Mario Molina and the Threat of CFCs to the Ozone Layer in the Stratosphere

Dan Y. Watanabe
Parkland College

MARIO MOLINA

and the threat of CFCs to the ozone layer in the stratosphere

CHE-101-005 | DR. MULLEN | PARKLAND COLLEGE

INTRODUCTION

Mario Molina is most famous for his research of the harmful effects of chlorofluorocarbon gases, or CFCs, to the Earth's ozone. Molina shared the Nobel Prize in chemistry with Paul J. Crutzen and F. Sherwood Rowland for discovering the harmful effects of CFCs in the stratosphere to the overall atmosphere and how they contribute to ozone depletion.

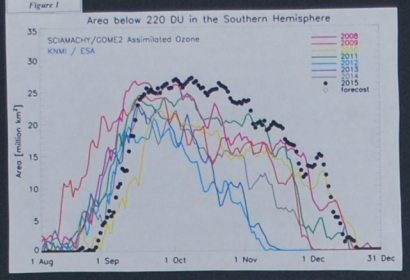
BIOGRAPHY

Photo Credit: Donna Coveney/MIT

Mario Molina was born on March 19, 1943 in Mexico City. As a child, Molina had a fascination for chemistry. He enjoyed performing experiments and studied material years ahead of his peers. Molina even converted his bathroom into his own makeshift laboratory. Later in his life, he completed his studies in Mexico and Switzerland and went to earn a bachelor's degree in chemical engineering at the National Autonomous University of Mexico.

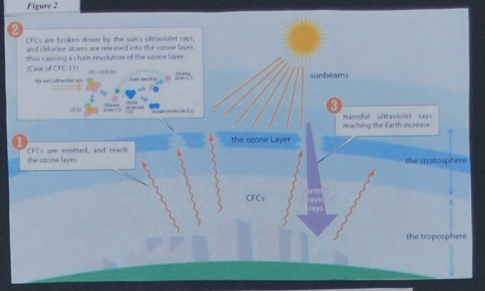
In 1972, Molina went on to receive a Ph.D. in chemistry at the University of California, Berkeley. There, he met his wife Luisa Y. Tan. In 1974, together with Sherwood Roland, Molina wrote an article in the *Nature* that called attention to the threat of CFCs to the ozone layer. Many scientists and corporations were skeptic to Molina's warnings and it took two years for action to be taken upon them. Molina is largely responsible for the global pursuit to eliminate all CFCs from aerosol cans and refrigerators and received a Nobel Prize in chemistry together with his partner, Rowland. After receiving his Nobel Prize, Molina continued his research and lectured at the University of California and Massachusetts Institute of Technology (MIT).

Figure 1



The size of the ozone hole from 2008 – 2015.
http://www.temis.nl/protocols/o3hole/o3_size.php?date=20160423&lang=0

Figure 2



The process from which CFCs are produced to the destruction of the ozone layer.
http://www.theozonehole.com/cfc.htm

FIELDS OF RESEARCH

Figure 5

Polar stratospheric clouds seen from the NASA DC-8
Photo Credit: Paul Newman

Mario Molina worked in the field of chemical engineering and chemical dynamics. Chemical engineers apply the principle of chemistry, biology, physics, and math to solve problems that involve the production or use of chemicals, fuel, drugs, food, and many other products (Bureau of Labor Statistics). In chemical dynamics, scientists study the rates and mechanisms of chemical reactions and how energy is transferred among molecules as they undergo collisions in gas-phase or condensed-phase environments (Simons 1). Molina also earned a Ph. D in physical chemistry. Physical chemistry is the study of how matter behaves on a molecular and atomic level and how chemical reactions occur (ACS.org). Physical chemistry deals with how physics can be applied/observed in chemistry. Additionally, Molina worked in the field of atmospheric chemistry; he began research in this field when he first decided to study CFCs. Atmospheric chemists study the chemical composition of the natural atmosphere, the way gases, liquids, and solids in the atmosphere interact with other and with the Earth's surface and associated biota, and how human activities may be changing the chemical and physical characteristics of the atmosphere (University of Waterloo).

WHAT IS POLAR OZONE DEPLETION?

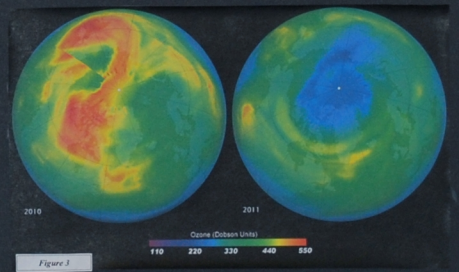


Figure 3

Ozone concentrations from the Arctic measured with the Ozone Monitoring Instrument (OMI) on NASA's Aura satellite.
https://www.nasa.gov/topics/earth/features/2011-ozone-hole.html#.VurEQTArK5h

Polar ozone depletion is a phenomenon that describes the decrease in stratospheric ozone around Earth's polar regions. The area of depleted ozone is referred to as the "ozone hole". The main culprits of polar ozone depletion are CFCs or chlorofluorocarbons. CFCs can be found in aerosols, refrigeration units, and cleaning agents. CFCs cause polar ozone depletion when they are broken down by the sun's UV radiation. When broken down they release chlorine atoms. These chlorine atoms destroy the ozone molecules and create ozone holes. Figure 2 shows the process in which CFCs are released into the atmosphere and cause polar ozone depletion. Figure 3 compares ozone levels in 2010 and 2011. In 2010 there was a considerable amount more ozone than in 2011.

RESEARCH & CONTRIBUTION

Mario Molina researched the effects of the photo-dissociation of Chlorofluorocarbons (CFCs) on the atmospheric ozone. In the 1970s, CFCs were thought to be harmless, however, Molina realized that that they were slowly accumulating and wondered what effects it had on the environment. As he progressed in his research, Molina discovered that the CFCs that were released into the atmosphere were being broken down by UV radiation and releasing chlorine atoms.

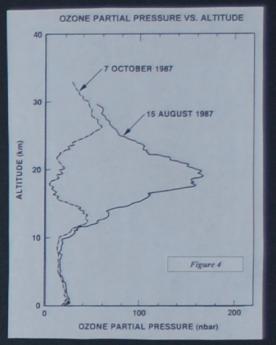


Figure 4

Balloon measurements of ozone profiles over Halley Bay, Antarctica.
http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1995/molina-lecture.pdf

He concluded that they were harmful to the atmospheric ozone because they produce significant amounts of chlorine atoms which results in the destruction of ozone molecules (O_3) and increase in oxygen molecules (O_2) in the atmosphere. The following reaction shows the process from the release of chlorine atoms to the destruction of ozone molecules and production of oxygen molecules:

$$Cl + O_3 \rightarrow ClO + O_2$$
$$ClO + O \rightarrow Cl + O_2$$
$$\text{Net: } O + O_3 \rightarrow 2\,O_2$$

Molina also discovered that the seasonal decline of the stratospheric ozone over the South Pole was drastic; he found that in cold weather a large amount of ozone disappears. In Figure 4, the graph shows the ozone partial pressure at different altitudes during the months of August and October. He found that cold weather allowed for polar stratospheric clouds or PSCs to form. PSCs act as a catalyst to the production of active free-radical chlorine atoms which destroy ozone molecules.

Mario Molina's contribution to our world was tremendous. He potentially saved our planet from becoming uninhabitable. With his research we are now able to implement stricter rules concerning CFCs and other pollutants that pose a threat to our environment. His research has brought the world together to work towards rebuilding our ozone layer.

WORKS CITED

"Atmospheric Chemistry." Atmospheric Chemistry. University of Waterloo, 12 Oct. 2012. Web. 23 Apr. 2016.
Bureau of Labor Statistics, U.S. Department of Labor, Occupational Outlook Handbook, 2016-17 Edition, Chemical Engineers, Web. 3 Apr 2016.
"Mario Molina and Susan Solomon | Chemical Heritage Foundation." *Mario Molina and Susan Solomon | Chemical Heritage Foundation*. Chemical Heritage Foundation, 03 Apr. 2016. Web. 03 Apr. 2016.
Molina, Mario J. "Mario J. Molina - Biographical". *Nobelprize.org*. Nobel Media AB 2014. Web. 3 Apr 2016.
Molina, Mario J. "Polar Ozone Depletion(Nobel Lecture)." *Angewandte Chemie International Edition in English Angew. Chem. Int. Ed. Engl*35.16 (1996): 1778-785. Web. 3 Apr. 2016.
"Physical Chemistry." American Chemical Society. N.p., 21 May 2011. Web. 23 Apr. 2016.
Simons, Jack. An Introduction to Theoretical Chemistry. Cambridge: Cambridge UP, 2003. Print.

By: Dan Y. Watanabe