Mark Scheme (Results)

Summer 2023

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 03: General and Practical Principles in Chemistry

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General Marking Guidance

- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:

  i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  iii) organise information clearly and coherently, using specialist vocabulary when appropriate

Using the Mark Scheme

Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:
- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.
( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.
Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.
ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

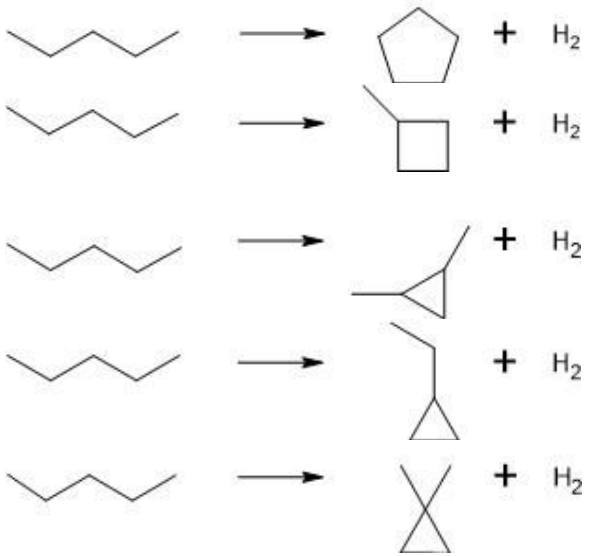
Quality of Written Communication
Questions which involve the writing of continuous prose will expect candidates to:
- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Additional Guidance	Mark
1(a)	• correct balancing	Example of equation C_6H_{14} + **9½**O_2 → **6**CO_2 + **7**H_2O Accept decimals/improper fractions Allow multiples 2:19:12:14 Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to **two** of the following points: • carbon / C **(1)** • carbon monoxide / CO **(1)** • nitrogen monoxide / NO / nitrogen dioxide / NO_2 / nitrogen oxides / NO_x / pentane / C_5H_{12} **(1)**	Do not award hydrogen / H_2 Allow particulates / soot Ignore carbon dioxide Ignore ‘unburnt hydrocarbons’	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(c)	An explanation that makes reference to the following points: • acid rain is formed **(1)** • because sulfur oxides / sulfur dioxide / SO_2 / sulfur trioxide / SO_3 (formed which dissolve in water) **(1)**	Causes respiratory difficulties/bronchitis Allow description of breathing difficulties Ignore just vague references to harm the environment Ignore reference to greenhouse effect/global warming Allow (formation of) sulfuric acid Allow SO_x but not SO	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(d)	• skeletal formulae **(1)** • hydrogen molecule (product) to balance the equation **(1)**	Examples of equations  Award (1) for use of non-skeletal formulae in balanced equation Ignore state symbols even if incorrect Allow formation of cyclopentene with $2H_2$ Do not award M2 if any other species is/are given in the equation but ignore any catalysts written above the arrow	**(2)**

(Total Question 1 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)(i)	• balanced equation **and** state symbols	Example of equation $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$ Accept multiples	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(a)(ii)	An explanation that makes reference to the following points: • reactivity increases **and** since ionisation energy decreases **(1)** (because) • outer/valence electrons are further from the nucleus **(1)** • (electrons) more shielded or (electrons) more repelled by inner electron shells **(1)**	Allow specific references of reactivity trend or that 'barium is the most reactive' Allow reactivity increases **and** easier to lose electron(s) Allow reactivity increases **and** reduced attraction between the nucleus and the (outer) electron(s) Allow atomic radius increases down the group Ignore just more electron shells Do not award ionic radius Do not award reference to charge density Ignore reference to increasing nuclear charge If response refers to trend going **up** Group 2 then allow reverse argument	**(3)**

Question Number		Additional Guidance	Mark
2(b)(i)	An answer that makes reference to the following point: • solubility decreases down the group	Accept reverse argument Allow answers which compare specific sulfates such as 'barium sulfate is less soluble than magnesium sulfate'	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(b)(ii)	An explanation that makes reference to the following points: • the (calcium) sulfate / $CaSO_4$ formed is insoluble/ $CaSO_4$ sparingly soluble **(1)** • (the reaction stops because) the layer/barrier formed (on the surface) prevents further reaction **(1)**	Mark independently Allow calcium sulfate solid/precipitate/ppt/ppte formed Ignore just calcium sulfate is less soluble If name and formula given then both must be correct Allow the layer/barrier prevents the sulfuric acid from coming into contact with the calcium	**(2)**

Question Number	Answer	Additional Guidance	Mark
2(c)(i)	An answer that makes reference to the following point: • relights a glowing splint	Allow relit/rekindle/reignite Do not award relights a lit splint Do not award reference to 'squeaky pop' or similar description of hydrogen result	**(1)**

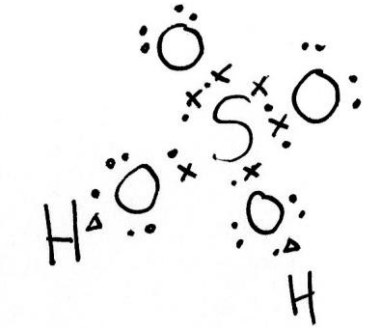
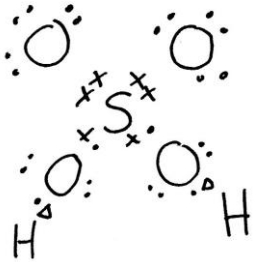
Question Number	Answer	Additional Guidance	Mark
2(c)(ii)	• balanced equation	<u>Example of equation</u> $NaNO_3 \rightarrow NaNO_2 + ½O_2$ Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
2(c)(iii)	An answer that makes reference to the following points: • oxygen is oxidised from −2 to 0 (in O_2) **(1)** • nitrogen is reduced from +5 to +3 (in $NaNO_2$) **(1)**	Accept an annotated equation Allow (1) for these four correct oxidation numbers which may be annotated on the equation	**(2)**

(Total Question 2 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	• equation	Example of equation $CH_3CH_2OH \rightarrow CH_2CH_2 + H_2O$ Allow displayed, semi-displayed, skeletal formulae and C_2H_5OH and C_2H_4 Ignore any catalyst, even if incorrect, written above the arrow Ignore state symbols even if incorrect Do not award use of molecular formula for ethanol Do not award inclusion of catalyst on both sides of the equation Do not award reversible arrow	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)	• H_3PO_4	Ignore any state symbols even if incorrect Ignore (V) written after the correct formula	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(c)	• 2 double bonds and 2 single bonds for sulfur **(1)** • rest of diagram correct **(1)**	<u>Example of diagram</u>  Allow  2 dative covalent bonds and 2 single bonds for sulfur scores (1) rest of diagram correct scores (1) Allow bond pairs to be show horizontally Ignore lines drawn between atoms to show covalent bonds Ignore arrows drawn between atoms to show coordinate bonds Allow (1) for diagram with all dots/crosses	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(d)(i)	An answer that makes reference to the following point: • (excess liquid) ethanol could 'run'/leak down the tube (to the catalyst)	Allow if test tube is horizontal then liquid ethanol would run down the tube Allow 'to keep the ethanol where it is' which implies movement otherwise Allow to prevent ethanol/ (mineral) wool and catalyst mixing Allow reactant for ethanol Allow the catalyst could slide (towards the ethanol) Ignore any reference to heating	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	An answer that makes reference to the following point: • ethanol (would evaporate) **and** pass over the catalyst without reaction	Ignore references to combustion and flammability of ethanol Ignore references to the mineral wool	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(d)(iii)	An answer that makes reference to the following point: • the clamp may burn	Allow the bung may burn / be set on fire / rubber may melt	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(d)(iv)	An answer that makes reference to the following point: • (the valve) prevents the flow of water / suck-back (up the delivery tube)	Allow prevents water entering the delivery tube	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(d)(v)	An answer that makes reference to the following point: • bromine (water/solution) **and** decolourisation or (orange / brown / yellow / red) to colourless	Ignore clear Allow any combination of stated colours Allow Acidified potassium manganate((VII)) **and** decolourisation / purple to colourless	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(d)(vi)	• calculation of number of moles of ethene **(1)** • calculation of the volume of ethene **(1)**	Example of calculation n(Ethene)= $(2.759 \times 10^{20} \div 6.02 \times 10^{23})$ $= 4.5831 \times 10^{-4}$ (mol) V(Ethene) = $(4.5831 \times 10^{-4} \times 24\,000)$ = 10.999 / 11.0 / 11 (cm^3) or V(Ethene) = $(4.5831 \times 10^{-4} \times 24 =)$ = 0.010999/ 0.011 (dm^3) Ignore SF except 1SF Correct answer without working scores (2) TE for the volume from number of moles Allow (1) for no. of molecules x 24(000) Allow use of pV=nRT for both marks 298 K gives 11.349 (cm^3) 293 K gives 11.159 (cm^3)	**(2)**

(Total Question 3 = 11 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*4 (a)</td>
<td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

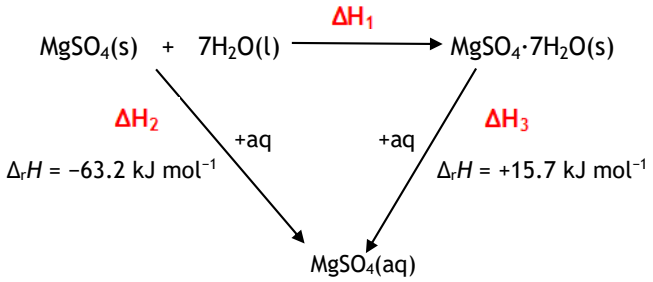
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>

The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td>
<td>
Guidance on how the mark scheme should be applied:
The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with four indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).
If there were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

More than one indicative marking point may be made within the same comment or explanation
</td>
<td>(6)</td>
</tr>
</table>

	Indicative content • **IP1 –** (accurately) weigh/ use a known mass of (hydrated) magnesium sulfate • **IP2 –** (accurately weigh) known mass of (distilled / deionised) **water** • **IP3 –** use of polystyrene cup (and lid) • **IP4 –** record initial temperature of the water (before adding solid) • **IP5 –** add magnesium sulfate (to the water in the cup) **and** stir • **IP6 -** record temperature (at suitable time intervals) / record final temperature	Allow amount for mass Allow any reasonable stated mass between 1−10g Allow any reasonable volume between 20−250cm^3 Allow insulated beaker/calorimeter/styro-foam cup Do not allow if heating is described Do not award recording initial temperature of solid Addition of water to the solid loses IP4 **only** Allow mix/stir the water and the solid Allow record the lowest or highest temperature reached Allow use of graphical extrapolation Do not award if the solution is being heated	

Question Number	Answer	Additional Guidance	Mark
4(b)	• rearrangement using Hess's law **(1)** • evaluation of answer with sign (and units) **(1)**	Example of calculation and Hess cycle  $\Delta H_1 = \Delta H_2 - \Delta H_3 = -63.2 - +15.7 = -78.9$ (kJ mol^{-1}) $\Delta_r H = (-63.2 - +15.7)$ $\Delta_r H = -78.9$ (kJ mol^{-1}) Correct answer with no working scores (2) If value converted to J mol^{-1} then both marks can be awarded for −78 900 J mol^{-1} but just −78 900 scores M1 only Allow (1) for (+)78.9 (kJ mol^{-1}) Allow (1) for −47.5 (kJ mol^{-1})	**(2)**

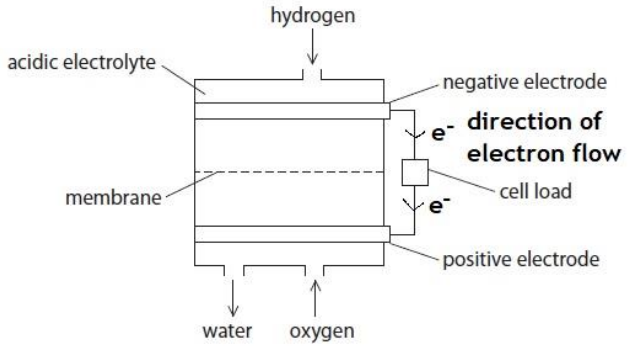
Question Number	Answer	Additional Guidance	Mark
4(c)	• the enthalpy change of hydration of magnesium/Mg (ion) will be more exothermic/more negative **(1)** • because the magnesium (ion) is smaller than the calcium (ion) but has the same charge (so the attraction between the water molecules and the gaseous ion is stronger) **(1)**	Do not award just 'enthalpy change is greater' Do not allow calcium (ion) enthalpy change of hydration is more positive/ endothermic Accept reverse argument Allow magnesium (ion) has a greater charge density Allow Mg^{2+} is smaller than Ca^{2+} Do not award atomic radius	**(2)**

(Total Question 4 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)	An answer which makes reference to the following points: • (**Y**) platinum / Pt **(1)** (**Z**) • manganese(II) nitrate / $Mn(NO_3)_2$ **and** potassium manganate(VII) / $KMnO_4$ (solution) **(1)** • sulfuric acid **(1)**	Names or formulae accepted but if both given then both must be correct All three are standalone marks Ignore reference to (platinum) black Allow $MnSO_4$ Allow sodium manganate(VII)/ $NaMnO_4$ Allow potassium permanganate for $KMnO_4$ Oxidation numbers essential if only the names are given Allow nitric acid Do not award use of hydrochloric acid Ignore concentrations throughout Penalise use of hydrochloric acid or manganese halides once only	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(b)	An explanation that makes reference to the following points: • (chromium(VI) reduced to) chromium +2 / (II) **(1)** because • $E^{\ominus}_{cell}$ value for the reduction of chromium(VI) to chromium(III) **(1)** • $E^{\ominus}_{cell}$ value for the reduction of chromium(III) to chromium(II) **(1)** • $E^{\ominus}_{cell}$ value for the reduction of chromium(II) to chromium **(1)** • first two reductions occur (because $E^{\ominus}_{cell}$ is positive in both cases) **and** final reaction does not occur (because $E^{\ominus}_{cell}$ is negative) **(1)**	Allow Cr^{2+} Allow TE on candidate $E^{\ominus}_{cell}$ values, e.g. all $E^{\ominus}_{cell}$ values positive then Cr(0) is the result $E^{\ominus}_{cell}$ = (+1.33 − −0.76 =) (+) 2.09 (V) $E^{\ominus}_{cell}$ = (−0.41 − −0.76 =) (+) 0.35 (V) $E^{\ominus}_{cell}$ = (−0.91 − −0.76 =) −0.15 (V) Accept feasible for occur Ignore equations even if incorrect Penalise reference to Zn^{2+} reacting in the written answer once only for M2 and M3	**(5)**

Question Number	Answer	Additional Guidance	Mark
5(c)	• half-equation	<u>Example of equation</u> $NO_3^- + 2H^+ + e^{(-)} \rightarrow NO_2 + H_2O$ Allow multiples / ⇌ Ignore state symbols even if incorrect	**(1)**

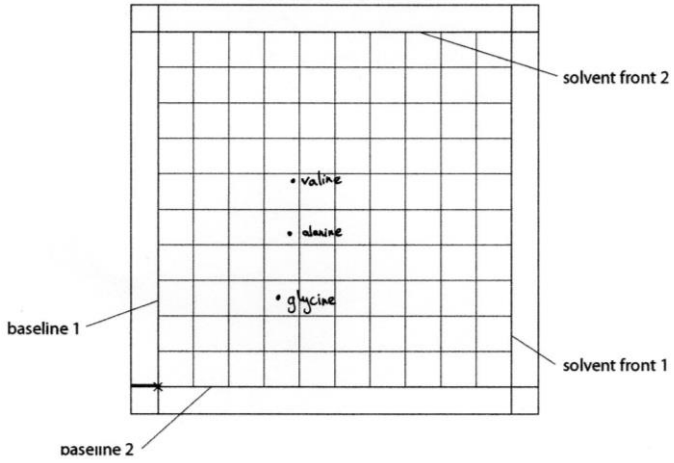
Question Number	Answer	Additional Guidance	Mark
5(d)	An answer that makes reference to the following points: • (electrons move) from the negative to the positive electrode **(1)** • (because) the hydrogen is being oxidised / losing electrons **and** the oxygen is being reduced / gaining electrons **(1)**	Allow annotation on diagram, see below Allow move from the top electrode to the bottom electrode Ignore just electrons move down/clockwise Do not allow movement through the middle of the fuel cell Allow anode for negative electrode and cathode for positive electrode Allow half-equations such as (Oxidation) $H_2 \rightarrow 2H^+ + 2e^{(-)}$ **and** (Reduction) $\frac{1}{2}O_2 + 2H^+ + 2e^{(-)} \rightarrow H_2O$ Do not award formation of O^{2-} ions M2 is not dependent on M1  	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(e)	An answer which makes reference to any **one** of the following points • harmless product/water compared to pollutants or less reliant on fossil fuels/non-renewable fuels or more efficient energy production or (can be) smaller and lighter fuel cell	 Accept named pollutants e.g. $CO/CO_2/SO_2/NO_x$ Allow hydrogen fuel cell **only** produces water Allow hydrogen (fuel) is renewable/sustainable Allow no use of fossil fuels Allow less/no green house gases produced Ignore just 'more efficient'	**(1)**

(Total Question 5 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following point: • each component in the mixture is attracted to mobile and stationary phases but more strongly to one than to the other	Allow affinity for 'attracted to' Allow different for 'more strongly' Allow solvent for mobile phase Do not allow reference to reacting with either of the phases	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)(i)	An answer that makes reference to the following point: • two of the amino acids present are the same	Ignore one amino acid has not moved from the original pencil line Ignore one amino acid is still 'seen' Ignore one amino acid is still present on the original pencil line Ignore one amino acid is insoluble	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	• 3 spots moved in correct (horizontal) position for solvent 1 **(1)** • 3 spots moved in correct (vertical) position for solvent 2 **(1)** • labelling of alanine, glycine and valine provided in correct R_f position for M1 or M2 **(1)**	Allow a tolerance of ±¼ 0.25 of a square within each large square Any alterations to the grid dimensions scores (0) Example of suitable diagram 	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(b)(iii)	An answer that makes reference to the following point: • ninhydrin	Allow phosphomolybdic acid (commonly referred to as PMA) or *p*-anisaldehyde or cerium molybdate (Hanessian's stain) or bromocresol green	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(c)	An answer that makes reference to the following point: • mass spectrometry	 Allow mass spectroscopy Allow just 'MS' Allow mass spec Allow infrared spectroscopy, UV spectroscopy, visible spectroscopy, fluorescence spectroscopy Allow NMR	**(1)**

(Total Question 6 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)(i)	An answer that makes reference to the following point: • expel some solution (to remove the air bubble and suck up again with the tip of the pipette in the solution) or (fill pipette above the line and) expel some solution (to remove the bubble)	Allow gently tap the side of the pipette to move the air bubble to the top and out of the solution Do not award answers referring to opening taps Do not award inverting the pipette	**(1)**

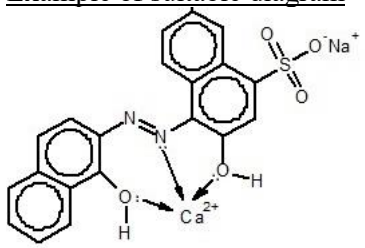
Question Number	Answer	Additional Guidance	Mark
7(a)(ii)	• calculation of maximum volume	<u>An example of calculation</u> 25.04 + 25.04 = 50.08 (cm^3)	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(a)(iii)	• calculation using one 25 cm^3 pipette twice **(1)** • calculation using one 50 cm^3 pipette **and** making a comparison **(1)**	<u>An example of calculation</u> % uncertainty = (100 × 0.08 ÷ 50) = 0.16 % % uncertainty = (100 × 0.05 ÷ 50) = 0.1(0) % e.g. Difference = 0.16 – 0.10 = 0.06 % or 0.16% > 0.10% TE on (a)(ii) Allow TE for M2 Ignore SF including 1SF	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	• unsuitable because the smallest volume you can measure is 10 cm^3	Allow unsuitable/No because 2 cm^3 is too small to measure in a 100 cm^3 measuring cylinder Allow unsuitable/No because the graduations are too big to measure such a small volume Allow unsuitable/No because the (percentage) uncertainty will be too large Allow unsuitable/No because the resolution is too low/is not precise enough Allow suitable/Yes because the volume doesn't have to be accurate and about 2 cm^3 can be estimated	**(1)**

Question Number	Answer		Additional Guidance	Mark
7(b)(ii)	Method 1		<u>Example of calculation</u>	(4)
	• (expression of K_a and) $[H^+]$	**(1)**	($K_a = ([NH_3] \times [H^+]) \div [NH_4^+]$ and) $[H^+] = (\text{inv log} -\text{pH} =) 1.0 \times 10^{-10}$ (mol dm^{-3})	
	• rearrangement of K_a expression & $[NH_4^+]$	**(1)**	$[NH_4^+] = ((18.1 \times 1 \times 10^{-10}) \div 5.62 \times 10^{-10} =) 3.22$ (mol dm^{-3})	
	• number of moles of NH_4Cl	**(1)**	$n(NH_4Cl) = ((3.22 \times (100 \div 1000) =) 0.322$ (mol)	
	• mass of NH_4Cl	**(1)**	$m(NH_4Cl) = 0.322 \times 53.5 = 17.227 / 17.23 / 17.2 / 17$ (g)	
			Final answer with or without working scores (4) TE at each stage	
			Ignore SF except 1SF	
	Method 2 (Use of Henderson-Hasselbalch equation)			
	• expression of pH	**(1)**	$pH = pKa + \log ([NH_3] \div [NH_4^+])$ $10 = 9.25 + \log (18.1 \div [NH_4^+])$	
	• rearrangement of pH expression & $[NH_4^+]$	**(1)**	$[NH_4^+] = (18.1 \div 10^{0.75}) = 3.22$ (mol dm^{-3})	
	• number of moles of NH_4Cl	**(1)**	$n(NH_4Cl) = ((3.22 \times (100 \div 1000) =) 0.322$ (mol)	
	• mass of NH_4Cl	**(1)**	$m(NH_4Cl) = 0.322 \times 53.5 = 17.227 / 17.23 / 17.2 / 17$ (g)	

Question Number	Answer	Additional Guidance	Mark
7(b)(iii)	An answer that makes reference to the following point: • use in fume cupboard / fume hood	Do not award use mask / well-ventilated room	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	• diagram with 3 dative or covalent bonds	<u>Example of suitable diagram</u>  Allow lines for arrows Allow absence of lone pairs Do not allow dashed lines Do not award arrows going from the calcium to the N/O Do not award arrows or line coming from any other atoms to those shown Do not award double-headed arrows or curly arrows	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	• 3 / three		**(1)**

Question Number	Answer	Additional Guidance	Mark
7(d)(i)	An answer that makes reference to the following point: • filter (off the precipitate)	Allow use of Buchner funnel / suction filtration / filtration under reduced pressure/ gravity filtration Ignore decant	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(d)(ii)	Method 1 Total Hardness • (**M1**) calculation of number of moles of $EDTA^{4-}$ **(1)** • (**M2**) calculation of number of moles of calcium ions in 1 dm^3 **(1)** • (**M3**) calculation of mass of calcium ions in 1 dm^3 **(1)** • (**M4**) calculation of total hardness **(1)** Permanent and Temporary Hardness (method as above) • (**M5**) calculation of permanent hardness **(1)** • (**M6**) calculation of temporary hardness **(1)**	<u>An example of calculation</u> $n(EDTA^{4-}) = ((12.80 \div 1000) \times 0.010 =) 1.28 \times 10^{-4}$ (mol) in 50 cm^3 $n(Ca^{2+}) = n(EDTA^{4-}) = 1.28 \times 10^{-4}$ (mol) in 1 dm^3 $n(Ca^{2+}) = 1.28 \times 10^{-4} \times 20 = 2.56 \times 10^{-3}$ (mol) $m(Ca^{2+}) = ((2.56 \times 10^{-3} \times 40.1 = 0.102656 =) 0.10266 / 0.103$ (g) Total Hardness = $(0.103 \times 1000 =) 103$ (mg dm^{-3}) Permanent hardness $= ((5.15 \div 1000) \times 0.010 \times 20 \times 40.1 \times 1000 = 41.303)$ $= 41$ (mg dm^{-3}) Temporary Hardness = $(103 - 41 =) 62$ (mg dm^{-3}) Accept Final answer without rounding = $(102.66 - 41.30 =) 61.36$ (mg dm^{-3}) Final answers without working scores (6) TE at each stage Accept M1 – M4 either from the calculation of total or the permanent hardness Use of 40 for calcium gives 41.2 and 61.2 which score full marks Ignore SF except 1SF	**(6)**

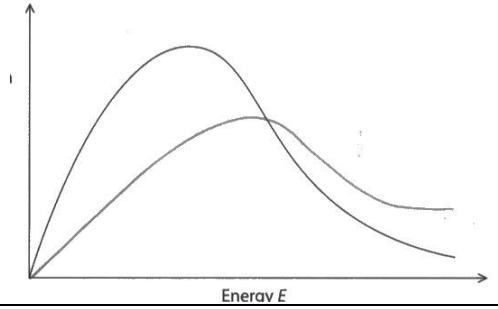
	Method 2 • (**M1**) calculation of volume of $EDTA^{4-}$ required for temporary hardness **(1)** • (**M2**) calculation of number of moles of $EDTA^{4-}$ for permanent hardness **(1)** • (**M3**) calculation of number of moles of calcium ions in 1 dm^3 for permanent hardness **(1)** • (**M4**) calculation of mass of calcium ions in 1 dm^3 for permanent hardness **(1)** • (**M5**) calculation of permanent hardness **(1)** • (**M6**) calculation of temporary hardness **(1)**	V=(12.80 – 5.15=) 7.65 (cm^3) $n(EDTA^{4-})$ = ((5.15 ÷ 1000) × 0.010 =) 5.15 × 10^{-5} (mol) in 50 cm^3 $n(Ca^{2+})$ = $n(EDTA^{4-})$ = 5.15 × 10^{-5} (mol) in 1 dm^3 $n(Ca^{2+})$ = 5.15 × 10^{-5} × 20 = 1.03 × 10^{-3} (mol) $m(Ca^{2+})$ = ((1.03 × 10^{-3} × 40.1 = 0.0413 (g) Permanent hardness =(0.0413 x 1000=) 41.3 (mg dm^{-3}) Temporary hardness =((7.65 ÷ 1000) × 0.010 × 20 × 40.1 x 1000=) = 61.4 (mg dm^{-3}) Final answers without working scores (6) TE at each stage Accept M2 – M5 either from the calculation of permanent or temporary hardness Use of 40 for calcium gives 41.2 and 61.2 which score full marks	

(Total Question 7 = 19 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)(i)	An answer that makes reference to any **two** of the following points: • colorimetry **(1)** • (electrical) conductivity **(1)** • quenching **and** titration with thiosulfate **(1)** • quenching with excess carbonate **and** titration with acid **(1)** • add fixed amount of sodium thiosulfate and a few drops of starch solution and find the time until a blue-black colour is seen **(1)**	Ignore just colour change Do not award c**a**lorimetry Allow cooling for quenching COMMENT Allow cooling **and** titration with alkali Allow dilatometry Ignore pH	**(2)**

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	An answer that makes reference to following point: • negative species / ions will repel (each other) or unlikely that four species / ions will simultaneously combine		**(1)**

Question Number	Answer	Additional Guidance	Mark
8(a)(iii)	• rate = $k[ClO_3^-][H^+]^2[I^-]$	Accept species in any order Allow rate = $k[ClO_3^-]^1[H^+]^2[I^-]^1$ Allow K for k Allow r/R for rate Ignore state symbols even if incorrect Do not award missing charges Do not award just $k[ClO_3^-][H^+]^2[I^-]$	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)(i)	• (increase in temperature) means peak shifts to the right **and** is lower	Do not award the line crossing the other line twice Do not award the curve crossing the x-axis Do not award a line which goes up on the right or that plateaus high above the x axis, e.g.  	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An explanation that makes reference to the following points: • the area under the curve to the right of the E_a line has increased (substantially) **(1)** • so that a greater proportion of particles exceed the **activation energy (1)**	Allow answer/shading on the M-B sketch Allow more molecules/particles have energy greater than the activation energy Do not award M2 if there is any reference to the activation energy decreasing	**(2)**

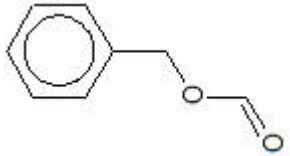
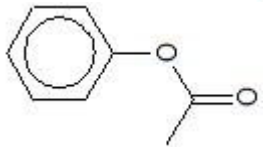
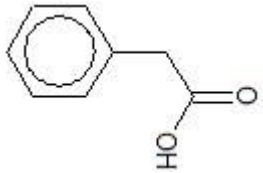
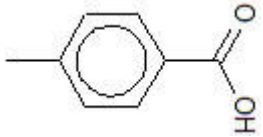
Question Number	Answer	Additional Guidance	Mark
8(c)(i)	• gradient of slope expression **(1)** • calculation of gradient **(1)** • calculation of activation energy with units **(1)**	<u>An example of calculation</u> Allow gradient = $\Delta y \div \Delta x$ or equivalent expression with values Gradient = $((-8 - -2) \div (1.31 \times 10^{-3} - 1.13 \times 10^{-3}))$ = (−) 33 333 / (−) 33 300 / (−) 33 000 (K) Allow range (−) 32475 to (−) 34159 E_a = − (−33 333 × 8.31 =) (+)276 997 J mol^{-1} / (+)277 000 J mol^{-1} / (+)276.997 kJ mol^{-1} / (+)277 kJ mol^{-1} Allow any answer in the range 270 to 284 Ignore SF except 1 SF Do not award M3 if E_a negative TE from M2 to M3	**(3)**

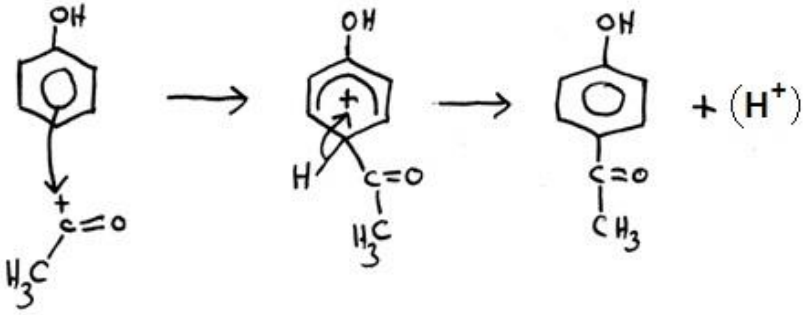
Question Number	Answer		Additional Guidance	Mark
8(c)(ii)	• calculation of expression with uncatalysed E_a	**(1)**	$e^{-\frac{Ea}{RT}} = e^{-\frac{50000}{8.31 \times 298}} = 1.70 \times 10^{-9}$	**(3)**
	• calculation of expression with catalysed E_a	**(1)**	$e^{-\frac{Ea}{RT}} = e^{-\frac{25000}{8.31 \times 298}} = 4.13 \times 10^{-5}$	
	• about 24000 (times) increase **and** in the fraction of molecules now able to react	**(1)**	Increase = $(4.13 \times 10^{-5} \div 1.70 \times 10^{-9}) = 24276$ Allow reference to $4.13 \times 10^{-5} >> 1.70 \times 10^{-9}$ resulting in many more molecules able to react Ignore just more molecules or bigger fraction Allow a calculation involving the determination of the difference/ratio between the two values	

(Total Question 8 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)(i)	An answer that makes reference to one of the following points: • benzoate (ion) / sodium benzoate / (sodium) salt produced (not benzoic acid) or the hydrogen ion protonates the benzoate ion or equation	Allow (acid needed) to displace the sodium (ion) and form benzoic acid Allow the benzoic acid is deprotonated in the hydrolysis e.g.  Allow the answer given in general terms of a carboxylate ion being protonated to the carboxylic acid or to protonate the conjugate base to give the acid Ignore reference to neutralising the hydroxide ions	(1)

Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	• equation	<u>Example of equation</u> $C_6H_5COOCH_3 + H_2O \rightleftharpoons C_6H_5COOH + CH_3OH$ Allow use of $C_6H_5CO_2CH_3$ and $C_6H_5CO_2H$ Allow → for ⇌ Allow displayed, semi-displayed, skeletal formulae Ignore state symbols even if incorrect Ignore H^+ or stated acid above the arrow Do not award molecular formulae	(1)

Question Number	Answer	Additional Guidance	Mark
9(b)	An answer that makes reference to the following points: • (**M1**) structure of **W** **(1)** • (**M2**) structure of **X** **(1)** • (**M3**) (justification for **W** and **X)** both have ester group **and** **W** must have HCOO group (and are monosubstituted) **(1)** • (**M4**) structure of **Y** **(1)** • (**M5**) (justification for **Y**) has a carboxylic acid group / COOH group (since carbonate broken down to give carbon dioxide and is monosubstituted) **(1)** • (**M6**) structure of **Z** **(1)** • (**M7**) (justification for **Z**) 1,4 / para orientation/ 6 different carbon environments (to give only 6 NMR peaks) **and** has a carboxylic acid group/COOH group/ makes an ester (with ethanol) **(1)**	Accept displayed / structural formulae   Accept **X** is made from ethanoic acid  Allow acid group  Allow 6 environments shown on a diagram Allow acid group	**(7)**

Question Number	Answer	Additional Guidance	Mark
9(c)(i)	• electron pair movement from ring to electrophile **(1)** • formula of intermediate ion **(1)** • curly arrow from C-H to reform delocalised ring (and correct piceol product) **(1)** • regeneration of catalyst **(1)**	Example of mechanism   Allow arrow starting anywhere within the hexagon Do not award curly arrow that ends at the CH_3 'Horseshoe' to cover at least three carbon atom and face the tetrahedral carbon and with some part of the plus sign inside 'horseshoe' Do not award dotted bonds unless part of a 3D structure Regeneration of catalyst can be shown as part of reaction mechanism where the $AlCl_4^-$ attacks the H which is being lost from the ring Square brackets around $AlCl_4^-$ are not essential Allow any Friedel-Crafts catalyst that would work, e.g. iron(III) halides Allow Kekulé structures	**(4)**

Question Number	Answer	Additional Guidance	Mark
9(c)(ii)	An answer that makes reference to the following point: • alkaline iodine / NaOH and I_2 or NaOCl with KI **(1)** • (pale) yellow precipitate / solid **(1)**	Ignore triiodomethane test/iodoform test Ignore concentrations Allow antiseptic smell M2 dependent on M1 or 'near miss' e.g. iodoform	**(2)**

(Total Question 9 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
10(a)	• $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$	Allow omission of superscripts Allow [Ar] for $1s^2 2s^2 2p^6 3s^2 3p^6$ Allow 2p and 3p split into x, y and z Ignore $4s^0$	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(b)(i)	• expression for entropies of reactants and products **(1)** • calculation of ΔS_{system} **(1)** • expression of $\Delta S_{surroundings}$ **(1)** • calculation of $\Delta S_{surroundings}$ **(1)** • calculation of ΔS_{total} with sign **and** units **(1)**	<u>Example of calculation</u> $\Delta S_{system} = (313.4) - ((4 \times 197.6) + 29.9)$ $\Delta S_{system} = -506.9$ (J mol^{-1} K^{-1}) $\Delta S_{surroundings} = -(\Delta H \div T) = -(-191\,000 \div 323)$ $\Delta S_{surroundings} = (+) 591.3$ (J mol^{-1} K^{-1}) $\Delta S_{total} = (591.3 - 506.9) = +84.4$ J mol^{-1} K^{-1} Ignore SF except 1SF Allow +0.0844 kJ mol^{-1} K^{-1} Accept units in any order Allow mol^{-} for mol^{-1} TE throughout Correct answer with no working scores (5)	**(5)**

Question Number	Answer	Additional Guidance	Mark
10(b)(ii)	An answer that makes reference to the following points: • negative (sign) **and** the reaction is feasible (since it is an industrial process) or negative (sign) **and** ΔS_{total} is positive (so reaction is feasible because the enthalpy change is negative)	Ignore just $\Delta G<0$ and $\Delta S_{total}>0$	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(b)(iii)	• (**M1**) calculation of equilibrium moles of $Ni(CO)_4$ **(1)** • (**M2**) calculation of CO and $Ni(CO)_4$ mole fractions **(1)** • (**M3**) calculation of CO and $Ni(CO)_4$ partial pressures **(1)** • (**M4**) expression of K_p **(1)** • (**M5**) calculation of K_p **(1)** • (**M6**) units **(1)**	<u>An example of calculation</u> $n(Ni(CO)_4)$ = ((50 – 0.75) ÷ 4 =) 12.3125 (mol) Total number of moles = 0.750 + 12.3125 = 13.0625 χCO = (0.75 ÷ 13.0625 =) 0.057416 $\chi Ni(CO)_4$ = (12.3125 ÷ 13.0625 =) 0.942584 $p(CO) = 0.057416 \times 1.5 = 0.086124$ (atm) $p(Ni(CO)_4) = 0.942584 \times 1.5 = 1.413876$ (atm) $K_p = (p(Ni(CO)_4) \div (p(CO)^4))$ Do not award square brackets $K_p = (1.413876 \div 0.086124^4)$ = 25698.9/25699/25700 TE throughout Ignore SF except 1SF Correct answer with or without working scores (5) atm^{-3}	**(6)**

Question Number	Answer	Additional Guidance	Mark
10(c)	An explanation that makes reference to the following points: • number of moles of gases increases (which have greater entropy) **(1)** • increase from forming 4CO(g) is larger in magnitude than the decrease from forming solid Ni **(1)**	Allow number of gaseous moles goes from 1 to 4 Allow particles for moles Allow more gaseous molecules Ignore just more molecules Ignore just equation Do not allow reference to nickel as molecule(s) Allow comparison such as 'entropy change is positive even though a solid made'	**(2)**

(Total Question 10 = 15 marks)

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