VCE Chemistry

Model Answers and mark scheme to Questions in the Sample VCE Chemistry Paper for the Accredited VCE Chemistry Course 2016 to 2021.

Attribution and disclaimer

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Section A – Multiple-choice questions

Question	Correct Answer	Comments	Page Reference Pearson text book[1]
1	D	Natural gas, coal seam gas and sediment on ocean floors are all non- renewable.	3, 6
2	B		25 (production) 27 (viscosity) 28 – 29 (emissions)
3	C	Human's don't have the ***cellulase*** enzyme and hence can't digest cellulose	546
4	C	Hydrolysis of polysaccharides eventually yield monosaccharides such as glucose, $C_6H_{12}O_6$	554
5	A	The primary structure links the amino acid residues via strong covalent bonds known as peptide bonds	475
6	A	Low accuracy – values not close to real manufacturer's value High precision – values are close together.	438
7	D	$n(H_2S) = 3 \times n(Al_2S_3) = 3 \times 0.200 = 0.600$ mol $V_{SLC}(H_2S) = n \times V_{M(SLC)} = 0.600 \times 24.8 = 14.9$ L D 14.7 L is the closest answer Refer to Data Booklet p5 for molar volume of an ideal gas at SLC and SLC conditions.	76
8	C	Controlled variables are all the variables that must be kept constant during the investigation	554 (Y11 Text)[2]
9	C	At pH = 13 (basic) Both $-NH_3^+$ and – COOH will act as acids and loose an H^+ Hence: $-NH_3^+$ will become $-NH_2$ and -COOH will become $-COO^-$	538 - 539

[1] Commons, C et al, 2017 *Heinemann Chemistry 2* 5th ed., Pearson Australia. Melbourne Victoria
[2] Commons, C et al, 2016 *Heinemann Chemistry 1* 5th ed., Pearson Australia. Melbourne Victoria

10	A	Infra-red spectroscopy could be used to distinguish the three compounds because of the difference in function groups present. Each compound would also produce unique IR spectrum. B – all three compounds are ***un***saturated hydrocarbons. C – all three compounds are practically insoluble in water due to long hydrocarbon chains D – retinal is aldehyde not ketone.	370 - 380
11	B	m/z = 74 represents the molecular ion peak for the ion: $[CH_3CH_2COOH]^+$ $M_r(CH_3CH_2COOH)$ =74.0 A – if a ^{13}C was present then M^+ = 75 C – peaks represent ions not molecules D – the base peak is the peak with 100 relative intensity.	393 - 399
12	B	$\Delta H = \Sigma H_{products} - \Sigma H_{reactants}$ = II A – the activation for the reverse reaction would be represented by III C – the energy required to break the bonds of the reactants would be represented by I D – the energy released by the formation of new bonds would be represented by III	40, 44
13	B	Catalysed reaction should have a reduced activation energy	185
14	C	Atom economy = $\frac{M(desired\ product)}{M(all\ reactants)}$ x 100 $= \frac{92}{180}$ x 100 = 51.1 % Equation in Data Booklet, page 5	363 – 364, 640
15	A		182
16	A		181
17	B	$n(CH_4.6H_2O) = n(CH_4)$ = 1000/124 = 8.06 mol Energy released = ΔH x n = 889 x 8.06 = 7170 kJ = 7.17×10^3 kJ	51
18	B	Rechargeable batteries – secondary cells act as galvanic cells when discharging	143 - 144
19	B		310 - 315
20	None of the provided answers are correct. D is	D would be correct if the answer was "changing the orientation of atoms at the active site of the **enzyme**." Coenzymes will always change the active site to enhance / make possible the role of an enzyme – although they don't	532 – 533, 641

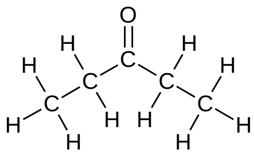
	the VCAA answer.	necessarily change the orientation of the atoms. B – incorrect as antioxidants act as reductants, therefore undergoes oxidation and loses electrons	
21	C	$K^+(l) + e^- \rightarrow K(l)$ $n(K) = n(e^-) = 0.152/39.1 = 0.00389$ mol $Q = n(e^-) \times F = 0.00389 \times 96500 = 375$ C $I = Q/t = 375/60 = 6.25$ A	255
22	D	$H_2O(l)$ is now the stronger oxidant and $OH^-(aq)$ is still the stronger reductant. Anode (oxidation): $2OH^-(aq) \rightarrow O_2(g) + 2H^+(aq) + 2e^-$ Cathode (reduction): $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	
23	A	$Al^{3+}(l) + 3e^- \rightarrow Al(l)$ $n(Al) = 1/3n(e^-) = 1/3 \times 0.60 = 0.20$ mol	
24	C	Both C and Mg are oxidised, therefore they are acting as reducing agents. Using oxidation numbers (ON): $C \rightarrow CO_2$ ON: $0 \rightarrow +2$ $Mg \rightarrow MgCl_2$ ON: $0 \rightarrow +2$	107
25	C		
26	C	An inert gas is not part of the equilibrium system. It only contributes to the overall pressure of the container.	225
27	B		306
28	D		358
29	A	$(NaOH) = c \times V = 0.125 \times 20.00 \times 10^{-3}$ $= 2.50 \times 10^{-3}$ mol $n(C_6H_8O_7) = 1/3n(NaOH) = 1/3 \times 2.50 \times 10^{-3}$ mol $= 8.33 \times 10^{-4}$ mol $c(C_6H_8O_7) = n/V = 8.33 \times 10^{-4} / 0.0236$ $= 0.0351$ M	
30	D	You assume you have reacted more NaOH than you did. Hence less v(NaOH) → less n(NaOH) → less $n(C_6H_8O_7)$ → less $c(C_6H_8O_7)$ This is a systematic error – repeating the experiment will not eliminate the error.	438

SECTION B: Short Answer

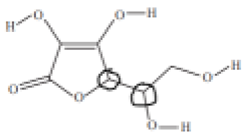
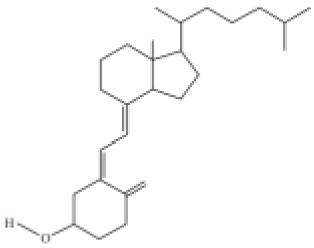
Question	Mark allocation	Maximum Marks	Pearson reference
1a	 linoleic acid	1	286, 492
1b	Linoleic acid is an omega-6 fatty acid. The C=C double bond begins on the 6th carbon atom from the end of the hydrocarbon chain.	1	489
1c	One mark each was awarded for either: • Linoleic acid – polyunsaturated (contains more than one C=C double bond) **OR** • Elaidic acid – monounsaturated (contains one C=C double bond)	1	488
1d	One mark each was awarded for: • Elaidic acid would have the higher melting point. • Comparison of elaidic acid and linoleic acid structure. Referencing the difference between linoleic acid having two *cis* double bonds and elaidic acid having a *trans* double bond **or** a comparison between elaidic acid having *one* double bond and linoleic acid having *two* double bonds. • Elaidic acid closer packing of the hydrocarbon chain. Hence it has stronger intermolecular dispersion forces, which require more energy to break, leading to a higher melting point.	3	490 - 491
2a	One mark each is awarded for a labelled diagram showing the following where: • A disaccharide binding to the active site of an enzyme with a completely complementary structure • The formation of an enzyme-substrate complex • The formation of products (monosaccharides broken apart) and the products moving away from the enzyme	3	528
2b	One mark is awarded for: • Referencing the flexible nature of the active site One mark is also awarded for one of the following: • Once the products leave, the active site returns to its original shape • The shape of the enzyme changes throughout the reaction process to favour (stabilise) the formation of the next molecule(s) in the reaction process	2	530
3a	One mark each for two of the following: 1, 4, 6, 8, 9 (more correct than incorrect but not entirely true – should include information about quaternary structure)	2	

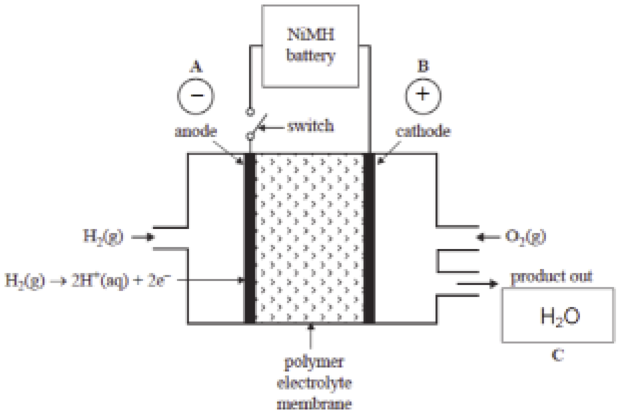
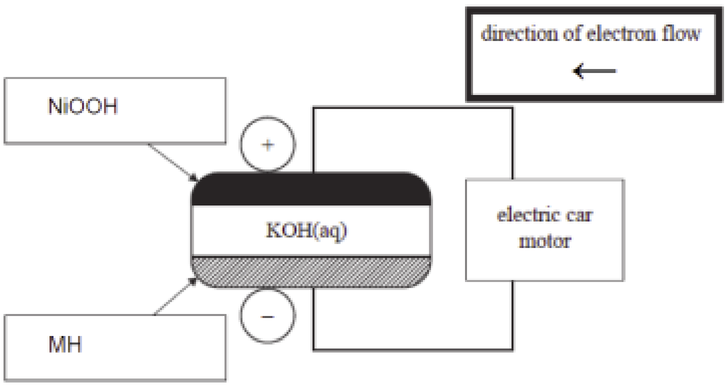
3b	One mark for identification of an incorrect statement and one mark for the explanation for two of the following: Statement 2: The hydrolysis of proteins requires the presence of the appropriate protease enzyme. Proteases do not require coenzymes to function. Statement 3: Enzymes continue to catalyse specific chemical reactions because they are not consumed in the reactions, so can catalyse a specific biochemical reaction many times. The tertiary structure/active site is not changed as a result of the reaction. Statement 5: Fats are saturated and solid at room temperature while oils are unsaturated and liquid at room temperature. The fatty acid tails in oils have a permanent kink due to the C=C double bonds so they cannot pack as closely together as fats and hence have weaker intermolecular forces. As a result, oils have lower melting points than fats. Or The fatty acid tails in fats are linear and symmetrical and can pack closer together, resulting in greater intermolecular forces and hence higher melting points than oils. Statement 7: Oxidative rancidity occurs when an ***unsaturated*** triglyceride is exposed to oxygen as the C=C double bond makes the triglyceride more susceptible to oxidation. Statement 9: Denaturation of a protein can involve the ***quaternary*** structure or tertiary structure only Statement 10: Heat can denature the quaternary, tertiary and secondary structures of proteins, but not the primary structure of proteins. Zwitterion forms of amino acids occur at a particular pH (isoelectric point) in an aqueous solution.	4	
4a	One mark for identifying the organic family: aldehyde or ketone One mark for justification: Transmittance band at ~1700 cm^{-1} corresponding to a C=O (carbonyl group) from either an aldehyde (1660-1745 cm^{-1}) or ketone (1680-1850 cm^{-1}). Note: • Absence of an O-H (hydroxyl group) indicates that this is not a carboxylic acid.	2	370 - 380

	• C=O at 1720-1840 cm^{-1} corresponds to an ester group, although the molecular formula contains only one oxygen atom, so the molecule cannot be an ester. • Transmittance band at ~3000 cm^{-1} corresponds to a C-H (2850-3090 cm^{-1}), present in all organic families.		

4b	One mark for structure:
	
	
	3 marks for the following explanation:
	1 mark for ^{13}C NMR explanation and 2 marks for ^{1}H NMR
	^{13}C NMR: 3 peaks indicate only 3 different carbon environments for the five carbon atoms. Hence some carbon atoms must be in the same environment.
	• 9 ppm peak suggests a methyl group
	  ○ R-CH_3 8-25 ppm
	• 35 ppm peak
	  ○ R-CH_2-R 20-45 ppm
	  ○ R_3-CH 40-60 ppm
	• 215 ppm peak
	  ○ R_2C=O 205-220 ppm Carbonyl in ketone
	^{1}H NMR: Two peaks indicate two different hydrogen environments
	• 1.0 ppm peak
	  ○ Data book: R-CH_3 0.9-1.0 ppm
	  ○ Splitting pattern: 2 H on adjacent carbon atom (-CH_2-)
	• 2.4 ppm peak
	  ○ Data book: $RCOCH_3$ 2.1-2.7 ppm
	  ○ Splitting pattern: 3 H on adjacent carbon atom (-CH_3)
	2 H environments with correct splitting pattern
		4	381 - 392

5a	I_3^-(aq)	1	
5b	Solution in mol/L i. n(I_3^-) = C x V n(I_3^-) = 2.000 x 10^{-4} x (15.65/1000) n(I_3^-) = 3.130 x 10^{-6} mol ii. n($C_6H_8O_6$) = n(I_3^-) n($C_6H_8O_6$) = 3.130 x 10^{-6} mol iii. n($C_6H_8O_6$ in 250 mL) = 3.130 x 10^{-6} x (250/25)	 1 1	446

	$n(C_6H_8O_6 \text{ in } 250 \text{ mL}) = 3.13 \times 10^{-5}$ mol $C(C_6H_8O_6) = n/V$ $C(C_6H_8O_6) = 3.130 \times 10^{-5}/(20/1000)$ $C(C_6H_8O_6) = 1.565 \times 10^{-3}$ mol/L = 1.565×10^{-3} M	1 1 1	
5ci	1 mark each for the 2 chiral centres in Vitamin C  vitamin C  vitamin D_3	2	283 - 284
5cii	1 mark for each of the following: • Active site of enzymes is specific to a molecule with a certain geometry • Naturally occurring vitamin C, and the other optical isomer have different geometries, only one of which will fit the active site of L-ascorbate oxidase.	2	281
5ciii	1 mark for each of the following: • Vitamin C is highly polar due to the presence of 4 hydroxyl groups which can hydrogen bond with water and is therefore water soluble. • Vitamin D_3 only contains one hydroxyl group, and has a large non-polar hydrocarbon structure, and is therefore not water soluble.	2	508
6a	1 mark for the following: • Glycaemic Index is a measure of how quickly carbohydrates are hydrolysed to glucose; pure glucose does not require any hydrolysis so will have a high value that can be used as a reference for other foods. Glucose is a convenient standard for comparison as it is available and easily measured as a comparison.	1	546
6b	1 mark for one of the following: • Available carbohydrates represent the fraction of carbohydrates that can be digested by human enzymes	1	
6c	1 mark for each of the following: • Athletes have a high energy requirement, especially for glucose as it is consumed by muscles as fuel during exercise • Including some High GI foods into their diet allows glucose to be made available in a short period time	2	548 - 549
6d	1 mark for each of the following: • A GI value of 62 places the food into the medium GI range (56-69), not the low GI range that was claimed.	2	

	• The variance in the data is quite large (average 15) which means that for some people the food would have been low GI (55 or below) but also high GI for others (70 or above)		
7ai	1 mark for each of the following: • Labelling the anode with a negative polarity and the cathode with a positive polarity. • Labelling product out "c" as H_2O, $H_2O(l)$ or water  	2	153 - 154
7aii	1 mark for correct equation: (from data book) $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$	1	
7aiii	1 mark for any of the following: • The only product from the fuel cell, water, is safe for disposal whereas the burning petrol with also produce CO_2 and other oxides which have negative environmental impacts • The fuel cell is much more efficient, allowing a higher proportion of the chemical energy to be transformed into useful energy rather than waste energy.	1	152, 158 - 159
7bi	1 mark for correct equation: (from data book) $MH(s) + NiOOH(s) \rightarrow M(s) + Ni(OH)_2(s)$	1	
7bii	1 mark for correct labelling of electrodes:  	1	
7biii	1 mark for correct labelling of direction of electron flow (pointing left). As shown in the above picture.	1	
7biv	1 mark awarded for: • Accurate calculation of charge • Accurate calculation of n(NiOOH) • Accurate calculation of m(NiOOH)	3	254 - 255

<table>
<tr><td></td><td>Q = It
= 1.15 × 60 × 60 (3600 seconds)
= 4.14×10^3 C

$n(e^-) = \frac{Q}{F}$
$= \frac{4.14 \times 10^3}{96500}$
= 0.0429 mol
$n(NiOOH) = n(e^-)$ = 0.0429 mol

m(NiOOH) = n(NiOOH) x M(NiOOH)
= 0.0429 × 91.7
= 3.9 g

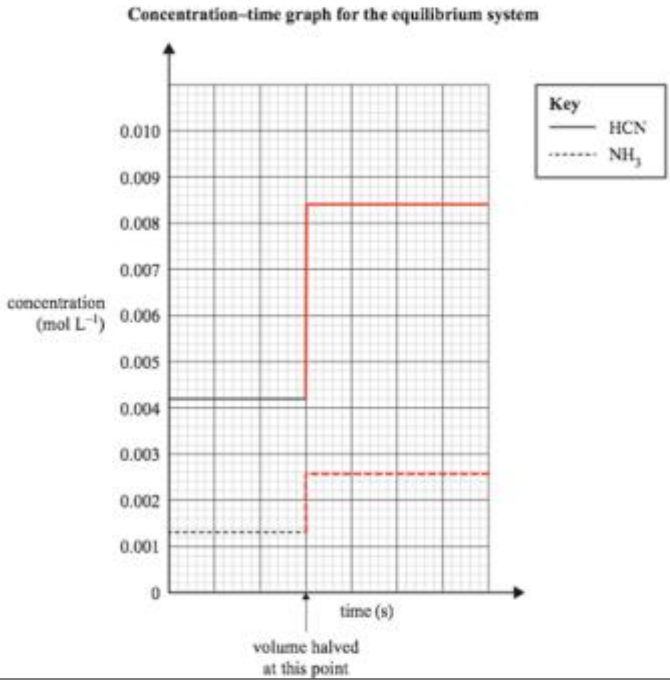
The use of 60 minutes in the calculations limits the significant figures to 2 for the answer.</td><td></td><td></td></tr>
<tr><td>8ai</td><td>$K_c = \frac{[HCN][CO_2][H_2]}{[CO]^2[NH_3]}$ (no units)</td><td>1</td><td>204</td></tr>
<tr><td>8aii</td><td>$[HCN]_i = 0$, $[HCN]_e = [CO_2]_e = [H_2]_e = 0.0042$ M

$[CO]_e = 0.0025$ M $[NH_3]_e = 0.00125$ M

$K_c = \frac{0.0042 \times 0.0042 \times 0.0042}{(0.0025)^2 \times 0.00125} = 9.5$ (no units)</td><td>2</td><td>213</td></tr>
<tr><td>8bi</td><td>One mark for each expected effect
<table>
<tr><td></td><td colspan="3">Expected effect on the amount of HCN</td></tr>
<tr><td></td><td>Increase</td><td>Decrease</td><td>No effect</td></tr>
<tr><td>Halve the volume of the gas mixture, keeping the temperature constant.</td><td></td><td></td><td>√</td></tr>
<tr><td>Return the volume of the gas mixture to 100 mL, then inject some powdered palladium into the gas syringe. (Palladium absorbs H_2 gas onto its surface.)</td><td>√</td><td></td><td></td></tr>
</table>

Explanations: (not required for marks)
Halving the volume has no effect on the position of equilibrium as there is no change to the CF, this is because there is an equal number of moles of gas on each side of the equation.

Adding Pd reduces the concentration of hydrogen gas, lowering the value of the concentration fraction. In order to return to equilibrium a forward reaction occurs until CF = K. The reaction proceeds forward to partially negate the loss of the product, hydrogen gas.</td><td>2</td><td>216</td></tr>
<tr><td>8bii</td><td>One mark for each correct annotation where [HCN] must finish at 0.0084M and $[NH_3]$ must finish at 0.0026M.</td><td>2</td><td>224</td></tr>
</table>

			
8c	$2C_4H_{10}(g) + 9O_2(g) \rightarrow 8CO(g) + 10H_2O(g)$	1	
8d	One mark for each of the following: • The value of K_2 is much larger than K_1. • **Explanation**: Both O_2 and CO are competing for haemoglobin – even if the concentration of CO is far less than O_2 (0.08% CO_2 compared to ~21% O_2which is the average oxygen content of air respectively) the CO still binds with the Hb more favourably, hence the equilibrium constant K_2 must be much larger than K_1.	2	207
9ai	$n(\text{glucose}) = \frac{m}{M} = \frac{2.002}{180.0} = 0.01112 \text{ mol} = 1.112 \times 10^{-2} \text{ mol}$ $E = \Delta H_c \times n = 2805 \times 1.112 \times 10^{-2} = 31.19 \text{ kJ} = 3.119 \times 10^4 \text{ J}$ $E = m \times C \times \Delta T; \quad \Delta T = \frac{E}{m \times C} = \frac{3.119 \times 10^4}{150.0 \times 4.182} = 49.72°\text{C}$ Therefore, the maximum temperature ***rise***: 49.72 ^{o}C (4 sig fig) (Therefore, the maximum temperature of water: 21.3 + 49.72 = 71.0 ^{o}C)	3	572
9aii	$\Delta T_{\text{theoretical rise}}$ = 49.72 ^{o}C and $\Delta T_{\text{experimental rise}}$ = 48.5 - 21.3 = 27.3 ^{o}C One mark for each of the following: • The experimental temperature is lower than the theoretical temperature rise by 45.3%. [percentage difference = |49.72 – 27.2/49.72| x 100 = 45.3%] • Hence the result obtained with this experimental technique is not accurate due to a large systematic error.	2	574 580

9bi	$E = VIt$ = 5.65 x 1.78 x 135 = 1357.695 J $CF = \frac{E}{\Delta T} = \frac{5.65 \times 1.78 \times 135}{1.150} = 1180.6 = 1.18 \times 10^3$ J °C^{-1}(3 sig fig) Note that the answer given in the question is incorrect and that 1160 kJ °C^{-1} is incorrect.	2	583
9bii	$n(\text{glucose}) = \frac{m}{M} = \frac{1.324}{180.0} = 0.007356 \text{ mol} = 7.356 \times 10^{-3}$ mol $CF = \frac{E}{\Delta T}$; $E = CF \times \Delta T = 1180 \times 17.32 = 2.04 \times 10^4$J $E = \Delta H_c \times n$; $\Delta H_c = \frac{E}{n} = -\frac{2.04 \times 10^4}{7.356 \times 10^{-3}} = -2.78 \times 10^3$ kJ mol^{-1} (3 sig fig)	3	585
9biii	$\Delta H_{c(experimental)} = -2.78 \ x\ 10^3$kJ mol^{-1} $\Delta H_{c(published)} = 2805$ kJ mol^{-1} [percentage difference = |2805 – 2780/2805| x 100 = 0.89%] The two values are very similar.	1	
9ci	One mark for any one of the following: • Incomplete combustion of glucose • Inefficient heat transfer from combustion of glucose to water due to heat loss from; flame to air, water to air, and sides of pot to air. • Heat required to increase temperature of copper pot	1	
9cii	The improved design feature identified in **c. ii.** must correspond to the design fault identified in **c. i.** Identification of improved design feature. Explanation of effect of improved design feature. • Pure oxygen is used rather than air, which is only part oxygen, to favour complete combustion of glucose. • Heat loss to the environment is minimised due to insulation of calorimeter. Hence more heat transferred to the water.	 1 1	577 580
10a	One mark for any 2 of the following: • Chris has some understanding of the collision theory. Chris is right that increasing H^+ concentration will result in more frequent collisions with Mg and hence a faster reaction rate. Chris doesn't mention that a successful collision requires the collision to have the correct collision geometry and the activation energy. Further, he has not shown understanding of how the rate will decrease as the reaction proceeds and H^+ are used up.	2	175

	• Chris's experimental design does allow for the determination of the rate of reaction at different concentrations of H^+. • Chris shows some confusion between factors that affect reaction rate and factors that affect yield. The hypothesis suggests that the concentration of H^+ ions will affect the total amount of hydrogen gas produced. • The amount of product is affected by the amount (in moles) of reactant available whereas the rate of the reaction is affected by concentration.		
10b	No. The concentration of HCl is the independent variable (manipulated by the experimenter). (The dependent variable (the variable that is measured or observed) the volume of hydrogen gas production over time – to determine the rate).)	1	
10c	• 1 mark – Identifying a feature of the experimental set-up that does improve accuracy. • 1 mark – Explanation how the feature will be able to assist Chris improve accuracy. • 1 mark – Explain how the likelihood of error will be decreased by the feature which will improve the accuracy of Chris' results. Examples: Video: The video recording improves accuracy by reducing human error that would be associated with attempting to record the volume of gas at the same time as recording the time. With the video footage, Chris will be able to pause the video to record data for both the volume of gas and time at any instant during the experiment. This should improve accuracy by obtaining results that are closer to the actual value. Stirrer: The magnetic stirrer improves accuracy by ensuring the HCl solution is consistently mixed throughout the reaction flask at all times during the experiment. If the solution was not stirred constantly, it would be possible for the concentration around the magnesium to be lower than the overall solution which would affect the rate of the reaction. This should improve accuracy by obtaining results that are closer to the actual value.	3	
10	• 1 mark – Commenting on the observations, in particular the difference in rates between the different concentrations. • 1 mark – Identifying the reaction as exothermic and the effect this would have on the rate.	3	

	• 1 mark – Discussion about how well the experiment was controlled. Suggestion for how to improve the experiment would strengthen students' responses. Example: • Differences in rate of bubbling: Rate of bubbling is an indication of rate of hydrogen gas production (reaction rate). The rate of reaction is proportional to [HCl] (and rate of bubbling observed). The slowing of bubbling over time is due to the depletion of H^+ in solution causing a decrease in reaction rate. The fact that the 1.5 M and 1.0 M solutions were still bubbling when timing stopped indicates the reaction had not gone to completion. • Temperature change: The flasks becoming hot indicates an exothermic reaction. Chris's observation that the 2.0 M HCl caused the flask to become the hottest suggests a faster rate of reaction, which resulted in more energy released in the given time. More reliable observations could have been obtained by measuring temperature changes in the flask. • Mg appeared to dissolve: The reaction has gone to completion as all Mg was used up (converted to Mg2+) • Control: Chris attempted to control the mass of Mg and volume of HCl used. The mass of Mg was not measured, rather the amount was controlled by cutting equal lengths of Mg ribbon (not very precise). By cutting equal lengths, Chris has also somewhat controlled surface area. Sanding to remove MgO from the surface of Mg would have helped to control surface area of Mg between trials. HCl volumes were measured using a graduated measuring cylinder. A glass pipette (or the syringe itself) would have enabled a more precise measurement of volume. Chris has also not controlled the temperature or pressure of the system.		
10e	• 1 mark – The conclusion that the rate of reaction increases a concentration increases. • 1 mark – Reference to this supporting his initial hypothesis. Example: • The greater the concentration of HCl, the greater the initial rate of reaction. • Higher concentrations of HCl result initially in more rapid production of hydrogen gas.	2	
10f	• 1 mark – Identifying a suitable question that could be posed for this experiment. • 1 mark – Changes to the experimental set-up are listed. • 1 mark - The process of answering the posed question is discussed Examples:		

	Research question: How does the surface area of Mg affect the rate of reaction? Independent variable: surface area of Mg Dependent variable: volume of hydrogen gas produced over time – to calculate rate of reaction Controlled variables: mass of Mg, volume of HCl, concentration of HCl, initial temperature of reaction Methodology: 1. Prepare standard solution of 1.0 M HCl 2. Set up apparatus as for previous experiment 3. Cut four pieces of Mg ribbon of equal length 4. Place the first piece of Mg into a conical flask (trial 1) 5. Cut the second piece of Mg into 4 pieces and place in a second conical flask (trial 2) 6. Cut the third piece of Mg into 8 pieces and place in a third conical flask (trial 3) 7. Cut the fourth piece of Mg into 12 pieces and place in a fourth conical flask (trial 4) 8. Run each trial of the experiment as before, adding 20 mL of 1.0 M HCl each time 2 Research question: How does temperature affect the rate of reaction? Independent variable: temperature of HCl Dependent variable: volume of hydrogen gas produced over time – to calculate rate of reaction Controlled variables: mass of Mg, surface area of Mg, volume of HCl, concentration of HCl 3. Research question: How does the nature of the metal (Zn, Mg, Fe) affect the rate of reaction? Independent variable: nature of metal e.g. Zn, Mg, Fe Dependent variable: volume of hydrogen gas produced over time – to calculate rate of reaction Controlled variables: mass of Mg, surface area of Mg, volume of HCl, concentration of HCl, initial temperature of reaction		