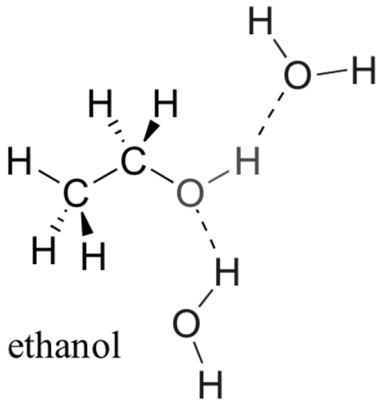
Organic Chemistry – Alcohols, Carboxylic Acids, Esters, Ethers, Ketones & Aldehydes

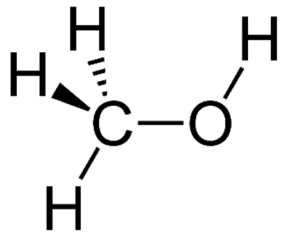
1. An **alcohol** is an organic molecule where a hydrocarbon has a **hydroxyl functional group** (-OH) attached. The **C-H bonds in hydrocarbons are non-polar**, but the **O-H bond is polar**, just like in water.

   The diagram below shows two water molecules **hydrating** an ethanol molecule.

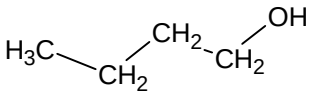


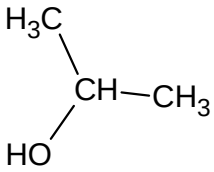
   a. Label the **partial charges** (δ+ and δ-) in the water molecules and the alcohol molecule above to explain the attractive forces between them.

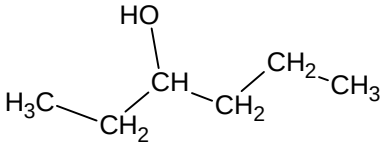
   b. Draw two water molecules showing the **hydration** of the methanol molecule below when it is dissolved in water.

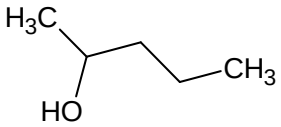


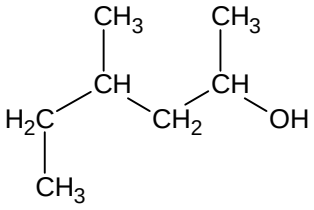
2. Give the IUPAC name for each **alcohol** below.

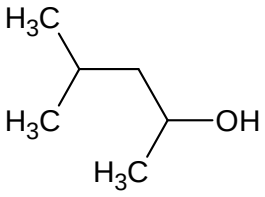
a. 

b. 

c. 

d. 

e. 

f. 

3. Draw each of the following **alcohols** using either a **bond-line formula** or a **condensed molecular formula**.

   a. 2-butanol

   b. 3-methyl-1-hexanol

   c. 2,2-dimethyl-3-octanol

   d. 4-ethyl-3-methyl-3-decanol

   e. 2,4-dimethyl-3-pentanol

   f. 3-chloro-2-methyl-2-heptanol

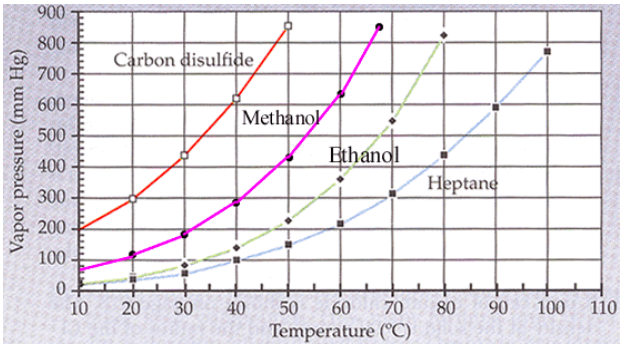
4. All **alcohols** are toxic, however humans have evolved the ability to digest small amounts of ethanol. Ethanol is the alcohol that is present an any alcoholic beverage. The **density** of pure ethanol is 0.789 g/mL.

   a. Draw a condensed molecular formula for ethanol.

   b. How many **molecules** of ethanol are present in a 10.0-mL sample?

   c. A student needs 0.200 mol of ethanol for an experiment. What **volume** (in mL) should she use?

5. Calculate the **percent oxygen** by mass in 2-pentanol.



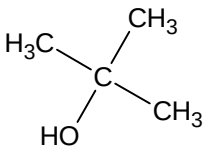
6. The vapor curves for four substances are shown above.
   a. Give the **molecular formula** for each of these compounds:
      i. Methanol
      ii. Ethanol
      iii. Heptane
   b. From the graph, estimate the **normal boiling point** for:
      i. Methanol
      ii. Ethanol
      iii. Heptane

7. **Alcohols** are highly flammable. How many moles of carbon dioxide would be produced by the combustion of 25.0 g of rubbing alcohol (2-propanol)?

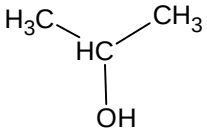
8. **Alcohols** are commonly used as **solvents**. They are less **polar** than water. The larger the **hydrocarbon chain**, the less polar the molecule will be.

   Many of these alcohol solvents have commonly used older names. For each alcohol below, give its proper **IUPAC name**.

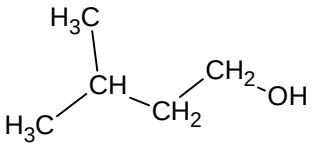
   a. Tert-butyl alcohol



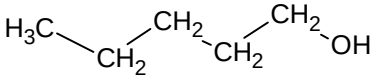
   b. Isopropyl alcohol



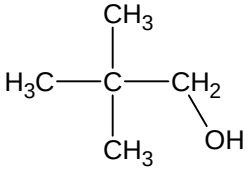
   c. Isopentyl alcohol



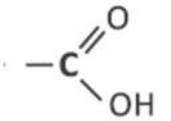
   d. Amyl alcohol



   e. Neopentyl alcohol

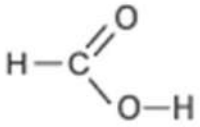


9. **Organic acids** have a **carboxyl functional group**. The acids are called **carboxylic acids**. Their names are based on the names of the parent chains, with the endings changed to "**-oic acid**".

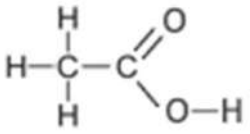


Carboxyl Group

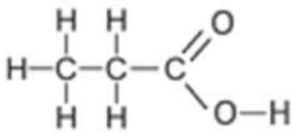
   a. The simplest example has only one carbon atom and used to be called **formic acid**, from the Latin for "ant". This acid is used as a defense mechanism by fire ants. What is its correct IUPAC name?



   b. The next is an acid with two carbon atoms. Its common name is **acetic acid**, from the Latin for "vinegar". White vinegar is a 5% solution of this acid. What is its correct IUPAC name?

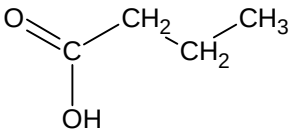


   c. The third carboxylic acid was once called **propionic acid**, from the Latin meaning "first fat". It got this name because it was the first carboxylic acid to share some properties with much larger "fatty acids". What is its correct IUPAC name?

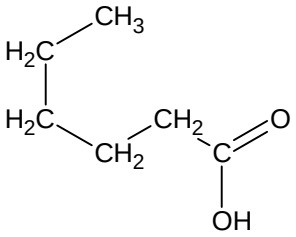


10. Give the **IUPAC name** for each of the following **carboxylic acids**.

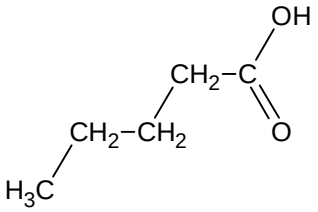
a.



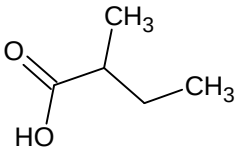
b.



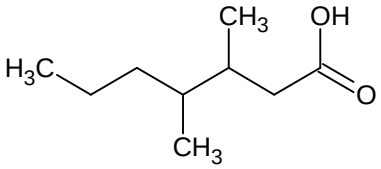
c.



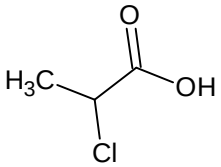
d.



e.



f.



11. Draw a **bond-line formula** for each of the following **carboxylic acids**.

a. 3-methylbutanoic acid

b. 2,3-dichloroheptanoic acid

c. 3-ethylpentanoic acid

d. 2-bromopropanoic acid

e. 2,3.4-trimethylhexanoic acid

f. 3-ethyl-6-propyldecanoic acid

12. Carboxylic acids, like any other acid, can be neutralized by a reaction with a base. A student decided to neutralize a 5.0-g sample of propanoic acid using sodium hydroxide. What **mass** of NaOH will be needed?

$C_2H_5COOH + NaOH \rightarrow NaC_2H_5COO + H_2O$

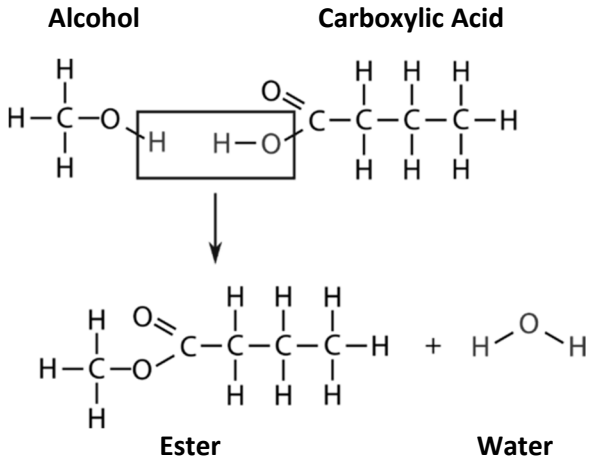
13. Carboxylic acids will react with sodium bicarbonate and produce carbon dioxide gas. The most common example of this is adding baking soda to vinegar. If an excess of sodium bicarbonate is added to 10.0 g of butanoic acid, **what volume of CO_2 will be produced**, measured at 20°C and 96.5 kPa?

$+ NaHCO_3 \rightarrow NaC_3H_7COO + CO_2 + H_2O$

Butanoic acid

14. What is the percent by mass of oxygen in hexanoic acid?

15. An **ester** is the product of the reaction between an **alcohol** and a **carboxylic** acid. The reaction is called an **esterification reaction**.



In the reaction, the **H** in the **alcohol hydroxyl group** combines with the **OH** in the **acid carboxyl group** to make **water**. Then the remainder of the alcohol attaches to the carboxylic acid to create the **ester** as shown above.

In the example above, give the names of …

The alcohol:

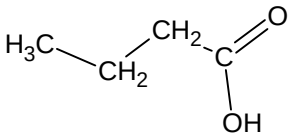
The carboxylic acid:

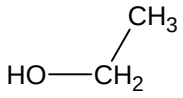
The ester:

16. Consider the **esterification reaction** shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the **IUPAC name** and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol



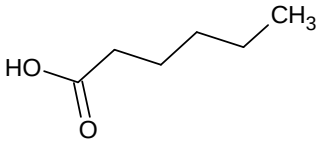


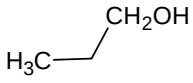
Ester

17. Consider the **esterification** reaction shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the **IUPAC name** and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol



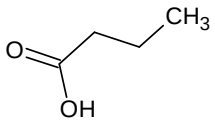


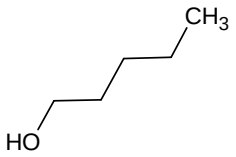
Ester

18. Consider the **esterification** reaction shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the **IUPAC name** and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol



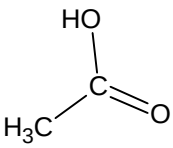


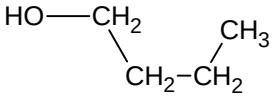
Ester

19. Consider the **esterification** reaction shown below. Write the names of the **carboxylic acid** and the **alcohol** being used. Then write the name and draw the **condensed molecular formula** for the **ester** that would form.

Carboxylic Acid

Alcohol





Ester

20. **Esters** are famous for their **smells** and **flavors**. They are found naturally in many fruits, vegetables and flowers and are added to many processed foods as **artificial flavors** and to **perfumes** for their odours. For each ester below, draw its structure and then give the name of both the **alcohol** and **carboxylic acid** that would be used to create the ester.

Methyl Ethanoate – Pineapple Flavor

Alcohol | Carboxylic Acid

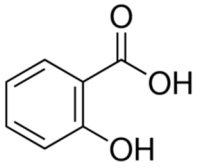
Butyl Methanoate – Raspberry Flavor

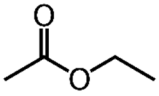
Alcohol | Carboxylic Acid

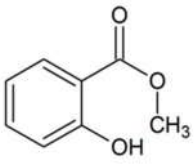
Ethyl Octanoate – Apple Flavor

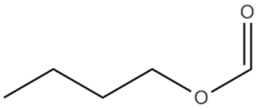
Alcohol | Carboxylic Acid

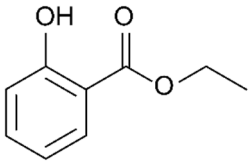
21. Give the IUPAC name for each **ester** below. Some are made using **salicylic acid**:

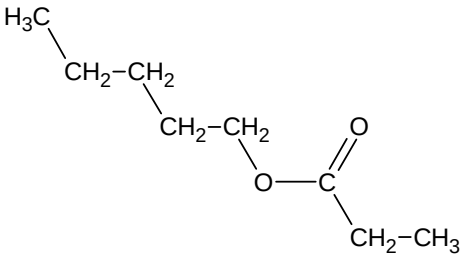


a. 

b. 

c. 

d. 

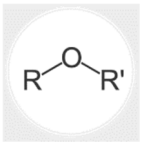
e. 

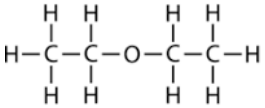
22. Methyl ethanoate is a very **volatile** – its **boiling point** is only 57°C. What **volume** would a 50.0-g sample of methyl acetate vapour occupy at 200.°C and 105 kPa?

23. Ethyl hexanoate is an oily liquid at room temperature, with a pleasant pineapple smell. It is the product of ethanol reacting with hexanoic acid. What **mass** of ethanol is required to make 10.0 g of ethyl hexanoate?

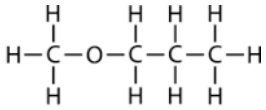
24. What is the percent oxygen by mass in butyl pentanoate?

25. An **ether** is an organic molecule where two hydrocarbon branches are bonded to the same oxygen atom.





diethyl ether



methyl propyl ether

In the example on the left above, the two hydrocarbon branches are identical – they are both 2-carbon "ethyl" branches. So this ether's IUPAC name is **diethyl ether**.

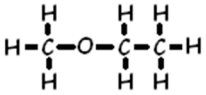
In the example on the right above, there is a methyl branch and a propyl branch. In this case, the branches are named alphabetically, and the molecule's IUPAC name is **methyl propyl ether**.

Diethyl ether was one of the first general anesthetics used in medicine.
In the 21st century, flammable ether has been replaced by safer substances which do not pose flammability hazards.

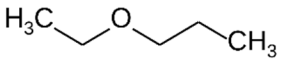
26. **Dimethyl ether** and **ethanol** have the same molecular formula. Dimethyl ether boils at -24°C while ethanol boils at 78°C. Draw the two molecules and explain the difference in their **boiling points** by describing the **intermolecular forces** involved.

27. Give the **IUPAC name** and the **molecular formula** for each **ether** below.

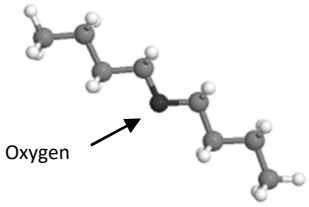
a.



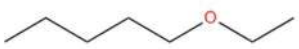
b.



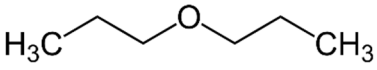
c.



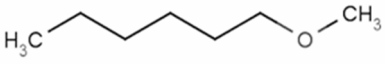
d.



e.



f.



28. Write a balanced chemical equation for the **combustion** of **butyl methyl ether**.

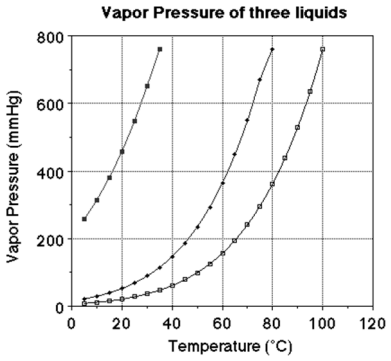
29. An ether is found to be 59.94% C, 13.44% H and 26.62% O by mass.
    a. Determine the **empirical formula** of the ether.

    b. When 1.00 g of the ether was dissolved in 10.0 mL of phenol, the resulting solution froze at 29.20°C. Pure phenol has a density of 1.07 g/mL and boils at 40.50°C. Phenol's freezing point depression constant is 7.27 °C mol/kg. Determine the **molar mass** of the ether.

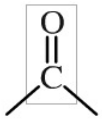
    c. What is the **molecular formula** for the ether? Draw and name **two** possible ethers with this formula.

30. A student needs to dissolve **dipentyl ether**. Which **solvent** would you recommend – water or cyclohexane? Sketch each molecule. Explain your choice referring to IMF's in all three substances.

31. The graph below shows the vapor pressure curves for water, ethanol and diethyl ether. Estimate the **normal boiling point** of the **diethyl ether** based on the graph.



32. **Ketones** and **aldehydes** are organic molecules with a **carbonyl functional group**.

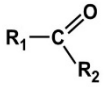


In an **aldehyde**, the carbonyl group is **terminal** – it includes a carbon at the end of a carbon chain.

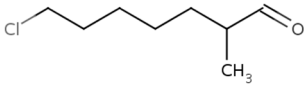
Carbonyl Group, Aldehyde

Carbonyl Group, Ketone

In a **ketone**, the carbonyl group includes a carbon that is **not terminal** within a carbon chain.

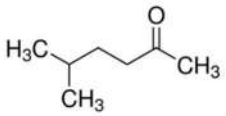


When naming **aldehydes**, the carbon in the carbonyl group is carbon #1 in the parent chain. The parent chain's name has the suffix "-**al**" added to it.



So the IUPAC name for the aldehyde shown above is **7-chloro-2-methylheptanal**.

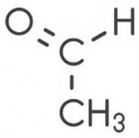
For **ketones**, start numbering the parent chain from the end closest to the carbonyl group. Then add the suffix "-**one**" to the parent chain's name.



So the correct IUPAC name for the ketone shown above is **5-methylhexan-2-one**.

33. **Formaldehyde** is an old name for an **aldehyde** with one carbon atom. Give its correct IUPAC name and draw its **structural formula**.

34. An important aldehyde in biochemistry is still known by its older name, acetaldehyde. Give its proper IUPAC name.



acetaldehyde

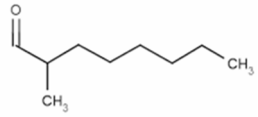
35. Acetone is an old name for a common **ketone** that has two additional carbons attached to the **carbonyl group**.

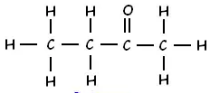
a. Draw the molecule and give its **IUPAC name**.

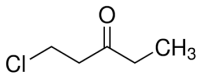
b. Write a balanced equation for its **combustion**.

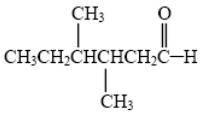
c. Based on its **SDS label** above, where would be the appropriate place to dispense acetone when being used in the lab?

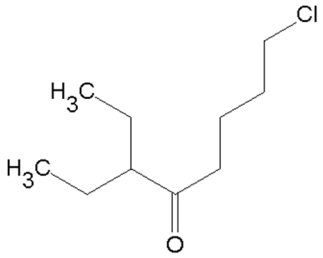
36. Give the correct IUPAC name for each molecule below. First decide if it's an aldehyde or a ketone!

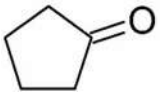
a. 

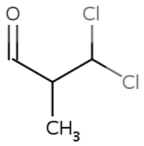
b. 

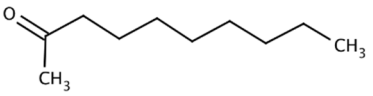
c. 

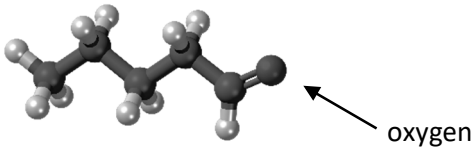
d. 

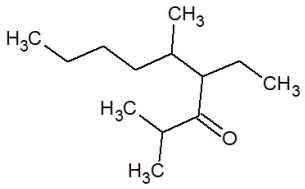
e. 

f. 

g. 

h. 

i. 

j. 

37. **Pentan-2-one** and **Pentan-2-ol** are both liquids at room temperature. Draw each molecule and indicate which would have the greater vapor pressure at room temperature. Also indicate which would have a higher normal boiling point.