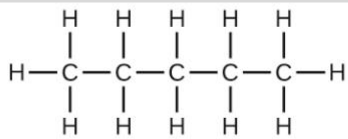
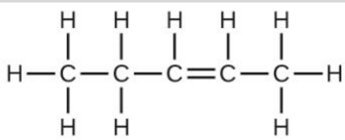
# *Chemistry 2e*
## 20: Organic Chemistry
### 20.1: Hydrocarbons

1. Write the chemical formula and Lewis structure of the following, each of which contains five carbon atoms:
(a) an alkane
(b) an alkene
(c) an alkyne

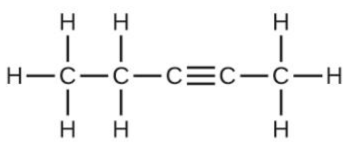
Solution
There are several sets of answers; one is:
(a) $C_5H_{12}$



;
(b) $C_5H_{10}$



;
(c) $C_5H_8$



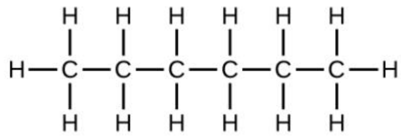
3. On a microscopic level, how does the reaction of bromine with a saturated hydrocarbon differ from its reaction with an unsaturated hydrocarbon? How are they similar?

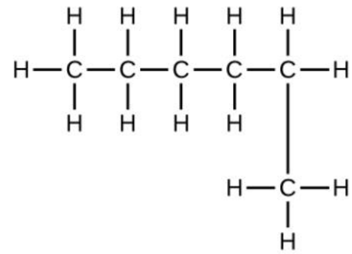
Solution
Both reactions result in bromine being incorporated into the structure of the product. The difference is the way in which that incorporation takes place. In the saturated hydrocarbon, an existing C–H bond is broken, and a bond between the C and the Br can then be formed. In the unsaturated hydrocarbon, the only bond broken in the hydrocarbon is the π bond whose electrons can be used to form a bond to one of the bromine atoms in $Br_2$ (the electrons from the Br–Br bond form the other C–Br bond on the other carbon that was part of the π bond in the starting unsaturated hydrocarbon).

5. Explain why unbranched alkenes can form geometric isomers while unbranched alkanes cannot. Does this explanation involve the macroscopic domain or the microscopic domain?

Solution
Unbranched alkanes have free rotation about the C–C bonds, yielding all orientations of the substituents about these bonds equivalent, interchangeable by rotation. In the unbranched alkenes, the inability to rotate about the $C=C$ bond results in fixed (unchanging) substituent orientations, thus permitting different isomers. Since these concepts pertain to phenomena at the molecular level, this explanation involves the microscopic domain.

7. Explain why these two molecules are not isomers:

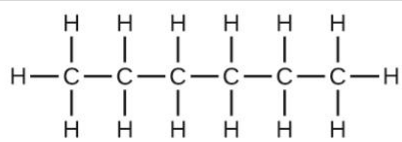




Solution
They are the same compound because each is a saturated hydrocarbon containing an unbranched chain of six carbon atoms.

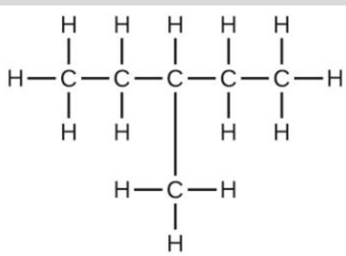
9. Write the Lewis structure and molecular formula for each of the following hydrocarbons:
(a) hexane
(b) 3-methylpentane
(c) *cis*-3-hexene
(d) 4-methyl-1-pentene
(e) 3-hexyne
(f) 4-methyl-2-pentyne

Solution
(a) $C_6H_{14}$



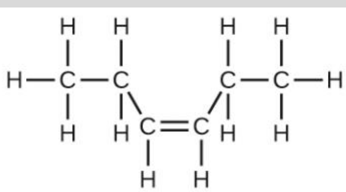
;

(b) $C_6H_{14}$



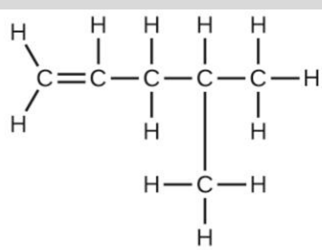
;

(c) $C_6H_{12}$



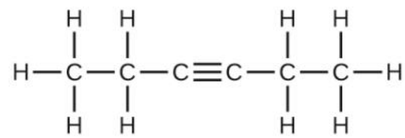
;

(d) $C_6H_{12}$

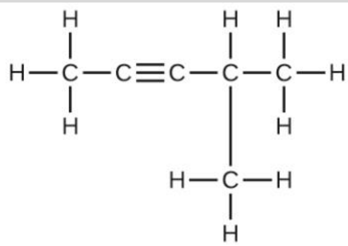


;

(e) $C_6H_{10}$

;

(f) $C_6H_{10}$

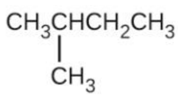


11. Give the complete IUPAC name for each of the following compounds:

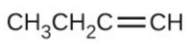
(a) $CH_3CH_2CBr_2CH_3$

(b) $(CH_3)_3CCl$

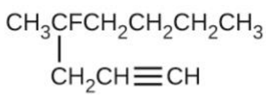
(c)



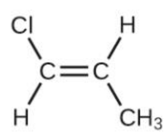
(d)



(e)



(f)



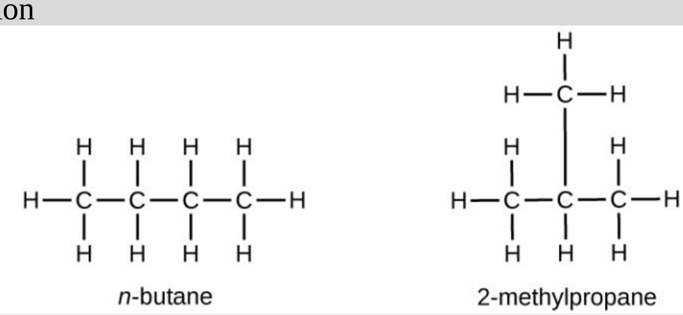
(g) $(CH_3)_2CHCH_2CH=CH_2$

Solution

(a) 2,2-dibromobutane; (b) 2-chloro-2-methylpropane; (c) 2-methylbutane; (d) 1-butyne; (e) 4-fluoro-4-methyl-1-octyne; (f) *trans*-1-chloropropene; (g) 4-methyl-1-pentene

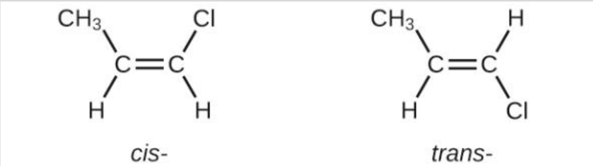
13. Butane is used as a fuel in disposable lighters. Write the Lewis structure for each isomer of butane.

Solution

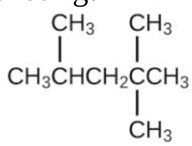



15. Write Lewis structures for the *cis–trans* isomers of $CH_3CH=CHCl$

Solution



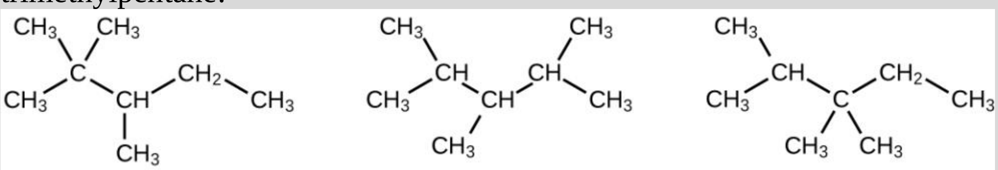

17. Isooctane is the common name of the isomer of $C_8H_{18}$ used as the standard of 100 for the gasoline octane rating:



(a) What is the IUPAC name for the compound?
(b) Name the other isomers that contain a five-carbon chain with three methyl substituents.

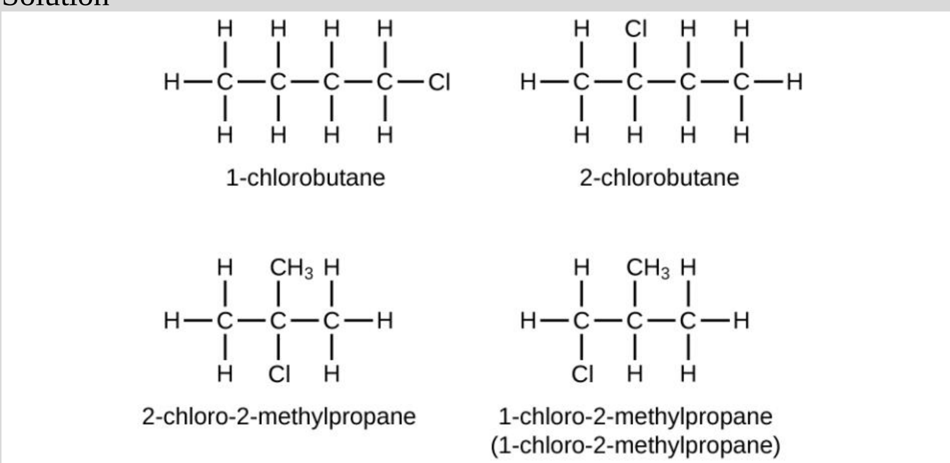
Solution

(a) 2,2,4-trimethylpentane; (b) 2,2,3-trimethylpentane, 2,3,4-trimethylpentane, and 2,3,3-trimethylpentane:



19. Write Lewis structures and IUPAC names for all isomers of $C_4H_9Cl$.

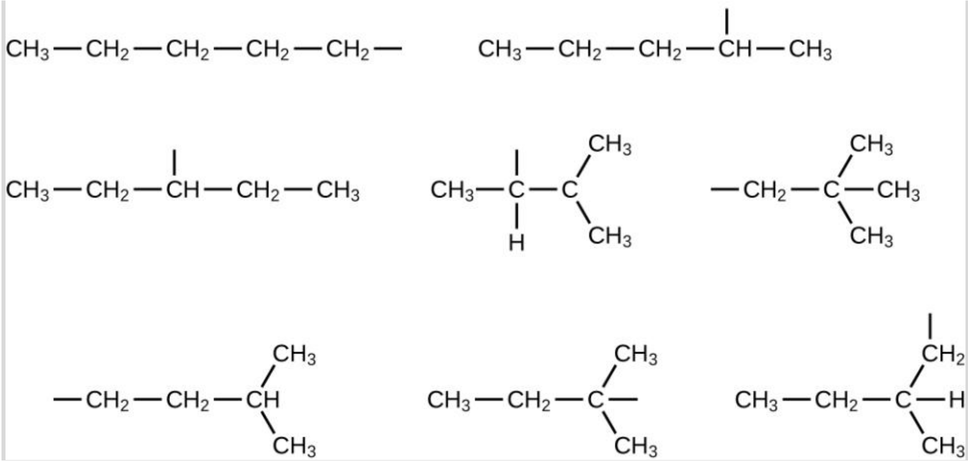
Solution




21. Write the structures for all the isomers of the $–C_5H_{11}$ alkyl group.

Solution

In the following, the carbon backbone and the appropriate number of hydrogen atoms are shown in condensed form:

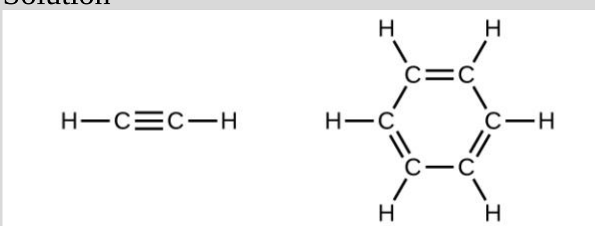


23. Benzene is one of the compounds used as an octaneenhancerin unleaded gasoline. It is manufactured by the catalytic conversion of acetylene to benzene:

$$3C_2H_2 \longrightarrow C_6H_6$$

Draw Lewis structures for these compounds, with resonance structures as appropriate, and determine the hybridization of the carbon atoms in each.

Solution



In acetylene, the bonding uses *sp* hybrids on carbon atoms and *s* orbitals on hydrogen atoms. In benzene, the carbon atoms are $sp^2$ hybridized.

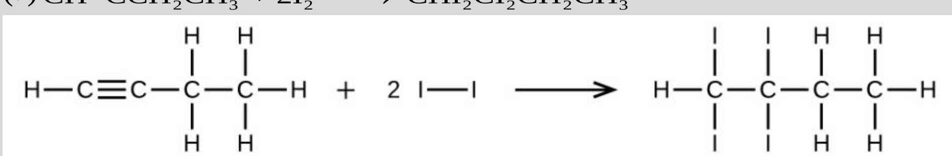
25. Write two complete, balanced equations for each of the following reactions, one using condensed formulas and one using Lewis structures.

(a) 1 mol of 1-butyne reacts with 2 mol of iodine.

(b) Pentane is burned in air.

Solution

(a) $CH{=}CCH_2CH_3 + 2I_2 \longrightarrow CHI_2CI_2CH_2CH_3$



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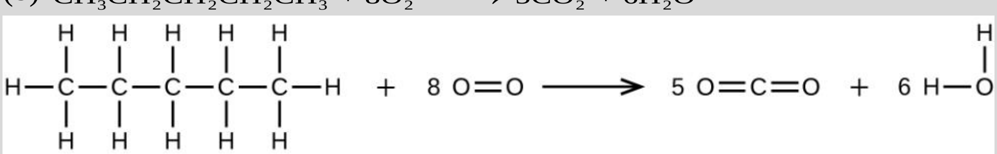
(b) $CH_3CH_2CH_2CH_2CH_3 + 8O_2 \longrightarrow 5CO_2 + 6H_2O$



27. What mass of 2-bromopropane could be prepared from 25.5 g of propene? Assume a 100% yield of product.

Solution

$$C_3H_7Br\text{ mass} = 22.5\text{ g} \times \frac{1\text{ mol }C_3H_6}{48.081\text{ g }C_3H_6} \times \frac{1\text{ mol }C_3H_7Br}{1\text{ mol }C_3H_6} \times \frac{122.993\text{ g }C_3H_7Br}{1\text{ mol }C_3H_7Br} = 65.2\text{ g}$$

29. How many kilograms of ethylene is produced by the pyrolysis of $1.000 \times 10^3$ kg of ethane, assuming a 100.0% yield?

Solution

$$1C_2H_6 \longrightarrow 1C_2H_4$$

$$\text{mass of ethylene} = 1 \times 10^3\text{ kg} \times \frac{1\text{ mol}}{30.07\text{ g}} \times \frac{28.05\text{ g}}{1\text{ mol}}$$

$$= 9.328 \times 10^2\text{ kg}$$

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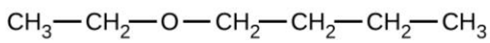
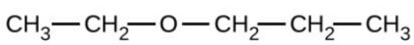
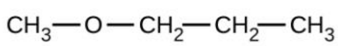
# *Chemistry 2e*
## 20: Organic Chemistry
## 20.2: Alcohols and Ethers

31. Write condensed formulas and provide IUPAC names for the following compounds:
(a) ethyl alcohol (in beverages)
(b) methyl alcohol (used as a solvent, for example, in shellac)
(c) ethylene glycol (antifreeze)
(d) isopropyl alcohol, $CH_3CH(OH)CH_3$, used in rubbing alcohol)
(e) glycerine

Solution
(a) ethyl alcohol, ethanol: $CH_3CH_2OH$; (b) methyl alcohol, methanol: $CH_3OH$; (c) ethylene glycol, ethanediol: $HOCH_2CH_2OH$; (d) isopropyl alcohol, 2-propanol: $CH_3CH(OH)CH_3$; (e) glycerine, l,2,3-trihydroxypropane: $HOCH_2CH(OH)CH_2OH$

33. Give the complete IUPAC name and the common name for each of the following compounds:
(a)


(b)


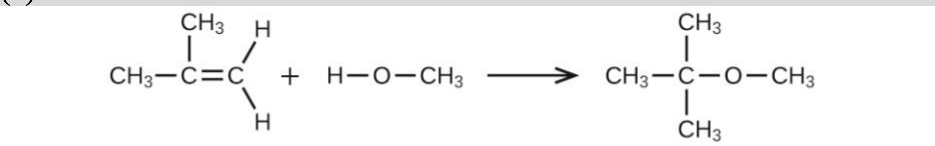
(c)



Solution
(a) 1-ethoxybutane, butyl ethyl ether; (b) 1-ethoxypropane, ethyl propyl ether; (c) 1-methoxypropane, methyl propyl ether

35. Write the condensed structures of all isomers with the formula $C_2H_6O_2$. Label the functional group (or groups) of each isomer.

Solution
$HOCH_2CH_2OH$, two alcohol groups; $CH_3OCH_2OH$, ether and alcohol groups

37. MTBE, Methyl *tert*-butyl ether, $CH_3OC(CH_3)_3$, is used as an oxygen source in oxygenated gasolines. MTBE is manufactured by reacting 2-methylpropene with methanol.
(a) Using Lewis structures, write the chemical equation representing the reaction.
(b) What volume of methanol, density 0.7915 g/mL, is required to produce exactly 1000 kg of MTBE, assuming a 100% yield?

Solution
(a)


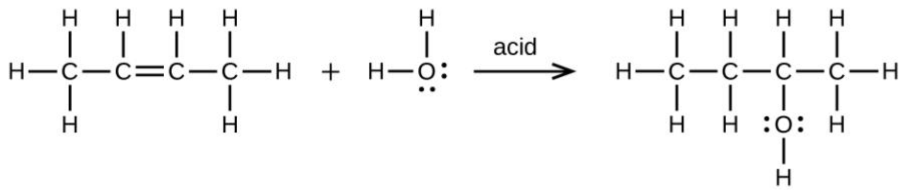
;

(b)
$$\text{mass MeOH} = 1.000 \times 10^6 \text{ g MTBE} \times \frac{1 \text{ mol MeOH}}{1 \text{ mol MTBE}} \times \frac{32.04 \text{ g mol}^{-1} \text{ MeOH}}{88.15 \text{ g mol}^{-1} \text{ MTBE}} = 363.5 \text{ kg}$$
$$\frac{363.5 \times 10^3 \text{ g}}{791.5 \text{ g L}^{-1}} = 4.593 \times 10^2 \text{ L}$$

39. Write two complete balanced equations for each of the following reactions, one using condensed formulas and one using Lewis structures.
(a) 2-butene is treated with water in dilute acid
(b) ethanol is dehydrated to yield ethene

Solution

(a) $CH_3CH{=}CHCH_3 + H_2O \longrightarrow CH_3CH_2CH(OH)CH_3$




;

(b) $CH_3CH_2OH \longrightarrow CH_2{=}CH_2 + H_2O$

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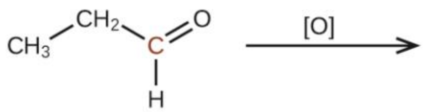
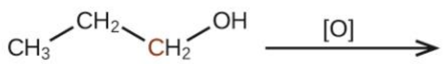
## *Chemistry 2e*
## 20: Organic Chemistry
## 20.3: Aldehydes, Ketones, Carboxylic Acids, and Esters

41. Predict the products of oxidizing the molecules shown in this problem. In each case, identify the product that will result from the minimal increase in oxidation state for the highlighted carbon atom:

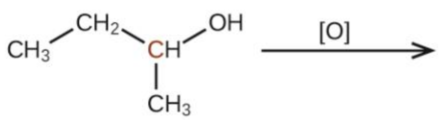
(a)




(b)

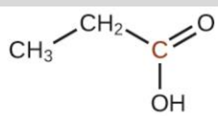



(c)




Solution

(a)

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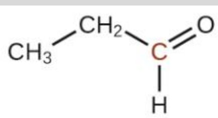
(b)

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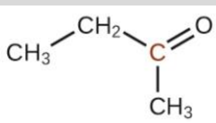
(c)




43. Explain why it is not possible to prepare a ketone that contains only two carbon atoms.

Solution

A ketone contains a group bonded to two additional carbon atoms; thus, a minimum of three carbon atoms are needed.

45. Fatty acids are carboxylic acids that have long hydrocarbon chains attached to a carboxylate group. How does a saturated fatty acid differ from an unsaturated fatty acid? How are they similar?

Solution

Since they are both carboxylic acids, they each contain the –COOH functional group and its characteristics. The difference is the hydrocarbon chain in a saturated fatty acid contains no double or triple bonds, whereas the hydrocarbon chain in an unsaturated fatty acid contains one or more multiple bonds.

47. Write a condensed structural formula, such as $CH_3CH_3$, and describe the molecular geometry at each carbon atom.

(a) 2-propanol

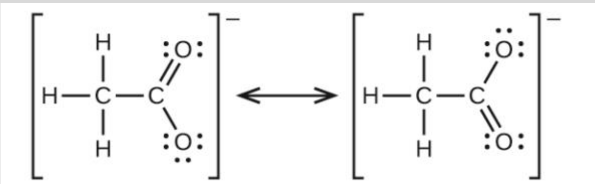
(b) acetone
(c) dimethyl ether
(d) acetic acid
(e) 3-methyl-1-hexene

Solution

(a) $CH_3CH(OH)CH_3$: all carbons are tetrahedral; (b) $CH_3C(=O) CH_3$: the end carbons are tetrahedral and the central carbon is trigonal planar; (c) $CH_3OCH_3$: all are tetrahedral; (d) $CH_3COOH$: the methyl carbon is tetrahedral and the acid carbon is trigonal planar; (e) $CH_3CH_2CH_2CH(CH_3)CHCH_2$: all are tetrahedral except the right-most two carbons, which are trigonal planar

49. Write the two-resonance structures for the acetate ion.

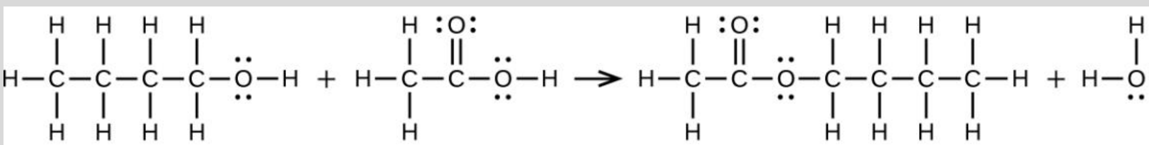
Solution



51. Write two complete balanced equations for each of the following reactions, one using condensed formulas and one using Lewis structures.
(a) 1-butanol reacts with acetic acid
(b) propionic acid is poured onto solid calcium carbonate

Solution

(a) $CH_3CH_2CH_2CH_2OH + CH_3C(O)OH \longrightarrow CH_3C(O)OCH_2CH_2CH_2CH_3 + H_2O$:



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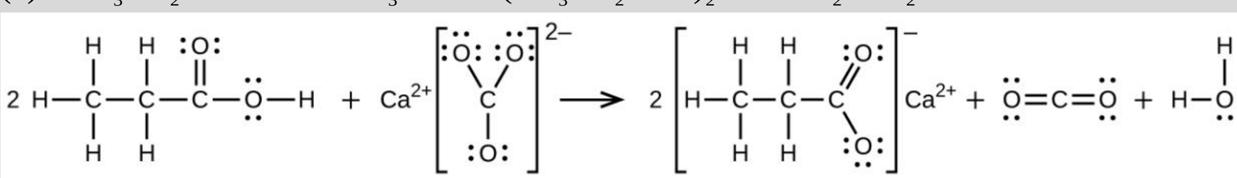
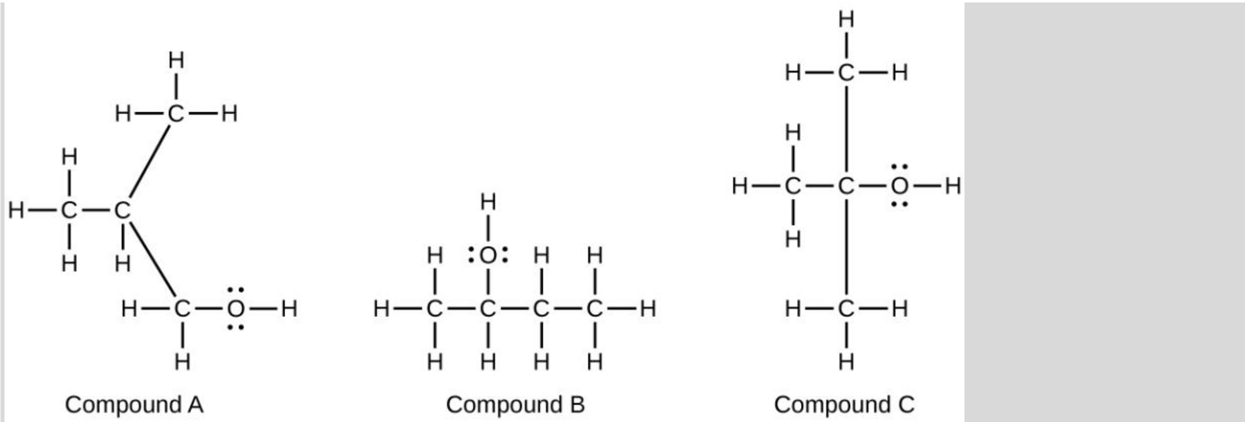
(b) $2CH_3CH_2COOH + CaCO_3 \longrightarrow (CH_3CH_2COO)_2Ca + CO_2 + H_2O$:



53. Alcohols A, B, and C all have the composition $C_4H_{10}O$. Molecules of alcohol A contain a branched carbon chain and can be oxidized to an aldehyde; molecules of alcohol B contain a linear carbon chain and can be oxidized to a ketone; and molecules of alcohol C can be oxidized to neither an aldehyde nor a ketone. Write the Lewis structures of these molecules.

Solution

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***Chemistry 2e***
**20: Organic Chemistry**
**20.4: Amines and Amides**

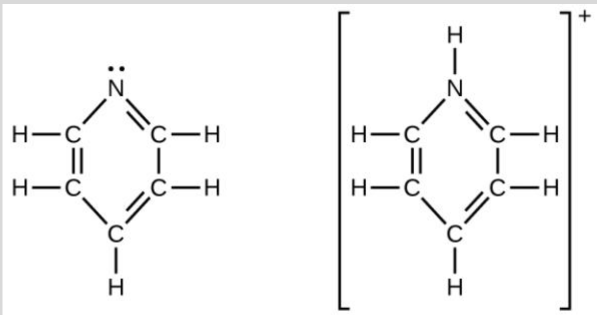
55. What is the molecular structure about the nitrogen atom in trimethyl amine and in the trimethyl ammonium ion, $(CH_3)_3NH^+$? What is the hybridization of the nitrogen atom in trimethyl amine and in the trimethyl ammonium ion?

Solution

Trimethyl amine: trigonal pyramidal, $sp^3$; trimethyl ammonium ion: tetrahedral, $sp^3$

57. Draw Lewis structures for pyridine and its conjugate acid, the pyridinium ion, $C_5H_5NH^+$.What are the geometries and hybridizations about the nitrogen atoms in pyridine and in the pyridinium ion?

Solution



pyridine, trigonal planar, $sp^2$ (nonlinear or bent)

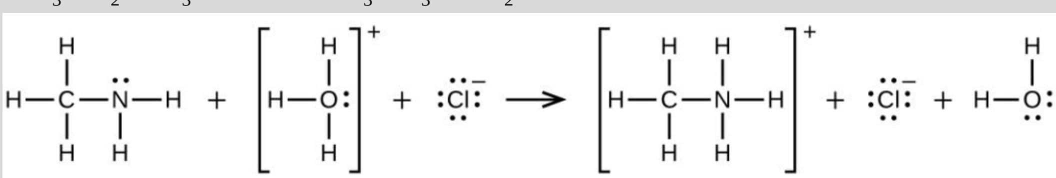
pyridinium ion, trigonal planar, $sp^2$ (trigonal planar)

59. Write two complete balanced equations for the following reaction, one using condensed formulas and one using Lewis structures.

Methyl amine is added to a solution of HCl.

Solution

$$CH_3NH_2 + H_3O^+ \longrightarrow CH_3NH_3^+ + H_2O$$



61. Identify any carbon atoms that change hybridization and the change in hybridization during the reactions in Exercise 26.

Solution

$$CH_3\underline{C}H{=}\underline{C}HCH_3(sp^2) + Cl \longrightarrow CH_3\underline{C}H(Cl)H(Cl)CH_3(sp^3);$$

$$2\underline{C}_6H_6(sp^2) + 15O_2 \longrightarrow 12\underline{C}O_2(sp) + 6H_2O$$

63. Identify any carbon atoms that change hybridization and the change in hybridization during the reactions in Exercise 51.

Solution

The carbon in $CO_3^{2-}$, initially at $sp^2$, changes hybridization to $sp$ in $CO_2$.

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