AlCohols

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Lecture 12

Lecture Goals

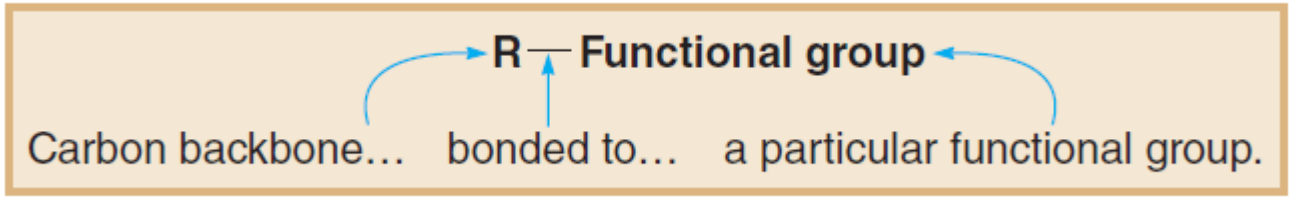
- In this chapter you will learn how to:
- Recognize the common functional groups and understand their importance.
- Identify alcohols, Amines and Carboxylic Acid
- Determine the properties of each functional group

1. Functional Groups

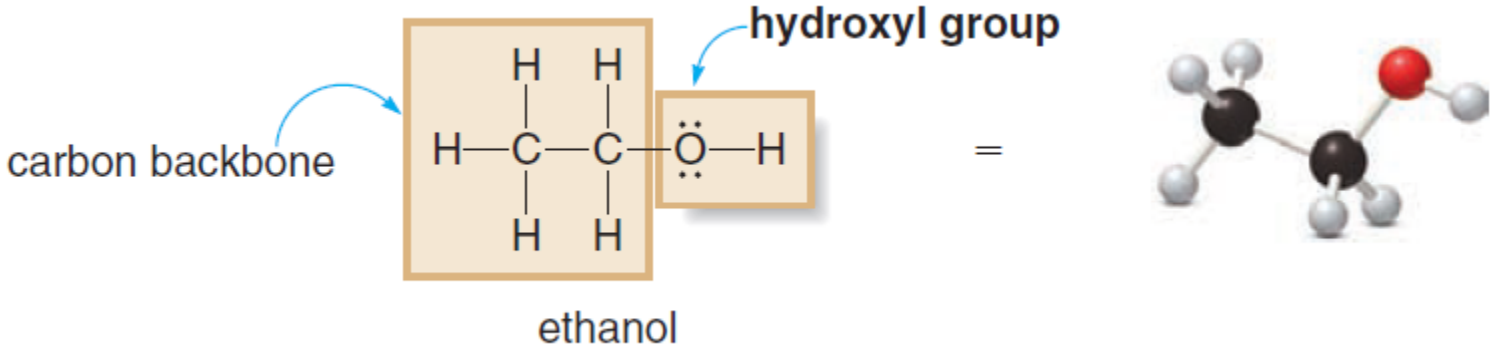
- In addition to strong C-C and C-H bonds, organic molecules may have other structural features as well. Although over 20 million organic compounds are currently known, only a limited number of common structural features, called functional groups, are found in these molecules.

  • A ***functional group*** is an atom or a group of atoms with characteristic chemical and physical properties.
  • A ***functional group*** contains a heteroatom, a multiple bond, or sometimes both a heteroatom *and* a multiple bond.

- A functional group determines a molecule's shape, properties, and the type of reactions it undergoes. A functional group behaves the same whether it is bonded to a carbon backbone.



For Example



The most common functional groups can be subdivided into three types.

- **Hydrocarbons**
- **Compounds containing a single bond to a heteroatom**
- **Compounds containing a C=O group**

Table 10.4 Compounds Containing a Carbon–Heteroatom Single Bond

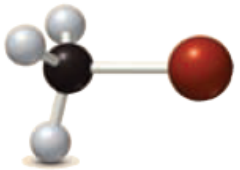
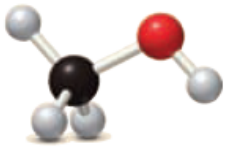
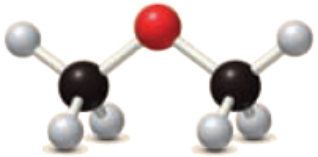
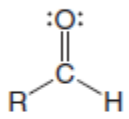
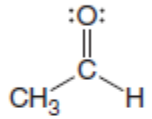
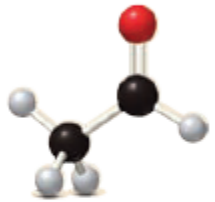
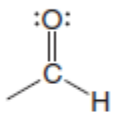
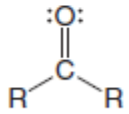
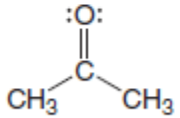
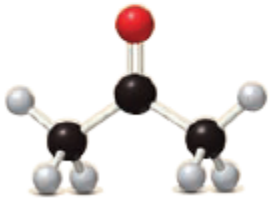
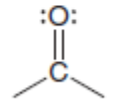
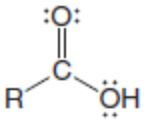
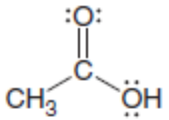
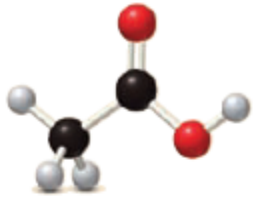
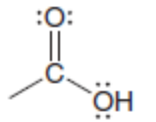
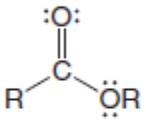
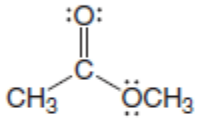
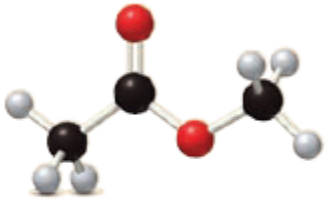
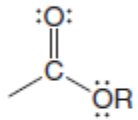
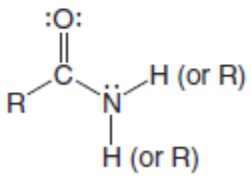
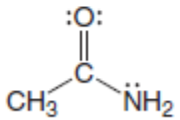
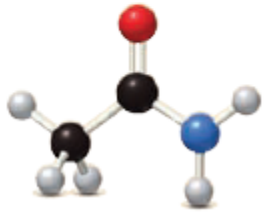
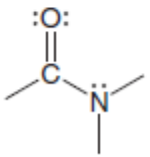
Type of Compound	General Structure	Example	3-D Structure	Functional Group
Alkyl halide	R—$\ddot{X}$: (X = F, Cl, Br, I)	CH_3—$\ddot{Br}$:		–X
Alcohol	R—$\ddot{O}$H	CH_3—$\ddot{O}$H		–OH hydroxyl group
Ether	R—$\ddot{O}$—R	CH_3—$\ddot{O}$—CH_3		–OR
Amine	R—$\ddot{N}H_2$ or $R_2\ddot{N}H$ or $R_3\ddot{N}$	CH_3—$\ddot{N}H_2$		–NH_2 amino group

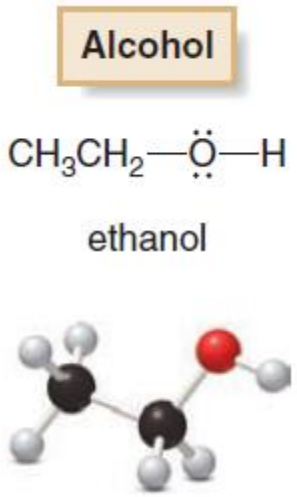
Table 10.5 Compounds Containing a C=O Group

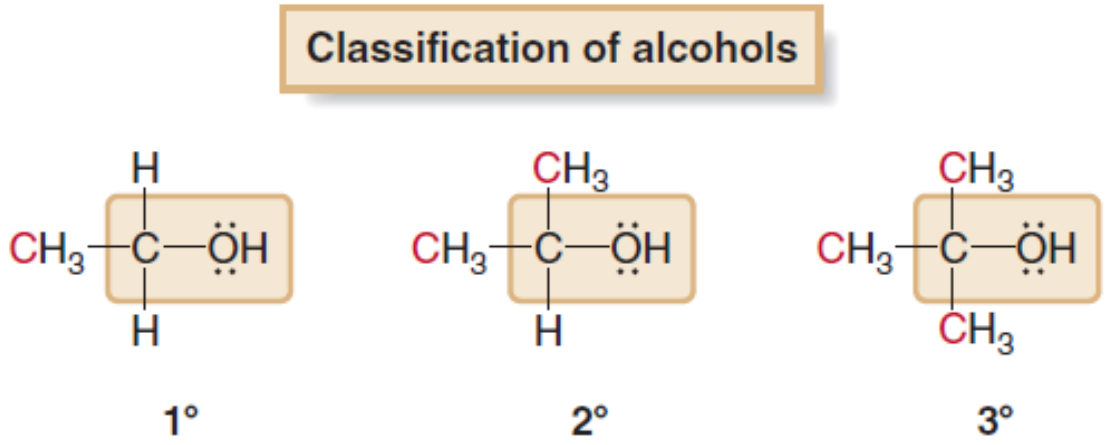
Type of Compound	General Structure	Example	3-D Structure	Functional Group
Aldehyde				
Ketone				
Carboxylic acid				 carboxyl group
Ester				
Amide				

2. Alcohols

- Alcohols contain a hydroxyl group (OH) bonded to carbon.

Alcohols (ROH) are classified as **primary (1°), secondary (2°)**, or **tertiary (3°)** based on the number of carbon atoms bonded to the carbon with the OH group.

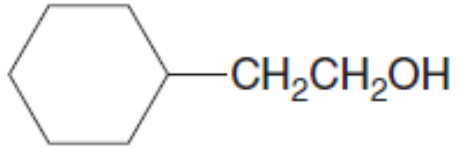


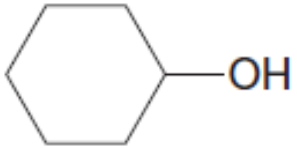


- **A primary (1°)** alcohol has an OH group on a carbon bonded to one carbon.
- **A secondary (2°)** alcohol has an OH group on a carbon bonded to two carbons.
- **A tertiary (3°)** alcohol has an OH group on a carbon bonded to three carbons.

PROBLEM

Classify each alcohol as 1°, 2°, or 3°.

a. 

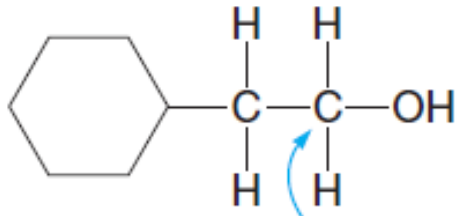
b. 

Analysis

To determine whether an alcohol is 1°, 2°, or 3°, locate the C with the OH group and count the number of C's bonded to it. A 1° alcohol has the OH group on a C bonded to one C, and so forth.

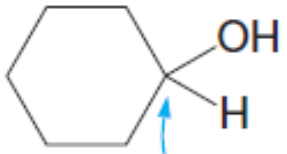
Solution

Draw out the structure or add H's to the skeletal structure to clearly see how many C's are bonded to the C bearing the OH group.

a. 

This C is bonded to 1 C.

1° alcohol

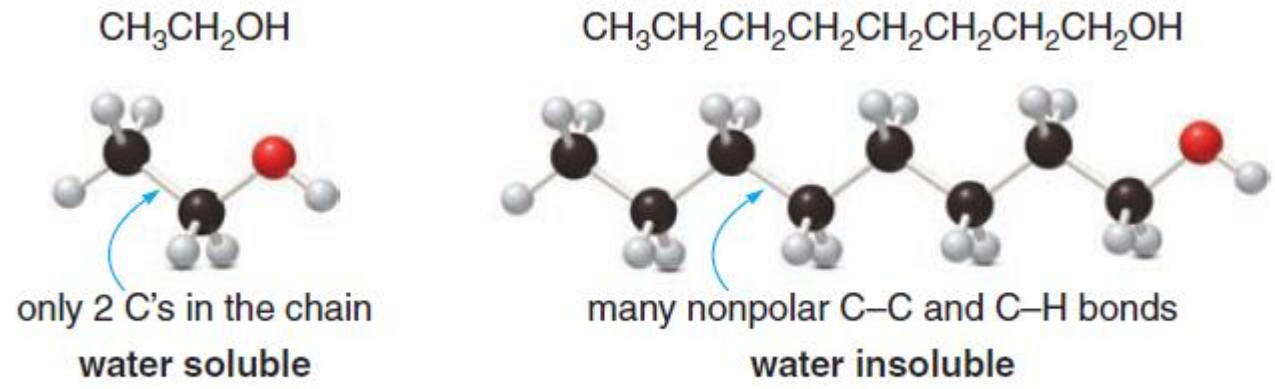
b. 

This C is bonded to 2 C's in the ring.

2° alcohol

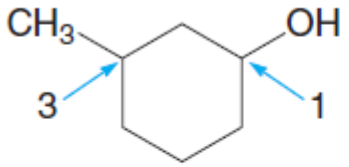
2.1. The Physical Properties of Alcohols

1. An alcohol contains an oxygen atom with a bent shape like H_2O.
2. Alcohols are capable of intermolecular hydrogen bonding.
3. Alcohols have **higher boiling points** and **melting points** than **hydrocarbons** of comparable size and shape.
4. Alcohols are soluble in **organic solvents**.
5. Low molecular weight alcohols (**those having less than six carbons**) are **soluble in water**.
6. Higher molecular weight alcohols (**those having six carbons or more**) are **not soluble in water**.



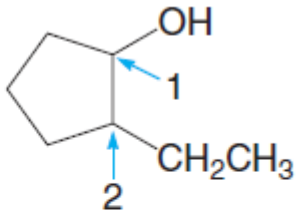
2.2. Nomenclature of Alcohols

- In the IUPAC system, alcohols are identified by the suffix ***-ol***. To name an alcohol:
- Find the longest carbon chain containing the carbon bonded to the OH group.
- Number the carbon chain to give the OH group the lower number, and apply all other rules of nomenclature.
- When an OH group is bonded to a ring, the ring is numbered beginning with the OH group, and the "1" is usually omitted from the name. The ring is then numbered in a clockwise or counterclockwise fashion to give the next substituent the lower number.



3-methylcyclohexanol

[The OH group is at C1; the second substituent (CH_3) gets the lower number.]



2-ethylcyclopentanol

[The OH group is at C1; the second substituent (CH_3CH_2) gets the lower number.]

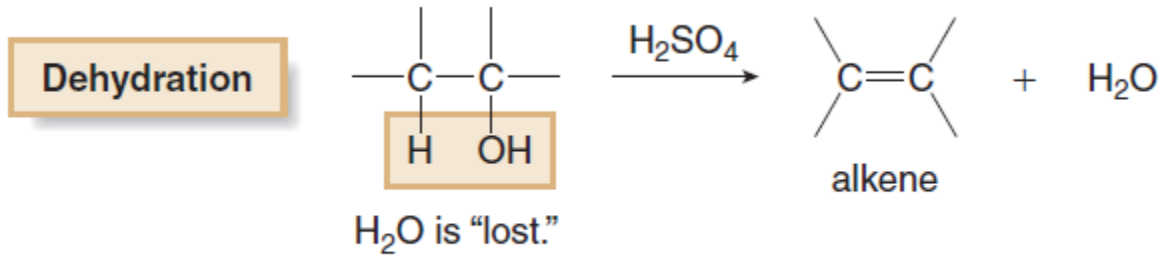
2.3. Reactions of Alcohols

- Alcohols undergo two useful reactions—**dehydration** and **oxidation**.

2.3A. Dehydration:

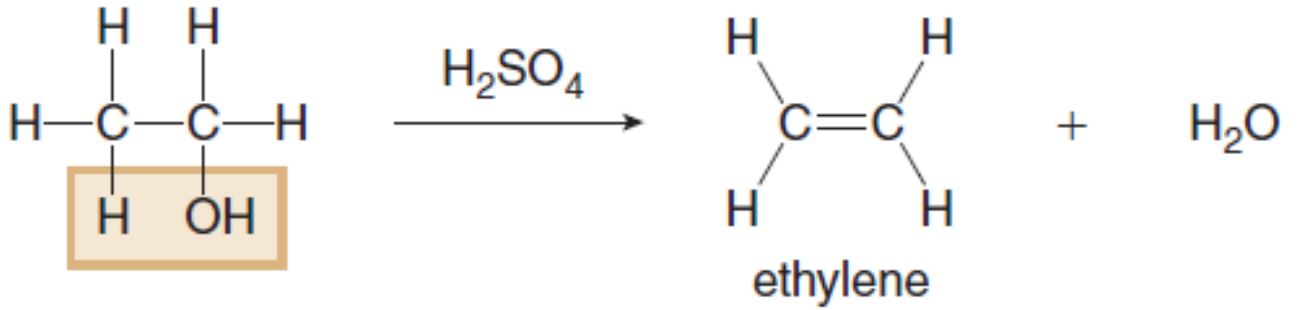
- When an alcohol is treated with a strong acid such as H_2SO_4, the elements of **water** are lost and an **alkene is formed** as product. ***Loss of H_2O from a starting material is called dehydration.***
- Dehydration takes place by breaking bonds on two adjacent atoms—the C-OH bond and an adjacent C-H bond.

Dehydration is an example of a general type of organic reaction called an **elimination reaction.**

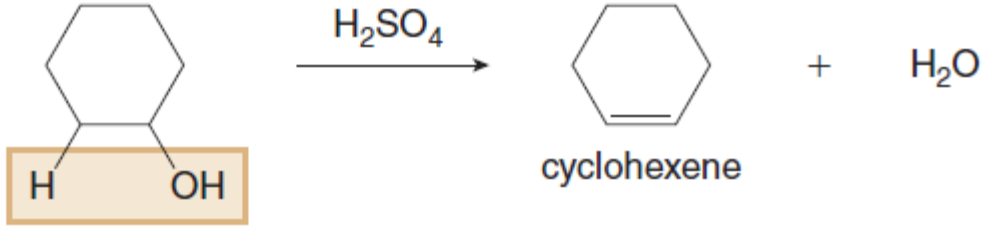


Elimination is a reaction in which elements of the starting material are "lost" and a new multiple bond is formed.

Examples



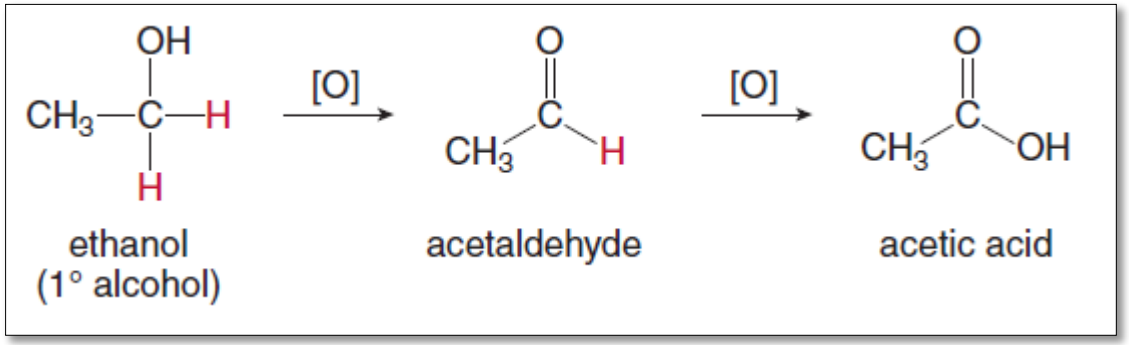
Elimination of H and OH from two adjacent atoms forms cyclohexene.



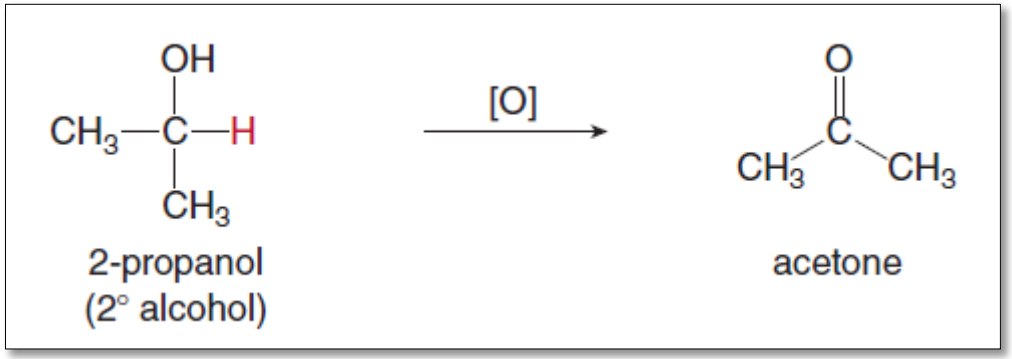
2.3A. Oxidation:

- Alcohols can be oxidized to a variety of compounds, depending on the type of alcohol and the reagent. **Oxidation occurs by replacing the C-H bonds on the carbon bearing the OH group by C-O bonds**. All oxidation products from alcohol starting materials contain a C=O, **a carbonyl group**.

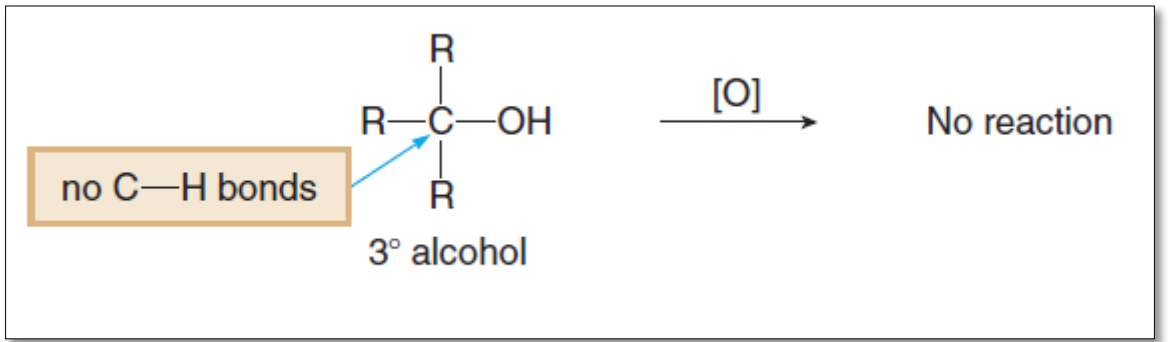
Primary (1°) alcohols are first oxidized to aldehydes (RCHO), which are further oxidized to carboxylic acids (RCOOH) by replacing one and then two C—H bonds by C—O bonds.



Secondary (2°) alcohols are oxidized to ketones (R_2CO), by replacing one C—H bond by one C—O bond.

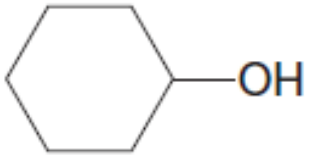


Tertiary (3°) alcohols have no H atoms on the carbon with the OH group, so they are not oxidized.



PROBLEM

Draw the carbonyl products formed when each alcohol is oxidized.

a. 

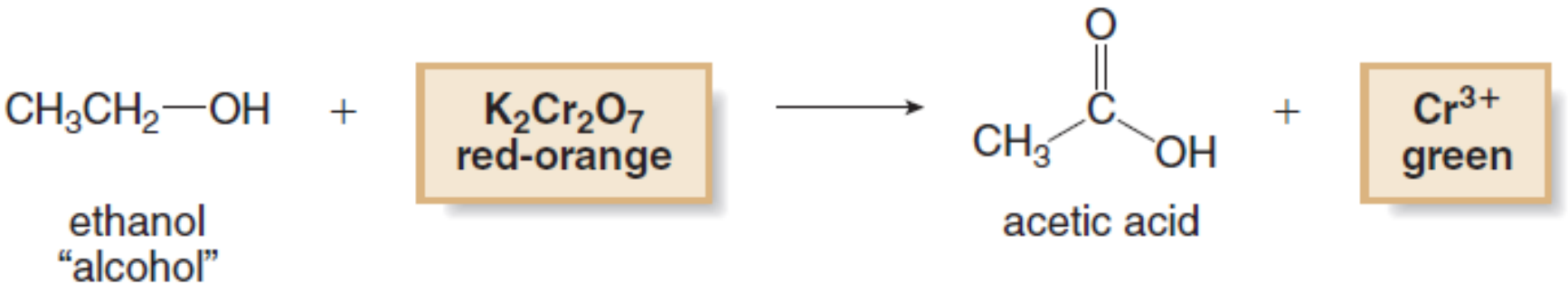
cyclohexanol

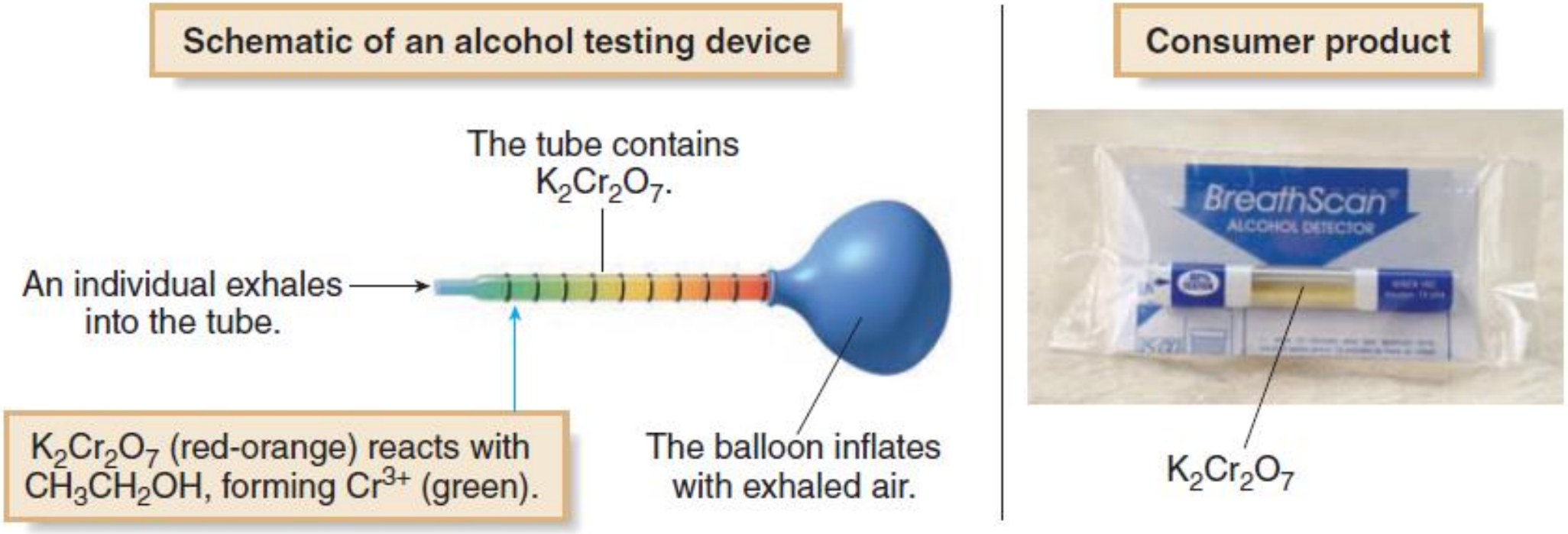
b. $CH_3CH_2CH_2CH_2OH$

1-butanol

2.4. Oxidation and Blood Alcohol Screening

- A common reagent for alcohol oxidation is potassium dichromate, $K_2Cr_2O_7$, a **red-orange** solid.
- Oxidation with this chromium reagent is characterized by a color change, as the **red-orange reagent** is reduced to a **green Cr^{3+}** product. The first devices used to measure blood alcohol content in individuals suspected of "driving under the influence," made use of this color change.
- Oxidation of CH_3CH_2OH, the 1° alcohol in alcoholic beverages, with red-orange $K_2Cr_2O_7$ forms CH_3COOH and green Cr^{3+} .



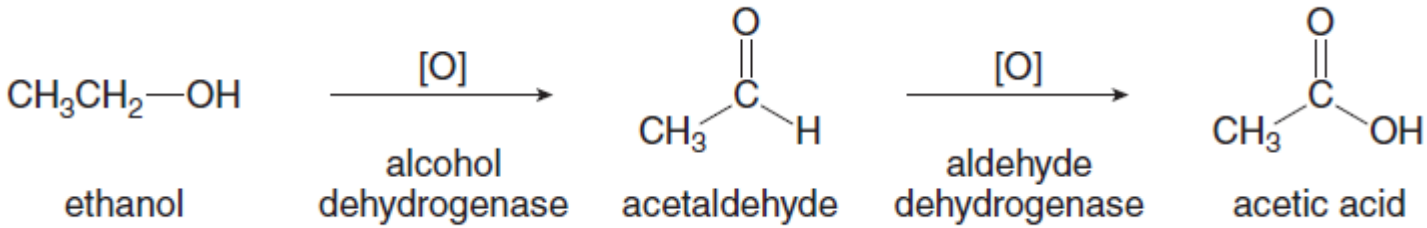


- The oxidation of CH_3CH_2OH with $K_2Cr_2O_7$ to form CH_3COOH and Cr^{3+} was the first available method for the routine testing of alcohol concentration in exhaled air. Some consumer products for alcohol screening are still based on this technology.
- A driver is considered "under the influence" in most states with a blood alcohol concentration of 0.08%.

2.5. The Metabolism of Ethanol

(FOCUS ON HEALTH & MEDICINE)

- When ethanol is consumed, it is quickly absorbed in the **stomach** and **small intestines** and then rapidly transported in the **bloodstream** to other organs.
- Ethanol is metabolized in the **liver**, by a two-step oxidation sequence. ***The body does not use chromium reagents as oxidants***. Instead, high molecular weight enzymes, **alcohol dehydrogenase** and **aldehyde dehydrogenase**, and a small molecule called a **coenzyme** carry out these oxidations.



- If more ethanol is ingested than can be metabolized in a given time period, the concentration of acetaldehyde accumulates. This toxic compound is responsible for the feelings associated with a hangover.