

Markscheme

May 2018

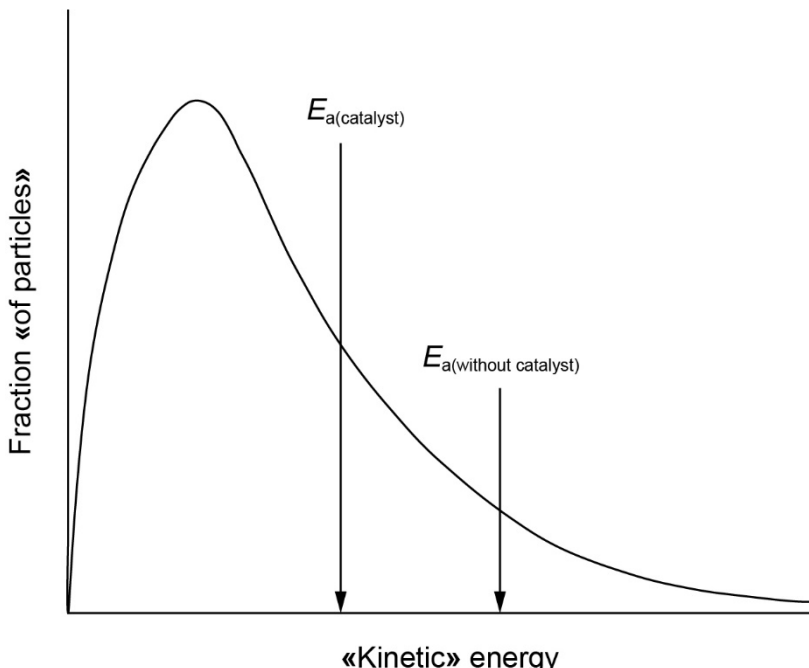
Chemistry

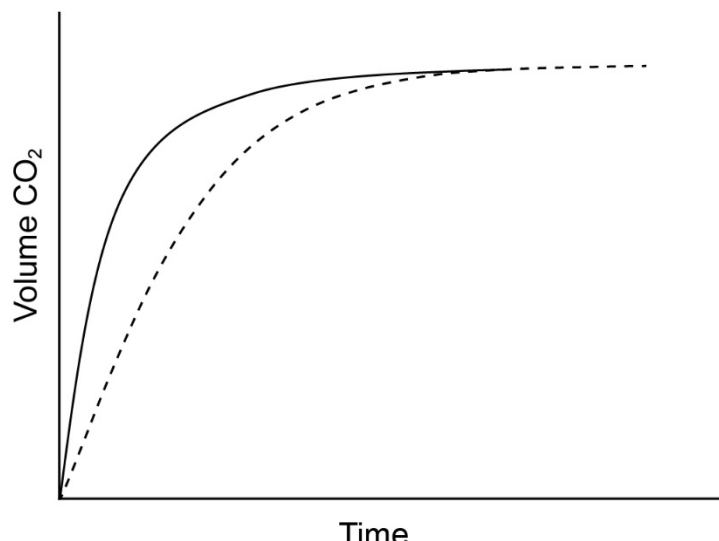
Higher level

Paper 2

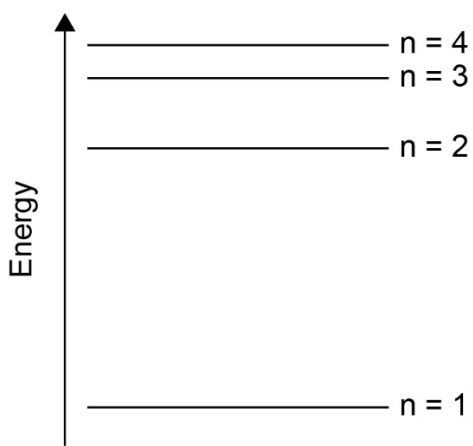
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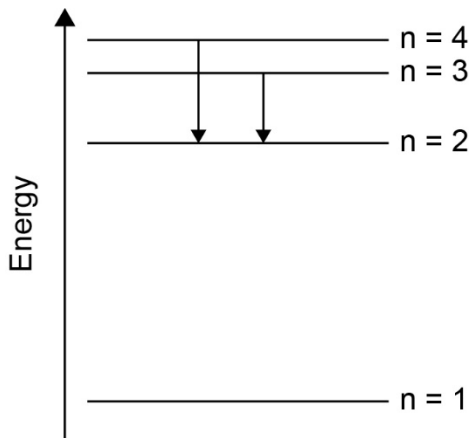
Question		Answers	Notes	Total
1.	a	$n(\text{H}_2\text{SO}_4) \llcorner = 0.0500 \text{ dm}^3 \times 0.100 \text{ mol dm}^{-3} \llcorner = 0.00500/5.00 \times 10^{-3} \llcorner \llcorner \text{mol} \llcorner \llcorner \checkmark$		1
1.	b	$\text{H}_2\text{SO}_4(\text{aq}) + \text{Mg}(\text{OH})_2(\text{s}) \rightarrow \text{MgSO}_4(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \checkmark$	<i>Accept an ionic equation.</i>	1
1.	c	$\llcorner n(\text{H}_2\text{SO}_4) = \frac{1}{2} \times n(\text{NaOH}) = \frac{1}{2} (0.02080 \text{ dm}^3 \times 0.1133 \text{ mol dm}^{-3}) \llcorner$ $0.001178/1.178 \times 10^{-3} \llcorner \llcorner \text{mol} \llcorner \llcorner \checkmark$		1
1.	d	$n(\text{H}_2\text{SO}_4) \text{ reacted} \llcorner = 0.00500 - 0.001178 \llcorner = 0.00382/3.82 \times 10^{-3} \llcorner \llcorner \text{mol} \llcorner \llcorner \checkmark$		1
1.	e	$n(\text{Mg}(\text{OH})_2) \llcorner = n(\text{H}_2\text{SO}_4) \llcorner = 0.00382/3.82 \times 10^{-3} \llcorner \llcorner \text{mol} \llcorner \llcorner \checkmark$ $m(\text{Mg}(\text{OH})_2) \llcorner = 0.00382 \text{ mol} \times 58.33 \text{ g mol}^{-1} \llcorner = 0.223 \llcorner \llcorner \text{g} \llcorner \llcorner \checkmark$	<i>Award [2] for correct final answer.</i>	2
1.	f	$\% \text{Mg}(\text{OH})_2 \llcorner = \frac{0.223 \text{ g}}{1.24 \text{ g}} \times 100 \llcorner = 18.0 \llcorner \llcorner \% \llcorner \llcorner \checkmark$	<i>Answer must show three significant figures.</i>	1
1.	g	to reduce random errors OR to increase precision \checkmark	<i>Accept "to ensure reliability".</i>	1

Question		Answers	Notes	Total
2.	a	 <p>both axes correctly labelled ✓ correct shape of curve starting at origin ✓ $E_{a(\text{catalyst})} < E_{a(\text{without catalyst})}$ on x-axis ✓</p>	<p>M1: Accept "speed" for x-axis label. Accept "number of particles", "N", "frequency" or "probability «density»" for y-axis label. Do not accept "potential energy" for x-axis label.</p> <p>M2: Do not accept a curve that touches the x-axis at high energy. Do not award M2 if two curves are drawn.</p> <p>M3: Ignore any shading under the curve.</p>	3

Question			Answers	Notes	Total
2.	b	i	 <p>curve starting from origin with steeper gradient AND reaching same maximum volume ✓</p>		1
2.	b	ii	<p>rate decreases OR slower reaction ✓</p> <p>«ethanoic acid» partially dissociated/ionized «in solution/water» OR lower $[H^+]$ ✓</p>	Accept "weak acid" or "higher pH".	2

Question			Answers	Notes	Total
2.	c		<p>«pH» converts «wide range of [H⁺]» into simple «log» scale/numbers OR «pH» avoids need for exponential/scientific notation OR «pH» converts small numbers into values «typically» between 0/1 and 14 OR «pH» allows easy comparison of values of [H⁺] ✓</p>	<p>Accept “uses values between 0/1 and 14”.</p> <p>Do not accept “easier to use”.</p> <p>Do not accept “easier for calculations”.</p>	1
2.	d	i	<p>A: CH₃COOH/ethanoic/acetic acid AND CH₃COO⁻/ethanoate/acetate ions ✓</p> <p>B: CH₃COO⁻/ethanoate/acetate ions ✓</p>	<p>Penalize “sodium ethanoate/acetate” instead of “ethanoate/acetate ions” only once.</p>	2
2.	d	ii	$K_a = 1.74 \times 10^{-5} = \frac{[H^+]^2}{0.10}$ <p>OR</p> <p>[H⁺] = 1.32 × 10⁻³ «mol dm⁻³» ✓</p> <p>«pH ⇒» 2.88 ✓</p>	<p>Accept [2] for correct final answer.</p>	2
2.	d	iii	<p>«forms weak acid and strong base, thus basic» CH₃COO⁻ (aq) + H₂O (l) ⇌ CH₃COOH (aq) + OH⁻ (aq) ✓</p>	<p>Accept → for ⇌.</p>	1
2.	d	iv	<p>less than 7 ✓</p>		1

Question			Answers	Notes	Total
2.	e	i	$2\text{NO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{HNO}_2(\text{aq}) + \text{HNO}_3(\text{aq}) \checkmark$		1
2.	e	ii	$2\text{HNO}_2(\text{aq}) + \text{CaCO}_3(\text{s}) \rightarrow \text{Ca}(\text{NO}_2)_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l})$ OR $2\text{HNO}_3(\text{aq}) + \text{CaCO}_3(\text{s}) \rightarrow \text{Ca}(\text{NO}_3)_2(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \checkmark$		1
3.	a	i	 <p>Energy</p> <p>n = 4</p> <p>n = 3</p> <p>n = 2</p> <p>n = 1</p> <p>4 levels showing convergence at higher energy \checkmark</p>		1

Question			Answers	Notes	Total
3.	a	ii	 <p>arrows (pointing down) from $n = 3$ to $n = 2$ AND $n = 4$ to $n = 2$ ✓</p>		1

(continued...)

(Question 3a continued)

Question			Answers	Notes	Total						
3.	a	iii	$IE \ll \Delta E = h\nu = 6.63 \times 10^{-34} \text{ J s} \times 3.28 \times 10^{15} \text{ s}^{-1} = 2.17 \times 10^{-18} \text{ «J»} \checkmark$		1						
3.	a	iv	$\ll \lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ ms}^{-1}}{3.28 \times 10^{15} \text{ s}^{-1}} = 9.15 \times 10^{-8} \text{ «m»} \checkmark$		1						
3.	b	i	same number of shells/«outer» energy level/shielding AND nuclear charge/number of protons/ Z_{eff} increases «causing a stronger pull on the outer electrons» \checkmark		1						
3.	b	ii	K^+ 19 protons AND Cl^- 17 protons OR K^+ has «two» more protons \checkmark same number of electrons/isoelectronic «thus pulled closer together» \checkmark		2						
3.	c	i	<table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>1</td></tr></table> <table border="1" style="display: inline-table; vertical-align: middle;"><tr><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr></table>	1	1	1	1	1	1		1
1											
1	1	1	1	1							
3.	c	ii	<i>Anode (positive electrode):</i> $\text{Cu(s)} \rightarrow \text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \checkmark$ <i>Cathode (negative electrode):</i> $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu(s)} \checkmark$	<i>Accept $\text{Cu(s)} - 2\text{e}^- \rightarrow \text{Cu}^{2+}(\text{aq})$.</i> <i>Accept \rightleftharpoons for \rightarrow.</i> <i>Award [1 max] if the equations are at the wrong electrodes.</i>	2						

(continued...)

(Question 3c continued)

Question			Answers	Notes	Total
3.	c	iii	«external» circuit/wire AND from positive/anode to negative/cathode electrode ✓	Accept “through power supply/battery” instead of “circuit”.	1
3.	c	iv	no change «in colour» ✓	Do not accept “solution around cathode will become paler and solution around the anode will become darker”.	1
3.	c	v	oxygen/O ₂ ✓	Accept “carbon dioxide/CO ₂ ”.	1
3.	d		<p><i>Transition metals:</i></p> <p>«contain» d and s orbitals «which are close in energy»</p> <p>OR</p> <p>«successive» ionization energies increase gradually ✓</p> <p><i>Alkali metals:</i></p> <p>second electron removed from «much» lower energy level</p> <p>OR</p> <p>removal of second electron requires large increase in ionization energy ✓</p>		2

Question		Answers	Notes	Total
4.	a	$\text{BrO}_3^- (\text{aq}) + 6\text{H}^+ (\text{aq}) + 6\text{I}^- (\text{aq}) \rightleftharpoons \text{Br}^- (\text{aq}) + 3\text{I}_2 (\text{s}) + 3\text{H}_2\text{O} (\text{l}) \checkmark$	Accept \rightarrow for \rightleftharpoons .	1
4.	b	$n = 6 \checkmark$ $\ll \Delta G^\ominus = -nFE^\ominus \gg$ $\ll E^\ominus = -\frac{\Delta G^\ominus}{nF} = \frac{514 \times 10^3 \text{ J mol}^{-1}}{6 \times 9.65 \times 10^4 \text{ C mol}^{-1}} \Rightarrow 0.888 \text{ «V» } \checkmark$		2
4.	c	$\ll E^\ominus = E^\ominus (\text{BrO}_3^-/\text{Br}^-) - E^\ominus (\text{I}_2/\text{I}^-) \gg$ $\ll E^\ominus (\text{BrO}_3^-/\text{Br}^-) = E^\ominus + E^\ominus (\text{I}_2/\text{I}^-) = 0.888 + 0.54 \Rightarrow \ll + \gg 1.43 \text{ «V» } \checkmark$		1

Question			Answers	Notes	Total
5.	a		<p>bonds broken: $4(\text{C-H}) + 2(\text{H-O}) / 4(414) + 2(463) / 2582$ «kJ» ✓ bonds made: $3(\text{H-H}) + \text{C}\equiv\text{O} / 3(436) + 1077 / 2385$ «kJ» ✓</p> $\Delta H \llcorner = \sum \text{BE}_{(\text{bonds broken})} - \sum \text{BE}_{(\text{bonds made})} = 2582 - 2385 = \llcorner + \gg 197$ «kJ» ✓	<p>Award [3] for correct final answer. Award [2 max] for -197 «kJ».</p>	3
5.	b	i	ΔH_f^\ominus for any element = 0 «by definition» OR no energy required to form an element «in its stable form» from itself ✓		1
5.	b	ii	$\Delta H^\ominus \llcorner = \sum \Delta H_f^\ominus(\text{products}) - \sum \Delta H_f^\ominus(\text{reactants}) = -111 + 0 - [-74.0 + (-242)] \gg$ $= \llcorner + \gg 205$ «kJ» ✓		1
5.	b	iii	«bond enthalpies» averaged values «over similar compounds» OR «bond enthalpies» are not specific to these compounds ✓		1
5.	c		$\llcorner \Delta S^\ominus = \sum S^\ominus_{\text{products}} - \sum S^\ominus_{\text{reactants}} = 198 + 3 \times 131 - (186 + 189) \gg \llcorner + \gg 216$ «J K ⁻¹ » ✓		1
5.	d		$\llcorner \Delta G^\ominus = \Delta H^\ominus - T\Delta S^\ominus = 205 \text{ kJ} - 298 \text{ K} \times \frac{216}{1000} \text{ kJ K}^{-1} \gg \llcorner + \gg 141$ «kJ» ✓		1

Question		Answers	Notes	Total
5.	e	$\Delta H^\ominus = T\Delta S^\ominus$ $T = \frac{\Delta H^\ominus}{\Delta S^\ominus} = \frac{205000 \text{ J}}{216 \text{ J K}^{-1}}$ $T = 949 \text{ K} \checkmark$	<p><i>Do not award a mark for negative value of T.</i></p>	1

Question			Answers	Notes	Total
6.	a		Q: non-equilibrium concentrations AND K_c : equilibrium concentrations OR Q: «measured» at any time AND K_c : «measured» at equilibrium ✓		1
6.	b		« $Q = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 [\text{O}_2]} = \frac{1.00^2}{1.00^2 \times 2.00}$ » = 0.500 ✓ reverse reaction favoured/reaction proceeds to the left AND $Q > K_c/0.500 > 0.282$ ✓	Do not award M2 without M1.	2
6.	c	i	$[\text{N}_2\text{O}_2]$ decreases AND exothermic «thus reverse reaction favoured» ✓	Accept “product” for $[\text{N}_2\text{O}_2]$. Do not accept just “reverse reaction favoured/shift to left” for “ $[\text{N}_2\text{O}_2]$ decreases”.	1

(continued...)

(Question 6c continued)

Question			Answers	Notes	Total
6.	c	ii	<p>ALTERNATIVE 1:</p> <p>«from equilibrium, step 1»</p> $K_c = \frac{[\text{N}_2\text{O}_2]}{[\text{NO}]^2}$ <p>OR</p> $[\text{N}_2\text{O}_2] = K_c [\text{NO}]^2 \checkmark$ <p>«from step 2, rate «= $k_1 [\text{N}_2\text{O}_2][\text{O}_2] = k_2 K [\text{NO}]^2 [\text{O}_2]$»</p> $\text{rate} = k [\text{NO}]^2 [\text{O}_2] \checkmark$ <p>ALTERNATIVE 2:</p> <p>«from step 2» rate = $k_2 [\text{N}_2\text{O}_2] [\text{O}_2] \checkmark$</p> <p>«from step 1, rate₍₁₎ = $k_1 [\text{NO}]^2 = k_{-1} [\text{N}_2\text{O}_2]$, $[\text{N}_2\text{O}_2] = \frac{k_1}{k_{-1}} [\text{NO}]^2$»</p> $\text{rate} = \frac{k_1}{k_{-1}} k_2 [\text{NO}]^2 [\text{O}_2] \checkmark$ <p>rate = $k [\text{NO}]^2 [\text{O}_2] \checkmark$</p>	Award [2] for correct rate expression.	2
6.	d		$\left\langle \ln \frac{k_1}{k_2} = \frac{E_a}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \right\rangle$ <p>$T_2 = \langle 273 + 35 \Rightarrow 308 \text{ K} \textbf{ AND } T_1 = \langle 273 + 25 \Rightarrow 298 \text{ K} \checkmark$</p> <p>$E_a = 52.9 \langle \text{kJ mol}^{-1} \rangle \checkmark$</p>	Award [2] for correct final answer.	2

Question			Answers	Notes	Total
7.	a	i	polar bonds «between H and group 16 element» OR difference in electronegativities «between H and group 16 element» ✓ uneven distribution of charge/electron cloud OR non-linear/bent/V-shaped/angular shape «due to lone pairs» OR polar bonds/dipoles do not cancel out ✓	M2: Do not accept “net/overall dipole moment” without further explanation. Accept “non-symmetrical «shape/distribution of charge»”.	2
7.	a	ii	number of electrons increases ✓ London/dispersion/instantaneous induced dipole-induced dipole forces increase ✓	M1: Accept “ M_r/A_r increases” or “molecules become larger in size/mass/surface area”.	2
7.	b		<i>Electron domain geometry:</i> tetrahedral ✓ <i>Molecular geometry:</i> bent/V-shaped/angular ✓	Both marks can be awarded for clear diagrams. Electron domain geometry requires a 3-D diagram showing the tetrahedral arrangement.	2

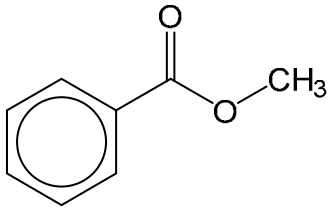
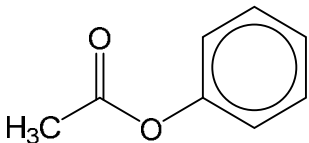
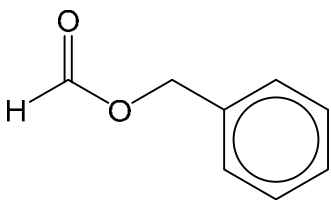
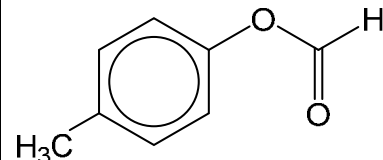
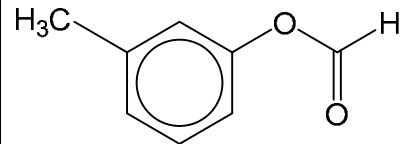
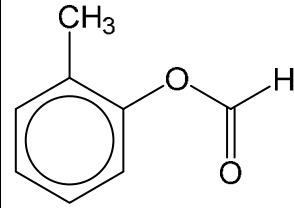
Question			Answers			Notes	Total
7.	c	i	Structure:	I	II	<i>Award [1] for any two correctly filled cells.</i>	2
			O atom labelled (1)	0	«+»1 ✓		
			O atom labelled (2)	0	-1 ✓		
7.	c	ii	structure I AND no formal charges OR structure I AND no charge transfer «between atoms» ✓				1
7.	d		O ₃ has bond between single and double bond AND O ₂ has double bond OR O ₃ has bond order of 1.5 AND O ₂ has bond order of 2 OR bond in O ₃ is weaker/longer than in O ₂ ✓ O ₃ requires longer wavelength ✓			<i>M1: Do not accept "ozone has one single and one double bond".</i>	2
7.	e		CO ₂ «non-polar» «weak» London/dispersion forces/instantaneous induced dipole-induced dipole forces between molecules ✓ SiO ₂ network/lattice/3D/giant «covalent» structure ✓			<i>M1: The concept of "between" is essential.</i>	2

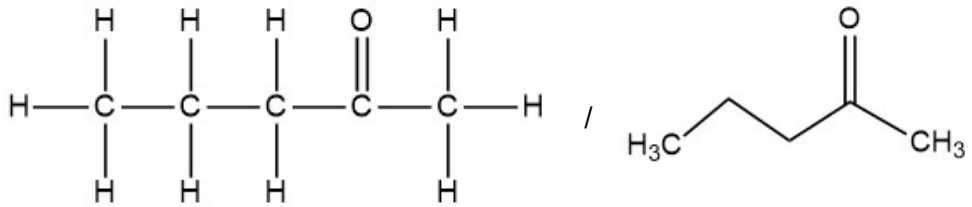
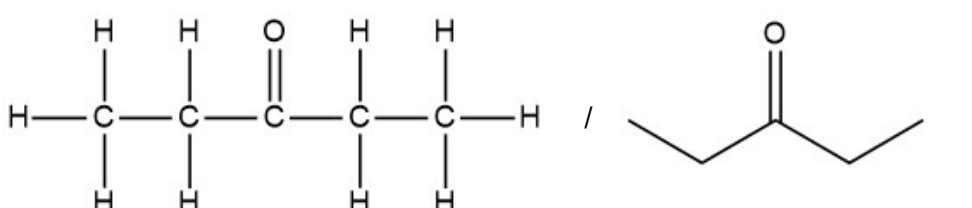
Question		Answers	Notes	Total
8.	a	<p><i>Physical evidence:</i> equal C–C bond «lengths/strengths» OR regular hexagon OR «all» C–C have bond order of 1.5 OR «all» C–C intermediate between single and double bonds ✓</p> <p><i>Chemical evidence:</i> undergoes substitution reaction «more readily than addition» OR does not discolour/react with bromine water OR substitution forms only one isomer for 1,2-disubstitution «presence of alternate double bonds would form two isomers» OR more stable than expected «compared to hypothetical molecule cyclohexa-1,3,5-triene» OR enthalpy change of hydrogenation/combustion is less exothermic than predicted «for cyclohexa-1,3,5-triene» ✓</p>	<p><i>M1:</i> Accept “all C–C–C bond angles are equal”.</p>	2

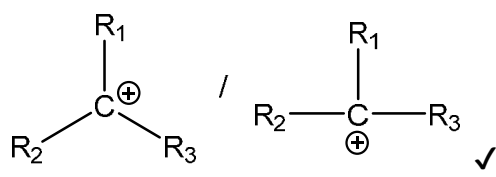
Question			Answers	Notes	Total
8.	b	i	$3\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}(\text{l}) + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 8\text{H}^+(\text{aq}) \rightarrow 3\text{CH}_3\text{CH}_2\text{CHO}(\text{aq}) + 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$ correct reactants and products ✓ balanced equation ✓		2
8	b	ii	Aldehyde: by distillation «removed from reaction mixture as soon as formed» ✓ Carboxylic acid: «heat mixture under» reflux «to achieve complete oxidation to –COOH» ✓	Accept clear diagrams or descriptions of the processes.	2
8.	c	i	$\left\langle \frac{136}{48 + 4 + 16} = 2 \right\rangle$ C ₈ H ₈ O ₂ ✓		1
8.	c	ii	A: C–H «in alkanes, alkenes, arenes» AND B: C=O «in aldehydes, ketones, carboxylic acids and esters» ✓		1

(continued...)

(Question 8c continued)

Question			Answers	Notes	Total
8.	c	iii	<p>Any two of:</p>  <p>OR $C_6H_5COOCH_3$ ✓</p>  <p>OR $CH_3COOC_6H_5$ ✓</p>  <p>OR $HCOOCH_2C_6H_5$ ✓</p>	<p><i>Do not penalize use of Kekule structures for the phenyl group.</i></p> <p><i>Accept the following structures:</i></p>    <p><i>Award [1 max] for two correct aliphatic/linear esters with the molecular formula $C_8H_8O_2$.</i></p>	2
8.	c	iv	<p>$C_6H_5COOCH_3$ «signal at 4 ppm (3.7–4.8 range in data table) due to alkyl group on ester» ✓</p>		1

Question			Answers	Notes	Total
9.	a	i	 	<p>Accept condensed formulas.</p> <p>✓</p> <p>✓</p>	2
9.	a	ii	<p>A: $\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ AND «peak at» 29 due to $(\text{CH}_3\text{CH}_2)^+ / (\text{C}_2\text{H}_5)^+ / (\text{M} - \text{CH}_3\text{CH}_2\text{CO})^+$</p> <p>OR</p> <p>$\text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3$ AND «peak at» 57 due to $(\text{CH}_3\text{CH}_2\text{CO})^+ / (\text{M} - \text{CH}_3\text{CH}_2)^+ / (\text{M} - \text{C}_2\text{H}_5)^+$ ✓</p> <p>B: $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$ AND «peak at» 43 due to $(\text{CH}_3\text{CH}_2\text{CH}_2)^+ / (\text{CH}_3\text{CO})^+ / (\text{C}_2\text{H}_3\text{O})^+ / (\text{M} - \text{CH}_3\text{CO})^+$ ✓</p>	<p>Penalize missing “+” sign once only.</p> <p>Accept “$\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$” by elimination since fragment CH_3CO is not listed” for M2.</p>	2

Question			Answers	Notes	Total
9.	b	i	heterolytic/heterolysis ✓		1
9.	b	ii	polar protic ✓		1
9.	b	iii	 Shape: triangular/trigonal planar ✓		2
9.	b	iv	«around» 50 % «each» OR similar/equal percentages ✓ nucleophile can attack from either side «of the planar carbocation» ✓	Accept "racemic mixture/racemate" for M1.	2
9.	c		Stage one: $\text{C}_6\text{H}_5\text{NO}_2(\text{l}) + 3\text{Sn}(\text{s}) + 7\text{H}^+(\text{aq}) \rightarrow \text{C}_6\text{H}_5\text{NH}_3^+(\text{aq}) + 3\text{Sn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \checkmark$ Stage two: $\text{C}_6\text{H}_5\text{NH}_3^+(\text{aq}) + \text{OH}^-(\text{aq}) \rightarrow \text{C}_6\text{H}_5\text{NH}_2(\text{l}) + \text{H}_2\text{O}(\text{l}) \checkmark$		2