DATE: NAME: CLASS:

CHAPTER 15 | HANDOUT | BLM 15.1.4

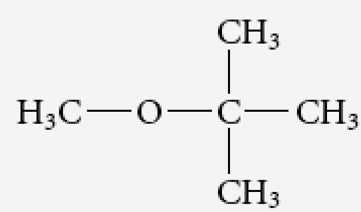
Thought Lab 15.2: Problem-Solving with Organic Compounds

Octane-Enhancing Compounds Reduce Engine Knocking

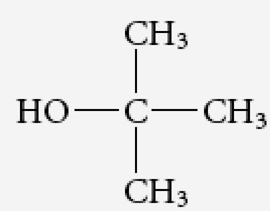
Automobile fuels are graded using an *octane rating*, or *octane numbers*, which measure the combustibility of a fuel. A high octane number means that a fuel requires a higher activation energy (higher temperature or higher pressure or both) to ignite. Racing cars with high-compression engines usually run on pure methanol, which has an octane number of 120.

Gasoline with too low an octane number can cause "knocking" in the engine of a car. This occurs when the fuel ignites too soon and burns in an uncontrolled manner. Knocking lowers fuel efficiency, and it can damage the engine.

As early as 1925, two of the first automobile engineers became aware of the need to improve the octane number of fuels. Charles Kettering advocated the use of a newly developed compound called tetra-ethyl lead, $Pb(C_2H_5)_4$. This compound acts as a catalyst to increase the efficiency of the hydrocarbon combustion reaction. Henry Ford believed that ethanol, another catalyst, should be used instead of tetra-ethyl lead. Ethanol could be produced easily from locally grown crops. As we now know, ethanol is also much better for the environment.



2-methoxy-2-methyl propane
(methyl tert-butyl ether)



2-methylpropan-2-ol
(tert-butyl alcohol)

Tetra-ethyl lead became the chosen fuel additive. Over many decades, lead emissions from car exhausts accumulated in many compartments in the environment, such as urban ponds and water systems. Many waterfowl that live in urban areas experience lead poisoning. Lead is also dangerous to human health.

Leaded fuels are now banned across Canada. In unleaded gasoline, simple organic compounds are added instead of lead compounds. These octane-enhancing compounds include methyl-t-butyl ether, t-butyl alcohol, methanol, and ethanol. Like lead catalysts, these compounds help to reduce engine knocking. In addition, burning ethanol and methanol produces fewer pollutants than burning hydrocarbon fuels, which contain contaminants. Since they can be made from crops, these alcohols are a renewable resource.

Replacing CFCs—At What Cost?

At the beginning of the twentieth century, refrigeration was a relatively new technology. Early refrigerators depended on the use of toxic gases, such as ammonia and methyl chloride. Unfortunately, these gases sometimes leaked from refrigerators, leading to fatal accidents. In 1928, a new, "miracle" compound was developed to replace these toxic gases. Dichlorodifluoromethane, commonly known as Freon®, was a safe, non-toxic alternative. Freon® and other chloro-fluorocarbon compounds, commonly referred to as CFCs, were also used for numerous other

Thought Lab 15.2: Problem-Solving with Organic Compounds (continued)

products and applications. They were largely responsible for the development of many conveniences, such as air-conditioning, that we now take for granted.

Today we know that CFCs break up when they reach the ozone layer, releasing chlorine atoms according to the reaction:

$CF_2Cl_2(g) \xrightarrow{\text{UV photon}} CF_2Cl(g) + Cl(g)$

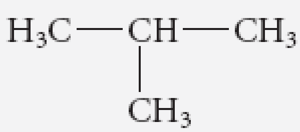
The chlorine atoms have an unpaired electron, making them extremely reactive. They react with ozone according to the following reaction:

$O_3(g) + Cl(g) \longrightarrow ClO(g) + O_2(g)$

Finally, the chlorine monoxide reacts with atomic oxygen as show below:

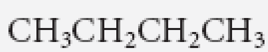
$ClO(g) + O(g) \longrightarrow Cl(g) + O_2(g)$

As you can see, after a chlorine atom breaks down ozone to form oxygen, the chlorine atom is regenerated and can continue to destroy more ozone molecules. The chlorine atoms are unchanged after the series of reactions and can therefore be considered to be acting as catalysts. Studies in the past ten years have shown dramatic drops in ozone concentrations at specific locations, especially over the South Pole. Since ozone protects Earth from the Sun's ultraviolet radiation, this decrease in ozone has led to increases in skin cancer, as well as damage to plants and animals. In addition, CFCs are potent greenhouse gases and contribute to global warming. Through the Montreal Protocol, and later "Earth Summit" gatherings, many countries—including Canada—have banned CFC production and use.

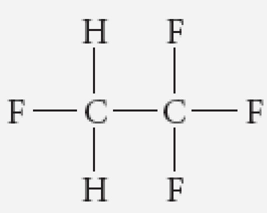


isobutane

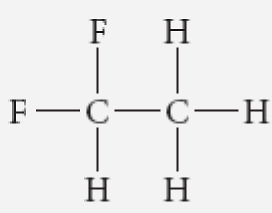
propane



butane



1,1,1,2-tetrafluoroethane



1,1-difluoroethane

Substitutes for CFCs are available, but none provides a completely satisfactory alternative. Hydrofluorocarbons (HFCs) are organic compounds that behave like CFCs but do not harm the ozone layer. For example, 1,1,1,2-tetrafluoroethane and 1,1-difluoroethane are HFCs that can be used to replace CFCs in refrigerators and air conditioners. Unfortunately, HFCs are also greenhouse gases.

Thought Lab 15.2: Problem-Solving with Organic Compounds (continued)

Simple hydrocarbons can also be used as CFC substitutes. Hydrocarbons such as propane, 2-methylpropane (common name: isobutane) and butane are efficient aerosol propellants. These hydrocarbons are stable and inexpensive, but they are extremely flammable. They are also greenhouse gases.

Procedure

After reading the articles, brainstorm with your group to come up with two other issues involving organic compounds, about which you have heard or read. You could consider such issues as food additives, the recycling of plastics, or pesticide pollution in the environment. For each situation, answer the following questions:

1. What was the original human or societal need for which the organic compounds were developed and used to meet?

2. How did organic compounds meet this need?

Thought Lab 15.2: Problem-Solving with Organic Compounds (continued)

3. What further problems (if any) were introduced by the use of these organic compounds?

4. Have these additional problems been resolved? If so, how have they been resolved?

5. Do you foresee any new problems arising? Explain your answer.

Thought Lab 15.2: Problem-Solving with Organic Compounds (continued)

Analysis

1. List four benefits society receives from its wide use of organic compounds.

2. Describe four unintended results that have occurred as a result of society's use of organic compounds.

3. In your opinion, is it worth finding organic compounds that will solve problems if the compounds may create more problems? Explain your answer. (You may want to debate this issue with your group or members of the class as a whole.)