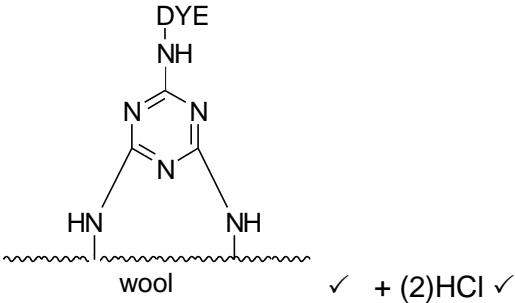


MARK SCHEME

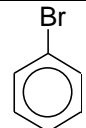
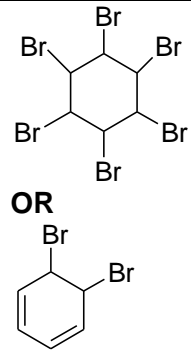
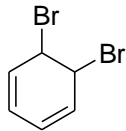
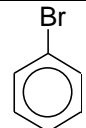
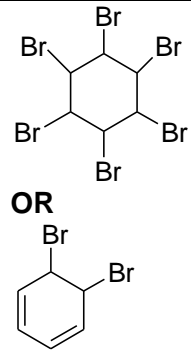
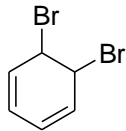
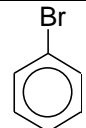
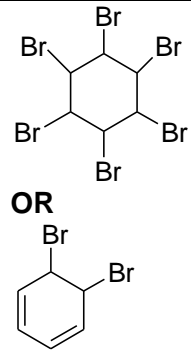
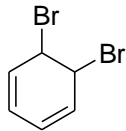
Before marking part 1a, please look at all the extra pages. (These come above part 1a on the display). If there is nothing on them, stamp each 'BP', otherwise link them to the appropriate question part. When marking that part, please ensure that there is some annotation on the extra page (eg, tick, cross, SEEN) to indicate that you have been there.

Question		Answer	Mark	Guidance
1	a	<p>temp: increased yield/ more products ✓ forward reaction [stated or implied] is <u>endothermic</u> (ora) ✓</p> <p>pressure: no effect on yield AW ✓ same number of (gaseous) moles/ molecules on each side (of equation) AW✓</p>	4	<p>ALLOW 'it increases' IGNORE 'equilibrium (position) moves to right' QWC: <u>endothermic</u> (or <u>exothermic</u> for ora) must be used and spelled correctly to score second mark</p> <p>ALLOW 'no effect on <u>position</u> of equilibrium' ALLOW 'no change of yield'/'no increase of yield' NOT 'little effect on yield' etc</p> <p>No ecf but mark separately within each pair.</p>
1	b	<p>speeds up achievement of equilibrium OR speeds up both (forward and back) reactions ✓</p> <p>no effect on K_c (AW) ✓</p>	2	Can score this alternative for the first marking point while explaining effect on K_c
1	c	<p>($K_c = [\text{H}_2\text{O}] [\text{CO}] / [\text{H}_2] [\text{CO}_2]$)</p> <p>1. $[\text{H}_2\text{O}] [\text{CO}] = 2.68496 \times 10^{-12}$ (3 or more sf) ✓</p> <p>2. either concentration = $1.63858 \dots \times 10^{-6}$ (2 or more sf) ✓</p> <p>3. both concentrations to 3 sf (1.64×10^{-6}) ✓</p> <p>4. concentrations equal ✓</p>	4	<p>award 1. if later answers correct</p> <p>3. award for any numbers to 3sf</p> <p>1.64×10^{-6} twice on the answer lines scores 4 marks without reference to working.</p>

Question			Answer	Mark	Guidance
1	d	i	the sun OR burning CO ✓	1	ALLOW 'uv'
1	d	ii	oxygen (is formed) ✓	1	any mention of oxygen that makes sense IGNORE references to CO ₂ and/or hydrogen
1	e	i	+42 ✓	1	plus sign essential
1	e	ii	1. $42 = 40000/T$ ✓ 2. $T = 950$ ✓ 3. K/ Kelvin ✓	3	ALLOW ecf from a positive (or no sign) value from (i) for 1. and 2. ($T = 40000/\text{ans to (i)}$). award both marks 1. and 2. if correct answer for T given ALLOW two sf up to calculator value (952.38...)(correctly rounded) 0.95/0.95238 etc scores 1 mark for 2. (but not 1.) no other ecf from 1. to 2. 3. mark separately ALLOW 'k' IGNORE + sign for temperature (– is CON) NOT degree sign before K
	e	iii	equilibrium const/ $K_c = 1$ OR reaction (equally) balanced/in the middle OR no tendency to go in either direction AW ✓	1	ALLOW rate of forward reaction = rate of back reaction
			Total	17	

Question			Answer	Mark	Guidance
2	a		$\text{SO}_3^-(\text{Na}^+)$ ✓ ion(-)dipole bonds/interactions (with water) ✓ OR OH/NH ✓ form hydrogen bonds (with water) ✓	2	ALLOW groups marked on formula of dye IGNORE names for first mark ALLOW ion-dipole bonds or ion attraction to $\text{H}^{\delta+}$ described Second mark depends on first being scored except... ‘alcohol’ is CON to OH for first mark but second mark can still be considered Correct name (sulfonate, phenol/hydrox(l), (secondary) amine) allows second mark of pair to be scored
2	b	i	(primary) amine ✓	1	ALLOW amino
2	b	ii	benzenediazonium chloride ✓	1	ALLOW benzene diazonium chloride ALLOW diazonium chloride/ (benzene)diazonium <u>ion/salt</u> IGNORE formulae
2	b	iii	coupling ✓	1	ALLOW electrophilic substitution IGNORE ‘synthesis’, ‘(di)azo’
2	b	iv	react with (hydrogen)carbonates/ formulae ✓ effervescence/fizz/give gas/give CO_2 ✓	2	ALLOW any carbonate (eg CaCO_3) <i>second mark depends on first</i> IGNORE other products of reaction or other correct reactions
2	c	i		2	Mark separately Structure must be correctly copied ALLOW N–H for ‘NH’ and carbon atoms shown






Question			Answer	Mark	Guidance
2	c	ii	<p>dye is 'fast' in water/ dye does not run when washing/dye is not washed out/ dye stays/ dye lasts longer/ does not dissolve AW ora ✓</p> <p>covalent bonds not broken by/in water/ covalent bonds not made between dye and water ✓</p> <p>hydrogen bonds are broken by/in water / hydrogen bonds made between dye and water ✓</p>	3	<p>ALLOW 'colour' for 'dye'</p> <p>IGNORE 'fading'</p> <p>IGNORE 'dye will not form hydrogen bonds with water'</p> <p>to score either of the second two marking points, there must be a clear implication that water is involved, i.e.: IGNORE 'covalent bonds are stronger than hydrogen bonds'</p>
2	d		<p>1. <u>Electron(s)</u> excited to/move to higher <u>energy level</u> ✓</p> <p>2. $\Delta E = h\nu$ / frequency absorbed related to energy gap ✓</p> <p>3. <u>Light/visible</u> (radiation) is <u>absorbed</u> ✓</p> <p>4. size of ΔE/frequency/wavelength depends on: EITHER length of/size of/bonding in/functional groups in chromophore OR amount of delocalisation ✓</p> <p>5. <u>complementary</u> colour <u>transmitted/reflected</u> ✓</p>	5	<p>ALLOW 'state' for 'level' IGNORE 'shell'</p> <p>Do not award this mark if in terms of d electrons</p> <p>In 2. ALLOW $E = h\nu$ only if energy <i>change</i> is clear</p> <p>ALLOW 'gap between energy levels' for 'ΔE'</p> <p>ALLOW 'hf' for '$h\nu$'</p> <p>ALLOW 'excitation energy' for ΔE</p> <p>NOT 'electrons falling' in connection with any radiation given out (only mpts 2. and 4. can be considered)</p> <p>QWC: only award 5. if 3. scored OR 'frequency absorbed' stated</p> <p>ALLOW 'complimentary'</p> <p>IGNORE 'emission'</p> <p>ALLOW 'colours/frequencies/wavelengths not absorbed' for 'complementary colour'</p>

Question			Answer	Mark	Guidance									
2	e	i	<table><tr><td></td><td>Structure C</td><td>Structure D</td></tr><tr><td>Type of reaction</td><td>substitution ✓</td><td>addition ✓</td></tr><tr><td>Skeletal formula of organic product</td><td></td><td> OR </td></tr></table>		Structure C	Structure D	Type of reaction	substitution ✓	addition ✓	Skeletal formula of organic product		 OR 	4	IGNORE 'electrophilic' or 'bromination' in 'type' boxes but 'nucleophilic' is CON to either or both ALLOW di or tri bromination of C ALLOW D with two double bonds brominated or brominated at 1,4. ALLOW substituted Kekulé benzene in lower left box IGNORE names and molecular and non-skeletal formulae IGNORE '+HBr' in bottom left box
	Structure C	Structure D												
Type of reaction	substitution ✓	addition ✓												
Skeletal formula of organic product		 OR 												
2	e	ii	different (bond) lengths ✓ double bonds are shorter than single bonds ✓	2	Second marking point also scores first									
2	f	i	$\text{C}_6\text{H}_6 + \text{Cl}_2 \xrightarrow{\text{Fe/FeCl}_3/\text{AlCl}_3} \text{C}_6\text{H}_5\text{Cl} + \text{HCl}$ equation ✓	2	mark separately IGNORE state symbols ALLOW any suitable structures for substances ALLOW catalyst formula over arrow in the question stem IGNORE (for second mark) names of catalysts and 'anhydrous' or 'reflux' or 'heat' Other reagents above or below arrow are CON									
2	f	ii	NaOH/ sodium hydroxide ✓	1	ALLOW any group 1 hydroxide IGNORE water/ H ₂ O									
Total				26										

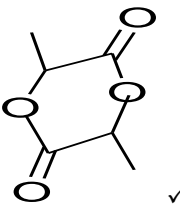
Question			Answer	Mark	Guidance
3	a	i	ethanol ✓	1	NOT ethan-1-ol
3	a	ii	propane – 1,2,3 – triol ✓	1	ALLOW errors in gaps, commas and dashes ALLOW propan – 1,2,3 – triol IGNORE glycerol/ glycerine
3	b		2/two ✓	1	
3	c	i	permanent (dipole)–permanent dipole ✓	1	No abbreviations allowed ALLOW mis-spellings on the ‘sounds like’ rule ALLOW permanent dipole-induced dipole
3	c	ii	<p><i>Type of imb and related reason</i> Ester G has weaker/ fewer/less instantaneous dipole–induced dipole bonds (ora) ✓ Ester G is a smaller molecule/shorter molecule/lower molecular mass/has fewer/less electrons/ molecules of G have smaller surface area/ fewer points of contact ora ✓ OR ester G has fewer/weaker permanent dipole – permanent dipole bonds ora ✓ ester G has fewer ester/C=O groups (allow ‘only one’ otherwise must be comparative) ora ✓</p> <p><i>Less energy to break</i> Less energy is needed to break/overcome im-bonds or separate the molecules (ora) ✓</p>	3	<p>Second mark in pair depends on first being scored; allow either reason if both id and pd bonds mentioned</p> <p>id–id bond or pd-pd can be abbreviated hydrogen bonds are CON to first two points</p> <p>IGNORE ‘chains’ or comments about molecules fitting more closely</p> <p>mark third mark separately</p>

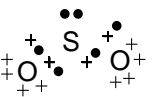

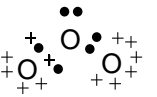
Question	Answer	Mark	Guidance
3 d i	<p>two arrows on left-hand structures ✓ intermediate ✓ two arrows on intermediate ✓</p> <p>Award one mark for one correct arrow on reactant and one on intermediate if there are no incorrect arrows (other detail can be incorrect)</p>	3	<p>curly arrows must start on correct atom, bond or charge (if projected backwards) and end pointing at correct bond or atom. (Left-hand arrow can either point to C or the line between the lone pair and C) ALLOW arrow from '–' sign on RO[–]:</p> <p>ALLOW right-hand arrow starting from a drawn lone pair on –O[–]</p> <p>Do not allow 'half arrows' (fish-hooks) the first time encountered, but allow by ecf subsequently.</p> <p>IGNORE partial charges</p>
3 d ii	nucleophile ✓	1	
3 e i	$\text{C}_7\text{H}_{11}\text{COOH} + \text{ROH} \rightleftharpoons \text{C}_7\text{H}_{11}\text{COOR} + \text{H}_2\text{O}$ <p>Equilibrium sign ✓ equation (with equm sign or arrow) ✓</p>	2	<p>ALLOW any unambiguous structural formulae</p> <p>ALLOW $\text{CH}_3\text{CHCHCH}_2\text{CHCHCH}_2\text{COOH} + \text{ROH} \rightleftharpoons \text{CH}_3\text{CHCHCH}_2\text{CHCHCH}_2\text{COOR} + \text{H}_2\text{O}$</p> <p>IGNORE errors in the chain as long as there are seven carbon atoms shown in the chain.</p> <p>Mark separately</p> <p>ALLOW reaction with ethanol ($\text{CH}_3\text{CH}_2\text{OH}$ or $\text{C}_2\text{H}_5\text{OH}$)</p>
3 e ii	<p>catalyst ✓</p> <p>removes/ reacts with/lowers concentration of water ✓</p>	2	<p>ALLOW 'provides H⁺ ions' / 'protonates' as <i>alternative</i> to 'catalyst' but only one can score.</p>
3 f i	<p>$\text{C}_2\text{H}_5\text{CH}(\text{CH}_3)\text{COOH}$ structure ✓</p> <p>chiral C marked on correctly bonded structure ✓</p>	2	<p>ALLOW any unambiguous indication of structure and any clear way of indicating chiral carbon (eg asterisk)</p>

Question			Answer	Mark	Guidance
3	f	ii	<p>No <u>broad</u> peak at 2500 – 3200 OR no O-H peak in range 2500 - 3200 OR no peak 1700 – 1725 (for acid C=O) ✓</p> <p>For ester C=O: EITHER Peak at 1741 OR peak in range 1735 – 1750 ✓</p>	2	<p>ALLOW 'around/at 3000' for '2500 – 3200'</p> <p>to score this way it must be stated that there is <u>no peak</u></p> <p>peak value, 'ester' and bond necessary for this mark</p> <p>IGNORE extra information even if wrong.</p>
3	f	iii	<p>1. structure: $\text{CH}_3\text{COOCH}(\text{CH}_3)_2$ ✓✓ $(\text{CH}_3)_2\text{CHCOOCH}_3$ ✓</p> <p>2. description of doublet (1.2): one H on adjacent <u>carbon</u> ✓</p> <p><i>Maximum of 2 from</i></p> <p>3. 3 <u>proton environments</u>/ <u>protons</u> in ratio 6:3:1 (or 1:3:6 etc)</p> <p>4. two CH_3 groups on one C / two CH_3 in same environment ✓</p> <p>5. CH attached to O/ CH-O/ O-CH (5.0) OR CH next to <u>carbon</u>(s) with many/six H (5.0) ✓</p> <p>6. CH_3 attached to C=O (2.0) OR CHC=O OR CH_3 next to <u>carbon</u> with no H ✓</p>	5	<p>ALLOW any unambiguous representation of the structure</p> <p>ALLOW 'H' for 'proton' but IGNORE H^+</p> <p>5. NOT CHO</p> <p>6. IGNORE CO for C=O</p> <p>IGNORE any incorrect points unless they directly contradict one that has been awarded a mark</p>
			Total	24	

Question			Answer	Mark	Guidance
4	a	i	(primary) amide ✓	1	'secondary' is CON
4	a	ii	$2 \text{ RCONH}_2 + \text{H}_2\text{SO}_4 + 2\text{H}_2\text{O} \rightarrow (\text{NH}_4)_2\text{SO}_4 + 2 \text{ RCOOH}$ species ✓ balancing with correct species ✓	2	IGNORE state symbols ALLOW multiples and halves
4	a	iii	hydrolysis ✓	1	ALLOW any unambiguous identification of the word
4	b	i	<div style="display: flex; align-items: center;">  <div style="margin-left: 10px;"> $\begin{array}{c} \text{H}^{\delta+} \\ \diagup \\ \text{O}^{\delta-} \\ \diagdown \\ \text{H} \end{array}$ </div> <div style="margin-left: 10px;"> (one of these needed for second mark) </div> </div> <div style="margin-top: 20px;">   <div style="margin-left: 20px;"> (three of either of these acceptable for first mark) </div> </div> <p>At least three water molecules around ion (can be shown as  or  with points towards ion) ✓</p> <p>correct formula for at least one water molecule, with bent shapes, $\delta+$ on at least one hydrogen, $\delta-$ on at least one oxygen, with oxygen pointing towards ion ✓</p> <p>ion–(permanent) dipole ✓</p>	3	<p>Mark separately</p> <p>detail of water molecule can be shown as separate diagram. Ignore wrong water molecules</p> <p>ALLOW 'ion dipole' (no hyphen)</p>

Question			Answer	Mark	Guidance
4	b	ii	<p> $1. 2\text{NH}_4^+(\text{g}) + \text{SO}_4^{2-}(\text{g}) \checkmark$ $2. \text{enthalpy (change) of hydration of ions} \checkmark$ $3. 2\text{NH}_4^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) / (\text{NH}_4)_2\text{SO}_4(\text{aq}) \checkmark$ $5. (\text{NH}_4)_2\text{SO}_4(\text{s}) \checkmark$ $4. \text{enthalpy (change) of solution} \checkmark$ </p> <p>State symbols must be shown correctly</p>	5	<p>Scale is not important Mark separately, but...</p> <p>ALLOW ecf between 1. and 3. if wrong species or numbers shown consistently in both ALLOW missing '+' sign between ions in 1. and 3.</p> <p>2. ALLOW 'solvation' for 'hydration' ALLOW $\Delta H_{\text{hyd(ration)}}$ for 'enthalpy (change) of hydration' (or $\Delta H_{\text{solv(ation)}}$) It must be clear that <u>both</u> ions are referred to and arrow must be present. ALLOW 'enthalpy(change) of hydration of cation(s)* + (enthalpy(change) of hydration of) anion*' *ALLOW if a cation and an anion are shown using wrong formulae</p> <p>4. To award mark for 'enthalpy (change) of solution', it must be endothermic and upward arrow must be shown ALLOW ΔH_{sol} / $\Delta H_{\text{solution}}$</p>
4	c	i	$\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$ acid base \checkmark	1	IGNORE 'conjugate'
4	c	ii	$\frac{[\text{NH}_3][\text{H}^+]}{[\text{NH}_4^+]} \checkmark$	1	<p>ALLOW multiplication signs State symbols not required, but any other than 'aq' [ignore absence of brackets] are CON.</p>

Question			Answer	Mark	Guidance
4	c	iii	$[H^+](\text{or } H^+) = 7.4(13102...) \times 10^{-6} \checkmark$ $K_a = (7.41 \times 10^{-6})^2 / 0.1 = 5.5 \times 10^{-10} \checkmark$ $\text{mol dm}^{-3} \checkmark$	3	ALLOW 2 or more sf for first marking point. first mark is automatically scored if correct answer is given to K_a value ALLOW ecf from first marking point, provided ' $H^+ =$ ' or ' $[H^+] =$ ' is shown and $[H^+]$ is smaller than 1×10^{-4} ALLOW any answer rounding to 5.5×10^{-10} mark last marking point separately
4	c	iv	$K_a \times K_b = K_w$ OR $K_b = K_w / K_a \checkmark$ $K_b = 1.0 \times 10^{-14} / (\text{answer to (c)(iii)})$ calculated (1.8×10^{-5} if (c)(iii) correct) \checkmark	2	ALLOW expressions with numbers substituted correct answer (with ecf from (c)(iii)) scores 2 without reference to working no ecf from first marking point ALLOW any answer rounding to 1.8×10^{-5}
4	d		H^+ added / more $H^+ \checkmark$ equilibrium <u>position</u> moves to left \checkmark large concentration/ large amount of $A^- \checkmark$ pH remains (virtually) unchanged/resists change in pH \checkmark	4	IGNORE 'acid added' ALLOW change in A^- concentration is very small compared to the initial A^- concentration IGNORE 'large concentration of HA'
4	e		OH/alcohol group reacts with acid/ $COOH$ group OR two molecules react/condense to lose (two molecules of) water \checkmark 	2	ALLOW any correct representation of structure
			Total	25	

Question			Answer	Mark	Guidance
5	a	i	 <p>both double bonds correct ✓ completely correct ✓</p>	2	<p>ALLOW electrons in lone pairs that are not close together Give BOD wherever possible on rubbing out etc. ALLOW double bonds as '•• x x' or </p> <p>IGNORE shape ALLOW other symbols for dots and crosses</p>
5	a	ii	<p>1. <u>three</u> groups/ sets/ regions of electrons/ areas of electron density (around S) ✓ 2. (electrons/ [as for 1.]) repel and get as far away from each other as possible/ repel to minimise repulsion ✓ 3. 120° ✓</p>	3	<p>1. IGNORE 'electron pairs/ bonds/ bonding pairs' 2. IGNORE 'bonds' and 'pairs' IGNORE 'repel as much as possible' 3. ALLOW 115 – 125</p> <p>Mark separately No ecf</p>
5	a	iii	 <p>One oxygen with dative bond and three lone pairs ✓ completely correct ✓</p>	2	<p>See guidance in 5ai</p> <p>ALLOW structure with dative bond and double bond reversed.</p>
5	a	iv	<p>SO₂(g/aq) + H₂O(l/g) ⇌ 2H⁺(aq) + SO₃²⁻(aq) OR SO₂(g/aq) + H₂O(l/g) ⇌ H⁺(aq) + HSO₃⁻(aq) equation ✓ state symbols ✓</p>	2	<p>ALLOW arrow instead of ⇌. ALLOW equations with oxygen forming SO₄²⁻ or HSO₄⁻ [eg 2SO₂(g/aq)+2H₂O(l/g) +O₂(g) ⇌ 4H⁺(aq)+2SO₄²⁻(aq)] ss mark can be awarded if equation is unbalanced but correct species are present (and only those).</p>
5	b	i	<p>SO₂ + 2H₂S → 3S + 2H₂O +4 ✓ -2 ✓ 0 ✓</p>	3	<p>NOT sign after numbers, but give one mark for 4+ AND 2-</p>

Question			Answer	Mark	Guidance
5	b	ii	<p>1.BOTH moles $\text{SO}_2 = 44.3/64(.1)$ or 0.69 AND moles $\text{H}_2\text{S} = 44.3/34(.1)$ or 1.3 ✓</p> <p>2.SO_2 in excess/ H_2S is limiting (AW)✓</p> <p>3.mass S formed ($= 1.3 \times 1.5 \times 32.1$) = 62.6 g [62.4 if 32 used as A_r]✓ (Allow any number between 62.4 and 63)</p>	3	<p>ALLOW any numbers rounding to 0.69 and 1.3 ALLOW ecf from 1. to 2. and 3.</p> <p>Answer alone scores third mark only Answers from use of moles of SO_2 (allow any number between 66 and 67) can score mark 3. but not 2. ALLOW 2 or more sf</p>
5	b	iii	<p>low mpt ✓ weak intermolecular bonds/ weak instantaneous dipole–induced dipole bonds ✓</p> <p>non-conductor/ poor conductor (of electricity)/good insulator ✓ no ions/ no charged particles / no free (or delocalised) electrons ✓</p>	4	<p>QWC: second mark in each pair depends on first being scored. IGNORE 'S is a gas' IGNORE 'not ionic' IGNORE 'in solution'</p> <p>IGNORE references to solubility or boiling point or strength</p>
5	c	i	<p>1.an <u>element</u> in group 6 OR 'sulfur/S/oxygen/O is/are in group 6' ✓</p> <p>2.<u>compound</u> of S/O/ element with hydrogen ✓</p>	2	<p>ALLOW 'atom/element with 6 outer electrons'</p> <p>ALLOW 'bonded to'/ 'combined with'/ 'reacted with' 'molecule containing' instead of 'compound' ALLOW 'bonded to a hydrogen' award second mark without first if some element or atom described</p>
5	c	ii	<p>O/oxygen is more electronegative ora✓</p> <p><i>and one from ✓</i></p> <ul style="list-style-type: none"> • O/oxygen is smaller so gets closer to H (ora) • O–H more strongly polarised/ molecule more strongly polarised/ H more positive (ora) 	2	<p>must be comparative</p> <p>ALLOW 'water/H_2O forms hydrogen bonds, H_2S forms pd-pd bonds' (allow abbreviation and just 'pd')</p>

Question			Answer	Mark	Guidance
5	c	iii	density decreases on freezing because: EITHER <u>molecules</u> get further apart (ora) OR 'more open structure' ✓ hydrogen bonding keeps ice in a lattice/ regular arrangement/ crystalline structure/ tetrahedral structure/ordered (AW) ✓	2	allow any idea of greater separation of molecules here, including anything between the <u>molecules</u> . mention of 'air','oxygen' between molecules CONs second mark. IGNORE 'empty space' or 'open space' for second mark
5	d	i	$1s^2 2s^2 2p^6 3s^2 3p^6$ / [Ne] $3s^2 3p^6$ ✓	1	ALLOW capital letters but electron numbers must be superscripts
5	d	ii	$(\text{NH}_4)_2\text{S} + 2\text{NaOH} \rightarrow 2\text{NH}_3 + \text{Na}_2\text{S} + 2\text{H}_2\text{O}$ Na_2S as a product ✓ completely correct ✓	2	ALLOW $(\text{NH}_4)_2\text{S} + 2\text{NaOH} \rightarrow 2\text{NH}_4\text{OH} + \text{Na}_2\text{S}$ IGNORE state symbols NOT formulae or equation containing ions formulae must be represented in conventional way but... ALLOW otherwise correct balanced equation forming $(\text{Na})_2\text{S}$ for 1 mark
			Total	28	