(i) Use organic solvents in a well-ventilated location or fume hood, away from ignition sources such as electrical sparks, open flames, and hot surfaces. Do not store solvents in direct sunlight or near heat sources, or in basements. Return unused portions immediately to the appropriate storage containers. Dispose of small amounts of ethanol (according to environmental restrictions) in the sink, followed by plenty of water.

(j) Detergents are made from long hydrocarbon chains and sulfuric acid. They are similar to soap molecules, which also have long carbon chains and a salt group at one end. Advantages of detergents are that they do not produce an insoluble "scum" with the calcium and magnesium ions in hard water, and they are generally less expensive than soap. Disadvantages of detergents are that they are generally not biodegradable and may damage the environment. They are made from non-renewable petroleum products.

UNIT 3 REVIEW

(Pages 256–259)

Understanding Concepts

1. (a) $HC{\equiv}CH$
   (b) $CH_3CH(OH)CH_3$
   (c) $\begin{array}{l} CH_3CCH_3 \\ \quad\ \ \| \\ \quad\ \ O \end{array}$
   (d) CH_3COOH
2. (a) Fractional distillation separates the mixture of hydrocarbons in petroleum, collecting the fractions used in gasoline. Cracking converts larger straight-chain hydrocarbons into the shorter branched-chain hydrocarbons that are valuable in gasoline.
   (b) Three other useful fuels are jet fuel, kerosene, and diesel oil.
3. C, B, D, A. The reason for this order is that more polar compounds have higher boiling points as a result of increased intermolecular forces. C is an alkane and is nonpolar. B is more polar than C because of its carbonyl group. D is more polar than B because of its –OH group, which is capable of hydrogen bonding. A is more polar than D because it has an –OH group and a carbonyl group.
4. (a) acetone (propanone)

   $\begin{array}{l} CH_3CCH_3 \\ \quad\ \ \| \\ \quad\ \ O \end{array}$

   (b) acetic acid (ethanoic acid)

   $\begin{array}{l} CH_3COH \\ \quad\ \ \| \\ \quad\ \ O \end{array}$

   (c) formaldehyde (methanal)
   $HCHO$
   (d) glycerol (1,2,3-propantriol)

   $\begin{array}{ccccc} CH_2 & — & CH & — & CH_2 \\ | & & | & & | \\ OH & & OH & & OH \end{array}$

   (e) diethyl ether (ethoxyethane)
   $CH_3CH_2—O—CH_2CH_3$
5. (a) ethanol, 1-pentanol: Both molecules have a polar hydroxyl group, but the longer hydrocarbon chain in the pentanol increases its intermolecular van der Waals attractions.
   (b) ethoxyethane, propanone: The carbonyl group in the ketone makes it more polar. Therefore, it has stronger intermolecular attractions.
   (c) ethanal, ethanoic acid: The acid has an additional hydroxyl group that the aldehyde does not have, making it more polar and capable of hydrogen bonding; thus, the acid has stronger intermolecular attractions.
6. (a) propane, 1-propanol: Propane does not contain any polar groups and is therefore insoluble in water. Propanol contains a hydroxyl group, which allows hydrogen bonding and solubility in water.

(b) Methyl ethanoate, ethanoic acid: The ester is less soluble in water than is the carboxylic acid because the acid has a carbonyl group and a hydroxyl group capable of hydrogen bonding with water, but in the ester, the hydroxyl group is lost in the ester linkage; thus, the acid is more soluble in water.

(c) 2-butanone, 2-butanol: The ketone has a carbonyl group, but the alcohol has a hydroxyl group that can hydrogen bond with water. Therefore, 2-butanol is more soluble in water.

7. (a) 2-butanol:

$$\begin{array}{l} \quad\;\; \mathrm{OH} \\ \quad\;\;\; | \\ \mathrm{CH_3CHCH_2CH_3} \end{array}$$

(b) ethoxyethane: $CH_3CH_2OCH_2CH_3$

(c) 2-butanone:

$$\begin{array}{l} \quad\;\; \mathrm{O} \\ \quad\;\; \| \\ \mathrm{CH_3CCH_2CH_3} \end{array}$$

(d) ethanoic acid:

$$\begin{array}{l} \quad\;\; \mathrm{O} \\ \quad\;\; \| \\ \mathrm{CH_3COH} \end{array}$$

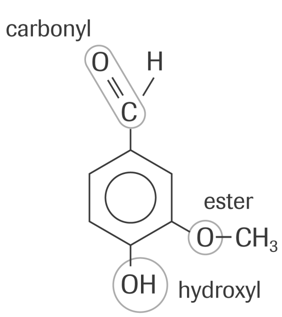
(e) methyl methanoate:

$$\begin{array}{l} \;\; \mathrm{O} \\ \;\; \| \\ \mathrm{HCOCH_3} \end{array}$$

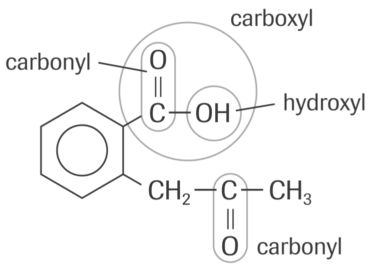
8. The solid formed is the ester. The ester has a lower melting point and solubility in aqueous solvents because it lacks the hydroxyl group present in both alcohols and carboxylic acids, and thus does not hydrogen bond.

9. (a) triple bond in carbon chain: alkyne
(b) –OH (hydroxyl) group: alcohol
(c) –COOH (carboxyl) group: carboxylic acid
(d) terminal C=O (carbonyl) group: aldehyde
(e) oxygen bonded to two carbon atoms: ether
(f) $–NH_2$ group: amine
(g) C=O (carbonyl) group bonded to two carbon atoms: ketone
(h) COO group: ester
(i) C=O (carbonyl) group bonded to N atom: amide
(j) C=O (carbonyl) group bonded to two carbon atoms: ketone
(k) –COOH (carboxyl) group: carboxylic acid
(l) double bond in carbon chain: alkene
(m) oxygen bonded to two carbon atoms: ether
(n) –OH (hydroxyl) group: alcohol
(o) triple bond in carbon chain: alkyne
(p) COO group: ester
(q) terminal C=O (carbonyl) group: aldehyde
(r) C=O (carbonyl) group bonded to two carbon atoms: ketone
(s) $–NH_2$ group: amine
(t) –OH (hydroxyl) groups: alcohol
(u) C=O (carbonyl) group bonded to N atom: amide
(v) double bonds in carbon chain: alkene

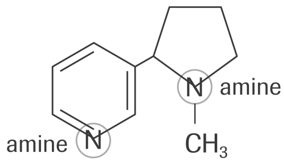
10. (a)



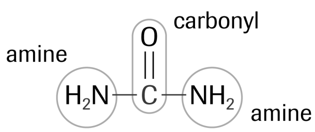
(b)



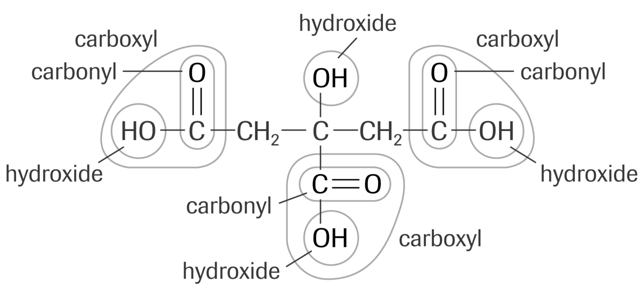
(c)



(d)



(e)



11. (a)

$$\mathrm{CH_2{=}CHCH_3 + Cl{-}Cl \rightarrow \overset{Cl}{\overset{|}{C}}H_2\overset{Cl}{\overset{|}{C}}HCH_3}$$

propane + chlorine → 1,2-dichloropropane
alkane inorganic alkyl halide
addition reaction

(b)

$$\mathrm{CH_3CH_2CH_2\overset{O}{\overset{\|}{C}}{-}OH + CH_3OH \rightarrow CH_3CH_2CH_2\overset{O}{\overset{\|}{C}}{-}OCH_3 + HOH}$$

butanoic acid + methanol → methyl butanoate + water
carboxylic acid alcohol ester
esterification reaction, condensation reaction

(c)

$$\mathrm{H{-}\underset{H}{C}{=}C{=}C{=}\underset{H}{C}{-}\overset{H}{C}{=}\underset{H}{C}{-}\overset{H}{\underset{H}{C}}{-}H + 9\,O_2 \rightarrow 7\,CO_2 + 4\,H_2O}$$

alkene + oxygen → carbon dioxide + water
combustion reaction

(d)

$$NH_3 + CH_3CH_2CH_2CH_2\overset{\displaystyle O}{\overset{\|}{C}} — OH \rightarrow CH_3CH_2CH_2CH_2\overset{\displaystyle O}{\overset{\|}{C}} — NH_2 + HOH$$

ammonia +	pentanoic acid	$\rightarrow$	pentanamide + water
inorganic	carboxylic acid		amide
condensation reaction			

12. (a) $CH_3CH_2OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$
    (b) $CH_2{=}CHCH_2CH_3 + H_2O \xrightarrow{H_2SO_4} CH_3CH(OH)CH_2CH_3$
    (c) $CH_3COOH + HN(CH_2CH_2CH_3)_2 \rightarrow CH_3CON(CH_2CH_2CH_3)_2 + H_2O$
13. (a) Intermolecular bonding restores the polymer strands to their original position, after any stretching or other deformation, which makes the polymer elastic.
    (b) For intermolecular bonding to occur, a monomer must be able to form bonds other than the bonds forming the polymer chain itself; that is, it must have an additional functional group (e.g., double bond, hydroxyl group, carboxyl group), other than the two involved in the polymer linkages, to link with another polymer chain.

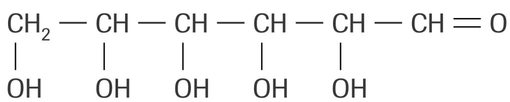
Applying Inquiry Skills

14. The three alcohols have different boiling points that increase in the following order: methanol, ethanol, and 1-pentanol. The alcohols can be separated by fractional distillation, using common laboratory equipment. Each alcohol is collected at its boiling point and condensed. All three alcohols have hydroxyl groups capable of hydrogen bonding. The larger alcohols have longer nonpolar hydrocarbon chains that increase the van der Waals attractions between them.
15. Carefully read and follow the recommendations on the MSDS for every chemical substance that you use.
    Be aware of the flammability and combustibility of solvents.
    Use organic solvents in a well-ventilated location or in a fume hood, away from ignition sources such as electrical sparks, open flames, and hot surfaces.
    Do not store organic solvents in direct sunlight or near heat sources.
    Do not use or store organic solvents in basements. Return unused solvents immediately to the appropriate storage containers.
    Organic solvents may be toxic; never eat or drink in the vicinity of organic solvents and always wash your hands after use.
    Dispose of waste solvents according to environmental restrictions. Never pour them down the sink.
16. Looking at states of matter: the alcohol is more likely to be a liquid. The short chain carboxylic acid may be a liquid or a solid, and the long chain carboxylic acid is more likely a solid. The reason for this conclusion is that alcohols have hydroxyl groups that allow hydrogen bonding. The carboxyl groups have a carbonyl group in addition to a hydroxyl group, and thus have stronger intermolecular forces, and are more likely to be solids. The long-chain carboxylic acid also has stronger van der Waals forces and is thus most likely to be a solid.
    When testing solubility in polar and nonpolar solvents, the alcohol and the short-chain carboxylic acid will likely be soluble in a polar solvent such as water because of the presence of hydroxyl groups. The long-chain carboxylic acid may be more soluble in nonpolar solvents because of the long hydrocarbon chain.
    Using the litmus test, the alcohol would not change blue litmus to pink, but the two acids would.
17. (a) ethanol, CH_3CH_2OH
    (b) ethanoic acid (acetic acid), CH_3COOH
    (c) $CH_3COOH + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + H_2O$
    (d) Esterification reaction (or condensation reaction)
    (e) Eye protection, lab apron, test tubes, pipettes, hot water bath (large beaker of hot water), evaporating dish, sulfuric acid
    (f) Working in a fume hood, place a small volume of the ethanoic acid in a test tube, with a few drops of concentrated sulfuric acid as a catalyst. Add a small volume of ethanol to the contents of the test tube. Heat the test tube and contents in the hot water bath for a few minutes. Pour the contents of the test tube into some cold water in an evaporating dish.
    (g) Wear eye protection and a lab apron. Wear gloves when handling concentrated sulfuric acid. Work in a fume hood or a well-ventilated area. Keep the ethanol away from open flames, electric sparks, and hot surfaces. Immediately return unused materials to the proper storage containers. Waft when smelling the ester produced. Dispose of waste solvents in proper containers.

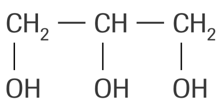
18. (Model-building exercise)
19. (a) The borax forms crosslinks between the molecules of glue, changing the glue from a thick liquid to a soft solid.
 (b) Make several batches of slime using the same ingredients, but make each batch with a different quantity of borax. Decreasing or increasing the amount of borax added would probably decrease or increase the elasticity of the slime because the number of crosslinks formed would change.

Making Connections

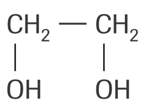
20. (a) methyl chloride: CH_3Cl
 chlorofluorocarbon (CFCs, Freon) e.g., CF_2Cl_2
 hydrochlorofluorocarbons (HCFCs) e.g., $CHFCl_2$
 hydrofluorocarbons (HFCs) e.g., CH_2F_2
 (b) These molecules all contain carbon and some combination of hydrogen, chlorine, or fluorine. They were all considered unreactive and safe to use and to discharge into the environment.
 (c) Methyl chloride is toxic. Leakage of the coolant resulted in several deaths. Freon appears to damage the upper ozone layer, causing ozone “holes” that leave us unprotected from harmful UV radiation. HCFCs and HFCs cause less damage to the ozone layer, but HFCs release carbon dioxide, a major greenhouse gas.
 (d) In the presence of UV light, Freon decomposes, releasing highly reactive chlorine atoms. The chlorine destroys the ozone molecules in the stratosphere. HCFCs and HFCs readily decompose in the atmosphere and have less time to cause damage to the ozone layer. HCFCs still contain chlorine, but HFCs contain no chlorine and are the preferred substitute for CFCs.
21. (a) glucose



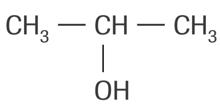
glycerol



ethylene glycol



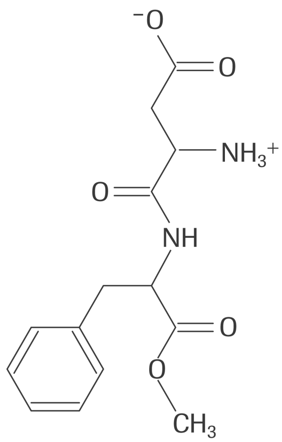
rubbing alcohol (2-propanol)



 (b) In order of increasing melting points and boiling points: rubbing alcohol, ethylene glycol, glycerol, glucose. The reason for this order is the increasing number of hydroxyl groups (1, 2, 3, 6, respectively), which increase the number of hydrogen bonds formed, thus increasing the amount of energy required to separate the molecules to melt or to boil.
 (c) All four substances should be soluble in water because of the number of polar hydroxyl groups that can hydrogen bond with water. All four substances are probably not soluble in a nonpolar solvent, such as gasoline, because they do not contain long nonpolar hydrocarbon chains.
 (d) Ethylene glycol is highly toxic and has a sweet taste. Animals or young children may taste ethylene glycol spills and drink it because of its sweetness.
 (e) These four compounds seem to have increasing sweet taste as the number of hydroxyl groups per molecule increases. This trend may support the hypothesis that taste receptors respond to functional groups—in this case, the hydroxyl groups.
22. (a) $CH_3COOH + CH_3CH_2CH_2CH_2CH_2OH \rightarrow CH_3COOCH_2CH_2CH_2CH_2CH_3$
 (b) Student answers will vary, but should refer to the raw materials and the method of synthesis.
 (c) The most commonly used natural source of vanilla flavouring is the vanillin plant, *Vanilla planifolia*, a member of the orchid family. Vanillin, a glucoside, is extracted from ripe vanillin beans, using ethanol and water, under cool temperatures to reduce flavour loss. The extract is then aged from a few days to several years.

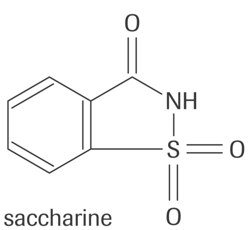
Synthetic vanilla flavouring contains a blend of natural vanilla and synthetic chemicals, and cannot be legally labelled "natural." The first synthetic vanilla was made from coniferin, and later from euganol, found in cloves. More recently, synthetic vanilla is made from ethyl vanillin (made from coal tar), or lignin vanillin, a byproduct of the paper industry. In the 1930s, the Ontario Paper Company solved an environmental problem by turning their industrial waste, a sulfite liquor, into synthetic vanilla.

23.



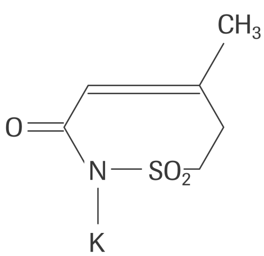
aspartame

Advantages: is relatively easy to make; has not been shown to cause cancer; is 200 times sweeter than sugar.
Disadvantages: has a shelf life of about six months, after which it loses its sweetness; breaks down at high temperatures, so it cannot be used in baking



saccharine

Advantages: is easy to make; is stable when heated; is approximately 300 times sweeter than sugar
Disadvantages: may cause cancer in rats (Some studies show that saccharin increases bladder cancer, while other studies show that there is no correlation between the amount of saccharin and the rate of cancer in rats.)



acesulfame potassium

Advantages: is stable at high temperatures; has a very long shelf life (about 3–4 years); has not been shown to cause cancer
Disadvantages: none known

24. Desired properties of polymers for use in the dental industry include high tensile strength, durability, insolubility in water, non-toxicity, resistance to softening at high temperatures (e.g., hot drinks).
    - Dental polymers have three main components: a polymer matrix; fillers of various types, sizes, shapes; and a phase that bonds the other two phases. Shrinkage of the polymer is a common shortfall.
    - Monomers may form branched or linear polymer chains. The linear polymer chains can have a parallel alignment and form crosslinks between chains, which allows for a crystalline structure that produces more of the desired properties. Dental monomers form strong hydrogen bonds, influencing the polymerization process and the network structure formed.
    - The polymerization process is usually initiated by chemical reduction–oxidation reactions, or by photochemical redox reactions. Dental fillings are generally cured using a curing lamp, a process that results in 2–3% shrinkage,

which leads to eventual detachment of the filling from the cavity. Pulse lasers can cause numerous initiations of the polymerization at the onset of curing, and may reduce the shrinkage of the fillings.

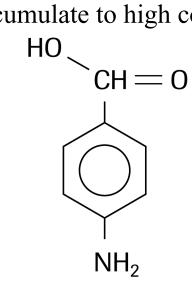
25. [Sample answers] paper (natural, polymer); plastic pen (synthetic, polymer); cotton and polyester shirt (natural and synthetic, polymer); running shoes (synthetic, polymer); ketchup (natural, polymer); vinegar (natural, not polymer); butter (natural, not polymer); gasoline (natural, not polymer); television set (synthetic, not polymer); CDs (synthetic, polymer)
26. Students might give any three of the following:

Synthetic polymer	Use	Monomer	Type of reaction
polyethene	sheet plastic, garbage bags	ethane	addition reaction
polypropene	rope	propene	addition reaction
polystyrene	foam cups	styrene	addition reaction
nylon	fabrics	dicarboxylic acids and diamines	condensation reaction
Dacron	fabrics	dicarboxylic acids and diamines	condensation reaction

27. Student answer will vary. Here are some sample points in a report on gasohol.
Ethanol and gasoline blends provide environmental benefits:
- Ethanol is clean burning, with lower carbon monoxide emissions than regular gasoline.
- Ethanol is low in reactivity and high in oxygen content, making it an effective tool in reducing ozone pollution.
- Ethanol provides a safe replacement for toxic octane enhancers in gasoline such as benzene, toluene, and xylene.
- Ethanol has a nonpolar carbon chain, making it a good solvent for the nonpolar hydrocarbons in gasoline; however, the polar hydroxyl group renders it soluble in water, so dissolved water droplets may form ice at low temperatures, blocking gasoline flow.

Extension

28. The solubility of organic halides in water is related to the length of the nonpolar hydrocarbon portion of the alkyl group. If the alkyl group is small, the halide may be water-soluble and thus can be excreted by an organism as waste. If the alkyl group is large, the molecule may be insoluble in polar solvents such as water, and soluble in nonpolar solvents such as the fat tissue in the organism. In this case, the organic halide is not excreted and is stored in the body. When organisms higher in the food chain eat a number of the affected organisms, the stored organic halides accumulate to high concentrations in the consumer, reaching toxic levels.
29. (a)



(b) PABA is benzoic acid with an added NH_2 group, in position 4; thus, it has an additional polar group that is capable of hydrogen bonding. Prediction: PABA is a solid at room temperature, with a boiling point higher than that of benzoic acid. The presence of the carboxyl group and the amino group makes the molecule highly polar and capable of hydrogen bonding, so PABA might be soluble in water. The presence of the benzene ring probably makes it soluble in nonpolar solvents such as alcohol and ether. With the presence of both a carboxyl group and an amino group, PABA can undergo condensation reactions with other molecules, or undergo condensation polymerization with other PABA molecules.

(c) [Sample answer] Sunscreens provide physical barriers to UV light (zinc oxide and titanium dioxide compounds), or chemical barriers. PABA is a chemical sunscreen that absorbs radiation in wavelengths that are invisible to the human eye. PABA is not soluble in water and therefore must be dissolved in alcohol for use; however, most of the PABA derivatives are water soluble. Sunlight consists of UVA rays (that penetrate deep into the base layer of skin) and UVB rays (burning rays). Both types of UV rays contribute to skin burning and skin cancer. PABA provides mostly UVB coverage between 260 and 330 nm. Consumers should select a sunscreen that screens out both UVA and UVB rays—the “broad spectrum” sunscreens.

There are some hazards to using PABA. Although sunscreens should be used every day to prevent premature aging and skin cancer (80% of the Sun's ultraviolet rays pass through the clouds on a cloudy day), sun exposure is needed for vitamin D. Thus, regular users of sunscreen may require vitamin D supplements. The original PABA was sometimes unpopular because it stained clothing. PABA esters, such as glycerol PABA, pentyl dimethyl PABA, and octyl dimethyl PABA, are now used. Some people are sensitive to PABA and its esters and should use other sunscreens.

30. The surfactant in bubble bath is usually sodium lauryl sulfate (or, in more expensive or milder brands, sodium laureth sulfate or sodium lauryl sulfoacetate). Castile soap (made from olive oil) can also be used. To help the surfactant to form bubbles, glycerine (or sometimes coconut or olive oil) is added. The surfactant ("surface active agent") reduces the surface tension of water by interacting with the water molecules. With less surface tension, bubbles of air in the water remain trapped just below the surface. The addition of glycerine or oil helps the foam to last longer by slowing down the rate at which the bubbles' water "skin" evaporates.

31. (a) Starch is the main method of energy storage for plants, as seeds or in tubers. Starches are polymers of glucose, joined in branched or unbranched chains. These chains have a helical structure, and are sufficiently small to be soluble in water, which makes the molecules mobile and transportable to different parts of the plant, an important property for an energy source.

(b) Glycogen is a starch-like molecule produced by animals. It is stored in the muscles as a ready source of energy, and also in the liver, where it helps to regulate the blood glucose level. Like starch, glycogen has a helical structure, which makes it soluble in water and readily transportable to different parts of the animal for energy.

(c) Cellulose is made in plants and provides structure and support. In cellulose, the glucose monomers are joined to form linear chains that align side by side, favouring hydrogen bonding between neighbouring polymer chains. These interlinked chains produce a rigid structure of layered sheets, giving cellulose its exceptional strength, and making it insoluble in water.