**7** **(a)** State the relative acidities of bromoethanoic acid, $BrCH_2COOH$, chloroethanoic acid, $ClCH_2COOH$, ethanoic acid, $CH_3COOH$ and ethanol, $CH_3CH_2OH$.

Explain your answer.

..... ..... ..... .....
most acidic least acidic

.....

.....

.....

.....

.....

.....

.....

[4]

**(b)** Fig. 7.1 shows the reaction of methylbenzene and ethanedioic acid with $KMnO_4$.

Predict the major carbon-containing product for each of these reactions.

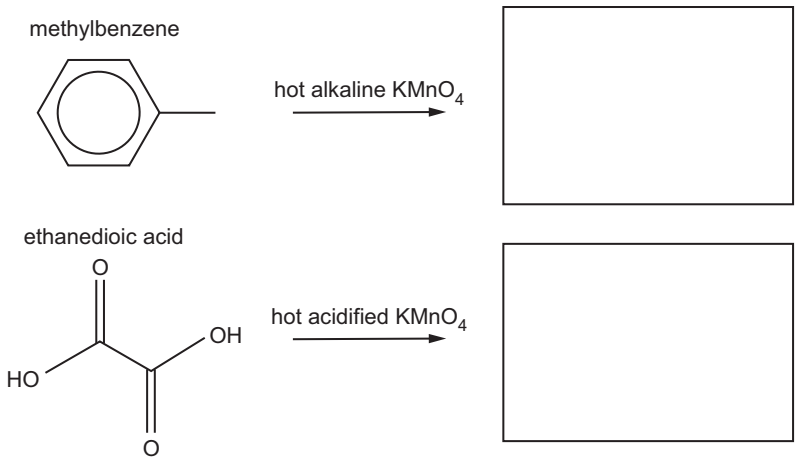



**Fig. 7.1**

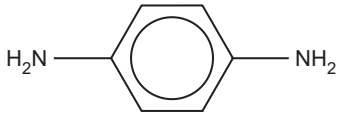
[2]





**(c)** Polyamide **X** can be synthesised from ethanedioic acid and benzene-1,4-diamine.

benzene-1,4-diamine




**(i)** Draw the repeat unit of polyamide **X** in the box.

The new functional group formed should be shown displayed.

polyamide **X**

[2]

**(ii)** Benzene-1,4-diamine can be formed by reduction of 1,4-dinitrobenzene.

Complete the equation for this reduction.

[H] represents one atom of hydrogen from a reducing agent.

+ ..... [H] → $H_2N$ — $NH_2$ + .....

.....

[1]

**(d)** Fig. 7.2 shows the two-step synthesis of the azo compound **W**.

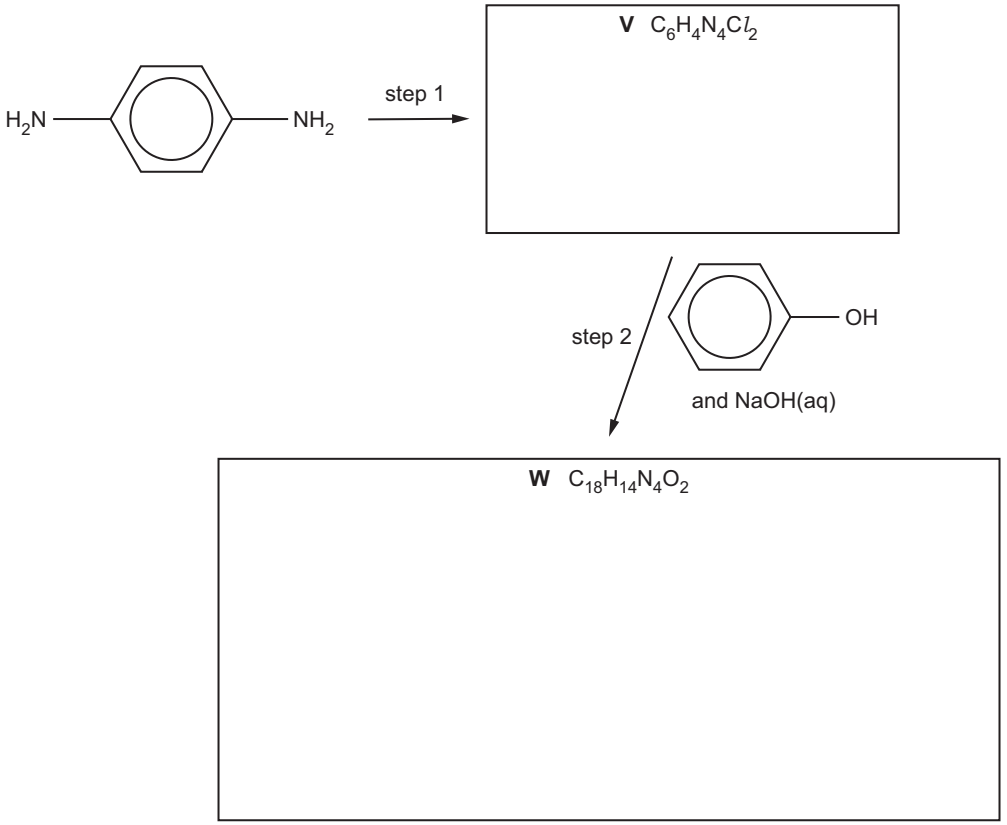



**Fig. 7.2**

**(i)** Suggest structures for compounds **V** and **W** and draw them in the boxes in Fig. 7.2. [2]

**(ii)** Give the reagents and conditions for step 1.

..... [1]

[Total: 12]





**9** **(a)** Explain why amides are much weaker bases than amines.

.....

.....

.....

..... [2]

**(b)** Fig. 9.1 shows the preparation of 2-phenylethylamine, $C_6H_5CH_2CH_2NH_2$, by three different routes.

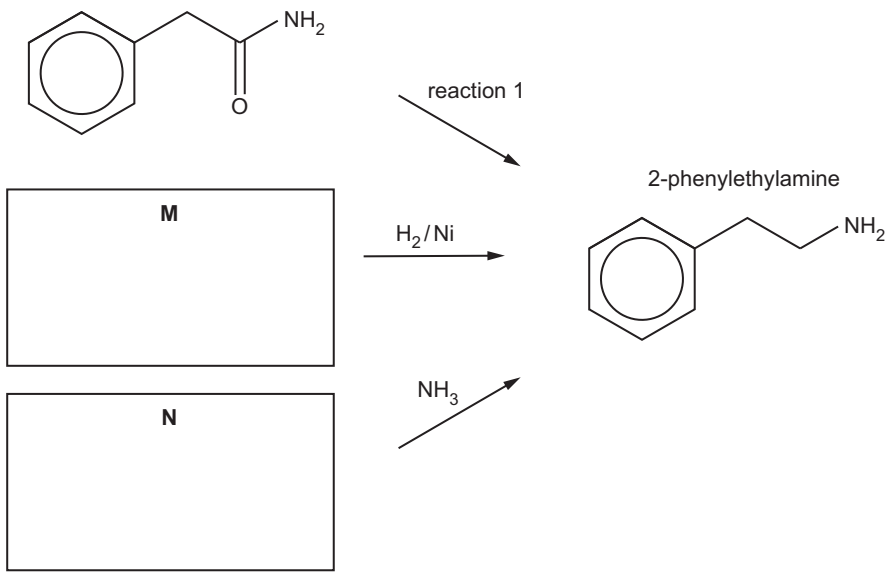



**Fig. 9.1**

**(i)** Suggest structures for compounds **M** and **N** and draw them in the boxes in Fig. 9.1. [2]

**(ii)** Give the reagents and conditions for reaction 1.

..... [1]

**(c)** Fig. 9.2 shows compound **H** which is a useful starting material in organic synthesis.

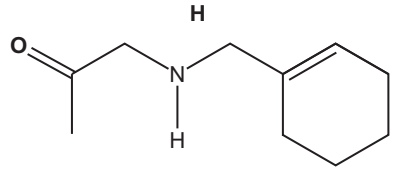



**Fig. 9.2**

**H** contains an alkene and an amine functional group.

Name the **other** functional group and give the classification of the amine group in **H**.

**other** functional group in **H** .....

classification of amine .....

[1]

**(d)** Ozonolysis involves the oxidative cleavage of a C=C bond in alkenes using ozone, $O_3$, as shown in Fig. 9.3.

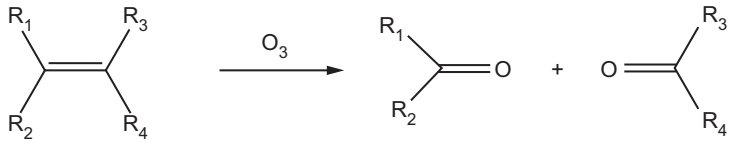



**Fig. 9.3**

Fig. 9.4 shows the first step in this reaction which involves the formation of an ozonide intermediate.

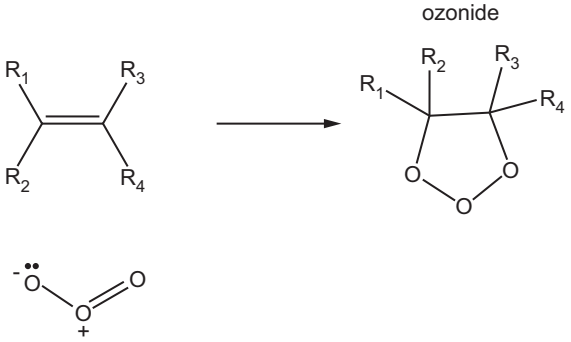



**Fig. 9.4**

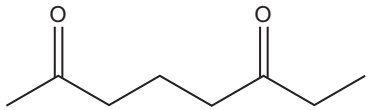
**(i)** On Fig. 9.4, draw **three** curly arrows to complete the mechanism of this step. [2]





**(ii)** **L** is formed from alkene **K**, $C_8H_{14}$, by a similar reaction to that shown in Fig. 9.3.

**L**




Suggest the structure of **K**.

**K** $C_8H_{14}$

[1]

[Total: 9]

**Important values, constants and standards**

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

**The Periodic Table of Elements**

| Group 1 | 2 | | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | 1 H hydrogen 1.0 | | | | | | 2 He helium 4.0 |
| 3 Li lithium 6.9 | 4 Be beryllium 9.0 | | | | | | | | | | | | 5 B boron 10.8 | 6 C carbon 12.0 | 7 N nitrogen 14.0 | 8 O oxygen 16.0 | 9 F fluorine 19.0 | 10 Ne neon 20.2 |
| 11 Na sodium 23.0 | 12 Mg magnesium 24.3 | | | | | | | | | | | | 13 Al aluminium 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 102.9 | 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 oganesson – |

**Key**

atomic number
atomic symbol
name
relative atomic mass

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| lanthanoids | 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 |
| actinoids | 89 Ac actinium – | 90 Th thorium 232.0 | 91 Pa protactinium 231.0 | 92 U uranium 238.0 | 93 Np neptunium – | 94 Pu plutonium – | 95 Am americium – | 96 Cm curium – | 97 Bk berkelium – | 98 Cf californium – | 99 Es einsteinium – | 100 Fm fermium – | 101 Md mendelevium – | 102 No nobelium – | 103 Lr lawrencium – |





**8** Asparagine and aspartic acid are two naturally occurring amino acids. Their structures and isoelectric points are shown in Table 8.1.

**Table 8.1**

| amino acid | structure | isoelectric point |
|---|---|---|
| asparagine | $HOOCCH(NH_2)CH_2CONH_2$ | 5.41 |
| aspartic acid | $HOOCCH(NH_2)CH_2COOH$ | 2.77 |

**(a)** Define isoelectric point.

.....

..... [1]

**(b)** Draw the structures of asparagine and aspartic acid at pH 2.

| asparagine at pH 2 | aspartic acid at pH 2 |
|---|---|
| | |

[2]

**(c)** Asparagine and aspartic acid are treated separately with an excess of $LiAlH_4$.

Draw the structures of the organic products of these reactions.

| product of asparagine treated with an excess of $LiAlH_4$ | product of aspartic acid treated with an excess of $LiAlH_4$ |
|---|---|
| | |

[2]

**(d)** Propanedioic acid, $HOOCCH_2COOH$, is treated with an excess of thionyl chloride, $SOCl_2$. Propanedioyl chloride, $ClOCCH_2COCl$, is formed.

**(i)** Write an equation for this reaction.

..... [1]

**(ii)** Propanedioyl chloride reacts with an excess of asparagine to form compound **G** with molecular formula $C_{11}H_{16}N_4O_8$.

Each molecule of compound **G** has four amide groups.

Draw the structure of compound **G**.

Compound **G**, $C_{11}H_{16}N_4O_8$

[2]

**(e)** Asparagine is hydrolysed with an excess of hot NaOH(aq).

Draw the structure of the organic product of this reaction.

[2]

**(f)** A polymer can form from asparagine, $HOOCCH(NH_2)CH_2CONH_2$, as the only monomer.

Draw a length of the polymer chain containing **three** monomer residues.

Clearly label the repeat unit of the polymer on your diagram.

[3]





**(g)** Aspartic acid exists in two optically active forms.

**(i)** Plane polarised light is passed through pure samples of these two optically active forms in solutions of the same concentration.

Describe **two** similarities and **one** difference in their effect on the plane polarised light.

similarities .....

.....

difference .....

.....

[2]

**(ii)** Give the term used to describe a mixture of equal amounts of the two optically active forms.

..... [1]

[Total: 16]

**Question 9 starts on page 20.**