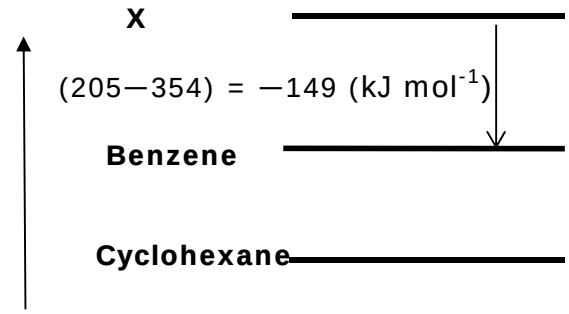
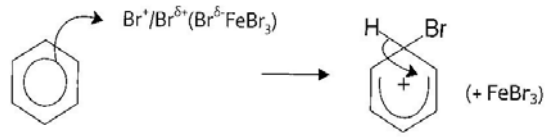
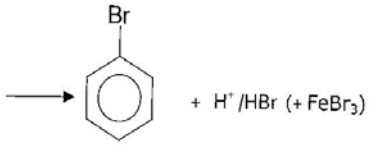
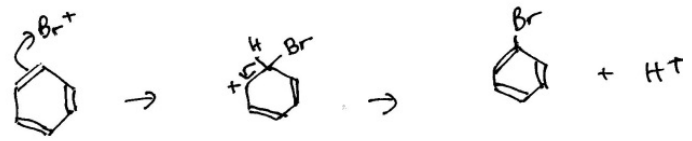
Question Number	Acceptable Answers	Reject	Mark
1(a)	All carbon to carbon bonds same length/ longer C-C and shorter C=C not present IGNORE Just "benzene has a delocalised ring" Benzene does not have C=C double bonds Any references to shape/ bond angles		1

Question Number	Acceptable Answers	Reject	Mark
1(b)(i	(3 x -118) = -354 (kJ mol^{-1})		1

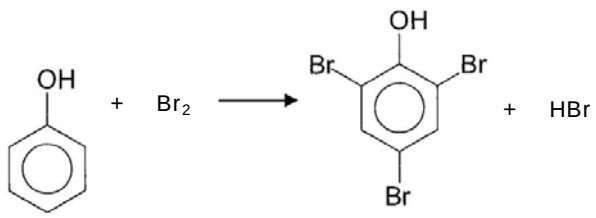
Question Number	Acceptable Answers	Reject	Mark
1(b)(ii)	 **First mark** Relative levels with names or formulae (1) **Second mark** Value —149 (kJ mol^{-1}) + arrow in correct direction ALLOW double-headed arrow (1) TE from value in (b)(ii) IGNORE $3H_2$ if shown / cyclohexene / other arrows/values	Diagram inverted scores 0 +149	2

Question Number	Acceptable Answers	Reject	Mark
1(b)*(iii)	The p/pi-/Π/6 electrons (of carbon) (1) are delocalised in benzene (but not in **X**) (1)		2

Question Number	Acceptable Answers	Reject	Mark
1(c)	**First mark:** $FeBr_3 + Br_2 \rightarrow FeBr_4^- + Br^+$ OR $Br\text{-}Br + FeBr_3 \rightarrow Br^{\delta+}\ldots Br^{\delta-}FeBr_3$ (1) Ignore state symbols even if wrong **Second, third and fourth marks:** **Either**   Arrow from benzene ring electrons (from **inside** the hexagon) to **Br^+ / $Br^{\delta+}$** (….. $Br^{\delta-}FeBr_3$) (1) Correctly drawn intermediate with delocalisation covering at least three carbon atoms, but not the carbon atom bonded to the bromine , with the positive charge shown inside the horseshoe The bonds to H and Br may be dotted (1) Arrow from / close to C-H **bond** to inside the hexagon **and** H^+ / HBr as product (1) **OR**  Use of Kekulé structure for benzene and intermediate with arrow from C=C double bond to **Br^+ / $Br^{\delta+}$** (….. $Br^{\delta-}FeBr_3$) (1) Correctly drawn intermediate with + charge on the C atom next to the C bonded to H and Br	Gap in wrong place	4

	The bonds to H and Br may be dotted (1) Arrow from / close to C-H **bond** to bond beside + charged C **and** H^+ / HBr as product (1) Each marking point is independent		

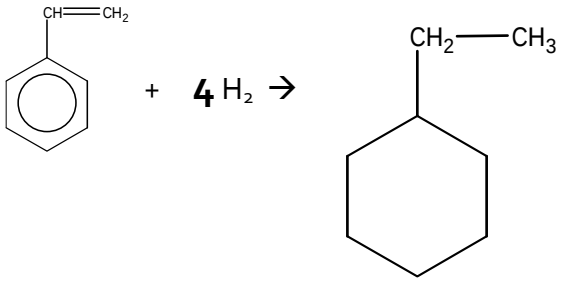
Question Number	Acceptable Answers	Reject	Mark
1(d)(i)	Bromine goes colourless OR It/the mixture goes from brown to colourless ALLOW Red-brown/ Orange/ yellow/ combinations of these colours Bromine is decolorised (1) White precipitate/solid forms / Steamy fumes (1) IGNORE Antiseptic smell Gets hot	Goes clear Red to colourless Bromine is discoloured Effervescence	2

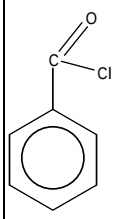
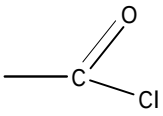
Question Number	Acceptable Answers	Reject	Mark
1(d)(ii)	 Organic product with structure shown (1) Rest of equation correct ALLOW C_6H_5OH or Kekule for phenol (1) $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$ Scores MP2 only Substitution of 1Br or 2Br in any position in balanced equation scores MP2 only.		2

Question Number	Acceptable Answers	Reject	Mark
***1(d)(iii)**	**Lone pair of electrons on oxygen** (may be shown on a diagram) **and** EITHER overlaps with pi cloud OR Feeds into / donates into / interacts with benzene ring (1) Activating benzene ring / increasing electron density of ring / making attack by **electrophiles** easier (1) COMMENT 'Lone pair of electrons on oxygen increases electron density of ring' scores (2) ALLOW benzene becomes a better nucleophile for MP2	OH group overlaps Just 'making it more reactive'.	2

Question Number	Acceptable Answers	Reject	Mark
2(a)(i)	Addition / reduction / free-radical addition IGNORE references to 'hydrogenation'	'redox' 'electrophilic addition' 'nucleophilic addition'	**1**

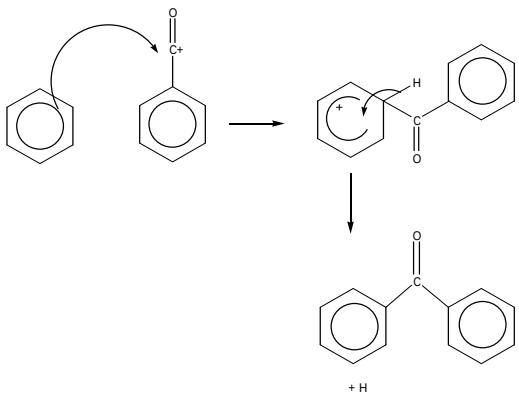
Question Number	Acceptable Answers	Reject	Mark
2(a)Iii)	**mark:** **Delocalization** (of π/p electrons in benzene ring) **(1)** IGNORE reference to 'resonance' **Second mark:** Results in more **energy** needed to **break** the **bonds** in benzene (compared with three separate π bonds) **(1)** ALLOW confers **stability** on the molecule / makes benzene **more stable** (than expected) IGNORE Reference to carbon-carbon bond lengths Values of any enthalpy changes Mark the two points independently		**2**

Question Number	Acceptable Answers	Reject	Mark
2(a)(iii)	 + **4** H_2 → (ΔH =) **— 328 (**kJ mol^{-1}) **First mark**: For "4" **Second mark**: Product as above / correct skeletal formula of product ALLOW Side chain written as $-C_2H_5$ **Third mark**: —328 (kJ mol^{-1}) **NOTE** **One** H_2 added showing a CQ correct product with only side chain reduced and cq ΔH = —120 **(**kJ mol^{-1}) scores **(2)** **Three** H_2 added showing a CQ correct product with only the benzene ring reduced and cq ΔH = —208 (kJ mol^{-1}) scores **(2)** **Five** H_2 added with fully correct product drawn and ΔH = —448 (kJ mol^{-1}) scores **(2)** **Three and a half** H_2 added showing a fully correct product and ΔH = —268/—293(.3)(kJ mol^{-1}) scores **(2)** **NOTE** Mark scoring points independently		**3**

Question Number	Acceptable Answers	Reject	Mark
2(b)(i)	 Mark awarded for displaying 		**1**

Question Number	Acceptable Answers	Reject	Mark
2(b)(ii)	Electrophilic substitution **BOTH** words needed IGNORE references to 'acylation' and /or 'Friedel-Crafts'		**1**

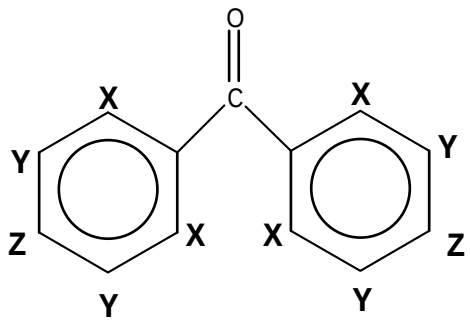
Question Number	Acceptable Answers	Reject	Mark
2(b)(iii)	Friedel **and** Crafts **BOTH** names are needed for this mark		**1**

Question Number	Acceptable Answers	Reject	Mark
2(b)(iv)	**First mark:** $\mathbf{C_6H_5COCl}$ + $AlCl_3$ → $\mathbf{C_6H_5CO^+}$ + $AlCl_4^-$ **(1)** **+** can be anywhere on the C_6H_5CO in the equation for the first mark  ($AlCl_4^-$ + H^+ → HCl + $AlCl_3$) **NOTE:** If ethanoyl chloride or any other acid chloride or the generic RCOCl is used **instead** of benzoyl chloride, no first mark can be awarded but the 2nd, 3rd and 4th marks can be awarded consequentially **Second mark**: First curly arrow, as shown, to start from inside the hexagon to the correct C+ carbon (i.e. not to the benzene ring) Note the + must be on the C of the C=O/CO for this mark **(1)** **Third mark:** Intermediate correctly drawn **(1)** **NOTE** + ca be shown anywhere in the ring or at the C atom where electrophile is bonded. The 'horseshoe' in the intermediate to cover at least three carbon atoms **Fourth mark:** Second curly arrow as shown from C—H bond to reform the ring, not from the H atom in this bond **(1)** **NOTE** Products do not have to be shown nor the equation for regeneration of the catalyst given		**4**

Question Number	Acceptable Answers	Reject	Mark
2(b)(v)	Absorbs / reflects / blocks / protects from / shields against / **uv** (light/ radiation) IGNORE 'non-toxic' / references to IR	**adsorbs** uv light	**1**

Question Number	Acceptable Answers	Reject	Mark
2(c)(i)	Any **TWO** of the following (1) for identifying the bond by formula as shown and (1) for wavenumber in each matching pair **UNITS** are not required **NOTE** ALLOW Correct wavenumber range, or any number within the correct range, **for C=O** Mark identification of the bond and the wavenumber independently (eg a correct bond with a wrong wavenumber, or vice-versa, scores one of the two marks in each case) IGNORE nmr values / chemical shifts		**4**

Bond	Wavenu range/wavenumber (cm^{-1})
C=C	1600 / 1580 / 1500 / 1450 **All four values needed**
C=O	1700 – 1680
C-	3030
C-	750 / 700 **Both values needed**

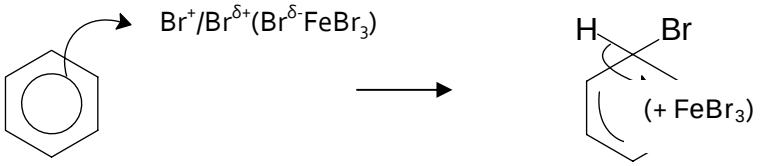
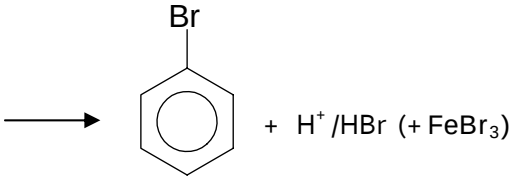
Question Number	Acceptable Answers	Reject	Mark
2(c)(ii)	 **First mark** **EITHER** Identifies correctly the **three** different proton environments ALLOW If the three different proton environments are only shown on one of the benzene rings **NOTE** On right-hand ring, clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments and /or On left-hand ring, anti-clockwise from C=O, positions 2, 3 and 4 And /or 2,4 and 5 are shown as different environments **OR** Identifies proton Z correctly on both benzene rings **(1)** **Second mark** Fully correct labelling both rings using the letters **X**, **Y** and **Z** **NOTE** **X** and **Y** labels are interchangeable, **Z** is not **(1)**		**2**

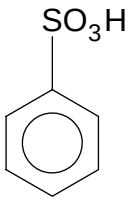
Question Number	Acceptable Answers	Reject	Mark
3(a)(i)	(3 x -120) = -360 (kJ mol^{-1}) IGNORE ΔH, and case of letters in units e.g allow Kj	No sign or + sign in answer, ie 360/+360 Any other wrong units ΔE	**1**

Question Number	Acceptable Answers	Reject	Mark
***3(a)(ii)**	• (Bonding in) benzene/it is more **stable** (than Kekule) by **152** kJ mol^{-1} (consequential on (a)(i)) **(1)** IGNORE sign • **π /p/double bond electrons** are delocalized (around the ring) OR six **p electrons** shared between six (ring) carbon atoms OR delocalized because of overlap of **p orbitals** OR resonance hybrid of C=C's and C-C's **(1)** • **Substitution** reactions (rather than addition) **(1)** NOTE: **Nucleophilic** substitution negates the substitution mark because it is wrong additional information • Maintains/regains delocalized system OR maintains/regains stability OR maintains/regains stabilization energy **(1)**	Attack by electrophiles with no mention of substitution	**4**

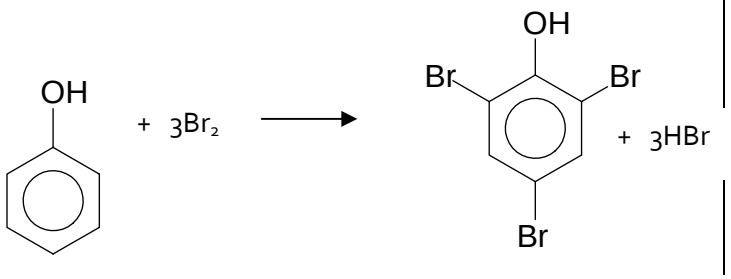
Question Number	Acceptable Answers	Reject	Mark
3(b)(i)	Concentrated nitric acid/HNO_3 **(1)** Concentrated sulfuric acid/H_2SO_4 **(1)** Allow conc or c. in place of 'concentrated' ALLOW Concentrated nitric acid and sulfuric acid OR Concentrated HNO_3 and H_2SO_4 **(2)** Second mark depends on nitric acid Max. (1) if no mention of concentrated Nitric acid and concentrated sulfuric acid scores (1) NOTE: conc. HNO_3 and H_2SO_4(aq) scores (1) but conc. HNO_3 and conc H_2SO_4(aq) scores (2)	Concentrated hydrochloric acid	**2**

Question Number	Acceptable Answers	Reject	Mark
3(b)(ii)	Electrophile/electrophilic ALLOW Electrophyl(e)	Acid Base Oxidizing agent Reducing agent	**1**

Question Number	Acceptable Answers	Reject	Mark
3(b)(iii)	$Br_2 + FeBr_3 \rightarrow FeBr_4^- + Br^+$ OR $Br\text{-}Br + FeBr_3 \rightarrow Br^{\delta+}\ldots\ldots Br^{\delta-}FeBr_3$ **(1)** IGNORE state symbols even if wrong   Arrow from benzene ring electrons (from **inside** the hexagon) to **Br^+ / $Br^{\delta+}$**($\ldots\ldots Br^{\delta-}FeBr_3$) **(1)** Correctly drawn intermediate with delocalization covering at least three carbon atoms, but not the carbon atom bonded to the bromine with the positive charge shown inside the hexagon The bonds to H and Br may be dotted **(1)** Arrow from or close to **bond** to H to centre of ring **and** H^+/HBr as a product **(1)** ALLOW Kekulé structure for benzene and intermediate **Each marking point is independent**	lack of charges	**4**

Question Number	Acceptable Answers	Reject	Mark
3(b)(iv)	 OR $C_6H_5SO_3H$ accept: displayed $-SO_3H$ $-SO_3^-H^+$ $-SO_2OH$ If two formulae are given both must be correct **(1)** Penalise if bond **clearly** goes to O or H rather than S **Benzenesulfonic acid** **(1)** ALLOW **phenyl sulfonic acid**	Benzenesulfuric acid/benzosulfonic acid/benzylsufonic acid	**2**

Question Number	Acceptable Answers	Reject	Mark
3(c)(i)	**Non-bonding/lone pair** electron**s** from **oxygen**... **(1)** ...are delocalized/incorporated/donated into the ring (electron system) (Could be shown in diagram) OR increases electron density on the ring **(1)** makes it (the ring) more susceptible to electrophilic attack/makes it (the ring) a better nucleophile **(1)**	...from methyl/methoxy Makes it more electronegative	**3**

Question Number	Acceptable Answers	Reject	Mark
3(c)(ii)	 **(1)** organic formula **(1)** balancing ALLOW • Condensed structural formulae, for example $C_6H_5OH + 3Br_2 \rightarrow C_6H_2Br_3OH + 3HBr$ **(1)** **(1)** balancing • multiples • substitution to any positions IGNORE: H_2O Position of bond to OH NOTE: Correct balanced equations giving mono and disubstitution phenols score **1 mark**		**2**

Question Number	Acceptable Answers	Reject	Mark
3(d)	(Chloromethyl)benzene/chloromethylbenzene/ chlorophenylmethane/ benzyl chloride OR dichloromethane **(1)** ALLOW phenylchloromethane Aluminium chloride **(1)** ACCEPT formulae eg C_7H_7Cl, $C_6H_5CH_2Cl$, CH_2Cl_2, $AlCl_3$ ACCEPT other halogen carriers eg $FeCl_3$/iron**(III)** chloride/$ZnCl_2$ ACCEPT bromine in place of chlorine for either/both marks Correct formula and wrong name or correct name and wrong formula or any other wrong additional information loses mark	CH_2Cl	**2**