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Mark Scheme (Results)

Summer 2016

Pearson Edexcel
International Advanced Level
in Chemistry (WCH04) Paper 01
General Principles of Chemistry I

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Summer 2012
Publications Code 46664_MS*

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.
TE/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.

Section A (multiple choice)

Question Number	Correct Answer	Reject	Mark
1	C		**(1)**

Question Number	Correct Answer	Reject	Mark
2	D		**(1)**

Question Number	Correct Answer	Reject	Mark
3(a)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
3(b)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
4(a)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
4(b)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
4(c)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
4(d)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
4(e)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
5	C		**(1)**

Question Number	Correct Answer	Reject	Mark
6(a)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
6(b)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
7(a)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
7(b)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
8(a)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
8(b)	B		**(1)**

Question Number	Correct Answer	Reject	Mark
9(a)	A		**(1)**

Question Number	Correct Answer	Reject	Mark
9(b)	D		**(1)**

Question Number	Correct Answer	Reject	Mark
10(a)	C		**(1)**

Question Number	Correct Answer	Reject	Mark
10(b)	D		**(1)**

TOTAL FOR SECTION A = 20 MARKS

Section B

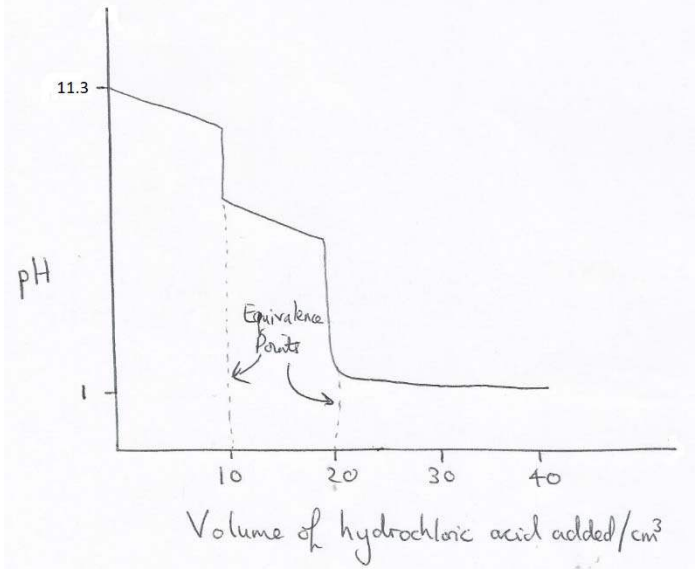
Question Number	Acceptable Answers	Reject	Mark
11(a)	(K_{a1} =) $\frac{[H_3O^+(aq)]\,[HCO_3^-(aq)]}{[H_2CO_3(aq)]}$ **(1)** (K_{a2} =) $\frac{[H_3O^+(aq)][\,CO_3^{2-}(aq)]}{[HCO_3^-(aq)]}$ **(1)** **ALLOW** $H^+(aq)$ for $H_3O^+(aq)$ **IGNORE** state symbols, even if incorrect	$[H_3O^+]^2$ numerator $[H_3O^+]^2$ numerator	**(2)**

Question Number	Acceptable Answers	Reject	Mark
11(b)(i)	$H_2CO_3(aq) \leftrightarrows H_3O^+(aq) + HCO_3^-(aq)$ Initially 0.100 0 0 At eqm 0.100 x x $K_{a1} = \frac{x^2}{0.100}$ **M1** $x^2 = 4.17 \times 10^{-8}$ ($mol^2\ dm^{-6}$) (1) **M2** ($x = 2.0421 \times 10^{-4}$) $[HCO_3^-] = 2.04 \times 10^{-4} / 0.000204$ ($mol\ dm^{-3}$) (1) Final answer for **M2** must be to 3 SF Correct final answer without working scores (2) **ALLOW** **M2** TE on candidate's value for **M1**, as long as final answer to 3 sf **IGNORE** units even if incorrect		**(2)**

Question Number	Acceptable Answers	Reject	Mark
11(b)(ii)	(pH = -log 2.04×10^{-4} =) 3.69 / 3.7	pH = 4	**(1)**

	TE on answer to (b)(i), provided pH <7 pH = 3.19 / 3.2 from a $[HCO_3^-]$ value of 6.46×10^{-4} (mol dm^{-3}) **ALLOW** any SF except 1 SF	pH = 3	

Question Number	Acceptable Answers	Reject	Mark
***11(b)(iii)**	Max 2 if HA and A^- used for H_2CO_3 **Any THREE from:** **Assumption 1** $[H_2CO_3]_{equilibrium} = [H_2CO_3]_{initial}$ OR The dissociation of H_2CO_3/the acid is negligible OR 2.04×10^{-4} is (very) small compared to the initial concentration of H_2CO_3/0.100 (hence a valid assumption), or reverse argument **Assumption 2** $[H_3O^+] = [HCO_3^-]$ OR $[H^+] = [HCO_3^-]$ OR Negligible H^+ from (the dissociation of) water / H^+ only from H_2CO_3 **Assumption 3** Negligible dissociation of HCO_3^- / HCO_3^- doesn't (significantly) dissociate further OR K_{a2} very much smaller than K_{a1} ALLOW Stage 2 does not occur (significantly) **Assumption 4** Measurements at 298 K / standard **temperature** IGNORE References to the concentration of water References **just** to 'standard conditions'		**(3)**

Question Number	Acceptable Answers	Reject	Mark
11(c)	 **M1** General shape of a weak base-strong acid curve with pH decreasing and either one or two vertical sections shown. Penalise vertical section ≥ 8 pH units (1) **M2** (Approximately) vertical section at 10 cm^3 (1) **M3** (Approximately) vertical section at 20 cm^3 (1) **M4** Any (mid-point of a) vertical section identified as an equivalence point (1) **M5** Initial pH = 11-12 **and** line becomes asymptotic to pH range 1-2 ALLOW a recognisable plateau in the pH range 1 – 2 If curve is the wrong way round the starting pH should be pH 1-2 and the asymptote or plateau should be pH 11-12 Curve does **not** need to reach 40 cm^3 (1)	pH rising by half a square or more at any point	**(5)**

	ALLOW Two vertical sections **not** at 10/20 cm^3 scores (1) if **M2** and **M3** not awarded		

(Total for question 11 = 13 Marks)

Question Number	Acceptable Answers	Reject	Mark
12(a)(i)	Effervescence / bubbles / fizzing IGNORE gas evolved / temperature increase		**(1)**

Question Number	Acceptable Answers	Reject	Mark
***12(a)(ii)**	A statement that entropy is positive needs to be made once only and can be used to award M1 and M2 Penalise omission of statement that entropy is positive once only **M1** Entropy (of the system) positive **and** solid and liquid reactants form (a solid, a liquid and) a gas ALLOW gas formed / gas is a product (1) **M2** Entropy (of the system) positive **and** **EITHER** 3 moles → 4 moles OR more moles of products (than reactants) ALLOW 'molecules' for moles **OR** More ways of distributing energy OR	If entropy of system is negative / decreases scores (0) particles	**(2)**

	More ways of distributing quanta (1)		

Question Number	Acceptable Answers	Reject	Mark
12(b)(i)	$\Sigma S^{\ominus}_{(\text{reactants})}$ = (31.8) + 3(2x 158.6) =) +983.4 J mol^{-1} K^{-1} (1) $\Delta S^{\ominus}_{\text{system}}$ = (291.7− 983.4 =) −691.7 J mol^{-1} K^{-1} / −0.6917 kJ mol^{-1} K^{-1} (1) Correct answer no working scores (2) If monoclinic sulfur is used (32.6) final answer = –692.5 scores (1)		**(2)**

Question Number	Acceptable Answers	Reject	Mark
12(b)(ii)	$\Delta S^{\ominus}_{\text{surroundings}} = (-\Delta H \div T) = - \frac{-1209000 \text{ J mol}^{-1}}{298 \text{ K}}$ (1) = (4057.04698) = + 4057 J mol^{-1} K^{-1} / + 4.057 kJ mol^{-1} K^{-1} (1) Correct answer without working scores 2		**(2)**

Question Number	Acceptable Answers	Reject	Mark
12(b)(iii)	$\Delta S^{\ominus}_{\text{total}} = \Delta S^{\ominus}_{\text{system}} + \Delta S^{\ominus}_{\text{surroundings}}$ $\Delta S^{\ominus}_{\text{total}}$ = ans (b)(i) + ans (b)(ii) = −691.7 + 4057 = +3365.3 J mol^{-1} K^{-1} / +3.3653 kJ mol^{-1} K^{-1} TE on answers from (b)(i) and (b)(ii)		**(1)**

Question Number	Acceptable Answers	Reject	Mark
12(b)(iv)	Marking points may be in any order Mark all 3 points independently **M1:** $\Delta S^{\ominus}_{\text{surroundings}}$ becomes less positive / smaller (magnitude) / decreases (in magnitude) (because you are dividing $-\Delta H$ by a larger T) **(1)** **M2:**		**(3)**

	$\Delta S^{\ominus}_{system}$ / ΔH_f /ΔH is not (significantly) affected (by an increase in temperature) **(1)** **M3:** (So) $\Delta S^{\ominus}_{total}$ decreases / less positive **(1)**	Becomes negative	

Question Number	Acceptable Answers	Reject	Mark
12(c)(i)	Accept reverse arguments throughout **M1** sulfates get less soluble as you descend Group 2 (1) **ALLOW** barium sulfate is less soluble than magnesium sulfate **M2** (total) entropy / $\Delta S^{\ominus}_{total}$ gets more negative/ less positive as you go from $MgSO_4$ to $BaSO_4$ **ALLOW** $\Delta S^{\ominus}_{total}$ is positive for $MgSO_4$ and negative for $BaSO_4$ (1) IGNORE Re-stating the numerical entropy values No TE on incorrect trend	References to exothermic / endothermic Just "decreases", "gets smaller"	**(2)**

Question Number	Acceptable Answers	Reject	Mark
12(c)(ii)	(K= inv ln (20/8.31)=) 11.098 = 11 **IGNORE** any units **ALLOW** any SF except 1SF		**(1)**

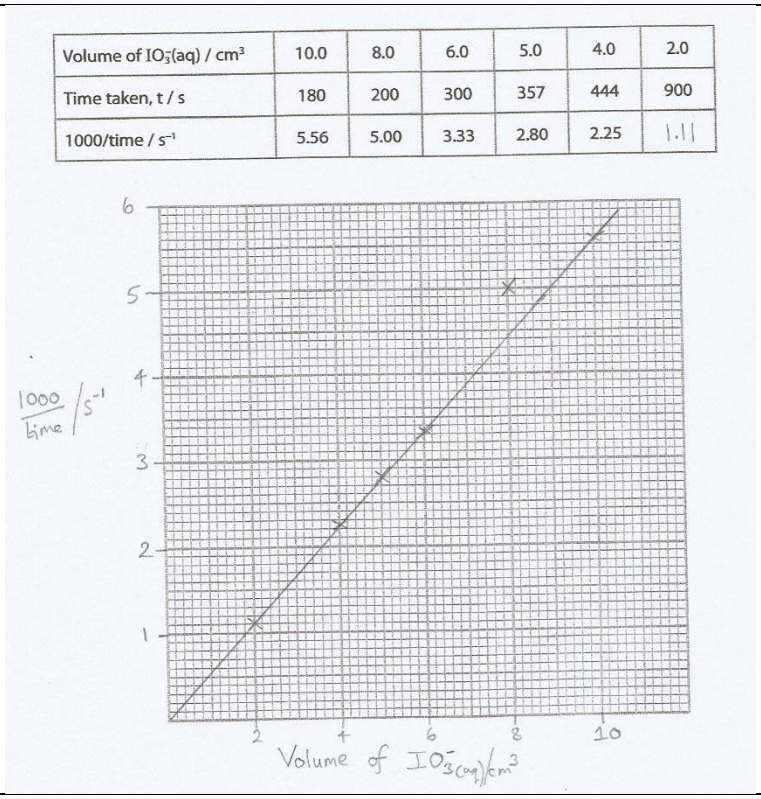
(Total for question 12 = 14 Marks)

Question Number	Acceptable Answers	Reject	Mark
13(a)	blue-black / blue / black (complex) colour would never form OR no colour change would be seen OR no (excess) iodine would form OR no iodine left to react with starch OR iodine would be reduced back to iodide OR iodine would react with hydrogensulfate as soon as it forms IGNORE Just hydrogensulfate would not get used up	Any other colours	**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(b)	So the kinetics of reaction 1 can be studied OR iodine complex colour would form too soon / solution would go blue-black too soon **IGNORE** reference to RDS		**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(c)(i)	Because temperature affects reaction rate **ALLOW** Increase in temperature increases reaction rate' or reverse argument for decreasing temperature OR To keep the rate of reaction the same OR So no change in rate constant **IGNORE** references to validity, reliability or 'fair test' or so temperature is not a variable		**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(c)(ii)	**M1:** Completed table with value 1.11 **(1)** **M2:** Axes correct with sensible, linear scales so at least half of the graph paper on both axes is covered **(1)** **ALLOW** even if graph scales do not start at (0, 0) **M3:** Axes labels fully correct with units **(1)** **ALLOW** 1000 t / s^{-1} or 1000 / t / s^{-1} on y-axis **ALLOW** volume / cm^3 on x-axis **M4:** All points plotted correctly (± 1 small square) **(1)** Award M4 TE on the table value at 2 cm^3 Do not penalise missing crosses/ circles if line is correct **M5:** Straight line drawn **through (0, 0)** and through all points except anomalous result at 8 cm^3 **(1)** <u>Exemplar:</u>	Axes reversed OR decreasing scale	**(5)**

Volume of IO_3^-(aq) / cm^3	10.0	8.0	6.0	5.0	4.0	2.0
Time taken, t / s	180	200	300	357	444	900
1000/time / s^{-1}	5.56	5.00	3.33	2.80	2.25	1.11

Question Number	Acceptable Answers	Reject	Mark
13(c)(iii)	burette / (graduated) pipette	measuring cylinder teat pipette volumetric flask syringe	**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(c)(iv)	volume (of iodate(V) ions) and concentration are (directly) proportional IGNORE Concentration varies as volume varies volume is proportional to rate volume is proportional to number of moles		**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(c)(v)	**M1** First order (1) **Note:** this mark is independent of the graph drawn **M2** because the graph is a straight line (through the origin) OR rate is proportional to $[IO_3^-]$ / rate is proportional to volume of IO_3^- OR as concentration/volume increases by (factor of) 2, rate increases by 2 (or any other numbers, including 'x') OR rate increases linearly (with concentration) (1) **ALLOW** Gradient of line is constant **M2** dependent on **M1**	Just 'graph is a best fit line' References to constant half-life	**(2)**

Question Number	Acceptable Answers	Reject	Mark
13(c)(vi)	(repeat the experiment with) double the concentration of HSO_3^- and the rate doubles (keeping the iodate(V) concentration constant) OR Any other ratio i.e. any change to the concentration having the same effect on the rate **ALLOW** Vary the concentration and the effect on the rate is the same OR Methods involving plotting concentration/time graph and measuring constant half-life	refs to the <u>gradient</u> doubling	**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(c)(vii)	**M1** rate = k $[IO_3^-][HSO_3^-]$ ALLOW r = k $[IO_3^-][HSO_3^-]$ (1) TE on order wrt IO_3^- given in part (v) **M2** $dm^3\ mol^{-1}\ s^{-1}$ ALLOW the units in any order (1) TE on candidate's stated rate equation in **M1** e.g. if rate = *k* $[HSO_3^-]$, then award **M2** as TE for units of s^{-1}	Round brackets	**(2)**

Question Number	Acceptable Answers	Reject	Mark
13(d)(i)	(measure the) time taken (for the blue-black colour to appear) **and** temperature **ALLOW** measure the rate and temperature **IGNORE** references to ln *k* and 1/T		**(1)**

Question Number	Acceptable Answers	Reject	Mark
13(d)(ii)	**M1** Temperature converted to kelvin ALLOW Kelvin given in (i) **(1)** COMMENT Only M1 can be transferred from (i) to (ii). Nothing can be credited from (ii) to (i) **M2** The vertical axis should be ln rate / ln 1/t **ALLOW** ln *k* **(1)** **M3** The horizontal axis should be 1/T **(1)** **M4** Straight line (with a negative gradient) **(1)** ALLOW **M1, M2, M3, M4** shown on a sketch graph **M5** Any mention of **gradient** (of the line) **(1)** **M6** States that: E_a = **−**gradient x *R* **(1)** **NB** Negative sign **must** be shown or mentioned specifically **NOTE:** Plot "ln rate against/vs 1/T" scores **M2** and **M3** Plot "1/T against/vs ln rate" does not score either **M2** or **M3** If axes clearly the wrong way round max (4) ie only marks **M1**, **M4**, **M5** and **M6** are possible	1/T 1/t 1/time	**(6)**

(Total for question 13 =22 Marks)

TOTAL FOR SECTION B = 49 MARKS

Section C

Question Number	Acceptable Answers	Reject	Mark
14(a)	**M1** $LiAlH_4$/lithium aluminium hydride/ lithium tetrahydridoaluminate((III))/ $NaBH_4$/sodium borohydride/ sodium tetrahydridoborate((III)) (1) **M2** 4 ([H]) (1) **M3** $CH_3CHOHCHOHCH_3$ OR correct displayed (or skeletal) formula (1)	If another product e.g. water is given in the equation	**(3)**

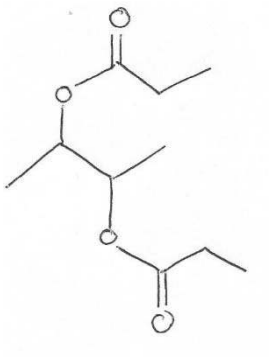
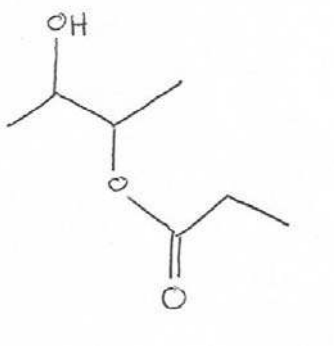
Question Number	Acceptable Answers	Reject	Mark
14(b)	(turns from yellow-green to) colourless / yellow-green colour disappears/fades **IGNORE** bubbles	just "colour change" colour change with incorrect starting colour	**(1)**

Question Number		Reject	Mark
14(c)(i)	butane-2,3-diol **and** because it has hydrogen bonds (between the molecules) If other intermolecular forces listed then it must be clear that **only** butane-2,3-diol has hydrogen bonds Ignore References to intramolecular hydrogen bonding	hydrogen bonding to water	**(1)**

Question Number	Acceptable Answers	Reject	Mark
14(c)(ii)	Both molecules can form hydrogen bonds **with water**		**(1)**

Question Number	Acceptable Answers	Reject	Mark
14(d)	Mark **M2** and **M1** independently **M1** optical (isomerism) (1) **IGNORE** stereoisomers **M2** (molecule contains) two chiral carbon atoms OR a chiral carbon / a carbon with four different groups attached / chiral centre OR molecule exists as non-superimposable mirror images OR exists as a pair of enantiomers ALLOW chiral molecule (1)	Geometric isomerism scores (0) …four different atoms / molecules attached.	**(2)**

Question Number	Acceptable Answers	Reject	Mark
14(e)(i)	**REAGENT** propanoyl chloride / CH_3CH_2COCl / C_2H_5COCl displayed / structural / skeletal formulae COMMENT ALLOW propanyl chloride (1) **Marks 2 and 3 are independent of the reagent mark** Any **two** differences from: reaction irreversible/not an equilibrium / goes to completion (1) **IGNORE** references to yield OR Hydrogen chloride / HCl produced (instead of water) (1) OR reaction faster / does not need be heated / does not need acid/catalyst / more exothermic / more vigorous (1) **IGNORE** references to chloride as a leaving group **NOTE:** ALLOW propanoic anhydride / $(CH_3CH_2CO)_2O$ / $C_2H_5CO)_2O$ for reagent mark and Propanoic acid produced(instead of water)	propyl chloride acyl chloride Hydrochloric acid propyl anhydride acyl anhydride	**(3)**

Question Number	Acceptable Answers	Reject	Mark
14(e)(ii)	**IGNORE** bond angles and bond lengths in all diagrams Structural / displayed formulae unless no skeletal formula Correct diagram with two ester groups = (2)  **M1** for **both** ester groups shown **M2** for the rest of the molecule correct **ALLOW** 1 mark for a fully-correct structure with only 1 ester bond show i.e.  **ALLOW** 1 mark for a fully-correct structure using displayed / structural formula **only**		**(2)**

Question Number	Acceptable Answers	Reject	Mark
14(f)	<table><tr><th>**Molecule**</th><th>**Peak /**(cm^{-1})</th><th>**Bond**</th><th></th></tr><tr><td>butanedione</td><td>1700-1680</td><td>C=O</td><td>(1)</td></tr><tr><td>butane-2,3-diol</td><td>3750-3200</td><td>O−H</td><td>(1)</td></tr></table> ALLOW (if neither mark awarded) 1 mark for wavenumbers identified with correct molecules	Individual values Additional wavenumbers or ranges	**(2)**

Question Number	Acceptable Answers	Reject	Mark
***14(g)**	IGNORE TMS Peak at Chemical shift δ = 0 ppm **M1** **Three** (different) proton / hydrogen environments OR **Three** sets of peaks shown on the spectrum (1) **M2** One singlet **and** one triplet **and** one quartet only OR shown on diagram (1) **M3** "n+1" rule correctly applied to at least one peak e.g. quartet formed because 3 adjacent **protons**/**hydrogens**. (1) **M4** (Area ratios of peaks) is 3:2:1 **and** related to C**H**$_3$:C**H**$_2$:COO**H** OR shown on molecular structure Note that the word 'ratio' or the mathematical symbol as above is required (1) **M5** (Chemical shift values, δ ppm) COO**H** = 10.0 - 12.0; C**H**$_2$= 1.8 - 3.0; C**H**$_3$ = 0.1 - 1.9 OR shown on diagram as any peaks centred at these chemical shifts ALLOW		**(5)**

	individual chemical shift values within the ranges (1)		

Question Number	Acceptable Answers	Reject	Mark
14 (h)	Radio waves **IGNORE** electromagnetic radiation	In combination with any other radiation	1

Total for question 14 = 21 Marks)

TOTAL FOR SECTION C = 21 MARKS

TOTAL FOR PAPER = 90 MARKS

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