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Chlorine Radicals Take Over

The effectiveness of the 1987 Montreal Protocol initiated a competitive race to discover climate-friendly alternatives for chlorofluorocarbons (CFCs), a man-made, Freon that has contributed to the enhancement of greenhouse gases and depletion of stratospheric ozone. Preserving the ozone layer is crucial because it is a natural gas shield that prevents ultraviolet B radiation (UVB) from penetrating earth's surface to hinder phytoplankton reproductive cycles and escalate human skin cancer cases (Anon. 2018). CFCs in the stratosphere, struck by UVB, contribute to ozone depletion by breaking down into chlorine radicals that split ozone molecules to construct chlorine monoxide and oxygen. As chlorine monoxide and chlorine radicals are developed, they create a chair reaction that makes small amounts of CFCs destroy large abundances of the ozone layer (Brennan 2017; Diezel 2018). As an alternative to CFCs used in refrigeration devices, aerosol propellants, and air conditioners, researchers have developed hydrochlorofluorocarbons and hydrofluorocarbons that reduce ozone depletion potentials (ODP) but have failed to eradicate the ozone depletion issue.

Compared to CFCs, HCFCs and HFCs are an improvement in both ozone depletion and global warming properties because they have lower ODP, are less stable and more reactive in the troposphere (Good and Francisco 2003). Because HCFCs and HFCs contain hydrogen-carbon bonds, hydroxyl radicals break them down before they enter the stratosphere, unlike CFCs. HCFCs contain chlorine atoms, but have lower lifespans and radiative forcing values, making the compound a compelling and competitive candidate for replacing CFCs. According to the NOAA's Earth System Research Laboratory in 2005, HCFCs are a temporary solution for researchers to develop compounds that will eliminate the possibility of chlorine atoms developing in the stratosphere to deplete ozone. Although both chlorine and bromine atoms break down ozone, chlorine is most relevant to CFCs. While HCFCs are aimed to be removed from industries by 2030, alternatives like HFCs prevail to sustain the CFC-reliant industries. Based on Good and Francisco's article (2003), HFCs have an ODP of zero because of their lack of chlorine atoms, whereas HCFC-141b is 0.10 and CFC-11 is 1.0. However, both HCFCs and HFCs do contribute to global warming in how increases of fluorine concentrations enhance the molecule's ability to absorb infrared radiation (IR). Therefore, ideal CFC replacements would contain low ozone depletion potentials, short lifetimes to prevent chlorine atoms from depleting the ozone layer, and thermophysical properties similar to CFCs (Good and Francisco 2003). Alternatives should be nonflammable, stable, nontoxic, simple, and easy to manufacture so that manufacturers are incentivized into implementing regulations. Preferably, substitutes should replenish stratospheric ozone and not be a volatile organic compound that impedes long-term human health. Despite HCFC and HFC properties that reduce ozone depletion and global warming impacts, researchers, industries, and politicians have yet to find the absolute alternative.

Because of the Montreal Protocol, stratospheric CFC concentrations have dropped dramatically in lieu with the ozone layer replenishing itself without the accumulated interference of long-living chlorine radicals. Despite international efforts, the "ozone hole" is still present today because of the massive CFC concentrations emitted by humans in the past. Although global warming and ozone depletion are main concerns for developing alternatives, HCFCs and HFCs are currently implemented in refrigerants and are ceaselessly contributing to these problems. HFCs might be the closest substitute found for they do not release chlorine atoms but do absorb infrared radiation. If researchers are to develop a CFC replacement, they must consider the costs and benefits of prioritizing the ozone layer over climate change concerns or vice versa to prevent detrimental human and environmental health effects.

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