
| 10 | 30 | 54 | 9 | 7 | 0 | <p>Adding PCl₅ to an empty container will cause the mass of PCl₅ to decrease as the reaction proceeds to equilibrium. However, the law of conservation of mass implies the conversion of PCl₅ to PCl₃ and Cl₂ does not change the total mass of gas present in the container.</p> |
| 11 | 11 | 11 | 65 | 14 | 0 | <p>$2\text{NOCl}(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}); K = 1.6 \times 10^{-5}$ $2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{NOCl}(\text{g}); K = (1/1.6 \times 10^{-5})$ $\text{NO}(\text{g}) + \frac{1}{2}\text{Cl}_2(\text{g}) \rightleftharpoons \text{NOCl}(\text{g}); K = (1/1.6 \times 10^{-5})^{1/2}$ $= \sqrt{1 / 1.6 \times 10^{-5}}$ $= 2.5 \times 10^2$</p> |
| 12 | 36 | 22 | 25 | 17 | 0 | <p>$\text{CH}_3\text{CH}_2\text{COOH}(\text{aq}) + \text{NaOH}(\text{aq}) \rightarrow \text{CH}_3\text{CH}_2\text{COONa}(\text{aq}) + \text{H}_2\text{O}(\text{l})$ 100 mL 100 mL 0.16 M 0.080 M $n = 0.016 \text{ mol}$ $n = 0.0080 \text{ mol}$ 0.0080 mol CH₃CH₂COOH will react giving 0.0080 mol CH₃CH₂COONa. In the resulting solution there will be 0.0080 mol CH₃CH₂COOH(aq) and 0.0080 mol CH₃CH₂COO⁻(aq), that is, equal amounts of propanoic acid and its conjugate base. The pH of the resulting solution will be higher than the original propanoic acid solution, since the concentration of CH₃CH₂COOH is lower. As propanoic acid is a weak acid, there was a small (but negligible in this case) amount of CH₃CH₂COO⁻ ions present before the addition of NaOH.</p> |
| 13 | 40 | 19 | 6 | 34 | 0 | <p>Ethyl ethanoate, an ester, is an organic liquid and must be disposed of in an 'organic liquids' waste container. Similarly, lead compounds are hazardous and must be disposed of in a 'dry solids' container.</p> |
| 14 | 13 | 24 | 55 | 7 | 1 | <p>From the specific heat capacity of water – 4.18 J mL⁻¹ K⁻¹ – we can deduce that 418 J is required to raise the temperature of 100 ml of water by one degree. However, during calibration, factors such as heat loss from the calorimeter and energy required to also raise the other calorimeter contents by one degree must also be considered. Hence slightly more than 418 J is required to increase the temperature of the calorimeter and its contents by one degree.</p> |
| 15 | 43 | 27 | 12 | 18 | 0 | <p>Heat of combustion = 2016 kJ mol⁻¹ (data book) = 2016 / 60.0 kJ g⁻¹ = 33.6 kJ g⁻¹ Choosing option B indicated that students were not able to convert from kJ mol⁻¹ to kJ g⁻¹.</p> |



| Question | % A | % B | % C | % D | % No Answer | Comments |
|----------|-----|-----|-----|-----|-------------|--|
| 16 | 13 | 21 | 19 | 47 | 1 | In NaF(l) the oxidant, Na ⁺ is reduced to Na at the cathode and the reductant, F ⁻ , is oxidised to F ₂ at the anode. In NaF(aq) the strongest oxidant, H ₂ O, is reduced to H ₂ at the cathode and the strongest reductant, H ₂ O, is oxidised to O ₂ at the cathode. Skill in using the electrochemical series to identify the strongest oxidant and strongest reductant needs to be emphasised. |
| 17 | 18 | 23 | 43 | 16 | 0 | Three of the oxidant/reductant pairs are on the electrochemical series. Pb ²⁺ + 2e ⁻ → Pb Co ²⁺ + 2e ⁻ → Co Fe ²⁺ + 2e ⁻ → Fe The location of the Cr ³⁺ / Cr ²⁺ pair is deduced from reactions 1 and 3. Cr ³⁺ is a weaker oxidant than Co ²⁺ but a stronger oxidant than Fe ²⁺ . Hence the order in terms of decreasing oxidant strength is: Pb ²⁺ + 2e ⁻ → Pb Co ²⁺ + 2e ⁻ → Co Cr ³⁺ + e ⁻ → Cr ²⁺ Fe ²⁺ + 2e ⁻ → Fe For a spontaneous reaction the oxidant must be above the reductant in the electrochemical series. Such questions are quite challenging for many students. Students should look to the electrochemical series to see what assistance it provides. |
| 18 | 29 | 14 | 12 | 45 | 0 | In a galvanic cell the reductant is oxidised; oxidation occurs at the anode; the anode is the negative electrode. In each cell the stronger reductant is at the negative electrode. According to the data relative reductant strengths are: I and IV Cu > P; II and IV Q > Cu; III and IV R > Cu; II and III R > Q Hence, the order of increasing reductant strength is P < Cu < Q < R. Students who chose option A interpreted the data effectively but for some reason chose the order of decreasing reductant strength. There are a variety of approaches to solving such a problem. |
| 19 | 16 | 9 | 36 | 39 | 0 | The number of mole of electrons is proportional to the electric charge, so each reaction produces the same n(e ⁻) per coulomb of electric charge (i.e. 1/96500 mol e ⁻). Relative amounts of CO ₂ , i.e., n(CO ₂) are A. n(e ⁻)/6; B. n(e ⁻)/6; C. n(e ⁻)/7; D. n(e ⁻)/5. |
| 20 | 5 | 5 | 49 | 41 | 0 | The electrochemical series provides no indication of reaction rate. It was surprising that so many students overlooked this accepted fact and were drawn to option D. Since Sn ²⁺ and Cu ²⁺ can react spontaneously but Sn ²⁺ and Zn ²⁺ cannot, the reaction between Sn ²⁺ and Cu ²⁺ may be expected to proceed further to the right than the reaction between Sn ²⁺ and Zn ²⁺ . Hence option D can be predicted from the electrochemical series. |

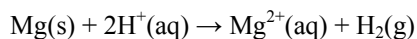
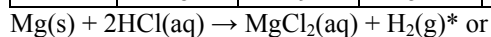
Future students are advised that multiple-choice questions are very much about **application** of understanding rather than mere factual recall.

Section B – Short-answer questions

For each question, an outline answer (or answers) is provided. In some cases the answer given is not the only answer that could have been awarded marks. Asterisks (*) are used in some questions to show where marks were awarded.

Question 1a.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|---------|
| % | 18 | 29 | 54 | 1.4 |



*One mark was awarded on this equation for 'all' states being correct.

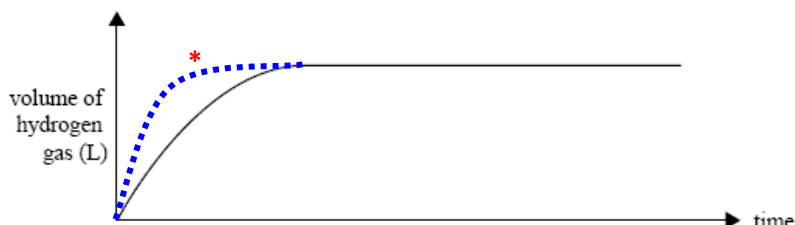
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The most common error was the use of MgCl as the chemical formula of magnesium chloride.

Question 1b.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|---------|
| % | 12 | 15 | 73 | 1.6 |



Powdered Mg has a **greater surface area** so the reaction occurs **faster***.

Question 2a.

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|-------|----|----|----|----|----|---------|
| % | 22 | 12 | 11 | 13 | 43 | 2.5 |

$$n(\text{CH}_3\text{CH}_2\text{OH}) = 2.09 / 46.0^*$$

$$= 0.0454 \text{ mol}$$

$$\text{Energy released} = 0.0454 \times 1364^*$$

$$= 62.0 \text{ kJ}$$

$$\text{CF} = 62.0/33.2$$

$$= \mathbf{1.87}^{**}$$

The fourth mark was awarded for the correct number of significant figures.

The question often arises about the impact of relative atomic masses on significant figures, particularly H given as 1.0 in the data book. It may be appropriate to quote the accepted rules for the use of significant figures in calculations.

- For multiplication and division, the result contains the same number of significant figures as the measurement with the fewest significant figures.
- For example, the mass of 0.251 mol $\text{H}_2 = 0.251 \times 2.0 = 0.50$. For addition and subtraction, the result has the same number of decimal places as the measurement with the fewest decimal places. For example, $M(\text{C}_2\text{H}_6\text{O}) = 2 \times 12.0 + 6 \times 1.0 + 1 \times 16.0 = 46.0$. For example, $34.652 - 2.36 = 32.29$.

Question 2b.

| Marks | 0 | 1 | 2 | 3 | Average |
|-------|----|----|----|----|---------|
| % | 42 | 14 | 17 | 27 | 1.3 |

$$E = 0.60 \times 62.0^*$$

$$= 37.2 \text{ kJ } (37.2 \times 10^3 \text{ J})$$

$$E = 4.18 \times m(\text{H}_2\text{O}) \times \Delta T$$

$$\Delta T = E / (4.18 \times m(\text{H}_2\text{O}))$$

$$\Delta T = 37.2 \times 10^3 / (4.18 \times 200)^*$$

$$= 44.5 \text{ }^\circ\text{C}$$

$$\text{Final T} = 25.3 + 44.5$$

$$= \mathbf{69.8}^* \text{ (}^\circ\text{C)}$$

The most common error on this question was attempting to use the calibration factor from Question 2a., rather than the energy, in the calculations. Many students, while correctly using the specific heat capacity of water, did not convert the energy to J.

Question 3a.

| Marks | 0 | 1 | Average |
|-------|----|----|---------|
| % | 24 | 76 | 0.8 |

II*/acid with pH 3

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Question 3b.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|---------|
| % | 29 | 41 | 29 | 1.0 |

III*

The lowest possible pH of a 0.1 M solution of a monoprotic acid is 1.0*/pH is less than it should be for a 0.1 M solution of a monoprotic acid.

The second mark was awarded for a coherent explanation of why III must have more than one acid hydrogen in each molecule.

Question 3c.

| Marks | 0 | 1 | Average |
|-------|----|----|---------|
| % | 53 | 47 | 0.5 |

$$\begin{aligned} \text{\% ionisation} &= ([\text{H}^+] / [\text{acid}]) \times 100 \\ &= (10^{-2.1} / 0.1) \times 100 \\ &= 7.9 \text{ * (\%)} \end{aligned}$$

Question 3d.

| Marks | 0 | 1 | Average |
|-------|----|----|---------|
| % | 57 | 43 | 0.5 |

$$\text{II} - [\text{OH}^-] = 10^{-14} / 10^{-3} = 10^{-11} \text{ M}$$

$$\text{I} - [\text{OH}^-] = 10^{-14} / 10^{-1} = 10^{-13} \text{ M}$$

$$\begin{aligned} \text{Ratio} &= 10^{-11} / 10^{-13} \\ &= 100 \text{ *} \end{aligned}$$

Question 3e.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|---|---------|
| % | 82 | 13 | 5 | 0.3 |

Greater for acid I than for acid IV

For acid IV the equilibrium $[\text{HA} \rightleftharpoons \text{H}^+ + \text{A}^-]$ moves slightly to the right following the dilution*/Acid I is a strong acid whereas acid IV is a weak acid.

This question was not well handled. Most students seemed to be drawn directly to the 'factor of 10' and generally argued something along the lines of 'a change in concentration by a factor of 10 corresponds to a one unit change in pH'. While this statement is quite accurate for strong acids, it is certainly not true for weak acids. This can be demonstrated to students by calculating the pH of 0.10 M ethanoic acid (2.9) and 0.010 M ethanoic acid (3.4).

Question 3fi-ii.

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|-------|----|----|----|---|----|---------|
| % | 31 | 13 | 17 | 7 | 32 | 2 |

3fi.

$$K_a (\text{HCOOH}) = 1.8 \times 10^{-4}$$

$$\text{pH } 2.1 \rightarrow [\text{H}^+] = 10^{-2.1} (7.9 \times 10^{-3})$$

$$1.8 \times 10^{-4} = (10^{-2.1})^2 / [\text{HCOOH}] \text{ *}$$

$$\begin{aligned} [\text{HCOOH}] &= (10^{-2.1})^2 / 1.8 \times 10^{-4} \\ &= 0.35 \text{ * (M)} \end{aligned}$$

3fii.

- increase*
- the increase in temperature pushes the equilibrium $[\text{HCOOH} \rightleftharpoons \text{HCOO}^- + \text{H}^+]$ to the left, so the $[\text{H}^+]$ decreases*

Question 4a.

| Marks | 0 | 1 | 2 | 3 | Average |
|-------|----|----|----|----|---------|
| % | 21 | 21 | 14 | 44 | 1.9 |

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$$n(\text{NO}_2)_{\text{eqm}} = 0.36 \text{ mol}$$

$$n(\text{N}_2\text{O}_4)_{\text{reacted}} = 0.18 * \text{ mol}$$

$$n(\text{N}_2\text{O}_4)_{\text{eqm}} = 0.45 - 0.18$$

$$= 0.27 * (\text{mol})$$

$$K = 0.36^2 / 0.27$$

$$= 0.48 *$$

Question 4b.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|---------|
| % | 21 | 15 | 64 | 1.5 |

endothermic*

K value is lower at the lower temperature*/reverse reaction favoured at lower temperature

Question 5a.

| Marks | 0 | 1 | Average |
|-------|----|----|---------|
| % | 63 | 37 | 0.4 |

| | | | | | | | | | |
|---------------|--------------|--------------|--------------|---------------|---------------------------|---------------------------|----------------|---------------|----------------|
| ammonia | H_2 | N_2 | O_2 | CO_2 | C_6H_{14} | C_8H_{18} | FeS_2 | NH_3 | SiO_2 |
| ethene | H_2 | N_2 | O_2 | CO_2 | C_6H_{14} | C_8H_{18} | FeS_2 | NH_3 | SiO_2 |
| nitric acid | H_2 | N_2 | O_2 | CO_2 | C_6H_{14} | C_8H_{18} | FeS_2 | NH_3 | SiO_2 |
| sulfuric acid | H_2 | N_2 | O_2 | CO_2 | C_6H_{14} | C_8H_{18} | FeS_2 | NH_3 | SiO_2 |

As the table suggests, a variety of combinations were accepted. Sulfuric acid was by far the most popular choice, but a large proportion of students who selected it did not circle FeS_2 and missed out on the mark.

Question 5b.

| Marks | 0 | 1 | Average |
|-------|----|----|---------|
| % | 32 | 68 | 0.7 |

Fundamentally, any balanced equation describing a reaction involved in the production of the chemical was accepted.

Question 5c.

| Marks | 0 | 1 | Average |
|-------|----|----|---------|
| % | 41 | 59 | 0.6 |

The mark was awarded for any common sense use of waste heat, including preheating reactants, generating electricity, heating water to raise steam.

Question 5di-ii.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|---------|
| % | 32 | 51 | 17 | 0.9 |

The range of possibilities in this question depended on the chemical chosen. Some of the options included (but were not limited to):

- NH_3 – ammonium nitrate, ammonium sulfate, urea
- HNO_3 – ammonium nitrate, potassium nitrate
- C_2H_4 – ethanol, chloroethane, polyethylene
- H_2SO_4 – ammonium sulfate, superphosphate, hydrogen, sodium sulfate, oleum.

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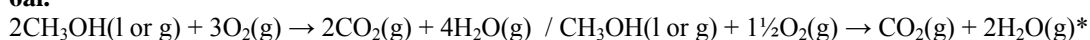
If the substance identified is 'formed from the chemical' (interpreted as having components of the chemical in its structure) it was accepted.

Question 5dii. proved very challenging for students who selected sulfuric acid as their chemical. Many students identified superphosphate but struggled to write the equation for its production. There was a very small number of students who provided a correctly balanced equation. Many students selected reactions in which acid is involved but the product identified is not actually formed 'from' sulfuric acid, for example, C from the dehydration of glucose. In this instance the C does not come from the sulfuric acid and so was not accepted. Esters were also not accepted. Also common were equations involved in the production of sulfuric acid. The equation for the production of oleum was accepted since oleum is a recognised dehydrating agent and is used in the production of products such as nitrotoluenes.

Question 6ai-ii.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|------------|
| | 36 | 40 | 25 | 0.9 |

6ai.



6aii.

$$\Delta H = -1450 \text{ kJ mol}^{-1} / \Delta H = -725 \text{ kJ mol}^{-1}^*$$

Some students simply added the two half equations together to get the overall equation (the reverse of the required equation) but then did not give ΔH as $+1450 \text{ kJ mol}^{-1}$. It should have been clear from the question that CH_3OH was a reactant. A number of students showed the correct formulae but did not balance the equation. However, if the ΔH was consistent with their equation, they were able to access the mark for Question 6aai. There was evidence that the use of the data book and the meaning of 'molar enthalpy' of combustion are areas worth addressing with students.

6bi-iii.

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | Average |
|-------|----|----|---|----|----|---|------------|
| % | 18 | 11 | 8 | 18 | 39 | 7 | 2.8 |

6bi.

$$Q = 25.5 \times 24 \times 60 \times 60 \\ = 2.20 \times 10^6 \text{ J}^*$$

6bii.

$$n(e^-) = 2.20 \times 10^6 / 96500^* \\ = 22.8 \text{ mol} \\ n(\text{CH}_3\text{OH}) = 22.8 / 6^* \\ = 3.81 \text{ mol} \\ m(\text{CH}_3\text{OH}) = 3.81 \times 32.0 \\ = 122 \text{ g}^*$$

6biii.

Side reactions occur/loss of methanol by evaporation/methanol escapes from the cell*

Question 6biii. was not well handled. It was stated in the question that the 'experimental readings of current, time and 'measured' mass of methanol are accurate'. Thus the calculated $n(e^-)$ will be accurate and the 'calculated' mass of methanol (if calculated correctly) will be accurate. If the measured mass of methanol is less than the calculated mass, either some of the methanol was lost from the solution or there was a side reaction, such as the reduction of some of the CO_2 to methanoic acid rather than methanol. 'Heat loss' (presumably assuming some of the current was used up in producing thermal energy) was a relatively common, but incorrect in this context, response.

6c.

| Marks | 0 | 1 | Average |
|-------|----|----|------------|
| % | 66 | 34 | 0.4 |

No change in total CO_2 levels because the $n(\text{CO}_2)$ required to produce 1 mol CH_3OH is the same as the $n(\text{CO}_2)$ produced when 1 mol CH_3OH undergoes complete combustion*.

This question was more poorly handled than expected. Many students simply focussed on the production of CO_2 from the combustion of methanol.

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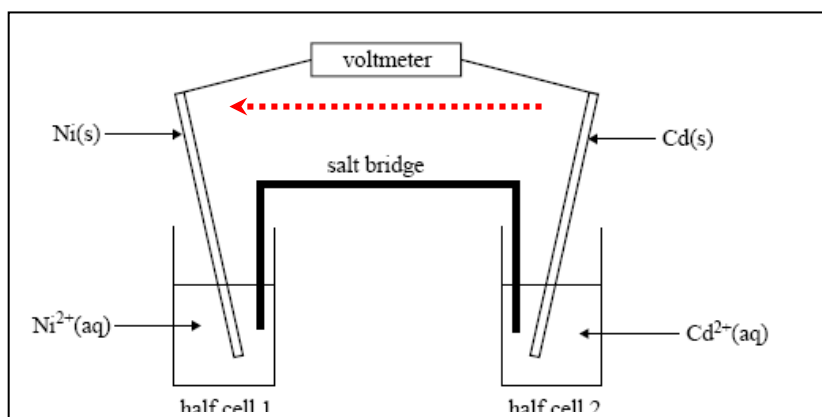
It was possible for a student to gain the mark for 'increase in CO₂ levels' if the explanation included references to other sources of CO₂ production associated with the production and use of methanol.

Question 7

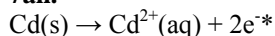
7ai-iii.

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|-------|---|----|----|----|----|---------|
| % | 8 | 13 | 19 | 28 | 31 | 2.7 |

7ai.



7aii.



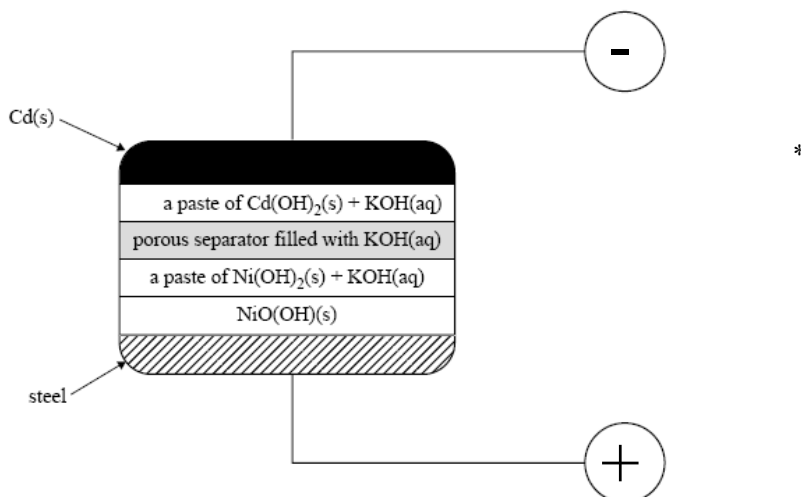
7aiii.

Must be soluble/ionic compound/must not react/will not form precipitate in half-cell**

7bi-iv.

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|-------|----|----|----|----|---|---------|
| % | 22 | 33 | 24 | 15 | 6 | 1.6 |

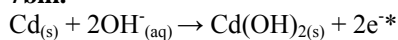
7bi.



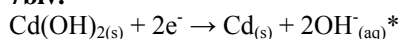
7bii.

The products of the discharge reaction, Cd(OH)₂ and Ni(OH)₂, stay in contact with the electrodes*

7biii.



7biv.



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Questions 7biii. and 7biv. proved difficult for most students. In Question 7biii. it was expected that the product at the (-) electrode, that is, $\text{Cd}(\text{OH})_2$, would be part of the half equation. Many students achieved this incorrectly by using H_2O as a reactant and H^+ as a product. Students need to be aware that H^+ as a product in an alkaline environment is not logical chemistry. The mark for Question 7biv. was awarded if the answer was consistent with the student's response to 7biii.

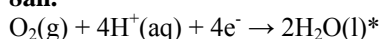
Question 8ai-ii.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|------------|
| % | 37 | 20 | 43 | 1.1 |

8ai.



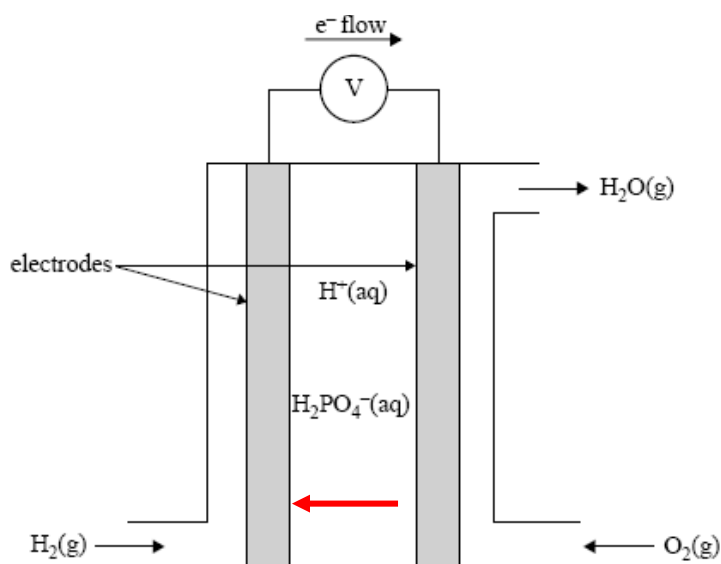
8aai.



These half equations could be obtained directly from the electrochemical series.

Question 8b.

| Marks | 0 | 1 | Average |
|-------|----|----|------------|
| % | 48 | 52 | 0.6 |



Question 8ci-ii.

| Marks | 0 | 1 | 2 | 3 | Average |
|-------|----|----|---|----|------------|
| % | 71 | 12 | 4 | 13 | 0.6 |

8ci.

$$n(\text{e}^-) = 2 \text{ mol}$$

$$Q = 2 \times 96500* \text{ C}$$

$$E = QV$$

$$= 2 \times 96500 \times 0.92$$

$$= 1.78 \times 10^5 \text{ J}$$

$$= 1.8 \times 10^2* \text{ (kJ)}$$

Question 8ci. was poorly done with most students unable to make the links between $E = VI$ and $Q = It$ to get the required relationship $E = VQ$. In 8cii. the heat of combustion of H_2 was available from the data book.

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8cii.

$$\begin{aligned} \text{Efficiency} &= (178 / 286) \times 100 \\ &= \mathbf{62.0\%} \end{aligned}$$

Question 8d.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|------------|
| % | 21 | 35 | 44 | 1.3 |

- advantage: Less energy is lost as heat/less noisy/more efficient energy conversion/no CO₂ produced/only product is H₂O*
- disadvantage: Cost/hydrogen is difficult to produce/store/distribute*

Question 9a.

| Marks | 0 | 1 | Average |
|-------|----|----|------------|
| % | 62 | 38 | 0.4 |

$$\begin{aligned} m(\text{CO}_2) &= [(0.58 - 0.42) / 100] \times 5.15 \times 10^{18} \\ &= \mathbf{8.2 \times 10^{15} \text{ kg}} \end{aligned}$$

Question 9b.

| Marks | 0 | 1 | 2 | Average |
|-------|----|----|----|------------|
| % | 42 | 43 | 15 | 0.8 |

$$\begin{aligned} n(\text{CO}_2) &= 4.1 \times 10^{15} \times 10^3 / 44^* \\ &= 9.4 \times 10^{16} \text{ mol} \end{aligned}$$

$$\begin{aligned} \text{Energy produced} &= 9.4 \times 10^{16} \times 394 \\ &= \mathbf{3.7 \times 10^{19} \text{ (kJ)}} \end{aligned}$$

The first mark was awarded for correctly calculating $n(\text{CO}_2)$ from the answer to Question 9a. The second mark was awarded for correctly calculating the energy from the calculated $n(\text{CO}_2)$. There were many points where 'mistakes' occurred in this question, including not dividing $m(\text{CO}_2)$ by 2, not converting kg to g, and dividing by $M(\text{C})$ rather than $M(\text{CO}_2)$.