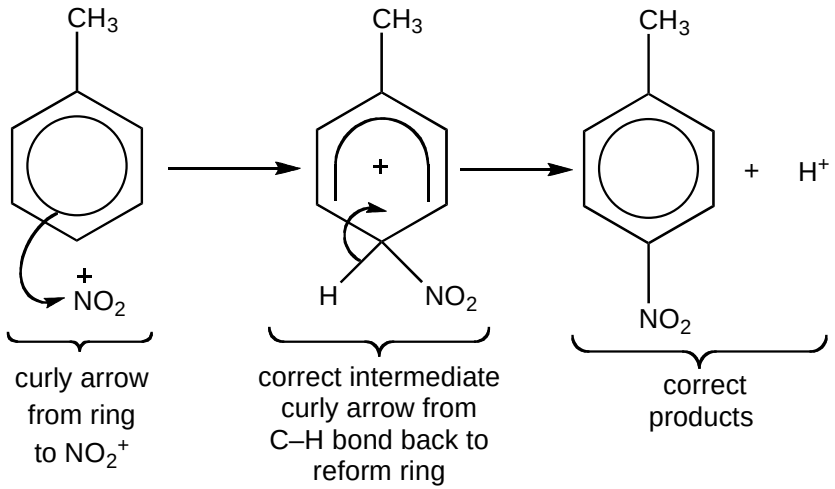
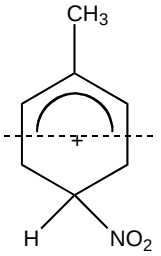
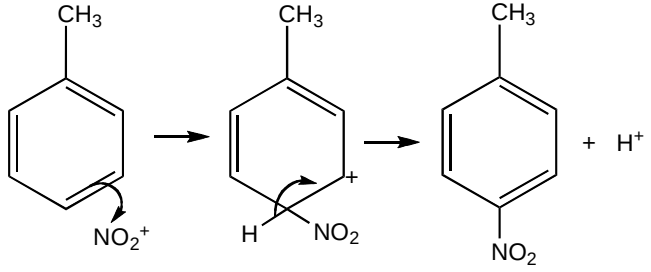
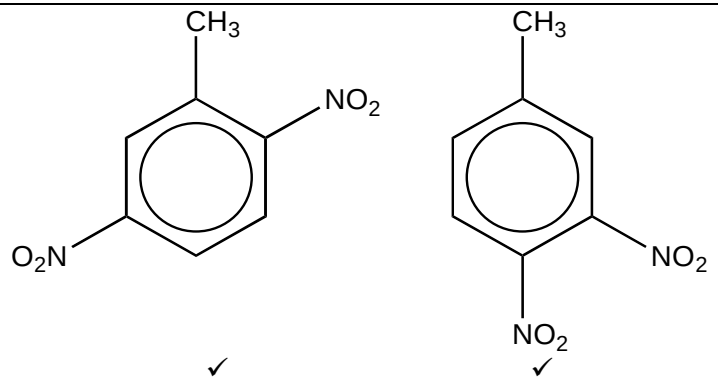
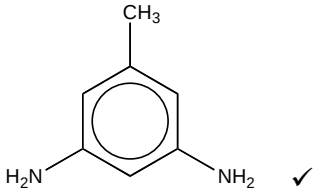
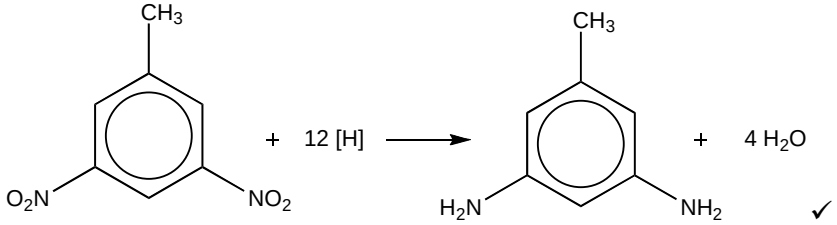
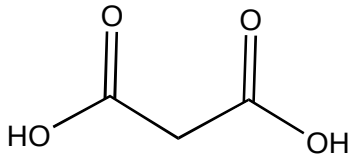
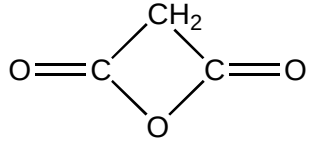
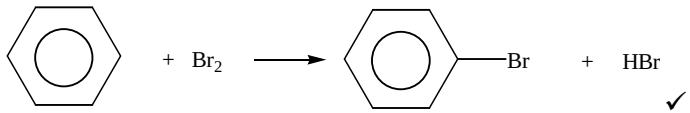
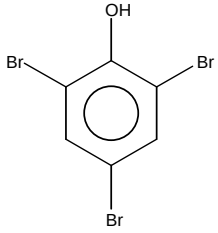
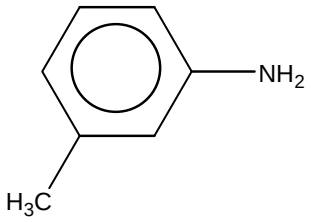
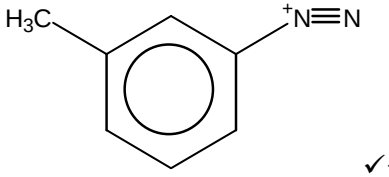
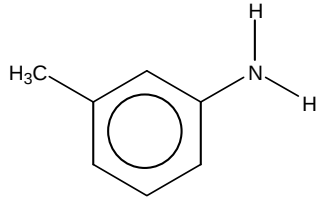
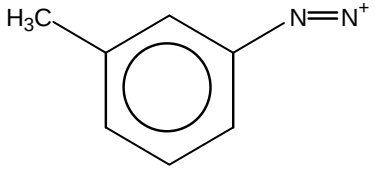
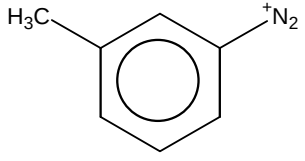
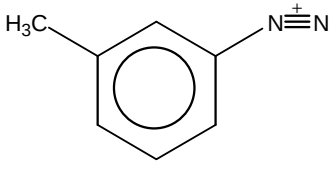
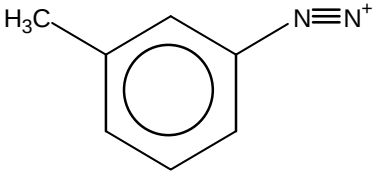
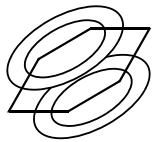
Question			Answer	Mark	Guidance
1	(a)		 curly arrow from ring to NO_2^+ correct intermediate curly arrow from C–H bond back to reform ring correct products ✓ ✓ ✓ ✓ 1 mark for intermediate 1 mark for curly arrow	4	***ANNOTATIONS MUST BE USED*** **ALLOW** skeletal CH_3 **ALLOW** $^+NO_2$ **OR** NO_2^+ **ALLOW** 1st 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 less than halfway down:  Horseshoe must have open end towards NO_2 **ALLOW** Kekulé mechanism:  **ALLOW** double bonds shown in other Kekulé arrangement **IF** CH_3 has been omitted completely (*ie* benzene shown), **DO NOT AWARD** intermediate mark **OR** products mark **(max 2)** **IF** NO_2 is shown in incorrect position in intermediate or product, **DO NOT AWARD** intermediate mark but award other marks **(max 3)**

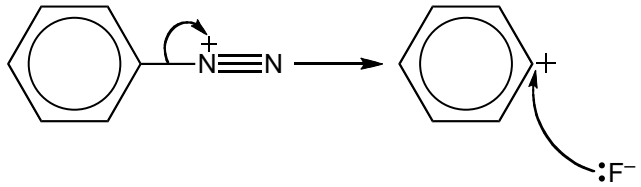
Question			er	Mark	Guidance
1	(b)		 ✓ ✓	2	**ALLOW** any correct unambiguous structures **ALLOW** NO_2– **Note**: connectivity is **NOT** being assessed in this part
1	(c)		**1st stage** *isomer*: **isomer 3** ✓ *product*:  ✓ *reagents*: Sn **AND** (conc) HCl ✓ *equation*:  ✓		***ANNOTATIONS MUST BE USED*** **ALLOW** structure of **isomer 3** shown separately **OR** in equation **ALLOW** structure of **product** shown separately **OR** in equation **ALLOW** correct name (3,5-diaminomethylbenzene) **IGNORE** incorrect name **DO NOT ALLOW** $CH_3C_6H_3(NH_2)_2$ **ALLOW** Zn + HCl/H_2 + metal catalyst/$LiAlH_4$/Na in ethanol **IGNORE** $NaBH_4$ **ALLOW** Sn and HCl followed by NaOH **DO NOT ALLOW** Sn and HCl and NaOH **IF** isomer **3 OR** product are given in equation but not shown previously then credit here Also credit reagents here if shown (*eg* above arrow) **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous

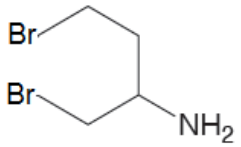
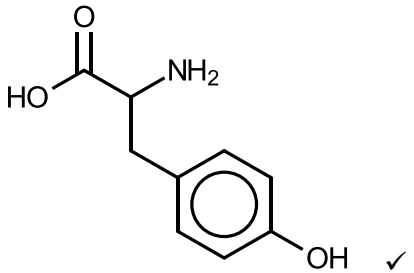
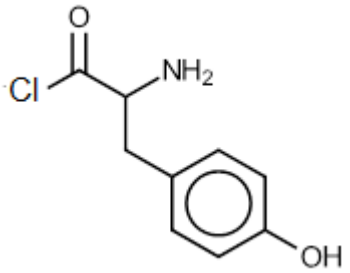
Question			er	Mark	Guidance
	(c)	(i)	**2nd stage** *organic compound*: $HOOC–CH_2–COOH$ ✓	6	 **DO NOT ALLOW** molecular formula **ALLOW** name of compound: propanedioic acid **OR** propane-1,3-dioic acid **ALLOW** absence of 'e' after 'propan' **ALLOW** acyl dichloride: $ClOC–CH_2–COCl$ **ALLOW** cyclic acid anhydride of propanedioic acid: 
			type of polymer: polyamide ✓		**ALLOW** Nylon or Kevlar **DO NOT ALLOW** polypeptide **DO NOT ALLOW** amide
			Total	**12**	

Question			Expected Answers	Marks	Additional Guidance
2	(a)		 ✓	1	**ALLOW** $C_6H_6 + Br_2 \longrightarrow C_6H_5Br + HBr$ **DO NOT ALLOW** multiple substitution **DO NOT ALLOW** Br^+
	(b)	(i)	White precipitate **OR** white solid **OR** white crystals ✓  ✓	2	**DO NOT ALLOW** colourless **DO NOT ALLOW** white ppt and bubbles **DO NOT ALLOW** $Br_3C_6H_2OH$ **OR** 2,4,6-tribromophenol **OR** tribromophenol
		(ii)	1,2-Dibromocyclohexane ✓	1	**ALLOW** 1,2dibromocyclohexane **OR** 1-2dibromocyclohexane **OR** 12dibromocyclohexane **OR** cyclo-1,2-dibromohexane **DO NOT ALLOW** dibromocyclohexane **OR** $C_6H_{10}Br_2$ **OR** structures
		(iii)	**MUST** spell delocalised/delocalized or localised/localized correctly once in the answer to obtain all 5 marks **benzene** electrons or π-bonds are delocalised ✓ **phenol** a lone or non-bonded pair of electrons on the oxygen or the OH group is (partially) delocalised into the ring ✓ **cyclohexene** electrons are localised **OR** delocalised between two carbons ✓ benzene has a lower **electron density OR** phenol has a higher electron density **OR** cyclohexene has a higher electron density ✓ benzene cannot **polarise** or induce a dipole in Br_2 **OR** phenol can polarise the Br_2 **OR** cyclohexene can polarise Br_2 or the Br–Br bond ✓	5	**ALLOW** diagram to show overlap of all 6 p-orbitals for delocalisation **DO NOT ALLOW** benzene has delocalised structure or ring **ALLOW** diagram to show movement of lone pair into ring for phenol **ALLOW** diagram or description of overlap of 2 adjacent p-orbitals for bonding in cyclohexene **DO NOT ALLOW** cyclohexene has a C=C double bond **IGNORE** slip if cyclohexene is written as cyclohexane but π - bonding correctly described **DO NOT ALLOW** charge density **OR** electronegativity instead of electron density **ALLOW** $Br^{\delta+}$ **OR** electrophile Br^+ as alternate to polarise

	(c)		 ✓  ✓✓ **ALLOW** ECF ✓✓ on incorrect amine HNO_2 + HCl and temp < 10 ^oC **OR** $NaNO_2$ + HCl and temp < 10 ^oC ✓ alkaline **AND** phenol (if temperature stated must be below 10 ^oC) ✓	**5**	**ALLOW**  **IGNORE** Cl^- ion **DO NOT ALLOW** if ring is connected to the N triple bond in the diazonium or if diazonium has a negative charge **ALLOW** one mark for correct displayed diazonium if alkyl group is not shown **ALLOW**  for both marks **ALLOW**  for one mark **ALLOW**  for one mark **ALLOW**  for one mark **ALLOW** NaOH **OR** KOH & C_6H_5OH **OR** phenoxide ion **OR** $C_6H_5O^-$ **ALLOW** reagents and conditions from the equations
			Total	**14**	

Question			Answer	Mark	Guidance
3	(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)		$(CH_3)_2CHBr + FeBr_3 \rightarrow (CH_3)_2CH^+ + FeBr_4^-$	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**	