Mark Scheme (Results)

GCE Chemistry June 2017

Paper 9CH0/02 Advanced Organic and Physical 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.

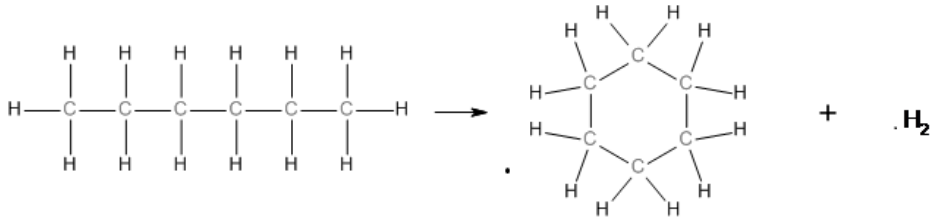
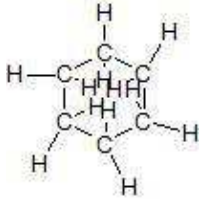
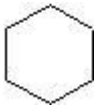
Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)	**The only correct answer is D** (free radical substitution) ***A*** *is not correct because electrophilic addition would be the reaction mechanism between alkenes, such as ethene, and chlorine but the substance in the question is the alkane, ethane* ***B*** *is not correct because electrophilic substitution involves the reactions of aromatic systems but this question refers to the reaction of the alkane, ethane* ***C*** *is not correct because the mechanism of reaction between an alkane such as ethane and chlorine involves substitution and not addition*	**(1)**

Question Number	Answer	Mark
1(b)	**The only correct answer is B** (4-ethyl-3-methylheptane) ***A*** *is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not pentane but heptane, with the consequential effect on the numbering and length of side chains* ***C*** *is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not hexane but heptane, with the consequential effect on the numbering and length of side chains* ***D*** *is not correct because the longest consecutive carbon chain involves the seven carbon atoms from the top left of the molecular drawing down to the bottom right which means that the stem of the name is not hexane but heptane, with the consequential effect on the numbering and length of side chains*	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(i)	An explanation that makes reference to the following points: • different alkanes have different boiling temperatures/points **(1)** • because of (different) chain length/molar mass /strength of intermolecular forces/ number of electrons **(1)**	Allow Volatility for boiling temperature Allow Different alkanes condense at different temperatures Ignore melting temperatures if given with boiling temperatures Ignore densities Accept London /dispersion /van der Waals forces Allow reference to size A comparison such as 'longer alkanes have higher boiling points' scores 2 Ignore any reference to surface area Do not award references to cracking Do not award reference to just weight/mass Do not award incorrect trend	**(2)**

Question Number	Answer	Additional Guidance	Mark
1(c)(ii)	Correct equation	<u>Example of equation:</u> $C_8H_{18} \rightarrow C_2H_4 + C_6H_{14}$ OR $C_8H_{18} \rightarrow 2C_2H_4 + C_4H_{10}$ OR $C_8H_{18} \rightarrow 3C_2H_4 + C_2H_6$ Allow $CH_2=CH_2$ for C_2H_4 Products can be given in either order Do not award equations forming H_2	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)(iii)	Correct equation	<u>Example of equation:</u>  Accept bonds to hydrogen atoms inside the ring, e.g.  Allow skeletal or structural formulae for hexane  or $CH_3(CH_2)_4CH_3$ and for cyclohexane  or $(CH_2)_6$ Ignore $C_6H_{14} \rightarrow C_6H_{12} + H_2$	**(1)**

(Total for Question 1 = 6 marks)

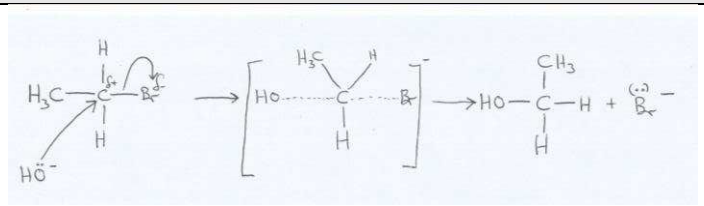
Question Number	Answer	Mark
2(a)	**The only correct answer is C** (hexagonal rings within a layer) ***A*** *is not correct because in the layers of graphite and graphene the carbon atoms are bonded to three other carbon atoms and not four* ***B*** *is not correct because graphite and graphene do not have pentagonal rings within their layers* ***D*** *is not correct because graphene is a two-dimensional structure consisting of a single layer*	**(1)**

Question Number	Answer	Mark
2(b)	**The only correct answer is D** (all 120˚) ***A*** *is not correct because the angles within a layer of graphite and graphene are neither 90˚ nor 109.5˚ but are all 120˚* ***B*** *is not correct because the angles within a layer of graphite and graphene are not 109.5˚ but are all 120˚* ***C*** *is not correct because there are no angles within a layer of graphite and graphene that are 109.5˚ but they are all 120˚*	**(1)**

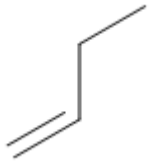
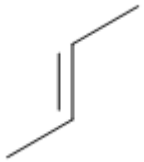
Question Number	Answer	Mark
2(c)	**The only correct answer is C** (poor electrical conductivity) ***A*** *is not correct because both graphene and graphite are similar to diamond in having a high melting temperature* ***B*** *is not correct because neither graphene nor graphite nor diamond have a precise molecular formula since they are giant molecular structures* ***C*** *is not correct because graphene, graphite and diamond are all giant molecular structures*	**(1)**

(Total for Question 2 = 3 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points: • reactivity increases down Group (7) **(1)** • because (C—X) bond enthalpy decreases / because (C—X) bond gets weaker down Group 7 **(1)**	Accept reverse argument References to halogen reactivity scores (0) Do not award references to ions/halides Do not award explanation in terms of just electronegativity or C—X dipoles Ignore references to atom size, shielding etc and references to intermolecular forces No TE on incorrect reactivity trend	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(b)(i)	• dipole on C—Br bond **and** curly arrow from C-Br bond to Br or just beyond **(1)** • curly arrow from **lone pair** on oxygen of hydroxide ion to carbon bonded to Br **(1)** • formula of transition state with correct charge, partial bonding **(1)** • correct final products **(1)**	 Dipole and curly arrow may be shown on transition state Allow curly arrow to C^+ of carbocation Do not award if carbocation formed as intermediate Square brackets are not essential Allow charge on Br or OH of transition state Allow longer bonds for partial bonding Ignore geometry of transition state Allow NaBr product if mechanism starts with NaOH Only penalise horizontal bond from the H of OH to C in the product e.g. $OH{-}CH_2CH_3$ Use of incorrect halogenoalkane loses this mark One mark max deducted for omission of charge on ions, including transition state S_N1 mechanism can score M1, M2 and M4 but not M3. M2 can be awarded for curly arrow from the lone pair on the oxygen of the hydroxide ion to the C+ of the carbocation intermediate	**(4)**

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	Reagents: nitric acid / HNO_3 **and** silver nitrate (solution) /$AgNO_3$ **(1)** (Result) cream/off-white precipitate **(1)**	Use of hydrochloric acid/HCl OR sulfuric acid/H_2SO_4 scores **(0)** Do not award acidified silver nitrate If name and formula given then both must be correct Allow (very) **pale** yellow Do not award just white or just yellow Ignore subsequent additions of ammonia even if incorrect Result mark dependent on reagents mark or 'near miss' such as omitting to add nitric acid, using ethanolic silver nitrate, incorrect formulae	**(2)**

Question Number	Answer			Additional Guidance	Mark
3(c)	 **(1)**	 **(1)**	 **(1)**	Accept formulae in any order Award 2 if 3 correct displayed/structural formulae given Award 1 if 2 correct displayed/structural formulae given If more than 3 skeletal formulae drawn then deduct one mark for each additional formula 2-methylpropene negates a correct formula only if four formulae given View any formulae given with skeletal formula as working and ignore Ignore names even if incorrect Penalise any other alkenes such as pentenes, once only	**(3)**

Question Number	Answer	Additional Guidance	Mark
3(d)	An explanation that makes reference to the following points: • (only) ethanol has hydrogen bonding (and dipole-dipole and London forces) **(1)** • ethene (only) has (weaker) London/ instantaneous dipole –induced dipole forces **(1)** • more **energy** required to break the (stronger) intermolecular forces/hydrogen bonds in alcohols **(1)**	Ignore references to ethanol having stronger London forces Accept dispersion /van der Waals forces A comparison is needed Allow overcome for break Allow 'heat' for energy Accept reverse argument Do not award if the more energy required is given in response to just breaking stronger London forces for ethanol Do not award M3 for covalent bonds breaking	**(3)**

(Total for Question 3 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
4(a)(i)	• conversion of pressure, volume and temperature to correct units **(1)** • rearrangement of ideal gas equation so n=PV ÷ RT and calculation of n **(1)** • conversion of answer into mass to 2/3 SF **(1)**	Example of calculation: 207kPa = 207 000 Pa 8.98 dm^3 = 0.00898 m^3, 20°C = 293 K n= $\frac{207\,000 \times 0.00898}{8.31 \times 293}$ = = 0.7634… = 0.7634…. x 28 = 21.37647.. = 21.4 / 21 (g) Correct answer with no working scores 3 TE on both parts of the calculation	**(3)**

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	• The temperature increase will result in an increase in pressure because p is (directly) proportional to T (at constant volume and moles of gas)	Allow $p \propto T$ Reference to p=nRT/V	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to the following points: • fewer protons (in nitrogen) **(1)** • result in a weaker **nuclear** attraction because shielding is the same/electrons are in the same (sub)shell (in oxygen)/same number of electron shells **(1)**	Reference to molecule scores **(0)** Accept reverse arguments in terms of oxygen Allow weaker (effective) nuclear charge Allow smaller atomic number Do not award if incorrect numbers of protons stated or if ions referred to Do not award 'charge density' Ignore references to electron repulsion and electronegativity	**(2)**

(Total for Question 4 = 6 marks)

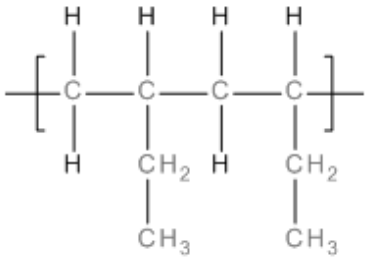
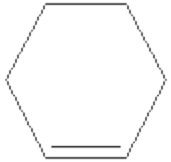
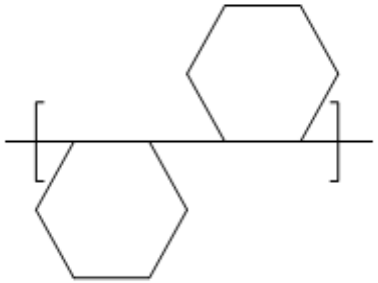
Question Number	Answer	Additional Guidance	Mark
5(a)(i)	Correct equation	$2NO + 2CO \rightarrow N_2 + 2CO_2$ Accept multiples Ignore catalysts and conditions if stated	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	A description that makes reference to the following points: • **adsorption** of gases to catalytic surface **(1)** • weakening of bonds (and chemical reaction) on catalytic surface **(1)** • desorption of products from catalytic surface **(1)**	Absence of reference to the catalytic surface results in a deduction of one mark Do not award absorption or "stick" Allow bonds break (and reaction occurs) on catalytic surface Ignore the type of interaction referred to between the reactants and the catalytic surface Allow 'release' of products from catalytic surface Allow de-adsorbed	**(3)**

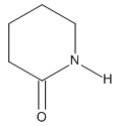
Question Number	Answer	Mark
5(b)	**The only correct answer is A** (area A) ***B*** *is not correct because this is the area representing the number of particles with sufficient energy to react in the absence of a catalyst* ***C*** *is not correct because this area subtraction does not represent the increase in the number of particles with sufficient energy to react* ***D*** *is not correct because this sum of areas represents the total number of particles with sufficient energy to react in the presence of a catalyst*	**(1)**

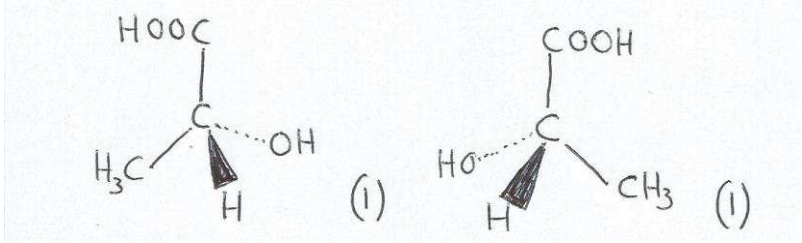
Question Number	Answer	Mark
5(c)	**The only correct answer is B** (2.15×10^{22}) ***A*** *is not correct because the molar mass of carbon dioxide has been used in the calculation instead of that of carbon monoxide* ***C*** *is not correct because this is the number of molecules that are in one mole and not one gram of carbon monoxide* ***D*** *is not correct because this is the result of incorrectly using the molar mass of carbon monoxide rather than the number of moles of carbon monoxide*	**(1)**

(Total for Question 5 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	($CH_2=CHCH_2CH_3\rightarrow$)  **(1)** ( →)  **(1)**	Accept skeletal, structural or displayed formulae or combination of which is clear, e.g. $-C_2H_5$ Brackets are not essential Ignore 'n' Ignore orientation of side chains Ignore bond length Ignore where bond goes to for the ethyl groups Penalise lack of 'end-bonds' once only Award 1 mark max if only one repeat unit given for each polymer Ignore more than 2 repeat units	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(b)	• $HOOC — (CH_2)_4 — COOH$ or $ClOC — (CH_2)_4 — COCl$ **(1)** • $H_2N — (CH_2)_4 — NH_2$ **(1)**	Accept skeletal, structural or displayed formulae Penalise use of C_4H_8 once only Penalise missing H's once only The monomers can be in either order Do not award monofunctionality	**(2)**

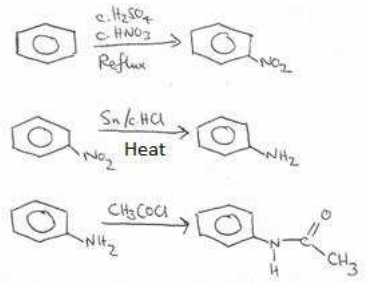
Question Number	Answer	Additional Guidance	Mark
6(c)	$H_2N - (CH_2)_4 - COOH$	Accept skeletal, structural or displayed formulae Allow $H_2N - (CH_2)_4 - COCl$ Ignore connectivity Allow  Allow use of C_4H_8 here only Penalise missing hydrogens	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	Allow 	Diagram must be 3-dimensional with either wedges or dashes to score 2 marks Ignore orientation of group at the top Ignore vertical bond to H of OH group	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	• They **rotate** the plane of plane-polarised light (equally) and in opposite/different directions OR Determine in which direction they **rotate** the plane of plane-polarised light	Allow one plane	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	• Does not accumulate in the environment/does not occupy landfill	Accept answers that outline the benefit of avoiding other means of disposal such as incineration, use of toxic chemicals Ignore just less harm to environment/less harm to animal life/less pollution/less of an "eyesore"/less energy to break it down	**(1)**

(Total for Question 6 = 9 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	A synthetic pathway that consists of: • (reagents and conditions for the nitration of benzene) conc. Nitric (HNO_3) and sulfuric acids (H_2SO_4) **and** 55°C/heat/reflux **(1)** • structure of nitrobenzene **(1)** • (reduction of nitrobenzene) tin and conc. hydrochloric acid and heat/reflux **(1)** • structure of phenylamine **(1)** • (reaction of phenylamine with) ethanoyl chloride **(1)**	Example of synthetic pathway  The compounds used can be stated or given within equations. Ignore any unbalanced, incorrect equations or reaction mechanisms Allow any single value or range between 50-60°C/warm/<55 °C Intermediate marks are standalone Allow iron & c.HCl Do not award dilute Ignore subsequent addition of NaOH Penalise lack of heat once only in M1 and M3 Penalise just the names of intermediates once only Ignore heat Do not award use of $AlCl_3$	**(5)**

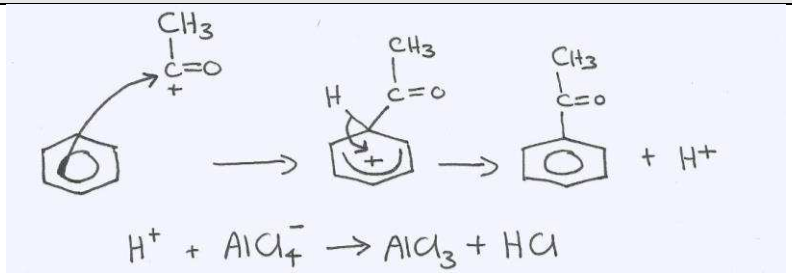
Question Number	Answer	Mark
7(b)	**The only correct answer is B** (6) ***A*** *is not correct because four carbon atoms in the aromatic ring are non-equivalent and not just three, so the correct total of non-equivalent carbon atoms and therefore peaks is six* ***C*** *is not correct because there are two sets of equivalent carbon atoms in the aromatic ring and not just one which means that the correct total of non-equivalent carbon atoms and therefore peaks is six* ***D*** *is not correct because this is the total number of carbon atoms in antifebrin but carbon atoms 2 and 6 in the aromatic ring are equivalent, as are 3 and 5, which gives a correct total of six non-equivalent carbon atoms and therefore six peaks*	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)	An explanation that makes reference to the following points: • **lone pair** (of electrons) from the **oxygen** **and** will interact with the delocalised ring of electrons / increase the (pi/π) electron density of the benzene ring **(1)** • which increases the reactivity toward electrophiles (such as bromine)/ which means that the bromine is more easily polarised **(1)**	Allow reference to the **lone pair** (of electrons) from the **nitrogen** Ignore activation of ring Do not award charge density Allow $Br^+/Br^{\delta+}$ for electrophile Allow reference to benzene as being a stronger nucleophile Do not award references to electrophilic addition	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(d)	• conversion of moles to mass of paracetamol **(1)** • conversion of answer into percentage to 2/3 SF **(1)**	Example of calculation: (mass of paracetamol = $3.10 \times 10^{-3} \times 151$ = 0.4681 (g) % = (0.4681÷ 0.500) x 100 = 93.62%) =94 (%)/93.6 (%) Allow TE for second mark from incorrect molar mass as long as value derived from dividing by 0.500/500mg and percentage is less than 100% Correct answer without working scores 2	**(2)**

(Total for Question 7 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)(i)	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	Accept use of $FeCl_3$/Fe +Cl_2 Allow displayed formulae Do not award C_2H_3OCl Ignore state symbols even if incorrect	(1)

Question Number	Answer	Additional Guidance	Mark
8(a)(ii)	• electron pair movement from ring to electrophile **(1)** • • formula of intermediate ion **(1)** • curly arrow from C−H bond to reform delocalised ring **(1)** • correct product and equation to show regeneration of catalyst and HCl **(1)**	 Do not award curly arrow that ends at the CH_3 Allow arrow starting anywhere within the hexagon 'Horseshoe' to cover at least three carbon atoms and face the tetrahedral carbon and with some part of the plus sign inside 'horseshoe' Allow Kekulé diagrams Do not award dotted bonds unless part of a 3D structure Could be shown in reaction mechanism Ignore curly arrows	(4)

Question Number	Answer	Mark
8(b)(i)	**The only correct answer is B** (alkaline iodine solution) ***A*** *is not correct because this oxidising agent would react with phenylethanal and not with phenylethanone which is the wrong way round* ***C*** *is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round* ***D*** *is not correct because test is for aldehydes and so would react with phenylethanal and not with phenylethanone which is the wrong way round*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(b)(ii)	An answer that makes reference to the following points: • formation of yellow/orange/red (crystalline) precipitate **(1)** • (Filter then) recrystallisation of products **(1)** • determination of melting temperature **(1)** • comparison (and hence identification) from use of database/known values **(1)**	Colour and state are both required Allow solid for ppt Ignore any conditions given with the use of 2,4-DNPH Penalise M3 if any reference to boiling temperature Award only in the context of melting temperature of the hydrazones or as a TE of boiling temperature Max 3 out of 4 if test is only carried out with one of the carbonyls	**(4)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>*8(b)(iii)</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).

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

If there is no mention of protons/hydrogens in the response then deduct one structure and reasoning mark
</td>
<td>(6)</td>
</tr>
</table>

	Indicative content **Similarities** • **IP1**: aromatic hydrogens will give similar/same peaks • **IP2**: both have a peak in the range 1.7-3.0 (ppm) (due to the hydrogen of the H−C−C=O type) **Differences** • **IP3** (Hydrogen environments): Phenylethanone has one less peak/hydrogen environment than phenylethanal • **IP4** (Splitting patterns): a singlet for phenylethanone but a doublet and a triplet in phenylethanal • **IP5** (Peak area ratios): relative peak (area) ratio in phenylethanone is 3 but in phenylethanal the peak (area) ratio is 2 to 1 • **IP6** (Chemical shifts): (Only) phenylethanal has an aldehyde (hydrogen) peak in the range 9 – 10.1 (ppm)	Ignore references to C^{13} nmr Accept annotations on a structure towards crediting the following IPs Allow either a single chemical shift value or a range within the stated values Penalise incorrect chemical shifts Both have peaks in the range 6.5-8.4 (ppm) Ignore any splitting description Ignore any splitting pattern given for this peak to award this mark Allow any difference of one in the number of peaks stated All these splitting patterns required for this IP Ignore the splitting pattern for this IP and ignore any peak areas given for the aryl hydrogens Ignore the splitting pattern for this IP	

Question Number	Answer	Additional Guidance	Mark
8(c)	• Reagent: lithium tetrahydridoaluminate((III)) /$LiAlH_4$ **(1)** • Conditions: (dry) ether/ethoxyethane **(1)**	Allow lithium aluminium hydride Accept sodium tetrahydridoborate /sodium borohydride/ $NaBH_4$ In water/alcohol for 2 marks Ignore reference to addition of acid after use of $LiAlH_4$ in dry ether Do not award with additional reagents Ignore heat The mark for conditions is dependent on correct reagent or near miss such as incorrect formula $LiAlH_3$/LiAlH/LiAl	**(2)**

(Total Question 8 = 18 marks)

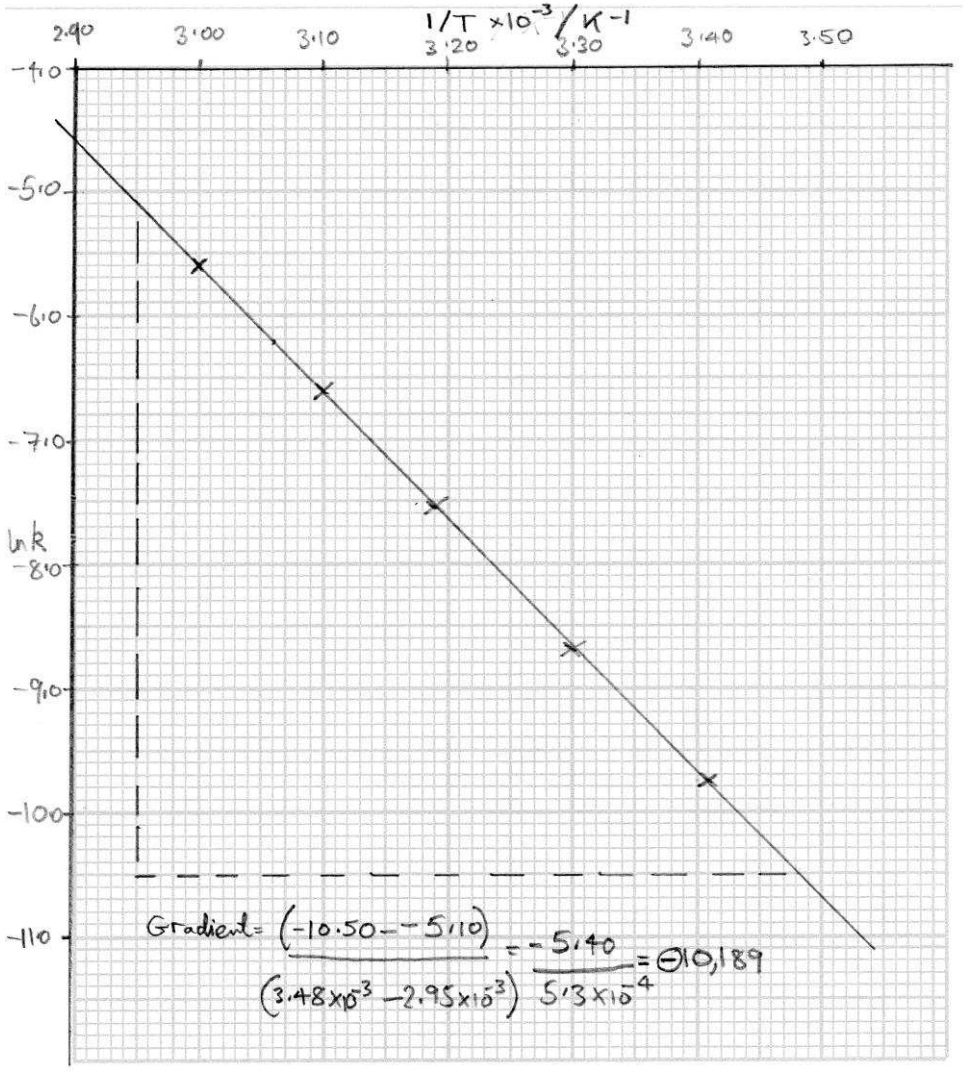
Question Number	Answer	Additional Guidance	Mark
9(a)	Correct answer to 2 SF	<u>Example of calculation:</u> (Four half-lives to decrease 600 g to 37.5 g so 4 x 14 mins) = 56 (mins) Penalise wrong units, e.g. "m"	**(1)**

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	Reaction Orders: • **X** First/1 **(1)** • **Y** Second/2 **(1)** • **Z** Zero/0 **(1)**	Allow "none"/"no order"	**(3)**

Question Number	Answer	Additional Guidance	Mark
9(b)(ii)	Marking point 1 • Rate = $k[X][Y]^2[Z]^0$ **(1)** Marking point 2 • rearrangement of rate expression **(1)** Marking point 3 • calculation of value for k to 2/3 SF **(1)** Marking point 4 • units $dm^6\ mol^{-2}\ s^{-1}$ **(1)**	Reactants can be in any order Z does not have to be included in the rate equation TE from (b)(i) which will apply for all four marking points <u>Example of calculation:</u> $k = rate / [X][Y]^2$ $k = \frac{2.17 \times 10^{-6}}{0.00100 \times 0.00300^2}$ $= 241.11$ $= 241/240$ Any 'run' can be used No TE on incorrect rearrangement Allow units in any order Correct answer without working and with correct units to 2/3 SF scores marking points 2, 3 and 4	**(4)**

Question Number	Answer	Mark
9(c)(i)	**The only correct answer is D** (Fourth) ***A*** *is not correct because this is the individual reaction order with respect to bromate(V) ions and with respect to bromide ions but is not the overall reaction order* ***B*** *is not correct because this is the reaction order with respect to hydrogen ions but is not the overall reaction order* ***C*** *is not correct because this is the number of species in the rate equation but is not the overall reaction order*	**(1)**

Question Number	Answer		Additional Guidance	Mark
9(c)(ii)	• rearrange rate equation so $[Br^-]$ =	**(1)**	Example of calculation: $[Br^-] = \frac{\text{rate}}{k\,[BrO_3^-][H^+]^2}$	**(2)**
	• calculation of value to 2/3 SF	**(1)**	$= 0.255/0.26$ (mol dm^{-3}) Correct answer without working to 2/3 SF scores 2 marks If units given then must be correct No TE on incorrect rearrangement	

Question Number	Answer	Additional Guidance	Mark
9(d)	Example of suitable graph 		(7)

	• calculation of all three 1/T values x 10^{-3} **(1)**	(3.41), 3.30, 3.19, 3.10, (3.00)	
	• calculation of all three ln k values **(1)**	(−9.75), −8.70, −7.55, −6.60, (−5.58) Allow omission of end zero Penalise more than 3SF once only	
	• axes: correct way round, labelled, suitable scale **(1)**	Plotted points must cover at least ½ the graph paper on each axis Do not award 1/t	
	• all points plotted correctly, with best-fit straight line **(1)**	Allow ±½ square	
	• calculation of gradient with sign **(1)**	Gradient = − 10200 Allow ±500 Allow this mark if the value is seen in the E_a calculation	
	• units of gradient **(1)**	K	
	• use of gradient to calculate activation energy **(1)**	E_a = 10200 x 8.31 / 1000 = (**+**) 84.8 (kJ mol^{-1}) Final answer must be positive and in the range (+) 80.6 – 88.9 (kJ mol^{-1}) Allow value given in J mol^{-1} but then these units are essential Ignore SF for gradient and activation energy values	

(Total for Question 9 = 18 marks)

TOTAL FOR PAPER = 90 MARKS

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