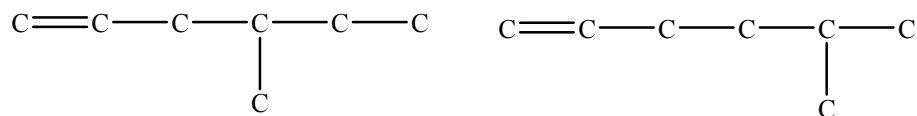
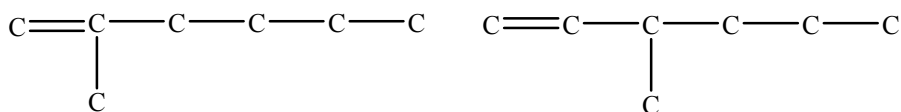


CHAPTER 15 ORGANIC COMPOUNDS AND THE ATOMIC PROPERTIES OF CARBON

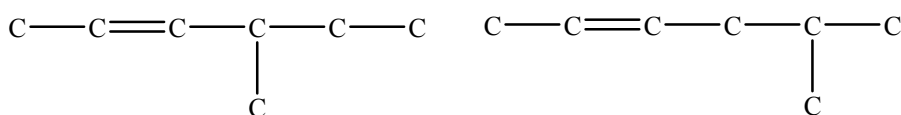
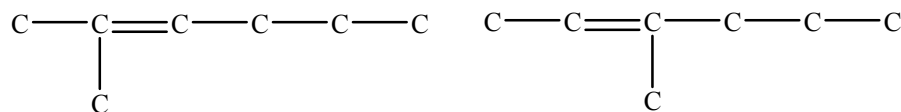
- 15.1 Organic: Methane (natural gas) CH₄ Acetic Acid (in vinegar) C₂H₄O₂
 Inorganic: Calcium Carbonate CaCO₃ Sodium Bicarbonate NaHCO₃
- 15.2 In the early 19th century, many prominent thinkers believed that an unobservable spiritual energy, a “vital force,” existed within compounds from living things, which made them impossible to synthesize and fundamentally different from compounds of the mineral world. The finding that urea (present in mammal urine) could be synthesized from inorganic ammonium cyanate led to the downfall of vitalism.
- 15.3 a) Carbon’s electronegativity is midway between the most metallic and nonmetallic elements of period 2. To attain a filled outer shell, carbon forms covalent bonds to other atoms in molecules (e.g., methane, CH₄), network covalent solids (e.g., diamond) and polyatomic ions (e.g., carbonate, CO₃²⁻).
 b) Since carbon has 4 valence shell electrons, it forms four covalent bonds to attain an octet.
 c) Two noble gas configurations, He and Ne, are equally near carbon’s configuration. To reach the He configuration, the carbon atom must lose 4 electrons, requiring too much energy to form the C⁴⁺ cation. This is confirmed by the fact that the value of the ionization energy for carbon is very high. To reach the Ne configuration, the carbon atom must gain 4 electrons, also requiring too much energy to form the C⁴⁻ anion. The fact that a carbon anion is unlikely to form is supported by carbon’s electron affinity. The other possible ions would not have a stable noble gas configuration.
 d) Carbon is able to bond to itself extensively because carbon’s small size allows for closer approach and greater orbital overlap. The greater orbital overlap results in a strong, stable bond.
 e) The C–C bond is short enough to allow the sideways overlap of unhybridized *p* orbitals on neighboring C atoms. The sideways overlap of *p* orbitals results in double and triple bonds.
- 15.4 a) The elements that most frequently bond to carbon are other carbon atoms, **hydrogen, oxygen, nitrogen, phosphorus, sulfur, and the halogens, F, Cl, Br, and I.**
 b) In organic compounds, heteroatoms are defined as atoms of any element other than carbon and hydrogen. The elements **O, N, P, S, F, Cl, Br, and I** listed in part a) are heteroatoms.
 c) Elements more electronegative than carbon are **N, O, F, Cl, and Br.** Elements less electronegative than carbon are **H and P.** Sulfur and iodine have the same electronegativity as carbon.
 d) The more types of atoms that can bond to carbon, the greater the variety of organic compounds that are possible.
- 15.5 Atomic and bonding properties produce three crucial differences between C and Si. Si is larger, forms weaker bonds, and unlike C, has *d* orbitals available.
- 15.6 Oxidation states of carbon range from –4 to +4. In carbon dioxide (CO₂) carbon has a +4 oxidation state. In methane (CH₄), carbon has a –4 oxidation state.
- 15.7 Chemical reactivity occurs when unequal sharing of electrons in a covalent bond results in regions of high and low electron density. The C–H, C–C, and C–I bonds are unreactive because electron density is shared equally between the two atoms. The **C=O** bond is reactive because oxygen is more electronegative than carbon and the electron rich pi bond is above and below the C–O bond axis, making it very attractive to electron-poor atoms. The **C–Li** bond is also reactive because the bond polarity results in an electron-rich region around carbon and an electron-poor region around Li.
- 15.8 a) An alkane is an organic compound consisting of carbon and hydrogen in which there are no multiple bonds between carbons, only single bonds. A cycloalkane is an alkane in which the carbon chain is arranged in a ring. An alkene is a hydrocarbon with at least one double bond between two carbons. An alkyne is a hydrocarbon with at least one triple bond between two carbons.

- b) The general formula for an alkane is C_nH_{2n+2} .
 The general formula for a cycloalkane is C_nH_{2n} . Elimination of two hydrogen atoms is required to form the additional bond between carbons in the ring.
 For an alkene, assuming only one double bond, the general formula is C_nH_{2n} . When a double bond is formed in an alkane, two hydrogen atoms are removed.
 For an alkyne, assuming only one triple bond, the general formula is C_nH_{2n-2} . Forming a triple bond from a double bond causes the loss of two hydrogen atoms.
- c) For hydrocarbons, “saturated” is defined as a compound that cannot add more hydrogen. An unsaturated hydrocarbon contains multiple bonds that react with H_2 to form single bonds. The **alkanes and cycloalkanes** are saturated hydrocarbons since they contain only single C–C bonds.
- 15.9 a) Constitutional isomers are those with different sequences of bonded atoms.
 b) Geometric isomers have different orientation of groups around a double bond or a cyclic structure.
 c) Optical isomers are a type of stereoisomerism that arises when a molecule and its mirror image cannot be superimposed on each other.
 Constitutional and geometric isomers are not stereoisomers.
- 15.10 Alkynes are linear about the triple bond. Aromatics can only assume one (planar) orientation in space.
- 15.11 An asymmetric molecule has no plane of symmetry.
 a) A circular clock face numbered 1 to 12 o’clock is **asymmetric**. Imagine that the clock is cut in half, from 12 to 6 or from 9 to 3. The one-half of the clock could never be superimposed on the other half, so the halves are not identical. Another way to visualize symmetry is to imagine cutting an object in half and holding the half up to a mirror. If the original object is “re-created” in the mirror, then the object has a plane of symmetry.
 b) A football is symmetric and has two planes of symmetry — one axis along the length and one axis along the fattest part of the football.
 c) A dime is **asymmetric**. Either cutting it in half or slicing it into two thin diameters results in two pieces that cannot be superimposed on one another.
 d) A brick, assuming that it is perfectly shaped, is symmetric and has three planes of symmetry at right angles to each other.
 e) A hammer is symmetric and has one plane of symmetry, slicing through the metal head and down through the handle.
 f) A spring is **asymmetric**. Every coil of the spring is identical to the one before it, so a spring can be cut in half and the two pieces can be superimposed on one another by sliding (not flipping) the second half over the first. However, if the cut spring is held up to a mirror, the resulting image is not the same as the uncut spring. Disassemble a ballpoint pen and cut the spring inside to verify this explanation.
- 15.12 A polarimeter is used to measure the angle that the plane of polarized light is rotated. A beam of light consists of waves moving in all planes. A polarizing filter blocks all waves except those in one plane, so the light emerging through the filter is plane-polarized. An optical isomer is said to be optically active because it rotates the plane of the polarized light. The dextrorotatory isomer (designated *d* or *+*) rotates the plane of light to the right; the levorotatory isomer (designated *l* or *–*) is the mirror image of the first and rotates the plane to the left.
- 15.13 Aromatic hydrocarbons have carbon in sp^2 hybridization while cycloalkanes have carbon in sp^3 hybridization. Aromatic hydrocarbons are planar while most cycloalkanes assume puckered ring structures.
- 15.14 To draw the possible skeletons, it is useful to have a systematic approach to make sure no structures are missed.
 a) Since there are 7 C atoms but only a 6 C chain, there is one C branch off of the chain. First, draw the skeleton with the double bond between the first and second carbons and place the branched carbon in all possible positions starting with C #2. Then move the double bond to between the second and third carbon and place the branched carbon in all possible positions. Then move the double bond to between the third and fourth carbons and place the branched carbon in all possible positions. The double bond does not need to be moved further in the chain since the placement between the second and third carbon is equivalent to placement between the fourth and fifth carbons and placement between the first and second carbons is equivalent to placement between the fifth and sixth carbons. The other position to consider for the double bond is between the branched carbon and the 6 C chain.

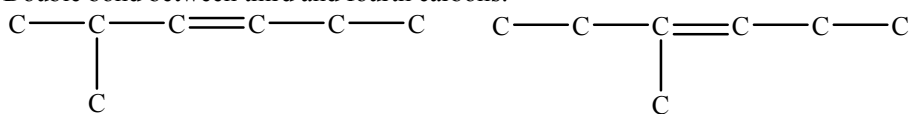
Double bond between first and second carbons:



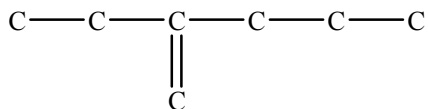
Double bond between second and third carbons:



Double bond between third and fourth carbons:



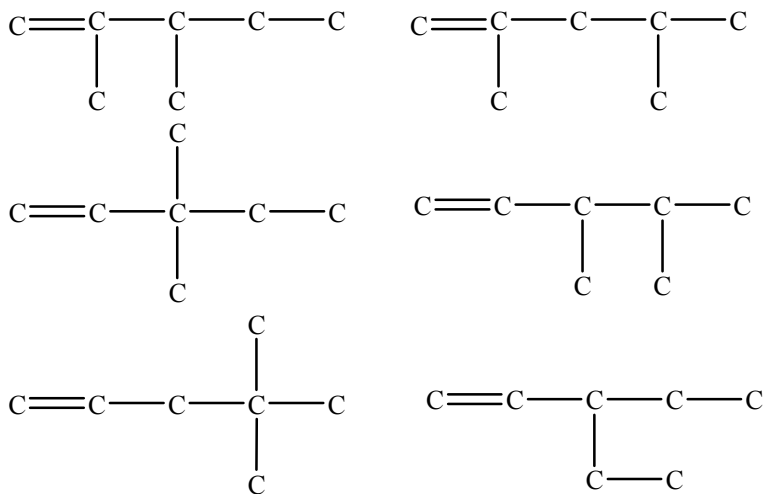
Double bond between branched carbon and chain:



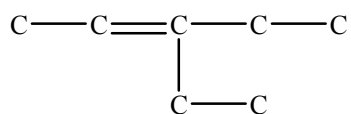
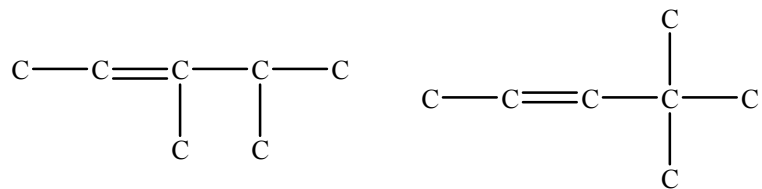
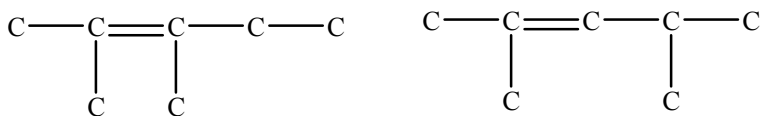
The total number of unique skeletons is 11. To determine if structures are the same, build a model of one skeleton and see if you can match the structure of the other skeleton by rotating the model and without breaking any bonds. If bonds must be broken to make the other skeleton, the structures are not the same.

b) The same approach can be used here with placement of the double bond first between C #1 and C #2, then between C #2 and C #3. Since there are 7 C atoms but only 5 C atoms in the chain, there are two C branches.

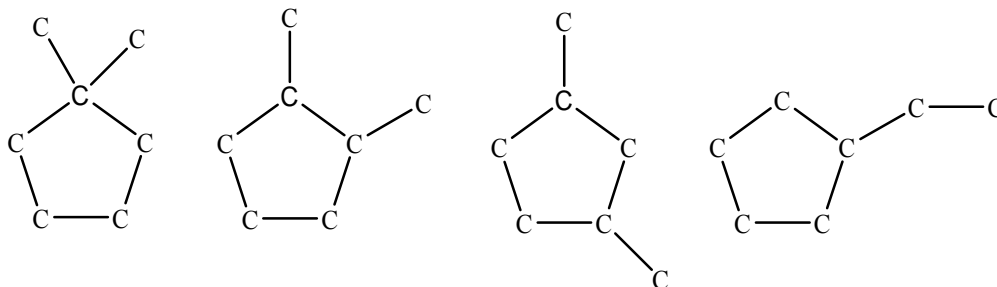
Double bond between first and second carbons:



Double bond between second and third carbons:

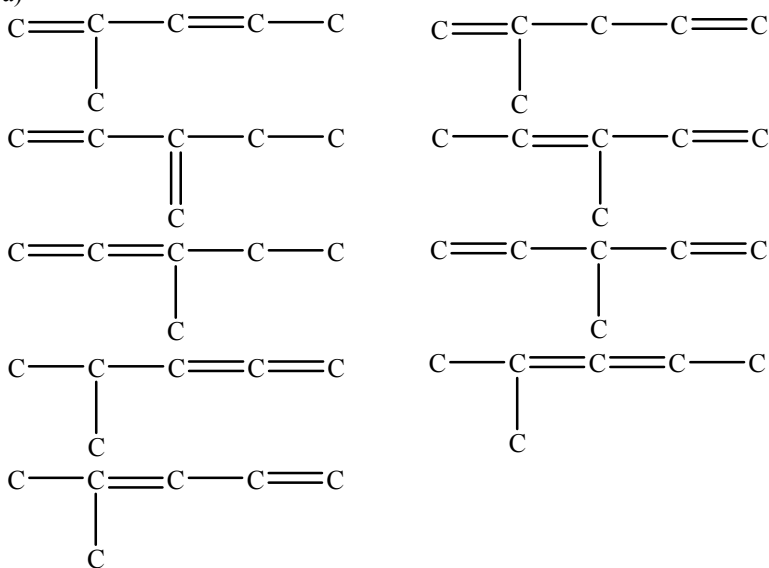


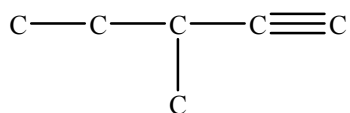
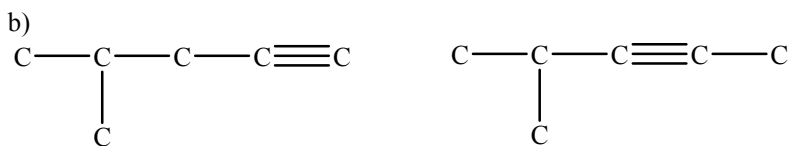
c) Five of the carbons are in the ring and two are branched off the ring. Remember that all the carbons in the ring are equivalent and there are two groups bonded to each carbon in the ring.



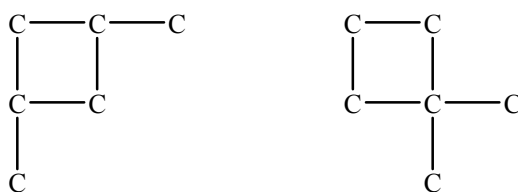
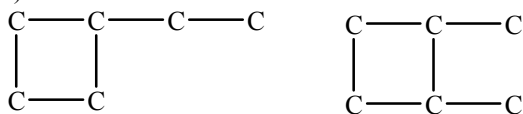
15.15 To draw the possible skeletons it is useful to have a systematic approach to make sure no structures are missed.

a)

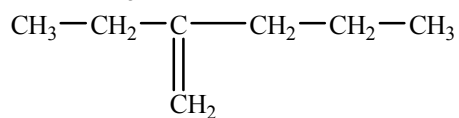
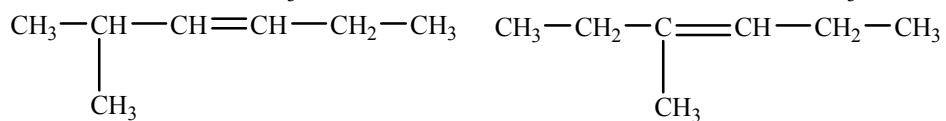
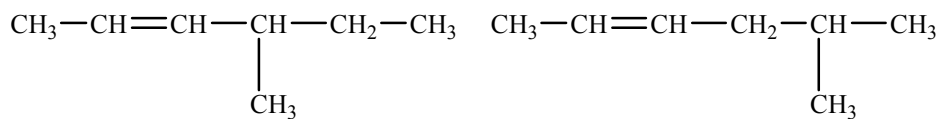
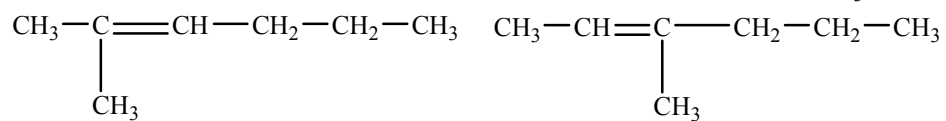
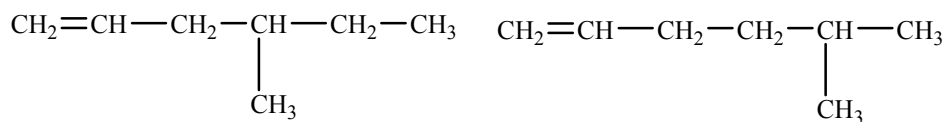
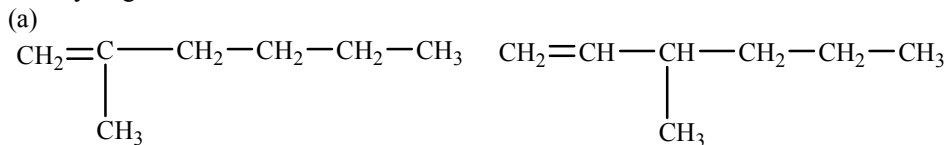




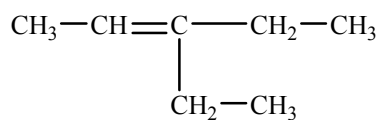
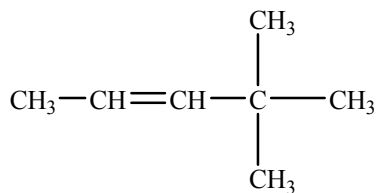
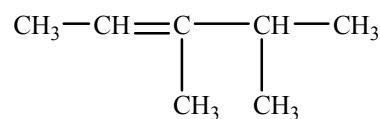
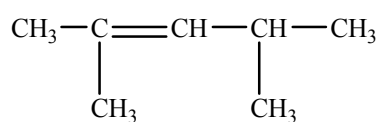
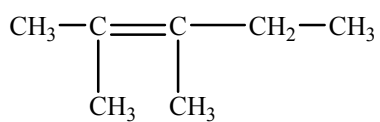
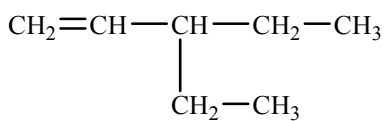
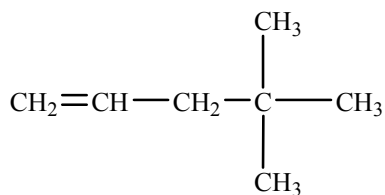
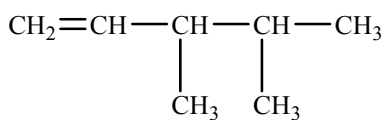
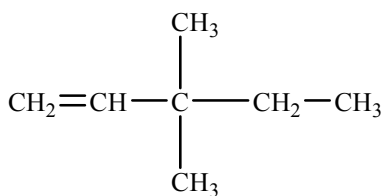
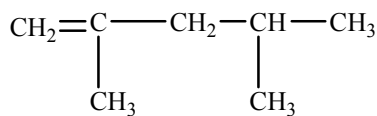
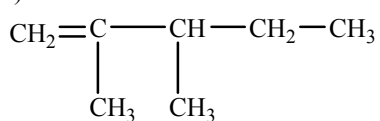
c) There are *cis-trans* isomers not shown because the topic has not been covered at this point.



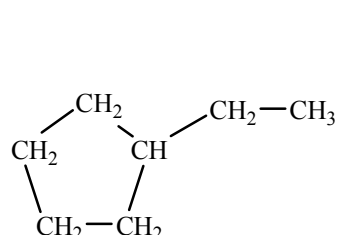
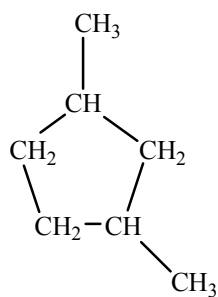
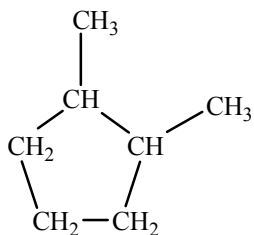
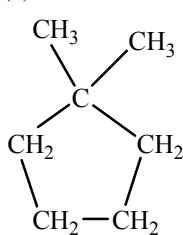
15.16 Add hydrogen atoms to make a total of four bonds to each carbon.



(b)

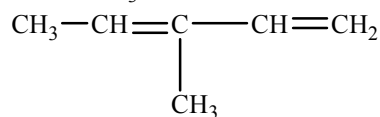
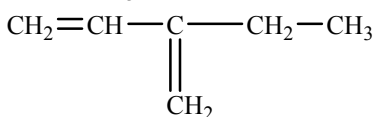
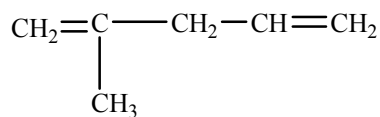
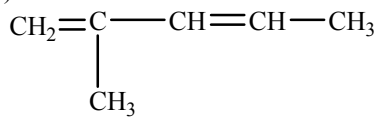


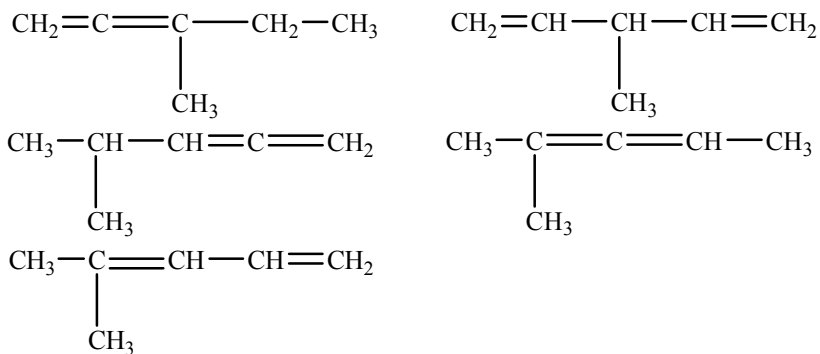
(c)



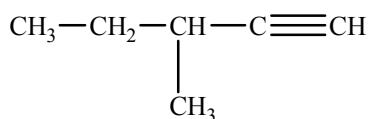
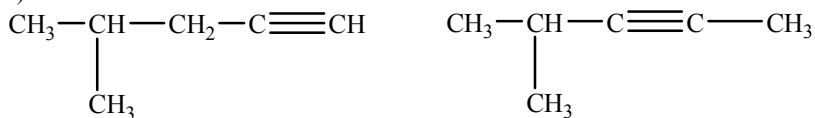
15.17 Add hydrogen atoms to make a total of 4 bonds to each carbon.

a)

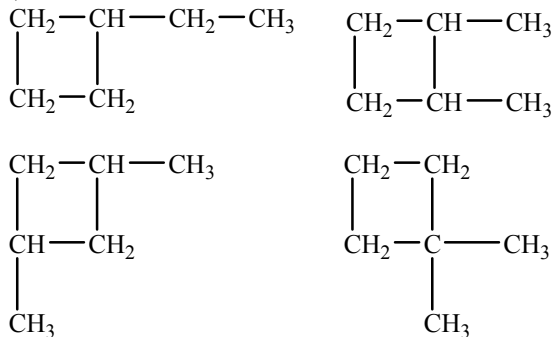




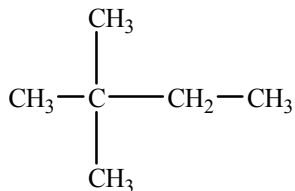
b)



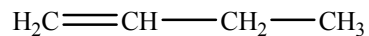
c) There are *cis-trans* isomers not shown because the topic has not been covered at this point.



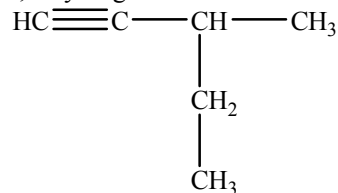
- 15.18 a) The second carbon from the left in the chain is bonded to five groups. Removing one of the groups gives a correct structure.



b) The first carbon in the chain has five bonds, so remove one of the hydrogens on this carbon.

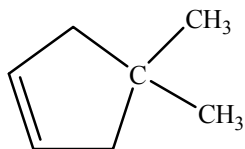


c) The second carbon in the chain has five bonds, so move the ethyl group from the second carbon to the third. To do this, a hydrogen atom must be removed from the third carbon atom.

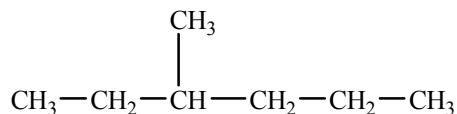


d) Structure is correct.

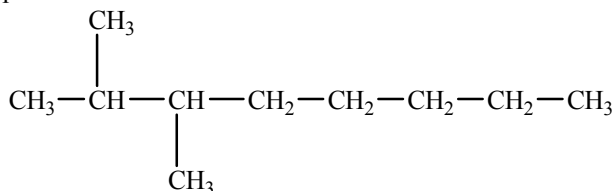
- 15.19 a) Structure is correct.
b)



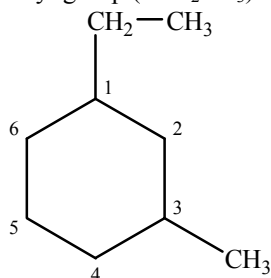
- c)
 $\text{CH}_3 - \text{C} \equiv \text{C} - \text{CH}_2 - \text{CH}_3$
d)



- 15.20 a) *Octane* denotes an eight carbon alkane chain. A methyl group ($-\text{CH}_3$) is located at the second and third carbon position from the left.



- b) *Cyclohexane* denotes a six-carbon ring containing only single bonds. Numbering of the carbons on the ring could start at any point, but typically, numbering starts at the top carbon atom of the ring for convenience. The ethyl group ($-\text{CH}_2\text{CH}_3$) is located at position 1 and the methyl group is located at position 3.

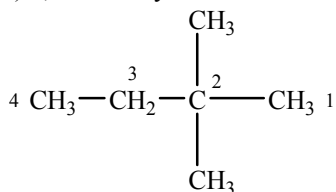


- c) The longest continuous chain contains seven carbon atoms, so the root name is “hept.” The molecule contains only single bonds, so the suffix is “ane.” Numbering the carbon chain from the left results in side groups (methyl groups) at positions 3 and 4. Numbering the carbon chain from the other will result in side groups at positions 4 and 5. Since the goal is to obtain the lowest numbering position for a side group, the correct name is **3,4-dimethylheptane**. Note that the prefix “di” is used to denote that two methyl side groups are present in this molecule.

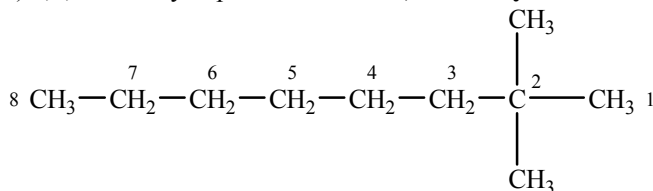
- d) At first glance, this molecule looks like a 4 carbon *ring*, but the two $-\text{CH}_3$ groups mean that they cannot be bonded to each other. Instead, this molecule is a 4-carbon *chain*, with two methyl groups (dimethyl) located at the position 2 carbon. The correct name is **2,2-dimethylbutane**.

Numbering is good for this structure, but the fact that there are two methyl groups must be indicated by the prefix di- in addition to listing 3,3. The branch names appear in alphabetical order. Correct name is **4-ethyl-3,3-dimethyloctane**.

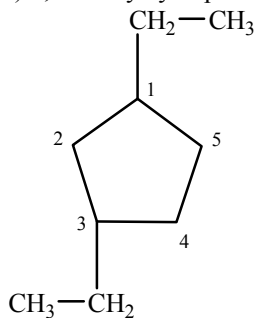
15.23 a) 3,3-dimethylbutane should be **2,2-dimethylbutane**.



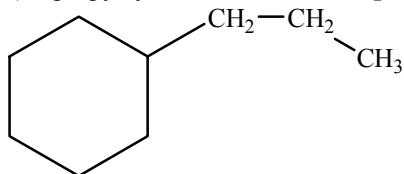
b) 1,1,1-trimethylheptane should be **2,2-dimethyloctane**.



c) 1,4-diethylcyclopentane should be **1,3-diethylcyclopentane**.

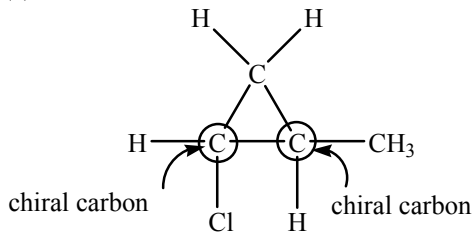


d) 1-propylcyclohexane should be **propylcyclohexane**.

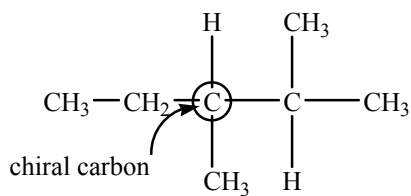


15.24 A carbon atom is chiral if it is attached to four different groups. The circled atoms below are chiral.

(a)

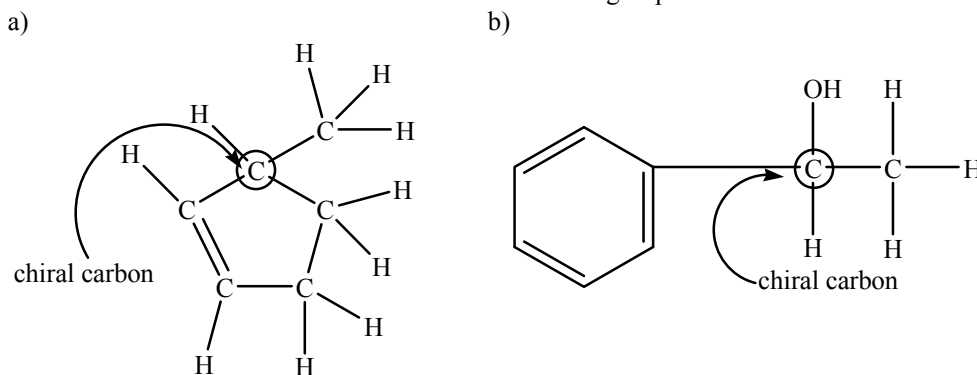


(b)



Both can exhibit optical activity.

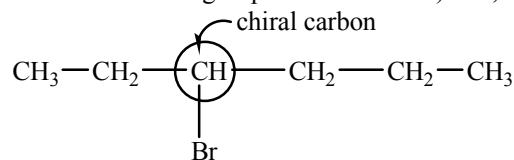
15.25 A carbon atom is chiral if it is attached to four different groups. The circled atoms below are chiral.



Both can exhibit optical activity.

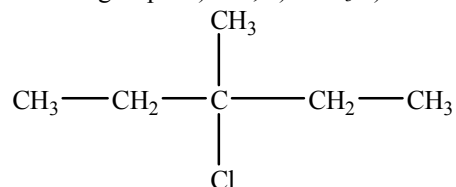
15.26 An optically active compound contains at least one chiral center, a carbon with four distinct groups bonded to it.

a) This compound is a 6 carbon chain with a Br on the third carbon. 3-bromohexane is optically active because carbon #3 has four distinct groups bonded to it: 1) -Br, 2) -H, 3) -CH₂CH₃, 4) -CH₂CH₂CH₃.

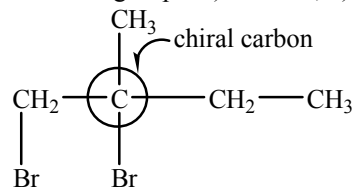


b) This compound is a 5 carbon chain with a Cl and a methyl (CH₃) group on the third carbon.

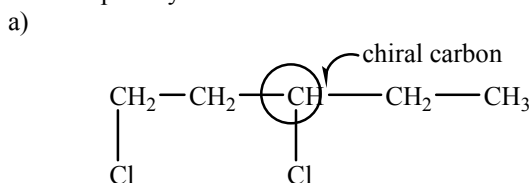
3-chloro-3-methylpentane is not optically active because no carbon has four distinct groups. The third carbon has three distinct groups: 1) -Cl, 2) -CH₃, 3) two -CH₂CH₃ groups.



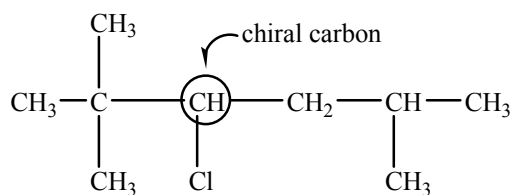
c) This compound is a 4 carbon chain with Br atoms on the first and second carbon atoms and a methyl group on the second carbon. 1,2-dibromo-2-methylbutane is optically active because the 2nd carbon is chiral, bonded to the four groups: 1) -CH₂Br, 2) -CH₃, 3) -Br, 4) -CH₂CH₃.



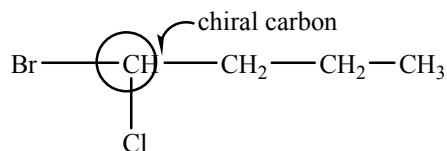
15.27 All are optically active.



b)

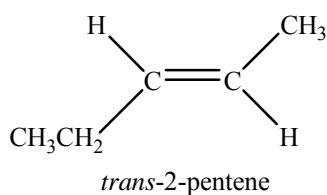
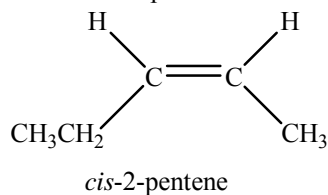


c)

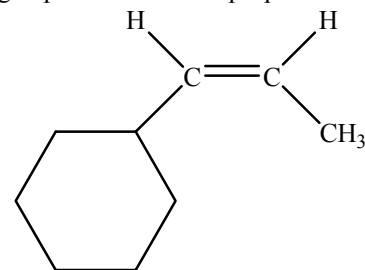


15.28 Geometric isomers are defined as compounds with the same atom sequence but different arrangements of the atoms in space. The *cis-trans* geometric isomers occur when rotation is restricted around a bond, as in a double bond or a ring structure, and when two different groups are bonded to each atom in the restricted bond.

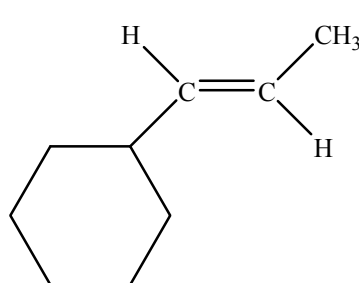
a) Both carbons in the double bond are bonded to two distinct groups, so geometric isomers will occur. The double bond occurs at position 2 in a five-carbon chain.



b) *Cis-trans* geometric isomerism occurs about the double bond. The ring is named as a side group (cyclohexyl) occurring at position 1 on the propene main chain.



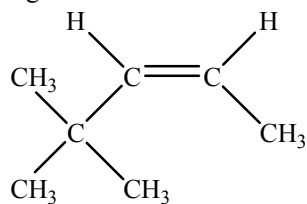
cis-1-cyclohexylpropene



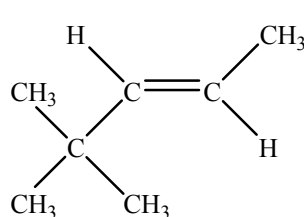
trans-1-cyclohexylpropene

c) No geometric isomers occur because the left carbon participating in the double bond is attached to two identical methyl ($-\text{CH}_3$) groups.

15.29 a) *Cis-trans* geometric isomerism occurs about the double bond.



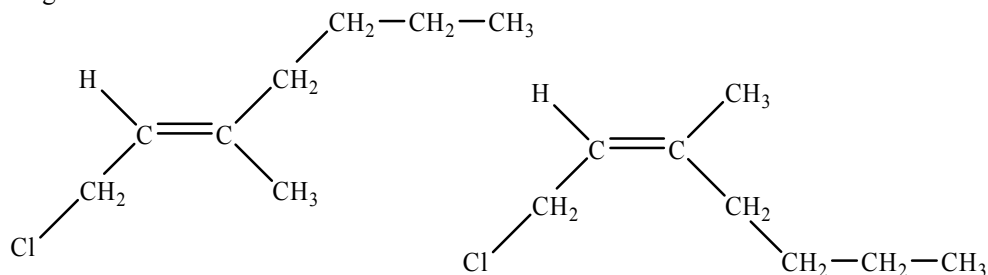
cis-4,4-dimethyl-2-pentene



trans-4,4-dimethyl-2-pentene

b) No, geometric isomers occur because the right carbon participating in the double bond is attached to two identical methyl ($-\text{CH}_3$) groups.

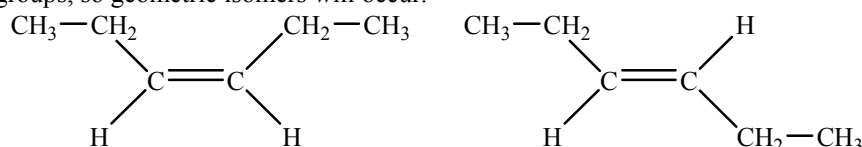
c) *Cis-trans* geometric isomerism occurs about the double bond.



trans-1-chloro-3-methyl-2-heptene

cis-1-chloro-3-methyl-2-heptene

- 15.30 a) The structure of propene is $\text{CH}_2=\text{CH}-\text{CH}_3$. The first carbon that is involved in the double bond is bonded to two of the same type of group, hydrogen. Geometric isomers will not occur in this case.
 b) The structure of 3-hexene is $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_3$. Both carbons in the double bond are bonded to two distinct groups, so geometric isomers will occur.

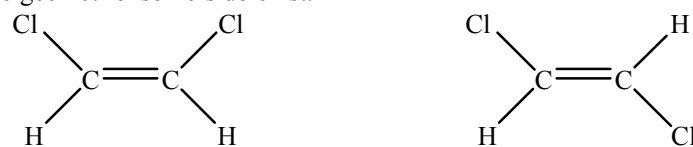


cis-3-hexene

trans-3-hexene

c) The structure of 1,1-dichloroethene is $\text{CCl}_2=\text{CH}_2$. Both carbons in the double bond are bonded to two identical groups, so no geometric isomers occur.

d) The structure of 1,2-dichloroethene is $\text{CHCl}=\text{CHCl}$. Each carbon in the double bond is bonded to two distinct groups, so geometric isomers do exist.

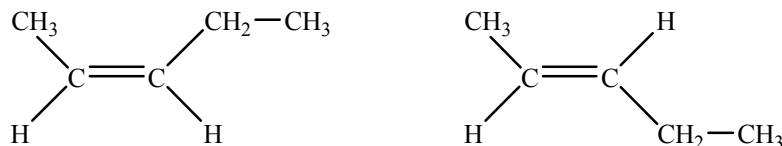


cis-1,2-dichloroethene

trans-1,2-dichloroethene

- 15.31 a) The structure of 1-pentene is $\text{CH}_2=\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_3$. The first carbon that is involved in the double bond is bonded to two of the same type of group, hydrogen. Geometric isomers will not occur in this case.

b)



cis-2-pentene

trans-2-pentene

c)

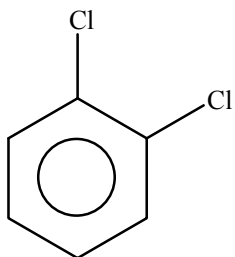


cis-1-chloropropene

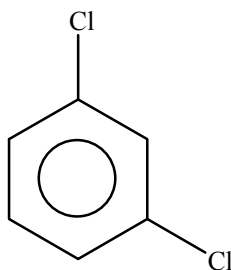
trans-1-chloropropene

d) There are no geometric isomers because the first carbon has two hydrogens attached to it.

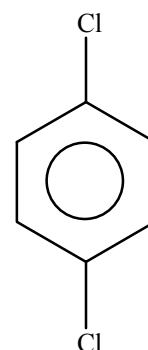
- 15.32 Benzene is a planar, aromatic hydrocarbon. It is commonly depicted as a hexagon with a circle in the middle to indicate that the π bonds are delocalized around the ring and that all ring bonds are identical. The *ortho*, *meta*, *para* naming system is used to denote the location of attached groups in benzene compounds only, not other ring structures like the cycloalkanes.



1,2-dichlorobenzene
(*o*-dichlorobenzene)

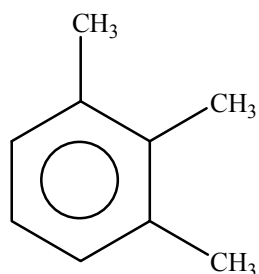


1,3-dichlorobenzene
(*m*-dichlorobenzene)

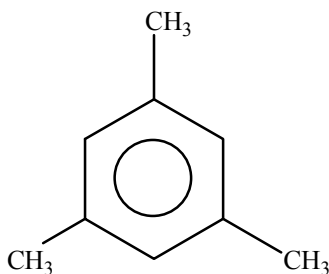


1,4-dichlorobenzene
(*p*-dichlorobenzene)

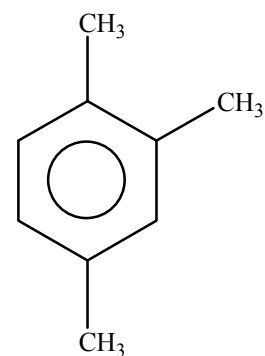
15.33



1,2,3-trimethylbenzene

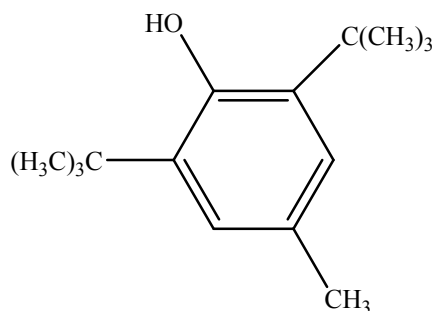


1,3,5-trimethylbenzene

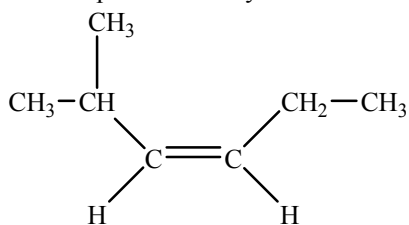


1,2,4-trimethylbenzene

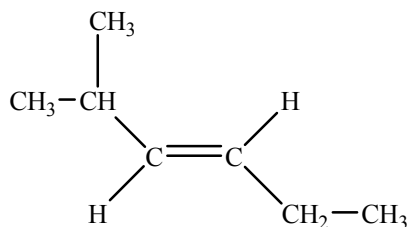
- 15.34 Analyzing the name gives benzene as the base structure with the following groups bonded to it: 1) on carbon #1 a hydroxy group, $-\text{OH}$; 2) on carbons #2 and #6 a *tert*-butyl group, $-\text{C}(\text{CH}_3)_3$; and 3) on carbon #4 a methyl group, $-\text{CH}_3$.



15.35 The compound 2-methyl-3-hexene has *cis-trans* isomers.

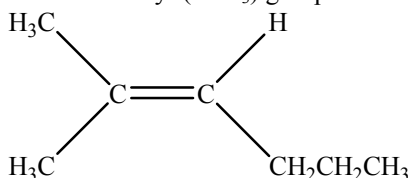


cis-2-methyl-3-hexene



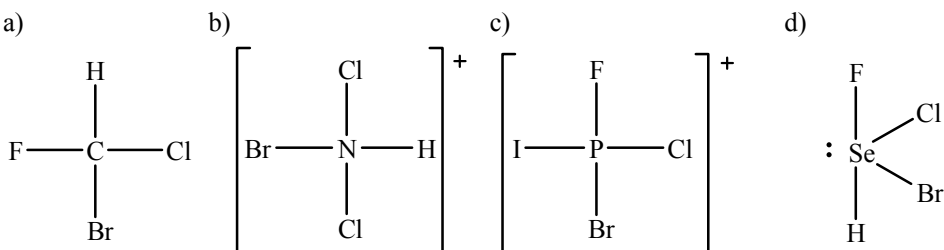
trans-2-methyl-3-hexene

The compound 2-methyl-2-hexene does not have *cis-trans* isomers because the #2 carbon atom is attached to two identical methyl ($-\text{CH}_3$) groups:



2-methyl-2-hexene

15.36



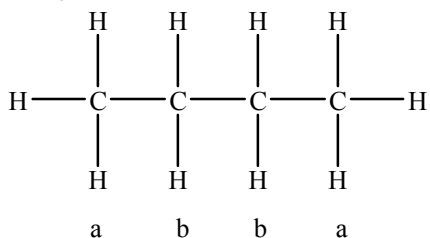
a) is **optically active**, because the carbon has four different groups attached.

b) is **not optically active**, because the N does not have four different groups attached (there are two Cl's).

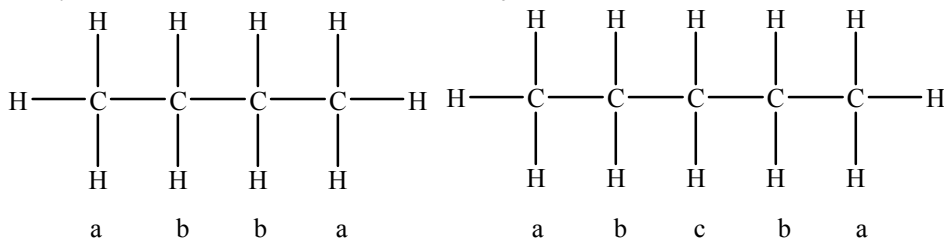
c) is **optically active**, because the phosphorus has four different groups attached.

d) is **not optically active**, the compound is irregular tetrahedral (see-saw), and the lone pair makes a fifth group.

15.37 C_4H_{10}



C_5H_{12}



In C_4H_{10} there will be two peaks, one from the hydrogens attached to the carbons labeled "a" and one from the hydrogens attached to the carbons labeled "b."

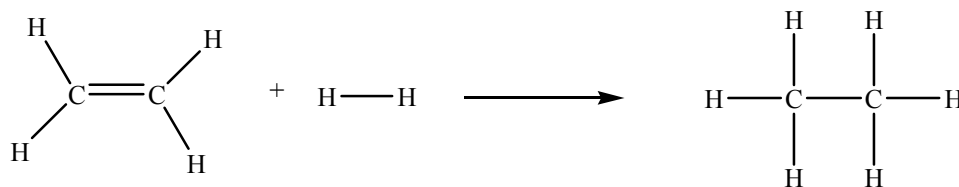
In C_5H_{12} there will be three peaks, one from the hydrogens attached to the carbons labeled "a," one from the hydrogens attached to the carbons labeled "b," and one from the hydrogens attached to the carbons labeled "c."

15.38 a) **addition** b) **elimination** c) **substitution**

15.39 In an addition reaction, a double bond is broken to leave a single bond, and in an elimination reaction, a double bond is formed from a single bond. A double bond consists of a σ bond and a π bond. It is the π bond that breaks in the addition reaction and that forms in the elimination reaction.

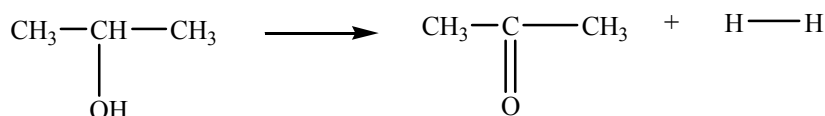
15.40 Yes, an addition, elimination, or substitution reaction can be a redox reaction.

Addition:



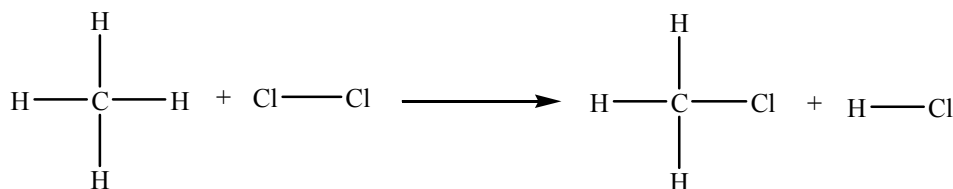
(Reduction: addition of H₂)

Elimination:



(Oxidation: loss of H₂)

Substitution:

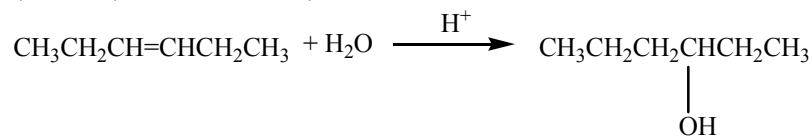


(Loss of e⁻)

- 15.41 a) HBr is removed in this **elimination reaction**, and an unsaturated product is formed.
 b) This is an **addition reaction** in which hydrogen is added to the double bond, resulting in a saturated product.

- 15.42 a) **addition reaction** b) **substitution reaction**

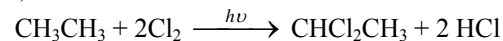
- 15.43 a) Water (H₂O or H and OH) is added to the double bond:



- b) H and Br are eliminated from the molecule, resulting in a double bond:

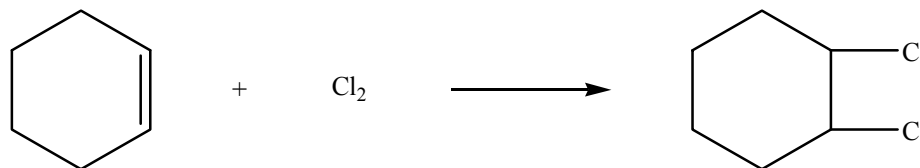


- c) Two chlorine atoms are substituted for two hydrogen atoms in ethane:

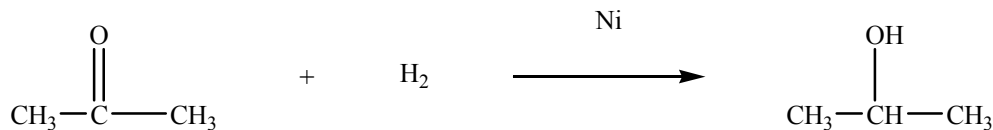


- 15.44 a) $\text{CH}_3\text{CHBrCH}_3 + \text{KI} \rightarrow \text{CH}_3\text{CHICH}_3 + \text{KBr}$

b)



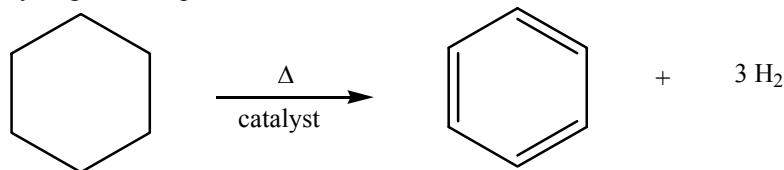
c)



- 15.45 To decide whether an organic compound is oxidized or reduced in a reaction relies on the rules in the chapter:
 A C atom is oxidized when it forms more bonds to O or fewer bonds to H because of the reaction.
 A C atom is reduced when it forms fewer bonds to O or more bonds to H because of the reaction.
 a) The C atom is **oxidized** because it forms more bonds to O.
 b) The C atom is **reduced** because it forms more bonds to H.
 c) The C atom is **reduced** because it forms more bonds to H.

- 15.46 Assuming that the observed carbon is bonded to carbon:
 a) **oxidation** b) **reduction** c) **oxidation**

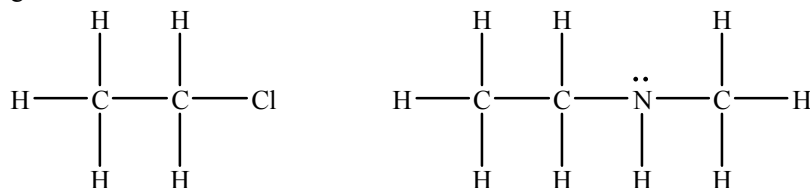
- 15.47 a) The reaction $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_2\text{CH}_3 \rightarrow \text{CH}_2\text{CH}(\text{OH})-\text{CH}(\text{OH})\text{CHCH}_2\text{CH}_2\text{CH}_3$ shows the second and third carbons in the chain gaining a bond to oxygen: C-O-H. Therefore, the 2-hexene compound has been **oxidized**.
 b) The reaction shows that each carbon atom in the cyclohexane loses a bond to hydrogen to form benzene. Fewer bonds to hydrogen in the product indicates **oxidation**.



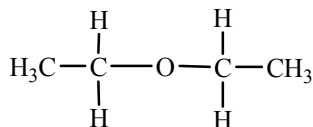
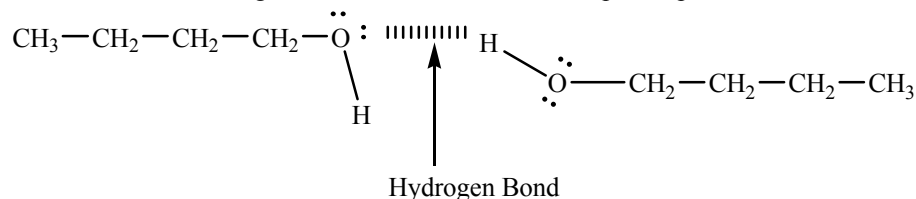
- 15.48 a) **reduced** b) **oxidized**

- 15.49 Step 1 **substitution** Step 2 **addition**

- 15.50 a) The structures for chloroethane and methylethylamine are given below. The compound **methylethylamine** is more soluble due to its ability to form H-bonds with water. Recall that N-H, O-H, or F-H bonds are required for H-bonding.

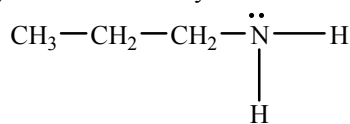


- b) The compound 1-butanol is able to H-bond with itself (shown below) because it contains covalent oxygen-hydrogen bonds in the molecule. Diethylether molecules contain no O-H covalent bonds and experience dipole-dipole interactions instead of H-bonding as intermolecular forces. Therefore, **1-butanol** has a higher melting point because H-bonds are stronger intermolecular forces than dipole-dipole attractions.

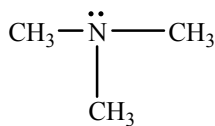


diethyl ether

c) **Propylamine** has a higher boiling point because it contains N–H bonds necessary for hydrogen bonding. Trimethylamine is a tertiary amine with no N–H bonds, and so its intermolecular forces are weaker.

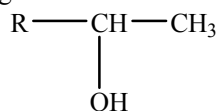


Propylamine

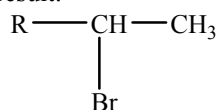


Trimethylamine

15.51 Upper right result:



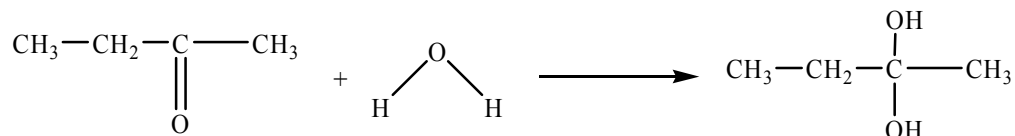
Bottom result:



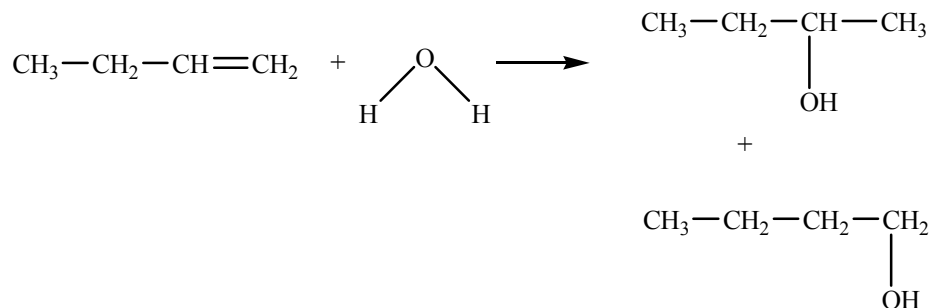
15.52 Addition reactions do not occur readily with benzene due to resonance stability of the aromatic ring.

15.53 The C=C bond is nonpolar while the C=O bond is polar, since oxygen is more electronegative than carbon. Both bonds react by addition. In the case of addition to a C=O bond, an electron-rich group will bond to the carbon and an electron-poor group will bond to the oxygen, resulting in one product. In the case of addition to an alkene, the carbons are identical, or nearly so, so there will be no preference for which carbon bonds to the electron-poor group and which bonds to the electron-rich group. This may lead to two isomeric products, depending on the structure of the alkene.

When water is added to a double bond, the hydrogen is the electron-poor group and hydroxyl is the electron-rich group. For a compound with a carbonyl group, only one product results as H bonds to the O atom in the double bond and –OH bonds to the carbon atom in the double bond:

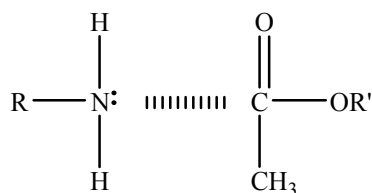


However, when water adds to a C=C, two products result since the OH can bond to either carbon in the double bond:

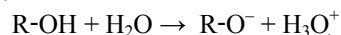


In this reaction, very little of the second product forms.

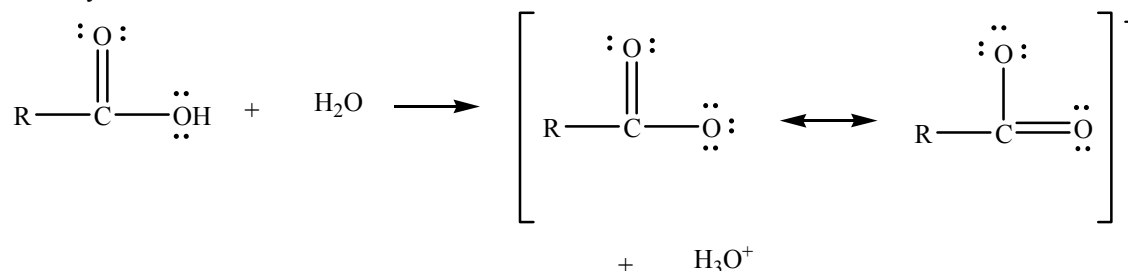
15.54



15.55 Alcohol:

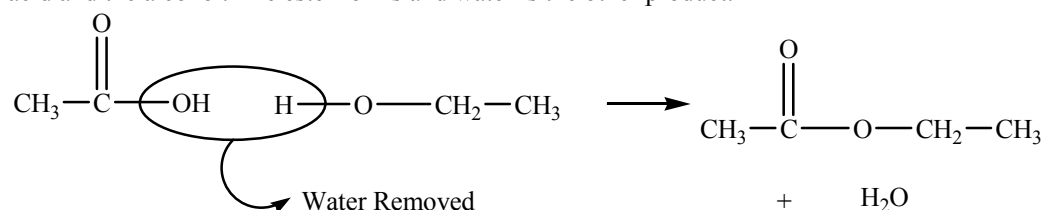


Carboxylic acid:



The resonance-stabilized carboxylate ion allows the transfer of the proton to water. The alkoxide ion cannot show any resonance stabilization.

15.56 Esters and acid anhydrides form through **dehydration-condensation** reactions. Dehydration indicates that the other product is **water**. In the case of ester formation, condensation refers to the combination of the carboxylic acid and the alcohol. The ester forms and water is the other product.

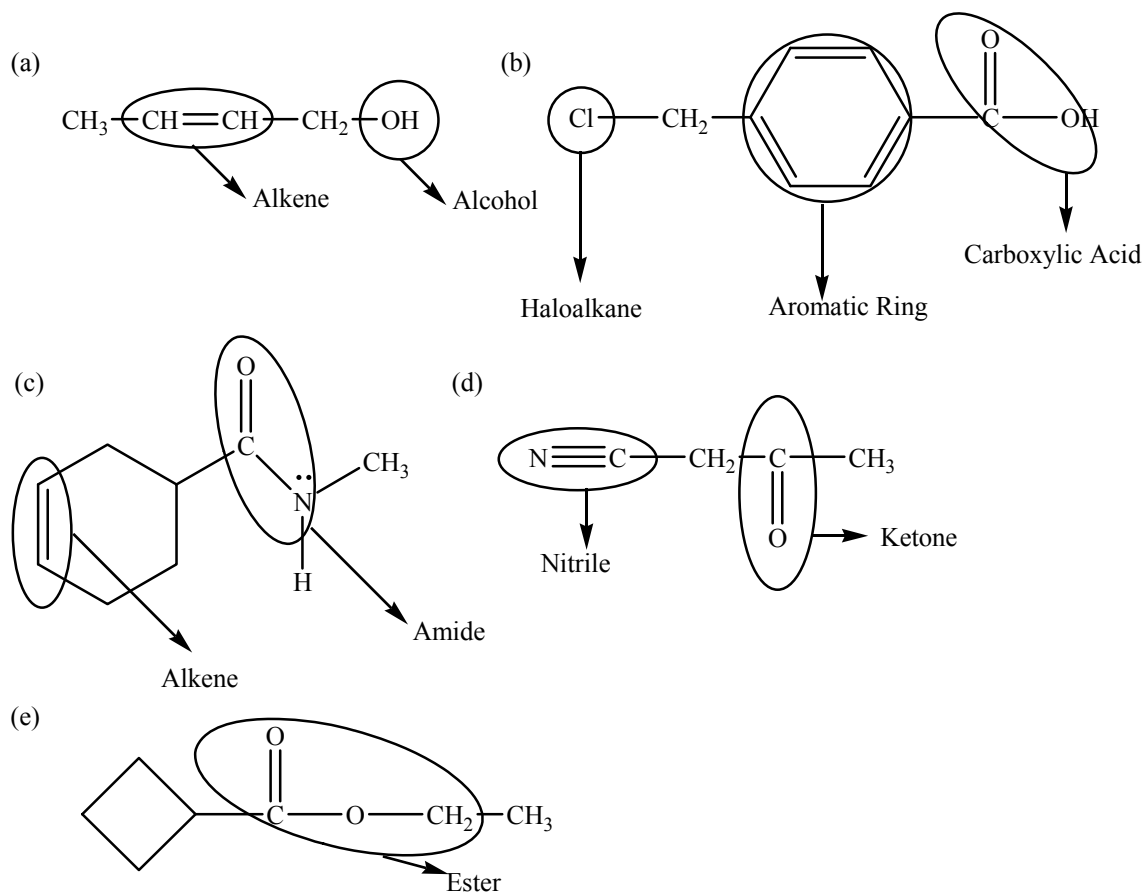


15.57 Alcohols undergo substitution at a saturated carbon while acids undergo substitution at the carboxyl carbon.

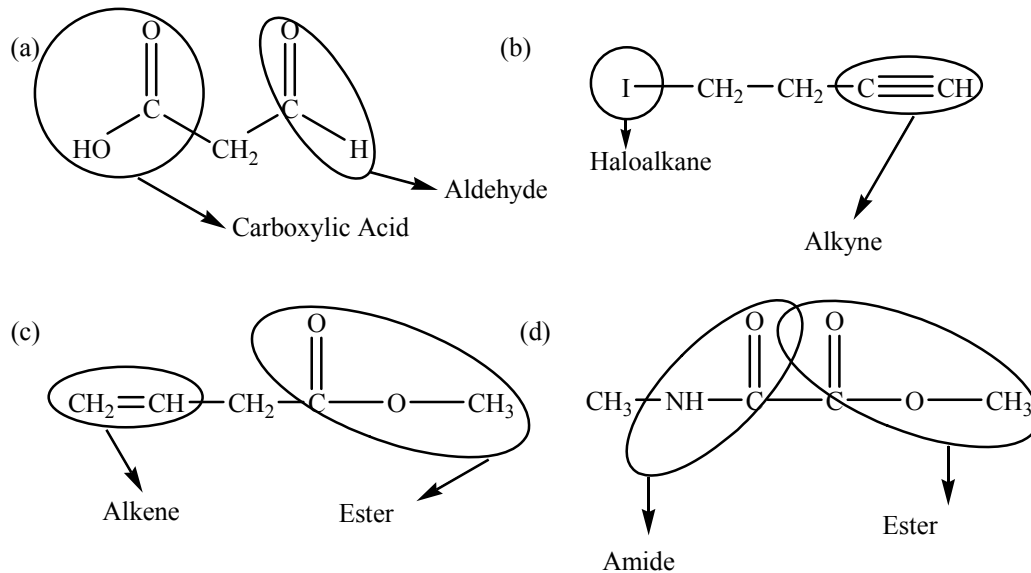
- 15.58
- Halogens, except iodine, differ from carbon in electronegativity and form a single bond with carbon. The organic compound is an **alkyl halide**.
 - Carbon forms triple bonds with itself and nitrogen. For the bond to be polar, it must be between carbon and nitrogen. The compound is a **nitrile**.
 - Carboxylic acids** contain a double bond to oxygen and a single bond to oxygen. Carboxylic acids dissolve in water to give acidic solutions.
 - Oxygen is commonly double-bonded to carbon. A carbonyl group (C=O) that is at the end of a chain is found in an **aldehyde**.

15.59 a) **amide** b) **alkene** c) **ketone** d) **amine**

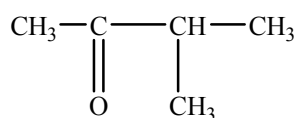
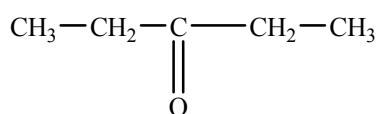
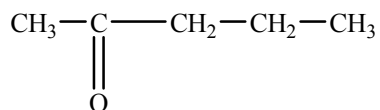
15.60



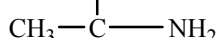
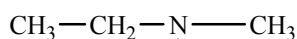
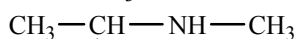
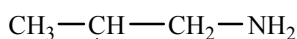
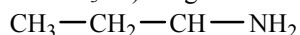
15.61



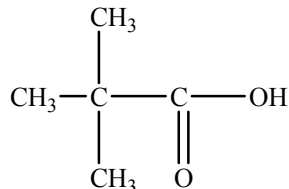
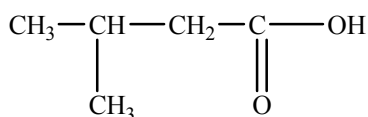
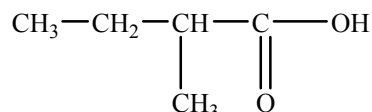
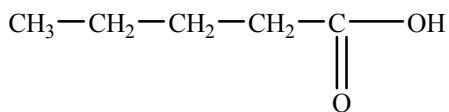
Ketones:



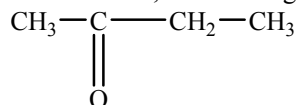
- 15.64 First, draw all primary amines (formula R-NH_2). Next, draw all secondary amines (formula R-NH-R'). There is only one possible tertiary amine structure (formula $\text{R}_3\text{-N}$). Eight amines with the formula $\text{C}_4\text{H}_{11}\text{N}$ exist.



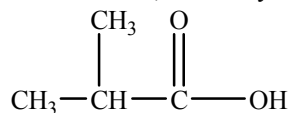
15.65



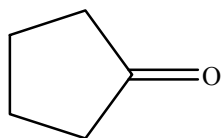
- 15.66 a) With mild oxidation, an alcohol group is oxidized to a carbonyl group. The product is 2-butanone.



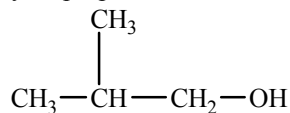
- b) With mild oxidation, an aldehyde is oxidized to a carboxylic acid. The product is 2-methylpropanoic acid.



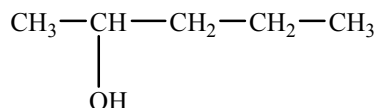
c) Mild oxidation of an alcohol produces a carbonyl group. The product is cyclopentanone.



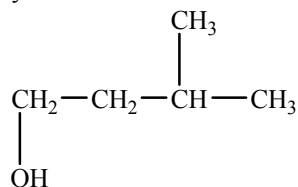
15.67 a) 2-methyl-1-propanol



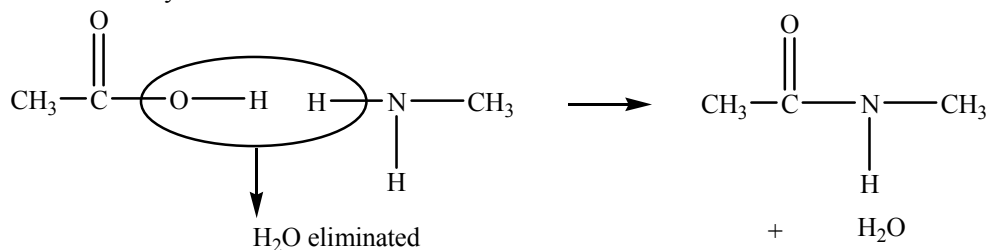
b) 2-pentanol



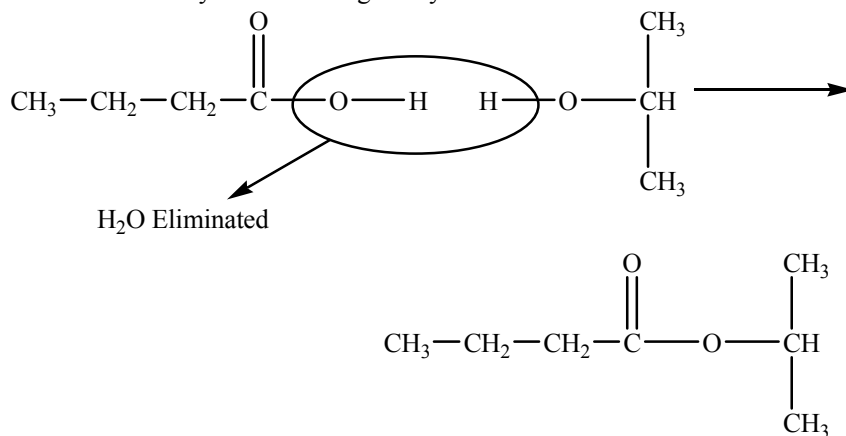
c) 3-methyl-1-butanol



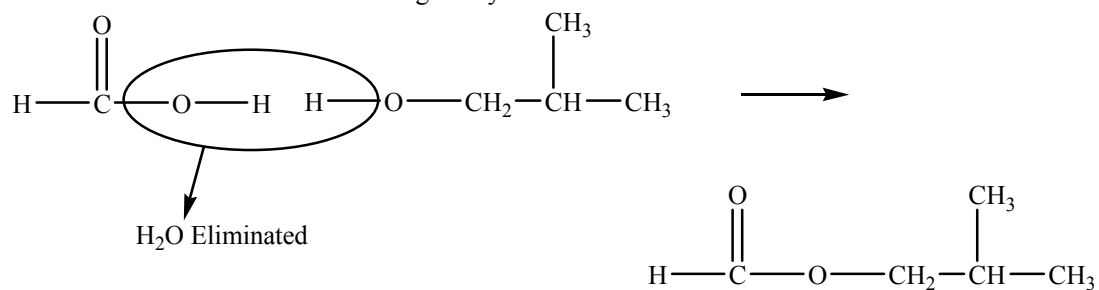
15.68 a) This reaction is a dehydration-condensation reaction.



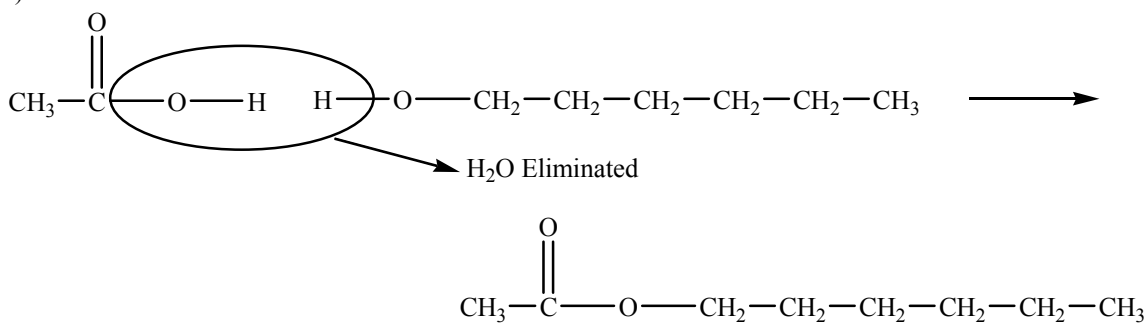
b) An alcohol and a carboxylic acid undergo dehydration-condensation to form an ester.



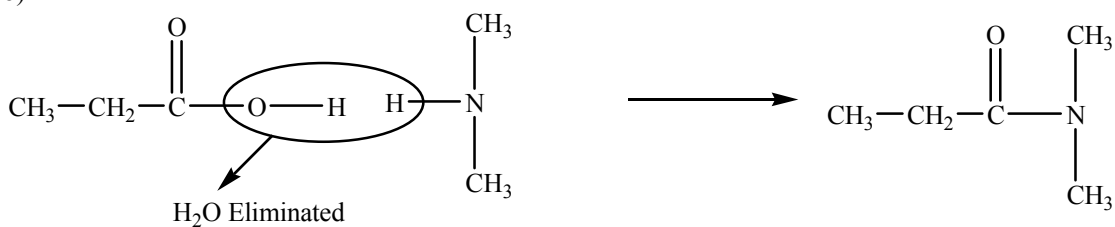
c) This reaction is also an ester formation through dehydration-condensation.



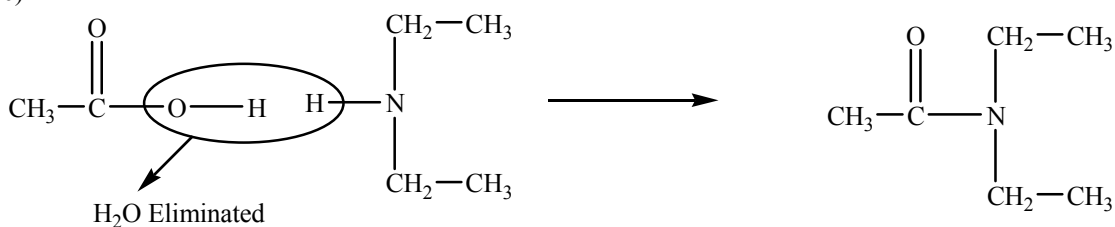
15.69 a)



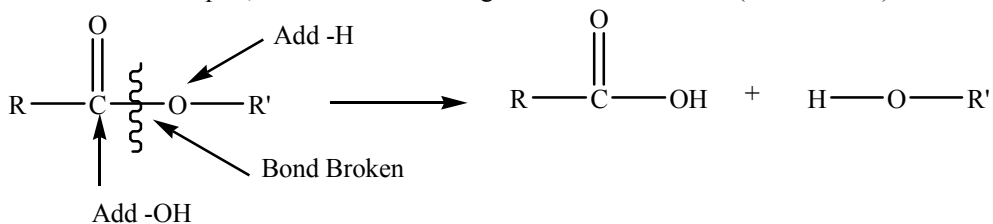
b)



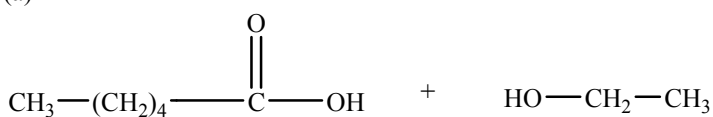
c)

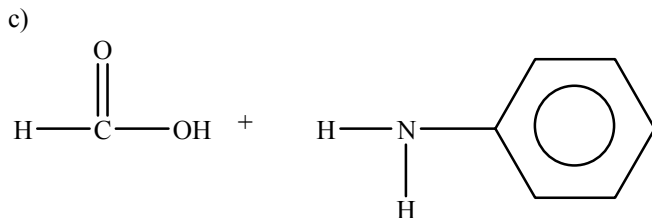
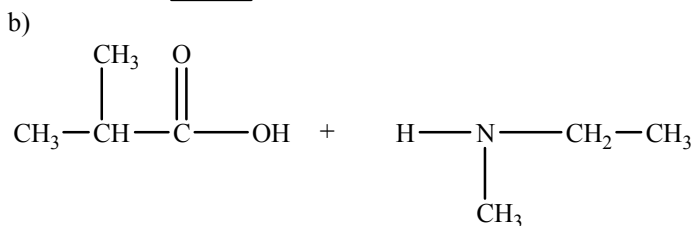
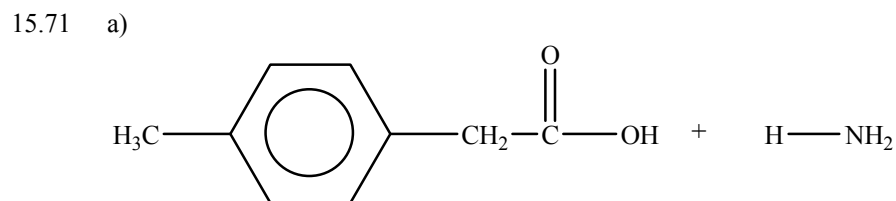
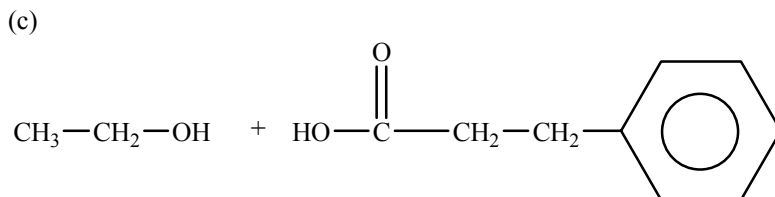
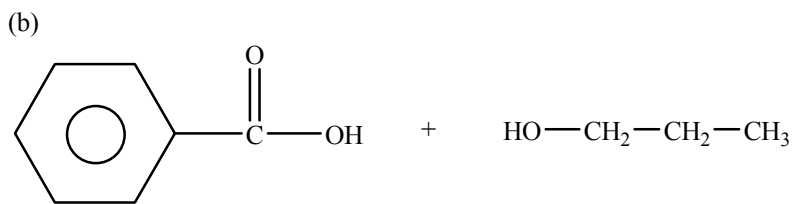


15.70 To break an ester apart, break the $-\text{C}-\text{O}-$ single bond and add water ($-\text{H}$ and $-\text{OH}$) as shown.

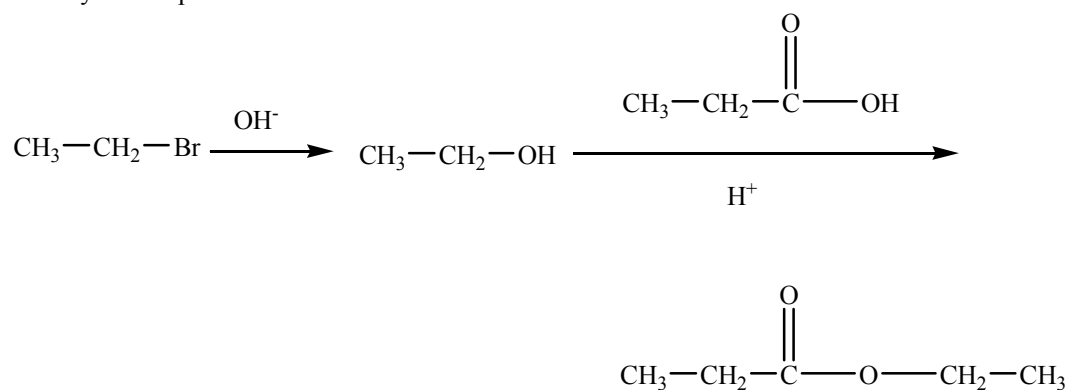


(a)

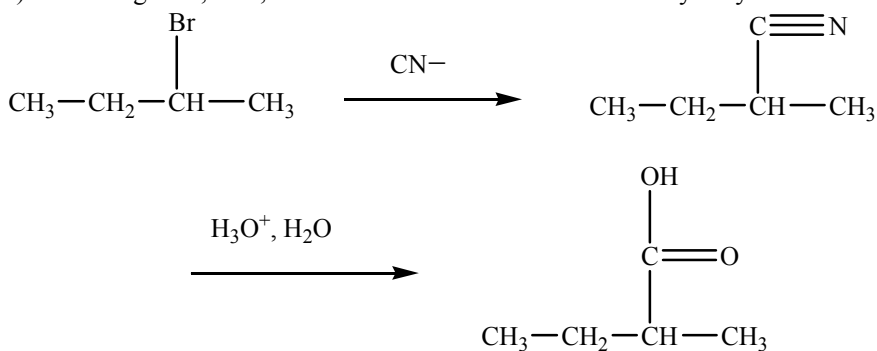




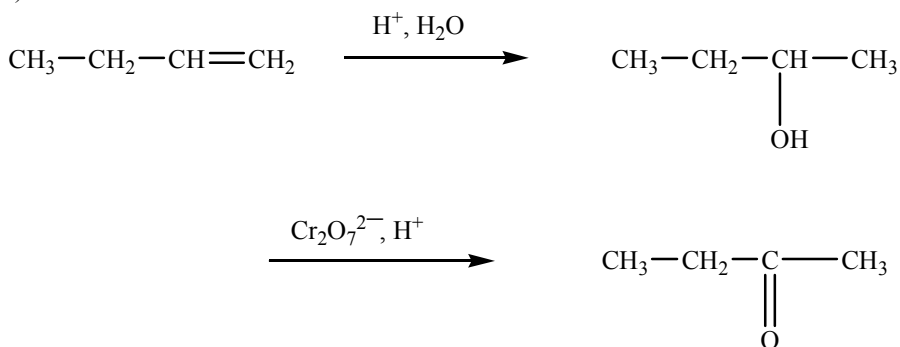
15.72 a) Substitution of Br^- occurs by the stronger base, OH^- . Then a substitution reaction between the alcohol and carboxylic acid produces an ester:



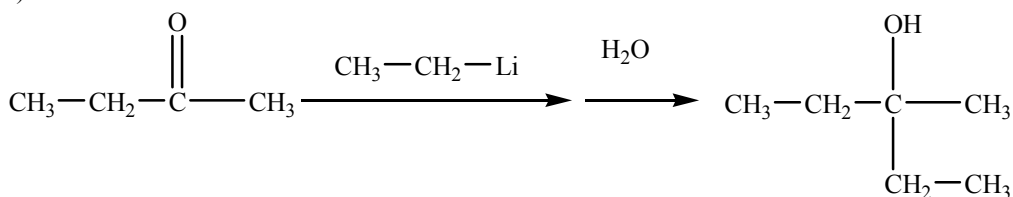
b) The strong base, CN^- , substitutes for Br. The nitrile is then hydrolyzed to a carboxylic acid.



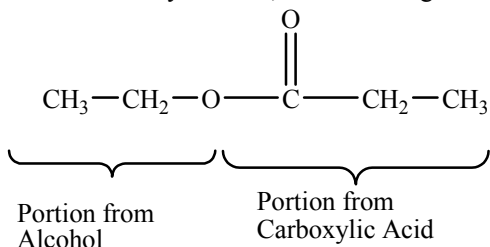
15.73 a)



b)

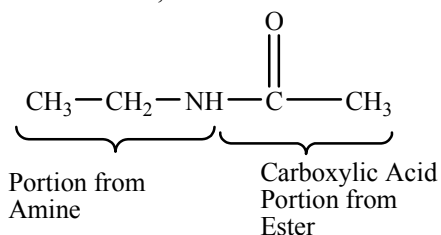


15.74 a) The product is an ester and the given reactant is an alcohol. An alcohol reacts with a carboxylic acid to make an ester. To identify the acid, break the single bond between the carbon and oxygen in the ester group.



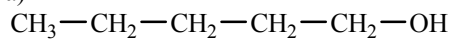
The missing reactant is **propanoic acid**.

b) To form an amide, an amine must react with an ester to replace the $-\text{O}-\text{R}$ group. To identify the amine that must be added, break the $\text{C}-\text{N}$ bond in the amide. The amine is **ethylamine**.

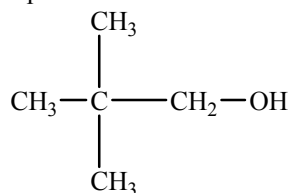


15.75 a) KOH ; Br_2 b) $\text{K}_2\text{Cr}_2\text{O}_7$, H^+ ; $\text{C}_6\text{H}_5\text{-CH}_2\text{-OH}$; H^+

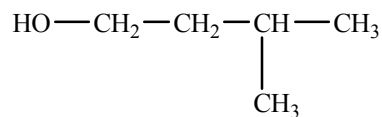
15.76 a)



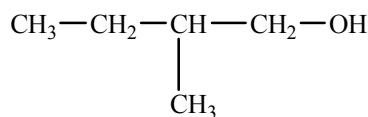
1-pentanol



2,2-dimethyl-1-propanol

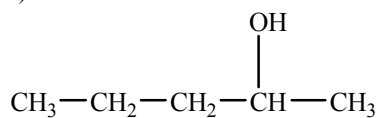


3-methyl-1-butanol

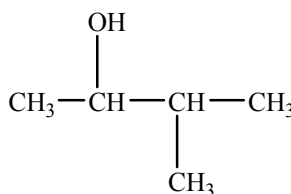


2-methyl-1-butanol

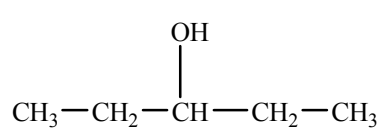
b)



2-pentanol

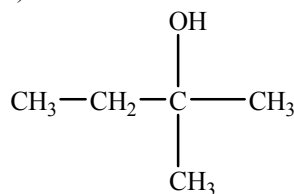


3-methyl-2-butanol

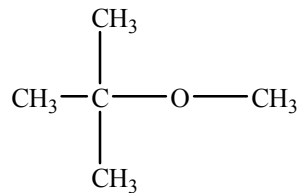
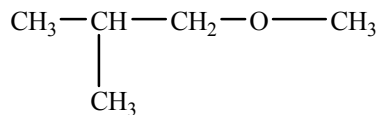
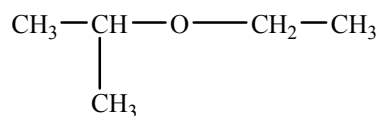
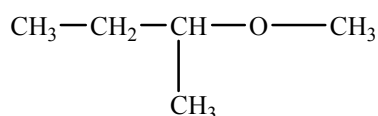
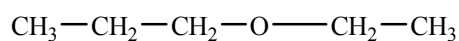
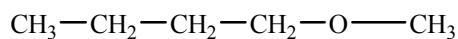


3-pentanol

c)

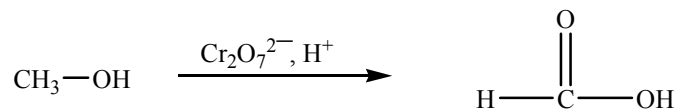


2-methyl-2-butanol

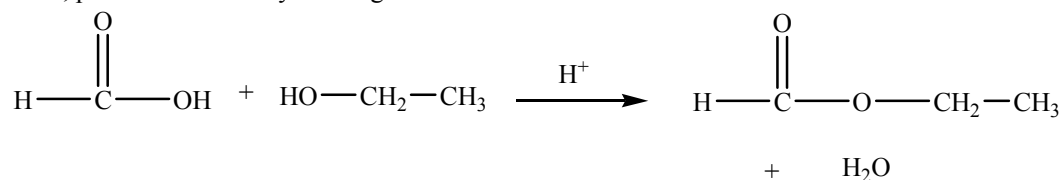


d) The names for the alcohols are given with their structures.

15.77 First, oxidize the methanol to formic acid.

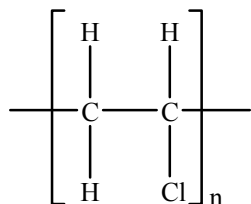


Then, produce the ester by reacting the formic acid with the ethanol.

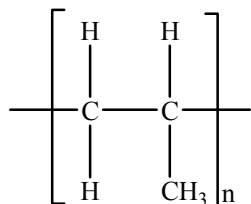


- 15.78 **Addition reactions** and **condensation reactions** are the two reactions that lead to the two types of synthetic polymers that are named for the reactions that form them.
- 15.79 A double bond is common in the monomer resulting in addition polymers. Substituents on the alkene make the monomers different.
- 15.80 A free radical is an atom or group of atoms with one unpaired electron that are highly reactive. They are used to initiate a chain reaction.
- 15.81 Polyethylene comes in a range of strengths and flexibilities. The intermolecular dispersion forces (also called London forces) that attract the long, unbranched chains of high-density polyethylene (HDPE) are strong due to the large size of the polyethylene chains. Low-density polyethylene (LDPE) has increased branching that prevents packing and weakens intermolecular dispersion forces.
- 15.82 Condensation polymers are more similar chemically to biopolymers. Both are formed by the loss of water from two monomers.
- 15.83 Nylon is formed by the condensation reaction between an **amine and a carboxylic acid** resulting in an amide bond. Polyester is formed by the condensation reaction between a **carboxylic acid and an alcohol** to form an ester bond.
- 15.84 Both PVC and polypropylene are addition polymers. The general formula for creating repeating units from a monomer is given in the chapter.

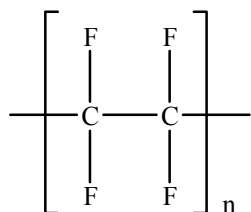
(a)



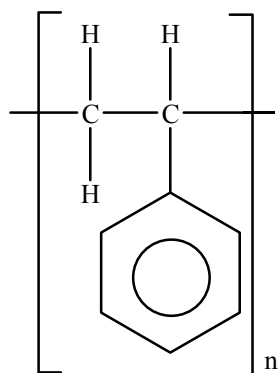
(b)



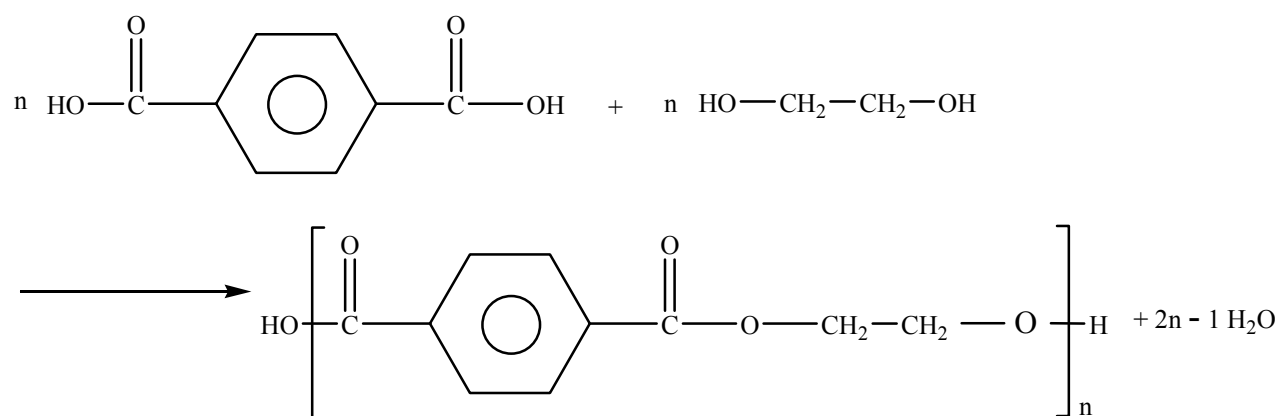
15.85 a)



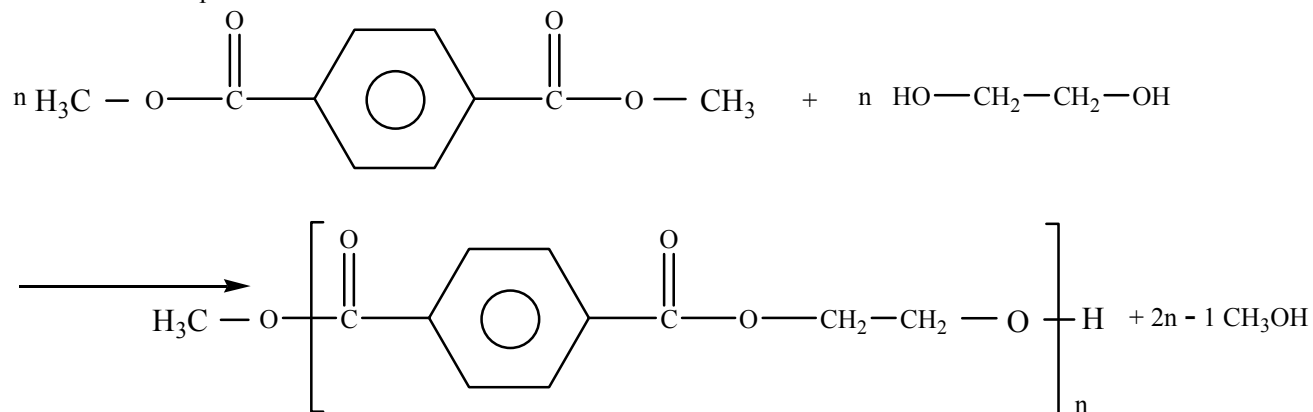
b)



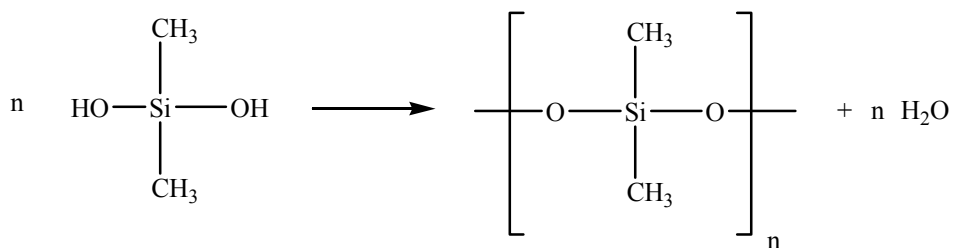
15.86 A carboxylic acid and an alcohol react to form an ester bond in a dehydration condensation reaction:



The displacement reaction is:



15.87



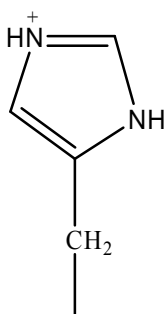
- 15.88 a) Amino acids form **condensation** polymers, called proteins.
 b) Alkenes form **addition** polymers, the simplest of which is polyethylene.
 c) Simple sugars form **condensation** polymers, called polysaccharides.
 d) Mononucleotides form **condensation** polymers, called nucleic acids.
- 15.89 Fibrous proteins are shaped like extended helices or sheets. The R groups come mostly from glycine, serine, alanine, and proline. Globular proteins are more compact in structure. Their R groups have more extended non-bonded interactive attraction for each other.
- 15.90 The amino acid sequence in a protein determines its shape and structure, which determine its function.
- 15.91 A phosphate ester linkage joins the nucleotides in the DNA strands.
- 15.92 DNA exists as two chains wrapped around each other in a double helix. The negatively charged sugar-phosphate backbone faces the aqueous surroundings, and each base in one chain pairs with a base in the other by H-bonds.
- 15.93 The DNA base sequence contains an information template that is carried by the RNA base sequence (messenger and transfer) to create the protein amino acid sequence. In other words, the DNA sequence determines the RNA sequence, which determines the protein amino acid sequence.

15.94 Locate the specific amino acids in the figure in the chapter.

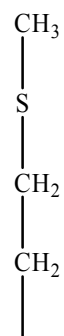
a) alanine



b) histidine



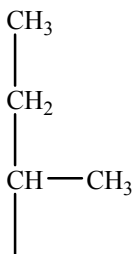
c) methionine



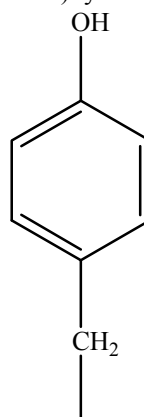
15.95 a) glycine



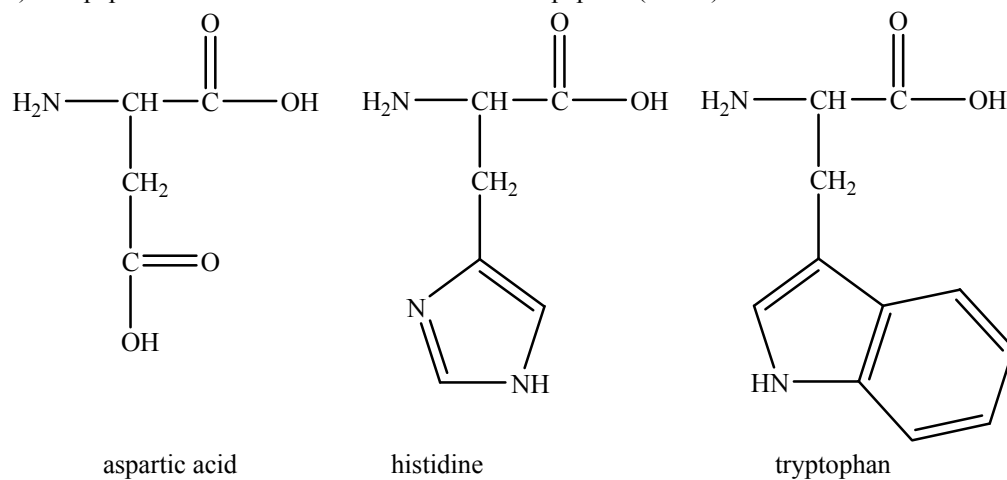
b) isoleucine



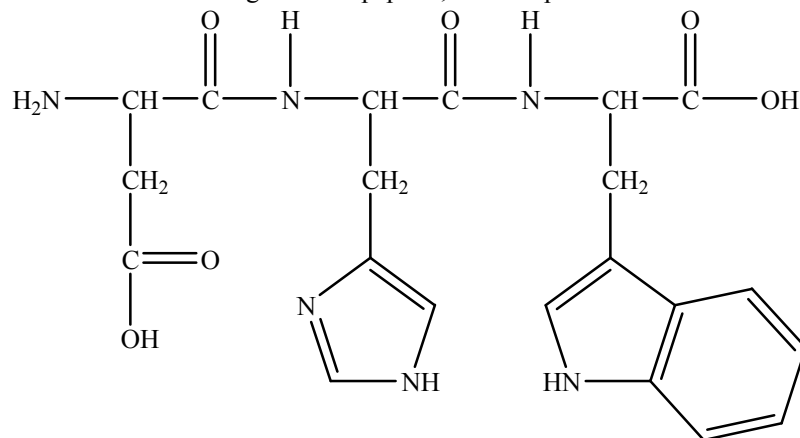
c) tyrosine



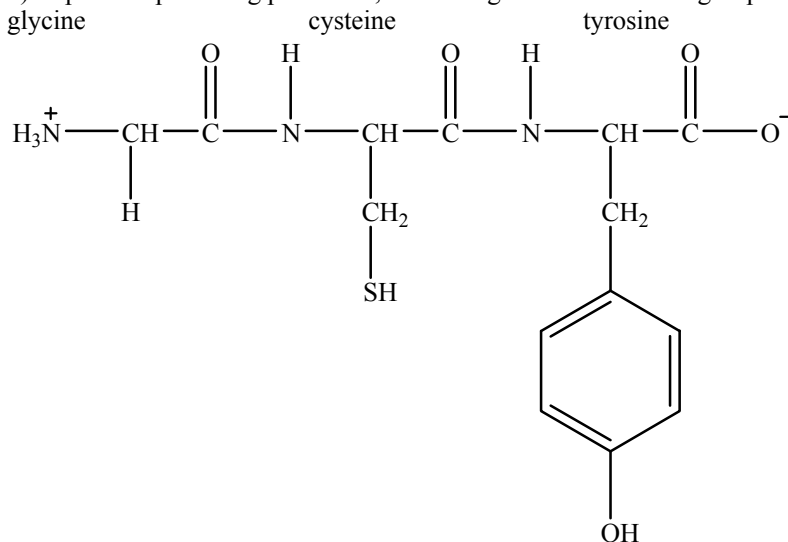
15.96 a) A tripeptide contains three amino acids and two peptide (amide) bonds.

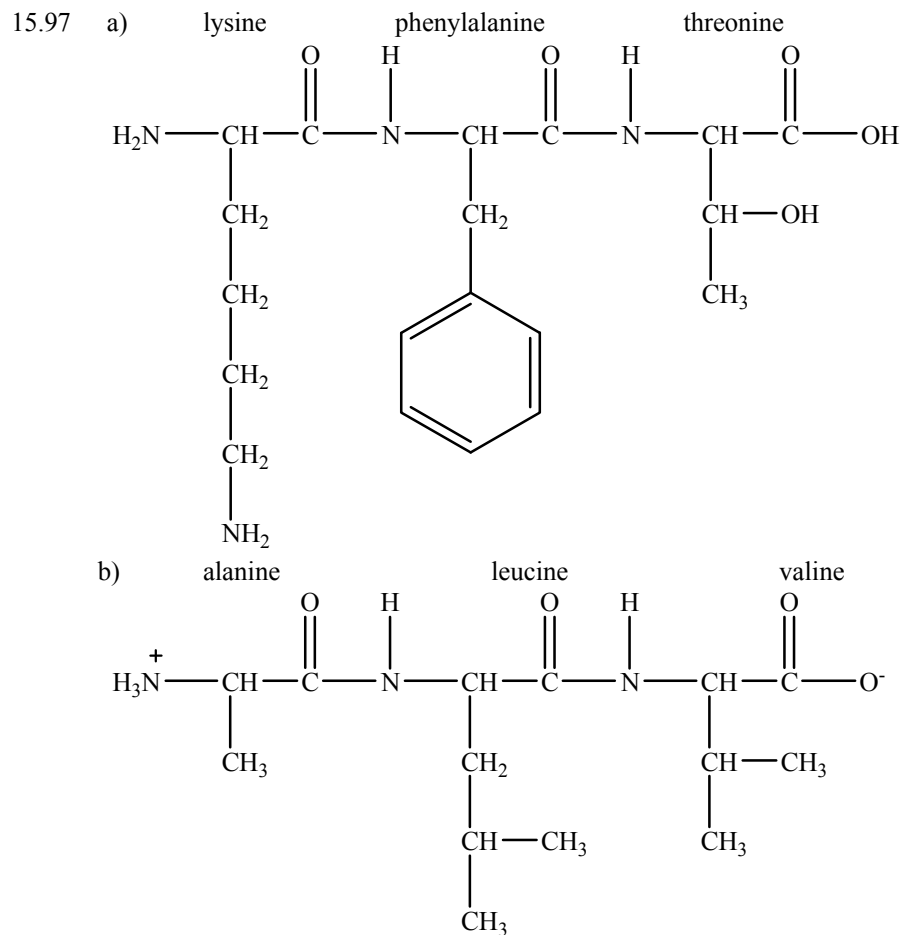


Join the three acids to give the tripeptide; water is produced:



b) Repeat the preceding procedure, with charges on the terminal groups.





15.98 Base A always pairs with Base T; Base C always pairs with Base G.

a) Complementary DNA strand is **AATCGG**.

b) Complementary DNA strand is **TCTGTA**.

15.99 a) **CCAATG** b) **GGGCTT**

15.100 Uracil (U) substitutes for thymine (T) in RNA. Therefore, A pairs with U. The G-C pair and A-T pair remain unchanged. The RNA sequence is derived from the DNA template sequence **ACAATGCCT**. A three-base sequence constitutes a word, and each word translates into an amino acid. There are three words in the sequence, so **three** amino acids are coded in the sequence.

15.101 **CATAGTTACTTGAAC**; **five**

15.102 a) Both side chains are part of the amino acid **cysteine**. Two cysteine R groups can form a **disulfide bond** (covalent bond).

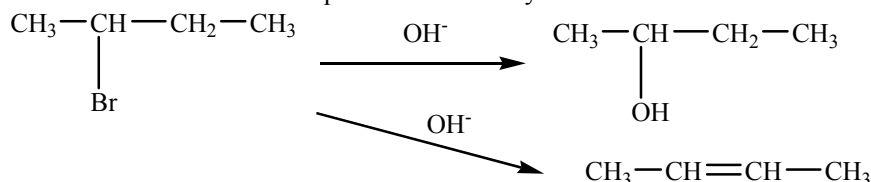
b) The R group $-(\text{CH}_2)_4-\text{NH}_3^+$ is found in the amino acid **lysine** and the R group $-\text{CH}_2\text{COO}^-$ is found in the amino acid **aspartic acid**. The positive charge on the amine group in lysine is attracted to the negative charge on the acid group in aspartic acid to form a **salt link**.

c) The R group in the amino acid **asparagine** and the R group in the amino acid **serine**. The $-\text{NH}-$ and $-\text{OH}$ groups will **hydrogen bond**.

d) Both the R group $-\text{CH}(\text{CH}_3)-\text{CH}_3$ from **valine** and the R group $\text{C}_6\text{H}_5-\text{CH}_2-$ from **phenylalanine** are nonpolar, so their interaction is **through dispersion forces**.

$$15.103 \quad \left(\frac{5 \times 10^5 \text{ g}}{\text{mol DNA}} \right) \left(\frac{1 \text{ Amino Acid}}{100 \text{ g}} \right) = 5 \times 10^3 \text{ Amino Acids / DNA}$$

15.104 The desired reaction is the displacement of Br^- by OH^- .



However, the elimination of HBr also occurs in the presence of a strong base to give the second product.

A simple test to detect the presence of a double bond is the addition of liquid Br_2 . Bromine is reddish-brown in color and adds easily to the double bond to form a brominated alkane, which has no color. The reddish-brown color of liquid Br_2 disappears if added to an alkene.

15.105 a) $\text{C}_4\text{H}_8 + \text{CH}_3\text{OH} \rightarrow \text{C}_5\text{H}_{12}\text{O}$

b) $[(16.00 \text{ g O}) / (88.15 \text{ g MTBE})] \times 100\% = 18.150879\% \text{ O in MTBE (unrounded)}$

$$\text{Mass of MTBE} = (2.7 \text{ g oxygen}) \left(\frac{100 \text{ g MTBE}}{18.150879 \text{ g oxygen}} \right) = 14.8753 = \mathbf{15 \text{ g MTBE / 100. g gasoline}}$$

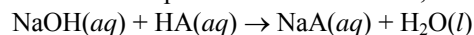
$$\begin{aligned} \text{c) } & \left(\frac{14.8753 \text{ g MTBE}}{100. \text{ g Gasoline}} \right) \left(\frac{0.740 \text{ g Gasoline}}{1 \text{ mL Gasoline}} \right) \left(\frac{1 \text{ mL}}{10^{-3} \text{ L}} \right) \left(\frac{1 \text{ mL MTBE}}{0.740 \text{ g MTBE}} \right) \left(\frac{10^{-3} \text{ L}}{1 \text{ mL}} \right) \\ & = 0.148753 = \mathbf{0.15 \text{ L MTBE/L gasoline}} \end{aligned}$$

d) $2 \text{ C}_5\text{H}_{12}\text{O}(l) + 15 \text{ O}_2(g) \rightarrow 10 \text{ CO}_2(g) + 12 \text{ H}_2\text{O}(g)$

$$\begin{aligned} \text{Moles O}_2 &= (1.00 \text{ L MTBE}) \left(\frac{1 \text{ mL}}{10^{-3} \text{ L}} \right) \left(\frac{0.740 \text{ g MTBE}}{\text{mL}} \right) \left(\frac{1 \text{ mol MTBE}}{88.15 \text{ g MTBE}} \right) \left(\frac{15 \text{ mol O}_2}{2 \text{ mol MTBE}} \right) \\ &= 62.96086 \text{ mol O}_2 \text{ (unrounded)} \end{aligned}$$

$$\begin{aligned} V = nRT / P &= \frac{(62.96086 \text{ mol O}_2) \left(0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right) ((273 + 24) \text{ K})}{1.00 \text{ atm}} \left(\frac{100\%}{21\%} \right) \\ &= 7.310566 \times 10^3 = \mathbf{7.3 \times 10^3 \text{ L air}} \end{aligned}$$

15.106 a) Symbolize the monoprotic acid as HA. Then, the balanced chemical equation will be:



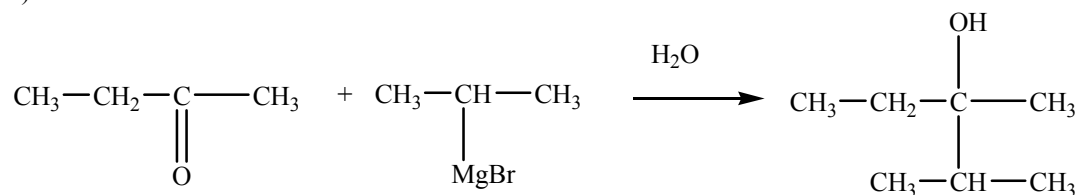
$$\begin{aligned} (0.2003 \text{ g HA}) & \left(\frac{1 \text{ mol NaOH}}{1 \text{ mol HA}} \right) \left(\frac{\text{L NaOH}}{0.03811 \text{ mol NaOH}} \right) \left(\frac{1 \text{ mL NaOH}}{10^{-3} \text{ L NaOH}} \right) \left(\frac{1}{45.25 \text{ mL NaOH}} \right) \\ & = 116.1511 = \mathbf{116.2 \text{ g HA/mol}} \end{aligned}$$

b) To convert an alcohol to an acid, the alcohol loses two hydrogens and gains an oxygen. This process must be reversed to get to the original alcohol:

$$(116.1511 \text{ g/mol}) + 2 (1.008 \text{ g H/mol}) - (16.00 \text{ g O/mol}) = 102.1671 = \mathbf{102.2 \text{ g/mol}}$$

15.107 a) $\text{CH}_3\text{CHO} + \text{C}_6\text{H}_5\text{-MgBr} \rightarrow \text{C}_6\text{H}_5\text{CH}(\text{OH})\text{CH}_3$

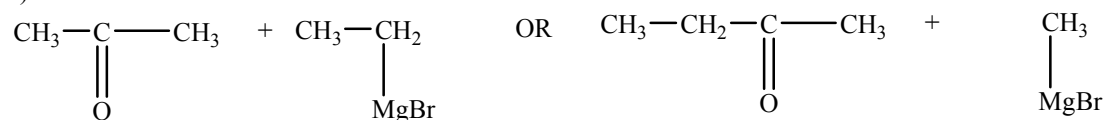
b)



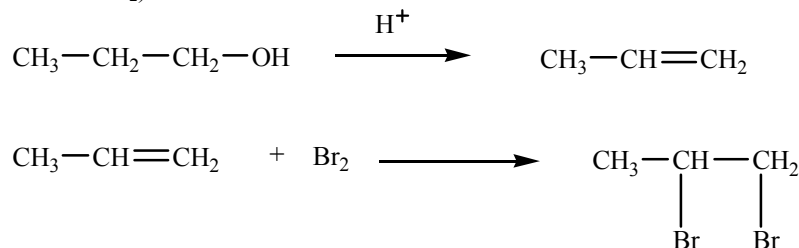
c) CH_3MgBr and $\text{C}_6\text{H}_5\text{CHO}$

d) **HCHO** (formaldehyde)

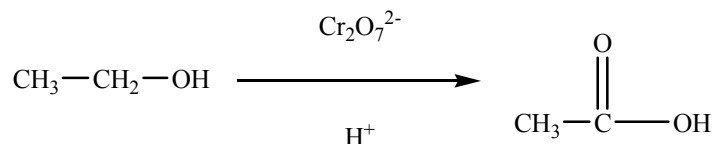
e)



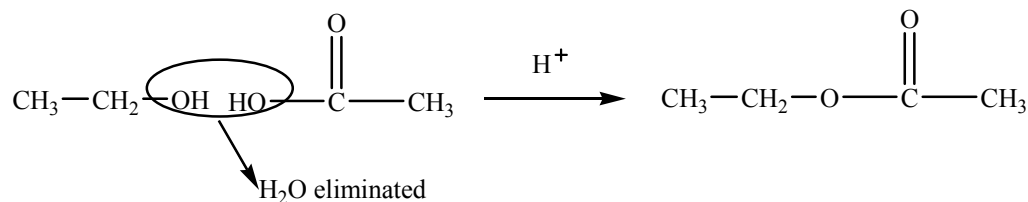
15.108 a) Perform an acid-catalyzed dehydration of the alcohol (elimination), followed by bromination of the double bond (addition of Br₂):



b) The product is an ester, so a carboxylic acid is needed to prepare the ester. First, oxidize one mole of ethanol to acetic acid:



Then, react one mole of acetic acid with a second mole of ethanol to form the ester:



15.109 a) Obtain the molar mass of A by using the Ideal Gas Equation to find the moles of the 2.48 g sample of A.

$$\text{Moles of A} = n = \frac{PV}{RT} = \frac{(1.00 \text{ atm})(1.00 \text{ L})}{\left(\frac{0.0821 \text{ L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}\right)(273 + 160) \text{ K}} = 0.02812998 \text{ mol}$$

$$\text{Molar mass of A} = \frac{2.48 \text{ g A}}{0.02812998 \text{ mol}} = 88.162264 \text{ g/mol}$$

Obtain the molecular formula of A from the combustion analysis:

$$\text{Moles of H} = (0.409 \text{ g H}_2\text{O}) \left(\frac{2 \text{ mol H}}{18.02 \text{ g H}_2\text{O}} \right) = 0.0454 \text{ mol H}$$

$$\text{Mass of H} = (0.0454 \text{ mol H}) \left(\frac{1.008 \text{ g H}}{1 \text{ mol H}} \right) = 0.04576 \text{ g H}$$

$$\text{Moles of C} = (1.00 \text{ g CO}_2) \left(\frac{1 \text{ mol C}}{44.01 \text{ g CO}_2} \right) = 0.0227 \text{ mol C}$$

$$\text{Mass of C} = (0.0227 \text{ mol C}) \left(\frac{12.01 \text{ g C}}{1 \text{ mol C}} \right) = 0.2726 \text{ g C}$$

$$\text{Moles of O} = (0.500 \text{ g A} - (0.04576 + 0.2726) \text{ g O}) \left(\frac{1 \text{ mol O}}{16.00 \text{ g O}} \right) = 0.01135 \text{ mol O}$$

$$\text{C: } \frac{0.0227 \text{ mol C}}{0.01135 \text{ mol}} = 2$$

$$\text{H: } \frac{0.0454 \text{ mol H}}{0.01135 \text{ mol}} = 4$$

$$\text{O: } \frac{0.01135 \text{ mol O}}{0.01135 \text{ mol}} = 1$$

Empirical formula = C₂H₄O with a molar mass of 44.05 g/mol. Since the molar mass of Compound A = 88.16 g/mol, the molecular formula of Compound A is C₄H₈O₂.

Compound B is acidic so it must be a carboxylic acid.

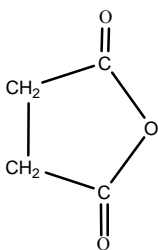
$$\text{Moles of COOH} = \left(\frac{0.5 \text{ mol NaOH}}{\text{L}} \right) (33.9 \text{ mL}) \left(\frac{10^{-3} \text{ L}}{1 \text{ mL}} \right) \left(\frac{1 \text{ mol COOH}}{1 \text{ mol NaOH}} \right) = 0.01695 \text{ mol COOH}$$

The 1.00 g sample of Compound B has 0.01695 moles of COOH or 1.00 g/0.01695 mol = 59 g/mol COOH. Since Compound A has a molar mass of 88 g/mol, Compound B must be a dicarboxylic acid with a molar mass of 118 g/mol and a molecular formula of C₄H₆O₄ since there are four carbon atoms.

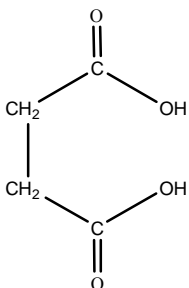
Compound C forms when Compound B is heated and loses water so Compound C must be the anhydride of B.

Compound C has the molecular formula (Compound B, C₄H₆O₄ - H₂O) = C₄H₄O₃.

The NMR of Compound C has only one peak so it has only one kind of hydrogen atom; all of the hydrogen atoms in Compound C are identical so it must be a symmetrical compound. The structures of B and C that fit are:

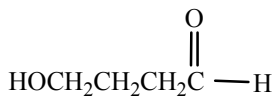


C



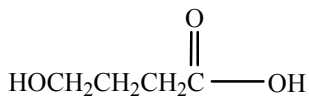
B

Compound A is not acidic so it does not have COOH groups. A is 4-hydroxybutanal.



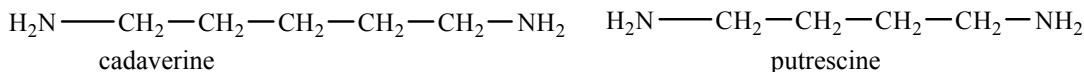
A

b) Only one oxygen atom is added to Compound A to produce the carboxylic acid GHB, C₄H₈O₃. The aldehyde is oxidized to the acid 4-hydroxybutanoic acid:

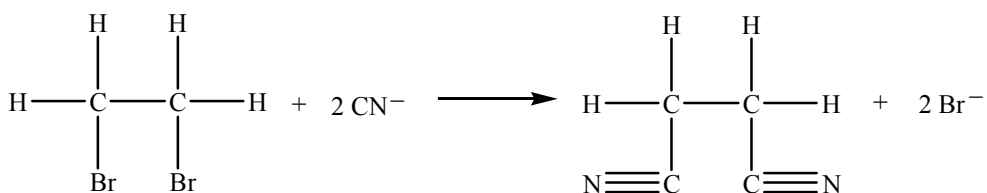


GHB

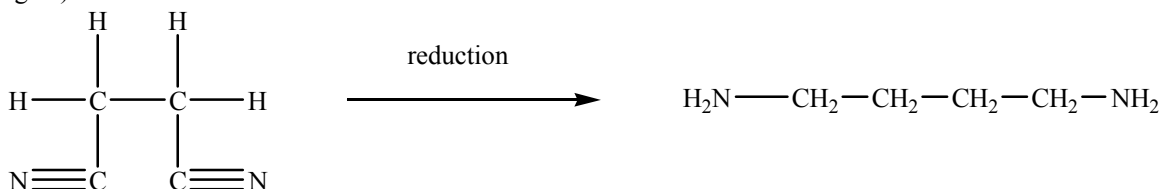
15.110 The two structures are:



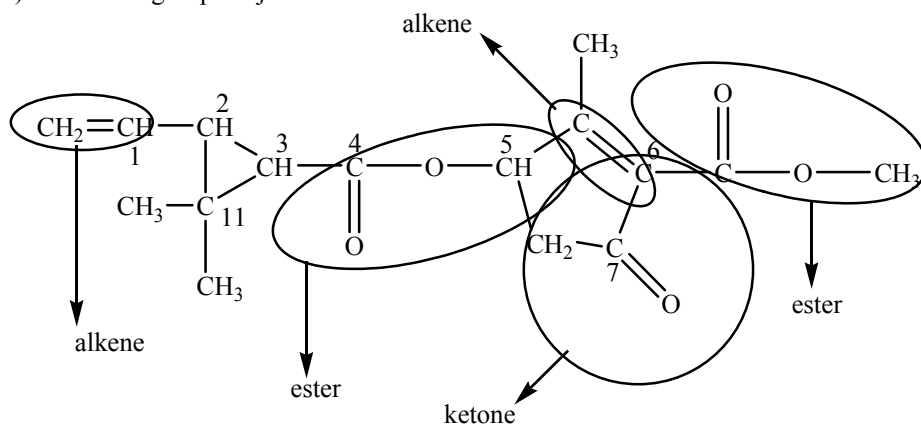
The addition of cyanide, [C≡N]⁻, to form a nitrile is a convenient way to increase the length of a carbon chain:



The nitrile can then be reduced to an amine through the addition of hydrogen (NaBH_4 is a hydrogen-rich reducing agent):



15.111 a) Functional groups in jasmolin II:



b) Carbon atoms surrounded by four electron regions (4 single bonds) are sp^3 hybridized. Carbon atoms surrounded by three electron regions (2 single bonds and 1 double bond) are sp^2 hybridized.

Carbon 1 is sp^2 hybridized.

Carbon 2 is sp^3 hybridized.

Carbon 3 is sp^3 hybridized.

Carbon 4 is sp^2 hybridized.

Carbon 5 is sp^3 hybridized.

Carbon 6 and 7 are sp^2 hybridized.

c) Carbons 2, 3, and 5 are chiral centers as they are each bonded to four different groups.

15.112 a) Initial mole determination:

$$\text{Moles C} = (1.25 \text{ g CO}_2) \left(\frac{1 \text{ mol CO}_2}{44.01 \text{ g CO}_2} \right) \left(\frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \right) = 0.0284026 \text{ mol C}$$

$$\text{Moles H} = (0.613 \text{ g H}_2\text{O}) \left(\frac{1 \text{ mol H}_2\text{O}}{18.02 \text{ g H}_2\text{O}} \right) \left(\frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \right) = 0.0680355 \text{ mol H}$$

Save the moles and now determine the masses of C and H:

$$\text{Grams C} = (0.0284026 \text{ mol C}) \left(\frac{12.01 \text{ g C}}{1 \text{ mol C}} \right) = 0.341115 \text{ g C}$$

$$\text{Grams H} = (0.0680355 \text{ mol H}) \left(\frac{1.008 \text{ g H}}{1 \text{ mol H}} \right) = 0.06857978 \text{ g H}$$

Determine the mass and then the moles of O:

$$0.500 \text{ g (C, H and O)} - (0.341115 \text{ g C} + 0.06857978 \text{ g H}) = 0.0903052 \text{ g O}$$

$$\text{Moles O} = (0.0903052 \text{ g O}) \left(\frac{1 \text{ mol O}}{16.00 \text{ g O}} \right) = 0.005644075 \text{ mol O}$$

Divide by the smallest number of moles: (Rounding is allowed here.)

$$\left(\frac{0.0284026 \text{ mol C}}{0.005644075 \text{ mol O}} \right) = 5 \qquad \left(\frac{0.0680355 \text{ mol H}}{0.005644075 \text{ mol O}} \right) = 12 \qquad \left(\frac{0.005644075 \text{ mol O}}{0.005644075 \text{ mol O}} \right) = 1$$

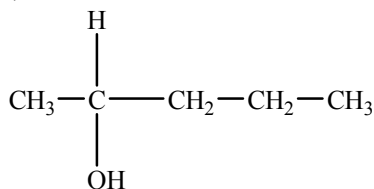
Empirical formula A = **C₅H₁₂O** (Empirical formula mass = 88.15 g/mol.

$$\text{b) } \mathcal{M} = mRT / PV = \frac{(0.225 \text{ g}) \left(0.0821 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} \right) ((273 + 97) \text{ K})}{(755 \text{ torr})(78.0 \text{ mL})} \left(\frac{1 \text{ mL}}{10^{-3} \text{ L}} \right) \left(\frac{760 \text{ torr}}{1 \text{ atm}} \right)$$

= 88.206 = 88.2 g/mol This is nearly the same as the molar mass of the empirical formula so the empirical and molecular formulas are the same.

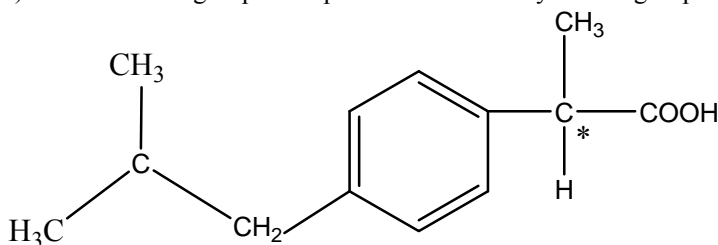
Molecular formula A = **C₅H₁₂O**

c) Since careful oxidation yields a ketone, compound A must be a secondary alcohol. Compound A is branched and chiral, so the structure must be:

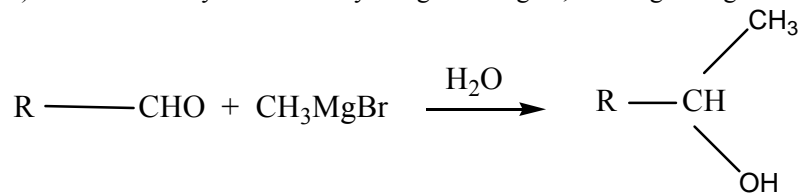


This is not the only possible correct answer.

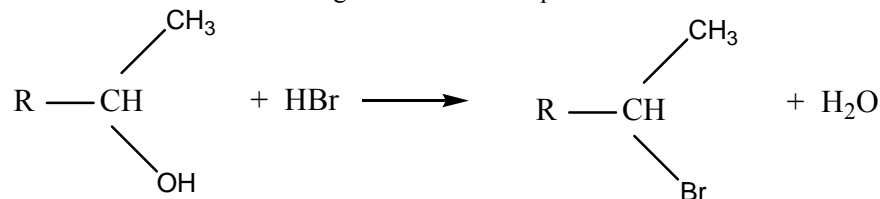
15.113 a) The functional group in ibuprofen is the carboxylic acid group COOH. The chiral center is RC*(H)(CH₃)COOH.



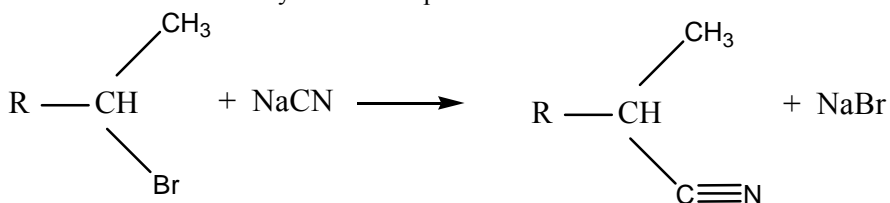
b) React the aldehyde with methyl Grignard reagent, CH₃MgBr to get the alcohol.



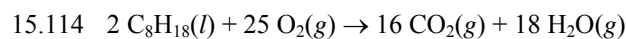
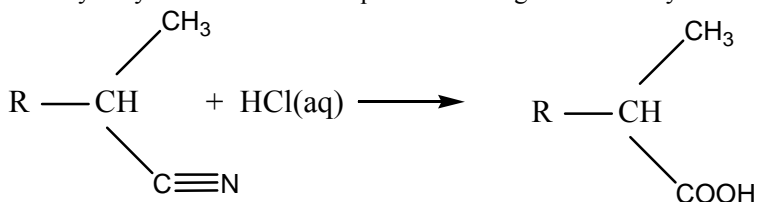
React the alcohol with HBr to get the brominated product.



React the bromide with cyanide ion to produce the nitrile.



Then hydrolyze the nitrile with aqueous HCl to get the carboxylic acid.



$$\left(\frac{18000 \text{ mi}}{y}\right) \left(\frac{\text{gal}}{15 \text{ mi}}\right) \left(\frac{4 \text{ qt}}{1 \text{ gal}}\right) \left(\frac{1 \text{ L}}{1.057 \text{ qt}}\right) \left(\frac{1 \text{ mL}}{10^{-3} \text{ L}}\right) \left(\frac{0.74 \text{ g}}{\text{mL}}\right) \left(\frac{1 \text{ mol C}_8\text{H}_{18}}{114.22 \text{ g}}\right) \left(\frac{16 \text{ mol CO}_2}{2 \text{ mol C}_8\text{H}_{18}}\right)$$

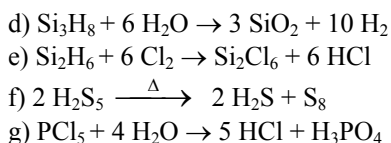
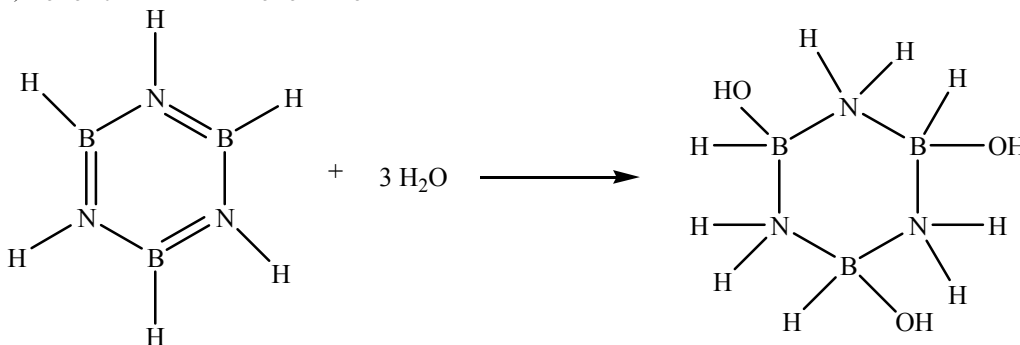
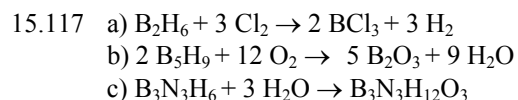
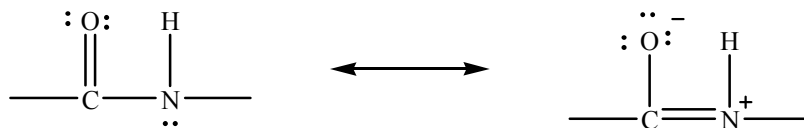
$$= 2.35367 \times 10^5 \text{ mol CO}_2 / y \text{ (unrounded)}$$

$$\text{Mass} = \left(\frac{2.35367 \times 10^5 \text{ mol CO}_2}{y}\right) \left(\frac{44.01 \text{ g CO}_2}{1 \text{ mol CO}_2}\right) \left(\frac{1 \text{ kg}}{10^3 \text{ g}}\right) \left(\frac{1 \text{ Metric Ton}}{10^3 \text{ kg}}\right)$$

$$= 10.3585 = \mathbf{10 \text{ metric tons/year}}$$

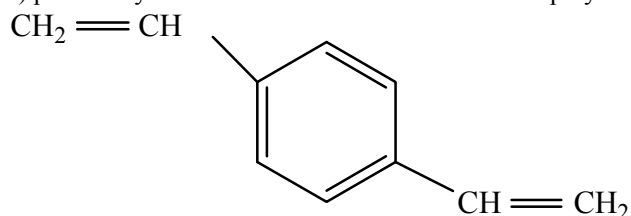
15.115 Retinal is a polyunsaturated aldehyde with extensive conjugation.

15.116 The resonance structures show that the bond between carbon and nitrogen will have some double bond character that restricts rotation around the bond.



- 15.118 a) Serine–threonine–alanine–tyrosine–methionine–alanine–asparagine–leucine–lysine
 b) AGGTGTCGGATATACCGTTTGAAGCTTC
 c) 6

- 15.119 a) To prepare a polymer with a benzene containing backbone, styrene, $C_6H_5-CH=CH_2$ can be used to produce polystyrene, $-(-CH(C_6H_5)-CH_2-)_n$.
 b) p-diethenylbenzene can be used to crosslink the polymer.



- 15.120 a) The hydrolysis process requires the addition of water to break the peptide bonds.
 b) Convert each mass to moles, and divide the moles by the smallest number to determine molar ratio, and thus relative numbers of the amino acids.

$$\begin{aligned} (3.00 \text{ g gly}) / (75.07 \text{ g/mol}) &= 0.0399627 \text{ mol glycine (unrounded)} \\ (0.90 \text{ g ala}) / (89.10 \text{ g/mol}) &= 0.010101010 \text{ mol alanine (unrounded)} \\ (3.70 \text{ g val}) / (117.15 \text{ g/mol}) &= 0.0315834 \text{ mol valine (unrounded)} \\ (6.90 \text{ g pro}) / (115.13 \text{ g/mol}) &= 0.0599322 \text{ mol proline (unrounded)} \\ (7.30 \text{ g ser}) / (105.10 \text{ g/mol}) &= 0.0694576 \text{ mol serine (unrounded)} \\ (86.00 \text{ g arg}) / (174.21 \text{ g/mol}) &= 0.493657 \text{ mol arginine (unrounded)} \end{aligned}$$

Divide by the smallest value (0.01010214 mol alanine), and round to a whole number.

$$\begin{aligned} (0.0399627 \text{ mol glycine}) / (0.010101010 \text{ mol}) &= \mathbf{4} \\ (0.01010214 \text{ mol alanine}) / (0.010101010 \text{ mol}) &= \mathbf{1} \\ (0.0315834 \text{ mol valine}) / (0.010101010 \text{ mol}) &= \mathbf{3} \\ (0.0599322 \text{ mol proline}) / (0.010101010 \text{ mol}) &= \mathbf{6} \\ (0.0694576 \text{ mol serine}) / (0.010101010 \text{ mol}) &= \mathbf{7} \\ (0.493657 \text{ mol arginine}) / (0.010101010 \text{ mol}) &= \mathbf{49} \end{aligned}$$

c) Minimum $\mathcal{M} = (4 \times 75.07 \text{ g/mol}) + (1 \times 89.09 \text{ g/mol}) + (3 \times 117.15 \text{ g/mol}) + (6 \times 115.13 \text{ g/mol}) + (7 \times 105.09 \text{ g/mol}) + (49 \times 174.20 \text{ g/mol}) = \mathbf{10,700 \text{ g/mol}}$

- 15.121 a) $CH_3CH(OH)CH_2OH(l) + 4 O_2(g) \rightarrow 3 CO_2(g) + 4 H_2O(l)$

b)
$$\left(\frac{4 \text{ mol } O_2}{1 \text{ mol } CH_3CH(OH)CH_2OH} \right) \left(\frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} \right) \left(\frac{1 \text{ mol } CH_3CH(OH)CH_2OH}{76.09 \text{ g } CH_3CH(OH)CH_2OH} \right)$$

$= 1.682218 = \mathbf{1.682 \text{ g } O_2/\text{g propylene glycol}}$

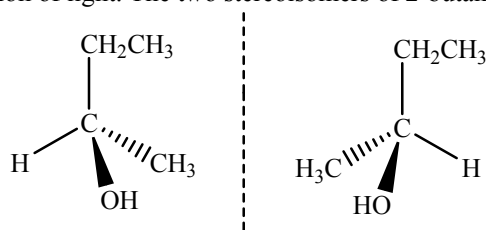
c) Liters of solution containing a mole of propylene glycol:

$$\left(\frac{90.0\%}{100\%} \right) \left(\frac{76.09 \text{ g } CH_3CH(OH)CH_2OH}{1 \text{ mol } CH_3CH(OH)CH_2OH} \right) \left(\frac{\text{mL}}{1.036 \text{ g}} \right) \left(\frac{10^{-3} \text{ L}}{1 \text{ mL}} \right) = 0.066101 \text{ L/mol (unrounded)}$$

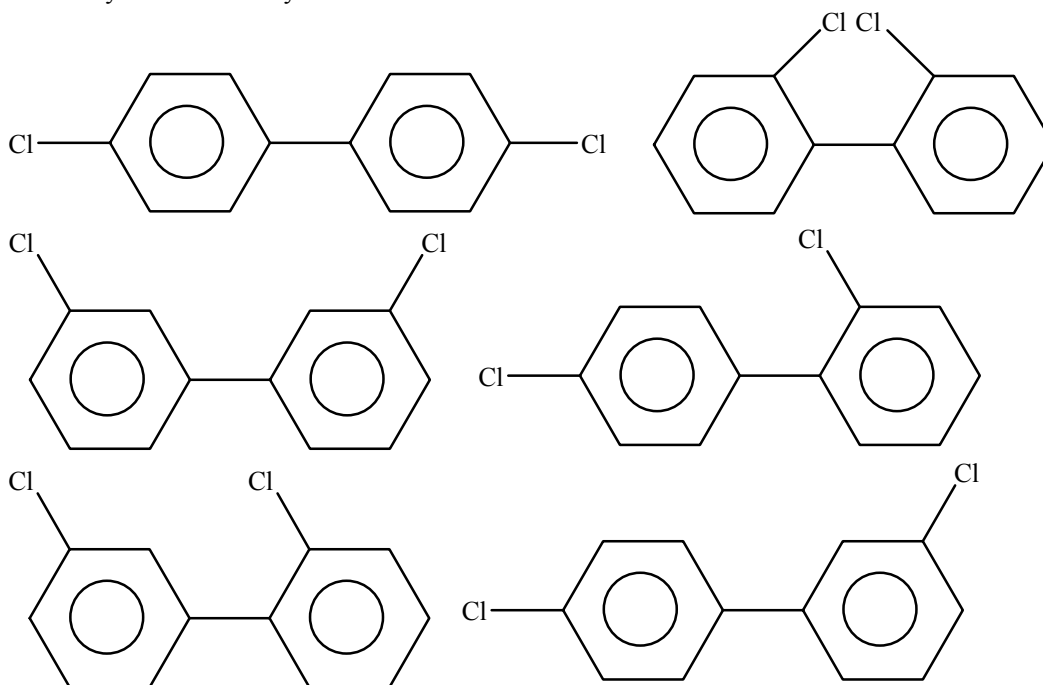
$$\left(\frac{4 \text{ mol } O_2}{1 \text{ mol } CH_3CH(OH)CH_2OH} \right) \left(\frac{32.00 \text{ g } O_2}{1 \text{ mol } O_2} \right) \left(\frac{1 \text{ mol } CH_3CH(OH)CH_2OH}{0.066101 \text{ L}} \right)$$

$= 1.93643 \times 10^3 = \mathbf{1.94 \times 10^3 \text{ g } O_2/\text{L propylene glycol}}$

- 15.122 When 2-butanone is reduced, equal amounts of both isomers are produced because the reaction does not favor the production of one over the other. In a 1:1 mixture of the two stereoisomers, the light rotated to the right by the other isomer cancels the light rotated to the left by one isomer. The mixture is not optically active since there is no net rotation of light. The two stereoisomers of 2-butanol are shown below.



- 15.123 These may be drawn in any order:



- 15.124 From protein:

$$\left(\frac{8.0 \text{ g C}_{16}\text{H}_{24}\text{O}_5\text{N}_4}{\text{L}}\right)\left(\frac{1 \text{ mol C}_{16}\text{H}_{24}\text{O}_5\text{N}_4}{352.39 \text{ g C}_{16}\text{H}_{24}\text{O}_5\text{N}_4}\right)\left(\frac{16 \text{ mol C}}{1 \text{ mol C}_{16}\text{H}_{24}\text{O}_5\text{N}_4}\right)\left(\frac{12.01 \text{ g C}}{1 \text{ mol C}}\right) = 4.3624 \text{ g C/L (unrounded)}$$

From carbohydrate:

$$\left(\frac{12.0 \text{ g CH}_2\text{O}}{\text{L}}\right)\left(\frac{1 \text{ mol CH}_2\text{O}}{30.03 \text{ g CH}_2\text{O}}\right)\left(\frac{1 \text{ mol C}}{1 \text{ mol CH}_2\text{O}}\right)\left(\frac{12.01 \text{ g C}}{1 \text{ mol C}}\right) = 4.7992 \text{ g C/L (unrounded)}$$

From fat:

$$\left(\frac{2.0 \text{ g C}_8\text{H}_{16}\text{O}}{\text{L}}\right)\left(\frac{1 \text{ mol C}_8\text{H}_{16}\text{O}}{128.21 \text{ g C}_8\text{H}_{16}\text{O}}\right)\left(\frac{8 \text{ mol C}}{1 \text{ mol C}_8\text{H}_{16}\text{O}}\right)\left(\frac{12.01 \text{ g C}}{1 \text{ mol C}}\right) = 1.49879 \text{ g C/L (unrounded)}$$

$$\text{TOC} = (4.3624 \text{ g C/L}) + (4.7992 \text{ g C/L}) + (1.49879 \text{ g C/L}) = 10.66039 = \mathbf{10.7 \text{ g C/L}}$$