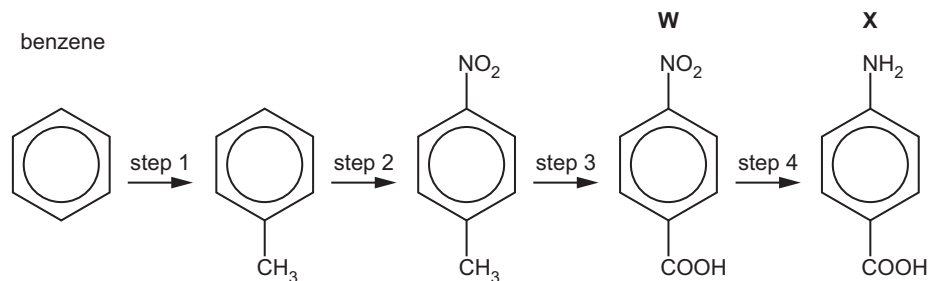


9 Compound **X** is made from benzene by the route shown in Fig. 9.1.



(a) Describe the bonding in benzene, C_6H_6 .

Your answer should include:

- the hybridisation of the six carbon atoms
- the types of bond between the carbon atoms
- the orbitals that overlap to produce the bonds between the carbon atoms
- the type of bond between the carbon atoms and the hydrogen atoms
- the orbitals that overlap to produce the bonds between the carbon atoms and the hydrogen atoms.

[3]

(b) Describe the reagents and conditions required for step 1 in Fig. 9.1.

[1]

(c) In step 1 of Fig. 9.1 benzene reacts with $^+CH_3$.

Complete Fig. 9.2 to show the mechanism for this reaction, including:

- the movement of electron pairs using curly arrows
- the structure of the intermediate involved.

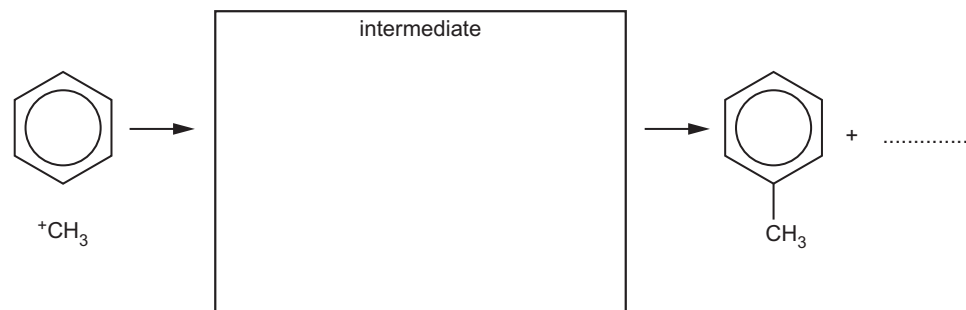


Fig. 9.2

[3]

(d) Describe the reagents and conditions required for step 2 of Fig. 9.1.

[2]

(e) Identify the reagents required for step 3 of Fig. 9.1. Compound **W** is the product of this step.

[1]

(f) Name compound **W**.

[1]

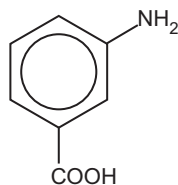
(g) The reagents commonly used for step 4 will **not** reduce the $-COOH$ group.

Identify the reagents and conditions required for step 4 of Fig. 9.1.

[1]

(h) Benzene can also be used as a starting material to make compound Y.

compound Y



Describe how the route described in Fig. 9.1 (repeated below) can be changed to give compound Y instead of compound X.

Explain your answer.

.....
.....
.....
..... [2]

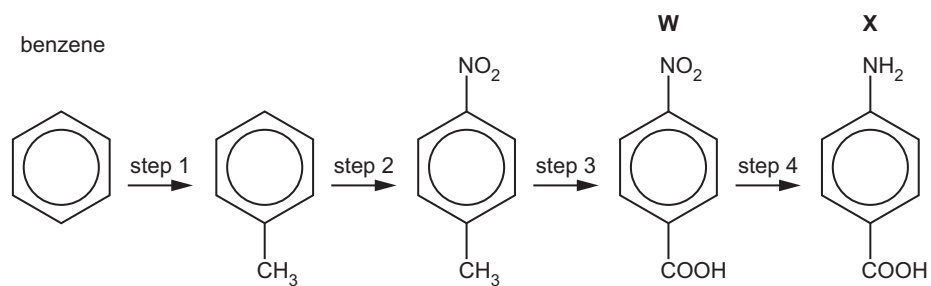


Fig. 9.1

[Total: 14]

Important values, constants and standards

molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Faraday constant	$F = 9.65 \times 10^4 \text{ C mol}^{-1}$
Avogadro constant	$L = 6.02 \times 10^{23} \text{ mol}^{-1}$
electronic charge	$e = -1.60 \times 10^{-19} \text{ C}$
molar volume of gas	$V_m = 22.4 \text{ dm}^3 \text{ mol}^{-1}$ at s.t.p. (101 kPa and 273 K) $V_m = 24.0 \text{ dm}^3 \text{ mol}^{-1}$ at room conditions
ionic product of water	$K_w = 1.00 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$ (at 298 K (25 °C))
specific heat capacity of water	$c = 4.18 \text{ kJ kg}^{-1} \text{ K}^{-1}$ ($4.18 \text{ J g}^{-1} \text{ K}^{-1}$)

The Periodic Table of Elements

Group																																																																															
1	2	Key														17	18																																																														
3 Li lithium 6.9	4 Be beryllium 9.0	atomic number atomic symbol relative atomic mass																1 H hydrogen 1.0	2 He helium 4.0																																																												
11 Na sodium 23.0	12 Mg magnesium 24.3	13 Al aluminum 27.0	14 Si silicon 28.1	15 P phosphorus 31.0	16 S sulfur 32.1	17 Cl chlorine 35.5	18 Ar argon 39.9	19 K potassium 39.1	20 Ca calcium 40.1	21 Sc scandium 45.0	22 Ti titanium 47.9	23 V vanadium 50.9	24 Cr chromium 52.0	25 Mn manganese 54.9	26 Fe iron 55.8	27 Co cobalt 58.9	28 Ni nickel 58.7	29 Cu copper 63.5	30 Zn zinc 65.4	31 Ga gallium 69.7	32 Ge germanium 72.6	33 As arsenic 74.9	34 Se selenium 79.0	35 Br bromine 79.9	36 Kr krypton 83.8	37 Rb rubidium 85.5	38 Sr strontium 87.6	39 Y yttrium 88.9	40 Zr zirconium 91.2	41 Nb niobium 92.9	42 Mo molybdenum 95.9	43 Tc technetium —	44 Ru ruthenium 101.1	45 Rh rhodium 106.4	46 Pd palladium 106.4	47 Ag silver 107.9	48 Cd cadmium 112.4	49 In indium 114.8	50 Sn tin 118.7	51 Sb antimony 121.8	52 Te tellurium 127.6	53 I iodine 126.9	54 Xe xenon 131.3	55 Cs caesium 132.9	56 Ba barium 137.3	57–71 lanthanoids	72 Hf hafnium 178.5	73 Ta tantalum 180.9	74 W tungsten 183.8	75 Re rhenium 186.2	76 Os osmium 190.2	77 Ir iridium 192.2	78 Pt platinum 195.1	79 Au gold 197.0	80 Hg mercury 200.6	81 Tl thallium 204.4	82 Pb lead 207.2	83 Bi bismuth 209.0	84 Po polonium —	85 At astatine —	86 Rn radon —	87 Fr francium —	88 Ra radium —	89–103 actinoids	104 Rf rutherfordium —	105 Db dubnium —	106 Sg seaborgium —	107 Bh bohrium —	108 Hs hassium —	109 Mt meitnerium —	110 Ds darmstadtium —	111 Rg roentgenium —	112 Cn copernicium —	113 Nh nihonium —	114 Fl flerovium —	115 Mc moscovium —	116 Lv livermorium —	117 Ts tennessine —	118 Og oganeson —

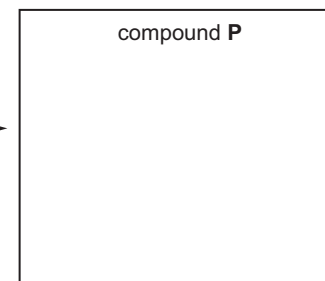
lanthanoids

actinoids

57 La lanthanum 138.9	58 Ce cerium 140.1	59 Pr praseodymium 140.9	60 Nd neodymium 144.2	61 Pm promethium —	62 Sm samarium 150.4	63 Eu europium 152.0	64 Gd gadolinium 157.3	65 Tb terbium 158.9	66 Dy dysprosium 162.5	67 Ho holmium 164.9	68 Er erbium 167.3	69 Tm thulium 168.9	70 Yb ytterbium 173.1	71 Lu lutetium 175.0
87 Fr francium —	88 Ra radium —	89-103 actinoids —	104 Db dubnium —	105 Sg seaborgium —	106 Bh bohrium —	107 Hs hassium —	108 Mt meitnerium —	109 Ds darmstadtium —	110 Rg roentgenium —	111 Cn copernicium —	112 Nh nihonium —	113 Fl flerovium —	114 Lv livermorium —	115 Ts tennessine —



reaction 1



reaction 2

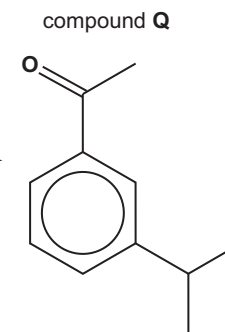


Fig. 8.1

8 (a) In the electrophilic substitution of arenes, different substituents can direct to different ring positions.

(i) Describe the directing effect of the NO_2 group. Explain your answer.

..... [1]

(ii) The nitration of arenes uses a mixture of concentrated HNO_3 and concentrated H_2SO_4 to generate the NO_2^+ electrophile.

Write an equation for the formation of the NO_2^+ electrophile.

..... [1]

(b) Carbon-carbon bond formation is an important reaction in organic synthesis.

Fig. 8.1 shows the synthesis of compound Q from benzene in two reaction steps.

(i) Draw the structure of compound P in the box in Fig. 8.1.

[1]

(ii) Suggest reagents and conditions for reactions 1 and 2 in Fig. 8.1.

reaction 1

reaction 2

[2]

- (c) Separate samples of $\text{C}_6\text{H}_5\text{Br}$ and $\text{C}_6\text{H}_5\text{CH}_2\text{Br}$ are added to warm $\text{AgNO}_3(\text{aq})$.

State the expected observations, if any. Explain your answer.

$\text{C}_6\text{H}_5\text{Br}$ with $\text{AgNO}_3(\text{aq})$

$\text{C}_6\text{H}_5\text{CH}_2\text{Br}$ with $\text{AgNO}_3(\text{aq})$

explanation

.....

.....

.....

[3]

- (d) Acyl bromides, RCOBr , react readily with H_2O .

The mechanism of this reaction is similar to that of the reaction of H_2O with acyl chlorides, RCOCl .

- (i) Name the mechanism of this reaction.

..... [1]

- (ii) Complete the mechanism in Fig. 8.2 for the reaction of RCOBr with H_2O .

Include all relevant lone pairs of electrons, curly arrows, charges and dipoles.

Draw the structure of the intermediate.

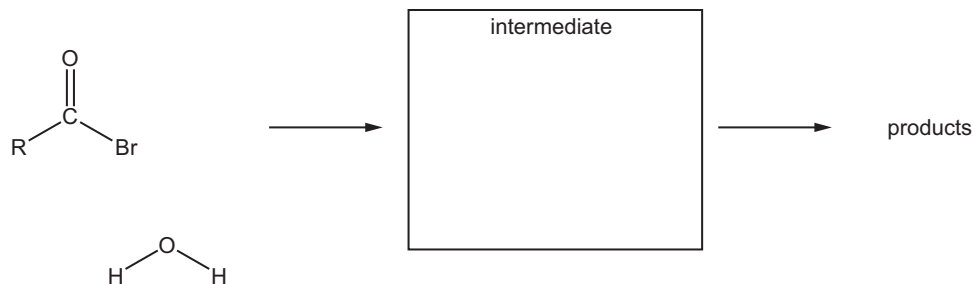


Fig. 8.2

[4]

[Total: 13]

- 5 (a) Describe and explain the shape of benzene.

In your answer, include:

- the shape and bond angle in the ring
- the hybridisation of the carbon atoms
- how orbital overlap forms σ and π bonds between the carbon atoms in the ring.

.....

.....

.....

.....

.....

.....

.....

..... [4]

- (b) Fig. 5.1 shows two reactions of benzoic acid.

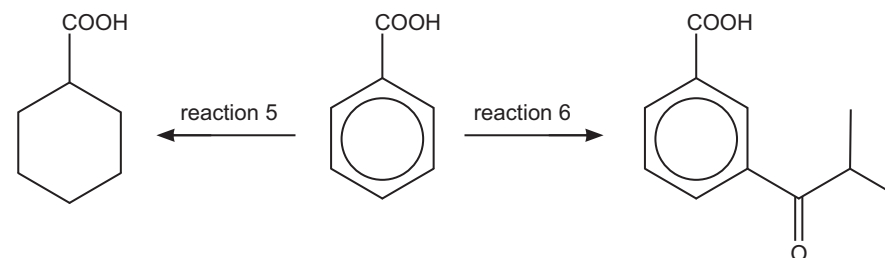


Fig. 5.1

- (i) Suggest reagents and conditions for reaction 5 and for reaction 6 in Fig. 5.1.

reaction 5

reaction 6

[2]

- (ii) State the type of reaction for reaction 5 in Fig. 5.1.

..... [1]

(c) In the electrophilic substitution of arenes, different substituents can direct to different ring positions.

(i) Describe the directing effect of the $-\text{CH}_2\text{CH}_3$ group.

Explain your answer.

.....
..... [1]

(ii) The alkylation of arenes uses a mixture of $\text{CH}_3\text{CH}_2\text{Br}$ and FeBr_3 to generate the CH_3CH_2^+ electrophile.

Write an equation for the formation of the CH_3CH_2^+ electrophile.

..... [1]

(iii) Complete the mechanism in Fig. 5.2.

Include all relevant curly arrows and charges. Draw the structure of the organic intermediate.

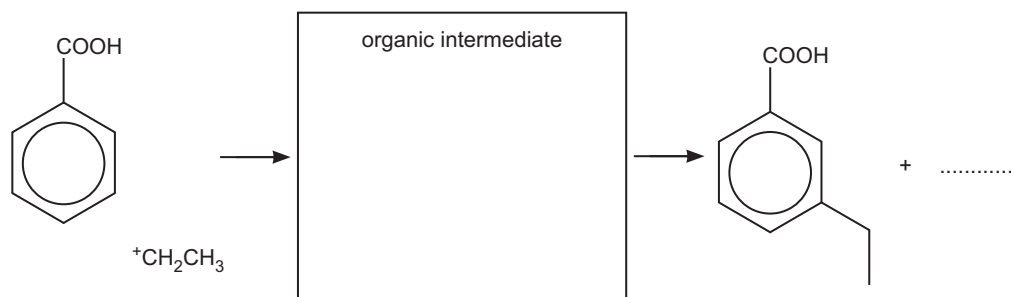


Fig. 5.2

[3]

(iv) Write an equation to show how FeBr_3 is regenerated after the reaction in Fig. 5.2.

..... [1]

[Total: 13]