Pre-Health Post-Baccalaureate Program Study Guide and Practice Problems

Course: CHM2046

Textbook Chapter: 15 (Silberberg 6e)

Topics Covered: Introduction to Organic Chemistry

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1. What's so special about carbon?

As you will see in this chapter and for the next two semesters, organic chemistry is built around carbon. In the case of carbon, form follows function, and its chemical diversity arrives from the many structures that it can take.

Carbon has four more valence electrons than helium and four fewer valence electrons than neon. Being right in the middle means that gaining or losing four electrons to form ions is incredibly unlikely due to carbon's extreme ground-state stability.

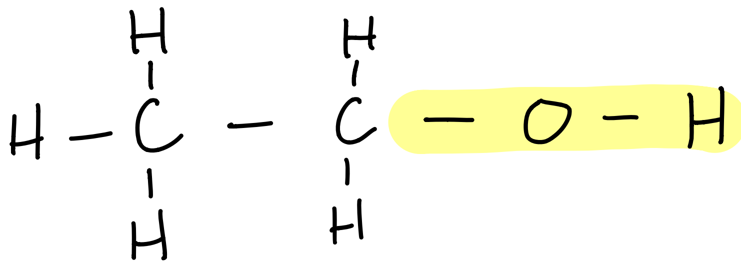
Carbon has four valence electrons and can form single, double, and triple bonds - usually to other carbon atoms and non-metals. Carbon is small, and forms very strong, stable (unreactive) bonds with other carbon atoms. Carbon forms non-polar and relatively stable bonds with hydrogen. When carbon bonds with oxygen, however, the larger electronegativity difference makes the bond polar. Recall that a polar bond indicates that the two electrons that make up the covalent bond are unevenly shared between the two atoms. Because oxygen "hogs" the electrons, the bond is unstable and therefore quite reactive.

2. Functional Groups

A functional group is a specific sequence of atoms that commonly exists in organic molecules, that has certain chemical characteristics. In organic reactions, the “action” usually takes place at the functional group.

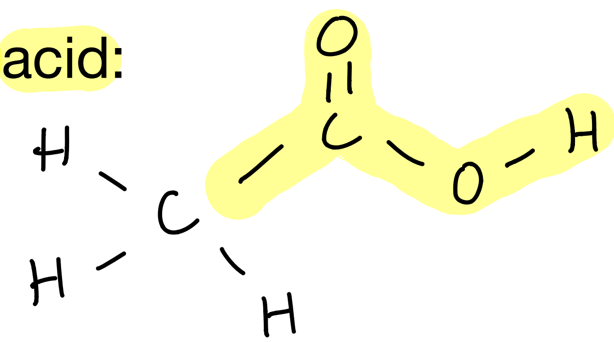
Take a look at the following examples of functional groups:

Alcohol:



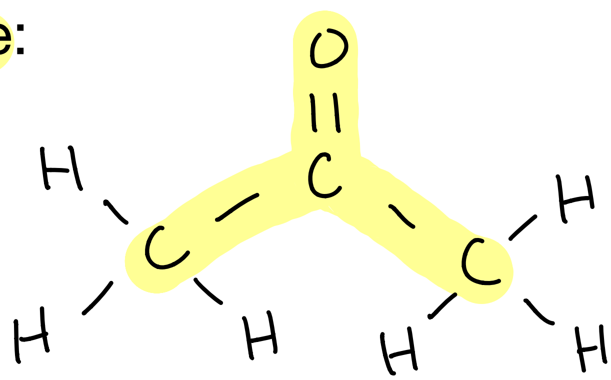
Ethanol (alcohol present in beverages)

Carboxylic acid:



Acetic acid (vinegar)

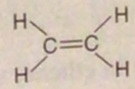
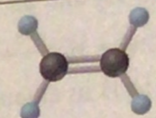
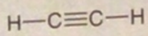
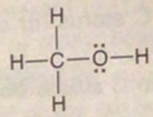
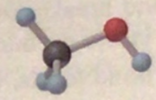
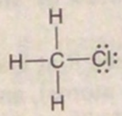
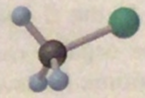
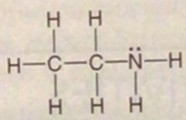
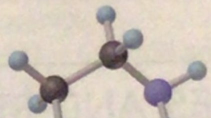
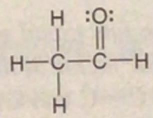
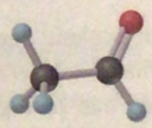
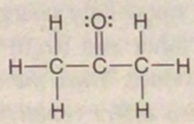
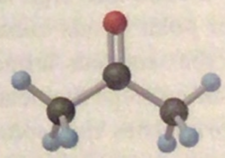
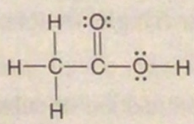
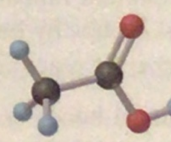
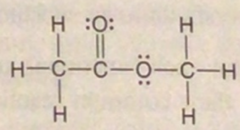
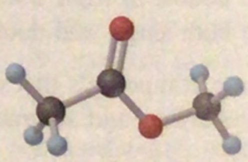
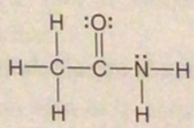
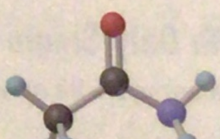
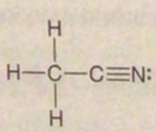
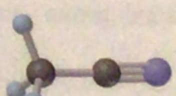
Ketone:



Acetone (nail polish remover)

See the photo on the next page for a chart of the major functional groups:

Table 15.5 Important Functional Groups in Organic Compounds

Functional Group	Compound Type	Prefix or Suffix of Name	Example: Lewis Structure	Example: Ball-and-Stick Model	Example: Systematic Name (Common Name)
C=C	alkene	-ene			ethene (ethylene)
—C≡C—	alkyne	-yne			ethyne (acetylene)
—C—Ö—H	alcohol	-ol			methanol (methyl alcohol)
—C—X: (X = halogen)	haloalkane	halo-			chloromethane (methyl chloride)
—C—N—	amine	-amine			ethanamine (ethylamine)
:O: ‖ —C—H	aldehyde	-al			ethanal (acetaldehyde)
:O: ‖ —C—C—C—	ketone	-one			2-propanone (acetone)
:O: ‖ —C—Ö—H	carboxylic acid	-oic acid			ethanoic acid (acetic acid)
:O: ‖ —C—Ö—C—	ester	-oate			methyl ethanoate (methyl acetate)
:O: ‖ —C—N—	amide	-amide			ethanamide (acetamide)
—C≡N:	nitrile	-nitrile			ethanenitrile (acetonitrile, methyl cyanide)

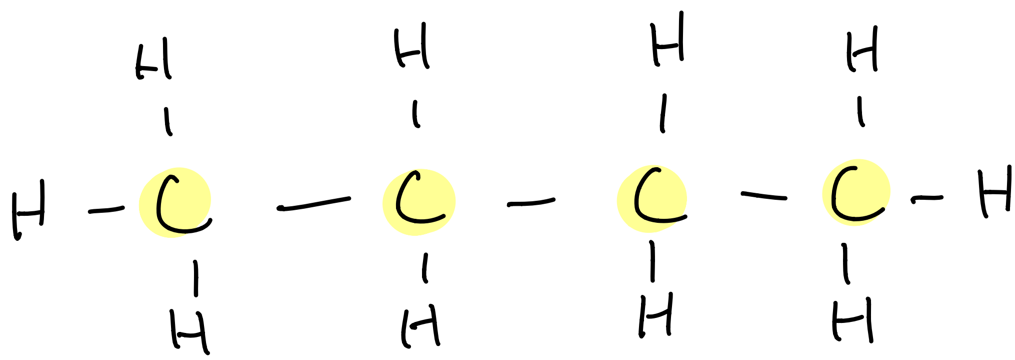
3. Hydrocarbons

Hydrocarbons are very simple organic molecules, made up of, you guessed it, carbon and hydrogen atoms.

A hydrocarbon can be represented in several ways. We will look at butane as an example:

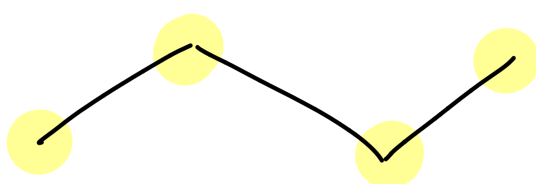
Formula: C_4H_{10}

Expanded:



Condensed: $H_3C-CH_2-CH_2-CH_3$

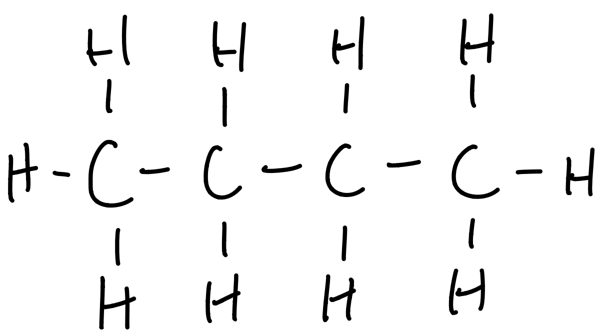
Carbon-skeleton (line-angle):



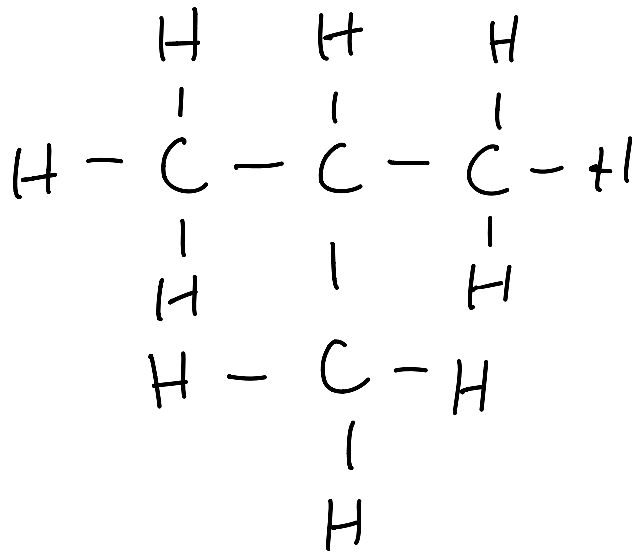
4. Isomerism

Constitutional (or structural) isomers have the same chemical formulas but different structures:

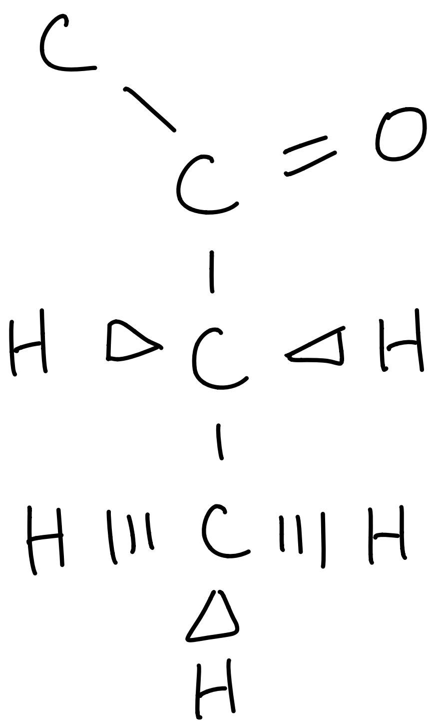
C_4H_{10}

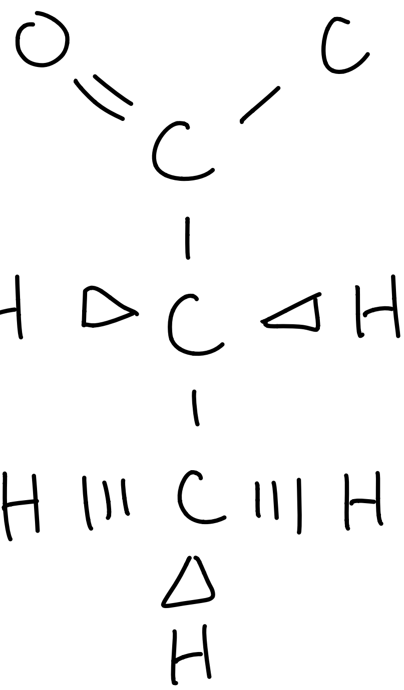


C_4H_{10}



Stereoisomers have the same structures but different orientations in space:





The above molecules have a chiral center, are mirror images, and cannot be superimposed onto one another, therefore we can say that the molecules are chiral. Think about chirality as a left and right hand pair of molecules. We can say that chiral molecules are “optically active” because they can rotate the plane of polarized light.

5. Nomenclature

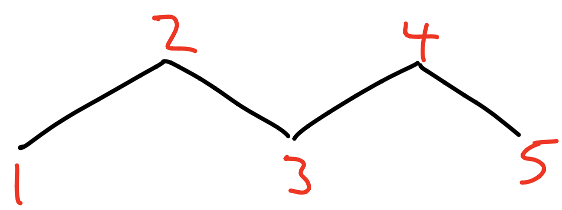
We name hydrocarbons based upon the number of carbons in the molecule's longest chain and the types of bonds (functional groups) present.

Number of carbons:	Root:
1	meth
2	eth
3	prop
4	but
5	pent
6	hex
7	hept
8	oct
9	non
10	dec

Type of bond:	Suffix:
All single	ane
Double	ene
Triple	yne

Examples:

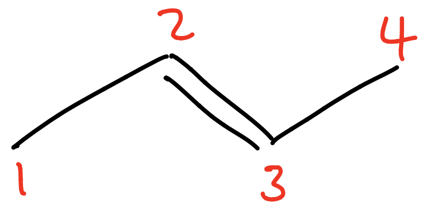
Pentane:
↳ 5 ↳ single bonds only



2-Butene:

↳ 4

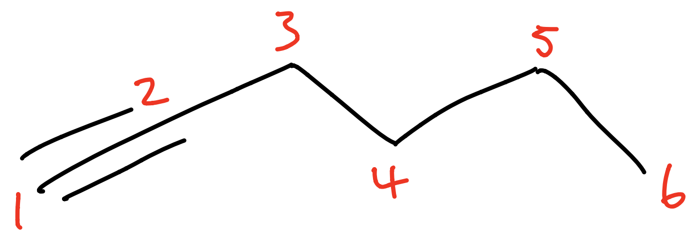
↳ double bond @ C2



1-Hexyne:

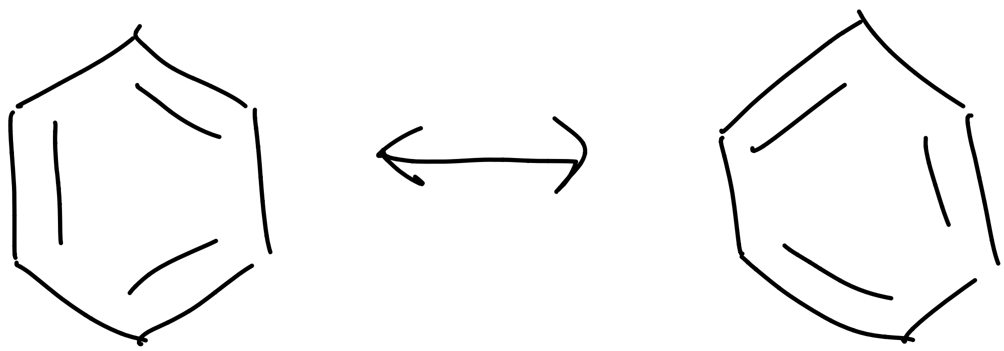
↳ 6

↳ triple bond @ C1

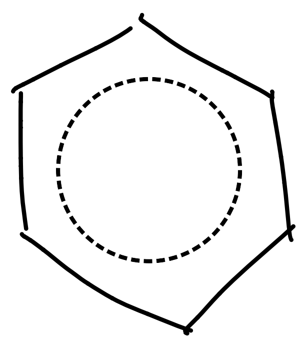


6. Aromatic hydrocarbons

To best understand aromatic hydrocarbons, we should look at a molecule called benzene. Benzene is a six-carbon ring with three double bonds. The two resonance structures are shown below:



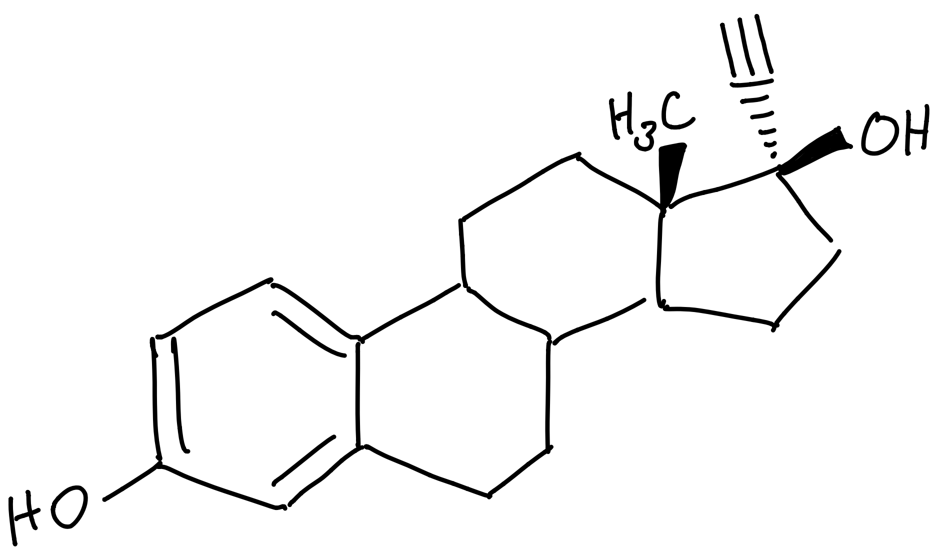
However, it is wrong to think that a double bond actually exists between any two carbons. Instead, all of the pi electrons are delocalized around all carbons in the molecule:



Problems

The line angle structure of Ethinyl estradiol (the birth control pill) is shown below.

a. What is the molecular formula?
b. How many lone pairs are present?
c. How many atoms are sp2 hybridized?
d. Which functional groups are present?



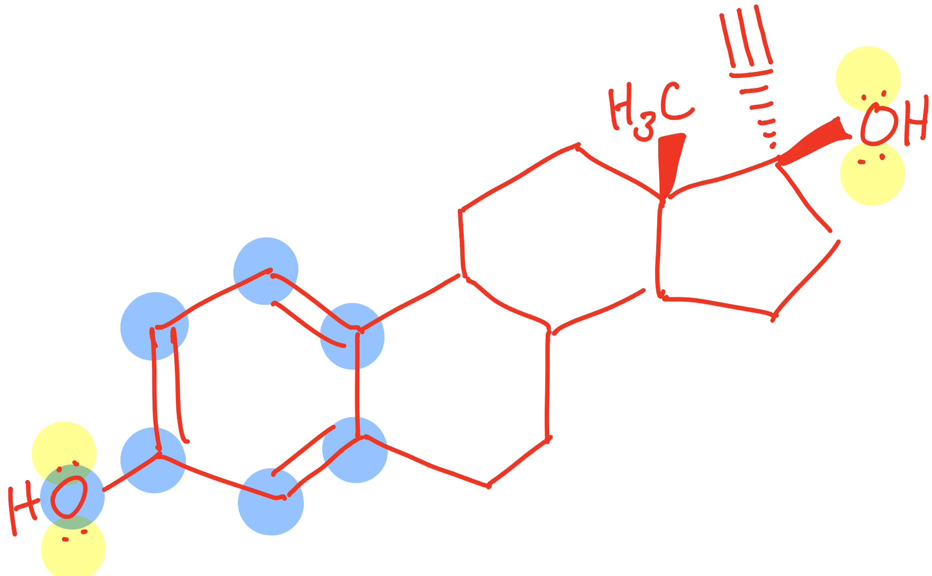
The line angle structure of Ethinyl estradiol (the birth control pill) is shown below.

a. What is the molecular formula? $C_{20}H_{24}O_2$

b. How many lone pairs are present? 4

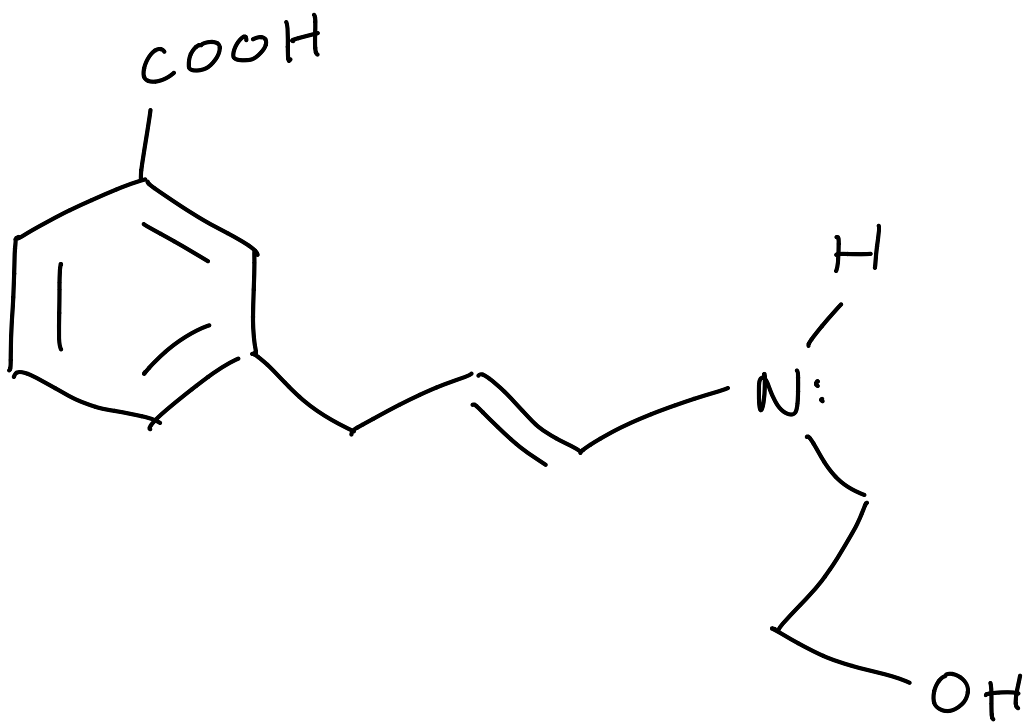
c. How many atoms are sp2 hybridized? 7

d. Which functional groups are present? alcohol x2
alkyne
benzene ring



Which of the following functional groups is not present in the molecule below?

A) amine
B) amide
C) carboxylic acid
D) alkene



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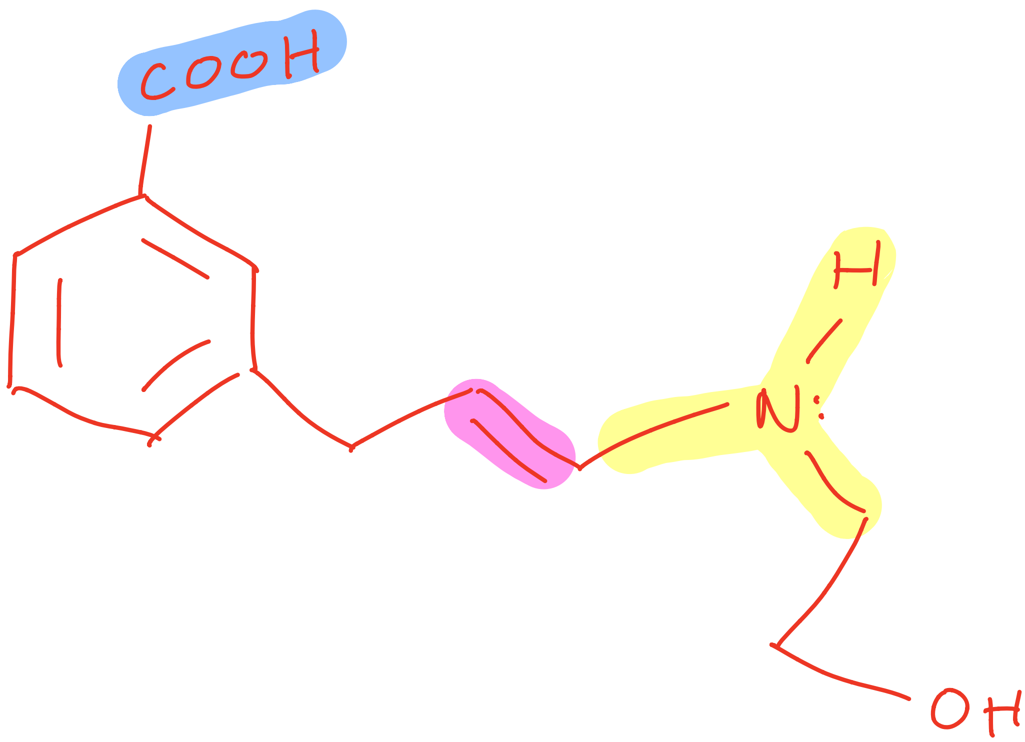

In your own words: what makes carboxylic acids fairly acidic?

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Resonance...

Something is acidic if it easily gives up a proton. When will a chemical species likely give up a proton? When it is stable upon deprotonation. Due to resonance, CAs are very stable when they give up their proton.