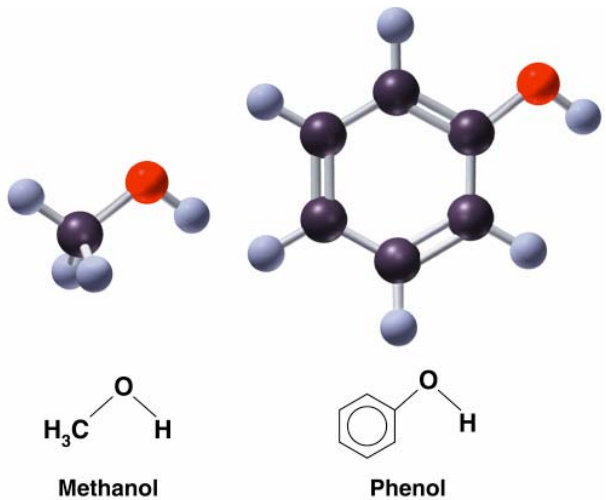
Chapter 14

Some compounds with Oxygen, sulfur, or a Halogen: Alcohols, Phenols, Ethers, and Thiols

Structure and Classification of Alcohols

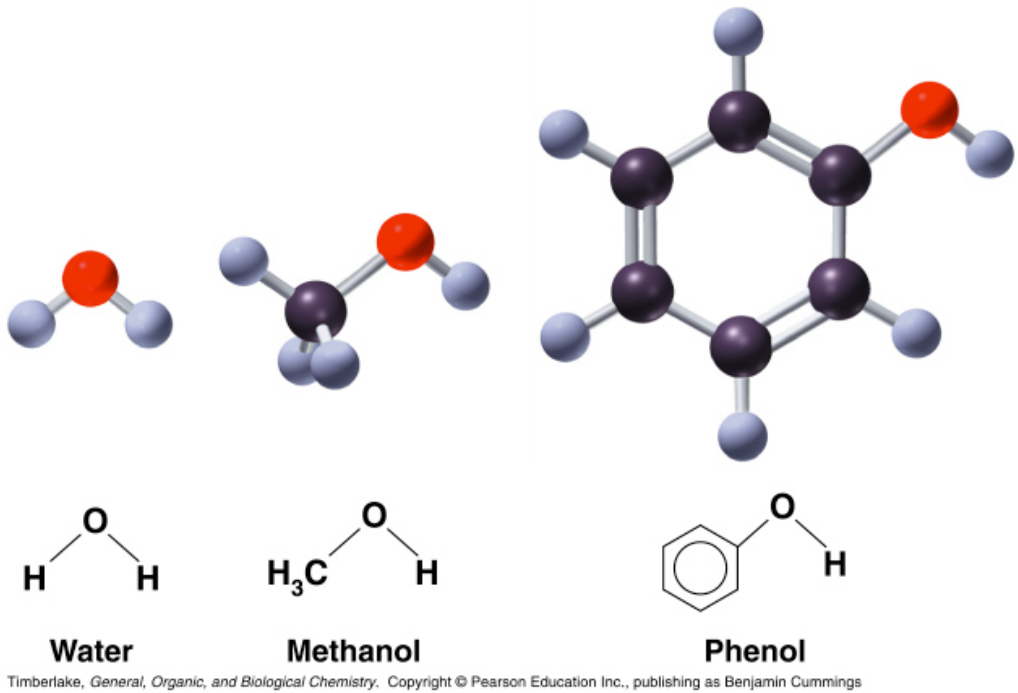
14.3 Naming Alcohols, Phenols, and Thiols

14.4 Some Important Alcohols and Phenols



Alcohols

- **In an alcohol, a hydroxyl group (—OH) is attached to a carbon chain.**
- **In a phenol, a hydroxyl group (—OH) is attached to a benzene ring.**



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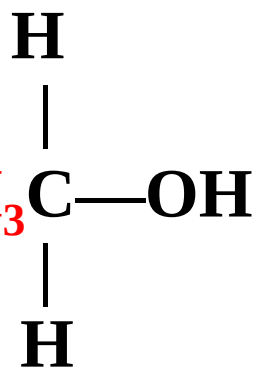
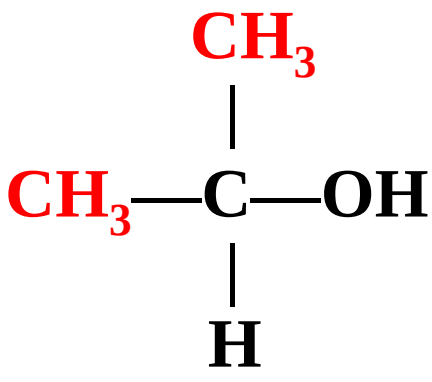
Classification of Alcohols

- **Alcohols are classified as primary, secondary, or tertiary.**
- **Classification is determined by the number of alkyl groups attached to the carbon bonded to the hydroxyl.**

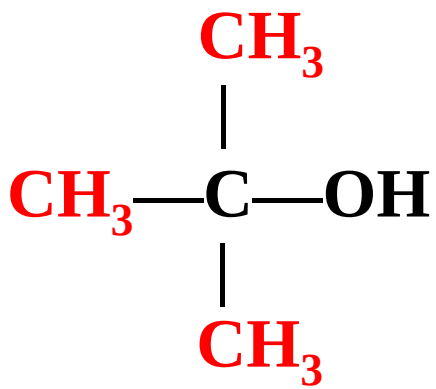
Primary (1º)
1 group



Secondary (2º)
2 groups



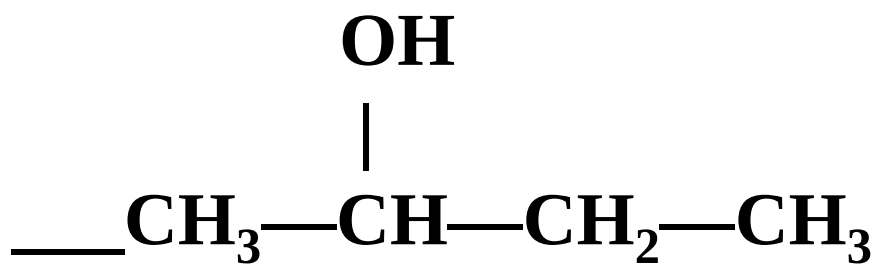
Tertiary (3º)
3 groups

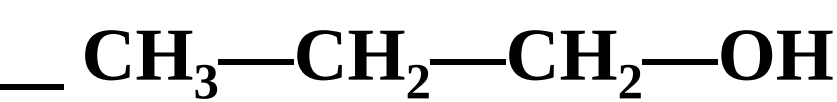


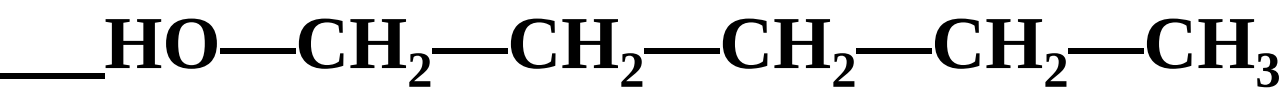
Learning Check

Classify each alcohol as

1) primary, 2) secondary, or 3) tertiary.

A. 

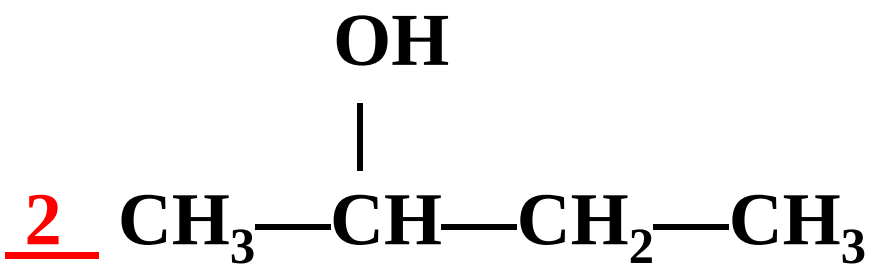
B. 

C. 

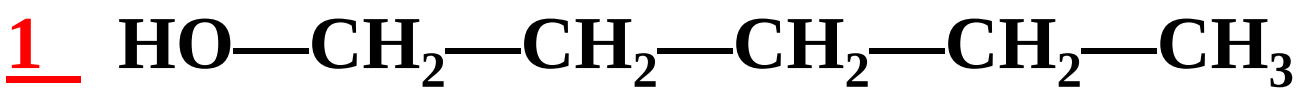
Solution

Classify each alcohol as

1) primary, 2) secondary, or 3) tertiary.

A. **2** 

B. **1** 

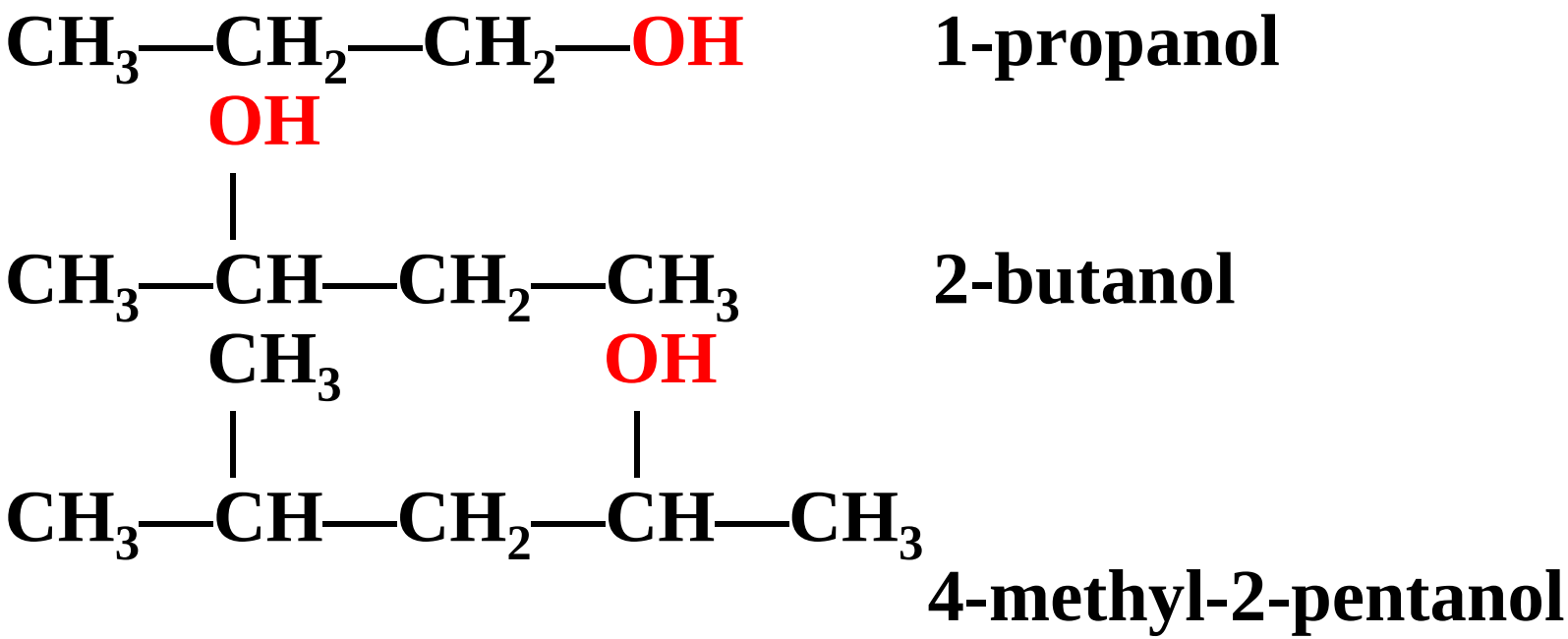
C. **1** 

Naming Alcohols

- **The IUPAC system replaces the *-e* in the name of the alkane main chain with *–ol*.**
- **Common names for simple alcohols use the alkyl name followed by *alcohol*.**
- **CH_4 methane** **CH_3OH methanol (methyl alcohol)**
- **CH_3CH_3ethane** **CH_3CH_2OH ethanol (ethyl alcohol)**

Naming Alcohols

- **In the IUPAC names for longer chains, the chain is numbered from the end nearest the -OH group.**



Some Typical Alcohols

“rubbing alcohol”

2-propanol (isopropyl alcohol)

antifreeze $HO—CH_2—CH_2—OH$

1,2-ethanediol (ethylene glycol)

glycerol

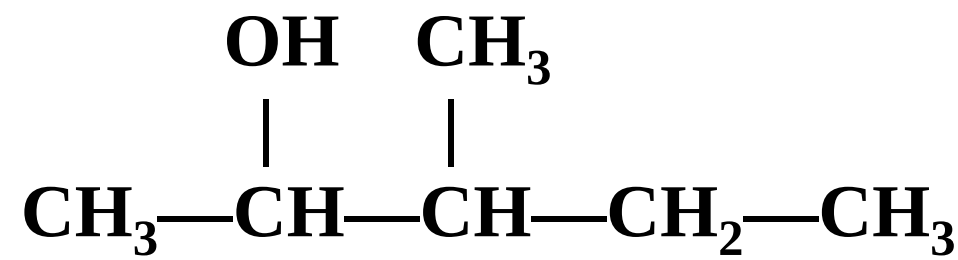
1,2,3-propanetriol

Learning Check

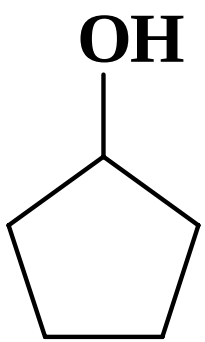
Name the following:

A. $CH_3—CH_2—CH_2—CH_2—OH$

B.



C.

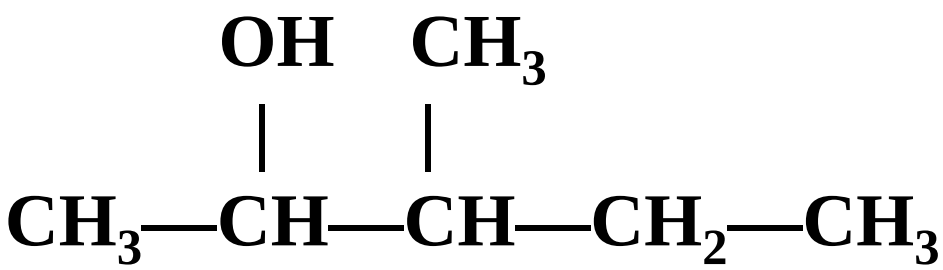


Solution

A. $CH_3—CH_2—CH_2—CH_2—OH$

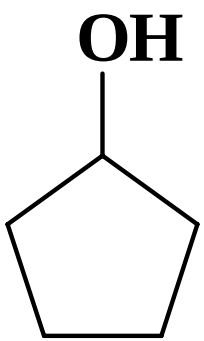
1-butanol

B.



3-methyl-2-pentanol

C.



cyclopentanol

Learning Check

Write the structure of each of the following:

A. 3-pentanol

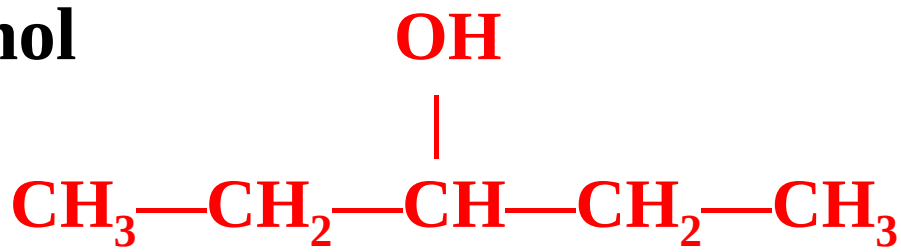
B. ethyl alcohol

C. 3-methylcyclohexanol

Solution

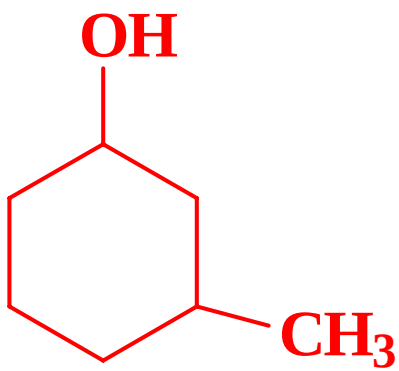
Write the structure of the following:

A. 3-pentanol



B. ethyl alcohol $CH_3—CH_2—OH$

C. 3-methylcyclohexanol

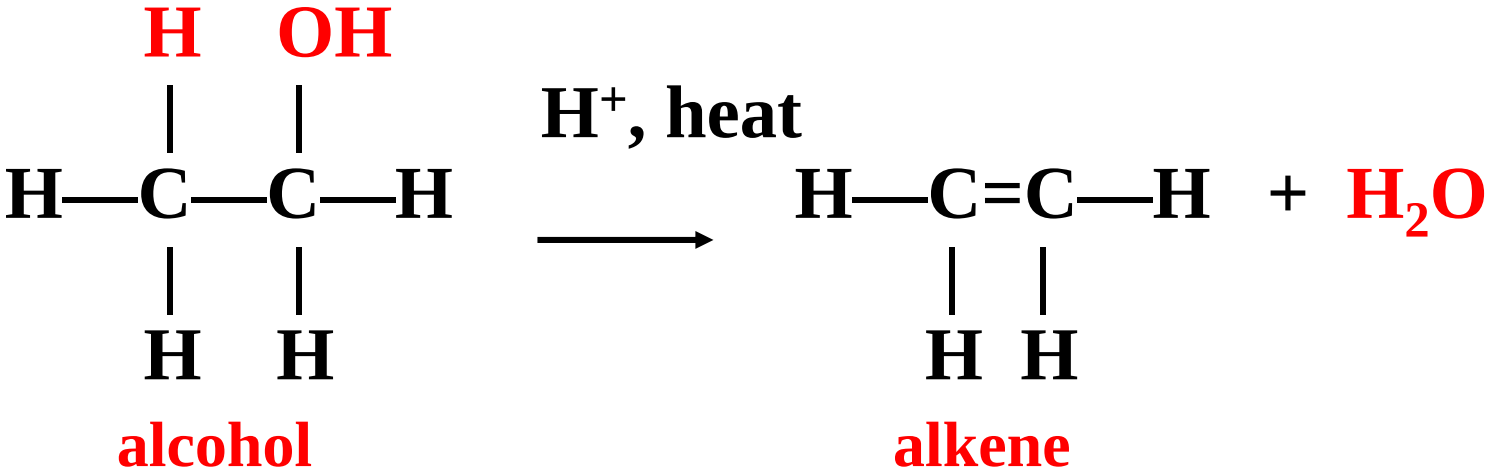


14.5
Reactions of Alcohols

- **Alcohols undergo combustion with O_2 to produce CO_2 and H_2O.**

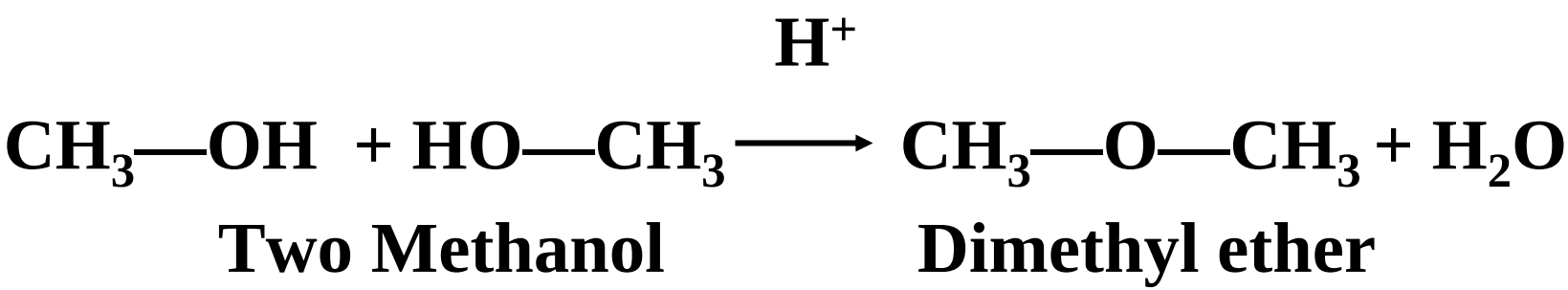
$$2CH_3OH + 3O_2 \longrightarrow 2CO_2 + 4H_2O + \text{Heat}$$

- **Dehydration removes H- and -OH from *adjacent* carbon atoms by heating with an acid catalyst.**



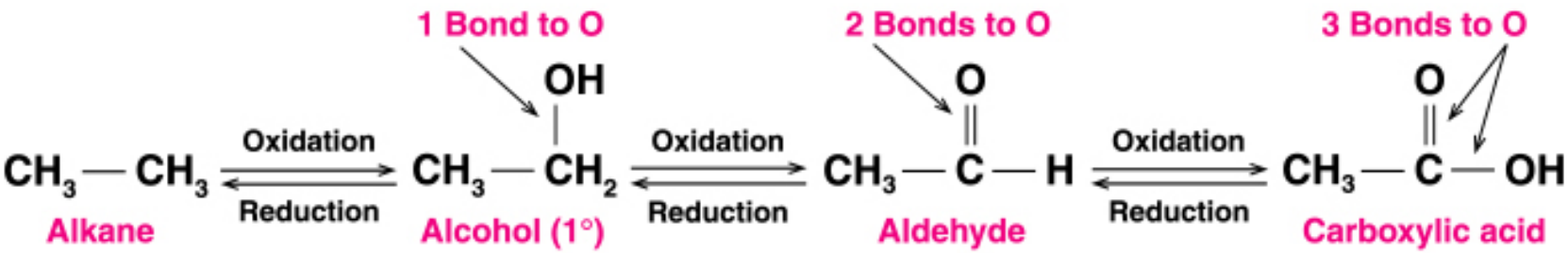
Formation of Ethers

- **Ethers form when dehydration takes place at low temperature.**



Oxidation and Reduction

- In organic chemistry, **oxidation** is a loss of hydrogen atoms or a gain of oxygen.
- In an oxidation, there is an increase in the number of C-O bonds.
- **Reduction** is a gain of hydrogen or a loss of oxygen. The number of C-O bonds decreases.



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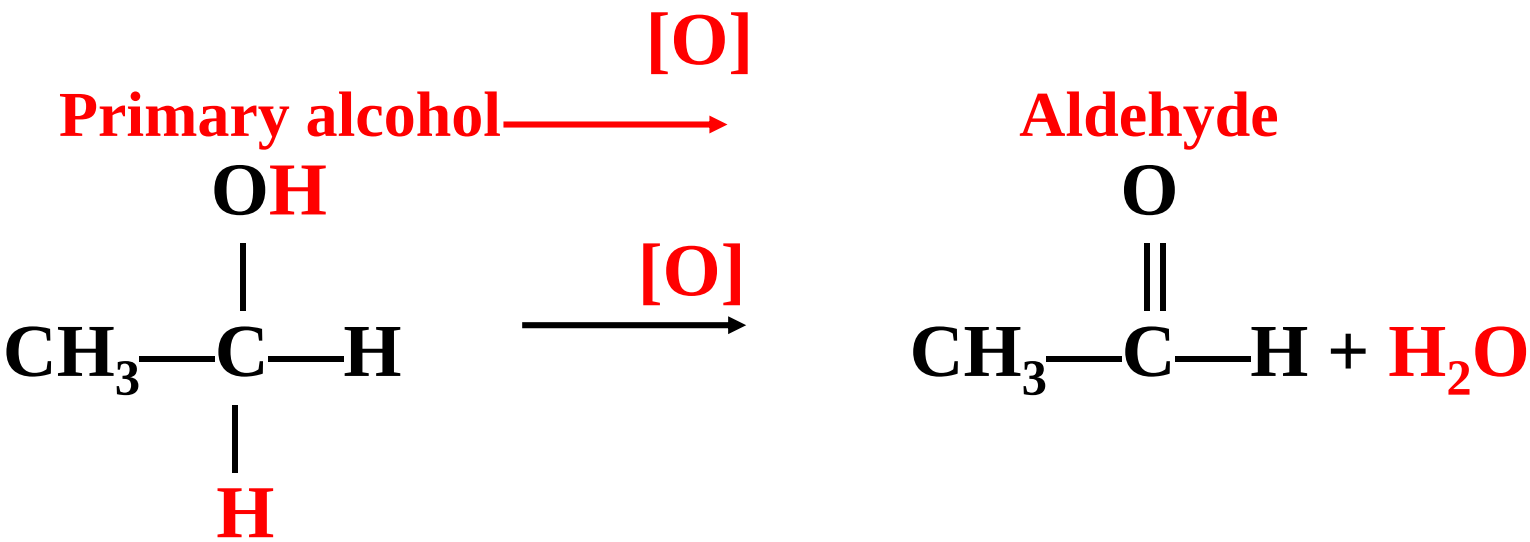
Oxidation of Primary Alcohols

- **In the oxidation [O] of a primary alcohol, one H is lost from the –OH and another H from the carbon bonded to the OH.**

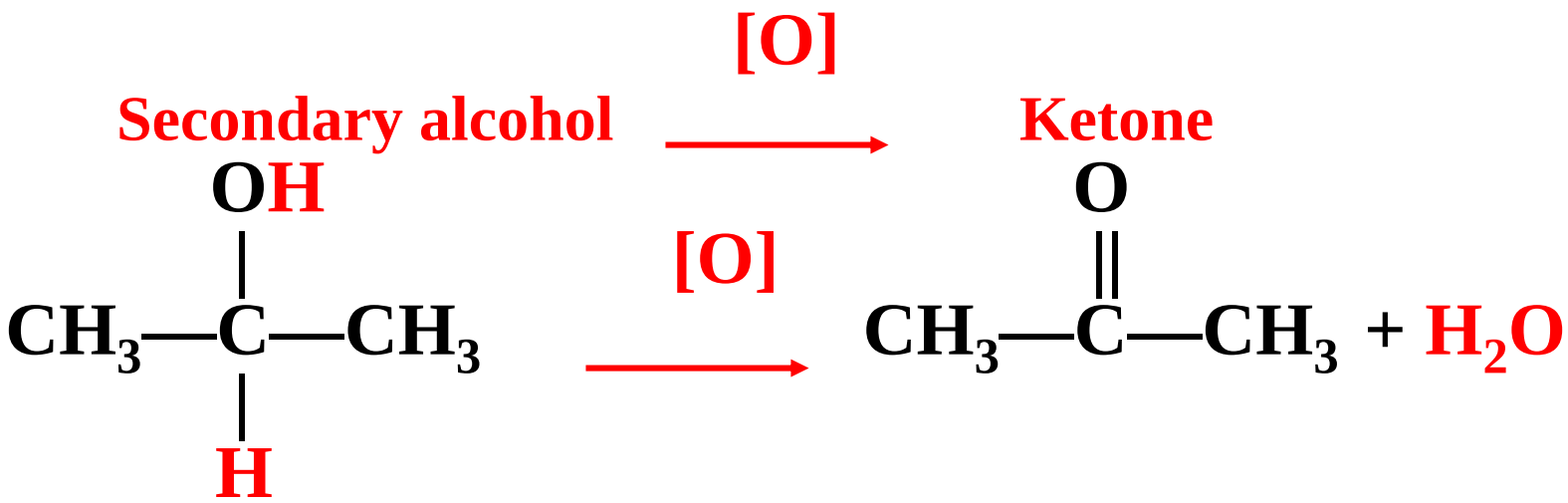


Ethanol (ethyl alcohol)

Ethanal (acetaldehyde)

Oxidation of Secondary Alcohols

- **The oxidation of a secondary alcohol removes one H from –OH and another H from the carbon bonded to the –OH.**



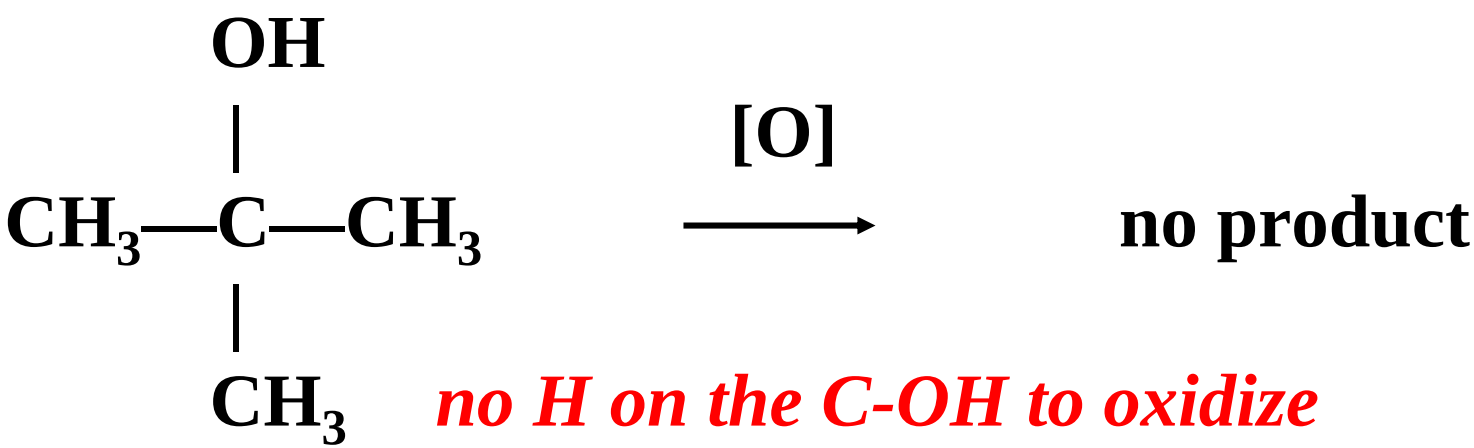
2-Propanol (Isopropyl alcohol)

Propanone (Dimethylketone; Acetone)

Oxidation of Tertiary Alcohols

- **Tertiary alcohols are resistant to oxidation.**

Tertiary alcohols $\xrightarrow{[O]}$ **no reaction**



no H on the C-OH to oxidize

2-Methyl-2-propanol

Learning Check

Select the product for the reaction of

$CH_3—CH_2—CH_2—OH$ with the following reagents:

A. H^+, heat

B. [O]

C. O_2, spark

Solution

A. H^+, heat ⟶ 1) $CH_3—CH=CH_2$

B. [O] ⟶ 3) $CH_3—CH_2—\overset{\overset{O}{\|}}{C}—H$

C. O_2 spark ⟶ 2) $CO_2 + H_2O$

Ethanol CH_3CH_2OH

Ethanol:

- **Acts as a depressant.**
- **Kills or disables more people than any other drug.**
- **Is metabolized at a rate of 12-15 mg/dL per hour by a social drinker.**
- **Is metabolized at a rate of 30 mg/dL per hour by an alcoholic.**

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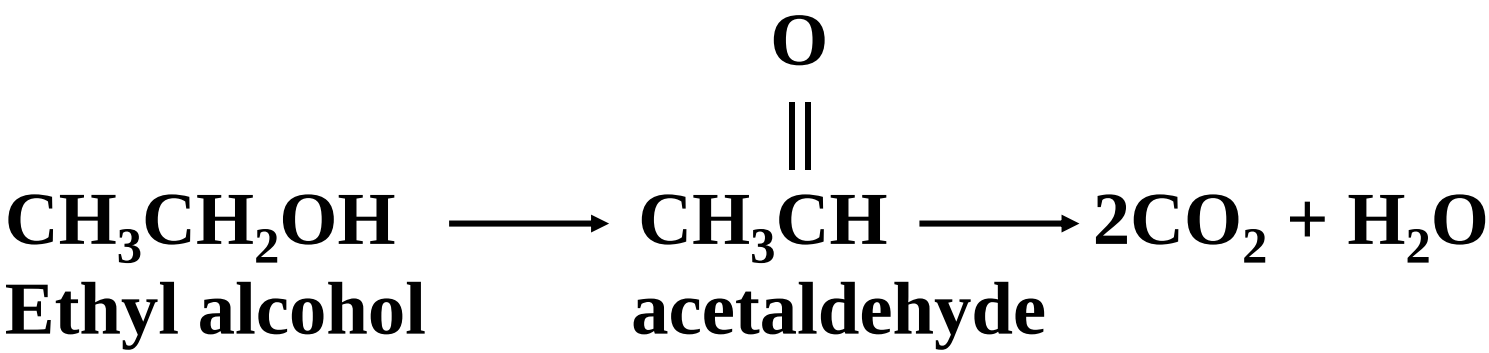
Oxidation of Alcohol in the Body

- **Enzymes in the liver oxidize ethanol.**
- **The aldehyde produced impairs coordination.**
- **A blood alcohol level over 0.4% can be fatal.**



Effect of Alcohol on the Body

Table 14.2 Typical Behaviors Exhibited by a 150-lb Person Consuming Alcohol

Number of Beers (12 oz) or Glasses of Wine (5 oz)	Blood Alcohol Level (w/v %)	Typical Behavior
1	0.025	Slightly dizzy, talkative
2	0.05	Euphoria, loud talking, and laughing
4	0.10	Loss of inhibition, loss of coordination, drowsiness, legally drunk in most states
8	0.20	Intoxicated, quick to anger, exaggerated emotions
12	0.30	Unconscious
16–20	0.40–0.50	Coma and death

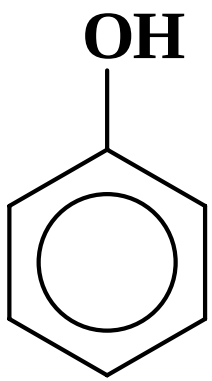
Alcohol Contents in Common Products

% Ethanol	Product
50%	Whiskey, rum, brandy
40%	Flavoring extracts
15-25%	Listerine, Nyquil, Scope
12%	Wine, Dristan, Cepacol
3-9%	Beer, Lavoris

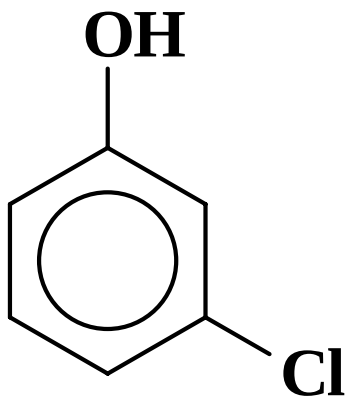
14.6 Phenols

- **A phenol is a benzene ring with a hydroxyl group.**
- **For two substituents, assign C-1 to the carbon attached to the –OH.**
- **Number the ring to give the lowest numbers.**
- **The prefixes *o*, *m*, and *p* are used for common names.**

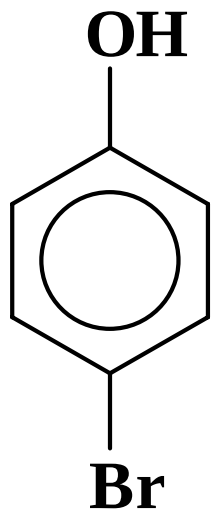
Examples of Phenols



Phenol



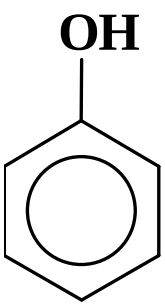
3-Chlorophenol
(*m*-Chlorophenol)



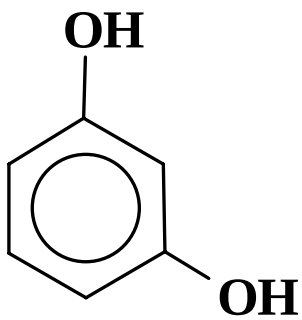
4-Bromophenol
(*p*-Bromophenol)

Phenols in Medicine

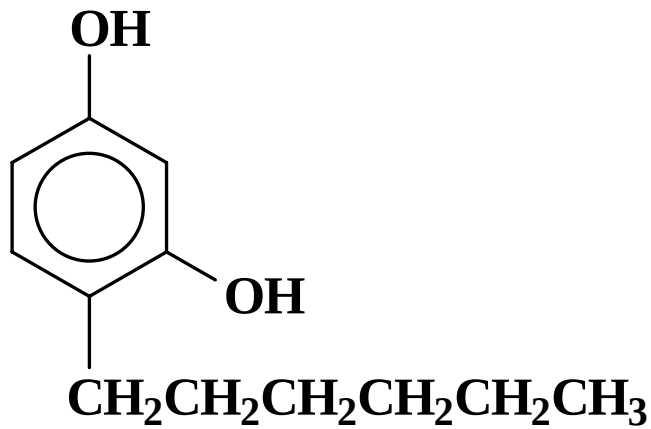
- **Many phenols are used as antiseptics and disinfectants.**



Phenol



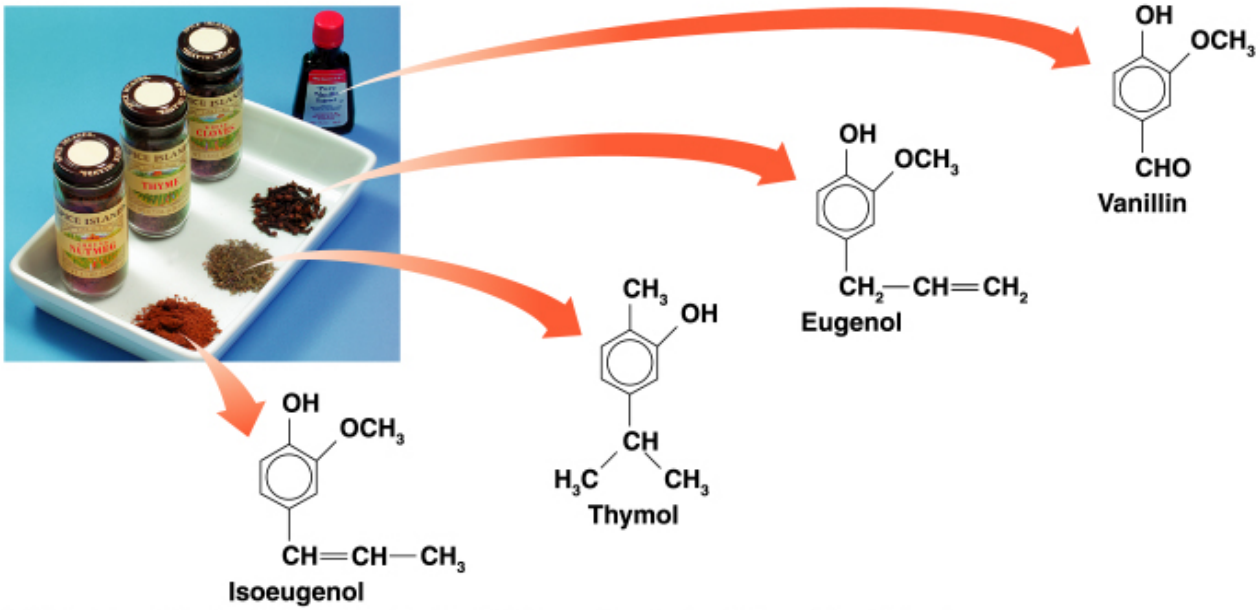
Resorcinol (antiseptic)



4-Hexylresorcinal (antiseptic)

Derivatives of Phenol

- **Compounds of phenol are the active ingredients in the essential oils of cloves, vanilla, nutmeg, and mint.**



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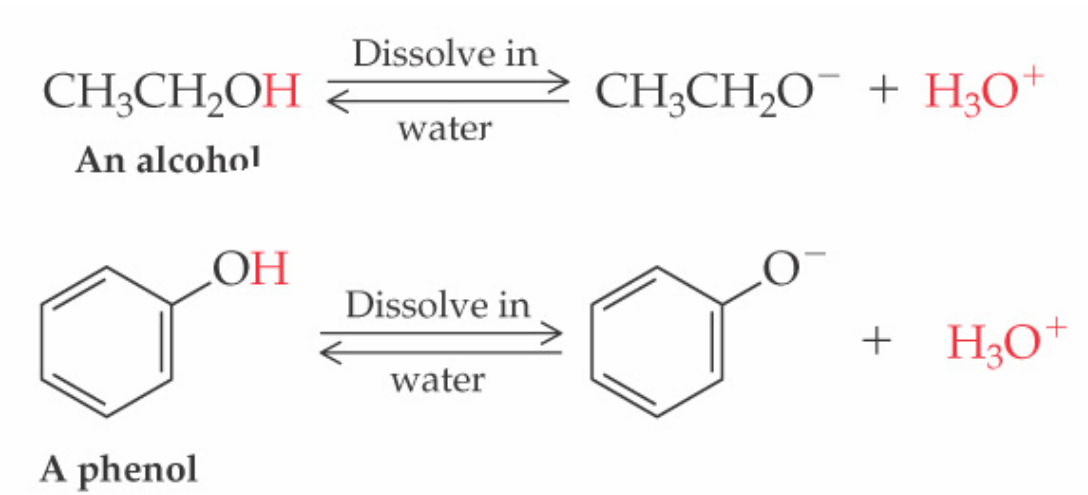
14.7 Acidity of Alcohols and Phenols

- Alcohols and phenols are weakly acidic. They dissociate slightly in aqueous solution and establish equilibria between neutral and anionic forms.



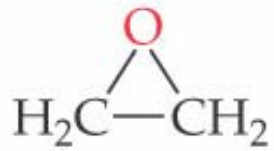
- Alcohols are about as acidic as water. K_a values near 10^{-15}. Thus, an alkoxide ion (RO^-) is as strong a base as hydroxide, HO^-, ion.

- Phenols are considerably more acidic than water. K_a value 1.0×10^{-10}.

14.8 Ethers

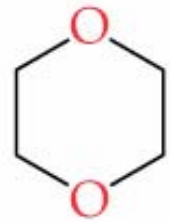
- **Ethers contain an -O- between two carbon groups.**
- **Simple ethers are named by listing the alkyl names in alphabetical order followed by *ether*.**

$CH_3—O—CH_3$	dimethyl ether
$CH_3—O—CH_2—CH_3$	ethyl methyl ether
$CH_3—CH_2—O—CH_2—CH_3$	diethyl ether



Ethylene oxide

Tetrahydrofuran
(a solvent)

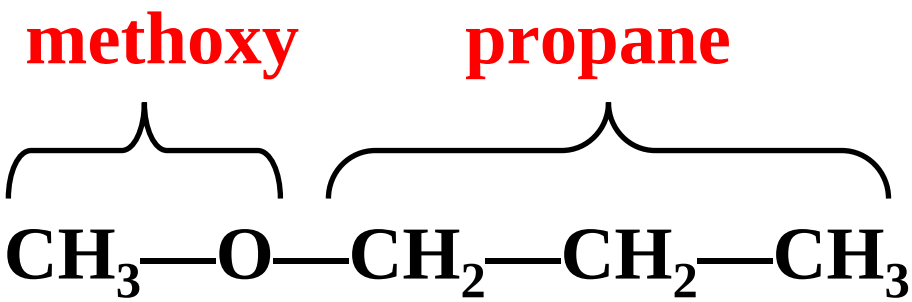


1,4-Dioxane
(a solvent)

- An –OR group is known as an alkoxy group. -OCH_3 is a methoxy, -OCH_2CH_3 is a ethoxy group, and so on. These names are used when the ether functional group is present in a compound that also has other functional groups.

IUPAC Names for Ethers

- **In the IUPAC system, the shorter alkyl group and the oxygen are named as an alkoxy group attached to the longer alkane.**



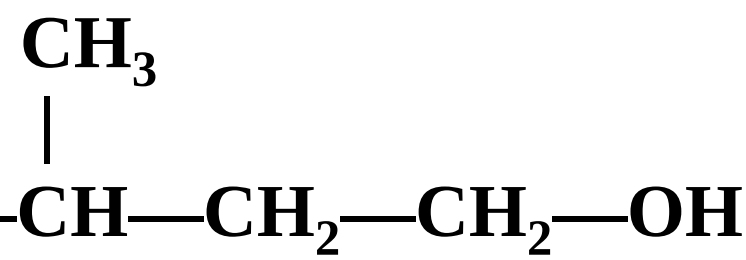
- **Numbering the longer alkane gives 1-methoxypropane.**

Learning Check

Name each of the following compounds:

A. $CH_3—CH_2—O—CH_2—CH_3$

B.



C. $CH_3—CH_2—CH_2—SH$

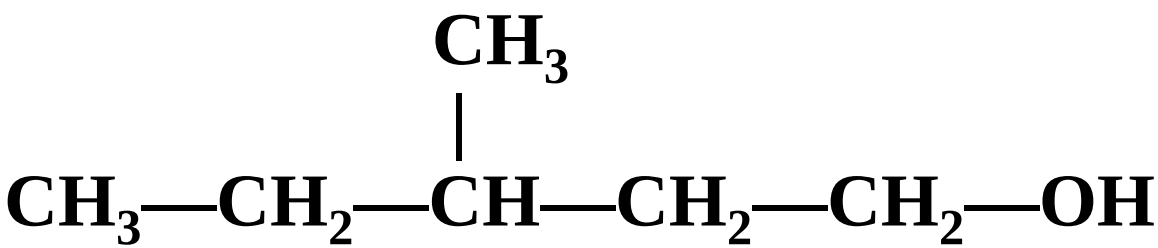
Solution

Name each of the following compounds:

A. $CH_3—CH_2—O—CH_2—CH_3$

Diethyl ether or ethoxyethane (IUPAC)

B.



3-Methyl-1-pentanol

C. $CH_3—CH_2—CH_2—SH$

1-Propanethiol

Learning Check

Draw the structure of each compound.

A. 2-Butanethiol

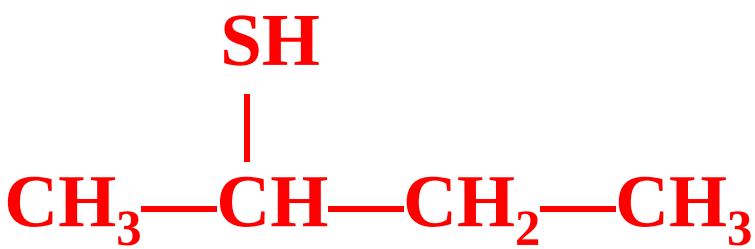
B. Ethyl methyl ether

C. 2-Methyl-1-butanol

Solution

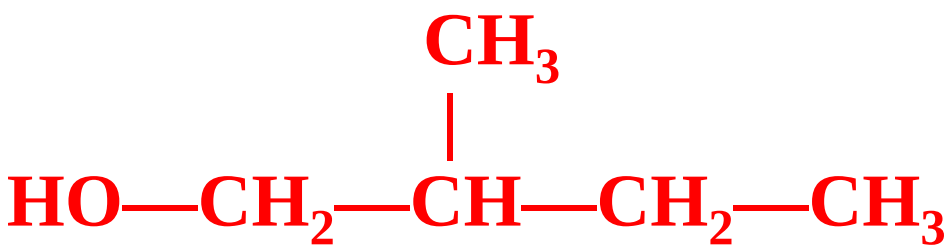
Draw the structure of each compound.

A. 2-Butanethiol



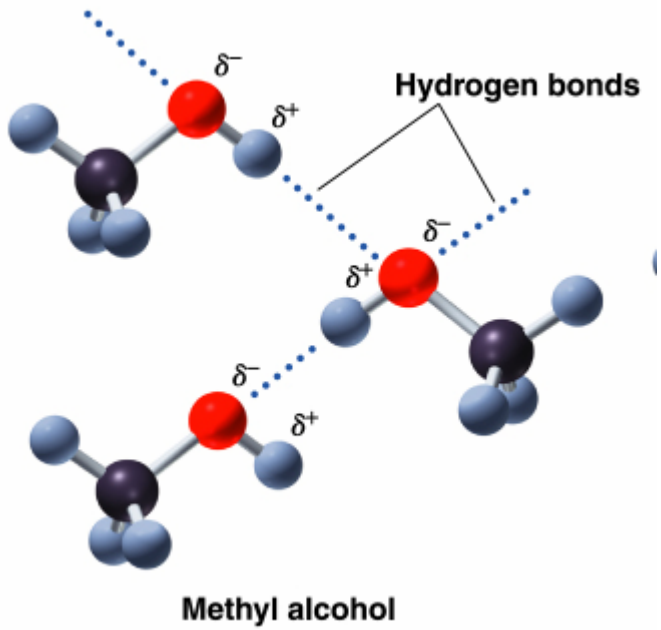
B. Ethyl methyl ether $CH_3—CH_2—O—CH_3$

C. 2-Methyl-1-butanol



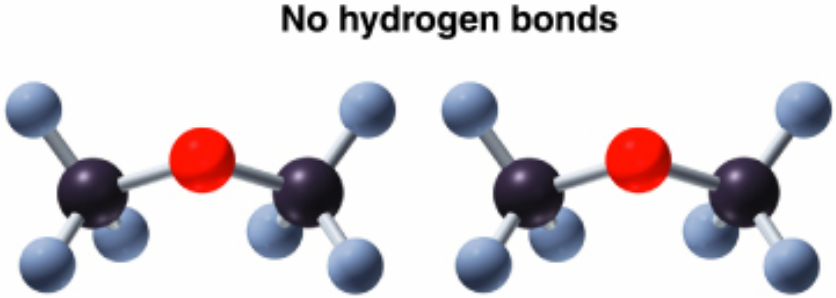
Boiling Points of Alcohols

- Alcohols contain a strongly electronegative O in the OH groups.
- Thus, hydrogen bonds form between alcohol molecules.
- Hydrogen bonds contribute to higher boiling points for alcohols compared to alkanes and ethers of similar mass.



Boiling Points of Ethers

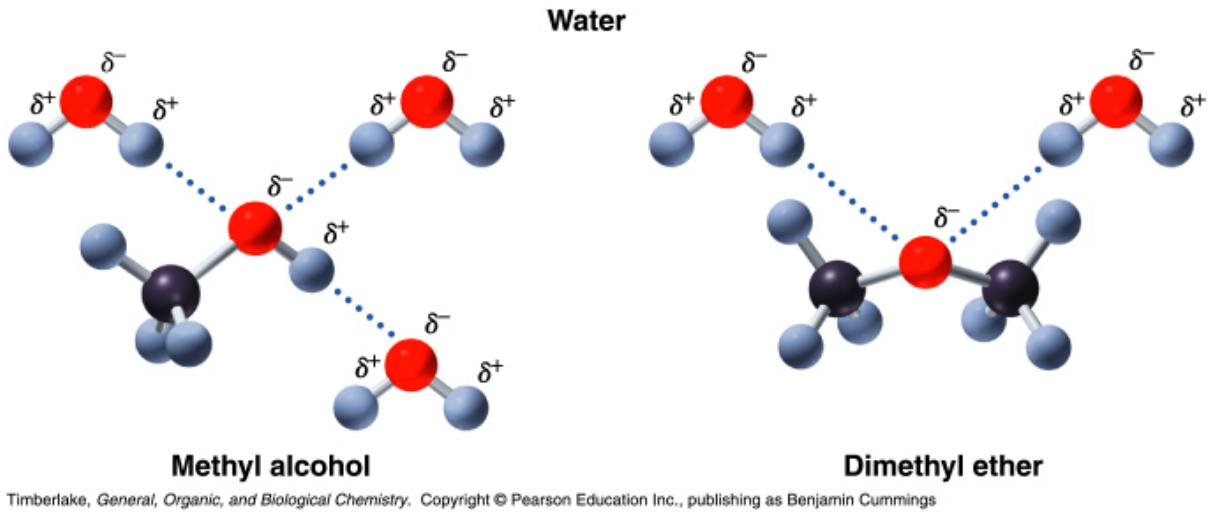
- **Ethers have an O atom, but there is no H attached.**
- **Thus, hydrogen bonds cannot form between ether molecules.**



Dimethyl ether

Solubility of Alcohols and Ethers in Water

- **Alcohols and ethers are more soluble in water than alkanes because the oxygen atom can hydrogen bond with water.**
- **Alcohols with 1-4 C atoms are soluble, but alcohols with 5 or more C atoms are not.**



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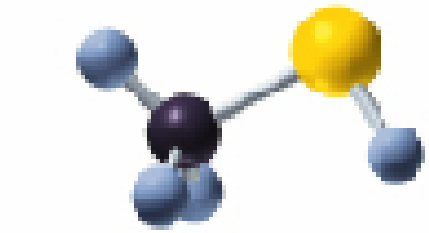
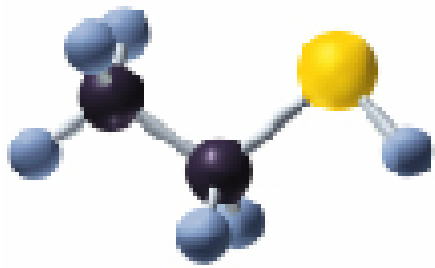
14.9 Thiols

- **Thiols are carbon compounds that contain the –SH group.**

- **In the IUPAC name, *thiol* is added to the alkane name of the longest carbon chain.**



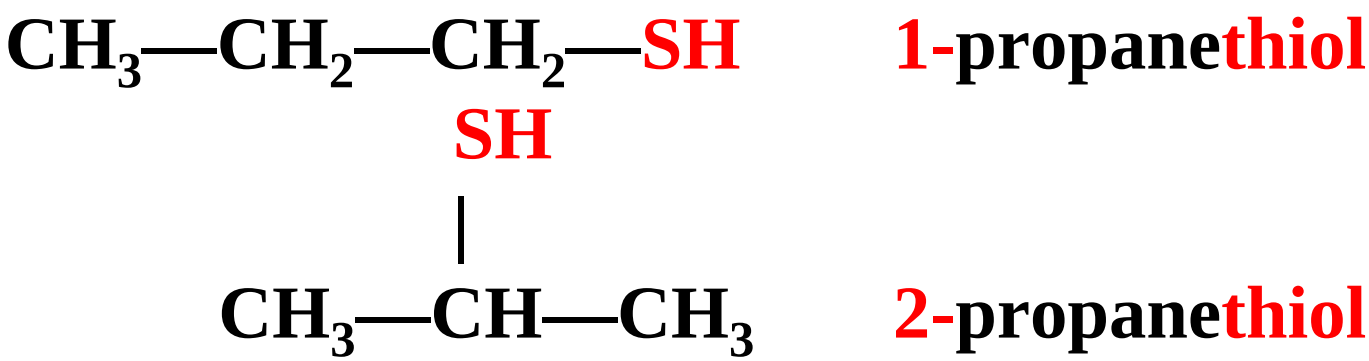
$CH_3—SH$
Methanethiol



$CH_3—CH_2—SH$
Ethanethiol

Naming Thiols

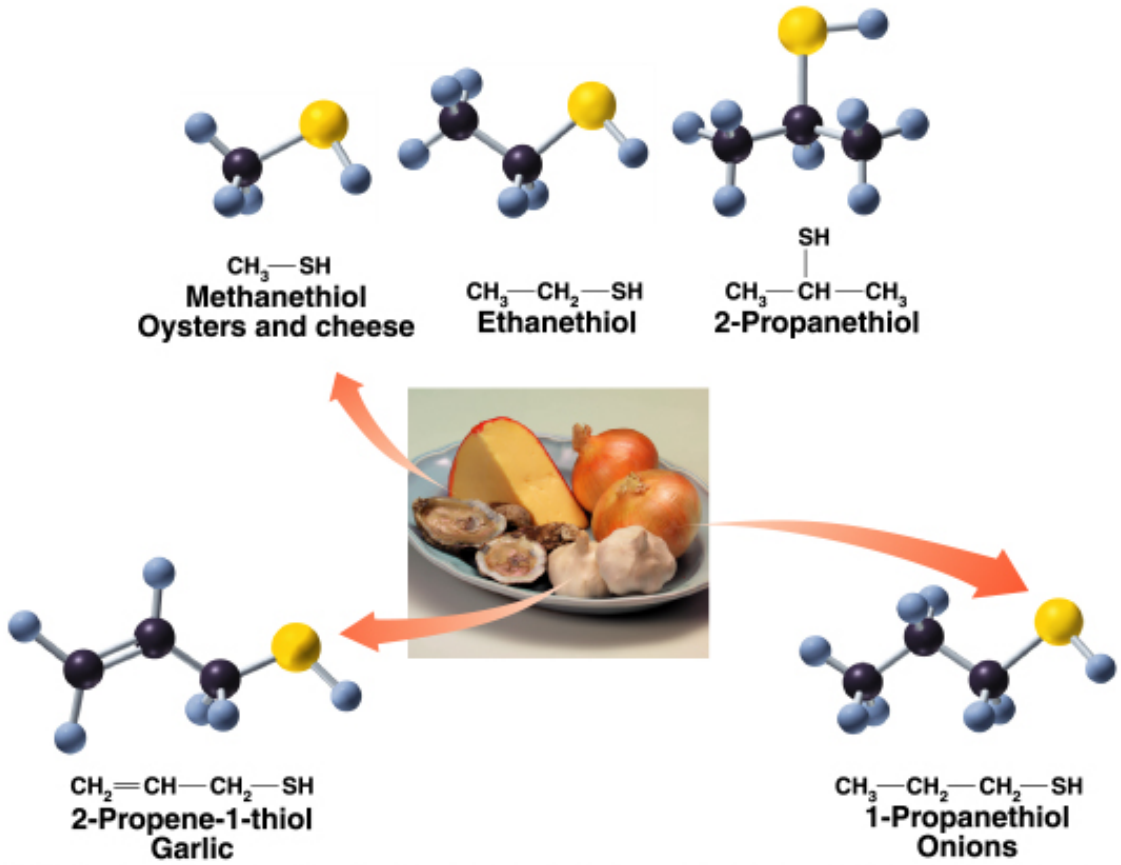
- **In thiols with long carbon chains, the chain is number to locate the -SH group.**



Thiols in Nature

Thiols:

- **Often have strong or disagreeable odors.**
- **Are used to detect gas leaks.**
- **Are found in onions, oysters, and garlic.**



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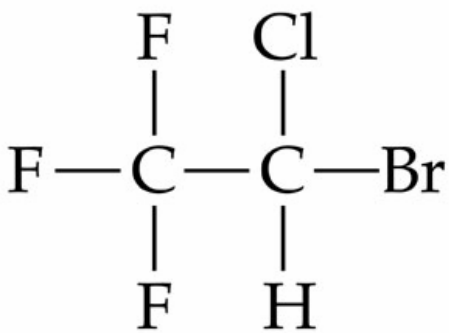
14.10 Halogen Containing Compounds

- Akyl halide (RX): The simplest halogen containing compounds. In alkyl halides, an alkyl group is bonded to a halogen atom.
- The common names of alkyl halides are formed by giving the name of the alkyl group followed by the halogen name with an –ide ending. Examples, CH_3Br – methyl bromide; CH_3CH_2I – Ethyl iodide

- Systematic names are obtained by considering the halogen atom as a substituent on a parent alkane. The parent alkane is named by selecting the longest chain and numbering from the end nearer the first substituent, either halogen or alkyl.

- Halogenated organic compounds are used as
- Anesthesia. For example, halothane is an important anesthetic.



Halothane

- Solvents
- insecticides
- Feed stock in chemical industries

Chapter Summary

- Alcohols has, R-OH, –OH group attached to a saturated alkane-like carbon atom.
- Phenols, Ph-OH, has –OH group attached to an aromatic ring.
- Thiols are sulfur analog of alcohols, R-SH.
- Alkyl halides contain a halogen atom bonded to an alkyl group.
- Alcohols are named using the –ol ending, and phenols are named using the phenol ending.

Chapter Summary Contd.

- Ethers are named by identifying the two organic groups attached to oxygen, followed by the word ether.
- Thiols use the name ending –thiol.
- Alkyl halides are named as halogen substituted alkane.
- Alcohols and phenols are polar, they are capable of participating in hydrogen bonding.

Chapter Summary Contd.

- Solubility of alcohols in water decreases as the size of the organic group increases.
- Ethers do not hydrogen bond, and more like alkane in their properties.
- Alcohols and phenols are weak acids. Alcohols are similar to water in acidity; phenols are more acidic than water.
- Alcohols undergo dehydration reaction (loss of water) to yield alkene when treated with a strong acid.

Chapter Summary Contd.

- Alcohols undergo oxidation reaction to yield carbonyl (C=O) group containing product.
- Oxidation of primary alcohols produce either aldehyde (RCH=O) or carboxylic acid (RCO_2H), depending on the reaction conditions.
- Oxidation of secondary alcohols produce ketones (RCH=O).
- Tertiary alcohols generally does not participate in oxidation reactions.

End of Chapter 14