Cambridge Assessment

A Level

Chemistry A

Session: 2010 June
Type: Mark scheme
Code: H034-H434
Units: F321; F322; F324; F325

OCR
RECOGNISING ACHIEVEMENT

GCE

Chemistry A

Advanced Subsidiary GCE **F321**

Atoms, Bonds and Groups

Mark Scheme for June 2010

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Question			Expected Answers	Marks	Additional Guidance
1	a	i	^{118}Sn 50p 68n 50e Complete row ✓	1	
		ii	$^{120}_{50}$Sn has (two) more neutrons / 70 neutrons ✓ ora	1	**ALLOW** There is a different number of neutrons **IGNORE** correct reference to protons / electrons **DO NOT ALLOW** incorrect references to protons / electrons **ALLOW** ECF for stated number of neutrons from **1a(i)**
	b	i	The (weighted) mean **mass** of an **atom** (of an element) **OR** The (weighted) average **mass** of an **atom** (of an element) ✓ compared with 1/12th (the mass) ✓ of (one atom of) carbon-12 ✓	3	**ALLOW** average atomic mass **DO NOT ALLOW** mean mass of an element **ALLOW** mean mass of isotope**s OR** average mass of isotope**s** **DO NOT ALLOW** the singular; 'isotope' For second **and** third marking points **ALLOW** compared with (the mass of) carbon-12 which is 12 **ALLOW** mass of **one mole** of **atoms** ✓ compared to 1/12th ✓ (mass of) **one mole OR** 12**g** of carbon-12 ✓ **ALLOW** mass of **one mole** of atoms / 1/12th mass of **one mole** OR 12**g** of carbon-12
	c		moles of Sn = $\frac{2080}{118.7}$ = 17.52 ✓ $17.52 \times 6.02 \times 10^{23} = 1.05 \times 10^{25}$ atoms ✓	2	**ALLOW** 17.5 up to (correctly rounded) calculator value of 17.52316765 **DO NOT ALLOW** use of 118, which makes moles of Sn = 17.63 **ALLOW** 105×10^{23} atoms **DO NOT ALLOW** answers which are not to three sig figs for second marking point **ALLOW** two marks for answer only of 1.05×10^{25} **ALLOW** one mark for answer only if not 3 sig figs up to calculator value of $1.054894693 \times 10^{25}$ **Eg 100 × 1** **ALLOW** ECF for **any calculated** moles of Sn (based on use of any A_r value) × 6.02×10^{23} if shown to 3 sig figs **DO NOT ALLOW** mass of Sn × 6.02×10^{23}

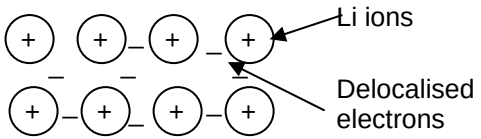
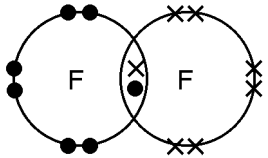
Question			Expected Answers	Marks	Additional Guidance
1	d		$\frac{78.8}{118.7}$ and $\frac{21.2}{16.0}$ **OR** = 0.66(4) and = 1.3(25) ✓ $\frac{0.66(4)}{0.66(4)}$ = 1 $\frac{1.325}{0.66(4)}$ = 2 ans = SnO_2 ✓	2	**ALLOW** SnO_2 for one mark if no working shown **ALLOW** use of 118 for this part **IGNORE** incorrect rounding provided given to two sig figs **IGNORE** incorrect symbols e.g. T or Ti for Tin, as long as correct A_r of tin (118.7 or 118) used **ALLOW** Sn_2O for 1 mark ECF if **both** inverted mole calculations are shown **ALLOW** Sn_3O_5 with **evidence** of use of **both** atomic numbers for one mark **ALLOW** 2 marks if candidate has adopted the following approach 78.8% of mass = 118.7 100% of mass = 118.7/0.788 = 150.6 (151) 150.6 – 118.7 = 31.9 (32) **Both** masses would get one mark 31.9/16 = 2
			Total	**9**	

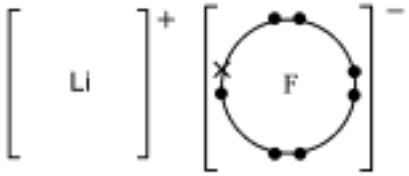
Question			Expected Answers	Marks	Additional Guidance
2	a	i	Any **two** from ✓✓ H^+ SO_4^{2-} HSO_4^-	2 max	**DO NOT ALLOW** OH^- **IGNORE** state symbols Charge is essential **ALLOW** H_3O^+ for H^+ and SO_4^{-2} for SO_4^{2-} One answer incorrect = 1 mark max Two answers incorrect = 0 marks
		ii	Effervescence **OR** fizzing **OR** bubbling **OR** gas produced ✓ K_2CO_3 dissolves **OR** disappears **OR** colourless solution is formed ✓ $H_2SO_4 + K_2CO_3 \rightarrow K_2SO_4 + CO_2 + H_2O$ ✓	3	**DO NOT ALLOW** 'carbon dioxide produced' without 'gas' **DO NOT ALLOW** incorrectly named gas produced **DO NOT ALLOW** 'precipitate forms' = CON **ALLOW** 'it' for K_2CO_3 **DO NOT ALLOW** mark for 'dissolves' from state symbols in equation **DO NOT ALLOW** 'potassium' **IGNORE** state symbols **ALLOW** ionic equation
	b	i	$\frac{24.6}{1000} \times 0.100 = 0.00246$ mol ✓ (2.46×10^{-3} mol)	1	**DO NOT ALLOW** 0.0025 as this would lead to 100% in part **(iii)** **DO NOT ALLOW** 0.0024 due to incorrect rounding
		ii	$0.00246 \times 2 = 0.00492$ mol ✓ (4.92×10^{-3} mol)	1	**ALLOW** ECF for ans **(i)** × 2
		iii	Moles of NaOH in 250 cm^3 = $0.00492 \times \frac{250}{25} = 0.0492$ mol ✓ Mass of NaOH in original sample $= 0.0492 \times 40.0 = 1.968$ g ✓ % purity $\frac{1.968}{2.00} \times 100 = 98.4\%$ ✓	3	**ALLOW** ECF for ans **(ii)** × 10 **ALLOW** 1.97g **ALLOW** ECF for moles of NaOH × 40 **ALLOW** 98.5% (from use of 1.97) **ALLOW** ECF for $\frac{\text{mass of NaOH}}{2.00} \times 100$ **DO NOT ALLOW** ECF for 3rd marking point if answer >100% **ALLOW** ECF for 3rd marking point if answer = 100% **ALLOW** molar approach for second and third marks i.e. mol of (expected) NaOH in 2.00 g = 2/40 = 0.05(00) mol $(0.0492/0.0500) \times 100 = 98.4\%$ 1.6% (the percentage of the impurity present) is likely to be 2 marks, but please check 9.84% has not multiplied up by 10 for first marking point is likely to be 2 marks, but please check
			Total	**10**	

Question			Expected Answers	Marks	Additional Guidance
3	a		3d 4p ✓	1	Correct order is essential **ALLOW** '3D'
	b	i	A region (within an atom) that can hold (up to) two electrons ✓ (with opposite spin)	1	**ALLOW** 'can be found' for 'can hold' **ALLOW** 'area' **OR** 'volume' **OR** 'space' for region **DO NOT ALLOW** 'place' for region **DO NOT ALLOW** path of an electron **IGNORE** references to 'orbitals being parts of sub-shells'
		ii	11 ✓	1	
	c		18 ✓	1	
	d	i	2nd, 3rd **OR** 1817, 2745 ✓ 10th, 11th **OR** 38458, 42655 ✓	2	Mark as pairs **IGNORE** references to 12th and 13th Three answers with one correct pair = 1 mark Four answers with one correct pair = 1 mark Five answers with both pairs correct = 1 mark Five answers with only one pair correct = 0 marks Six (or more) answers = 0 marks
		ii	$Al^{2+}(g) \rightarrow Al^{3+}(g) + e^{-}$ ✓✓	2	**ALLOW** $Al^{2+}(g) - e^{-} \rightarrow Al^{3+}(g)$ for 2 marks **ALLOW** 1 mark for $Al(g) \rightarrow Al^{3+}(g) + 3e^{-}$ as states are correct **ALLOW** 1 mark for $Al^{2+}(g) + 2e^{-} \rightarrow Al^{3+}(g) + 3e^{-}$ as states are correct **ALLOW** 1 mark if symbol of Al is incorrect, but equation is otherwise fully correct. **ALLOW** e for electron (i.e. no charge) **IGNORE** states on electron
			Total	**8**	

Question			Expected Answers	Marks	Additional Guidance
4	a	i	1 = purple / lilac / violet / pink / mauve ✓ 3 = orange ✓	2	**ALLOW** any combination of these but no others for 1 **ALLOW** yellow as an alternative for 3 **DO NOT ALLOW** 'precipitate' in either
		ii	$Cl_2 + 2Br^- \longrightarrow 2Cl^- + Br_2$ ✓	1	**IGNORE** state symbols **ALLOW** correct multiples, including fractions
		iii	Addition of $Br_2(aq)$ to $I^-(aq)$ ions ✓	1	**ALLOW** Addition of bromine to iodide (i.e. aqueous not needed) **DO NOT ALLOW** Addition of bromine to iodine **ALLOW** Addition of I_2 to Br^-, but NOT if accompanied by description of displacement of bromine **ALLOW** $Br_2 + I^-$ even if seen in an unbalanced equation
	b	i	Cl_2 is 0 **AND** HCl is –1 **AND** HClO is (+)1 ✓ Chlorine has been both oxidised and reduced **OR** Chlorine's oxidation state has increased and decreased ✓ Chlorine has been oxidised (from 0) to +1 **AND** chlorine has been reduced (from 0) to –1 ✓ (These two points together subsume the second marking point)	3	**ALLOW** 1– **ALLOW** 1+ Oxidation states may be seen above the equation **DO NOT ALLOW** Cl^- in HCl **DO NOT ALLOW** Cl^+ in HClO in text of answer **DO NOT ALLOW** chlor**IDE** in place of 'chlorine' **IF CORRECT OXIDATION STATES ARE SEEN, ALLOW** second **and** third marking points for: Chlorine is oxidised to form HClO Chlorine is reduced to form HCl **ALLOW** Cl or Cl_2 for 'chlorine' **IGNORE** reference to electron loss / gain if correct **DO NOT ALLOW** 3rd mark for reference to electron loss / gain if incorrect **ALLOW** one mark for 'disproportionation is when a species is both oxidised and reduced' if chlorine / chloride is not mentioned
		ii	Kills bacteria **OR** 'kills germs' kills micro-organisms **OR** makes water safe to drink **OR** sterilises water ✓ **OR** 'disinfects'	1	**ALLOW** to make water potable **ALLOW** 'removes' for 'kills' **IGNORE** 'virus' **IGNORE** 'purifies water'
	c	i	**Thermal** decomposition ✓	1	**DO NOT ALLOW** just 'decomposition' or 'thermodecomposition'
		ii	$\frac{1.47}{84.3}$ = 0.0174 mol of $MgCO_3$ ✓ $0.0174 \times 24.0 = 0.418\ dm^3$ **OR** (Calculator value $\times$ 24.0) = 0.419 dm^3 ✓	2	**ALLOW** mol of $MgCO_3$ as calculator value of 0.017437722 or correct rounding to 2 sig figs or more **DO NOT ALLOW** 0.0175 (this has taken M_r of $MgCO_3$ as 84) **ALLOW**, for 2nd mark **calculated moles of $MgCO_3$** $\times$ 24(.0) as calculator value or correct rounding to 2 sig figs or more [e.g. 0.017 $\times$ 24(.0) = 0.408] **DO NOT ALLOW** 84.3 or 1.47 $\times$ 24(.0) as no mole calculation has been done **ALLOW** two marks for correct answer with no working shown

Question			Expected Answers	Marks	Additional Guidance
4	c	iii	The ease of (thermal) decomposition decreases (down the group) ora ✓	1	**ALLOW** (thermal) stability increases **IGNORE** more heat would be needed **IGNORE** 'takes longer' or 'is slower' **IGNORE** reference to trend in reactivity **IGNORE** answers which include 'more / less mol of CO_2'
			Total	**15**	

Question			Expected Answers	Marks	Additional Guidance
5	a		 Diagram showing a regular arrangement of **labelled** '**Li^+**' or **'+ ions'** with some attempt to show electrons ✓ Scattering of **labelled** electrons **between** other species **OR** a statement anywhere of **delocalised** electrons (can be in text or in diagram) ✓ The attraction between + ions and e^- is strong **OR** metallic bonding is strong ✓	3	Lattice diagram must have at least two rows of correctly charged ions and a minimum of 2 ions per row **ALLOW** as label: + ions, positive ions, cations If '+' is unlabelled in diagram, award label from a correct statement within the text below **DO NOT ALLOW** 2+, 3+ etc ions **DO NOT ALLOW** for label or in text: nuclei **OR** positive atom **OR** protons **ALLOW** e^- **OR** e as label for electron **ALLOW** a lot of energy is needed to break the (metallic) bond **DO NOT ALLOW** incorrect particles or incorrect attraction e.g. 'intermolecular attraction' or 'nuclear attraction'
	b	i	 Dot and cross bond + 6 matching electrons on each F atom ✓	1	**ALLOW** diagram consisting of all dots **OR** all crosses Circles not essential **ALLOW** 'Fl' for fluorine
		ii	F_2 has induced dipoles **OR** temporary dipoles **OR** van der Waals' forces (between the molecules) ✓ which are **weak** ✓	2	**ALLOW** little energy needed to overcome intermolecular bonding for **second mark** **ALLOW** 'weak' intermolecular bonding for **second mark** **ALLOW** max 1 mark if structure is referred to as giant with first and second marking points correct Award no marks if 'weak' is applied to incorrect bonding. E.g. ionic, covalent, metallic or unspecified bonding

Question			Expected Answers	Marks	Additional Guidance
5	c	i	 Li shown with either 2 or 0 electrons **and** F shown with 8 electrons with 7 crosses and one dot (or *vice versa*) ✓ correct charges on both ions ✓	2	**For first mark**, if 2 electrons are shown in the cation then the 'extra' electron in the anion must match symbol chosen for electrons in the cation **IGNORE** inner shell electrons **ALLOW** 'Fl' for fluorine Circles not essential **DO NOT ALLOW** Li^+ with 8 electrons Second mark is independent
		ii	Ions cannot move in a solid ✓ **Ions** can move **OR** are mobile when molten ✓	2	**ALLOW** ions are fixed in place **IGNORE** electrons **IGNORE** 'charge carriers' or 'charged particles' **DO NOT ALLOW** ions can move when in solution **IGNORE** charge carriers **IGNORE** 'delocalised ions' or 'free ions' **ALLOW** '**Ions** can only move when molten' for one mark Any mention of electrons moving when molten is a **CON**
	d	i	$2B + 3F_2 \longrightarrow 2BF_3$ ✓	1	**ALLOW** B_2 **ALLOW** multiples including fractions
		ii	*Shape*: trigonal planar ✓ *Bond angle:* 120° ✓ *Explanation*: **Pairs** of electrons repel (one another equally) ✓ **Boron** has 3 bonded pairs (and 0 lone pairs) ✓	4	**'Trigonal planar' must be seen and spelt correctly at least ONCE** **DO NOT ALLOW** 'atoms repel' or 'electrons repel' **ALLOW** 'bonds repel' **ALLOW** diagram showing B atom with three dot-and-cross pairs of electrons, but **no** lone pairs for 4th mark Must refer to boron / central atom **ALLOW** 'bonds' for 'bonded pairs'

Question			Expected Answers	Marks	Additional Guidance
5	e		F is more electronegative than N **OR** $^{\delta-}$F–N$^{\delta+}$ ✓ Dipoles do not cancel **OR** NF_3 is pyramidal (in words) / asymmetrical ✓	2	**ALLOW** F attracts electrons more than N **ALLOW** N has a partial positive charge **and** F has a partial negative charge (partial must be seen) **DO NOT ALLOW** diagrams that contradict statements about polarity **ALLOW** unsymmetrical, non-symmetrical etc
	f		(As you go across the period) The atomic radii decreases ✓ The nuclear charge increases **OR** protons increase ✓ electrons are added to the same shell **OR** shielding remains the same ✓ great**er** (nuclear) attraction on (outer) electrons / (outer) shell(s) ✓	4	**Use annotations with ticks, crosses ECF etc. for this part** Assume 'across the period from Li to F' **ALLOW** (outer shell) electrons get closer (to nucleus) **IGNORE** 'atomic number increases', but **ALLOW** 'proton number' increases **IGNORE** 'nucleus gets bigger' 'Charge increases' is insufficient **ALLOW** 'effective nuclear charge increases' **OR** 'shielded nuclear charge increases' **Nuclear OR proton(s) OR nucleus spelt correctly ONCE and used in context of 2nd marking point** **ALLOW** shielding is similar **ALLOW** screening for shielding **DO NOT ALLOW** 'subshells' **DO NOT ALLOW** 'distance is similar' This will CON first marking point **ALLOW** 'greater (nuclear) pull for greater nuclear attraction' **DO NOT ALLOW** 'pulled in more' as this is a restatement of the first marking point
			Total	**21**	

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Chains, Energy and Resources

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Highlighting is also available to highlight any particular points on the script.

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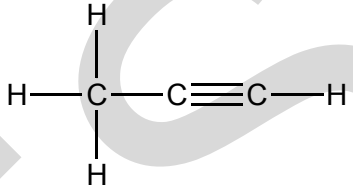
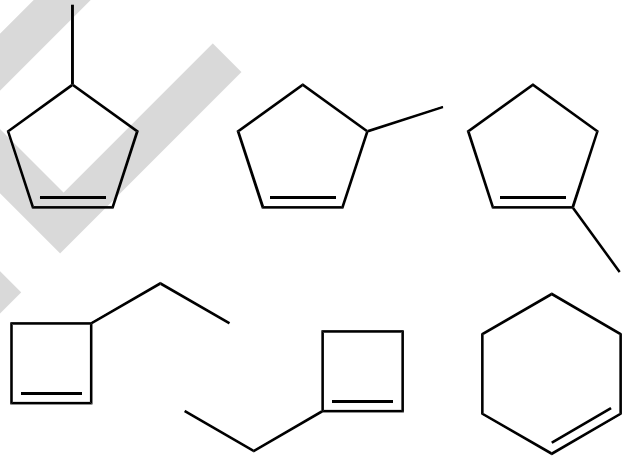
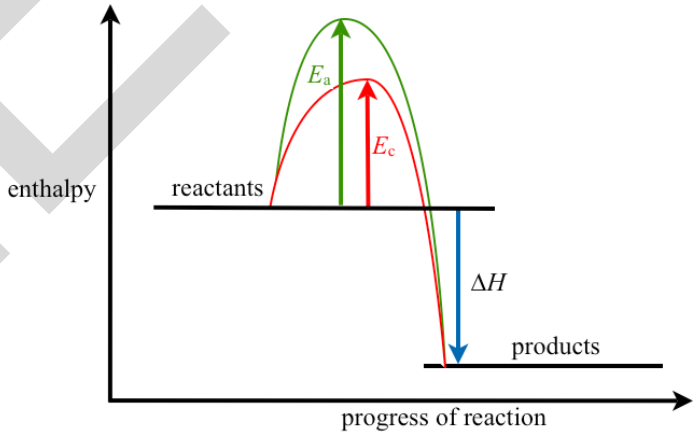
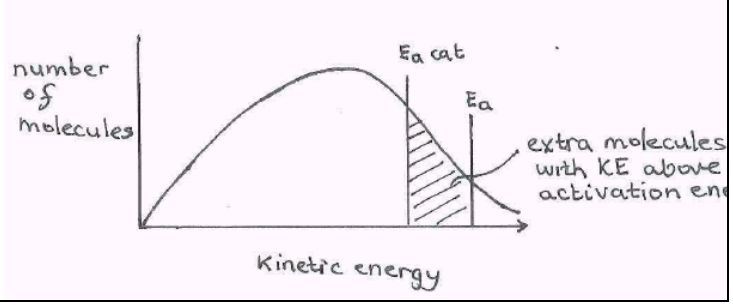
1	a	i	Series having same functional group and a general formula ✓	1	**ALLOW** same functional group and members vary by CH_2 **ALLOW** organic compounds with the same functional group that differ in length of their hydrocarbon chain
		ii	More surface contact **OR** bigger molecules ✓ More van der Waals' forces ✓	2	**BOTH answers need to be comparisons** **ALLOW** higher relative formula mass **OR** has more electrons **OR** longer chain length **OR** more carbon atoms **IGNORE** surface area / bigger compounds **ALLOW** stronger van der Waals' forces / stronger induced dipoles VDW forces is not sufficient More intermolecular forces is **not** sufficient **DO NOT ALLOW** breaking bonds within the chain / breaking covalent bonds **IGNORE** reference to bonds if not linked to covalent bonds
	b	i	Pent-1-yne **OR** pent-2-yne ✓	1	**ALLOW** pentyne Look for answer in the table if not on answer line but answer line takes precedence
		ii	C_nH_{2n-2} ✓	1	**ALLOW** $C_nH_{2(n-1)}$

Question			Expected Answers	Marks	Additional Guidance
1	b	iii	Correct displayed formula ✓	1	
		iv	Correct skeletal formula of cyclic hydrocarbon with formula C_6H_{10} ✓	1	Examples of correct skeletal formulae include 
	c		Energy required to break bonds = (+) 2912 ✓ Energy released to make bonds = (–)4148 ✓ Enthalpy of combustion = –1236 ✓	3	**ALLOW** full marks for correct answer with no working out **ALLOW** (2 × 415) + (837) + (2.5 × 498) **ALLOW** (4 × –805) + (2 × –464) **OR** (4 × 805) + (2 × 464) **ALLOW** ECF for calculation of enthalpy of combustion **ALLOW** 2 marks for +1236 with no working out

Question			Expected Answers	Marks	Additional Guidance
1	d	i	(Enthalpy change) when one mole of a compound ✓ is made from its elements (in their standard states) ✓ (Standard conditions are) 298 K and 100 kPa ✓	3	**IGNORE** energy required / energy released **ALLOW** (energy change) when one mole of a substance **DO NOT ALLOW** enthalpy change for one mole of products **ALLOW** 1 atmosphere pressure / 101 kPa / 10^5 Pa / 1.01×10^5 Nm^{-2} / 1000 millibars / 25 °C / any stated temperature in words **IGNORE** 1 mol dm^{-3} for solutions
		ii	From energy cycle Enthalpy change to get elements = −(−60) – (2 −286) / (+) 632 ✓ Enthalpy change from elements = −987 + (+227) / (−)760 ✓ Enthalpy change = −128 ✓	3	**ALLOW** full marks for −128 with no working out **ALLOW** ECF from errors in calculation **ALLOW two** marks for answer of −414 / +128 / –1392 / +1392 **ALLOW one** mark for answer of +414
	e	i	$\frac{26.0}{100.1} \times 100$ ✓ 26.0% ✓	2	First mark for 100.1 **OR** (64.1 + 36.0) **OR** (74.1 + 26.0) at **bottom** of fraction with or without × 100 **ALLOW full** marks for 26.0 or 26% with no working out **ALLOW** from two significant figures up to calculator value **ALLOW** 25.97 / 26% **NO ECF** for this part from incorrect numbers in first expression

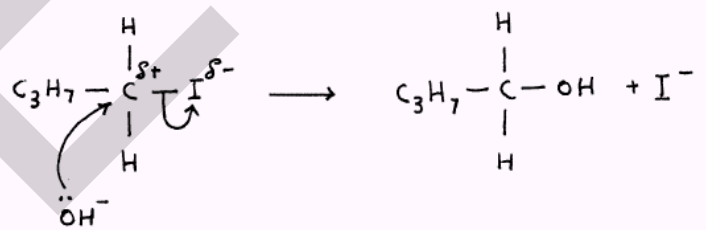
Question			Expected Answers	Marks	Additional Guidance
1	e	ii	1.56×10^4 **OR** 15600 **OR** 15601 ✓	1	**ALLOW** calculator value of 15600.62402 and any rounded value to a minimum of three significant figures
		iii	1.5×10^4 **OR** 15000 ✓	1	**ALLOW** 1.50×10^4 etc.
		iv	96.2 ✓	1	**ALLOW** ECF from **(iii)** ÷ **(ii)** **ALLOW** calculator value 96.1538461 and any rounded value to a minimum of two significant figures **ALLOW** 96.14768284 if 15601 is used **ALLOW** any value between 88 to 89 if answer to **(iii)** was calculated by dividing by 26
		v	**Any two from:** Low atom economy gives a poor sustainability **OR** low atom economy means lots of waste ✓ A use for the aqueous calcium hydroxide needs to be developed to increase atom economy ✓ Alternative process needs to be developed with high atom economy ✓	2	**ANNOTATE WITH TICKS AND CROSSES** **IGNORE** comments about percentage yield **ALLOW** ECF from **(i)** e.g. high atom economy will have good sustainability **ALLOW** find a use for the waste to increase atom economy
			Total	**23**	

Question			Expected Answers	Marks	Additional Guidance
2	a	i	Branched chain alkane of formula C_5H_{12} to C_9H_{20} e.g. 2-methylpentane, 3-methyloctane ✓	1	Must have position number **but ALLOW** methylbutane **DO NOT ALLOW** 1-methylpentane or 2-ethylpentane etc **DO NOT ALLOW** incorrect nomenclature e.g. 2-**methy**pentane etc
	b	i	Vibrate (more) ✓	1	**ALLOW** bend / stretch / oscillate **IGNORE** rotate **NOT** break / molecules vibrate
		ii	Incomplete combustion ✓	1	**ALLOW** not enough oxygen
		iii	NO for photochemical smog **OR low level** ozone ✓ CO is toxic ✓	2	**ALLOW** NO can (eventually) cause acid rain **OR** can result in respiratory irritation **OR** can (eventually) depletes high level ozone **OR** depletes ozone layer **IGNORE** greenhouse gas **ALLOW** poisonous **OR** kills **OR** lethal **ALLOW** CO reduces the capacity of blood to carry oxygen Oxygen combines with haemoglobin is insufficient **IGNORE** CO is harmful / suffocates / greenhouse gas
	c	i	Makes nitrogen **AND** carbon dioxide ✓ $2CO + 2NO \rightarrow N_2 + 2CO_2$ ✓	2	 **ALLOW** any correct multiples **IGNORE** state symbols

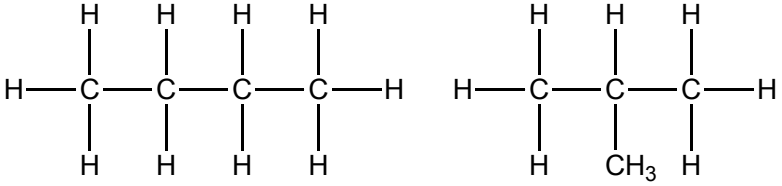
Question			Expected Answers	Marks	Additional Guidance
2	c	ii	One activation energy correctly labelled on enthalpy profile diagram ✓ Idea that activation energy is lowered ✓ Catalyst has a different reaction pathway **OR** different reaction mechanism **OR** two curves drawn on profile ✓ Correct diagram of reaction profile for exothermic reaction with product below reactants with y axis as enthalpy or energy and ΔH label – arrow should go down. Ignore a small gap between at either end of ΔH line ✓ Drawing of Boltzmann distribution – axes labelled number of molecules and energy ✓ More molecules with energy above activation energy with a catalyst ✓ More effective collisions **OR** more successful collisions ✓	7	**ANNOTATE WITH TICKS AND CROSSES** With the line/arrow no more than 1 mm from top of curve or reactant line – arrow can be double headed for activation energy **ALLOW** vertical line with no arrows **DO NOT ALLOW** arrow just pointing downwards Marks can be awarded via, reaction profile, in words or from Boltzmann  Boltzmann distribution – must start at origin and must not end up at 0 on *y*-axis i.e. must not touch *x*-axis 

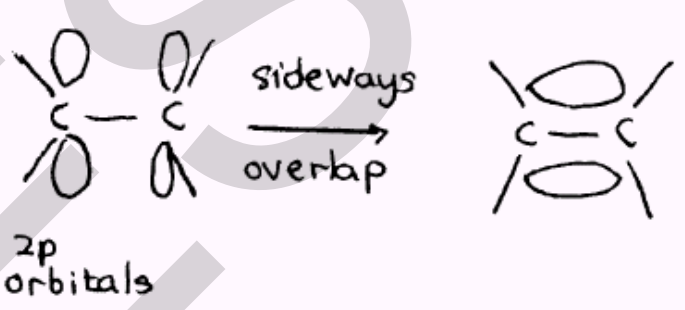
Question			Expected Answers	Marks	Additional Guidance
2	d		**Any two benefits from**:	3	ANNOTATE WITH TICKS AND CROSSES
			Save crude oil **OR** no risk of large scale pollution from exploitation of crude oil ✓		**ALLOW** decrease the need for fossil fuels
			Biodiesel is renewable **OR** diesel is non-renewable ✓		**ALLOW** plants are a renewable resource / crude oil non-renewable resource / biodiesel is more sustainable / diesel is not sustainable
			Use of biodiesel is (more) carbon-neutral **OR** plants take up the carbon dioxide released during combustion ✓		**ALLOW** lower carbon footprint **IGNORE** can be used by diesel powered cars with or without any conversion
			and one disadvantage		
			Land not used to grow food crops **OR** (rain)forests have to be cut down to provide land **OR** food prices may rise because less is grown ✓		**IGNORE** comments about availability / fertilisers / pesticides Destroys habitats is not sufficient
			Total	**17**	

Question			Expected Answers	Marks	Additional Guidance
3	a		Answers clockwise from top left $CH_3CH_2CH_2COOH$ ✓ $CH_3CH_2CHCH_2$ ✓ $CH_3COOCH_2CH_2CH_2CH_3$ ✓ $CH_3CH_2CH_2CHO$ ✓	4	**ALLOW** skeletal formula **ALLOW** butanoic acid **ALLOW** but-1-ene **ALLOW** butyl ethanoate **ALLOW** butanal If name and structure given both must be correct If C_3H_7 used instead of $CH_3CH_2CH_2$ penalise once and then apply ECF If wrong carbon skeleton used then penalise once then apply ECF If a hydrogen is missing then penalise once

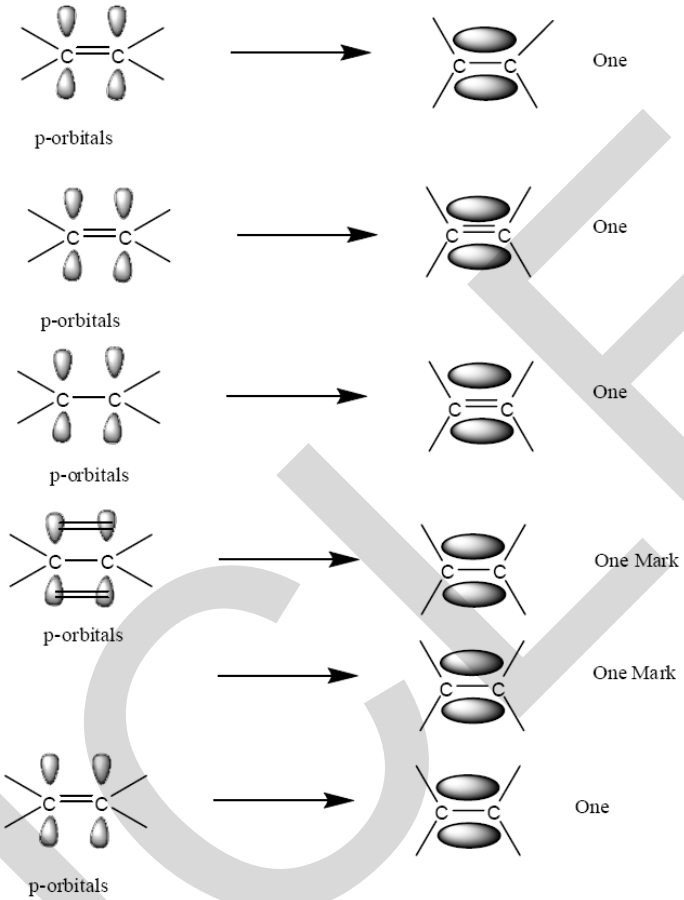
Question			Expected Answers	Marks	Additional Guidance
3	b	i	Nucleophilic substitution ✓ Heterolytic ✓ Dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ ✓ Curly arrow from OH^- to carbon atom of C–I bond ✓ Curly arrow from C–I bond to the iodine atom ✓	5	**ANNOTATE WITH TICKS AND CROSSES** **DO NOT ALLOW** fish hooks No need to show lone pair on OH^- or I^- Curly arrow must come from the negative sign or lone pair on the oxygen of the hydroxide ion  **ALLOW S_N1 mechanism** dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ ✓ curly arrow from C–I bond to the iodine atom ✓ curly arrow from OH^- to correct carbonium ion ✓
		ii	Use reflux **OR** heat for more than 20 minutes ✓ C–C*l* stronger bond (than C–I bond) **OR** C–C*l* shorter bond (than C–I bond) **OR** C–C*l* bond is harder to break **OR** needs more energy to break C–C*l* bond **OR** ora ✓	2	**ALLOW** heat stronger **OR** heat for longer **OR** heat at a higher temperature **OR** more heat Answer must refer to the C–C*l* bond or C–I bonds
			Total	**11**	

Question			Expected Answers	Marks	Additional Guidance
4	a	i	**Any two from:** Any value between 1000–1300 ✓ Any value between 2850–3100 ✓ Any value between 3200–3550 ✓	2	
		ii	Orange to green or blue ✓	1	
		iii	$CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$ **OR** $CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$ Correct organic product ✓ Balanced equation ✓	2	**IGNORE** any state symbols **ALLOW** CH_3COH in equation but not for the structure **ALLOW** equations with molecular formulae but not the product mark
	b	i	Absorption around 2850–3100 (cm^{-1}) so contains C—H bonds ✓ No other **important** absorptions present / no other **characteristic** absorptions ✓	2	Answer must have a reference to infrared spectrum i.e. use of cm^{-1} or data from the infrared spectrum 'Has no other peaks so no functional groups present' is **not** sufficient **BUT** There are no peaks due to functional groups is sufficient **ALLOW** peaks instead of absorption **ALLOW** no absorption due to C=O and O–H / no absorption due to carbonyl and hydroxyl
		ii	Peak furthest to right hand side is 58 / molecular ion peak is 58 / peak at highest mass ✓	1	**ALLOW** peak at *m/z* 58 marked on the mass spectrum / M peak is 58 / peak at 58 linked to the molecular mass **DO NOT ALLOW** highest peak but **ALLOW** 58 is the highest peak

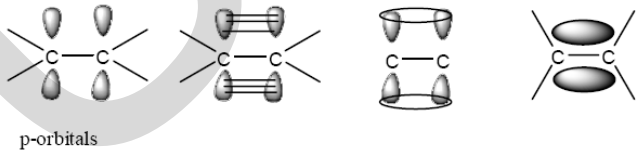
Question			Expected Answers	Marks	Additional Guidance
4	b	iii	 **BOTH** isomers correct ✓	1	If three structures are drawn then do not award mark **ALLOW** skeletal formulae / structural formulae **IGNORE** incorrect names
		iv	CH_3^+ ✓ $C_2H_5^+$ ✓ $C_3H_7^+$ / $CH_3CH_2CH_2^+$ / $(CH_3)_2CH^+$ ✓	3	Essentially marks are allocated as positive ions ✓ Formula of two fragments correct (ignore charge) ✓ **BUT** formulae of all three fragments correct (ignore charge) ✓✓
		v	$CH_3CH_2CH_2CH_3$ because there is a peak at m/z = 29 ✓	1	**ALLOW** name, displayed or skeletal structure **ALLOW** butane because there is a C_2H_5 fragment **ALLOW** butane because it gives all three fragments listed in **(iv)**
			Total	**13**	

Question			Expected Answers	Marks	Additional Guidance
5	a		**Sideways** overlap of two p orbitals on each carbon atom ✓ forms π-orbital or π-bond above and below plane of molecule ✓	2	Answers can be awarded from a labelled diagram see additional page with typical diagrams you might see  Drawings with a double bond drawn can score a maximum of one mark Drawing above with no labels scores one mark

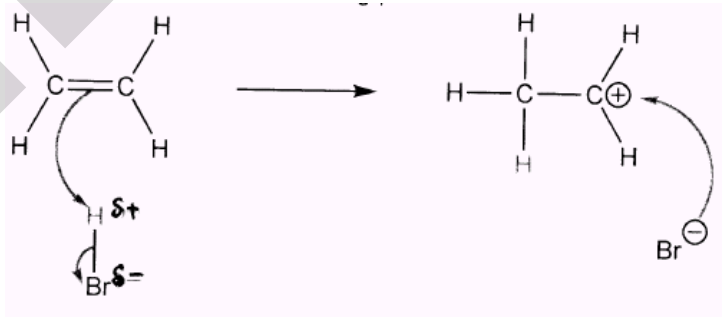
Each of the following diagrams is worth one mark. The words p-orbitals must be present to score the mark

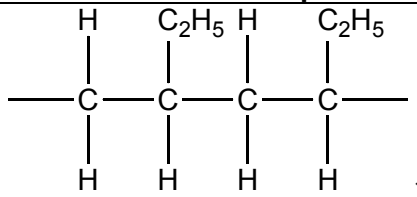


Each of the diagrams on its own scores no mark

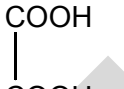
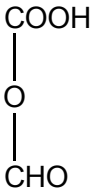


Question			Expected Answers	Marks	Additional Guidance
5	b	i	Double bond does not rotate / restricted rotation of the double bond ✓ Each carbon atom of double bond is bonded to (two) different groups ✓	2	**ALLOW** π bond does not rotate **ALLOW** each carbon atom of double bond is bonded to (two) different atoms / each end of the π-bond is bonded to different groups or atoms ✓
		ii	**C** and **E** ✓	1	

Question			Expected Answers	Marks	Additional Guidance
5	c		CH_3CH_2OH / ethanol ✓	1	**IGNORE** alcohol
	d			9	**ANNOTATE WITH TICKS AND CROSSES** **QWC** mark and **8 other** marking points
			C_4H_8 + HBr → C_4H_9Br ✓ C_2H_4 + HBr → C_2H_5Br ✓		The equation must be the overall equation not a series of steps as in a mechanism
			B makes $CH_3CH_2CH_2CH_2Br$ ✓ $CH_3CHBrCH_2CH_3$ ✓		**ALLOW** skeletal or displayed formulae **ALLOW B** makes 1-bromobutane and 2-bromo butane ✓ if marks for the structures not awarded
			QWC – number of products is linked to structure of alkene e.g. because **D** is symmetrical **OR B** is not symmetrical ✓		
			Movement of electron pair from double bond to attack hydrogen of H–Br and breaking of H–Br bond ✓ Correct dipole shown on H–Br ✓ Correct carbonium ion drawn ✓ Curly arrow from Br^- to the carbonium ion ✓		 **ALLOW** curly arrow from lone pair or minus sign of bromide ion **ALLOW** marks for the mechanism even if the wrong alkene is used e.g. for alkene **B** If two mechanisms are drawn mark the one for alkene **D**

Question			Expected Answers	Marks	Additional Guidance
5	e	i	 ✓	1	Must have at least two repeat units and the free bonds at the end All carbon–carbon bonds in the polymer chain must be shown **ALLOW** bond to ethyl group to any part of ethyl group **IGNORE** any brackets drawn
		ii	Poly(but-1-ene) ✓	1	**ALLOW** polybut-1-ene n.b. the bracket is part of the answer **DO NOT ALLOW** polybutene
	f	i	(Lots of) OH group present ✓ Can form hydrogen bonds with water ✓	2	**ALLOW** hydroxyl group present / hydroxy group Alcohol group is not sufficient
		ii	**Any two from:** Incineration to produce energy **OR** combustion to produce energy ✓ Sorting and recycling **OR** sorting and remoulding ✓ Cracked (to give monomers) **OR** as an organic feedstock ✓	2	Used as a fuel is not sufficient **IGNORE** use photodegradable or biodegradable polymers
			Total	**21**	

Question			Expected Answers	Marks	Additional Guidance
6	a		Low pressure because more (gas) molecules on right hand side of equation **OR** low pressure because ΔV = positive ✓ Low temperature because the (forward) reaction is exothermic ✓	2	**ALLOW** low pressure because more (gas) moles on right hand side of equation
	b		Increased pressure speeds up reaction / ora ✓ 900 ^{o}C increases the rate **OR** increased temperature speeds up reaction / ora ✓ Idea that high enough temperature without compromising yield **OR** idea that high enough pressure without compromising yield ✓	3	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** 'pushes gases through system'
	c	i	5.68×10^7 / 5.7×10^7 ✓	1	**ALLOW** two or more significant figures Calculator answer is 5.6812500×10^7
		ii	Used to heat the incoming gases ✓	1	**ALLOW** used to heat rest of factory **OR** sold to the national grid Provide energy to create conditions is not sufficient because one condition is pressure
			Total	**7**	

Question	Expected Answers	Marks	Additional Guidance
7	**Infrared** QWC – 1720 cm^{-1} indicates carbonyl group ✓ QWC – broad 2900 cm^{-1} indicates O–H bond in **carboxylic acid** ✓ QWC – 1080 cm^{-1} indicates C–O bond ✓ **Percentage composition** Mole ratio C : H : O = 2.23 : 2.22 : 4.44 ✓ Empirical formula is CHO_2 ✓ (mass of one mole is 90 g) so M_r is 90 ✓ QWC – molecular formula is $C_2H_2O_4$ with working out from M_r ✓ Structure is  ✓	8	**ANNOTATE WITH TICKS AND CROSSES** ✎ **QWC** –Structure linked to information at least once **ALLOW** 1720 indicates presence of aldehydes, ketones, esters, carboxylic acid, amides **ALLOW** 2900 indicates carboxylic acid **ALLOW** 1080 indicates alcohol, esters, carboxylic acids **ALLOW** 26.7/12.0. 2.22/1.0 and 71.1/16.0 **ALLOW** COOH **ALLOW two** marks for correct empirical formula with no working out **ALLOW** 0.0945/0.00105 = 90  **ALLOW**
	Total	**8**	

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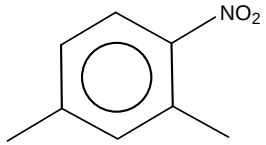
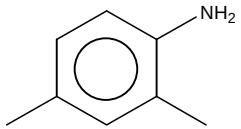
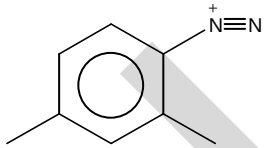
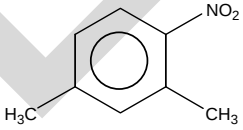
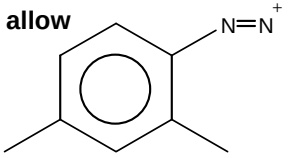
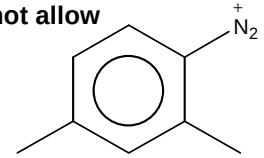
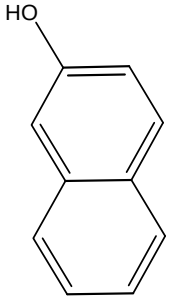
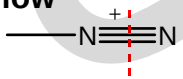
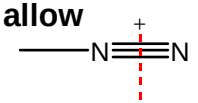
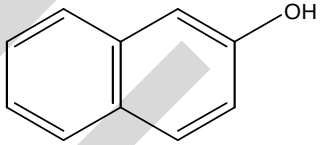
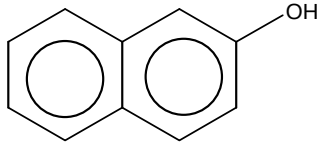
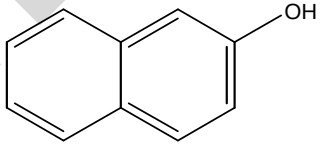
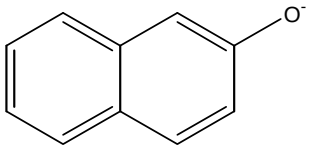
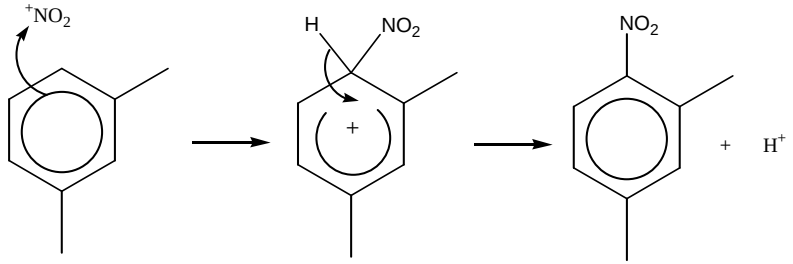
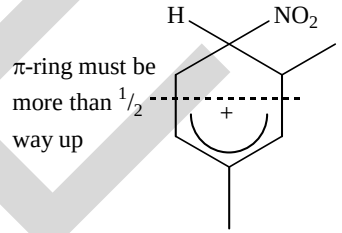
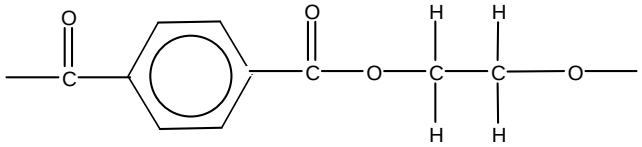
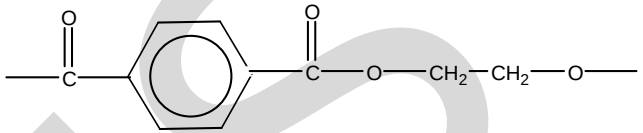
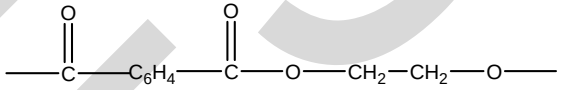
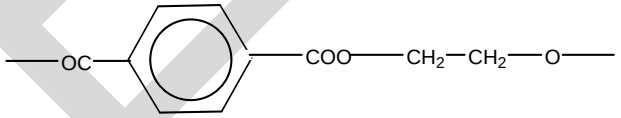
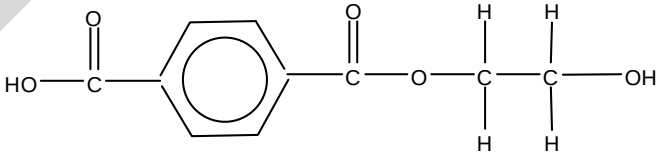
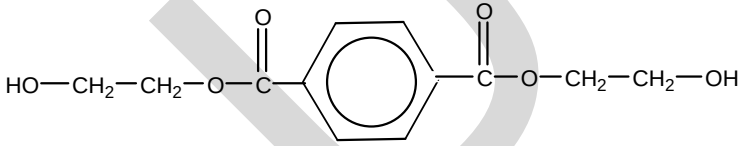
Allow Kekulé structures throughout

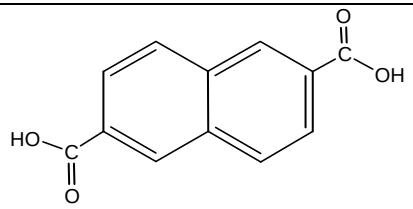
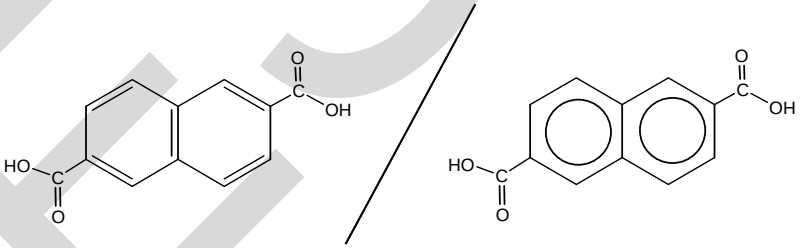
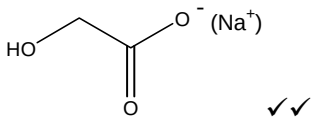
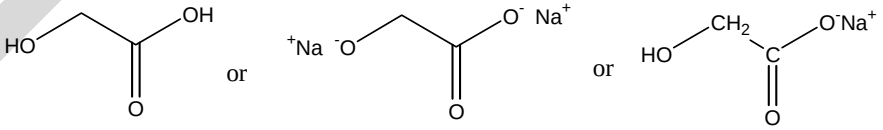
Question			Expected Answers	Marks	Additional Guidance
1	a		Bond length intermediate between/different from (short) C=C and (long) C–C ✓ ΔH hydrogenation less exothermic than expected (when compared to ΔH hydrogenation for cyclohexene) ✓ Only reacts with Br_2 at high temp or in presence of a halogen carrier / resistant to electrophilic attack ✓ **Please annotate, use ticks to show where marks are awarded**	3	**ALLOW** all carbon–carbon bonds the same length **ALLOW** ΔH hydrogenation less (negative) than expected **ALLOW** ΔH hydrogenation different from that expected **DO NOT ALLOW** ΔH halogenation/hydration **ALLOW** doesn't decolourise/react with/polarise Br_2 **ALLOW** doesn't undergo addition reactions (with Br_2)
	b	i	compound **A**  if NO_2 in wrong position penalise here and ECF for rest of **b(i)** and **b(ii)** ✓ compound **B**  ✓ compound **C**  ✓	4	**ALLOW** any 4-nitro-1,3-dimethylbenzene drawn in any orientation **ALLOW**  drawn in any orientation **ALLOW** any 4-amino-1,3-dimethylbenzene drawn in any orientation **ECF** amine of incorrect compound **A** (e.g. position of NO_2 or lack of methyl sticks/groups) **ALLOW** diazonium chloride salt of 1,3-dimethylbenzene **ECF** diazonium salt/compound of incorrect compound **B** **IGNORE** Cl^- ion **allow**  **not allow** 

Question	Expected Answers	Marks	Additional Guidance
	compound **D**  ✓		**ALLOW** if + charge is floating between the two Ns only if it is closer to the correct N **allow**  **not allow**  **ALLOW** any of     **ALLOW** O^- in place of OH

Question	Expected Answers	Marks	Additional Guidance
ii	***mark 1*** $HNO_3 + 2H_2SO_4 \rightarrow H_3O^+ + 2HSO_4^- + NO_2^+$ ✓ ***mark 4*** – curly arrow from C–H bond back to reform π ring **AND** correct products ✓  ***mark 2*** – curly arrow from π ring to $^+NO_2$ ✓ ***mark 3*** – intermediate with π ring broken in the correct place ✓ ***mark 5*** - $H^+ + HSO_4^- \rightarrow H_2SO_4$ ✓ Link to compound **A** in part **(i)** – cannot score full marks [in **b(i)** & **b(ii)**] if NO_2 is not adjacent to a methyl	5	Equation to show formation of NO_2^+ ion ✓ **ALLOW** $HNO_3 + H_2SO_4 \rightarrow H_2O + HSO_4^- + NO_2^+$ $HNO_3 + H_2SO_4 \rightarrow HSO_4^- + H_2NO_3^+ \rightarrow H_2O + NO_2^+$ **ALLOW** mark 2 curly arrow must be from 1,3-dimethylbenzene to NO_2^+ and **ECF** for marks 3 and 4 **DO NOT ALLOW** intermediate  π-ring must be more than $^1/_2$ way up **ALLOW** CH_3s shown **ALLOW** $H_3O^+ + HSO_4^- \rightarrow H_2O + H_2SO_4$
iii	2 ✓	1	No other correct response
	Total	**13**	

If NO_2 is in correct position do not penalise even if compound **A** in **b(i)** is not in correct position

Question			Expected Answers	Marks	Additional Guidance
2	a	i	 ✓✓ Ester group must be displayed to get both marks and must contain 4 Os	2	**ALLOW** for both marks  **ALLOW** for one mark  **ALLOW** for one mark  **ALLOW** Kekulé structure / $(CH_2)_2$ **ALLOW** one mark if end bonds missing **ALLOW** 1 mark if the CH_2CH_2 is drawn skeletally **ALLOW** for  **ALLOW** <u>1 mark</u> if repeat unit shows a displayed ester group and contains a benzene ring and two other carbons **DO NOT ALLOW** $-OCC_6H_4COOCH_2CH_2O-$
		ii	 ✓	1	**ALLOW** Kekulé structure/ $(CH_2)_2$ CO_2 for ester groups C_6H_4 if already penalised in **a(i)**

Question			Expected Answers	Marks	Additional Guidance
	b	i	$C_7H_5O_2$	1	**ALLOW** any order of elements **ALLOW** $C_{14}H_{10}O_4 \rightarrow C_7H_5O_2$ or $C_{14}H_{10}O_4 = C_7H_5O_2$
		ii	 ✓ ✓ **Penalise incorrect bond linkage in 2b(ii) only. Do not penalise elsewhere on the paper**	2	**ALLOW** COOH/CO_2H **ALLOW**  **ALLOW** $HO(CH_2)_2OH$
	c	i	 ✓✓	2	**ALLOW** any of the following for 1 mark  **DO NOT ALLOW** any other response
		ii	(PGA is) (bio)degradable **OR** photodegradable **OR** hydrolysed (but hydrocarbon based polymers are non-biodegradable) ✓ One of (bio)degradable **OR** photodegradable **OR** hydrolysed must be spelt correctly – if one spelt correctly and another incorrectly spelt – **ALLOW** mark	1	**ALLOW** broken down by bacteria (must be spelt correctly) **ALLOW** degrade as alternative to degradable **ALLOW** undergoes hydrolysis as alternative to hydrolysed **IGNORE** any additional information if the additional information is correct e.g. biodegradable and doesn't produce toxic gases **DO NOT ALLOW** any additional information if the additional information is incorrect e.g. biodegradable and can be recycled
			Total	**9**	

<table>
<tr><th colspan="3">Question</th><th colspan="2">Expected Answers</th><th>Marks</th><th>Additional Guidance</th></tr>
<tr><td>3</td><td>a</td><td></td><td colspan="2">Alternative approaches</td><td rowspan="2">4</td><td rowspan="2">ALLOW ammoniacal $AgNO_3$/ $Ag^+(NH_3)_2$ / $Ag^+(NH_3)$
ALLOW acidified dichromate OR Fehlings as an alternative to Tollens – observation ‘turn green’ OR ‘red precipitate’ respectively
ALLOW acidified manganagate(VII) and observation as either brown precipitate/decolourised/pale pink
ALLOW Brady’s (reagent)
ALLOW orange/red/yellow for colour of the 2,4-DNP(H) precipitate
ALLOW solid/crystals in place of precipitate
IGNORE any reference to melting points
ALLOW PCl_5 as a test for the acid – observation would be ‘white fumes (of HCl)’

ALLOW detection of (carboxylic) acid by reacting with an alcohol to make an ester but no mark for the observation.

DO NOT ALLOW detection of (carboxylic) acid by pH or indicator

Please annotate, use ticks to show where marks are awarded</td></tr>
<tr><td></td><td></td><td></td><td>Tollens’ test AND ‘silver precipitate/mirror’ ✓
is the aldehyde ✓

react with 2,4-DNP(H) and ‘orange precipitate’ ✓

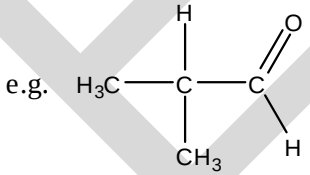
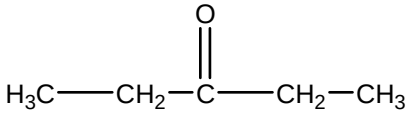
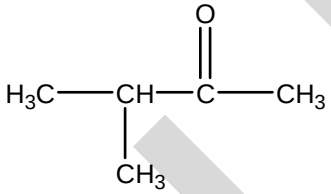
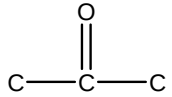
must be the ketone ✓</td><td>Tollens’ test AND ‘silver precipitate/mirror’ ✓
is the aldehyde ✓

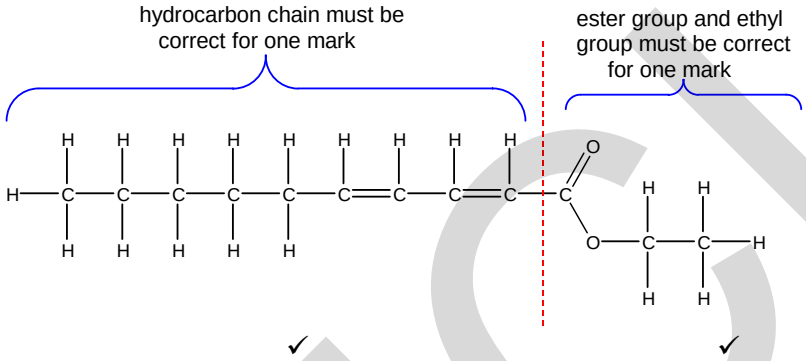
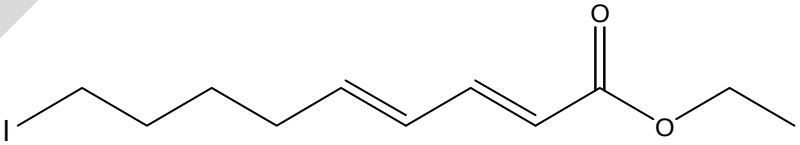
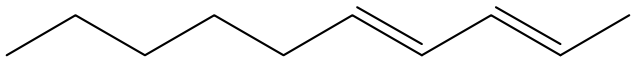
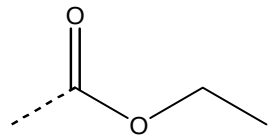
react with carbonate/ hydrogencarbonate/ Na/Mg and ‘fizzes/ bubbles/ effervesces/ gas evolved ✓

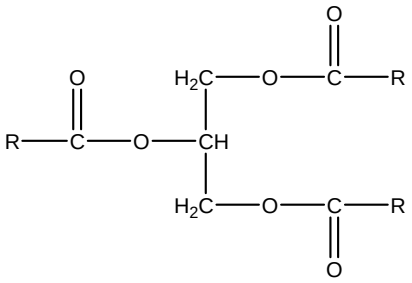
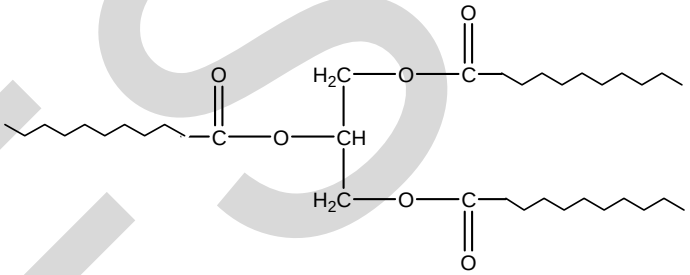
must be the (carboxylic) acid ✓</td></tr>
<tr><td></td><td></td><td></td><td>2,4-DNP(H) AND orange precipitate ✓
is either aldehyde OR ketone ALLOW carbonyl OR C=O✓

Tollens’ test & ‘silver ppt/mirror’ ✓
is the aldehyde ✓</td><td>2,4-DNP(H) and no orange precipitate ✓
is the (carboxylic) acid ✓

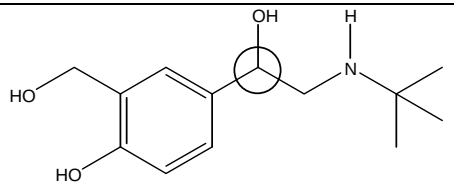
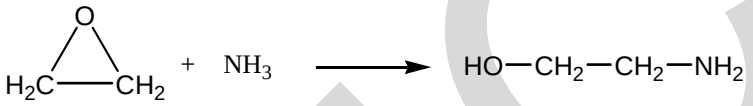
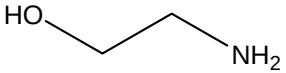
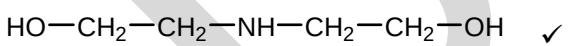
Tollens’ test & ‘silver ppt/mirror’ ✓
is the aldehyde ✓</td></tr>
<tr><td></td><td>b</td><td></td><td colspan="2">Peak in range 2500–3300 (cm^{-1}) or (around) 3000 shows O–H ✓
[need wavenumber (or range) <u>and</u> O–H bond]</td><td>1</td><td>DO NOT ALLOW single peak quoted within range 2500–3300 other than 3000 (cm^{-1}) for OH
DO NOT ALLOWrange 3200–3550 (cm^{-1})
IGNORE any reference to C-O or C=O</td></tr>
</table>

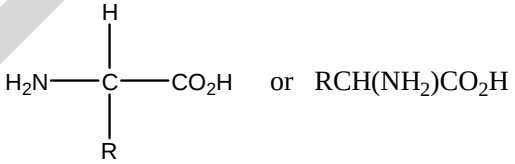
Question			Expected Answers	Marks	Additional Guidance
	c		**Alternative approaches depending on whether or not the aldehyde is correct** Doublet indicates adjacent C is bonded to only 1H **OR** (relative) peak area indicates 2 x CH_3 (in the same environment) ✓ If aldehyde is correct $(CH_3)_2CH{-}CH_2{-}CHO$ ✓ ✓ *If aldehyde is correct **only** need to explain doublet **OR** peak areas* Doublet indicates adjacent C is bonded to only 1H✓ **AND** (relative) peak area indicates 2 x CH_3 (in the same environment) ✓ If aldehyde identified is incorrect × *if aldehyde is incorrect **must** explain both doublet or peak areas*		**ALLOW** 3-methylbutanal , any correct unambiguous structure **ALLOW** two marks for correct aldehyde with no explanation **ALLOW** doublet/peak at 0.9ppm due to R–CH **ALLOW** the splitting shows adjacent to CH/environment that contains 1 H/proton **ALLOW** 6 Hs/ protons in same environment **DO NOT ALLOW** 6 Hs in same environment next to CHO e.g.  would score two marks if the doublet and the peak areas were correctly explained
	d	i	 ✓ ketone **3**	1	**ALLOW** displayed/skeletal formulae
		ii	There are 4 (different C) environments ✓ (therefore) it is ketone **2 /**  ✓ (C responsible for peak at δ = 210 ppm) is C=O/carbonyl carbon ✓	3	**ALLOW** 2 Cs are in same environment/equivalent **ALLOW** 3-methylbutan(-2-)one/ any correct unambiguous structure **ALLOW** 2-methylbutan-3-one **ALLOW** 
			Total	**12**	

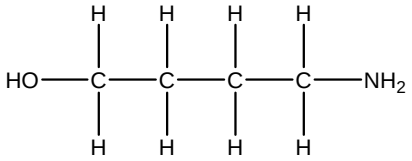
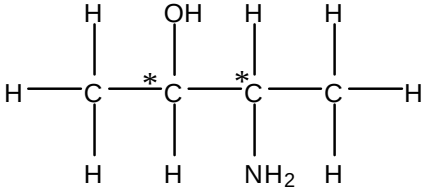
Question			Expected Answers	Marks	Additional Guidance
4	a	i	The time (from the injection of the sample) for the component to leave the column ✓	1	**ALLOW** time from injection to detection **ALLOW** time spent in column **ALLOW** time taken to reach detector
		ii	They have similar retention times ✓	1	**ALLOW** both are esters therefore partition/adsorption/retention times will be very similar **ALLOW ECF** if they describe R_f values in part **a(i)** **ALLOW** same retention times
		iii	Butylbutanoate ✓	1	**ALLOW** butyl butanoate **ALLOW** but-1-yl butanoate **DO NOT ALLOW** butanyl butanoate
	b	i		2	**ALLOW** any correct unambiguous structure/ $CH_3(CH_2)_4CHCHCHCHCOOCH_2CH_3$ / $CH_3(CH_2)_4CHCHCHCHCOOC_2H_5$ $CH_3(CH_2)_4(CH)_4COOCH_2CH_3$ **DO NOT ALLOW** $C_5H_{11}CHCHCHCHCOOCH_2CH_3$ etc **ALLOW** CO_2 for ester  **ALLOW** 1 mark for correct 2,4-decadiene structure e.g.  **ALLOW** 1 mark for correct ethyl … oate structure e.g.  or —$CO_2C_2H_5$ or —$COOC_2H_5$

Question	Expected Answers	Marks	Additional Guidance
ii		1	**ALLOW**  any orientation of the three fatty acids
c	**1.** react phenylethanal with $H_2SO_4/K_2Cr_2O_7$ ✓ **2.** to get phenylethanoic acid/$C_6H_5CH_2COOH$ ✓ mark **2** can be scored if dichromate is used without being acidified **3.** react phenylethanal with $NaBH_4$ ✓ **4.** to get 2-phenylethanol/$C_6H_5CH_2CH_2OH$ ✓ mark **3** must be correct to score mark **4** **5.** react phenylethanoic acid with 2-phenylethanol. If both already correctly named **ALLOW** acid and alcohol ✓ **6.** H_2SO_4 if linked to the reaction of an alcohol and acid ✓ **7.** reflux in either **(1)** or **(5)** or catalyst used in **(5)** ✓ QWC must spell catalyst or reflux correctly	7	**ALLOW** H^+ & $Cr_2O_7^{2-}$ or $H_2SO_4/Na_2Cr_2O_7$ - any other oxidising agent or other named acid – please consult with TL **ALLOW** $LiAlH_4$ as alternative to $NaBH_4$ phenylethanoic acid & phenylethanol must be unambiguously identified by either name or formula **DO NOT ALLOW** or oxidised to form(a carboxylic) acid or reduced to form alcohol for marks 2 and 4 **ALLOW** conc H_2SO_4 **DO NOT ALLOW** dilute or H_2SO_4(aq) **DO NOT ALLOW** just acid catalyst **DO NOT ALLOW** HCl, HNO_3 **Please annotate, use ticks to show where marks are awarded**
	Total	**13**	

if either phenylethanoic acid or 2-phenyethanol not prepared – automatically lose two marks

Question			Expected Answers	Marks	Additional Guidance
5	a	i	 ✓	1	**ALLOW** * in place of circle **ALLOW** if circle extends to include OH
		ii	**Mark 1** – production of a single isomer is more expensive/difficult **OR** separation of the single isomer is expensive/difficult✓ **Mark 2** – one of the isomers is more (pharmacologically) active or one of the isomers might have adverse/harmful/nasty side effects ✓ **Marks 3 and 4** – problems are overcome by using: Enzymes/bacteria/biological catalyst Chiral synthesis Chiral catalyst or transition metal complex Start with a natural chiral molecule or chiral pool ✓✓ any	4	**IGNORE** any reference to dosage **ALLOW** one is more effective/works (better) **DO NOT ALLOW** use naturally occurring isomer unless stated that it is a chiral compound **DO NOT ALLOW** transition metal ion **DO NOT ALLOW** pool synthesis Chiral pool synthesis scores 1 (not 2) marks
	b	i	 ✓	1	**ALLOW**  **ALLOW** epoxy ethane as C_2H_4O, $(CH_2)_2O$, CH_2OCH_2 **ALLOW** product as $HO(CH_2)_2NH_2$ **DO NOT ALLOW** product as C_2H_7NO
		ii	 ✓	1	**ALLOW** $(CH_2)_2$ **ALLOW** displayed/skeletal formula **DO NOT ALLOW** molecular formula

Question			Expected Answers	Marks	Additional Guidance
	c	i	$HO—CH_2—CH_2—NH_3^+ Cl^-$ Must show Cl^- ion ✓	1	**ALLOW** $HOCH_2CH_2NH_3Cl$ if formula is correct and both charges not shown **ALLOW** $(CH_2)_2$/ any correct unambiguous structure **DO NOT ALLOW** ions joined by covalent bonds
		ii	$HO—CH_2—CH_2—NH_3^+ HS^-$ Must show HS^- ion ✓	1	**ALLOW** if formula is correct and both charges not shown **ALLOW** $(CH_2)_2$/ any correct unambiguous structure **ALLOW** $\left(HO—CH_2—CH_2—NH_3^+\right)_2 S^{2-}$
	d	i	Both NH_2 and COOH are joined to the same C ✓	1	**ALLOW**  $H_2N—C(H)(R)—CO_2H$ or $RCH(NH_2)CO_2H$ The 4 groups/atoms attached to the C can be in any order but CH must be adjacent. ( ) not essential
		ii	$HO—CH_2—CH_2—NH_2 + 2[O] \rightarrow HO—C(=O)—CH_2—NH_2 + H_2O$ ✓	1	**ALLOW** $(CH_2)_2$ **DO NOT ALLOW** molecular formula
	e	i	**Question 5e is followed by two blank lined pages (15 and 16) which candidates can use instead of requesting additional paper. Please check to see whether or not pages 15 or 16 have been used**		

Question			Expected Answers	Marks	Additional Guidance
	e	i	Isomer **F**  ✓ Isomer **G**  * not required ✓	2	**ALLOW** $HO(CH_2)_4NH_2$/ **ALLOW** any correct unambiguous structure of 1-aminobutan-4-ol **ALLOW** $CH_3CH(OH)CH(NH_2)CH_3$ **ALLOW** any correct unambiguous structure of 2-aminobutan-3-ol.
			Total	**13**	

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GCE

Chemistry A

Advanced GCE **F325**

Equilibria, Energetics and Elements

Mark Scheme for June 2010

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Question			Expected Answers	Marks	Additional Guidance
1	a		**F** **B** **G** **E** **D** **FIVE** correct ✓✓✓ **FOUR** correct ✓✓ **THREE** correct ✓	3	**ALLOW** **1450** **736** **G** **76** **–642**
	b		Correct calculation –642 – (+76 + (2 × 150) + 736 + 1450 + (2 × –349)) ✓ –642 – 1864 = – 2506 ✓ (kJ mol^{-1})	2	**ALLOW** for 1 mark: –2705 (2 × 150 and 2 × 349 not used for Cl) –2356 (2 × 150 not used for Cl) –2855 (2 × 349 not used for Cl) +2506 (wrong sign) **DO NOT ALLOW** any other answers
	c		Magnesium ion **OR** Mg^{2+} has greater charge (than sodium ion **OR** Na^{+}) **OR** Mg^{2+} has greater charge density ✓ Magnesium ion **OR** Mg^{2+} is smaller ✓ Mg^{2+} has a stronger attraction (than Na^{+}) to Cl^{-} ion **OR** Greater attraction between oppositely charged ions ✓	3	***ANNOTATIONS MUST BE USED*** **ALLOW** magnesium/Mg is 2+ but sodium/Na is 1+ **DO NOT ALLOW** Mg **atom** is 2+ but Na **atom** is 1+ **ALLOW** 'charge density' here **only** **ALLOW** Mg **OR** magnesium is smaller **DO NOT ALLOW** Mg^{2+} has a smaller **atomic** radius **ALLOW** anion **OR** negative ion for Cl^{-} **DO NOT ALLOW** chlorine ions **DO NOT ALLOW** Mg has greater attraction **ALLOW** 'attracts with more force' for greater attraction but **DO NOT ALLOW** 'greater force (could be repulsion) **ALLOW** reverse argument throughout in terms of Na^{+}
			Total	**8**	

Question			Expected Answers	Marks	Additional Guidance
2	a		$BrO_3^- + 5Br^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$ ✓	1	**ALLOW** multiples
	b			1	***ANNOTATIONS MUST BE USED***
			graph:		**Both** explanation and 1st order required for mark
			Straight/diagonal line through origin **OR** 0,0 **AND** 1st order with respect to BrO_3^- ✓		**DO NOT ALLOW** diagonal line **OR** straight line **OR** constant gradient on its own (no mention of origin **OR** 0,0) **ALLOW** 'As BrO_3^- doubles, rate doubles' **AND** 1st order **ALLOW** rate is proportional to concentration **AND** 1st order
			initial rates data:	4	
			When $[Br^-]$ is doubled, rate × 2 ✓ 1st order with respect to Br^- ✓		Mark order and explanation independently Mark order first, then explanation
			When $[H^+]$ × 2, rate × 4 (2^2) ✓ 2nd order with respect to H^+ ✓		
			Rate equation rate = k $[BrO_3^-]$ $[Br^-]$ $[H^+]^2$ ✓	1	**ALLOW** ECF from candidate's orders above

Question	Expected Answers	Marks	Additional Guidance
	Calculation of rate constant (3 marks)	3	***ANNOTATIONS MUST BE USED***
	$k = \frac{\text{rate}}{[BrO_3^-][Br^-][H^+]^2}$		**Calculation can be from any of the experimental runs – they all give the same value of *k***
	OR $\frac{1.19 \times 10^{-5}}{(5.0 \times 10^{-2})(1.5 \times 10^{-1})(3.1 \times 10^{-1})^2}$ ✓		**ALLOW** $mol^{-3}\ dm^9\ s^{-1}$ **ALLOW** 1.6510579×10^{-2} and correct rounding to 1.7×10^{-2} **Correct numerical answer subsumes previous marking point**
	= 1.7×10^{-2} **OR** 1.65×10^{-2} ✓ $dm^9\ mol^{-3}\ s^{-1}$ ✓		**DO NOT ALLOW** fraction: $\frac{238}{14415}$ --- **ALLOW ECF from incorrect rate equation.** Examples are given below for 1st line of initial rates data. IF other rows have been used, then calculate the rate constant from data chosen.
			Example 1: 1st order with respect to H^+ *rate* = *k* $[BrO_3^-]\ [Br^-]\ [H^+]$ $k = \frac{\text{rate}}{[BrO_3^-][Br^-][H^+]}$ **OR** $\frac{1.19 \times 10^{-5}}{(5.0 \times 10^{-2})(1.5 \times 10^{-1})(3.1 \times 10^{-1})}$ ✓ = 5.1×10^{-3} **OR** 5.12×10^{-3} ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ **ALLOW** $5.11827957 \times 10^{-3}$ and correct rounding to 5.1×10^{-3} ---
			Example 2: Zero order with respect to BrO_3^- *rate* = *k* $[Br^-]\ [H^+]^2$ $k = \frac{\text{rate}}{[Br^-][H^+]^2}$ **OR** $\frac{1.19 \times 10^{-5}}{(1.5 \times 10^{-1})(3.1 \times 10^{-1})^2}$ ✓ = 8.3×10^{-4} **OR** 8.26×10^{-4} ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ **ALLOW** $8.255289629 \times 10^{-4}$ and correct rounding to 8.3×10^{-4}
	Total	**10**	

Question			Expected Answers	Marks	Additional Guidance
3	a		measured pH > 1 **OR** $[H^+] < 0.1$ (mol dm^{-3}) ✓	4	**ALLOW** C_2H_5 throughout question **ALLOW** $[H^+] < [CH_3CH_2COOH]$ **OR** $[H^+] < [HA]$ **ALLOW** measured pH is higher than expected **ALLOW** measured pH is not as acidic as expected **ALLOW** a quoted pH value or range > 1 and < 7 **OR** between 1 and 7
			$[H^+] = 10^{-pH}$ ✓		**ALLOW** $[H^+]$ = antilog –pH **OR** $[H^+]$ = inverse log –pH
			$K_a = \frac{[H^+][CH_3CH_2COO^-]}{[CH_3CH_2COOH]}$ **OR** $\frac{[H^+]^2}{[CH_3CH_2COOH]}$ ✓		**ALLOW** $\frac{[H^+][A^-]}{[HA]}$ **OR** $\frac{[H^+]^2}{[HA]}$
			Calculate K_a from $\frac{[H^+]^2}{0.100}$ ✓		**IF** K_a is **NOT** given and $K_a = \frac{[H^+]^2}{0.100}$ is shown, award mark for K_a also (i.e. $K_a = \frac{[H^+]^2}{0.100}$ is automatically awarded the last 2 marks)
	b		**Marks are for correctly calculated values.** **Working shows how values have been derived.** $[H^+] = 10^{-13.46} = 3.47 \times 10^{-14}$ (mol dm^{-3}) ✓ $[OH^-] = \frac{1.0 \times 10^{-14}}{3.47 \times 10^{-14}} = 0.29$ (mol dm^{-3}) ✓	2	**ALLOW** $3.467368505 \times 10^{-14}$ and correct rounding to 3.5×10^{-14} **ALLOW** 0.28840315 and correct rounding to 0.29, i.e. **ALLOW** 0.288 **ALLOW** alternative approach using pOH: pOH = 14 – 13.46 = 0.54 ✓ $[OH^-] = 10^{-0.54} = 0.29$ (mol dm^{-3}) ✓ Correct answer gets **BOTH** marks

Question	Expected Answers	Marks	Additional Guidance
c		7	***ANNOTATIONS MUST BE USED*** **ALLOW** C_2H_5 throughout question **ALLOW** Adding NaOH forms propanoate ions/sodium propanoate (imples that the NaOH is added to the propanoic acid)
	Propanoic acid reacts with sodium hydroxide forming propanoate ions/sodium propanoate **OR** $CH_3CH_2COOH + NaOH \rightarrow CH_3CH_2COONa + H_2O$ ✓		
	Some propanoic acid remains **OR** propanoic acid **AND** propanoate (ions) / sodium propanoate present ✓		**ALLOW**: weak acid **AND** its conjugate base/salt present Throughout, do not penalise comments that imply that pH is constant in presence of buffer
	equilibrium: $CH_3CH_2COOH \rightleftharpoons H^+ + CH_3CH_2COO^-$ ✓		**DO NOT ALLOW** HA and A^- in this equilibrium expression For description of action of buffer below, **ALLOW** HA for CH_3CH_2COOH; **ALLOW** A^- for $CH_3CH_2COO^-$ Equilibrium responses must refer back to a written equilibrium. **IF** no equilibrium shown, use the equilibrium as written in expected answers (which is also written on page 6 of the paper)
	Added alkali CH_3CH_2COOH reacts with added alkali **OR** $CH_3CH_2COOH + OH^- \rightarrow$ **OR** added alkali reacts with H^+ **OR** $H^+ + OH^- \rightarrow$ ✓		**ALLOW** weak acid reacts with added alkali
	$\rightarrow CH_3CH_2COO^-$ **OR** Equilibrium $\rightarrow$ right ✓		
	Added acid $CH_3CH_2COO^-$ reacts with added acid **OR** $[H^+]$ increases ✓		**ALLOW** conjugate base reacts with added acid **DO NOT ALLOW** salt reacts with added acid
	$\rightarrow CH_3CH_2COOH$ **OR** Equilibrium $\rightarrow$ left ✓		
		5	

Question			Expected Answers	Marks	Additional Guidance
	d		$HNO_3 + CH_3CH_2COOH \rightleftharpoons CH_3CH_2COOH_2^+ + NO_3^-$ ✓ acid 1 base 2 acid 2 base 1 ✓	2	State symbols **NOT** required **ALLOW** 1 **AND** 2 labels the other way around. **ALLOW** 'just acid' and 'base' labels throughout if linked by lines so that it is clear what the acid–base pairs are. **IF** proton transfer is wrong way around then **ALLOW** 2nd mark for idea of acid–base pairs, i.e. $HNO_3 + CH_3CH_2COOH \rightleftharpoons CH_3CH_2COO^- + H_2NO_3^+$ × base 2 acid 1 base 1 acid 2 ✓
	e	i	$2CH_3CH_2COOH + Mg \rightarrow (CH_3CH_2COO)_2Mg + H_2$ ✓	1	**IGNORE** state symbols **ALLOW** ionic equation: $2H^+ + Mg \rightarrow Mg^{2+} + H_2$ **IGNORE** any random charges in formula of $(CH_3CH_2COO)_2Mg$ as long as the charges are **correct (charges are treated as working)** i.e. $(CH_3COO^-)_2Mg$ **OR** $(CH_3COO)_2^-Mg$ should **not** be penalised However, Mg^{2+} instead of Mg on the left side of equation is obviously wrong
		ii	$2H^+ + CO_3^{2-} \longrightarrow H_2O + CO_2$ **OR** $2H^+ + CO_3^{2-} \longrightarrow H_2CO_3$ **OR** $H^+ + CO_3^{2-} \longrightarrow HCO_3^-$ ✓	1	State symbols **NOT** required
			Total	**17**	

Question			Expected Answers	Marks	Additional Guidance
4	a	i	Complete circuit (with voltmeter) and salt bridge linking two half-cells ✓ Pt electrode in solution of Fe^{2+}/Fe^{3+} ✓ Ag in solution of Ag^{+} ✓	3	**DO NOT ALLOW** 'solution of a silver halide', e.g. AgCl (as these are insoluble) but **DO ALLOW** any solution of any other silver salt (whether insoluble or not) **IF** candidate has used incorrect redox systems, then mark ECF as follows: **(i) each** incorrect system will cost the candidate **one** mark **(ii) ECF** if species have been quoted (see Additional Guidance below) **(iii) ECF** for equation **(iv) ECF** for cell potential ***YOU MAY NEED TO WORK OUT THESE ECF RESPONSES YOURSELF DEPENDING ON THE INCORRECT REDOX SYSTEMS CHOSEN***
		ii	electrons **AND** ions ✓	1	For electrons, **ALLOW** e^{-} For 'ions', **ALLOW** formula of an ion in one of the half-cells or salt bridge, e.g. Ag^{+}, Fe^{2+}, Fe^{3+} **ALLOW ECF** as in **(i)**
		iii	$Ag + Fe^{3+} \longrightarrow Ag^{+} + Fe^{2+}$ ✓	1	**ALLOW ECF** as in **(i)** **ALLOW** equilibrium sign
		iv	0.43 V ✓	1	**ALLOW ECF** as in **(i)**
	b	i	Cl_2 **OR** O_2 **AND** H^{+} ✓	1	**ALLOW** chlor**ine** **ALLOW** O_2 **AND** $4H^{+}$ **ALLOW** O_2 **AND** acid **DO NOT ALLOW** O_2 alone **DO NOT ALLOW** equation or equilibrium
		ii	I^{-} ✓	1	**ALLOW** $2I^{-}$ **OR** iod**ide** **DO NOT ALLOW** equation or equilibrium

Question			Expected Answers	Marks	Additional Guidance
	c		A fuel cell converts energy from reaction of a fuel with oxygen into a voltage/electrical energy ✓ $2H_2 + O_2 \rightarrow 2H_2O$ ✓ Two from: • under pressure **OR** at low temperature **OR** as a liquid • adsorbed on solid • absorbed within solid ✓✓ Energy is needed to make the hydrogen **OR** energy is needed to make fuel cell ✓	5	***ANNOTATIONS MUST BE USED*** **ALLOW** combustion for reaction of fuel with oxygen/reactants **ALLOW** a fuel cell requires constant supply of fuel **OR** operates continuously as long as a fuel (and oxygen) are added **ALLOW** multiples, e.g. $H_2 + ½O_2 \rightarrow H_2O$ **IGNORE** state symbols **ALLOW** 'material' **OR** metal for solid **ALLOW** as a metal hydride
			Total	**13**	

Question			Expected Answers	Marks	Additional Guidance
5	a	i	$(K_c =) \frac{[NH_3]^2}{[N_2]\,[H_2]^3}$ ✓	1	Must be square brackets
		ii	$dm^6\ mol^{-2}$ ✓	1	**ALLOW** $mol^{-2}\ dm^6$ **ALLOW ECF** from incorrect K_c expression
	b		**Unless otherwise stated, marks are for correctly calculated values. Working shows how values have been derived.** $[N_2] = \frac{7.2}{6.0}$ **OR** 1.2 (mol dm^{-3}) **AND** $[H_2] = \frac{12}{6.0}$ **OR** 2.0 (mol dm^{-3}) ✓ $[NH_3] = \sqrt{(K_c \times [N_2] \times [H_2]^3)}$ **OR** $\sqrt{(8.00 \times 10^{-2} \times 1.2 \times 2.0^3)}$ ✓ = 0.876 **OR** 0.88 (mol dm^{-3}) ✓ amount NH_3 = 0.876 × 6 = 5.26 **OR** 5.3 (mol) ✓	4	***ANNOTATIONS MUST BE USED*** For **all** parts, **ALLOW** numerical answers from 2 significant figures up to the calculator value 1st mark is for realising that concentrations need to be calculated. **Correct numerical answer with no working would score all previous calculation marks** **ALLOW** calculator value: 0.876356092 down to 0.88, correctly rounded **ALLOW** calculator value down to 5.3, correctly rounded

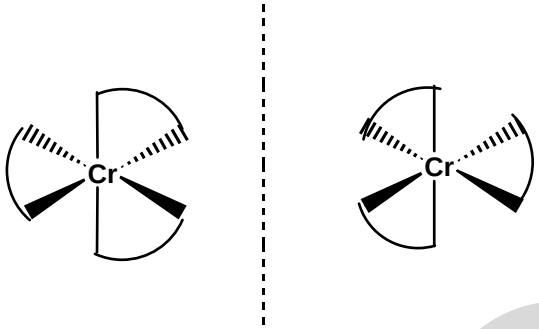
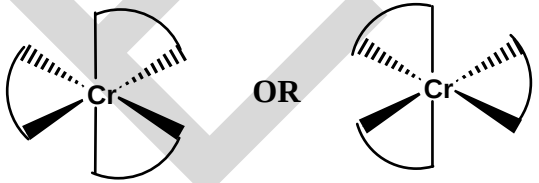
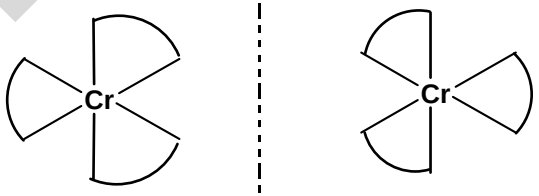
Question	Expected Answers	Marks	Additional Guidance
b	**EXAMPLES OF INCORRECT RESPONSES IN (b) THAT MAY BE WORTHY OF CREDIT**		--- **ALLOW ECF from incorrect concentrations (3 marks)** For example, If concentrations **not** calculated at start, then $[NH_3] = \sqrt{(8.00 \times 10^{-2} \times 7.2 \times 12.0^3)}$ ✓ = 31.5 mol dm^{-3} ✓ Equilibrium amount of $NH_3 = 31.5 \times 6 = 189.6$ (mol) ✓ --- **IF** candidate has K_c expression upside down, then all **4 marks** are available in **(b)** by **ECF** Correct $[N_2]$ AND $[H_2]$ ✓ $[NH_3] = \sqrt{\frac{[N_2]\,[H_2]^3}{K_c}} = = \sqrt{\frac{1.2 \times 2^3}{8.00 \times 10^{-2}}}$ ✓ = 11.0 mol dm^{-3} ✓ Equilibrium amount of $NH_3 = 11.0 \times 6 = 66.0$ (mol) ✓ --- **IF** candidate has used K_c value of 8.00×10^{-2} **AND** values for N_2 **AND** H_2 with powers wrong, mark by **ECF** from calculated as below (**3 max in (b)**) Correct $[N_2]$ AND $[H_2]$ ✓ $[NH_3]$ expression × **ECF**: Calculated $[NH_3]$ ✓ **ECF**: Equilibrium amount of NH_3 ✓

Question			Expected Answers	Marks	Additional Guidance
	c	i	Equilibrium shifts to right **OR** Equilibrium towards ammonia ✓ Right hand side has fewer number of (gaseous) moles ✓	2	**ALLOW** 'moves right' **OR** 'goes right' **OR** 'favours right' **OR** 'goes forwards' **ALLOW** 'ammonia side' has fewer moles **ALLOW** 'there are more (gaseous) moles on left'
		ii	K_c does not change ✓ Increased pressure increases concentration terms on bottom of K_c expression more than the top **OR** system is now no longer in equilibrium ✓ top of K_c expression increases and bottom decreases until K_c is reached ✓	3	***ANNOTATIONS MUST BE USED*** Any response in terms of K_c changing scores **ZERO** for Part **(ii)** **ALLOW** K_c is temperature dependent only **OR** K_c does not change with pressure **ALLOW** $\frac{[NH_3]^2}{[N_2]\,[H_2]^3}$ no longer equal to K_c
	d	i	$CH_4 + H_2O \longrightarrow 3H_2 + CO$ ✓	1	State symbols **NOT** required **ALLOW**: $CH_4 + H_2O \longrightarrow CH_3OH + H_2$ $CH_4 + 2H_2O \longrightarrow 4H_2 + CO_2$ $CH_4 + H_2O \longrightarrow 2H_2 + HCHO$ $CH_4 + 2H_2O \longrightarrow 3H_2 + HCOOH$
		ii	Electrolysis of water **OR** $H_2O \longrightarrow H_2 + ½O_2$ ✓	1	**ALLOW** electrolysis of brine **DO NOT ALLOW** reforming **DO NOT ALLOW** cracking **DO NOT ALLOW** reaction of metal with acid

Question			Expected Answers	Marks	Additional Guidance
	e	i	**Unless otherwise stated, marks are for correctly calculated values.** **Working shows how values have been derived.** $\Delta S = \Sigma S$(products) – ΣS(reactants) / = (2 × 192) – (191 + 3 × 131) ✓ = –200 (J K^{-1} mol^{-1}) **OR** –0.200 (kJ K^{-1} mol^{-1}) ✓ Use of 298 K (could be within ΔG expression below) ✓ $\Delta G = \Delta H - T\Delta S$ **OR** ΔG = –92 – (298 × –0.200) **OR** ΔG = –92000 – (298 × –200) ✓ = –32.4 kJ mol^{-1} **OR** –32400 J mol^{-1} ✓ **(Units must be shown)** For feasibility, $\Delta G < 0$ **OR** ΔG is negative ✓	5 1	***ANNOTATIONS MUST BE USED*** See **Appendix 1** for extra guidance for marking **5e(i)** and **5e(ii)** **NO UNITS** required at this stage **IGNORE** units **ALLOW** –32.4 kJ **OR** –32400 J **(Units must be shown)** Award all 5 marks **above** for correct answer with no working **IF** 25 ºC has been used instead of 298 K, correctly calculated ΔG values are = –87 kJ mol^{-1} **OR** –87000 J mol^{-1} **4 marks** are still available up to this point and maximum possible from **(e)(i)** is 5 marks
		ii	As the temperature increases, $T\Delta S$ becomes more negative **OR** $T\Delta S$ becomes more negative than ΔH **OR** $T\Delta S$ becomes more significant ✓ Eventually $\Delta H - T\Delta S$ becomes positive ✓	2	**ALLOW** $T\Delta S > \Delta H$ (i.e. assume no sign at this stage) **ALLOW** 'entropy term' as alternative for $T\Delta S$ **ALLOW** $-T\Delta S$ becomes more positive **ALLOW** $-T\Delta S$ decreases **ALLOW** ΔG becomes positive **OR** $\Delta G > 0$

Question			Expected Answers	Marks	Additional Guidance
		iii	Activation energy is too high **OR** reaction too slow ✓	1	**ALLOW** increases the rate **OR** more molecules exceed activation energy **OR** more successful collisions **ALLOW** rate constant increases **IGNORE** comments on yield
			Total	**22**	

Question			Expected Answers	Marks	Additional Guidance
6	a	i	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ ✓	1	**ALLOW** $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ (i.e. 4s before 3d) **ALLOW** $[Ar]4s^1 3d^5$ **OR** $[Ar]3d^5 4s^1$
		ii	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^3$ ✓	1	**ALLOW** $[Ar]3d^3$ **ALLOW** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^0$ **OR** $[Ar]3d^3 4s^0$
	b		$Zn \longrightarrow Zn^{2+} + 2e^-$ ✓ $Cr_2O_7^{2-} + 14H^+ + 8e^- \longrightarrow 2Cr^{3+} + 7H_2O$ ✓ $4Zn + Cr_2O_7^{2-} + 14H^+ \longrightarrow 4Zn^{2+} + 2Cr^{3+} + 7H_2O$ ✓	3	**ALLOW** multiples **WATCH** for balancing of the equations printed on paper **IF** printed equations and answer lines have different balancing numbers **OR** electrons, **IGNORE** numbers on printed equations (i.e. treat these as working) and mark responses on answer lines **only** **NO ECF** for overall equation i.e. the expected answer is the **ONLY** acceptable answer
	c	i	Ligand substitution ✓	1	**ALLOW** ligand exchange
		ii	$[Cr(H_2O)_6]^{3+} + 6NH_3 \longrightarrow [Cr(NH_3)_6]^{3+} + 6H_2O$ ✓ ✓	2	1 mark is awarded for each side of equation **ALLOW** equilibrium sign **ALLOW** 1 mark for 2+ shown instead of 3+ on both sides of equation **ALLOW** 1 mark for substitution of 4 NH_3: $[Cr(H_2O)_6]^{3+} + 4NH_3 \longrightarrow [Cr(NH_3)_4(H_2O)_2]^{3+} + 4H_2O$
	d	i	Donates an electron pair to a metal ion **OR** forms a coordinate bond to a metal ion ✓	1	**ALLOW** donates an electron pair to a metal **ALLOW** dative (covalent) bond for coordinate bond
		ii	Donates **two** electron pairs **OR** forms **two** coordinate bonds ✓ Lone pairs on two O atoms ✓	2	First mark is for the idea of two coordinate bonds **ALLOW** lone pair on O and N **DO NOT ALLOW** lone pairs on COO^- (could involve C) Second mark is for the atoms that donate the electron pairs Look for the atoms with lone pairs also on response to **(d)(iii)** and credit here if not described in **(d)(ii)**

Question	Expected Answers	Marks	Additional Guidance
iii	Forms two optical isomers **OR** two enantiomers **OR** two non-superimposable mirror images ✓  ✓✓ For each structure	3	**IGNORE** any charges shown **ALLOW** any attempt to show bidentate ligand. Bottom line is the diagram on the left. 1 mark for 3D diagram with ligands attached for ONE stereoisomer. Must contain 2 out wedges, 2 in wedges and 2 lines in plane of paper:  2nd mark for reflected diagram of SECOND stereoisomer. The diagram below would score the 2nd mark but not the first 

Question			Expected Answers	Marks	Additional Guidance
	e		N : H : Cr : O 11.1/14 : 3.17/1 : 41.27/52 : 44.45/16 **OR** 0.793 : 3.17 : 0.794 : 2.78 ✓	8	***ANNOTATIONS MUST BE USED***
			A: $N_2H_8Cr_2O_7$ ✓		**ALLOW A**: $(NH_4)_2Cr_2O_7$
			Ions: NH_4^+ ✓ $Cr_2O_7^{2-}$ ✓		**IF** candidate has obtained NH_4CrO_4 for A, **ALLOW** NH_4^+ **DO NOT ALLOW** CrO_4^-
			B: Cr_2O_3 ✓		
			Correctly calculates molar mass of **C** = 1.17 × 24.0 = 28.08 (g mol^{-1}) ✓		**ALLOW**: (relative) molecular mass **ALLOW**: 28 **ALLOW**: '**C** is 28'
			C: N_2 ✓		
			Equation: $(NH_4)_2Cr_2O_7 \longrightarrow Cr_2O_3 + 4H_2O + N_2$ ✓		**ALLOW** $N_2H_8Cr_2O_7$ in equation.
			Total	**22**	

Question			Expected Answers	Marks	Additional Guidance
7	a	i	$H_2O_2 \longrightarrow O_2 + 2H^+ + 2e^-$ ✓✓	2	All other multiples score 1 mark e.g. ½ $H_2O_2 \longrightarrow$ ½ $O_2 + H^+ + e^-$ $5H_2O_2 \longrightarrow 5O_2 + 10H^+ + 10e^-$
	b		**Marks are for correctly calculated values.** **Working shows how values have been derived.**		***ANNOTATIONS MUST BE USED***
			$n(KMnO_4) = \frac{0.0200 \times 23.45}{1000} = 4.69 \times 10^{-4}$ (mol) ✓		**DO NOT ALLOW** 4.7×10^{-4}
			$n(H_2O_2) = 5/2 \times 4.69 \times 10^{-4} = 1.1725 \times 10^{-3}$ (mol) ✓		**ALLOW** 1.173×10^{-3} OR 1.17×10^{-3} (i.e. 3 significant figures upwards) **ALLOW** by **ECF**: 5/2 × ans above
			$n(H_2O_2)$ in 250 cm^3 solution $= 10 \times 1.1725 \times 10^{-3} = 1.1725 \times 10^{-2}$ (mol) ✓		**ALLOW** by **ECF** 10 × ans above **ALLOW** concentration H_2O_2 = 0.0469 mol dm^{-3}
			concentration in g dm^{-3} of original H_2O_2 $= 40 \times 1.1725 \times 10^{-2} \times 34 = 15.9$ (g dm^{-3}) ✓	4	**ALLOW** by **ECF** 40 × $n(H_2O_2)$ × 34 **ALLOW** 0.0469 x 10 x 34 = 15.9 g dm^{-3} ✓ **ALLOW** two significant figures, 16 (g dm^{-3}) up to calculator value of 15.946 g dm^{-3}
			$n(O_2) = 5/2 \times 4.69 \times 10^{-4} = 1.1725 \times 10^{-3}$ (mol) ✓		**ALLOW** 0.028 dm^3 **OR** 0.02814 dm^3 **ALLOW** 28 cm^3 **OR** 28.14 cm^3 Value **AND** units required **DO NOT ALLOW** 0.03 dm^3
			volume $O_2 = 24.0 \times 1.1725 \times 10^{-3} = 0.0281$ dm^3 ✓	2	**ALLOW** by **ECF**: 24.0 × calculated moles of O_2 (2 significant figures up to calculator value)
			Total	**8**	

Appendix 1

Extra guidance for marking atypical responses to **5e(i)** and **5e(ii)**

Question			Expected Answer	Mark	Additional Guidance
5	e	i	**TOTAL ENTROPY APPROACH:** **ALL MARKS AVAILABLE** **Unless otherwise stated, marks are for correctly calculated values.** **Working shows how values have been derived.**		***ANNOTATIONS MUST BE USED***
			$\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$ / $= (2 \times 192) - (191 + 3 \times 131)$ ✓ $= -200$ (J K^{-1} mol^{-1}) **OR** -0.200 (kJ K^{-1} mol^{-1}) ✓		**NO UNITS** required at this stage **IGNORE** units
			Use of 298 K (could be within expression below) ✓		
			$\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings}$ $\Delta S_{surroundings} = -\frac{\Delta H}{T}$ **OR** $\Delta S_{total} = \Delta S_{system} - \frac{\Delta H}{T}$ **OR** $\Delta S_{total} = -0.200 - \frac{-92}{298}$ **OR** $\Delta S_{total} = -200 - \frac{-92000}{298}$ ✓ $= 0.109$ kJ (K^{-1} mol^{-1}) **OR** 109 J (K^{-1} mol^{-1}) ✓	5	**ALLOW** 0.109 kJ **OR** 109 J **IF** 25ºC has been used instead of 298 K, correctly calculated ΔS_{total} values are = 3.48 kJ K^{-1} mol^{-1} **OR** 3,480 J K^{-1} mol^{-1}
			Feasible when $\Delta S_{total} > 0$ ✓	1	

Question			Expected Answer	Mark	Additional Guidance
5	e	i	**MAX/MIN TEMPERATURE APPROACH:** **5 MARKS MAX AVAILABLE** **Unless otherwise stated, marks are for correctly calculated values.** **Working shows how values have been derived.**		***ANNOTATIONS MUST BE USED*** **This candidate has not answered the question but many marks are still available.**
			$\Delta S = \Sigma S$(products) – ΣS(reactants) / = (2 × 192) – (191 + 3 × 131) ✓ = –200 (J K^{-1} mol^{-1}) **OR** –0.200 (kJ K^{-1} mol^{-1}) ✓		**NO UNITS** required at this stage **IGNORE** units
			Use of 298 K (could be within ΔG expression below) ✓		
			$\Delta G = \Delta H - T\Delta S$ **OR** When $\Delta G = 0$, $0 = \Delta H - T\Delta S$; **OR** $T = \frac{\Delta H}{\Delta S} = \frac{-92}{-0.200}$ **OR** $T = \frac{\Delta H}{\Delta S} = \frac{-92000}{-200}$ ✓ = 460 K ✓ = 187 ºC (use of 298) ✓		
			The condition $\Delta G = 0$ because temperature at which $\Delta G = 0$ is the maximum temperature for feasibility **AND** justification for the being the maximum ✓		By this approach, the calculated temperature is the switchover between feasibility and non-feasibility but it cannot be assumed that this is the maximum temperature

Question			Expected Answer	Mark	Additional Guidance
5	e	ii	As the temperature increases, $\Delta H/T$ becomes **less** negative **OR** $\Delta H/T$ becomes **more** negative than ΔS(system) **OR** $\Delta H/T$ becomes **less** significant **OR** ΔS(surroundings) becomes **less** significant **OR** ΔS(system) > $\Delta H/T$ **OR** ΔS(system) > ΔS(surroundings) ✓ Eventually ΔS(total) becomes **negative** ✓	2	**ALLOW** $\Delta H/T > \Delta S_{system}$ (i.e. assume no sign at this stage) **ALLOW** $-\Delta H/T$ becomes more positive **ALLOW** $-\Delta H/T$ increases

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