Oil and Water Don't Mix

Model 1. When chemists think of *fats* they think of a large class of molecules called *lipids.* The word *lipids* comes from the greek "*lipos"* for fat. Natural fats and oils are made mostly of molecules called triglycerides. Fats are solid triglycerides, while oils are liquid triglycerides.

A triglyceride is made from the combination of fatty acids and glycerol; it has the basic structure shown in Figure 4.1. Fatty acids can be from 4 to 35 carbons long, but 14-20 carbon fatty acids are most common in food.

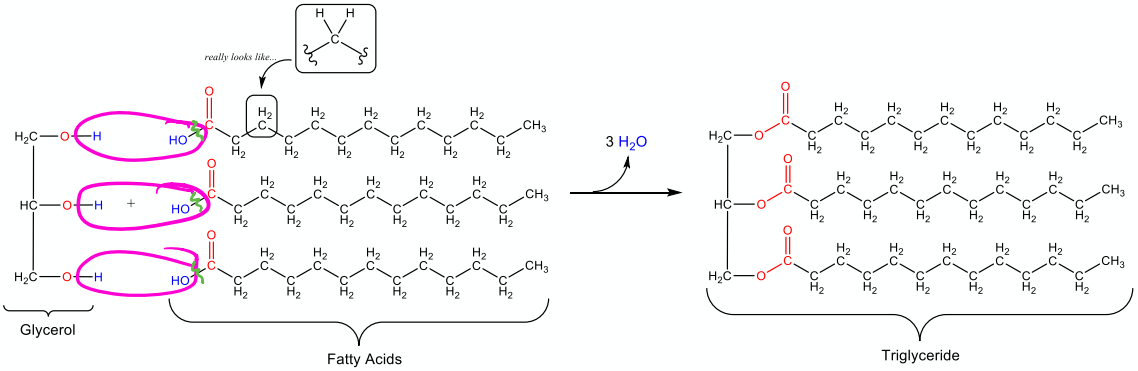
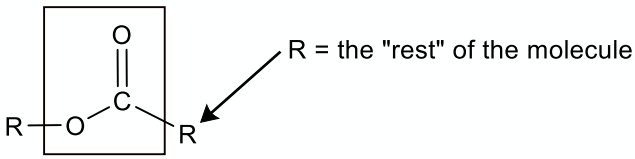


Figure 9.1. Glycerol and fatty acids combine to make a triglyceride.

When fatty acids and glycerol combine, bonds are broken and formed in a chemical reaction to produce a triglyceride and 3 molecules of water. In that process, a new group of atoms is formed called an *ester*. The properties of a given triglyceride depend upon the chemical structure of the three fatty acids it contains, and the properties of a lipid depend upon the particular mixture of triglycerides it contains.

Table 9.1. The comopositition of mono-, di- and triglycerides

Monoglyceride = Glycerol + One fatty acid
Diglyceride = Glycerol + Two fatty acids
Triglyceride = Glycerol + Three fatty acids



an *ester* functional group

Figure 9.2. An ester functional group

By definition, *Lipids* are insoluble in water, so that means triglycerides are *insoluble* in water. To be *soluble* means that two molecules will dissolve in one another to form a homogeneous mixture. When compounds are *insoluble*, the combination forms a heterogenous mixture. When a lipid (e.g. oil) is mixed with water, you will see boundaries form between the two *phases* – literally, the two cannot mix.

Key Concept

The polarity of a molecule is determined by the separation of charge between its atoms. In polar molecules most atoms are connected polar bonds. In non-polar molecules most atoms are connected by non-polar bonds.

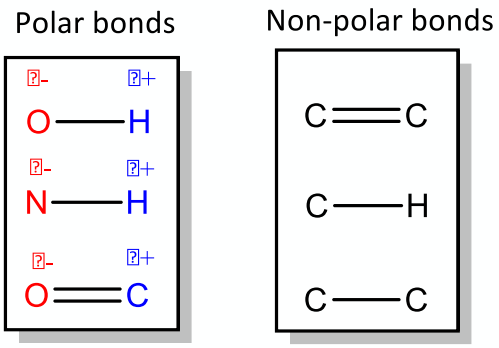


Figure 9.3. Non-polar versus polar bonds

Polar compounds can mix with or *dissolve /are soluble in* water (*hydrophilic*) to form homogeneous mixtures (i.e. sugar dissolving in water, lemon juice dissolving in water, vinegar dissolving in water). Non-polar compounds can mix with or *dissolve /are soluble in* oils (*hydrophobic*) to form homogenous mixtures (e.g. vanilla extract dissolving in oil, melted butter mixing with olive oil). These facts are described by the principle ***like dissolves like***.

BUT oil (non-polar, hydrophobic) and water (polar, hydrophilic) don't mix or dissolve in one another.

1. Why is a fatty acid called a fatty *acid*?

   It has a carboxylic acid group.

2. How many *ester* bonds are formed when a triglyceride is made?

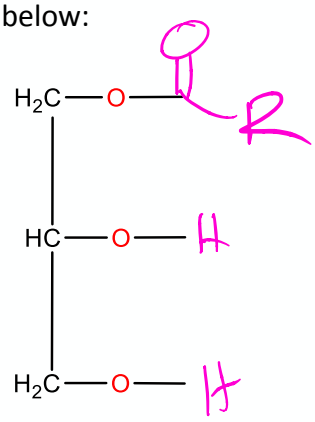
   3

3. On Figure 9.1, circle the atoms that become the water molecule, and draw squiggles through the bonds that break.

4. How many water molecules are produced when a monoglyceride is made?

   1

5. Using the glycerol backbone below, draw the structure of a generic monoglyceride below:



6. A triglyceride has some *polar* and some *non-polar* bonds – and yet the molecule as a whole is very hydrophobic (i.e. water hating).
   a. Why is the tryiglyceride – as a whole – water hating?
   b. Explain why the *non-polar* carbon chain is unable to interact with water.

   Lots of non-polar C-C + C-H bonds
   Not polar.

7. Define the phrase *non-polar bond*. Use the word *charge* in your answer.

Non-polar bond is one in which there is an equal sharing of electrons; therefore, there are no charges.

8. The words hydrophobic and hydrophilic are derived from the Greek: *hydro* = water, *phobos* = fear, and *phileo* = love. Explain why these words are consistent with the chemical properties of a triglyceride.

hydrophobic
↳ does not mix with water

Saturated and Unsaturated Fats

Model 2. Fatty acids come in different forms.

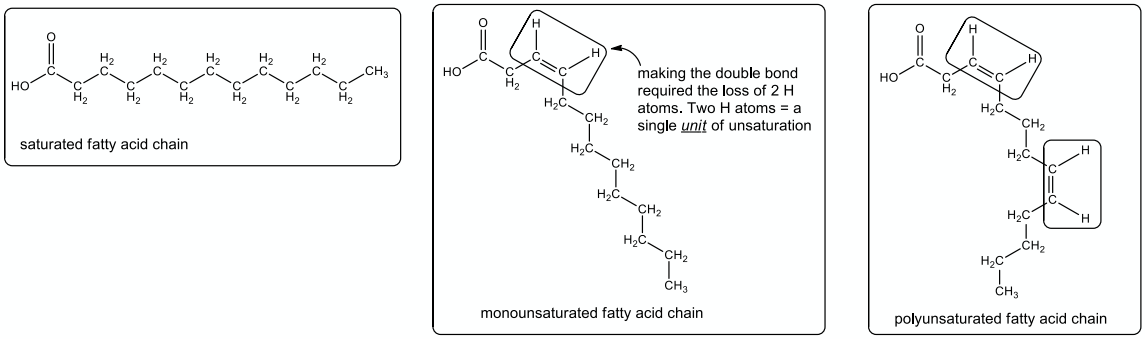


Figure 9.4. Saturated, Unsaturated and polyunsaturated Fatty Acids

Saturated, monounsaturated and polyunsaturated fatty acids can all be used to make triglycerides. A single triglyceride can be made of fatty acid chains of all of one type (e.g. all saturated) or a mixture of types, for example one saturated, one monounsaturated and one polyunsaturated fatty acid chain.

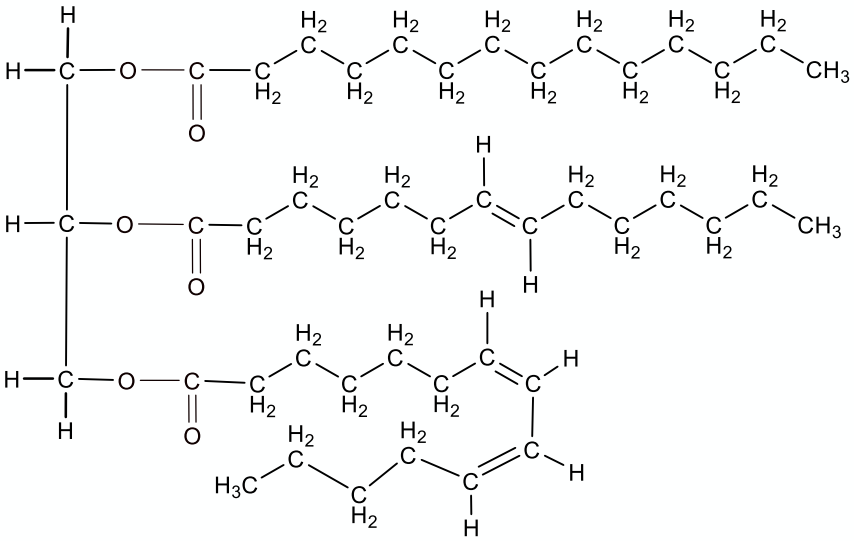


Figure 9.5. A triglyceride made with different types of fatty acids

The properties of a given triglyceride molecule depend on the structure (i.e. type) of the three fatty acids that make up the triglyceride, and their relative position on the glycerol backbone.

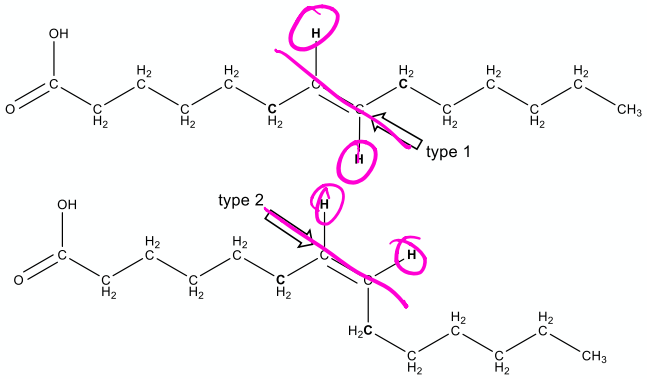


Figure 9.6. Different types of double bonds.

Fatty acids can have double bonds between carbon atoms. Double bonds come in two main types, as shown in Figure 9.6. The double bond between the carbons "fixes" all the atoms in place – in effect, the 4 atoms attached to the doubly bonded carbons (shown in boldface in figure 9.6) are "stuck there". Since these atoms are fixed in space, we can think of the double bond as having two "sides". This is in contrast to singly bonded atoms, which are able to rotate freely.

Nutrition Facts

Serving Size 16 crackers (34g)

Amount Per Serving	
Calories 155	Calories from Fat 50
	% Daily Values*
Total Fat 6g	**9%**
Saturated Fat 1g	**5%**
Trans Fat 0g	
Polyunsaturated Fat 3g	
Monounsaturated Fat 1g	
Cholesterol 0mg	**0%**
Potassium 96mg	**3%**
Sodium 238mg	**10%**
Total Carbohydrate 24g	**8%**
Dietary Fiber 2g	**8%**
Sugars 5g	
Protein 3g	**6%**

Calcium 3% • Iron 5%

*Percent Daily Values are based on a 2,000 calorie diet. Your Daily Values may be higher or lower depending on your calorie needs.

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2400mg	2400mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Figure. 9.7. On a nutrition label, Total fat includes Saturated, Polyunsaturated and Monounsaturated fats.

The generic food term "fat" refers largely to triglycerides. Therefore, for example, *saturated fat* is referring to the composition of the fatty acid chains that make up the triglycerides.

9. Using the information in Figure 9.4,
   a. What does it mean when a fatty acid is *unsaturated*?
   b. What do the prefixes *mono-* and *poly-* tell you about the unsaturation?
   c. If some fatty acids are *saturated*, what are they *saturated* with?

- has a C=C
- mono = 1 C=C ; poly = multiple C=C
- hydrogens

10. Draw a mixed triglyceride (a triglyceride that has fatty acids of different types) that is different from the one in Figure 9.5.

See Fig 9.5

11. Explain the phrases *polyunsaturated fat* and *monounsaturated fat* from the Nutrition Label, Figure 9.7

multiple C=C

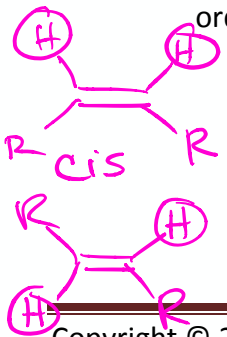
one C=C

12. Looking at Figure 9.6,
   a. What is the difference between the two types of double bonds?
   b. Chemists refer to these two types of double bonds as *cis* and *trans*. Considering that *trans* is Latin for "on the opposite side" and *cis* is Latin for "on the same side", which type of double bond (Figure 9.6, type 1 or 2) is *trans* and which type is *cis*? The arrows shown in Figure 9.6 denote the "axis" of the bond itself – draw an imaginary "line" extending from the arrow in order to make "sides".

look at H

cis

trans



Putting it all together:

13. It is possible to cook garlic in olive oil and transfer the flavors of the garlic to the oil. Since the flavors of garlic can all be attributed to molecules, what does this process tell you about the *polarity* of the garlic flavor molecules?

non-polar

14. Many salad dressings are a mixture of oil and vinegar, like the image shown below. Please explain why the mixture on the left is apparently *separated* into two *phases.*

Photo by Bill Keller

15. Some vitamins like vitamins A and D are *fat soluble*. What does that tell you about their structure?

lots of non-polar bonds

16. When cookies pastries, formation of gluten in the flour is largely undesirable (you want pastries to be crumbly and flaky, not tough and chewy). Pastry recipes therefore call for "cutting" or otherwise mixing the flour with the fat (butter usually) before adding any watery liquids. Mixing the flour with the fat coats the starch granules of the flour in fat molecules. Why would this process limit the formation of gluten? (remember, what does it take to form gluten?)

Slows mixing of flour with liquid

17. A friend tells you that she is eating "low fat". You notice that she is eating a food item that is labeled "No trans fat!". When you flip over the packaging and consult the nutrition label you see that indeed there is no *trans fat*, but there are over 20g per serving of saturated, monounsaturated and polyunsaturated fats (for something to be considered "low fat" it must have <3g of total fat per serving. Explain to your friend why "no trans fat!" doesn't mean "low fat".

Trans fat is just one type of fat

molecule