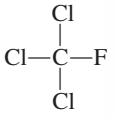
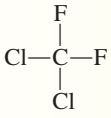
## CHEMICAL Connections — Chlorofluorocarbons and the Ozone Layer

Chlorofluorocarbons (CFCs) are compounds composed of the elements chlorine, fluorine, and carbon. CFCs are synthetic compounds that have been developed primarily for use as refrigerants. The two most widely used of the CFCs are trichlorofluoromethane and dichlorodifluoromethane. Both of these compounds are marketed under the trade name Freon.



Trichlorofluoromethane (Freon-11)



Dichlorodifluoromethane (Freon-12)

Freon-11 and Freon-12 possess ideal properties for use as a refrigerant gas. Both are inert, nontoxic, and easily compressible. Prior to their development, ammonia was used in refrigeration. Ammonia is toxic, and leaking ammonia-based refrigeration units have been fatal.

We now know that CFCs contribute to a serious environmental problem: destruction of the stratospheric (high-altitude) ozone that we commonly call the ozone layer. Once released into the atmosphere, CFCs persist for long periods without reaction. Consequently, they slowly drift upward in the atmosphere, finally reaching the stratosphere.

It is in the stratosphere, the location of the "ozone layer," that environmental problems occur. At these high altitudes, the CFCs are exposed to ultraviolet light (from the sun), which activates them. The ultraviolet light breaks carbon–chlorine bonds within the CFCs, releasing chlorine atoms.

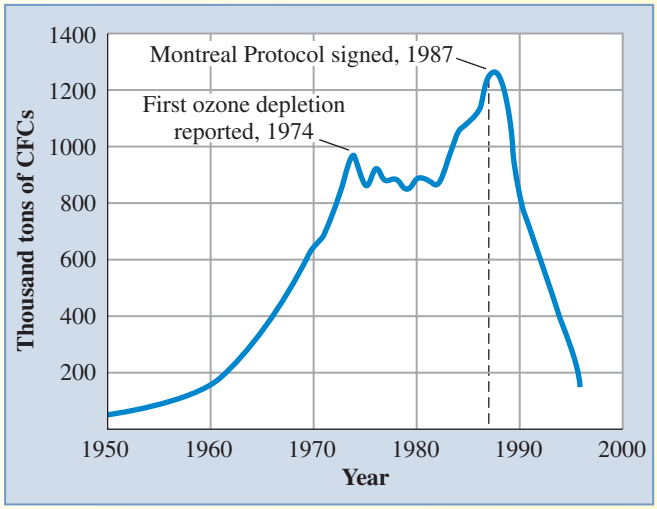
$$CCl_2F_2 + \text{ultraviolet light} \longrightarrow CClF_2 + Cl$$

The Cl atoms so produced (called atomic chlorine) are extremely reactive species. One of the molecules with which they react is ozone ($O_3$).

$$Cl + O_3 \longrightarrow ClO + O_2$$

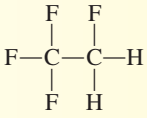
A reaction such as this upsets the $O_3$–$O_2$ equilibrium in the stratosphere (Section 9.8).

The Montreal Protocol of 1987 (an international agreement on substances that deplete the ozone layer), and later amendments to this agreement, limit—and in some cases ban—future production and use of CFCs. The following graph shows the effects of the implementation of this agreement.




Worldwide Production of CFCs (1950–1996)

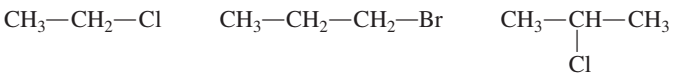
Replacements for the phased-out CFCs are HFCs (hydrogenfluorocarbons) such as



1,1,1,2-Tetrafluoroethane

Haloalkanes with some carbon–hydrogen bonds are more reactive than CFCs and are generally destroyed at lower altitudes before they reach the stratosphere. Unfortunately, however, their refrigeration properties are not as good as those of the CFCs.

(all bonds are covalent bonds). The following examples contrast the IUPAC names and the common names (in parentheses) of selected halogenated alkanes.



Chloroethane (ethyl chloride)



1-Bromopropane (propyl bromide)



2-Chloropropane (isopropyl chloride)

An alternative designation for a halogenated alkane is *alkyl halide.*

Several polyhalogenated methanes have acquired common names that are not clearly related to their structures. Five important examples of this additional nomenclature are $CH_2Cl_2$ (methylene chloride), $CHCl_3$ (chloroform), $CCl_4$ (carbon tetrachloride), $CCl_3F$ (Freon-11), and $CCl_2F_2$ (Freon-12). The compounds Freon-11 and Freon-12 are examples of chlorofluorocarbons (CFCs). CFCs are synthetic compounds that have been heavily used as refrigerants and as air conditioning chemicals. We now know that CFCs are factors in