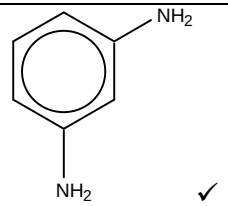
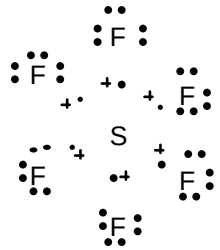
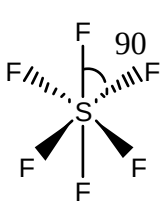
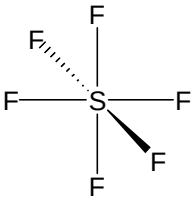
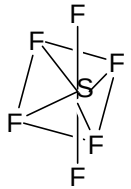
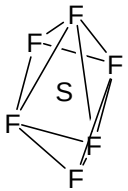
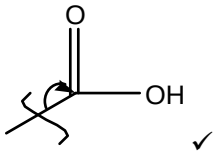
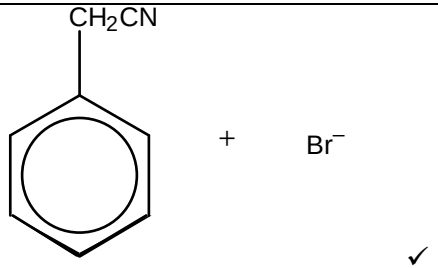
Question			Answer	Mark	Guidance
1	a	i	phenylamine/aniline ✓	1	**ALLOW** aminobenzene, 'phenyl amine' **IGNORE** formulae
1	a	ii	 ✓	1	amine groups meta in any positions NH_2 groups can be displayed any other groups or lines from benzene ring are **CON**
1	a	iii	below 5 ^{o}C **OR** a temperature between -10 and +5 ^{o}C ✓	1	**IGNORE** acid/alkali **ALLOW** 'ice cold' Anything else is **CON**
1	a	iv	electrophilic ✓; substitution ✓	2	any extra terms **CON** one awarded mark e.g. 'electrophilic addition' scores one mark, 'nucleophilic electrophilic substitution' scores one mark
1	b	i	orange / the dye colour is between brown and yellow ✓ two (amine groups) is between 1 and 3 ✓	2	**IGNORE** 'mixture of brown and yellow' **ALLOW** answers in terms of delocalisation, e.g. 'two (amine groups) have intermediate delocalisation' or in terms of chromophore size (AW) Must clearly imply 'between', not just a series. So 'more amine groups take colour from yellow to brown' does not score either mark; 'one has one more NH_2 and the other one less' does score second mark.

Question			Answer	Mark	Guidance
1	b	ii	**A** <u>electrons</u> are excited/move (up) ✓ **B** (move) to higher <u>energy level</u> ✓ **C** absorption of light / absorption of colour / absorption in the visible ✓ (only award if A or B scored: QWC) **D** frequency/wavelength depends on: energy <u>gap/difference</u> **OR** energy needed to excite electrons **OR** ∆E = hv /∆E = hf ✓ **E** complementary colour <u>transmitted/reflected</u> ✓ **F** different no. of amine groups / different amounts of delocalisation / different chromophores: affect ∆E / energy to excite electron / energy absorbed / frequency absorbed / wavelength absorbed ✓	**6**	**Please indicate with a tick where a marking point is scored** 'electrons move up energy levels' scores A and B. Can score **B** without reference to electrons must use absorbed/absorption **ALLOW** absorbtion **NOT** just E=hv unless 'energy gap'/'excite electrons' or similar are mentioned **IGNORE** 'emitted' in E **ALLOW** 'frequencies/ colours not absorbed' for 'complementary colour' **IGNORE** the direction of the effect of delocalisation/chromophore size on ∆E If 'light/energy is given out **<u>when electron drops/moves down</u>'** is stated then maximum of three.
1	c		**A** delocalisation (any mention of) ✓ **B** stability retained in substitution ✓ **C** addition product loses delocalisation/ is less stable/ has higher energy **OR** energy required to break delocalisation in addition ✓	**3**	mark separately **ALLOW** 'maintain delocalisation' if stability has been linked to delocalisation **ALLOW** lower energy product (of substitution reactions) **NOT** 'increase stability'
			Total	**16**	

Question			Answer	Mark	Guidance
2	a	i	S/sulfur ✓ from 0 to +4 ✓ S/sulfur ✓ from 0 to –2 ✓	4	second mark of each pair depends on first (i.e. 'S/sulfur' not present means **no** mark for that line) **ALLOW** 'sulphur' **NOT** signs after numbers, but use of 4+ and 2– scores **one** of the oxidation state marks
2	a	ii	$3SF_4 + O_2 \rightarrow 2SF_6 + SO_2$ ✓	1	**ALLOW** multiples **ALLOW** one missing '+' **ALLOW** $2SF_4 + O_2 \rightarrow SF_6 + F_2 + SO_2$
2	b	i	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ ✓	1	**ALLOW** [Ne] $3s^2\ 3p^4$ **ALLOW** capital letters but numbers **must** be superscripts
2	b	ii	 6 shared pairs with F ✓ 3 lone pairs on F ✓	2	shape not important **ALLOW** '•x' in a line between S and F **ALLOW** 'f' for fluorine mark separately **ALLOW** two fluorines with one lone pair missing but no single electrons on fluorine

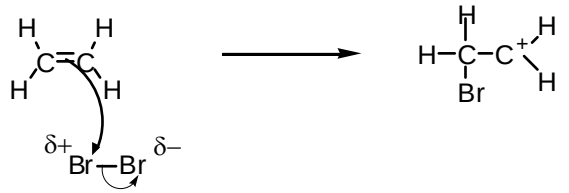
Question			Answer	Mark	Guidance
2	b	iii	 Fig 1  Fig 2  Fig 3  Fig 4 shapes as above ✓ bond angle clearly indicated ✓ bond angle labelled 90 ✓	3	Figs 1 and 2 - **ALLOW** dotted line for 'retreating wedge' **Do NOT allow** 2 wedges or 2 dashes at 180° Fluorines and S must be shown for first mark, but not others **ALLOW** 'f' for fluorine between any two adjacent bonds (even if bonds are 3-dimensionally incorrect)
2	c	i	*Mr* values Li = 6.9 (**or** 7) and SF_6 = 146.1 (**or** 146) ✓ *stated or implied* **ALLOW** 55.2 or 56 (8 moles) for Li 297/146.1 x 8 x 6.9 and evaluated (112.2) ✓ **2 or 3** sf for any calculated answer ✓	3	**If full marks are not given please indicate with a tick where marks are awarded** 110, 112 or 114 score all three marks with no reference to working **ALLOW** ecf for second and third mpts from wrong/rounded M_r **ALLOW** working **or** answer for second mpt **DO NOT AWARD** sf mark if rounding is incorrect
2	c	ii	lithium sulfide ✓	1	**ALLOW** 'lithium(I)' and 'sulphide' **NOT** 'dilithium sulfide' or 'sulfide(II)'
2	c	iii	metallic ✓ covalent ✓ ionic ✓	3	**IGNORE** 'giant' or 'network' **IGNORE** 'small' or 'molecule' or 'simple' or 'molecular' **IGNORE** references to intermolecular bonding **NOT** dative covalent **IGNORE** 'giant' or 'network'

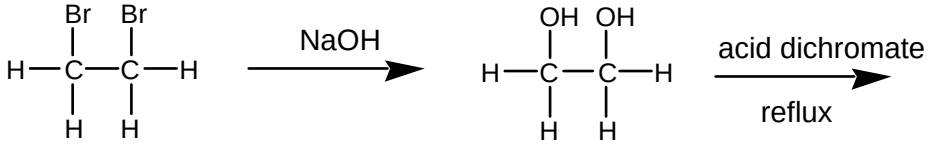
Question			Answer	Mark	Guidance
2	d	i	**A** SF_6 has instantaneous (dipole)-induced dipole (bonds) ✓ **B** hexanedioic acid has hydrogen bonds ✓ **C** imb in acid stronger than imb in SF_6 ✓ **D** (more) <u>energy/enthalpy</u> required to separate molecules / break (or overcome) (im) bonds* (AW)/boil/melt acid (ora) ✓ *this can score **C** also (if comparison)	**4**	*QWC* – 'instantaneous (dipole)-induced dipole' must be spelled correctly first time to score **IGNORE** other imb for hexanedioic acid in **B** **ALLOW C** whatever imb mentioned but needs to be a comparison – though can be achieved by 'weak' for SF_6 and 'strong' for hexanedioic acid **(not** e.g. 'hydrogen bonds are strong', but 'hydrogen bonds strongest' OK**)** **ALLOW** 'intermolecular forces'/imb/imf for 'intermolecular bonds' throughout **ALLOW** abbreviations for named imbs in B,C,D **IGNORE** references to covalent bonds **D** need not be comparison (e.g. just 'hydrogen bonds require (a lot of) energy to break') **IGNORE** 'activation' before 'enthalpy/energy' must imply imb
2	e	i	'products – reactants' expressed as numbers: ([6x36] + 40 – 292 – [8x29])✓ –268 ✓ no ecf	**2**	**ALLOW** first mark if multiples for LiF and Li are wrong or missing or if **one** number is mis-copied Correct answer scores both marks without reference to working +268 scores 1 mark
2	e	ii	use of $\Delta S_{sys} - \Delta H/T$ ✓ **(–**268 + 3000000/298) = +9799 ✓	**2**	Correct answer scores 2 with no reference to working. **ALLOW** only first mark if ΔH is not converted to J (i.e. -268 + 3000/298 [= -258], scores 1 overall) **ALLOW** ecf from value in (e)(i) **ALLOW** 1 or more sf (10000, 9800, 9799(114094)) but rounding must be correct to score second mark. Plus sign must be present for second mark –10335 (to any sf) (wrong sign for $\Delta H/T$) scores 1
2	f	i	$KClO_4$ ✓	**1**	
2	f	ii	(**(e)(ii)** shows reaction is) spontaneous / likely to occur / feasible / favourable ✓ (fuse implies) high activation enthalpy/energy/slow reaction ✓	**2**	**ecf** for negative ΔS values from (e)(ii): **ALLOW** reverse of points given for first mark **ALLOW** 'increases rate of reaction' mark separately
			Total	**29**	

Question			Answer	Mark	Guidance
3	a		$C_8H_8O_2$ ✓	1	**ALLOW** any order of atoms
3	b		$2C_8H_8O_2 + CaCO_3 \rightarrow (C_8H_7O_2)_2Ca + CO_2 + H_2O$ formation of calcium salt + CO_2 ✓ completely correct (with molecular formulae) ✓	2	salt can have Ca first **ALLOW** only $C_8H_8O_2Ca$ or $(C_8H_8O_2)_2Ca$ or $C_8H_7O_2Ca$ (or equivalent structural formulae) for first mark ecf for molecular formula from **(a)** including in salts above
3	c	i	 ✓	1	arrow **must** start on bond (or hit bond if arrow's curve is continued) and end on C of COOH (or hit this carbon if arrow's curve is extended) (arrow can be below bond rather than above and can start either side of the bond breaking sign)
3	c	ii	they do not exist **OR** they are (very) unstable (*AW*) **OR** cannot be obtained **OR** they are theoretical✓	1	**IGNORE** anything else
3	c	iii	 ✓	1	**ALLOW** displayed or partially displayed CH_2CN but must be correct **ALLOW** with missing '+'
3	c	iv	$H^+(aq)/H_2O$ reflux ✓	1	**ALLOW** the H_2O **or the** (aq) missing. **ALLOW** 'acid' or named mineral acid for 'H^+'
3	c	v	(equilibrium (position)) moves to left ✓ moves in endothermic direction (ora) ✓ (equilibrium constant) falls/gets smaller (*AW*) ✓	3	**ALLOW** 'in backwards direction' or 'towards reactant' or 'reverse reaction' for 'left' **ALLOW** anything implying 'goes towards endothermic' or 'going away from exothermic' mark separately – no ecf
3	d	i	ether ✓	1	**ALLOW** alkoxy/alkoxyl

Question			Answer	Mark	Guidance
3	d	ii	(secondary) amine ✓	1	**ALLOW** alkene **ACCEPT** indole primary amine is **CON**
3	d	iii	**Any one pair from:** C=O ✓ 1700 – 1725 (cm^{-1}) ✓ O–H ✓ 2500 – 3200 (cm^{-1}) ✓ C–H ✓ 2850 – 2950 (cm^{-1}) **or** 3000 – 3100 (cm^{-1}) ✓	2	**IGNORE** *descriptions* of bonds/groups (e.g. 'alcohol') **ALLOW** one mark for a correct bond with no/incorrect range or a correct range with no/incorrect bond Extra incorrect bonds and/or incorrect peaks **CON** ONE mark already scored (e.g. C=O and 1700-1725, followed by 'N-H and/or 3300-3500' scores ONE; C=O 1720 – 1740 followed by 'N-H and/or 3300-3500' scores zero) **ALLOW** 'OH' for 'O-H' and 'CH' for 'C-H' but NOT 'CO' for 'C=O' **IGNORE** arene absorptions (1450 – 1650)
3	d	iv	ring going around COOH group **AND** the CH_2 attached ✓	1	ring does not need to be a circle! it **must** cut the O–C bond somewhere, not through the CH_2 or the O
3	e	i	$C_6H_3Cl_2OCH_2COO^-$ ✓ $(CH_3)_2NH_2^+$ / $(CH_3)_2N^+H_2$ ✓	2	**ALLOW** any (correct) formula for anion and cation, e.g. as shown on left, full structural, skeletal etc. the plus charge must be on or around amine group mark separately
3	e	ii	the salt/it will be (much more) soluble ✓	1	**ALLOW** salt is less acidic (must be comparison)
3	f		any ***two*** from: ✓✓ • its usefulness/effectiveness (AW) **OR** nothing better to use **OR** no alternatives • it can be used with care (AW) / used in low concs / small amounts • greater yield of crop / greater profit / cheap / cheaper food	2	 **IGNORE** 'washing of crops' 'use with care' can mean 'keep away from humans/animals' or 'use responsibly'
			Total	20	

Question			Answer	Mark	Guidance
4	a		1,2-dibromoethane ✓ 1-bromo-2-chloroethane ✓	2	**IGNORE** spaces, gaps and dashes and commas **ALLOW** '2-bromo-1-chloroethane', '1-chloro-2-bromoethane' and '2-chloro-1-bromoethane' watch out for 'ethene' rather than 'ethane' but give BOD. If both have 'ethene' can award **one** if all else correct
4	b		**A** $C^{\delta+}$– hal(ogen)$^{\delta-}$ **OR** carbon slightly positive **and** halogen slightly negative (AW) ✓ **B** C and halogen differ in electronegativity **OR** halogen is more electronegative (than carbon) ✓ **C** CBr_3CBr_3 all dipoles cancel **OR** centre of negative charge is in same place as centre of positive charge ✓ **D** CH_2BrCH_2Cl – reverse of **C**. ✓ **E** difference in electronegativity between Br and Cl **OR** Cl more electronegative than Br (ora) **OR** difference in polarities of C-Cl and C-Br **OR** C-Cl more polar than C-Br **OR** partial charges of Cl and Br different ✓	5	**Please indicate with a tick where a marking point is scored. Beware of answers that repeat the question** (e.g. 'CBr_3CBr_3 has no overall dipole') **ALLOW** references to a specific halogen for mpt **A** and **B** **IGNORE** references to symmetry **ALLOW** 'charges cancel out/balance' (**NOT** 'electrons spread evenly') **ALLOW** one end/side has more (partial) negative/positive charge than the other **OR** charges don't cancel **OR** chlorine has (partial) negative charge the nature of the difference in electronegativity does not need to be stated in **A** and **E**, but if it is stated it must be correct **ALLOW** '(bond)polarities' for 'dipoles' **throughout**
4	c		gas-liquid (chromatography) ✓	1	**ALLOW** 'GLC'

Question			Answer	Mark	Guidance
4	d		**A** hydrogen bonds in water ✓ **B** dipole - dipole bonds in/between halogenoalkanes ✓ **C** similar imb are formed in the mixture as are found in the separate substances (AW) (only award **C** if **B** made: QWC) **OR** imb formed have similar energy/strength to those broken ✓ **D** hydrogen bonds stronger than imb <u>between water - halogenoalkanes</u> **OR** hydrogen bonds not formed <u>between halogenoalkanes and water</u> **OR** energy required to break hydrogen bonds is not provided by <u>imb between halogenoalkane and water</u> (*AW*) ✓	4	**Please indicate with a tick where a marking point is scored** **ACCEPT** pd-pd or id-id or pd-id or pd for **B** **ALLOW** any sort of dipole bond in **B** **ALLOW** abbreviations of imb throughout **ACCEPT** 'imf' for 'imb'
4	e	i	 for curly arrows ✓✓; dipole* ✓; intermediate ✓ * delta plus must be nearer to alkene	4	curly arrows must start at bonds and end on atom* (top one may end between Br and the C it is shown (in the intermediate) as bonding to) * or start and end there if curve of arrow followed **ALLOW** cyclic bromonium ion as intermediate **ALLOW** any clear structure for intermediate (e.g. $CH_2BrCH_2^+$) **IGNORE** anything formed from the intermediate **or** Br^- as a product **IGNORE** any extra delta pluses or minuses MAX 3 if any hydrogen atoms omitted Half-arrows – first one is CON to correct arrow, allow second as ecf
4	e	ii	positive / partially positive / electron deficient reagent **OR** attracted to area of high electron density ✓ receives electrons/lone pair **AND** forms (covalent) bond ✓	2	

Question			Answer	Mark	Guidance
4	e	iii	Cl^- is not an electrophile **OR** Cl^- cannot attack **OR** Cl^- is not attracted **OR** no Cl^+ present ✓ Cl^- attacks/reacts with/is attracted to intermediate/carbocation (once Br is there) ✓	2	**ALLOW** Cl^- is a nucleophile
4	f		 NaOH ✓; intermediate ✓; acid dichromate ✓; reflux ✓ starting compound need not be shown no ecf, mark step 1 and intermediate separately only allow acid dichromate and reflux marks if intermediate has at least **one** OH group	4	**ALLOW** any type of organic formula (except molecular) **ALLOW** KOH or OH^- for NaOH **IGNORE** conditions for first reaction **ALLOW** expanded names and **correct** formulae for 'acid dichromate'* (e.g. 'sulfuric acid and sodium dichromate') ***IGNORE** oxidation state of dichromate and small spelling errors (e.g. 'dicromate') **IGNORE** formula if correct name given 'reflux' scores **only** if dichromate (or its formula) is mentioned **IGNORE** state symbols and formula of product **IGNORE** attachment of H of OH to carbon must be clear which reagent performs which step
4	g		**Check spectrum for responses each time*** (errors on spectrum can be ignored) **A** CH_3CHBr_2 **OR** displayed ✓ **B** (two peaks hence) two hydrogen environments ✓ **C** hydrogens (in ratio) 3:1 ✓ **One from:** **D** CH_3/3H split into two by: CH **OR** one hydrogen on adjacent C **E** the CH/1H split into four by: the CH_3 **OR** three hydrogens on adjacent C ✓	4	**Please indicate with a tick where a marking point is scored** mark separately **C** cannot be scored *simply* from '3H' '1H' **ALLOW** 'proton' or H for 'hydrogen'. Use of 'H^+' or 'hydrogen molecule' for 'hydrogen' **CON**s one of B C, and D the first time it us used **B,C** and **D** can be indicated by appropriate labels on a formula (*or on spectrum) **NOT** just 'adjacent environment' peaks can be referred to by chemical shifts
			Total	28	

Question			Answer	Mark	Guidance
5	a	i	hydrogenphosphate(V) ✓✓ 'hydrogenphosphate' with no (or a wrong) number scores 1 mark	2	**ALLOW** gap ('hydrogen phosphate') **ALLOW** 'monohydrogen...' **ALLOW** spelling errors if names sound correct **IGNORE** '5' or '+5'
5	a	ii	H_3PO_4 ✓	1	**NOT** H_2PO_4H
5	b	i	$[HPO_4^{2-}]$ $[H^+]$ / $[H_2PO_4^-]$ ✓ **Please check carefully**	1	
5	b	ii	$[H^+] = \sqrt{(6.2 \times 10^{-8} \times 0.1)} = 7.87(40079) \times 10^{-5}$ ✓ $pH = -\log [H^+] = 4.1(038)$ ✓	2	**ALLOW** 2 or more sf for 1st mark. Working alone does NOT score. Second mark for correct manipulation of any **given** $[H^+]$ value* (to one or more decimal place) Correct answer scores 2 without reference to working (do NOT accept '4') * must say 'H^+ =' at least
5	c	i	little/no change in pH **OR** resists change in pH ✓ when <u>acid</u> or <u>alkali</u> added ✓ in <u>small</u> quantities ✓ cell <u>enzymes</u> work at specific/optimum pH **OR** change in pH can stop enzymes working *AW* ✓	4	Both acid **AND** alkali must be mentioned depends on mention of acid **or** alkali for second mark **ALLOW** 'denatured if pH changes'
5	c	ii	(increase $[H^+]$)moves equilibrium (position) to left ✓ removes H^+ **OR** restores pH / restores $[H^+]$ ✓ $[HPO_4^{2-}]$ large **OR** large amounts of HPO_4^{2-} ✓	3	must mention equilibrium **ALLOW** H^+ reacts with HPO_4^{2} for second mark **ALLOW** HA for $H_2PO_4^-$and A^- (or salt or conjugate base) for HPO_4^{2-}
5	c	iii	$[H^+]$ = Ka **OR** pH = pKa ✓ pH = 7.2 ✓	2	Correct answer scores 2 without reference to working **ALLOW** 7.2076 to one or more decimal places *no ecf*

Question			Answer	Mark	Guidance
5	d		**ALLOW** full sodium salt formulae instead of ion formulae throughout **ALLOW** [acid] for $[H_2PO_4^-]$ and [salt] for $[HPO_4^{2-}]$ $[H_2PO_4^-]$ / $[HPO_4^{2-}]$ = $[H^+]$ / Ka (or inverse) ✓ *stated or implied* $[H_2PO_4^-]$ / $[HPO_4^{2-}]$ = $1 \times 10^{-7} / 6.2 \times 10^{-8}$ = 1.61 ✓ (or inverse 0.62) divide ratio by 10 (0.161) moles of NaH_2PO_4 ✓ ans x 120 = 19.2 or 19.3 **or** 19.4 g ✓	**4**	**If marks awarded are not as below - please indicate with a tick where a marking point is scored** Award 4 marks for correct answer without reference to working (19, 19.2, 19.3, 19.4) 193/194 scores **3** overall; 7.44 scores **2** overall; 74 scores **1** overall **ALLOW** 2 or more sf MUST be with salt ratio or $[H_2PO_4^-]$ as subject, but can have values substituted ONLY scores if correctly evaluated, but expression scores first mark **ALLOW** 0.1 for $[HPO_4^{2-}]$ **AWARD** last mark if some number is shown as multiplied by 120 and correctly evaluated (to 2 or more sf)
5	e	i	indication of calculation/comparison of moles of substances ✓ statement of 1:2 ratio ✓	**2**	e.g. moles NaH_2PO_4 = 15 x 0.1/1000 moles NaOH = 7.5 x 0.4/1000 first mark must have indication of at least one reagent second mark can be scored from a '2' in the right place in a calculation **ALLOW** arguments such as 'twice as many moles of NaOH needed but solution 4x more concentrated, hence half as much needed' for 2 marks
5	e	ii	(weak acid) ionises/dissociates: as H^+ removed **OR** as the acid reacts with hydroxide/base *AW* **OR** (a weak acid) fully reacts with sodium hydroxide/strong base *AW* ✓	**1**	**NOT** whole molecule reacts

Question			Answer	Mark	Guidance
5	f		$\underline{Na^+(g)\ (+)\ OH^-(g)}$ ✓ sum ✓ of enthalpy change(s)$^+$ of hydration/solvation ✓ $\underline{NaOH(s)}$ enthalpy change of solution*✓ $\underline{Na^+(aq)\ (+)\ OH^-(aq)/NaOH(aq)}$ ✓	5	ΔH terminology may be used instead of 'enthalpy change of' (i.e $\Delta H_{hyd(ration)/solv(ation)}$ and $\Delta H_{sol/soln/solution}$) **ALLOW** 'enthalpy' for 'enthalpy change' marks for enthalpy changes include correct arrows * mark only scored if shown as exothermic + 'sum' mark is scored if answer says 'enthalpy changes' (plural) or both ions are referred to mark independently
			Total	**27**	