Making Connections

17. Acetylene becomes very reactive if compressed greatly, causing the gas to react violently with itself, forming hydrogen, carbon, and great heat, and exploding the container.
    For commercial use the gas is stored under lower relative pressure in cylinders containing fabric pads soaked with liquid acetone, $CH_3COCH_{3(l)}$. When not more than 100 volumes of acetylene are dissolved in 1 volume of acetone, the substance may be handled without danger.
18. A typical answer might be:
    Polyethylene's greatest use is as insulation for electrical wiring. Fabrics can be used for the same purpose (and were, historically), but they are nowhere near as durable, and are poorer insulators.
    The main problem with polyethylene has to do with its presence in waste material. It does not degrade significantly over time, so it persists in the environment.
19. Economic:
    Fossil fuels provide very inexpensive energy.
    Petrochemicals will become very expensive if fossil fuels become scarce.

    Social:
    Cheap energy from fossil fuels makes social improvements possible.
    Society has become dangerously dependent on fossil fuel energy.

    Environmental:
    Burning fossil fuels produces far fewer pollutants than burning wood.
    Burning fossil fuels produces greenhouse gas pollutants.

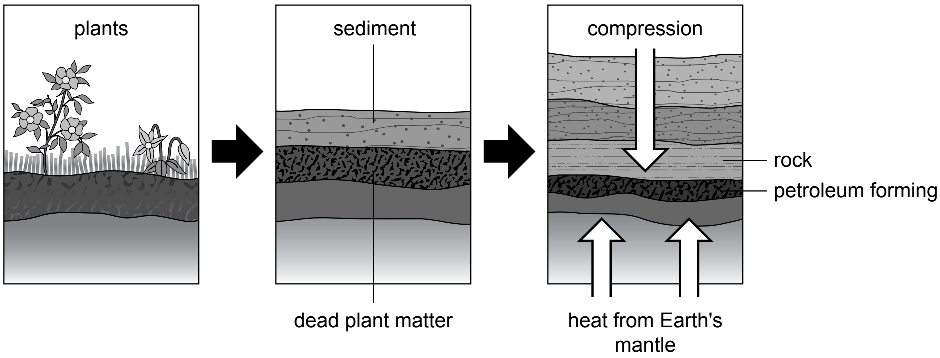
    Ethical:
    Burning fossil fuels improves the living standard of almost everyone.
    People should not use up a resource and thus deny it to future generations.

CHAPTER 11 REVIEW

(Page 561)

Understanding Concepts

1.



Currently accepted belief is that fossil fuels are formed when deposits of dead biological material are sealed in by sedimentary layers, and over geologic time are subjected to great pressure and high temperature deep beneath the Earth's surface.

2. The two fractions of raw petroleum are crude oil and natural gas — distinguished by their physical state on site — liquids and gases, respectively.
3. Fractionation is the principal physical process in petroleum refining.
4. Cracking and reforming are the principal chemical processes in petroleum refining.
5. Hydrocarbons are used technologically for fuels, and to manufacture petrochemical products.
6. Scientists suspect that organic compounds found on other planets might indicate non-earthly forms of life.

7. (a) $C_{13}H_{28(l)}$ kerosene
   (b) $C_{35}H_{72(s)}$ asphalts and tars
   (c) $C_7H_{16(l)}$ gasoline
   (d) $C_4H_{10(g)}$ gases
   (e) $C_{11}H_{24(l)}$ gasoline
8. Cracking and reforming reactions are designed to convert hydrocarbon molecules that are too small or too large into those suitable for blending into gasoline — which commands the most attractive price.
9. (a) Complete hydrocarbon combustion yields carbon dioxide and water.
   (b) Incomplete hydrocarbon combustion yields carbon dioxide and water plus carbon monoxide and (sometimes) carbon and unreacted hydrocarbons.
   (c) Limewater will test for the presence of carbon dioxide; and cobalt chloride will test for the presence of water.
10. (a) $CH_2 = CH—CH_2—CH_3 \quad + \quad CH_3—CH_2—CH_2—CH_2—CH_3$

    $\rightarrow \quad CH_3—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_2—CH_3$
    (b) 6-methyl-2-heptene reacts to form 2,4-dimethylhexane.
    (c) $CH_3(CH_2)_{22}CH_3 \quad + \quad 2\ H–H \quad \rightarrow \quad 3\ CH_3(CH_2)_6CH_3$
    (d) Butane reacts to form 2 ethanes and 1 hydrogen.
11. The great number of compounds formed by carbon is explained by chemists as resulting from the combination of these three atomic properties.
    (i) Carbon is a small atom that can form four bonds, more than atoms of most other elements.
    (ii) Carbon atoms have the special property of being able to bond together repeatedly to form chains, rings, spheres, sheets, and tubes.
    (iii) Carbon can form multiple combinations of single, double, and triple covalent bonds with itself and with atoms of other elements.
12. (a) alkanes, C_nH_{2n+2} — propane is a member of this family widely used as a fuel for camping, barbecues, and automobiles and trucks.
    (b) alkenes, C_nH_{2n} — ethene (ethylene) is a member of this family widely used as a beginning material for the manufacture of petrochemical products.
    c) alkynes, C_nH_{2n-2} — ethyne (acetylene) is a member of this family widely used as a fuel for welding torches.
13. (a) butane, $CH_3—CH_2—CH_2—CH_3$, has no isomers.
    (b) cyclobutane, $\begin{array}{ccc} CH_2 & — & CH_2 \\ | & & | \\ CH_2 & — & CH_2 \end{array}$, has as isomers:

    1-butene, $CH_2 = CH—CH_2—CH_3$,

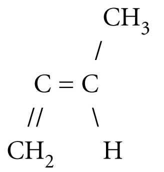
    2-butene, $CH_3—CH = CH—CH_3$, and

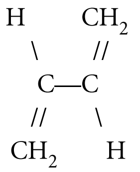
    methylpropene, $\begin{array}{l} CH_2 = C—CH_3 \\ \qquad\ \ | \\ \qquad CH_3 \end{array}$

    (c) 1-butene, $CH_2 = CH—CH_2—CH_3$
    For isomers, see (b) above.
    (d) 1-butyne, $CH \equiv C—CH_2—CH_3$, has as isomers,

    2-butyne, $CH_3—C \equiv C—CH_3$, and
    cyclobutene, $\begin{array}{ccc} CH & = & CH \\ | & & | \\ CH_2 & — & CH_2 \end{array}$

Note: Students may have discovered independently (or with guidance) that there exist two different dienes that are also isomers. These are



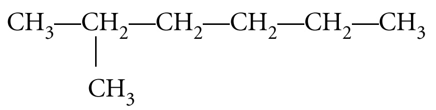


1,2-butadiene and 1,3-butadiene,

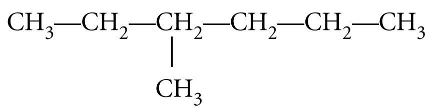
but students will not have a nomenclature system for these, yet, because they are not covered in this chapter.

14. The nine isomers of C_7H_{16} are:

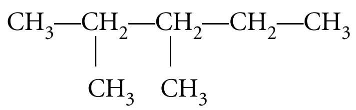
$CH_3—CH_2—CH_2—CH_2—CH_2—CH_2—CH_3$ heptane



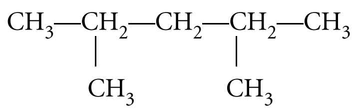
2-methylhexane



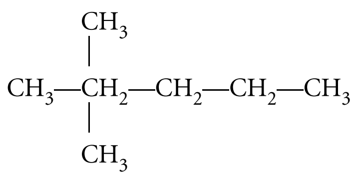
3-methylhexane



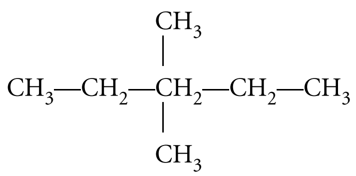
2,3-dimethylpentane



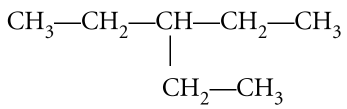
2,4-dimethylpentane



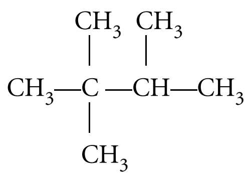
2,2-dimethylpentane



3,3-dimethylpentane

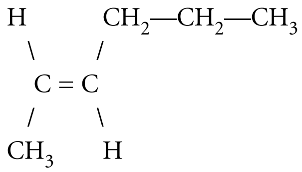


ethylpentane
(or 3-ethylpentane)

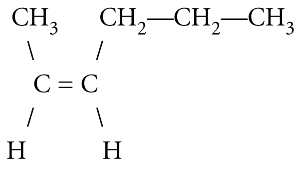


2,2,3-trimethylbutane

15. For 2-hexene, two geometric isomers exist.

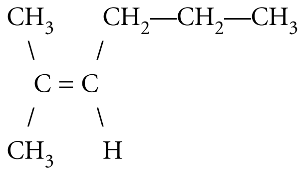


trans-2-hexene



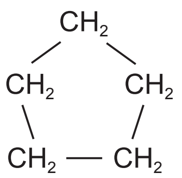
cis-2-hexene

Cis-trans geometric isomerism requires that *both* sides of the double bond have different structures bonded to them. Because the double bond is not free to rotate, exchanging the structures on either side then must result in a different molecular *shape*, even though the structural name is unchanged. As another example, consider 2-methyl-2-hexene, for which there are *no* geometric isomers.



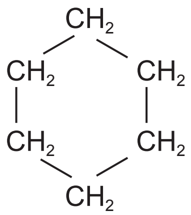
Since one side of the double bond is symmetrical, exchanging the groups on either side of the bond results in exactly the same molecule as before.

16. Saturated organic compounds have only single carbon–carbon bonds, so the total number of bonds (and hydrogens) is the maximum possible. Molecules of unsaturated hydrocarbons have at least one double or triple carbon–carbon bond.
17. (a) unsaturated
    (b) saturated
    (c) unsaturated
    (d) unsaturated
    (e) saturated
    (f) unsaturated
18. (a) C_5H_{10} could be cyclic;



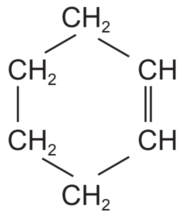
cyclopentane

(b) C_5H_{12} cannot be cyclic; it's an alkane.
(c) C_6H_{10} could be cyclic;



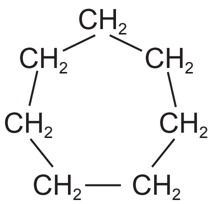
cyclohexene

(d) C_6H_{12} could be cyclic;



cyclohexane

(e) C_6H_{14} cannot be cyclic; it's an alkane.
(f) C_7H_{14} could be cyclic;



cycloheptane

19. (b) 3-pentyne should be: 2-pentyne
(c) 1,2-dimethylpropane should be: 2-methylbutane
(d) 3,3-dimethyl-3-hexene could be: 1,2-dimethylhexane

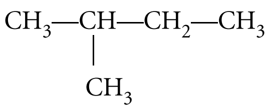
Note: The correct name for this misnamed substance is not readily apparent. There cannot be two methyl group branches *and* a double bond on carbon #3 of a hexene chain — that requires more bonds than the carbon can form. The correct name could be: (2,3 or 2,4 or 2,5 or 3,4 or 3,5 or 4,5 or 2,2 or 4,4 or 5,5)-dimethyl-3-hexene, assuming the substance really is a dimethyl-3-hexene. If the double bond is not on carbon #3, many more possibilities arise.

(e) 2-propene should be: propene (or 1-propene)

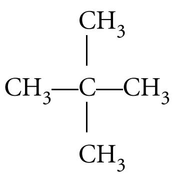
20. $2\ C_2H_{2(g)} + 2\ O_{2(g)} \rightarrow 3\ C_{(s)} + CO_{2(g)} + 2\ H_2O_{(g)}$

21. (a) pentane $CH_3—CH_2—CH_2—CH_2—CH_3$

2-methylbutane



2,2-dimethylpropane



If you draw a continuous line around the structural formulas for these isomers, it will help to show that dimethylpropane has the most nearly spherical structure. In a large group of spheres only small parts of the surface of one sphere are close to the next sphere. For intermolecular bonding with London forces, this means weaker bonding overall, resulting in a lower boiling point.

22. Assuming more branching means a lower isomer boiling point,
(a) 3-methylpentane 63°C
(b) hexane 69°C
(c) 2,2-dimethylbutane 50°C

23. (a) $C_3H_{6(g)} + H_{2(g)} \rightarrow C_3H_{8(g)}$
propene and hydrogen react to form—
propane. $CH_3—CH_2—CH_3$

(b) $C_9H_{18(l)} + H_{2(g)} \rightarrow C_9H_{20(l)}$

3-ethyl-2-methyl-3-hexene and hydrogen react to form —

3-ethyl-2-methylhexane. $CH_3—CH—CH—CH_2—CH_2—CH_3$
with CH_3 on C-2 and $CH_2—CH_3$ on C-3

(c) $C_5H_{8(l)} + 2\ H_{2(g)} \rightarrow C_5H_{12(l)}$
1-pentyne and hydrogen react to form—
pentane. $CH_3—CH_2—CH_2—CH_2—CH_3$

Applying Inquiry Skills

24. (a) **Analysis**

The substance labelled Liquid 2 must be the unsaturated hydrocarbon compound 2-methyl-2-butene, because it reacts rapidly with bromine. Of the remaining two substances, the straight-chain substance pentane should have stronger London intermolecular forces because of its molecular shape, and therefore have a higher boiling point — so Liquid 1 is probably the pentane. By elimination, Liquid 3 is the 2-methylbutane.

Making Connections

25. (a) A few of the polymers in common use are polyethylene, polystyrene, nylon, rayon, Teflon, polypropylene, and polyvinyl chloride. There are, of course, many, many more possible entries for this list.
(b) Polymers enable us to do many things that are not possible without them — they provide our clothing, utensils, appliances, transport, and shelter. Their main disadvantage is their chemical unreactivity. They present a waste disposal problem because they do not break down or biodegrade.
(c) Petrochemicals of all kinds will become more expensive if hydrocarbons from fossil fuels become scarce. Alternative sources are biological — organic compounds (for example, ethanol, for fuel and to make ethene) can be produced from crops of living material, like corn or rice. A "far-out" source for the future might be frozen volatiles obtained from carbonaceous asteroids, comets, the rings of Saturn, or moons of other planets of our solar system.

26. Automotive fuels are used in enormous quantity by our society. Any improvement in fuel characteristic, no matter how small, has a great impact on society as a whole. An important fuel characteristic concerns how much carbon dioxide it produces when burned, because CO_2 emissions increase the planetary "greenhouse" effect. Hydrogen is the best possible fuel from this perspective. A current concern is with sulfur levels in gasoline. Legislation is in effect to reduce fuel sulfur levels dramatically within this decade. This means pollution effects are another important fuel characteristic.

We require that fuels be relatively safe and easy to transport, and economical enough to permit free mobility to our population. At present, only propane, and the hydrocarbon mixtures called gasoline and kerosene (diesel fuel, jet fuel) are competitively priced.

27. (a) Petroleum distillate means any mixture of small liquid hydrocarbons obtained from fractionation of petroleum (crude oil).
(b) Hydrocarbons will dissolve grease or most other nonpolar substances; displace water from a metal surface because water is polar and not soluble in the hydrocarbons; and lubricate a coated surface because the hydrocarbon molecules are not "sticky" — they have weak intermolecular bonds.
(c) A chlorofluorocarbon is any molecule that is structured like a hydrocarbon with halogen (chlorine of fluorine) atoms in place of some or all of the hydrogens. CFCs released to the atmosphere are partially responsible for depleting the ozone layer in the stratosphere, and such release of these chemicals under most circumstances is now illegal in Canada.

28. (a) Pure oxygen reacts very much faster with any fuel than air, which is only about 20% oxygen. In oxyacetylene welding, for example, the reaction would not be fast enough or hot enough to melt metals if atmospheric air were used.

(b) $2\ C_2H_{2(g)} \quad + \quad 5\ O_{2(g)} \rightarrow 4\ CO_{2(g)} \quad + \quad 2\ H_2O_{(g)}$

$\quad 1.00\ L \qquad\qquad v$

All gases measured at the same temperature and pressure.

$$v_{O_2} = 1.00\ L \times \frac{5}{2}$$
$$v_{O_2} = 2.50\ L$$

or

$$v_{O_2} = 1.00\ \cancel{L}\ \cancel{C_2H_2} \times \frac{5\ L\ O_2}{2\ \cancel{L}\ \cancel{C_2H_2}}$$
$$v_{O_2} = 2.50\ L$$

The volume of pure oxygen required would be 2.50 L.

(c) If air (20% oxygen) were used,

$$v_{air} = 2.50\ L \times \frac{100}{20}$$
$$v_{air} = 12.5\ L$$

or

$$v_{air} = 2.50\ \cancel{L}\ \cancel{O_2} \times \frac{100\ L\ air}{20\ \cancel{L}\ \cancel{O_2}}$$
$$v_{air} = 12.5\ L$$

The volume of air required would be 12.5 L.

Exploring

29. Students will find that gasolines blended with ethanol are advertised as burning more cleanly than unblended fuels. The "green" concept has mostly to do with the fact that the ethanol is produced from plants, and is a renewable resource. More research will turn up the fact that there is a small energy penalty to pay — ethanol-blended gasoline is not quite as energy efficient as unblended fuels.
30. Information reference: *Asimov's Biographical Encyclopedia of Science and Technology* — by Isaac Asimov, Doubleday (1964).

    Jöns Jakob Berzelius (buhr-ZEE-lee-us), (1779–1848), made huge contributions to the field of chemistry. His first notable achievement was to perform so many analyses supporting Proust's law of definite proportions, that the scientific community was forced to accept the validity of this law. He then prepared a list of atomic weights — the first reasonably accurate one in history. His next contribution was the one that assures his place in history; he developed the system of symbols for elements that we still use today. He developed an idea about atomic groupings that move intact in reactions. He called his groupings "radicals"; and while much of his concept was incorrect, we use parts of this idea to explain polyatomic ions, like sulfate, SO_4^{2-}. Berzelius discovered the elements selenium, silicon, and thorium. By 1830 he was accepted as the world's leading chemistry authority.

    Pierre Eugène Marcelin Berthelot (behr-tuh-LOH), (1827–1907), destroyed all scientific opposition to the new concept that organic chemicals could be produced from nonliving sources. His doctoral thesis involved the synthesizing of several organic fats found in nature in animals. He synthesized hundreds of organic compounds from elementary raw materials, including methanol, ethanol, methane, benzene, and acetylene. He was the first to produce organic compounds that were *not* also found in living things, which was the final nail in the coffin of the "life-force" organic concept.

    Note: Later, Berthelot turned his attention to thermochemistry. He invented a calorimeter that enabled him to accurately measure the energy produced by chemical reactions — the subject of the next chapter of this text.