

GCE

Chemistry B (Salters)

Unit **F335**: Chemistry by Design

Advanced GCE

Mark Scheme for June 2016

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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Annotations used in RM Assessor:

Annotation	Meaning
✓	correct response – there must be one tick for every one mark awarded
✗	incorrect response – These should not be used for every mark lost; just use them in places where it makes your marking clearer.
bod	benefit of the doubt given. Please give a tick as well
nbod	benefit of the doubt not given
ECF	error carried forward
^	information omitted
I	Ignored
SEEN	to be used on any other page where there is a response but no other annotation
BP	indicates a blank page that has been checked.
CON	contradicts a correct response and negates the mark
SF	to draw attention to the significant figures

1. Subject-specific Marking Instructions that apply across the whole question paper to be included here.

Accept minor mis-spellings where the 'sound' is right (eg 'percipitate'), except where it changes a technical term (eg alkene/alkane)

If the answer on the answer line (or in box) differs from a previous answer (copying error), mark the answer on the answer line (or in box). If the answer line (or box) is blank, reward the answer elsewhere if possible.

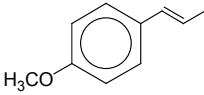
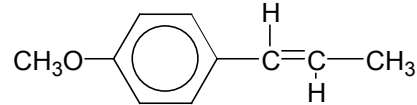
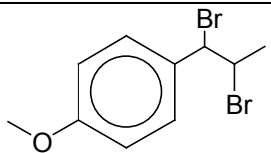
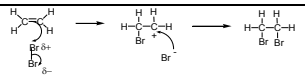
In calculations, rounding errors should not be rewarded, unless the Mark Scheme indicates otherwise. Where a numerical answer is carried forward from a previous part, either the answer in the previous part or the answer left in the calculator may be used.

If it says 'mark separately' marks can be awarded even if the answer does not hang together well without the other mark. However, if the later marking point has words in brackets before it, the mark should only be awarded in the context of those words.

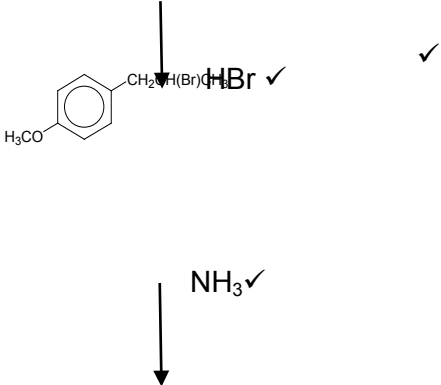
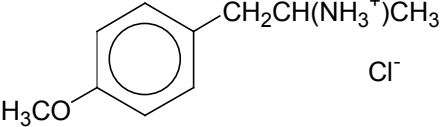
Formulae must have correct brackets and subscripts to score. Element symbols must have small second letters (eg not 'BA'). These errors and the use of a wrong symbol should, if possible, only result in the loss of ONE mark in a part (rather than more marks).

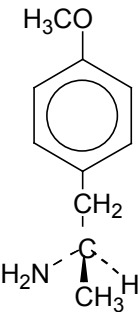
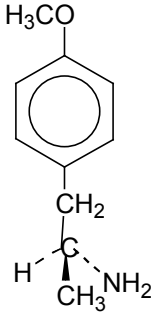
Multiples of equations are acceptable (including halves) unless specified otherwise.

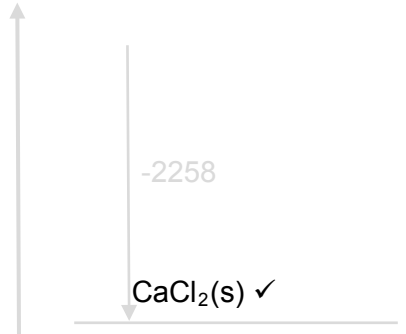
Allow the omission of one plus sign in an equation if the species are still well separated.

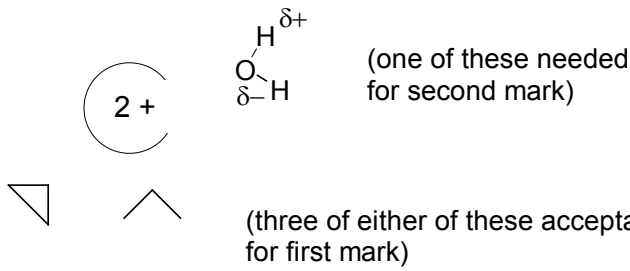
-Question			Expected Answers	Marks	Additional Guidance
1	a	i	$C_{10}H_{12}O$	1	ALLOW elements in any order
	a	ii	ether	1	ALLOW methoxy
	a	iii		1	ALLOW any appropriate structural formula or mixture of types of formula. ALLOW  IGNORE small errors in structure if trans is clear
	b			1	must be skeletal (including ether) ALLOW both bromines on same side
	c	i	 bromine attacking $C=C$ including curly arrow and curly arrow and dipole on bromine ✓ intermediate formula (could be cyclic)✓ Br^- attacking and formula of product ✓	3	curly arrows must start (when projected back) on bond (or – [or lone pair if drawn] on Br^-) and finish pointing at atoms shown or at the new bond to be formed. IGNORE half arrows. IGNORE partial charges on atoms (or bond) of $C=C$
					ALLOW last mark if there is no charge on carbocation

-Question			Expected Answers	Marks	Additional Guidance
	c	ii	(First) attack/attraction (AW) is by an electrophile (Br_2) OR by $\text{Br}^+/\text{Br}^{\delta+}$ ✓ (Then) H_2O/water can attack (AW) (carbocation)/ can act as nucleophile AW OR water is not an electrophile ✓	2	ALLOW 'OH' for 'water' but not OH^-
	d		1. Hydrogen bonds are formed between lone pair on O ✓ 2. and $\text{H}^{\delta+}$/ H polarised by O-H/ partially(AW) positive hydrogen/H ✓ 3. Anethole hydrogen bonds (with water) ✓ 4. hydrogen bonds in water are broken 5. hydrogen bonds in water are greater/stronger than imb between anethole and water OR more hydrogen bonds broken than made OR more energy is needed to break bonds than is released in making them OR anethole only forms one/two/few hydrogen bonds OR rest of anethole can't hydrogen bond (ORA)/ forms id-id ✓	5	ALLOW 1., 2. and 3. from diagram reference to hydrogens in anethole forming H-bonds CONS 2. (1. and 2. can be scored separately) 3. and 4. can be scored with some of the alternatives for 5. 5. ALLOW – for dissolving to occur strength/energy of bonds broken must (roughly) equal strength/energy of bonds made IGNORE other attempts at this point if one is correct

-Question			Expected Answers	Marks	Additional Guidance
	e	i	 Reaction scheme for question e.i: 4-methoxybenzyl bromide reacts with HBr to form an intermediate (4-methoxybenzyl bromide). This intermediate then reacts with NH₃ to form 4-methoxy-N,N-dimethylethanaminium chloride.	3	ALLOW any unambiguous formula for intermediate ALLOW 'NaBr/H⁺' for 'HBr' Can be names of reagents IGNORE state symbols on reagents ALLOW substitution of HCl/hydrochloric acid with chlorine on intermediate Mark all points separately. BUT For 1 mark, allow Br₂ or H₂O for first reagent followed by corresponding product in intermediate box.
	e	ii	 Chemical structure of 4-methoxy-N,N-dimethylethanaminium chloride.	1	ALLOW 'NH₃Cl' instead of ions but not 'NH₃-Cl' ALLOW N⁺H₃ and (NH₃)⁺ ALLOW without the chloride

-Question			Expected Answers	Marks	Additional Guidance
	e	iii	Drug X has C/chiral centre with four different groups/ asymmetric C ✓ indication of which C and which four groups ✓ no equivalent C in anethole (AW) ✓	3	second marking point can be scored from e(iv) if not scored here ALLOW 'nonsuperimposable mirror image' as alternative to first mpt
	e	iv	  one correct 3d structure ✓ mirror image ✓	2	ALLOW  instead of ----. ALLOW any unambiguous representation of the 3d structures, but straight lines must not be at 180°. (allow mirror image by ecf) IGNORE incorrect groups when marking mirror image IGNORE non-reflection of NH₂ etc IGNORE bonds to hydrogens rather than C/N ALLOW correct enantiomers even if not shown as mirror images ALLOW any indication of organic group even if slightly erroneous and ambiguous attachments
	e	v	peak/trough at 3300 - 3500 (cm⁻¹)/ one value in the range caused by N-H/NH₂/amine ✓ no peak at 1620 – 1680/ one value in the range caused by C=C/ alkene ✓	2	Both range and bond/group needed in each case. Award one mark for both ranges without bonds/groups or vice versa
			Total	7	

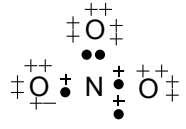
Question			Expected Answers	Marks	Additional guidance
2	a	i	$\text{Ca}^{2+}(\text{g}) + 2\text{Cl}^{-}(\text{g})$ ✓  $\text{CaCl}_2(\text{s})$ ✓ $\text{CaCl}_2(\text{aq})/\text{Ca}^{2+}(\text{aq}) + 2\text{Cl}^{-}(\text{aq})$ ✓ $\Delta H = -120 \text{ (kJ mol}^{-1}\text{)}$ ✓✓	5	allow ecf for omission of '2' on both energy levels IGNORE extra energy level for hydration in two steps ALLOW lack of plus signs between ions solution level need not be below solid level to score 120 scores 1 mark; +120 does not score; +244 (only one hydration of Cl^{-}) scores 1 mark if solution level is above solid level.
	a	ii	greater charge (density) (of Ca^{2+}) ✓ stronger attraction/bonds to water molecules (ora for chloride) OR more water molecules attracted OR stronger/more ion-dipole bonds formed ✓	2	Mark separately IGNORE 'hydration' or 'hydrated'

Question	Expected Answers	Marks	Additional guidance
b	 (one of these needed for second mark) (three of either of these acceptable for first mark) At least three water molecules around ion with 2+ charge (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 ✓	2	ALLOW Ca ²⁺ as ion label, circle not necessary
c	moles CaCl₂ = 58.5/111.1 or 0.527 ✓ lowering of fpt for CaCl₂ = 3.7 x 0.527 x 1.5 (= 2.9) so fpt is -2.9 °C multiplication by 1.5 ✓ rest ✓	3	Allow ecf from mpts 1 to 2 without reference to working: -2.9 on answer line scores 3 2.9 scores 2 -1.9(48....)(or -1.95) scores 2 1.9 etc scores 1 ALLOW slightly different values after checking any intermediate rounding ALLOW 2 or more significant figures
d i	CaCO ₃ + 2NaCl → Na ₂ CO ₃ + CaCl ₂ ✓✓	2	Unbalanced equation with just these species OR Balanced equation involving CaO, CO₂ instead of CaCO₃ scores 1 mark IGNORE state symbols IGNORE omission of plus signs or arrow if meaning is clear
d ii	Atom economy 100% AND No waste or both products useful ✓	1	

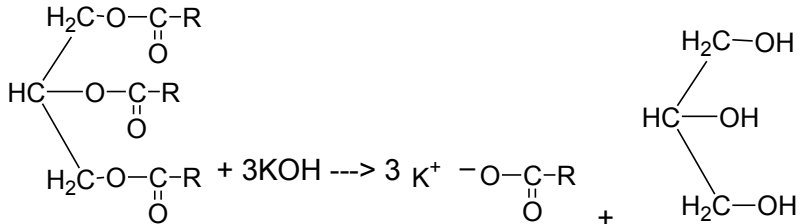
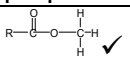
Question			Expected Answers	Marks	Additional guidance
	e		sodium hydrogencarbonate ✓ ammonium chloride ✓	2	allow 'sodium hydrogen carbonate' and (I) after sodium (but not ammonium)
	f		Entropy is a measure of disorder or number of ways of arrangement/distribution of molecules/particles/energy <u>quanta</u> ✓ (more) gas formed has more/higher entropy/disorder/ways of arrangement ✓	2	ALLOW 'disorder' or 'ways of arrangement' for 'entropy' NOT arrangement of a molecule IGNORE 'more molecules formed' needs to be mention of gas formed and it having higher/more entropy
	g		$\Delta S_{\text{sys}} = (+) 215 \text{ (J K}^{-1} \text{ mol}^{-1})$ ✓ $T = \Delta H / \Delta S_{\text{sys}}$ OR $T = 91000 / 215$ ✓ $T = (+) 423 \text{ (K)}$ ✓	3	ALLOW ecf from each step Second marking point can subsume first ALLOW two or more significant figures Negative answers do not score the third marking point even if they follow by ecf. If 423 shows in working but 424 given, mark can be awarded. Correct answer on answer line scores 3 marks

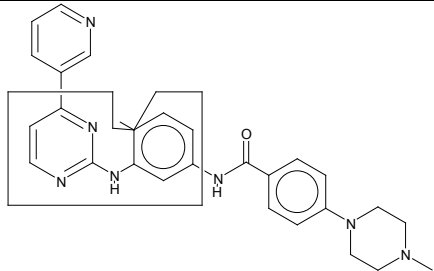
Question			Expected Answers	Marks	Additional guidance
	h	i	$\text{NH}_4^+ \rightleftharpoons \text{NH}_3 + \text{H}^+$ OR $\text{NH}_4^+ + \text{H}_2\text{O} \rightleftharpoons \text{NH}_3 + \text{H}_3\text{O}^+$	1	If ss are present they must be (aq) [or (l) for water]
	h	ii	$[\text{H}^+] = \sqrt{(5.6 \times 10^{-10} \times 0.01)}$ or $2.37 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$ ✓ pH = 5.6(3) ✓	2	ALLOW 'H ⁺ = ' for '[H ⁺] = ' Ecf for second mark for a [H ⁺] (or H ⁺) value larger than 1×10^{-7} and smaller than 1×10^{-3} . Must be to at least one decimal place Correct answer scores both marks without working
	h	iii	1. H ⁺ added ✓ 2. eqm <u>position</u> moves to left ✓ 3. large NH ₃ (concentration) ✓ 4. pH constant/little change ✓	4	1. IGNORE 'acid added' 2. This mark cannot be scored if it does not match the equation in (i) – allow ecf from equation in (i) but it must contain H ⁺ . QWC only allow 2nd mpt if 1st scored or it says 'acid added' 3. and 4. mark separately
	h	iv	Use of $[\text{H}^+] = K_a \times [\text{NH}_4^+]/[\text{NH}_3]$ or pH = pK _a – log $[\text{NH}_4^+]/[\text{NH}_3]$ or $[\text{H}^+] = 2.8 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$ ✓ pH = 9.55/ 9.6 ✓	2	Mark this part without reference to h(i). Correct answer scores 2 marks without reference to working; 8.95/ 9.0 (ratio wrong way up) scores 1 mark without reference to working; no other ecf. must be at least one decimal place
			Total	31	

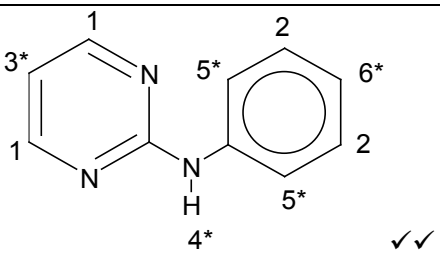
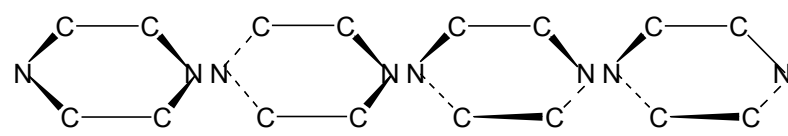
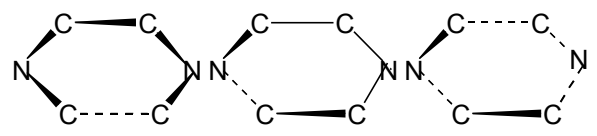
Question			Expected answer	Mark	Additional Guidance
3	a	i	Yes, and equal moles on each side OR units cancel	1	ALLOW 'particles' or 'molecules' or 'species' for 'moles'
	a	ii	exothermic AND K_c is lower/ eqm moves to the left/ conc of reactants is higher at higher temperatures ✓	1	
	a	iii	High temp to increase reaction rate ✓ Low temp to increase yield/ more products/ equilibrium(position) moves to right ✓	2	ALLOW on its own mark separately
	b	i	Ratio of CO (reacted) to H_2 (formed) is 1:1 OR H_2 formed is $1.5 \times 10^{-3} - 4 \times 10^{-5}$ ✓ Small amount of CO left/ 4×10^{-5} can be ignored OR 1.46×10^{-3} is 1.5×10^{-3} to 2 sf ✓	2	ALLOW same number of molecules/moles/amounts IGNORE CO and H_2O are 1:1 ALLOW 'virtually all CO converted/ reacted'
	b	ii	$[H_2] = [CO_2]$ ✓ $[H_2O] = (1.5 \times 10^{-3})^2 / 4 \times 10^{-5} \times 58$ $= 9.70 \times 10^{-4}$ (one or more sf) ✓ Answer to 1 sf = 1×10^{-3} ✓	3	scores if $(1.5 \times 10^{-3})^2$ seen in working. Correct answer to any sf scores 2 and correct answer to 1sf scores 3 without reference to working. ALLOW 10×10^{-4} Any answer to 1sf scores last mark separately.
	b	iii	concentration at 1 atm = $1/24 = 0.042 \text{ mol dm}^{-3}$. $1.5 \times 10^{-3} / 0.042$ $= 0.0357 / 0.04 \text{ atm}$ ✓	1	Answer alone scores mark ALLOW 1 or more sf
	c		The (kinetic) energy needed by (a pair) of molecules/particles to react when they collide OR the energy required to break the bonds in reactant (molecules) ✓ Catalyst provides a route of lower E_a ✓ More frequent/ higher proportion of collisions with energy greater than/equal to E_a OR more frequent successful collisions ✓	3	Must have ideas of particles and collision to score by first alternative. ALLOW 'successful collision' for 'react when they collide' IGNORE 'catalyst lowers E_a '. Must mention collisions

Question			Expected answer	Mark	Additional Guidance
	d	i	 five electrons from N ✓; completely correct ✓ +5 ✓	3	oxygen atoms can be in any position; the left-hand one (here) can be with a minus, as shown or an extra cross or another symbol. IGNORE brackets and minus signs Expansion of the octet does not score second mark NOT 5+ or 5
	d	ii	$\text{NH}_4\text{NO}_3 \rightarrow 2\text{H}_2\text{O} + \text{N}_2\text{O} \checkmark$ dinitrogen (mon)oxide or (di)nitrogen(I) (mon)oxide AND colourless (gas) ✓	2	IGNORE state symbols ALLOW halves and multiples IGNORE gaps in name second mark depends on N_2O being formed ALLOW ecf from NO or NO_2 formed in the equation.
				18	

Question			Expected Answers	Marks	Additional guidance
4	a	i	+3✓ $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$ ✓	2	NOT 3+ or 3 ALLOW capital letters but numbers must be superscripts. ALLOW ecf for Fe^{2+} only ($3d^6$) ALLOW repetition of ' $1s^2 2s^2$ ' IGNORE $4s^0$
4	a	ii	Amount of water = $0.216/18 = 0.012$ mol ✓ (Mass of anhydrous = $1.066 = 0.012$ mol so) $n = 1$ ✓	2	Mark separately $n = 1$ on the answer line (without first marking point) scores second mark only
	a	iii	Amount Fe = 0.012 mol = 0.670 g Mass O = $1.066 - 0.670 - 0.140 = 0.256$ ✓ Amount O = $0.256/16 = 0.016$, $y = 4$ ✓ OR 1 mole $FeO(OH) \rightarrow \frac{1}{3}$ mole Fe_3O_x so 0.012 mol $\rightarrow 0.004$ mol 0.004 moles have a mass of $(1.066 - 0.14)g = 0.926g$ ✓ 1 mole weighs $0.926/0.004 = 231.5g$ Mass of the 3 Fe atoms subtracted = $64g$ so 4 moles of O $y = 4$ ✓	2	working must be checked look for mass O = 0.256 or <u>0.004 moles</u> weigh $0.926g$ for 1 mark $y = 4$ without coherent working scores 1
	b	i	Yellow/green (or 'yellow/green' or orange) because: it reflects this/ reflects between red and blue	1	must say 'reflects' (or a derived word) or 'maximum reflectance' and give colour to score
	b	ii	(3)d energy levels/subshells/orbitals split (by ligands) ✓ electrons excited (or move) to higher energy level/shell/orbital or be excited/move up from lower level ✓ light absorbed and $\Delta E = hv$ or hf ✓ complementary frequency/colour/wavelength <u>reflected/transmitted</u> ✓	4	IGNORE 'D' ALLOW 'frequency <u>proportional</u> to energy gap/difference' for ' $\Delta E = hv$ ' (or $E = hv$ if 'energy gap/difference' is implied). (or 'photon energy hv ') ALLOW 'complimentary' or 'frequencies not absorbed are <u>reflected/transmitted</u> '. IGNORE 'emitted' but any indication of light being given out when electrons fall CONs last marking point.

Question			Expected Answers	Marks	Additional guidance
	c		Spectrum is coloured lines ✓ on dark/black (background) ✓ lines/spectrum/frequencies are unique/characteristic/specific to an element/Fe ✓ because energy gaps are unique OR compare with known data AW ✓	4	IGNORE atom, compound and molecule must imply 'gaps between levels' not just 'levels' to score
	d	i	 ester ✓; reaction with 3KOH and 3 salts formed ✓ propane-1,2,3-triol ✓	3	ALLOW any unambiguous structural formulae to score eg –OOCR etc for esters ALLOW with OH[–] as reactant and carboxylate ion as product, without K⁺ spectator ion ALLOW 'OK' but not 'O–K' for 'O[–] K⁺' Give one mark for ester and triol structures swapped as reactant and product
	d	ii		1	ALLOW 'RC' without bond
	d	iii	methanol and conc sulfuric acid/ conc hydrochloric acid ✓	1	ALLOW formulae IGNORE carboxylic acid if mentioned
	e		nitrogen/ argon other named noble gas ✓ high boiling point/ involatile/ non-volatile liquid ✓ some time unit ✓	3	ALLOW formulae
				23	

Question			Expected Answers	Marks	Additional guidance
5	a		the N atoms hydrogen bond (to water)	1	
	b	i		1	ALLOW lines cutting bonds to do so anywhere on the bond.
	b	ii	<i>shape</i>: it has correct shape/ similar shape to substrate/ complementary shape to the enzyme/active site ✓ <i>binds</i>: to fit into/binds/bonds with active site ✓ <i>blocking</i>: blocking it to <u>substrate</u>/competing with <u>substrate</u> AW✓ C: C fits into one/fewer enzyme(s) OR resembles the substrate more/ fits/binds better OR forms more/stronger imb AW ✓	4	QWC: word 'substrate' must be used and spelled correctly to score third marking point. This must be comparative can score first mark here
	c	i	conc nitric and sulfuric acids ✓ (below) 55 °C ✓	2	ALLOW formulae. 'Conc'/'concentrated'/'c.' must be mentioned once somewhere 'reflux' is CON Mark separately
	c	ii	tin and concentrated/conc hydrochloric acid	1	IGNORE formulae IGNORE 'hydrogen chloride'
	c	iii	(secondary) amide ✓ C_6H_5COCl ✓ benzoyl chloride ✓	3	ALLOW $C_6H_5CO-O-COC_6H_5$ ALLOW molecular formulae and any type of structural formula ecf: Name can match formula but only for benzoic anhydride or benzoic acid.

Question			Expected Answers	Marks	Additional guidance
	d	i	$C_{10}H_9N_3$	1	ALLOW elements in any order
	d	ii		2	Asterisked numbers can be transposed two marks for completely correct; <i>one mark if:</i> '5' and '5' shown as the same (NOT 1) and different from others on right-hand ring and '4' shown as a unique no. OR all correct except for the omission of a number on the NH ALLOW '4' above N
	e		109 (⁰) ✓ pyramidal ✓ 4 groups/pairs of electrons/ 4 areas of electron density ✓ (electrons) repel and get as far away from each other as possible ✓ diagram of either chair or boat or 3D structure (wedges and dashes) ✓ eg award the mark to: 	5	ALLOW 105 – 110 IGNORE 'trigonal', 'triangular' and 'tetrahedral' no ecf from angle on 3rd mark. QWC Do not award third mark if angle incorrect ALLOW 'minimise repulsion' IGNORE 'repel as much as possible' Examples shown are not exhaustive. Four adjacent atoms connected by the same three symbols is incorrect (no mark) eg:  IGNORE CH₃ groups on nitrogen or hydrogens or lone pairs or bond angles
	f		Each atom in the ring contributes one electron ✓ electrons delocalised ✓ two rings of electrons above and below ring (of atoms)/ plane/atoms/ molecule ✓	3	ALLOW N atoms contribute two/lone pair electrons must make it clear there are two rings
23					

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