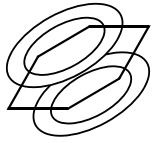
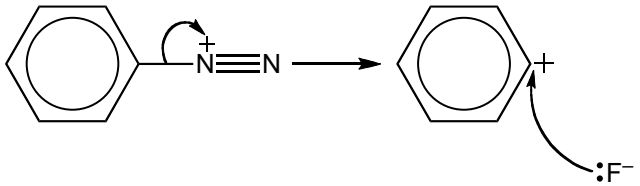
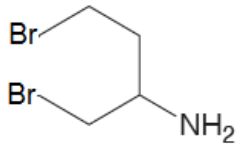
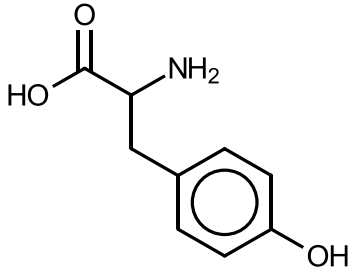
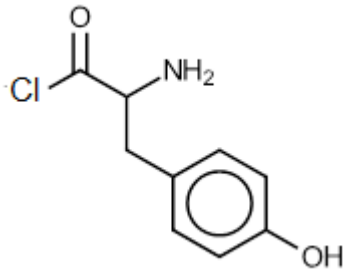
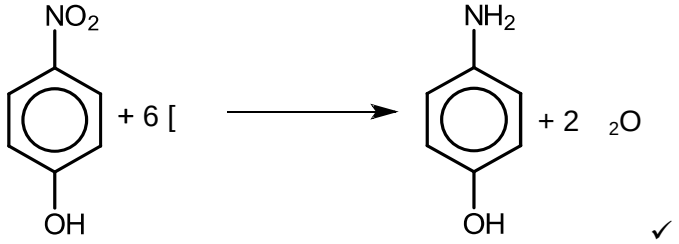
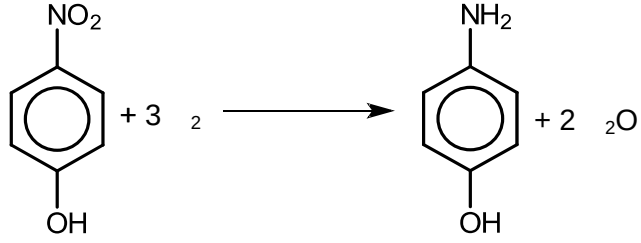
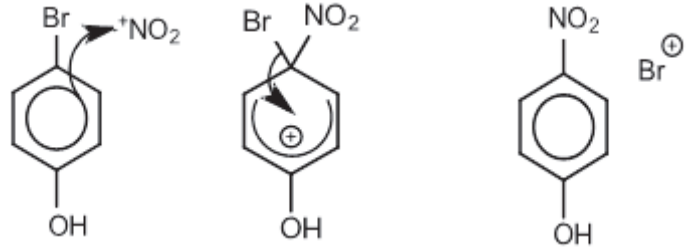
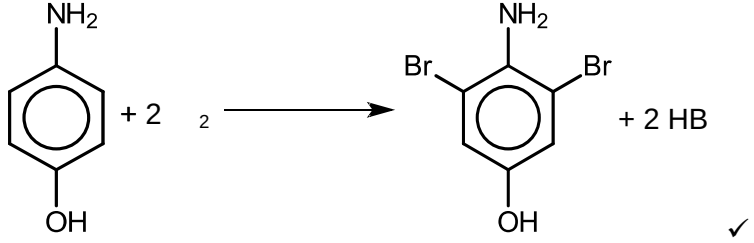
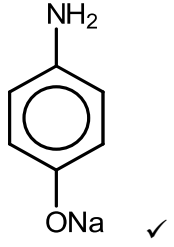
Question			Answer	Mark	Guidance
1	(a)	(i)	**M1** p-orbitals overlap (to form pi/π-bonds) ✓ **M2** π-bond(s) are <u>delocalised</u> in **structure B** ✓ **M3** π-bonds are localised/between two carbons in **structure A** ✓ **M4**  **AND**  **Diagrams** show correct **position** of delocalised and localised π-bonds/π-electrons **OR** correct position of p-orbital overlap ✓ ✎ **QWC** requires delocalised/delocalized **spelled correctly** and used in correct context	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** p-orbitals overlap to form sigma bonds **ALLOW** electrons are delocalised in structure B **IGNORE B** has delocalised structure or ring (must be electrons or π-bonds) **ALLOW π**-electrons/p-orbital overlap localised/between two carbons in structure A **ALLOW** p-orbitals overlap with one other carbon **IGNORE** electrons are localised **OR structure A** has localised structure (must be π-bonds/π-electrons/p-orbital overlap) **ALLOW** labelled diagram showing overlap of p-orbitals between two carbon atoms **DO NOT ALLOW** C=C in this diagram Diagram for structure A must show the full ring for **M4** **IGNORE** C=C in **M4** diagram **IGNORE** charge density **DO NOT ALLOW** electronegativity Structures do not need to be labelled A and B if the description matches the structure

Question			Answer	Mark	Guidance
		(ii)	**structure B/**delocalised structure is (more) stable ✓ **structure B** is a better because (enthalpy change of hydrogenation for benzene is) less (exothermic) than (-) 357 (kJ mol^{-1}) ✓	2	**ALLOW** structure **B** is low in energy **IGNORE** structure **B** is less reactive **ALLOW** enthalpy change/hydrogenation for benzene is less (negative) than 3 × (–)119 **IGNORE** more positive than (-)357 kJ mol^{-1} **ALLOW** enthalpy change is less than 3x enthalpy change for cyclohexene **ALLOW** structure **B** is more stable by 149 kJ mol^{-1} (2 marks) **DO NOT ALLOW** more/less energy needed for the reaction Answer must refer to data given in the question and must be a comparison **IGNORE** 360 kJ mol^{-1} No marks can be awarded if structure **A** is selected
	(b)		 curly arrow from C–N bond to N^+ ✓ curly arrow from lone pair on fluoride ion to positive charge on benzene ring ✓	2	First curly arrow must come from bond not from C atom **ALLOW** first curly arrow to nitrogen atom **OR** to positive charge on nitrogen atom **ALLOW** second curly arrow from negative charge on fluoride ion **ALLOW** second curly arrow to carbon atom with positive charge

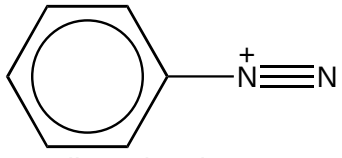
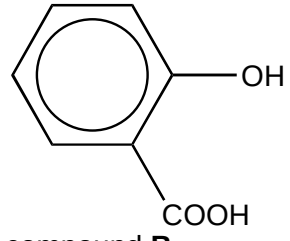
Question			Answer	Mark	Guidance
	(c)		$(CH_3)_2CHBr + FeBr_3 \longrightarrow (CH_3)_2CH^+ + FeBr_4^-$	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** positive charge anywhere on the electrophile **IGNORE** $AlCl_3$ **OR** $AlBr_3$
	(d)	(i)	First reactant = HNO_2 ✓ Second reactant =  ✓ Third reactant =  ✓	3	**ALLOW** $NaNO_2$ + HCl **OR** HNO_2 + HCl **IGNORE** conditions/concentration **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** 

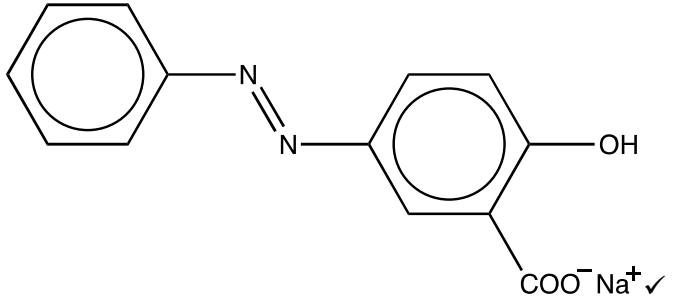
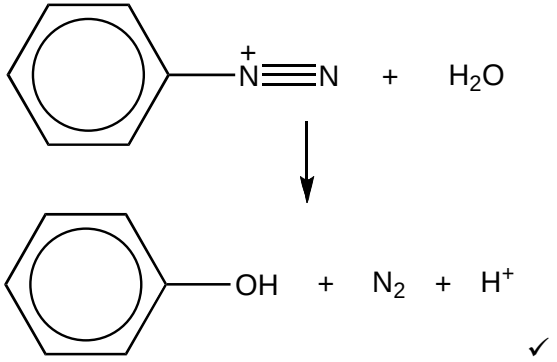
Question			Answer	Mark	Guidance
		(ii)	**FIRST CHECK THE ANSWER ON THE ANSWER LINE** **IF** answer = 1.35 (g) award 3 marks **IF** answer = 0.54 (g) award 2 marks (no scale-up) **IF** answer = 0.216 (g) award 2 marks (incorrect scale-up) *n*(compound D) = 1.73/346 = 0.00500 mol ✓ *n*(1,3-diaminobenzene) required = 100/40 x 0.005 = 0.0125 mol ✓ Molar mass of 1,3-diaminobenzene = 108 (g mol^{-1}) **AND** Mass of 1,3-diaminobenzene = (108)(0.0125) = 1.35 g ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **If there is an alternative answer, check to see if there is any ECF credit possible** **ALLOW ECF** from incorrect amount, scale-up or molar mass **Alternative 1** n(compound D) = 1.73/346 = 0.00500 mol Molar mass of 1,3-diaminobenzene = 108 (g mol^{-1}) **AND** Mass of 1,3-diaminobenzene = (0.00500)(108) = 0.540 g Mass of 1,3-diaminobenzene required = (0.540)(100/40) = 1.35 g **Alternative 2** 346 g gives 108 g 1.73 g gives 108/364 x 1.73 = 0.54 g 0.54/40 x100 = 1.35 g
		(iii)	(compound D has) **two** chiral centres ✓ Four optical isomers exist ✓ (Synthesis could) use enzymes **OR** bacteria **OR** use (chemical) chiral synthesis **OR** chiral catalysts **OR** use natural chiral molecules **OR** single isomers (as starting materials) ✓	3	**ALLOW** (Compound **D**) has two asymmetric carbons **OR** has two stereocentres **ALLOW** four enantiomers **OR** two pairs of enantiomers **INDEPENDENT MARK** **ALLOW** biological catalysts **ALLOW** chiral transition metal complex/catalyst **OR** stereoselective transition metal complex/catalyst **ALLOW** 'chiral pool'/chiral auxiliary
			Total	**18**	

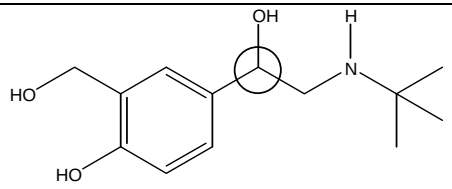
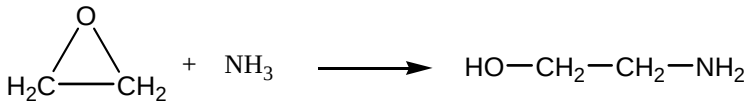
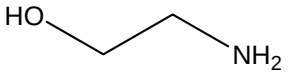
Question			Answer	Marks	Guidance
2	(a)		**Nitrogen** lone pair accepts a proton/H^+ ✓ *Requires position of lone pair on N*	1	**DO NOT ALLOW** Nitrogen/N lone pair accepts hydrogen *Proton/H^+ is required* **ALLOW nitrogen** donates a lone pair **IGNORE** NH_2 group donates a lone pair
	(b)		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **DO NOT ALLOW** 
	(c)		 ✓ curly arrow from ring to $^+NO_2$ ✓ correct intermediate ✓ curly arrow from C–Br to reform ring ✓ correct products **MUST HAVE** Br^+	4	**ALLOW** $^+NO_2$ **OR** NO_2^+ **ALLOW** first curly arrow from the ring **OR** from within the ring to any part of the NO_2^+ including the + charge **DO NOT ALLOW** intermediate with broken ring covering less than half the ring or incorrect orientation of broken ring + must be within the br ken ring **ALLOW** non-delocalized (Kekulé) structures with carbocation on either side of Br/NO_2 substituents **DO NOT ALLOW** M1 if a second arrow used on the diagram **DO NOT ALLOW** M3 ecf if arrow does not come from C-Br bond If OH missing on intermediate **do not** award M2. If OH missing on final product **do not** award M4
	(d)	(i)	hydrochloric acid/HC*l* ✓	1	**ALLOW** conc / dilute HC*l*

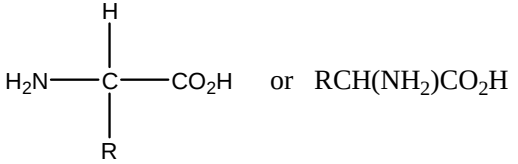
Question			Answer	Marks	Guidance
		(ii)	4-amino-3,5-dibromophenol ✓	1	**ALLOW** 3,5-dibromo-4-aminophenol **ALLOW** 2,6-dibromo-4-hydroxyphenylamine **ALLOW** 2,6-dibromo-4-hydroxy(-1-)aminobenzene **OR** (1-)amino-2,6-dibromo-4-hydroxybenzene **ALLOW** absence of hyphens numbers must be clearly separated **ALLOW** full stops **OR** spaces
		(iii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous
		(iv)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** $–O^-Na^+$ **OR** $–O^-$ **DO NOT ALLOW** –O-Na
	(e)	**(i)**	dyes/dyestuffs/pigments/food colourings ✓	1	**ALLOW** indicators / biological stains **DO NOT ALLOW** unqualified paint or food

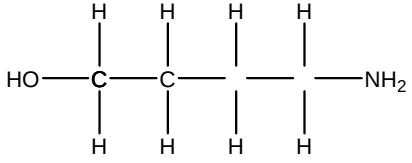
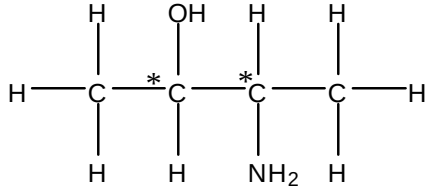
Question			Answer	Marks	Guidance
		(ii)		5	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous *No alternative pathway possible*
			reaction **1** HNO_2 (with or without HC*l*) **OR** $NaNO_2$ + HC*l* ✓		**ALLOW dilute** H_2SO_4 but **NOT** conc H_2SO_4 **ALLOW** conc HC*l*
			temp **<**10 °C ✓		
			compound **B** =  ✓		
			reaction **2** CuI ✓		
			reaction **3** alkali(ne) ✓		**ALLOW** KOH**(aq)/**NaOH**(aq)/**OH^-**(aq)** **IGNORE** temp < 10^oC **DO NOT ALLOW** heat/boil/warm **DO NOT ALLOW** use of phenol in M5
			Total	**16**	

Question			Answer	Mark	Guidance
3	(a)	(i)	donates a lone pair (on N) **OR** accepts a proton/H^+ ✓	1	**IGNORE** 'forms a dative covalent bond' (no direction of lone pair) **ALLOW** 'forms a dative covalent bond with/to $\mathbf{H^+}$' **ALLOW** mark for $N:\rightarrow H^+$ (can be from correct equation)
		(ii)	$(C_2H_5NH_3^+)_2SO_4^{2-}$ ✓ $C_2H_5NH_3^+$ CH_3COO^- ✓	2	**ALLOW** $(C_2H_5NH_3)_2\,SO_4$ **DO NOT ALLOW** $(C_2H_5NH_3)\,HSO_4$ **OR** $(C_2H_5NH_3^+)\,HSO_4^-$ *brackets not required* **ALLOW** $(C_2H_5NH_3)\,(CH_3COO)$ **OR** $(C_2H_5NH_3^+)\,(CH_3COO^-)$ *brackets not required* **ALLOW** separate ions with or without a '+' sign between them, e.g. $C_2H_5NH_3^+ + CH_3COO^-$
	(b)	(i)	 diazonium ion ✓  compound **B** ✓	2	In diazonium ion, **IGNORE** Cl^- **ALLOW** '+' sign up to halfway along triple bond from left-hand N In compound **B**, **ALLOW** –OH ionised as $–O^-$ **ALLOW** –COOH ionised as COO^-
		(ii)	conditions = alkaline /OH^- **AND** use = dye/pigment/colouring ✓	1	**BOTH** responses required for one mark **ALLOW** named alkali, e.g. NaOH/KOH **ALLOW** base **IGNORE** references to temperature **ALLOW** use = indicator

Question			Answer	Mark	Guidance
	(b)	(iii)	Organic product:  ✓ Other products: CO_2 **AND** H_2O ✓	**2**	**IGNORE** phenoxide: O^- **OR** O^-Na^+ **ALLOW** COO^- **OR** COONa **ALLOW** H_2CO_3 **Note**: must be formulae and not names (in question)
	(c)		 ✓	**1**	**ALLOW** N_2^+ on structural formula **ALLOW** $C_6H_5N_2^+ + H_2O \rightarrow C_6H_5OH + N_2 + H^+$ **ALLOW** $C_6H_5N_2Cl + H_2O \rightarrow C_6H_5OH + N_2 + HCl$ If + charge shown, **IGNORE** its position
			Total	**9**	

Question			Expected Answers	Marks	Additional Guidance
4	a		 ✓	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	$HO-CH_2-CH_2-NH-CH_2-CH_2-OH$ ✓	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**  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	$HO—CH_2—CH_2—NH_2 + 2[O] \longrightarrow HO—C(=O)—CH_2—NH_2 + H_2O$ ✓	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-o
			Total	**13**	