## Periodic graphics

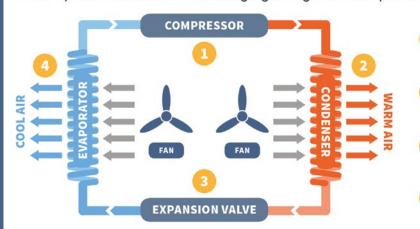
A collaboration between C&EN and Andy Brunning, author of the popular graphics blog Compound Interest

More

To see more of Brunning's work, go to compoundchem.com. To see all of C&EN's Periodic Graphics, visit cenm.aq/ periodicgraphics.

## THE CHEMISTRY OF AIR-CONDITIONING

Air-conditioning units can help you beat the heat on a hot summer day. Here, we take a look at how these systems work and the changing refrigerant compounds that help the units blast cool air.



In the compressor, refrigerant vapor gets pressurized, which also increases its temperature.

The hot, high-pressure vapor moves through condenser coils and loses heat, which gets vented outside by fans.

The refrigerant, now a liquid, is forced through an expansion valve. This turns the liquid into a mist and rapidly cools it.

The cold mist travels through evaporator coils. Air blown over the coils gets cooled. Heat from the air vaporizes the refrigerant.

## **CURRENT REFRIGERANTS**

Chlorofluorocarbons (CFCs) were discovered in 1928 and replaced more toxic refrigerants such as ammonia, methyl chloride, and propane.



In the upper atmosphere, ultraviolet radiation triggers reactions with CFCs that produce chlorine atoms, which destroy ozone. A 1987 international agreement, the Montreal protocol, required CFC production to stop. Hydrochlorofluorocarbons (HCFCs), used as CFC replacements, will be phased out in coming years.

Hydrofluorocarbons (HFCs) have replaced CFCs and HCFCs. These replacements do not contain chlorine atoms, so they pose no harm to the ozone layer.

ODP = 1.0 ODP = 0.05 ODP = 0 GWP = 10,900 GWP = 1,810 GWP = 14,800

ODP = ozone depletion potential (scale 0-1.0)

GWP = global warming potential (CO<sub>2</sub> = 1)

HFCs have a higher global warming potential than CFCs and HCFCs. As a result, a 2016 amendment to the Montreal protocol plans a phaseout of HFCs.

## THE NEXT GENERATION

Hydrofluoroolefin (HFO) refrigerants could replace HFCs. They have a lower global warming potential, but they are also more expensive.

$$F = \bigcap_{F} F$$
  $O = C = O$ 

ODP = 0 GWP=4 ODP = 0 GWP = 1

Some car air-conditioning units use HFO-1234yf. But scientists are concerned that it is flammable, so some manufacturers are using carbon dioxide instead. Some experimental systems in development do not use any refrigerant gases to cool air.

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