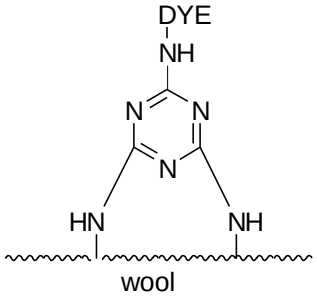
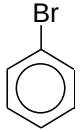
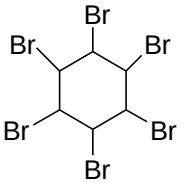
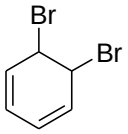
Question			Answer	Mark	Guidance
1	a		**temp:** increased yield/ more products ✓ forward reaction [stated or implied] is <u>endothermic</u> (ora) ✓ **pressure:** no effect on yield AW ✓ same number of (gaseous) moles/ molecules on each side (of equation) AW✓	4	**ALLOW** 'it increases' **IGNORE** 'equilibrium (position) moves to right' **QWC**: <u>endothermic</u> (or <u>exothermic</u> for ora) must be used and spelled correctly to score second mark **ALLOW '**no effect on <u>position</u> of equilibrium' **ALLOW '**no change of yield'/'no increase of yield' **NOT** 'little effect on yield' etc No ecf but mark separately within each pair.
1	b		speeds up achievement of equilibrium **OR** speeds up both (forward and back) reactions ✓ no effect on K_c (AW) ✓	2	Can score this alternative for the first marking point while explaining effect on K_c
1	c		($K_c = [H_2O]\,[CO] / [H_2]\,[CO_2]$) **1.** $[H_2O]\,[CO] = 2.68496 \times 10^{-12}$ (3 or more sf) ✓ **2.**either concentration = 1.63858.... x 10^{-6} (2 or more sf) ✓ **3.**both concentrations to 3 sf (1.64×10^{-6}) ✓ **4.** concentrations equal ✓	4	award **1.** if later answers correct **3.** award for any numbers to 3sf 1.64×10^{-6} twice on the answer lines scores 4 marks without reference to working.

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/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		$SO_3^-(Na^+)$ ✓ 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 $H^{\delta+}$ 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 ion/salt **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 $CaCO_3$) *second mark depends on first* **IGNORE** other products of reaction or other correct reactions
2	c	i	 ✓ + (2)HCl ✓	2	Mark separately Structure must be correctly copied **ALLOW** N–H for 'NH' and carbon atoms shown

Question			Answer	Mark	Guidance
2	c	ii	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 ✓ covalent bonds not broken by/in water/ covalent bonds not made between dye and water✓ hydrogen bonds are broken by/in water / hydrogen bonds made between dye and water ✓	3	**ALLOW** 'colour' for 'dye' **IGNORE** 'fading' **IGNORE '**dye will not form hydrogen bonds with water' 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'
2	d		**1.**Electron(s) excited to/move to higher energy level ✓ **2.**∆E = hv / frequency absorbed related to energy gap ✓ **3**. Light/visible (radiation) is absorbed ✓ **4.** size of ∆E/frequency/wavelength depends on: **EITHER** length of/size of/bonding in/functional groups in chromophore **OR** amount of delocalisation ✓ **5.**complementary colour transmitted/reflected ✓	5	**ALLOW** 'state' for 'level' **IGNORE** 'shell' Do not award this mark if in terms of d electrons In **2. ALLOW** E = hv only if energy *change* is clear **ALLOW** 'gap betwen energy levels' for '∆E' **ALLOW** 'hf' for 'hv' **ALLOW** 'excitation energy' for ∆E **NOT** 'electrons falling' in connection with any radiation given out (only mpts **2.** and **4.** can be considered) **QWC**: only award **5.** if **3.** scored **OR** 'frequency absorbed' stated **ALLOW** 'complimentary' **IGNORE** 'emission' **ALLOW** 'colours/frequencies/wavelengths not absorbed' for 'complementary colour'

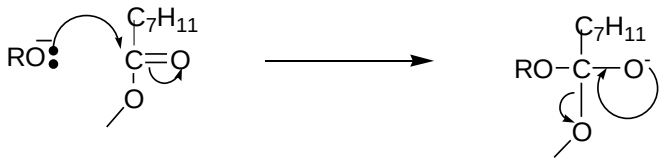
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>2</td><td>e</td><td>i</td><td>
<table>
<tr><td></td><td>Structure C</td><td>Structure D</td></tr>
<tr><td>Type of reaction</td><td>substitution ✓</td><td>addition ✓</td></tr>
<tr><td>Skeletal formula of organic product</td><td>  </td><td> 
OR
  </td></tr>
</table>
</td><td>4</td><td>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.

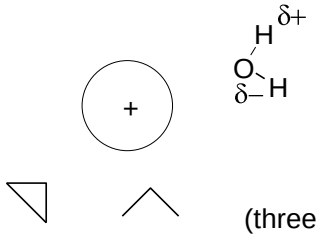
ALLOW substituted Kekulé benzene in lower left box

IGNORE names and molecular and non-skeletal formulae
IGNORE ‘+HBr’ in bottom left box</td></tr>
<tr><td>2</td><td>e</td><td>ii</td><td>different (bond) lengths ✓
double bonds are shorter than single bonds ✓</td><td>2</td><td>Second marking point also scores first</td></tr>
<tr><td>2</td><td>f</td><td>i</td><td>$Fe/FeCl_3/AlCl_3$ ✓
$C_6H_6 + Cl_2$ ----------> $C_6H_5Cl + HCl$
equation ✓</td><td>2</td><td>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</td></tr>
<tr><td>2</td><td>f</td><td>ii</td><td>NaOH/ sodium hydroxide ✓</td><td>1</td><td>ALLOW any group 1 hydroxide
IGNORE water/ H_2O</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>26</td><td></td></tr>
</table>

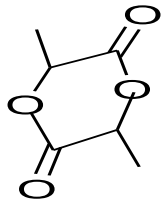
Question			Answer	Mark	Guidance
3	a	i	ethanol ✓	1	**NOT** ethan-1-ol
3	a	ii	propane – 1,2,3 – triol ✓	1	**ALLOW** errors in gaps, commas and dashes **ALLOW** propan – 1,2,3 – triol **IGNORE** glycerol/ glycerine
3	b		2/two ✓	1	
3	c	i	permanent (dipole)–permanent dipole ✓	1	No abbreviations allowed **ALLOW** mis-spellings on the 'sounds like' rule **ALLOW** permanent dipole-induced dipole
3	c	ii	*Type of imb and related reason* 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 ✓ *Less energy to break* Less energy is needed to break/overcome im-bonds or separate the molecules (ora) ✓	3	Second mark in pair depends on first being scored; allow either reason if both id and pd bonds mentioned id–id bond or pd-pd can be abbreviated hydrogen bonds are CON to first two points **IGNORE** 'chains' or comments about molecules fitting more closely mark third mark separately

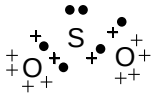
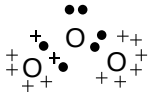
Question			Answer	Mark	Guidance
3	d	i	 two arrows on left-hand structures ✓ intermediate ✓ two arrows on intermediate ✓ Award one mark for one correct arrow on reactant **and** one on intermediate if there are no incorrect arrows (other detail can be incorrect)	3	curly arrows must start on correct atom, 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^-**:** **ALLOW** right-hand arrow starting from a drawn lone pair on $–O^-$ Do not allow 'half arrows' (fish-hooks) the first time encountered, but allow by ecf subsequently. **IGNORE** partial charges
3	d	ii	nucleophile ✓	1	
3	e	i	$C_7H_{11}COOH + ROH \rightleftharpoons C_7H_{11}COOR + H_2O$ Equilibrium sign ✓ equation (with equm sign **or** arrow) ✓	2	**ALLOW** any unambiguous structural formulae **ALLOW** $CH_3CHCHCH_2CHCHCH_2COOH + ROH \rightleftharpoons CH_3CHCHCH_2CHCHCH_2COOR + H_2O$ **IGNORE** errors in the chain as long as there are seven carbon atoms shown in the chain. Mark separately **ALLOW** reaction with ethanol (CH_3CH_2OH or C_2H_5OH)
3	e	ii	catalyst ✓ removes/ reacts with/lowers concentration of water ✓	2	**ALLOW** 'provides H^+ ions'/ 'protonates' as *alternative* to 'catalyst' but only one can score.
3	f	i	C_2H_5C$H(CH_3)COOH$ structure ✓ chiral C marked on correctly bonded structure✓	2	**ALLOW** any unambiguous indication of structure and any clear way of indicating chiral carbon (eg asterisk)

Question			Answer	Mark	Guidance
3	f	ii	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) ✓ For ester C=O: **EITHER** Peak at 1741 **OR** peak in range 1735 – 1750 ✓	2	**ALLOW** 'around/at 3000' for '2500 – 3200' to score this way it must be stated that there is <u>no peak</u> peak value, 'ester' and bond necessary for this mark **IGNORE** extra information even if wrong.
3	f	iii	**1.**structure: $CH_3COOCH(CH_3)_2$ ✓✓ $(CH_3)_2CHCOOCH_3$ ✓ **2.** description of doublet (1.2): one H on adjacent <u>carbon</u> ✓ *Maximum of 2 from* **3.** 3 <u>proton</u> <u>environments</u>/ <u>protons</u> in ratio 6:3:1 (or 1:3:6 etc) **4**. two CH_3 groups on one C / two CH_3 in same environment ✓ **5.** CH attached to O/ C**H**-O/ O-C**H** (5.0) **OR** CH next to <u>carbon</u>(s) with many/six H (5.0) ✓ **6.** CH_3 attached to C=O (2.0) **OR** C**H**C=O **OR** CH_3 next to <u>carbon</u> with no H ✓	5	**ALLOW** any unambiguous representation of the structure **ALLOW** 'H' for 'proton' but **IGNORE** H^+ **5. NOT** CHO **6. IGNORE** CO for C=O **IGNORE** any incorrect points unless they directly contradict one that has been awarded a mark
			Total	24	

Question			Answer	Mark	Guidance
4	a	i	(primary) amide ✓	1	'secondary' is CON
4	a	ii	2 $RCONH_2$ + H_2SO_4 + $2H_2O$ ➔$(NH_4)_2SO_4$ + 2 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	 (one of these needed for second mark) (three of either of these acceptable for first mark) At least three water molecules around ion (can be shown as  or Δ with points towards ion) ✓ correct formula for at least one water molecule, with bent shapes, δ+ on at least one hydrogen, δ– on at least one oxygen, with oxygen pointing towards ion ✓ ion–(permanent) dipole ✓	3	Mark separately detail of water molecule can be shown as separate diagram. Ignore wrong water molecules **ALLOW** 'ion dipole' (no hyphen)

Question			Answer	Mark	Guidance
4	b	ii	**1.** $2NH_4^+(g) + SO_4^{2-}(g)$ ✓ **2.** enthalpy (change) of hydration of ions ✓ **3.** $2NH_4^+(aq) + SO_4^{2-}(aq)$ / $(NH_4)_2SO_4(aq)$ ✓ **5.** $(NH_4)_2SO_4(s)$ ✓ **4.** enthalpy (change) of solution ✓ State symbols must be shown correctly	5	Scale is not important Mark separately, but… **ALLOW** ecf between **1.** and **3.** if wrong species or numbers shown consistently in both **ALLOW** missing '+' sign between ions in **1**. and **3**. **2. ALLOW** 'solvation' for 'hydration' **ALLOW** $\Delta H_{hyd(ration)}$ for 'enthalpy (change) of hydration'(or $\Delta H_{solv(ation)}$) It must be clear that both 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 **4.** To award mark for 'enthalpy (change) of solution', it must be endothermic and upward arrow must be shown **ALLOW** ΔH_{sol}/ $\Delta H_{solution}$
4	c	i	$NH_4^+ \rightleftharpoons NH_3 + H^+$ acid base ✓	1	**IGNORE** 'conjugate'
4	c	ii	$\frac{[NH_3]\,[H^+]}{[NH_4^+]}$ ✓	1	**ALLOW** multiplication signs State symbols not required, but any other than 'aq' [ignore absence of brackets] are CON.

Question			Answer	Mark	Guidance
4	c	iii	**$[H^+]$(or H^+) = 7.4(13102...) x 10^{-6}** ✓ K_a (= $(7.41 \times 10^{-6})^2$ / 0.1) = 5.5×10^{-10} ✓ mol dm^{-3} ✓	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** $K_b = K_w / K_a$ ✓ K_b = 1.0×10^{-14}/(answer to (c)(iii)) calculated (1.8×10^{-5} if (c)(iii) correct) ✓	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^+✓ equilibrium <u>position</u> moves to left ✓ large concentration/ large amount of A^- ✓ pH remains (virtually) unchanged/resists change in pH ✓	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 ✓  ✓	2	**ALLOW** any correct representation of structure
			Total	25	

Question			Answer	Mark	Guidance
5	a	i	 both double bonds correct ✓ completely correct ✓	2	**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 • x x • **IGNORE** shape **ALLOW** other symbols for dots and crosses
5	a	ii	**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˚ ✓	3	**1. IGNORE** 'electron pairs/ bonds/ bonding pairs' **2. IGNORE** 'bonds' and 'pairs' **IGNORE** 'repel as much as possible' **3. ALLOW** 115 – 125 Mark separately No ecf
5	a	iii	 One oxygen with dative bond and three lone pairs ✓ completely correct ✓	2	**See guidance in 5ai** **ALLOW** structure with dative bond and double bond reversed.
5	a	iv	$SO_2(g/aq) + H_2O(l/g) \rightleftharpoons 2H^+(aq) + SO_3^{2-}(aq)$ **OR** $SO_2(g/aq) + H_2O(l/g) \rightleftharpoons H^+(aq) + HSO_3^-(aq)$ equation ✓ state symbols ✓	2	**ALLOW** arrow instead of ⇌. **ALLOW** equations with oxygen forming SO_4^{2-} or HSO_4^- [eg $2SO_2(g/aq)+2H_2O(l/g)+O_2(g) \rightleftharpoons 4H^+(aq)+2SO_4^{2-}(aq)$] ss mark can be awarded if equation is unbalanced but correct species are present (and only those).
5	b	i	$SO_2 + 2H_2S$ ---> $3S + 2H_2O$ +4 ✓ –2 ✓ 0 ✓	3	**NOT** sign after numbers, but give one mark for 4+ **AND** 2–

Question			Answer	Mark	Guidance
5	b	ii	**1.BOTH** moles SO_2 = 44.3/64(.1) **or** 0.69 **AND** moles H_2S = 44.3/34(.1) **or** 1.3 ✓ **2.**SO_2 in excess/ H_2S is limiting (AW)✓ **3.**mass S formed (= 1.3 x 1.5 x 32.1) = 62.6 g [62.4 if 32 used as A_r]✓ **(**Allow any number between 62.4 and 63)	**3**	**ALLOW** any numbers rounding to 0.69 and 1.3 **ALLOW** ecf from **1.** to **2.** and **3.** **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
5	b	iii	low mpt ✓ weak intermolecular bonds/ weak instantaneous dipole–induced dipole bonds ✓ non-conductor/ poor conductor (of electricity)/good insulator ✓ no ions/ no charged particles / no free (or delocalised) electrons ✓	**4**	**QWC**: second mark in each pair depends on first being scored. **IGNORE** 'S is a gas' **IGNORE** 'not ionic' **IGNORE** 'in solution' **IGNORE** references to solubility or boiling point or strength
5	c	i	**1.**an <u>element</u> in group 6 **OR** 'sulfur/S/oxygen/O is/are in group 6' ✓ **2.** <u>compound</u> of S/O/ element with hydrogen ✓	**2**	**ALLOW** 'atom/element with 6 outer electrons' **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
5	c	ii	O/oxygen is more electronegative ora✓ *and **one** from* ✓ • O/oxygen is smaller so gets closer to H (ora) • O–H more strongly polarised/ molecule more strongly polarised/ H more positive (ora)	**2**	must be comparative **ALLOW** '<u>water/H_2O</u> forms hydrogen bonds, <u>H_2S</u> forms pd-pd bonds' (allow abbreviation and just 'pd')

Question			Answer	Mark	Guidance
5	c	iii	density decreases on freezing because: **EITHER** molecules 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 molecules. 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	$(NH_4)_2S + 2NaOH \rightarrow 2NH_3 + Na_2S + 2H_2O$ Na_2S as a product ✓ completely correct ✓	2	**ALLOW** $(NH_4)_2S + 2NaOH \rightarrow 2NH_4OH + Na_2S$ **IGNORE** state symbols **NOT** formulae or equation containing ions formulae must be represented in conventional way but... **ALLOW** otherwise correct balanced equation forming $(Na)_2S$ for 1 mark
			Total	**28**	