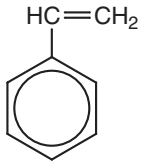
'THE POLYMER REVOLUTION' TEST

60 marks (1 hour)

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



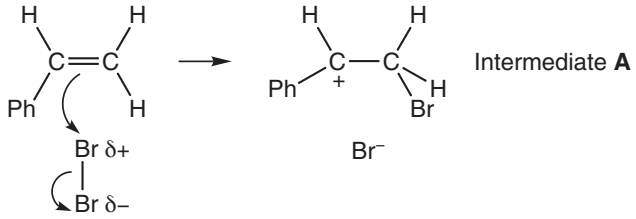
phenylethene

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  group is known as a phenyl group and is represented by the symbol Ph–.

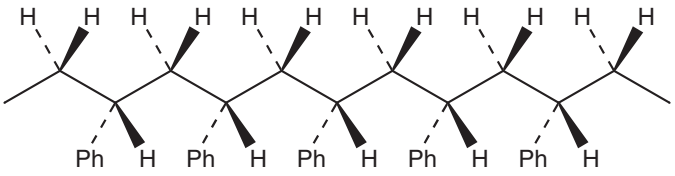


i What would you expect to **see** when phenylethene reacts with bromine? *(1 mark)*

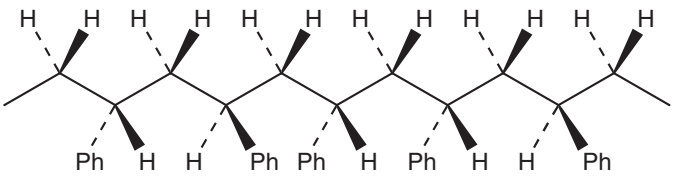
ii What name is given to the **type** of organic intermediate (**A**) formed in the reaction above? *(1 mark)*

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:



isotactic poly(phenylethene)



atactic poly(phenylethene)

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)*

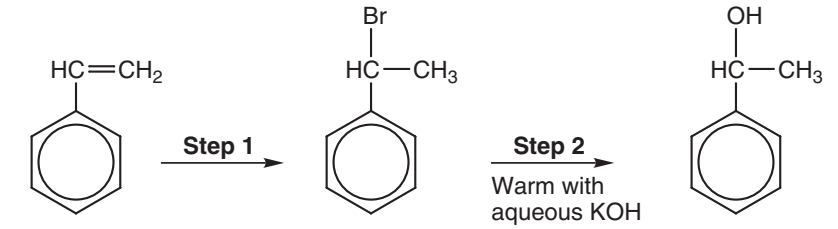
iv State the **type** of intermolecular forces that exist between chains of poly(phenylethene). *(1 mark)*

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.



phenylethene *1-phenylethanol*

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.

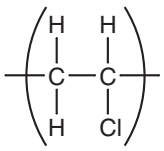
i Draw a diagram of a 1-phenylethanol molecule hydrogen-bonded to a water molecule. *(2 marks)*

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]

3 PVC (polyvinyl chloride) is a particularly versatile material; it is the second most widely used polymer. Its repeating unit is shown below.



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

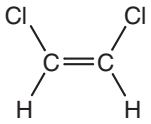
i Write the full structural formula of vinyl chloride. *(1 mark)*

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

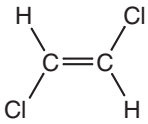
b The flow diagram below shows some of the steps in making vinyl chloride.

chlorine + ethene → 1,2-dichloroethane → vinyl chloride + hydrogen chloride

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



Isomer **A**



Isomer **B**

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

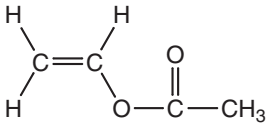
ii Explain why 1,2-dichloroethane does not have geometric isomers. *(2 marks)*

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.



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]