## Discussion

1 Only carbon can do this.
2 The sizes of the atom and bonds are out of proportion with the model size. An atom is not a ball and bonds, which are formed by overlapping orbitals, are not like sticks. The model is static, while the real molecule is dynamic.
3 Carbon atoms can form single, double and triple bonds with each other and with other atoms. Carbon has four valency electrons, two in s and two in p orbitals. All these electrons can combine in numerous ways to form compounds in straight-chain or cyclic compounds, or a combination of both.

**FOLLOW-UP**

1 *Hydrogen and halogens—chlorine, fluorine etc.*
2 *Methanol, carbonic acid and hydrogen cyanide are polar. Methanol contains a negative end (oxygen) and a positive end (hydrogen) attached to oxygen. Carbonic acid is slightly negative at the oxygen end and slightly positive at the other end (hydrogen attached to oxygen). Hydrogen cyanide is slightly negative at the nitrogen end due to the electron pair on the nitrogen atom, while the other end (hydrogen attached to carbon) is slightly positive.*
3 *nitrogen*
4 *Modelling was essential in decoding the DNA structure. It makes possible the prediction of reactions before laboratory experimentation in the design of new drugs and materials. Modelling is useful for modelling fullerenes for their application in nanotechnology.*

A risk assessment record is not necessary for this investigation, as no hazardous substances are used.

# Investigation 17

## Fractional distillation of an alcoholic drink

### Rationale

Students learn how to assemble fractional distillation apparatus and distil ethanol from an alcoholic drink or ethanol/water mixture. Students will observe the processes occurring inside the fractionating column, and learn the difference between distillation and fractional distillation.

**Syllabus**

*Perform a first-hand investigation and gather first-hand information using the process of fractional distillation to separate the components of a mixture such as ethanol and water.*

### Background knowledge

Students have learned about homologous series of hydrocarbons and alkanols and intermolecular forces in hydrocarbons and alkanols.

### Hints

- This could be a teacher demonstration if equipment is limited. It is a good demonstration of fractional distillation of a crude oil.
- If the fractionating column is too long, it may be necessary to wrap aluminium foil around it in order to keep it from cooling too fast.
- To test for the purity of ethanol, insert one end of a string into the distillate and light it with a match, or ignite 10 drops in a crucible or evaporating basin. Pure ethanol will quickly ignite and burn with a bluish flame. Distillate is 95% pure due to the alcohol–water binary azeotrope.

### Calculation

$$\text{percentage ethanol} = \frac{18.5\ \text{mL}}{50\ \text{mL}} \times 100 = 37\%$$

### Discussion

1 The alcohol content as stated on the bottle is 40%. The difference is due to some alcohol remaining in the mixture due to strong hydrogen bonding between alcohol and water. (If more than the stated amount is distilled, the distillate has too much water in it.)
2 The fractionating column contains spikes or beads that slow down and cool off molecules with higher boiling points, which return to the flask as liquid. Only molecules

**RESULTS** TABLE 1

| Liquid | Observation | Volume (mL) |
|---|---|---|
| whisky | clear, light reddish-brown liquid; strong, sweet, alcoholic smell | 50.0 |
| fraction 75–80°C | clear, colourless liquid; sharp alcohol smell | 18.5 |
| residue in the flask | darker reddish-brown; mild, sweetish smell | not measured |

with a lower boiling point can escape in the gaseous phase and enter the condenser. The condenser is cooled externally by the flow of cold water in the outer mantle, condensing hot gases to liquid.

**3** The distillate is not 100% pure because it is collected over a range of temperatures. It contains some water.

**4** If the fractionating column is removed, the distillate collected would contain too much water.

**5** $CH_3CH_2OH(l)$ + energy $\rightarrow$ $CH_3CH_2OH(g)$

**6** **a** As the size of the molecules increases, so does the boiling point.

**b** There are two intermolecular forces in alcohols: hydrogen bonding due to the OH group, and dispersion forces due to the non-polar hydrocarbon end. As the size of the molecules increases by increasing the number of $CH_2$ groups (while the number of OH groups stays the same), the molecules entangle and dispersion forces increase. This causes a higher boiling point.

**7** Hydrogen bonding is stronger between water molecules. Ethanol has a non-polar hydrocarbon part of the molecule, separating the OH group in one molecule from the OH group in the next molecule. As a result, hydrogen bonding is not as strong as it is between the smaller water molecules. Molecules therefore require less energy to overcome these intermolecular forces (i.e. hydrogen bonding).

**FOLLOW-UP**

**1** *Boiling point is the temperature at which molecules in a liquid state overcome intermolecular forces and change to a gaseous phase, exerting a pressure equal to atmospheric pressure. Above every liquid, there are some molecules in the gaseous phase even at low temperatures. The pressure of these gaseous molecules at any temperature below boiling point is called the volatility. Since boiling point is a measure of the strength of intermolecular forces, the lower the boiling point, the more molecules are in a gaseous phase—hence, the higher the volatility.*

**2** **a** *Crude oil is a mixture of hydrocarbons. They are separated on the basis of their boiling points. As the size of the hydrocarbon molecule increases, so does its boiling point.*

**b** *The first fraction consists of the dissolved gases of crude oil, which are liquefied and used as LPG gases. These include, ethane, propane and butane. Methane is usually recycled for use as a fuel. The second fraction contains petroleum ethers (hydrocarbons containing 5–7 carbons per molecule) such as pentane, hexane, heptane and some alkenes ($C_5H_{12}$ and $C_6H_{14}$ predominate). The third fraction contains hydrocarbons suitable for petrol ($C_5$ to $C_{12}$ hydrocarbons) such as heptane and octane ($C_7H_{16}$ and $C_8H_{18}$).*

**3** *When the volatility of a hydrocarbon is high, enough of the gaseous hydrocarbons exist to form a flammable mixture above the liquid at a certain temperature. An open flame or a spark could ignite this mixture of hydrocarbons and air, which will flash but not continue to burn. This indicates that the concentration of gases above the liquid is at the lower flammable limit. All flammable materials have defined flash point temperatures, which are important in determining the fire rating of a material. At ignition temperature, a substance has such a high concentration of gaseous flammable molecules that it will spontaneously ignite without a spark or a flame. This temperature is not related to volatility, but to the activation energy of a substance. Ignition temperature is very important for storage and transport of such materials.*

**4** *Complete combustion:* $C_2H_5OH(g) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$

*Incomplete combustion:* $C_2H_5OH(g) + 2O_2(g) \rightarrow C(s) + CO_2(g) + 3H_2O(g)$

A risk assessment record is not necessary for this investigation, as no hazardous substances are used.

# Investigation 18

## Combustion of wood and candlewax

### Rationale

Students will compare the ignition, flame and products of the combustion of wood and candles. They will make qualitative observations and quantitative measurements of the changes in mass of the wood and candles while they burn.

**Syllabus**

*Solve problems and perform a first-hand investigations to measure the change in mass when a mixture such as wood is burned in an open container. Analyse the structure of a burning candle to identify the changes of state involved in combustion.*

### Background knowledge

Students have learned about combustion, activation energy involved in combustion reactions, bonds breaking and bonds forming during chemical reactions. This investigation may be suitable as an introduction to the role of a catalyst in combustion reactions.

### Hints

- Let students experiment with the best arrangement of toothpicks for efficient combustion. The best method is to position sticks in a cross-pile so that air flows freely between the sticks. It is important that the wood burns completely and only white powder remains. This powder may be less then 0.01 g, and the class balance may not record it. Different groups could use a variety of wood shavings and compare different wood types for residue and combustion.
- The beaker should be placed in the fridge to cool down before testing for water condensation.