8. Glycerol is an alcohol with a three-carbon chain, and a hydroxyl group on each carbon atom. The extra hydroxyl groups form extra hydrogen bonds with water, which results in extra water molecules being held to the glycerol molecules, keeping the water from freezing.

Making Connections

9. (a) IUPAC name: 1,2-dihydroxyethane
   (b) Uses: most commonly used as an antifreeze, but also has many other product applications, including polyester resin (PET), film and fibres, and heat transfer and hydraulic fluids.
   (c) Properties: clear, colourless, odourless, viscous liquid with a sweet taste. Properties are a result of the two –OH groups (sweetness) and the formation of hydrogen bonds (a viscous liquid with a fairly high melting point and boiling point).

3.8 INVESTIGATION: PROPERTIES OF ALCOHOLS

PART 1: TRENDS IN PROPERTIES OF ALCOHOLS

(Pages 209–210)

Prediction

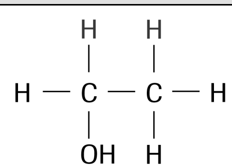
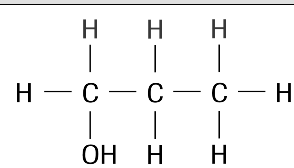
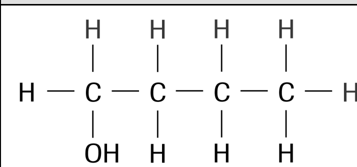
(a) Order of increasing melting points and boiling points: ethanol, 1-propanol, 1-butanol
Solubility in mineral oil (nonpolar solvent) and water (polar solvent): All three compounds are similarly soluble in polar solvents and very slightly soluble in nonpolar solvents.
Acidity: All three alcohols are basic (blue in litmus).

Hypothesis

(b) Melting point and boiling point: Each alcohol has a single hydroxyl group, so each one has similar hydrogen-bonding capabilities. The increasing size of the molecules increases the strength of the van der Waals forces, thus increasing the melting and boiling points.
Solubility: Since each alcohol has a single hydroxyl group, each one will be similarly soluble in polar solvents. Since they have small alkyl groups, they will be only slightly soluble, if at all, in nonpolar solvents.
Acidity: All three alcohols will also have similar basic properties due to the single hydroxyl group.

Observations

(c) and (d)

Property	Ethanol	1-Propanol	1-Butanol
structural formula	 ethanol	 1-propanol	 1-butanol
melting point	–117ºC	–126ºC	–89ºC
boiling point	78ºC	97ºC	117ºC
solubility in mineral oil	slightly soluble	slightly soluble	slightly soluble
solubility in water	soluble	soluble	soluble
colour with litmus	blue	blue	blue

Analysis

(e) Melting points and boiling points, from lowest to highest, are: ethanol, 1-propanol, 1-butanol
Solubility in nonpolar and polar solvents: All three alcohols are similarly soluble in polar solvents and very slightly soluble in nonpolar solvents.
Acidity: All three alcohols turn blue in litmus.

(f) The observations agree with our predictions. Reasons are as follows:
- The increasing size of the molecules increases the strength of the van der Waals forces, thus increasing the melting and boiling points.
- Since each alcohol has a single hydroxyl group, each will be similarly soluble in polar solvents. Since they have small alkyl groups, they will be only slightly soluble, if at all, in nonpolar solvents.
- All three alcohols will also have similar basic properties due to the single hydroxyl group.

Synthesis

(g) Boiling points
1-butanol: 118°C
2-methyl-2-propanol: 83°C
1-hexanol: 157°C
2,2-dimethyl butanol: 121°C
Trends: the straight-chain alcohols have higher boiling points than branched-chain alcohols of similar molar mass because there are more van der Waals forces of attraction between longer chains than between more spherically shaped molecules of similar molar mass. Of the straight-chain alcohols, longer-chain molecules have higher boiling points than shorter-chain alcohols because there are more van der Waals forces of attraction between longer chains than between shorter chains.

(h) Linear molecules have more surface area, and therefore more intermolecular forces, than do spherical molecules; therefore linear molecules have higher boiling points than spherical molecules of similar size.

PART 2: ALCOHOL AND ALKANE COMBUSTION

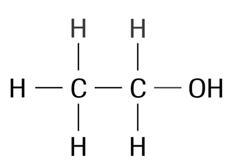
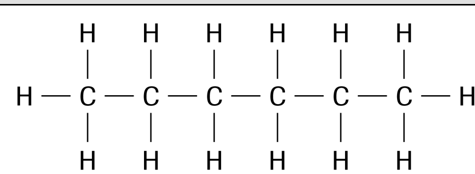
(Pages 210–211)

Prediction

(i) In the combustion of both ethanol and hexane, the products will be carbon dioxide and water.

Observations

(j) and (k)

Property	Ethanol	Hexane
structural formula		
organic family	alcohol	alkane
cobalt chloride test	positive	positive
limewater test	positive	positive

Analysis

(l) The positive cobalt chloride test indicates that water is produced by both reactions. The positive limewater test indicates that carbon dioxide is produced by both reactions.
$C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$
$2\ C_6H_{14} + 19\ O_2 \rightarrow 12\ CO_2 + 14\ H_2O$

(m) Oxygen in the air must be allowed to enter the beaker to enable combustion to continue.

Synthesis

(n) The wick burns at a higher temperature than ethanol and hexane, and thus will not burn until all the liquid has completely burned and the heat is used to evaporate the fuel.
(o) The products in both reactions are the same. Alcohols are liquids and are more easily transported and stored than the smaller hydrocarbons, which are generally gases. Gases must be compressed into liquids for storage. Compressed gases are dangerous.

3.9 ALDEHYDES AND KETONES

TRY THIS ACTIVITY: WHERE'S THE CUP?

(Page 213)

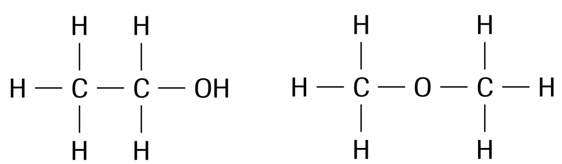
(a) The bottom of the Styrofoam cup "disappears" as it is dissolved by the acetone.
(b) The IUPAC name for acetone is propanone. Acetone is polar due to its carbonyl group, and also nonpolar due to its alkyl groups. This characteristic makes acetone miscible with both polar and nonpolar substances.
(c) Since Styrofoam dissolved in acetone, it probably has both polar and nonpolar characteristics.

SECTION 3.9 QUESTIONS

(Pages 213–214)

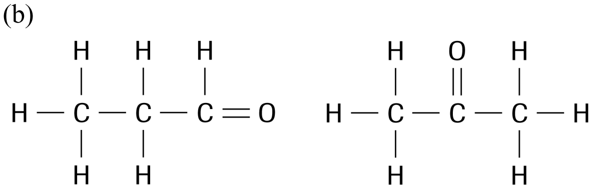
Understanding Concepts

1. In order of increasing boiling points: B, A, C. This order is predicted because A (1-propanone) contains a carbonyl group (with a polar double bond), making it more polar than B (propane), which gives A a higher boiling point than B. C (1-propanol) contains a hydroxyl group, which can hydrogen bond with other molecules, giving C a higher boiling point than A or B.
2. In increasing order of solubility: C, A, B. C (butane) is a nonpolar hydrocarbon and is less soluble in water than A (the ketone) and B (the alcohol). A has a polar carbonyl group, making it more soluble in water than C, but it is less soluble than B, which has a hydroxyl group that allows it to hydrogen bond.
3. (a)



alcohol ether

(b)



aldehyde ketone

(c)

Organic family	**Functional group**
alcohol	hydroxyl group
ether	oxygen bonded to two alkyl groups
aldehyde	carbonyl group at the end of the carbon chain
ketone	carbonyl group in the interior of the carbon chain