The Saga of Thomas Midgley, Jr.

Part One: Tetraethyl Lead and Automobiles

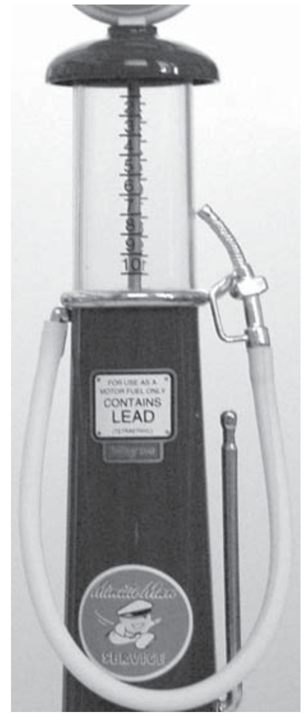
In 1916, Thomas J. Midgley, Jr. went to work for the Dayton Engineering Laboratories Company (Delco), established by Charles F. Kettering, the inventor of the automobile self-starter who later became a Vice President at General Motors. As an eager new mechanical engineer, Midgley asked, “What do you want me to do next, boss?” The answer was an assignment from the boss (Kettering) that would lead to a seven-year trail of research culminating in the marketing of a new product (Kettering, 1944).

“Midge” was assigned to solve the problem of the engine knock. Kettering was developing small kerosene engines to run home lighting systems, but the engines knocked horribly. First, Midgley needed to figure out the cause of the knock. In automobiles, knock sounds like loud shots under the hood or popcorn popping in a metal pot. Midgley found that engine knock is caused by a violent pressure rise that happens after ignition. The next step was to find something that would eliminate the knock.

According to Kettering, there was an epic search by the researchers for a practical anti-knock compound.

There was nothing in the books, so with homemade theories and cut and try methods, they added thousands of things to gasoline and observed their effects. For years this went on—day and night. New chemical compounds were imported from overseas and many other new ones were made in our own laboratories. Meals were forgotten, sleep was lost and the happy families of the researchers ceased to be “happy” (Today in History, 1959).

In Midge’s laboratory on the second floor of a tobacco warehouse, a large board with the periodic table of elements guided the experiments. It helped the researchers to organize the results of their many tests of various elements and compounds. Iodine worked, but it was not practical to put in gasoline. Tin compounds were also explored. Finally, in 1921, Thomas Midgley, Jr. created a fuel additive that would reduce engine knock—tetraethyl lead, $(C_2H_5)_4Pb$.



In 1923, gasoline with tetraethyl lead (TEL) was marketed under the name of “Ethyl gasoline.” “Lead” was not in the new name. The following year, Ethyl Gasoline Corporation was formed by General Motors and Standard Oil Company of New Jersey to market this “knockless” motor fuel. From the 1920s to the 1970s, the largest source of atmospheric lead was from combustion of leaded gasoline. In the 1970s, tetraethyl lead was used in about 80 to 90 percent of all gasoline worldwide.

But there were some problems with leaded gasoline. Midgley and three other General Motors laboratory employees experienced lead poisoning. During the years of 1923 to 1925, 17 workers died and 149 were injured due to lead poisoning during the process of making tetraethyl leaded gasoline. Midgley felt that the exhaust from the gasoline did not contain enough lead to worry about, despite warnings from experts and his own experiences. Even with public outcry and concern over the use of tetraethyl lead, Midgley continued to defend his additive.

In 1925, the U.S. Public Health Service (PHS) held a conference about the health effects of tetraethyl lead. At the conference, Alice Hamilton, a public health expert from Harvard University, vehemently opposed the use of lead in gasoline and labeled it a menace to public health. However, the PHS did not find grounds for prohibiting the use of ethyl gasoline. The PHS’s Surgeon General did caution that further studies should be carried out. It wasn’t until 1959 that the U.S. PHS fully reinvestigated the issue of tetraethyl lead. This time, the conclusion was different—tetraethyl lead in gasoline is a health risk.

The U.S. Environmental Protection Agency (EPA) asked for a phaseout of lead in gasoline in 1973. However, because of litigation, the regulation of tetraethyl lead in gasoline did not happen until 1976. Regulation was based on the health effects of lead, which prompted the phaseout of lead in gasoline. However, there was another reason to phase out lead. Lead deactivates the catalyst in catalytic converters. These converters were scheduled to be put on new vehicles in 1975 to reduce emissions of carbon monoxide, hydrocarbons, and nitrogen oxides. For catalytic converters to work correctly, there needed to be a phaseout of lead in gasoline. To discourage the use of leaded gas in new cars, large fueling nozzles that would not fit into new cars were used for leaded gas.

In 1982, 86% of the lead in the atmosphere was still from gasoline. In 1996, the Clean Air Act banned the sale of the small amount of leaded fuel for on-road vehicles that was still available in some parts of the country. However, fuel containing lead could continue to be sold for off-road uses, including aircraft, racing cars, farm equipment, and marine engines. Other parts of the world still use leaded gasoline. In 2001, over 90% of all gasoline sold in Africa and the Middle East was still leaded, while over 30% of Asian and Latin American gasoline was leaded.

In the 1920s, Midgley and his associates predicted that ethanol (ethyl alcohol) could become an important fuel of the future that could replace petroleum. In addition, vehicles needed to obtain more miles per gallon of fuel to reduce dependence on petroleum. Ethyl alcohol is made from farm crops or cellulose, and it can be blended with gasoline to boost octane (anti-knock) ratings. Gasoline blended with ethanol is commonly sold today.

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Questions

1. Why was tetraethyl lead a good thing for the automobile industry?

2. Did Midgley use good science to defend the use of tetraethyl lead? Why or why not?

3. Did the Public Health Service act in the best interest of the people? Why or why not?

4. What was the main reason why tetraethyl lead was finally taken out of gasoline?

5. Do you see any ethical problem with leaded gasoline being sold in other parts of the world? Explain your answer.

Part Two: Invention of CFCs and the Ozone Hole

Thomas Midgley, Jr.'s second contribution to American life provided a major breakthrough for refrigeration, but it also helped lead to the depletion of the ozone layer. In 1928, he was asked by the Frigidaire department of General Motors to find a nontoxic substitute for existing refrigerants such as ammonia, sulfur dioxide, and chloromethane, which were toxic or flammable.

In three days of work, Midgley had developed a new refrigerant—CFC-12 (dichlorofluoromethane), the first of the chlorofluorocarbons (CFCs). This compound, named Freon, was nontoxic, nonflammable, and chemically unreactive under normal conditions in the troposphere. Midgley demonstrated the safety of Freon by filling his lungs with the vapor and then exhaling over a lit candle to extinguish it.

Freon was first used in small ice cream cabinets. By 1934, it was used in refrigerators, and home and automobile air conditioning units. By 1943, CFCs were being used as propellants in spray cans such as, hair sprays, paints, deodorants, and insecticides. Chlorofluorocarbons have also been used in blowing agents for foam production, fire extinguishers, and insulation.

Chlorofluorocarbons (CFCs) are compounds that can exist in the troposphere for 100 years or longer. CFCs are made up of chlorine, fluorine, and carbon atoms. Scientists began studying the effects of CFCs and found that they contribute to the destruction of the ozone in the stratosphere, which is home to 90% of all ozone molecules. CFCs are broken down in the stratosphere by the sun's radiation. When chlorine from CFCs gets released into the stratosphere, it contributes to the depletion of the ozone layer. Release of CFCs into the air happened when coolants leaked, during foam production, or through spray can nozzles carrying with them a mist containing other ingredients.

In the 1970s, scientists first grew concerned that certain chemicals could damage the Earth's protective ozone layer. In 1976, a report was released stating CFC emissions were large enough to cause long-term decrease in stratospheric ozone, potentially increasing surface UV-B radiation. Increased levels of UV radiation can cause skin damage (skin cancers and premature aging), eye damage (including cataracts), and suppression of the immune system. In the early 1980s, these concerns were validated by the discovery of thinning of the ozone layer over Antarctica in the Southern Hemisphere. While the ozone did not completely disappear in this area, it was so thin that scientists and the popular press started talking about an "ozone hole."

Congress acted swiftly. In 1978, the sales and manufacturing of CFCs were banned in the United States. At that time, the United States was responsible for half the global production of CFCs used in spray cans. Since 1987, over 180 nations have ratified a landmark environmental treaty, the *Montreal Protocol on Substances that Deplete the Ozone Layer*. The Protocol's chief aim is to reduce and eventually eliminate the production and use of human-made ozone-depleting substances, or ODS. Under the *Clean Air Act Amendments of 1990*, the U.S. Environmental Protection Agency created several regulatory programs to address ozone depletion, including:

- Ending the production of ozone-depleting substances
- Ensuring that refrigerants and halon fire extinguishing agents are recycled properly
- Identifying safe and effective alternatives to ozone-depleting substances
- Banning the release of ozone-depleting refrigerants during the service, maintenance, and disposal of air conditioners and other refrigeration equipment
- Requiring that manufacturers label products either containing or made with the most harmful ozone depleting substances

Even with the regulations and ban of CFC production in the United States, it is not expected that the stratosphere will recover fully until 2050.

Besides leaded gasoline and CFCs for refrigerants, two other contributions of Thomas Midgley, Jr. are of note. He demonstrated that it is practical to get bromine from seawater. His research on rubber extended the knowledge of vulcanization and composition of natural and synthetic rubber. Held in high regard by his associates, Midgley was honored by the American Chemical Society, several Universities, and the National Academy of Science. With over 100 patents for his work, Midgley contributed to all phases of industrial research: investigation and invention, product development, and marketing the product.

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U.S. Environmental Protection Agency. *Ozone Depletion*. Retrieved June 20, 2005, http://www.epa.gov/ozone/.

Questions

1. How did Midgley’s creation of CFCs help the economy?

2. What problems have CFCs caused and how have the problems been addressed?

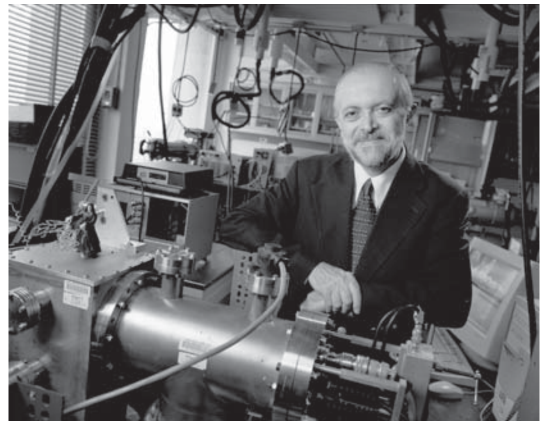
3. Some argue that Midgley’s work led to the two greatest environmental disasters of the twentieth century. What do you think and why?

4. How should history remember Thomas J. Midgley, Jr.?

STUDENT ASSESSMENT

Part Three: And the Rest of the Story

In 1973, Mario Molina was a postdoctoral researcher working in the laboratory of F. Sherwood Rowland at the University of California at Irvine, just south of Los Angeles, when he made an unsettling discovery. He had been investigating a class of compounds called chlorofluorocarbons, or CFCs. CFCs were used as refrigerants, aerosol sprays, and in making plastic foams. Molina wondered what happened to them once they were released into the atmosphere.



Mario Molina
Heinz Awards photo/Jim Harrison photographer

This was a hypothetical study, but his results showed disturbingly that CFCs could, in theory, destroy a compound called ozone under the conditions that exist in the upper atmosphere. Far above the earth's surface, a thin layer of ozone floats, protecting us from the sun's ultraviolet radiation. Molina, just a young scientist at the time, was nervous about showing Rowland his theory of how CFCs might destroy ozone. But if CFCs really could wipe out ozone, the whole world would be in trouble.

Rowland took his protégé seriously. Over the next two decades he and Molina became voices crying in the wilderness, alerting the world to the danger of CFCs and ozone depletion. They weren't always heeded. Bans on CFCs in aerosol sprays went into effect first in the United States in 1978, and later in Canada, Norway, and Sweden. CFC use for other purposes only increased. Scientists, activists, politicians, and CFC-producing companies would argue for years over the merit of Molina's theories.

Mario Molina was born in Mexico City, where Mario's father was a successful lawyer and a diplomat. As a child, Mario was fascinated with chemistry and converted one of the bathrooms in his family's house to a chemistry laboratory for himself. His aunt, Esther Molina, was a chemist, and she encouraged and mentored the boy by helping him carry out more advanced experiments than normally possible with a child's chemistry set. Recognizing his passion for science, Mario's parents sent him to a boarding school in Europe, where they thought his fascination with science would be nurtured.

Mario returned to Mexico City for college, earning an undergraduate degree in chemical engineering from the Universidad Nacional Autonoma de Mexico in Mexico City. After graduation, the young Molina studied at universities in Germany and France, but those studies did not provide the intellectual satisfaction he was seeking.

Finally, Molina was accepted for graduate study at the University of California at Berkeley, and his life changed. There he began to find his place in science and in life, and he married a fellow graduate student, Luisa Tan. After earning his doctoral degree, Molina made his way to UC Irvine, where he joined Sherwood Rowland's group as a postdoctoral researcher. It was then that Molina and Rowland began wondering what might be happening to CFCs released into the atmosphere.

As time went on, Molina moved on from UC Irvine to work at NASA's Jet Propulsion Laboratory where he continued to investigate ozone depletion. Over the years, evidence mounted in support of Molina's theories, leading to increased international regulation of CFCs. But this did not happen easily, nor did it happen overnight. As we'll see, it took a near disaster before most of the world would listen to Molina. But in the end, he would be vindicated, and in 1996 he was awarded the Nobel Prize for Chemistry, along with his old boss Rowland and Swedish scientist Paul Crutzen, for the work they had done in helping unravel the mysteries and dangers of CFCs.

Today Molina continues his research of gas-phase chemistry, including the effects of pollutants in the atmosphere at the University of California, San Diego. Not forgetting his roots, he has also been involved in studying ways of making the air in cities cleaner, looking for strategies to reduce urban air pollution. Mexico City has been the case study for this project. We hope that Molina's methods will help alleviate the choking pollution of his old hometown.

Source: Meet Mario Molina
http://www.chemheritage.org/EducationalServices/FACES/env/molina.htm.

Questions

1. Why didn't people want to believe Molina's theory about CFCs and ozone?

2. What would you have done if you had made this discovery?

3. How soon after the discovery was something done?

4. What was it like for Mario when he was growing up? How was it later in life?

5. How is Mario Molina giving back to his homeland?

Extra Credit: What is the Nobel Prize?