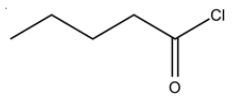
Pearson
Edexcel

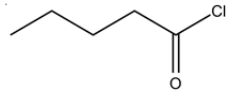
Mark Scheme (Results)

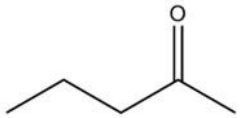
January 2020

Pearson International Advanced Level
In Chemistry (WCH14)
Paper 01 Rates, Equilibria and Further Organic Chemistry

Section A (multiple choice)

Question Number	Answer	Mark
1(a)	The only correct answer is **A** (compound 1)  *B is incorrect as aldehydes do not change the pH of water C is incorrect as ketones do not change the pH of water D is incorrect as amides do not change the pH of water*	**1**

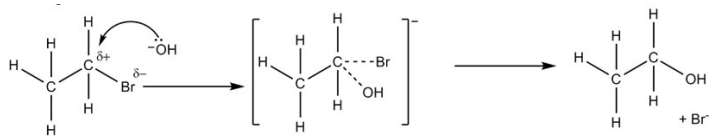
Question Number	Answer	Mark
1(b)	The only correct answer is **A** (compound 1)  *B is incorrect as aldehydes do not react with amines to form an N-substituted amide C is incorrect as ketones do not react with amines* *D is incorrect as amides do not react with amines*	**1**

Question Number	Answer	Mark
1 (c)	The only correct answer is **C** (compound 3)  *A is incorrect as it does not form iodoform B is incorrect as it does not form iodoform D is incorrect as it does not form iodoform*	**1**

Question Number	Answer	Mark
2	The only correct answer is **C** ($ClCH_2C(CH_3)(Cl)COOH$) *A is incorrect as compound 1 does not have a chiral carbon atom B is incorrect as compound 2 does not have a chiral carbon atom* *D is incorrect as compound 4 does not have a chiral carbon atom*	**1**

Question Number	Answer	Mark
3	The only correct answer is **B** (condensation) *A is incorrect as neither monomer has a carbon-carbon double bond C is incorrect as this is not a type ofpolymerisation* *D is incorrect as this is not a type of polymerisation*	**1**

Question Number	Answer	Mark
4	The only correct answer is **A (**NaOOCCH=CHCOONa) *B is incorrect as only one of the -COOH groups has reacted* *C is incorrect as OH groups have added across the double bond* *D is incorrect as only one of the -COOH groups has reacted, and a -COOH group has been reduced*	**1**

Question Number	Answer	Mark
5	The only correct answer is **C** Diagram 3  *A is incorrect as it shows a primary halogenoalkane forming a carbocation* *B is incorrect as it shows a primary halogenoalkane forming a carbocation and the electrons are moving to a lone pair in the second step* *D is incorrect as the electrons are moving to a lone pair in the first step*	**1**

Question Number	Answer	Mark
6	The only correct answer is **D** (phosphorus(V) chloride) *A is incorrect as chlorine will not react with ethanoic acid to form ethanoyl chloride* *B is incorrect as chloroethane will not react with ethanoic acid to form ethanoyl chloride* *C is incorrect as hydrogen chloride will not react with ethanoic acid to form ethanoyl chloride*	**1**

Question Number	Answer	Mark
7	The only correct answer is **B (**$Hg(l) \rightarrow Hg(g)$**)** *A is incorrect as the increase in disorder from (s) to (l) is less than that from (l) to (g) C is incorrect as there is a decrease in disorder as the gaseous ion is hydrated* *D is incorrect as there is no significant change in number of particles or state.*	**1**

Question Number	Answer	Mark
8	The only correct answer is **D (**W, X, Y and Z but there is more Y and Z than W and X**)** *A is incorrect as this requires in a very large value for* K_c *B is incorrect as this will result in a very small value for* K_c, < 1 *C is incorrect as this will result in a small value for* K_c *< 1*	**1**

Question Number	Answer	Mark
9	The only correct answer is **A** (sum of enthalpies of hydration of the gaseous ions) *B is incorrect as it would be* $Li(s) + ½Cl_2(g) \rightarrow LiCl(s)$ *C is incorrect as it would be* $LiCl(s) \rightarrow Li^+(aq) + Cl^-(aq)$ *D is incorrect as it would be* $Li^+(g) + Cl^-(g) \rightarrow LiCl(s)$	**1**

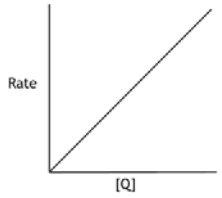
Question Number	Answer	Mark
10	The only correct answer is **D** (require 20 cm^3 of 0.10 mol dm^{-3} NaOH (aq) to react completely) *A is incorrect as one acid is strong, the other is weak* *B is incorrect as the solutions have different concentrations and ethanoic acid is a weak acid C is incorrect as the solutions have different concentrations and ethanoic acid is a weak acid*	**1**

Question Number	Answer	Mark
11	The only correct answer is **B** (*HCOOH(aq) and KOH(aq*)) *A is incorrect as both the acid and base are strong* *C is incorrect as the acid is strong and the base is weak D is incorrect as both the acid and base areweak*	**1**

Question Number	Answer	Mark
12	The only correct answer is **C** (between 11 and 13) *A is incorrect the solution is a strong base whose concentration is > $1x10^{-5}$ mol dm^{-3} B is incorrect the solution is a strong base whose concentration is > $1x10^{-3}$ mol dm^{-3} D is incorrect the solution is a strong base whose concentration is < $1x10^{-1}$ mol dm^{-3}*	**1**

Question Number	Answer	Mark
13(a)	The only correct answer is **C** (flasks 1 and 4 only) *A is incorrect as flask 4 also contains only substances from the right-hand side of the equilibrium (HCl(aq) includes some water)* *B is incorrect as flask 1 also contains only substances from the right-hand side of the equilibrium D is incorrect as flasks 2 and 3 do not contain any ester*	**1**

Question Number	Answer	Mark
13(b)	The only correct answer is **A** (the equilibrium reaction is slow) *B is incorrect as rapid hydrolysis would affect the position of the equilibrium C is incorrect as the acid is neutralised* *D is incorrect as although a buffer may form it does not affect the position of the ester equilibrium*	**1**

Question Number	Answer	Mark
14	The only correct answer is **C**  *A is incorrect as it shows a 0 order reaction B is incorrect as it shows a 0 order reaction* *D is incorrect as the concentration of Q remains constant*	**1**

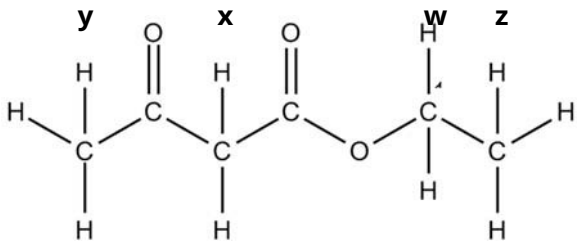
Question Number	Answer	Mark
15(a)	The only correct answer is **D** (when the concentration of nitrogen monoxide doubles and the concentration of oxygen quadruples, the rate increases by a factor of 8) *A is not an incorrect statement as the overall order is 3* *B is not an incorrect statement as the rate can be measured in units of mol dm^{-3} s^{-1}* *C is not an incorrect statement as increasing the pressure does increase the rate of the reaction*	**1**

Question Number	Answer	Mark
15(b)	The only correct answer is **D** (dm^6 mol^{-2} s^{-1}) *A is incorrect as these are the units for a fourth overall order rate equation B is incorrect as the exponent values are incorrect* *C is incorrect as the signs on the exponent values for mol and dm are incorrect.*	**1**

Question Number	Answer	Mark
15(c)	The only correct answer is **A** (1.31×10^{-2}) *B is incorrect as it is the value for $[NO]^2$* *C is incorrect as the values for $[O_2]$ and rate are the wrong way round in the calculation, and the square root of the calculated value has not been determined* *D is incorrect as the values for $[O_2]$ and rate are the wrong way round in the calculation*	**1**

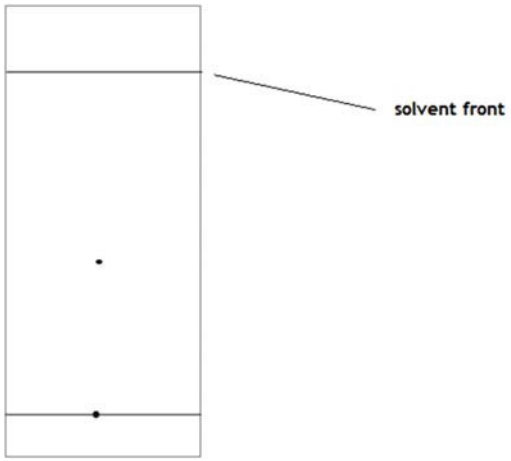
(Total for Section A = 20 marks)

Section B

Question Number	Answer	Additional Guidance	Mark
16(a)(i)	 (2) All 4 peaks correctly matched scores both marks 2 or 3 peaks correctly matched scores 1 mark 0 or 1 peak correctly matched scores 0 marks	NOTE Allow labels to/near to carbon of correct group	**2**

Question Number	Answer	Additional Guidance	Mark
16(a)(ii)	4.2 ppm quartet due to 3 hydrogen (atoms) on adjacent carbon (1) 1.3 ppm triplet due to 2 hydrogen (atoms) on adjacent carbon (1)	Allow 'due to adjacent CH_3' Allow 'due to adjacent CH_2' If neither mark awarded can score 1 for correct reference to n+1 rule If no reference to splitting patterns then allow 1 for correctly identifying both sets of adjacent hydrogens	**2**

Question Number	Answer	Additional Guidance	Mark
16(a)(iii)	$C(CH_3)_3COCOOH$	Allow skeletal or displayed formulae If more than 1 structure type given, both must be correct.	**1**

Question Number	Answer	Additional Guidance	Mark
16(b)(i)	Origin/start line shown above bottom of paper (1) Straight line for solvent front added and labelled (1) **Spot** due to ethyl-3-oxobutanoate in position consistent with R_f between 0.4 and 0.5 (1)	Ignore omission of initial spot, but if shown must be on baseline Allow 'distance travelled by solvent' Do not award wavy lines Do not award the top of the paper as the solvent front  	**3**

Question Number	Answer	Additional Guidance	Mark
16(b)(ii)	**M1** As only London forces form between them (so spot moves a shorter distance) / ethyl-3-oxobutanoate is polar, hexane is non-polar / (1) **M2** Weaker interaction between hexane and ethyl-3-oxobutanoate / ethyl-3-oxobutanoate is less soluble in hexane (1)	Allow reverse arguments Do not award M1 if reference to hydrogen bonds Allow solvent / mobile phase for hexane Allow ethyl-3-oxobutanoate does not dissolve in hexane	**2**

(Total for Question 16 = 10 marks)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>17</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 markfor lines of reasoning. Forexample, 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 an 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 score 2 reasoning marks, and 3 or 4 indicative points would score 1 reasoning mark. A total of 2, 1 or 0 indicative points would score 0 marks for reasoning.</td><td>6</td></tr>
</table>

	Indicative Points Similarities: **IP1 Both** react with 2,4-dinitrophenylhydrazine to form a yellow / orange / red precipitate **IP2 Both** can be reduced by $LiAlH_4$ / Lithium tetrahydrido aluminate / lithium aluminium hydride (in dry ether) Differences: **IP3** but propanal forms a primary alcohol, propanone forms a secondary alcohol **IP4** Propanal will react with acidified potassium dichromate ((VI)) but propanone will not react **IP5** Equation for oxidation reaction **IP6** Observation for named oxidising agent Eg. orange to green (with acidified dichromate(VI)) Comment – Ignore equations involving 2,4 DNP	Ignore Iodoform reaction Accept **Both** can be reduced by $NaBH_4$ If name given it must be correct Accept propanal forms propan- 1-ol / $CH_3CH_2CH_2OH$ and propanone forms propan-2-ol / $CH_3CHOHCH_3$ Accept any named suitable oxidising agent eg. Fehling's / Benedict's solution/ Tollens' reagent / acidified potassium manganate((VII)) $CH_3CH_2CHO + [O] \rightarrow CH_3CH_2COOH$ If reduction of metal shown in oxidation equation it must be correct. Fehling's / Benedict's : blue solution to red / orange ppt Tollen's : silver mirror / ppt Allow grey ppt. Additional incorrect equations for organic reduction loses one reasoning mark	

(Total for Question 17 = 6 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
18(a) (i)	• Calculation of 1/*T* value 1.19×10^{-3} **and** • Calculation ln*k* value -6.40 (1)	Both values must be given to 3sf.	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
18(a)(ii)	**M1** Axes correct way round and labelled (1) **M2** Suitable scale with points covering at least half the axes in both directions (1) **M3** All points plotted (± ½ square), **and** <u>straight</u> line of best fit (1)	If numbers used on x-axis are without the power of ten allow x 10^3 or 10^{-3} on the axis. Do not award M1 if units given for ln k on y-axis Do not award small "t" for "T" Ignore y-axis with increasing negative values going upwards. COMMENT: If wrong columns plotted allow M2 only	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
18(a)(iii)	M1 Calculation of gradient with sign, in the range -34200 to -31200 (1) M2 Units of gradient is K (1) M3 Calculation of activation energy (1)	Do not award positive gradient. Allow gradient as a fraction <u>Example of calculation:</u> (32700 x 8.31) / 1000 = (+)272 (kJ mol^{-1}) Allow any answer between (+)259 and 284 Allow answer in J mol^{-1} if units given Allow TE from M1 if Ea is positive. Ignore SF other than 1SF Do not award negative Ea	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
18(b)	The value is large, **Either** as a lot of energy is required (1) so the reactant is kinetically stable / rate of reaction is low (1) **Or** as a lot of energy is required (1) to break the strong C-C bonds in cyclopropane (1) **Or** as a lot of energy is required to break the strong C-C bonds in cyclopropane (1) so the reaction requires very high temperatures (1)	Comment – alternative approach Allow TE from (a)(iii) for a small positive value (less than 50); the value is small so not much energy is required (1) the bonds in cyclopropane are strained/ C-C-C bond angle is 60◦ rather than 109.5◦ (1) Ignore any references to catalysts	**2**

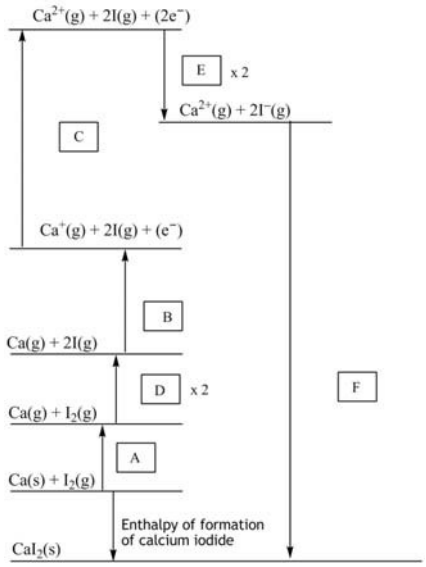
Question Number	Acceptable Answers	Additional Guidance	Mark
18(c)	As *T* increases *k* increases (rapidly) (1) As the (average) energy of molecules / particles increases (1) So a greater proportion of / more collisions have energy ≥ activation energy / (1)	Ignore any reference to equilibrium constant Ignore so a greater proportion of collisions are successful	**3**

(Total for Question 18 = 12 marks)

Question Number	Acceptable Answers	Additional Guidance	Mark
19(a)(i)	**M1** Expression for ΔS_{system} (1) **M2** Value for ΔS_{system} (1) **M3** Expression for $\Delta S_{surroundings}$ (1) **M4** Value for $\Delta S_{surroundings}$ (1) **M5** Value for ΔS_{total} to 2 or 3 SF andunits (1)	Example of calculation: (186.2 + 239.7) – (16.5 + (4 x 186.8)) —337.8 (J K^{-1} mol^{-1}) $\Delta S_{surroundings} = -\frac{\Delta H}{T} = -(-631.3 \times 10^3) / 298$ = (+) 2118.5 (J K^{-1} mol^{-1}) / (+)2.1185 (kJ K^{-1} mol^{-1}) (= 2118.5 + (– 337.8) = (+)1780.7 = (+)1780 / (+)1800 J K^{-1} mol^{-1} (+)1.78 / (+)1.80 kJ K^{-1} mol^{-1} Allow TE at each stage Correct answer with no working scores 5 (+)2340 J K^{-1} mol^{-1} scores 4 (1 x 186.8) (+) 2460 J K^{-1} mol^{-1} scores 3 (react-prod)	**5**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(a)(ii)	An answer that makes reference to: • A higher temperature would result in a less positive / lower $\Delta S_{surroundings}$ (ΔS_{system} is relatively unaffected by temperature) (1) • So ΔS_{total} is less positive / lower, which makes reaction less feasible /reduces yield (1) COMMENT: For M1 and M2 allow correct calculation of ΔS_{total} (at 973K) >0 to show that the reaction is feasible. • but high temperature is used to increase rate (1)	Ignore references to Le Chatelier for M1 and M2. Allow A highertemperature would result in a an insignificant change in $\Delta S_{surroundings}$ as its value is so large (ΔS_{system} is relatively unaffected by temperature) So ΔS_{total} is unchanged (in sign), which meansfeasibility of reaction is unchanged Ignore less easily / readily Standalone mark	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(a)(iii)	Recall of expression for K (1) Rearrangement of expression and calculation of ln K and value for K (1) **Allow TE from (a)(i) but no TE if incorrect expression given in M1.**	Example of calculation: $\Delta S_{total} = R\ln K$ $\ln K = \Delta S_{total}/R = 1780.7 / 8.31$ $= 214.1998$ 1.15440×10^{93} Allow any answer between 1.06×10^{93} and 1.18×10^{94} Ignore any units; Ignore SF Correct answer with no working scores 2	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(b)(i)	Arrows upwards for first and second ionisation energies for calcium and correct labels, B and Cin boxes (1) Downward arrows for electron affinity and lattice enthalpy and correct labels E x 2 and Fin boxes (1) Correct species including state symbols on horizontal lines (1)  	Only penalise lack of arrow once in M1 and M2. If electrons are included, they must be correct but allow e for e^-	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(b)(ii)	Correct expression (1) Evaluation (1)	Example of calculation: [(178.2 + 590 + 1145+ (106.8 x 2) – (295.4 x 2)] – 2074 = —538 (kJ mol^{-1}) If E x 2 penalised in b(i), allow use of 1 x 295.4 as TE. In this case only -242.6(kJ mol^{-1}) scores 2 However, if E x 2 not penalised in b(i) then penalise failure to multiply by 2 once only in b(ii) -349.4(kJ mol^{-1}) scores 1 (misses both x 2) -242.6(kJ mol^{-1}) scores 1 (misses 2 x 295.4) -644.8 (kJ mol^{-1}) scores 1 (misses 2 x 106.8) +538 (kJ mol^{-1}) scores 1 (expression wrong way round) ignore SF except 1 SF	**2**

Question Number	Acceptable Answers	Additional Guidance	Marks
19(b)(iii)	Bonding in calcium fluoride is (virtually) 100% ionic (1) Whereas bonding in calcium iodide has a degree of covalency / some covalent character (1) Then any **2** from these 3 marking points The calcium **ion** is polarising (1) The fluoride (ion) is small so not easily polarised / electron cloud not so easily distorted (1) the iodide (ion) is larger and so is easily polarised / electron cloud is easily distorted (1)	Allow Iodide / I^- has some covalent character Penalise the use of fluorine and iodine once only	**4**

Question Number	Acceptable Answers	Additional Guidance	Mark
19(c)	**M1** More exothermic / more negative / greater in magnitude (1) **M2** As (the atomic radius of) chlorine is smaller / less shielding between nucleus and electron (to be gained) / chlorine has fewer shells (of electrons) (1) **M3** Stronger attraction (between nucleus and electron to be gained) (1)	Ignore larger / less / higher Allow 'more energy released' Do not award chloride for chlorine Allow chlorine is more electronegative than iodine Allow reverse argumentfor M2 and M3	**3**

(Total for Question 19 = 22 marks) (Total for Section B = 50 marks)

Section C

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(i)	3- methylbutyl ethanoate or 3-methyl-1-butyl ethanoate	Allow butanyl for butyl Do not award butanoyl Allow methly formethyl	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(ii)	• Calculation of M_r of ester (1) • Calculation of mass of ester (1) • Calculation of percentage of ester (1)	<u>Example of calculation</u> M_r of ester = 130 Mass of ester = $6.06 \times 10^{-3} \times 130$ = 0.7878 (g) TE on incorrect M_r of ester % of ester = (0.7878/1.07) x 100 =73.6 % Allow 73.8% as M2 rounded to 0.79 Correct answer with no working scores 3 marks. Allow TE from M2 Ignore SF except 1SF	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(iii)	• Calculation of mol of excess sodium hydroxide (1) • Calculation of concentration of excess sodium hydroxide (1) • Calculation of pH to at least 1 dp (1)	<u>Example of calculation</u> Excess amount of sodium hydroxide = (0.025 x 0.980) – 6.06 x 10^{-3} = 0.01844 (mol) Concentration of excess sodium hydroxide = 0.01844/0.025 = 0.7376 (mol dm^{-3}) allow TE from M1 if some attempt at subtraction pH = 14–(–log(0.7376)) = 13.8678 = 13.9 allow TE from M2 if pH is greater than7 and less than or equal to 14 Allow 1 mark for pH =13.99 (based on 0.98 mol dm^{-3} NaOH)	3

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(iv)	• student C is correct as the titration is between a strong acid and a strong base (1) • Both methyl orange and phenolphthalein change colour at equivalence / vertical section of the graph (1)	Allow A and B are incorrect Allow both pK_{IN} values / range of indicators are within vertical section (of thegraph) If values are quoted they must be correct PP = 9.3 ; MO = 3.7	**2**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(a)(v)	Add (excess) HCl(aq) (1)	Allow 'add a strong acid' Allow name or formula of any strong acid but if both are given, both must be correct Ignore references to dilute / conc / heat / reflux	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(b)(i)	**M1** Calculates moles of CH_3COONa/ NaOH (1) **M2** Calculates moles ofexcess CH_3COOH (1) **M3** Calculates / shows ratio of $[CH_3COOH]$ to $[CH_3COONa]$ OR ratio of moles CH_3COOH to CH_3COONa (1) **M4** re-arranges K_a or pK_a expression correctly and substitutes appropriate values to find $[H^+]$ (1) **M5** Calculation of pH (1)	<u>Example of calculation</u> Moles of NaOH = moles of CH_3COONa = $(30/1000) \times 0.142 = 4.26 \times 10^{-3}$ (mol) Moles of excess CH_3COOH = $[(50/1000) \times 0.15] - 4.26 \times 10^{-3} = 3.24 \times 10^{-3}$ (mol) $[CH_3COOH] = 3.24 \times 10^{-3} / (80/1000) = 0.0405$ (mol dm^{-3}) $[CH_3COONa] = 4.26 \times 10^{-3} / (80/1000) = 0.05325$ (mol dm^{-3}) □ 0.0405 / 05325 Allow ratio using moles as V cancels NOTE can be subsumed in M4 $[H^+] = 1.70 \times 10^{-5} \times (0.0405/0.05325) = 1.29 \times 10^{-5}$ (mol dm^{-3}) Or pH=pKa – log([acid]/[base]) / pH= 4.77-log (0.0405/0.05325) pH = 4.89 Correct answer with no working scores 5 marks Ignore SF except 1SF Allow TE throughout Comment 4.52 will score 4 (omission of subtraction)	**5**

Question Number	Acceptable Answers	Additional Guidance	Mark
20(b) (ii)	**M1** (Large) 'reservoir' of CH_3COOH and CH_3COO^- (1) **M2** The OH^- ions react with CH_3COOH / H^+ ions (1) **M3** $H^+ + OH^- \rightarrow H_2O$ or $CH_3COOH + OH^- \rightarrow CH_3COO^- + H_2O$ (1) **M4** The H^+ ions react with CH_3COO^- or $H^+ + CH_3COO^- \rightleftharpoons CH_3COOH$ (1) **M5** The ratio of acid to base remains (almost) constant (1)	If both equations given both must be correct If equation given must be correct Allow base/salt remains (almost) constant Allow $[H^+]$ remains(almost) constant	**5**

(Total for Question 20 = 20 marks)

(Total for Section C = 20 marks)

Total for Paper = 90marks