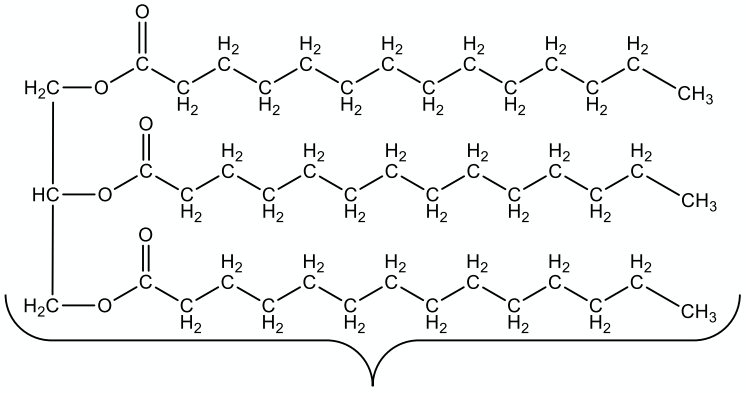
Fats: Melting and smoking

Model 1. A pure substance has a clearly defined melting point (as pure glycerol trimyristate in Figure 11.1), but a mixture (a.k.a. an *impure* substance) melts over a broad range of temperature.



glycerol trimyristate
(a triglyceride made from glycerol and three 14C fatty acids called myristic acid)
melting point: 56-57°C

Figure 11.1. Glycerol trimyristate, a pure triglyceride.

Key Concept

A pure substance has a clearly defined melting point (i.e. melts over a narrow range of temperature), but a mixture (a.k.a. an *impure* substance) melts over a broad range of temperature.

Table 11.1: Melting Characteristics of Butterfat[1]

Temperature (°C)	Solid Content (%)	Temperature (°C)	Solid Content (%)
5	43-47	30	6-8
10	40-43	35	1-2
20	21-22	40	0

Butter is comprised of triglycerides with 62% saturated, 29% monounsaturated and 4% polyunsaturated fatty acids. Butter melts over a wider temperature range: 82.4 - 96.8 °F (28-36 °C). Most fats (like butter) do not have a sharply defined melting point, instead they soften gradually over a broad temperature range. As the temperature rises, the

[1]Belitz, Hans-Dieter and Grosch, Werner. *Food Chemistry*. New York: Springer, 1999: 485.

different kinds of fat molecules melt at different points and slowly weaken the whole structure. This property is what makes butter spreadable at room temperature. Fats will melt into oils when warmed, but if the heat is raised, most do not boil. Before the fat can reach a boil it *smokes* and breaks down instead (eventually, it can actually light on fire!). The breakdown of fat at high temperatures is due to several factors:

- Oxygen from the air: We know the oxygen can *oxidize* the double bonds in unsaturated fats – creating smelly and off-tasting by products and turning the fat rancid. Some of these oxidation products of fats can be toxic and others are hazardous to cardiovascular health. This *oxidation* is accelerated at high temperatures.
- Water: At high temperatures, water from the air (or contaminating the fat) reacts with the triglyceride to break off a free fatty acid from the glycerol backbone (Figure 5.6). *Free fatty acids* taste bad and are less hydrophobic – which compromises the quality of the oil – therefore this process is called *hydrolytic rancidity*
- Purity of the fat: Contaminants like *free fatty acids*, proteins, sugars will burn in the oil at high temperatures producing dark colors and off-tasting molecules. Free fatty acids are naturally present in fats and oils in very small amounts, but the amount of *free fatty acids* increases as fats/oils are heated.

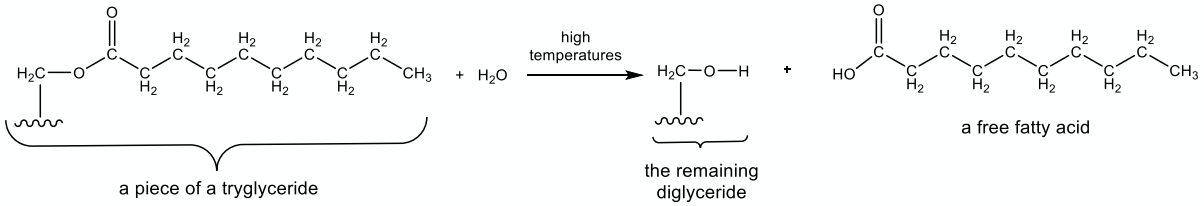


Figure 11.2. Free Fatty Acids are produced from *hydrolysis* (breakdown by water) of triglycerides.

The *smoke point* of an oil is a temperature at which the oil begins to break down into visual gaseous products. It is known that the smoke point is dependent upon that small concentration of *free fatty acids* in the fat/oil. *So what affects free fatty acid content*?

- The type of oil. Animal fats/oils have higher free fatty acid content than plant oils.

- Oil refining (a method of purification). Refined oils have lower free fatty acid content than unrefined oils.
- Age. The longer a fat/oil sits exposed to oxygen and water (along with heat, in the case of cooking) the more *free fatty acids* will form. One use of an oil at high temperature can lower the *flash point* (or burst-in-to-flames point) by as much as 100˚F due to the increase in free fatty acid content.

A fresh, refined vegetable oil will begin to smoke at ~450˚F, while a fresh, refined animal fat will begin to smoke around ~375˚F.

Questions:

1. Explain why butter is chemically considered a *mixture* or an *impure substance*.

Does not have a single melting point; it has a range

2. Lard is an animal fat (specifically from pork) that is comprised of a mixture of saturated, monounsaturated and polyunsaturated triglycerides. Would you expect lard to melt over a narrow temperature (1-2 degrees) range or over a wide temperature range (≥10 degrees)? Why?

Wide range because a mixture of molecules

3. Considering that "hydro" means "water" and "lytic" means "to break", why does the phrase *hydrolytic rancidity* correctly describe the process by which free fatty acids are formed?

The triglycerides break down in the presence of water to form glycerol + fatty acids

4. Why do you suppose there are FDA regulations on changing the oil in a deep fryer (for example, in a fast food restaurant)?

Each use ↑ impurities and ↓ smoke point

5. In stir frying, vegetables are chopped small and cooked on an extremely hot metal surface (>400˚F), with a little oil and constant stirring (to keep them from burning). It is important to heat the pan *before* adding the oil – in fact, you heat the pan and add the oil just a few seconds before the vegetables.
    a. What oil characteristics would be essential for safe and tasty stir frying?
    b. Why is the oil added immediately before the vegetables? If you add the oil too soon (as one cook describes) it becomes "unpalatable, viscous and sticky". Why is this?

a) smoke, flash, + fire temperatures
b) Oil begins to become rancid / decomposes as soon as it is heated.

Putting it all together

6. Butter is comprised of ~80% fat and 20% water with small amounts of protein and sugar from the milk used to make the butter. Corn oil (a common kitchen vegetable oil) has negligible amounts of water, protein or sugar in it.
    a. Which of these fats is more prone to *hydrolytic rancidity*? Why?
    b. When heated, which of these fats will have a lower *smoke point*. Give all the reasons why.

a) Butter (because of water)
b) Butter because of the impurities.

7. It is possible to start a fire by heating oil too hot! This is why you should always have a fire extinguisher in the kitchen. Splashing water on an oil fire is totally ineffective at quenching the flames….considering what you know about oil and water, why would this be?

Water would fall to the bottom of the pan and immediately vaporize and throwing the oil around the room