1 Phenylethene is a product of the petrochemical industry and is used in large quantities to produce poly(phenylethene), commonly known as polystyrene.

Polystyrene is formed from phenylethene by addition polymerisation.

a Another important polymer, poly(ethene) is formed by addition polymerisation. Draw the repeating unit in a chain of poly(ethene). (1 mark)

b In the laboratory polymerisation of phenylethene, any unreacted phenylethene can be detected by shaking the polymerisation mixture with a solution of bromine in an organic solvent. The first step in the mechanism for this reaction is shown below.

The \( \text{Ph} \) group is known as a phenyl group and is represented by the symbol \( \text{Ph}^- \).

i What would you expect to see when phenylethene reacts with bromine? (1 mark)

ii What name is given to the type of organic intermediate \( \text{A} \) formed in the reaction above? (1 mark)

iii If bromine solution containing some potassium chloride is added to phenylethene, some 1-chloro-2-bromo-1-phenylethane is formed as well as 1,2-dibromo-1-phenylethane. Use the above mechanism to explain why both these compounds are formed. (3 marks)

c Poly(phenylethene) can be produced in two forms called isotactic and atactic. The structures of these two polymers are shown below:
Atactic poly(phenylethene) is non-crystalline, whereas the isotatic form is highly crystalline.

i Explain the term *highly crystalline* when used in relation to a polymer such as poly(phenylethene). (2 marks)

ii Suggest a reason why the atactic form is non-crystalline. (2 marks)

iii Describe two ways in which you would expect the properties of the two forms to differ. Give reasons for your answer. (3 marks)

iv State the type of intermolecular forces that exist between chains of poly(phenylethene). (1 mark)

d The isotactic form was made using a Ziegler-Natta catalyst. What are Ziegler-Natta catalysts, and why was their discovery important? (3 marks)

e Poly(phenylethene) was made ‘on purpose’ by chemists investigating the polymerisation of substituted ethenes. Name one polymer that was discovered by accident, giving brief details of its discovery. (2 marks)

[TOTAL: 19 MARKS]

2 The compound 1-phenylethanol smells strongly of flowers and is used in the perfume industry. It can be prepared in the laboratory in two steps, starting from phenylethene, as shown below.

```
<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>phenylethene</td>
<td>1-phenylethanol</td>
</tr>
<tr>
<td></td>
<td>Br</td>
</tr>
<tr>
<td></td>
<td>OH</td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th>Step 1</th>
<th>Step 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>phenylethene</td>
<td>1-phenylethanol</td>
</tr>
<tr>
<td></td>
<td>Br</td>
</tr>
<tr>
<td></td>
<td>OH</td>
</tr>
</tbody>
</table>
```

Step 1: Warm with aqueous KOH

a i For step 1, choose two words from the list below that describe the type of reaction involved.

- electrophilic
- radical
- nucleophilic
- addition
- substitution

(2 marks)

ii State the reagents and conditions that you would use in step 1. (2 marks)

iii On an industrial scale, it would be better to convert phenylethene into 1-phenylethanol in one step. Suggest the reagent(s) and conditions that could be used in a possible method of accomplishing this. (3 marks)

b Although 1-phenylethanol forms hydrogen bonds with water molecules, it does not dissolve in water.

i Draw a diagram of a 1-phenylethanol molecule hydrogen-bonded to a water molecule. (2 marks)

ii Draw a diagram to show how hydrogen bonds can form between several water molecules. Indicate on your diagram the 3–D arrangement around the oxygen atoms. (2 marks)

iii Using your answers to i and ii, suggest why 1-phenylethanol does not dissolve in water. (2 marks)

[TOTAL: 13 MARKS]
PVC (polyvinyl chloride) is a particularly versatile material; it is the second most widely used polymer. Its repeating unit is shown below.

\[
\begin{array}{c}
\text{H} \\
\text{C} \quad \text{C} \\
\text{H} \quad \text{H} \\
\end{array}
\]

a The monomer from which PVC is made has the trivial name vinyl chloride.

i Write the full structural formula of vinyl chloride. (1 mark)

ii Give the systematic name for vinyl chloride. (1 mark)

b The flow diagram below shows some of the steps in making vinyl chloride.

\[
\text{chlorine + ethene} \rightarrow 1,2\text{-dichloroethane} \rightarrow \text{vinyl chloride + hydrogen chloride}
\]

Some dichloroethene is also produced in the second step. This has two geometric isomers shown below.

\[
\begin{array}{c}
\text{Cl} \\
\text{C} \quad \text{C} \\
\text{H} \quad \text{H} \\
\end{array}
\quad
\begin{array}{c}
\text{H} \\
\text{C} \quad \text{C} \\
\text{Cl} \quad \text{Cl} \\
\end{array}
\]

i Name isomer A and isomer B. (3 marks)

ii Explain why 1,2-dichloroethane does not have geometric isomers. (2 marks)

iii The C–Cl bond is said to be polar. Explain what this means. (2 marks)

iv Explain why one of the isomers of 1,2-dichloroethene (isomer A or isomer B above) has a dipole while the other does not, even though they both have the same bonds. (3 marks)

v Suggest and describe a difference in properties of the two isomers that results from their different dipoles. (2 marks)

c PVC needs to be made more flexible for certain uses. This can be achieved by incorporating another monomer into the PVC chain. Such a monomer is ethenyl ethanoate, whose structure is shown below.

\[
\begin{array}{c}
\text{H} \\
\text{C} \quad \text{C} \\
\text{O} \quad \text{C} \quad \text{CH}_3 \\
\end{array}
\]

ethenyl ethanoate

i What name is given to this type of addition polymer, made from two different monomers? (1 mark)

ii Draw a portion of the polymer chain showing one unit of vinyl chloride and one unit of ethenyl ethanoate linked together. (2 marks)

iii Name all the types of intermolecular forces that attract PVC chains to each other, and state which is strongest. (3 marks)

iv Name the strongest type of intermolecular force that would attract poly(ethenyl ethanoate) chains to each other. (1 mark)

v Suggest why incorporating some ethenyl ethanoate molecules into a PVC chain makes it more flexible. (3 marks)

vi PVC has relatively weak attractive forces between its chains, and softens when heated. What name is given to the type of polymer that behaves in this way when heated? (1 mark)

vii Name another type of polymer that is rigid and does not soften when heated. Explain how these properties arise. (3 marks)

[TOTAL: 28 MARKS]