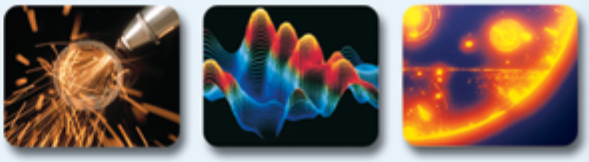
Chemistry in Action



Catalytic Converters

To see an important example of *heterogeneous catalysis*, you do not need to look any farther than the streets near your home. The *catalytic converter,* an important part of a vehicle's exhaust system, uses metal catalysts to reduce harmful gaseous pollutants.

In an automobile engine, hydrocarbon molecules in gasoline or diesel fuel undergo a combustion reaction with oxygen from air to make carbon dioxide, CO_2, and water. The correct stoichiometric ratio of fuel to oxygen is required for the fuel to be completely burned in the reaction. Additional reaction products are formed when not enough oxygen or excess oxygen is present. These products include carbon monoxide, CO, and NO_x compounds, such as nitric oxide, NO, and nitrogen dioxide, NO_2. There is also leftover unburned fuel, which is called a volatile organic compound (VOC).

The Clean Air Act, enacted in 1990, regulates automobile emissions of CO, NO_x, and VOCs. Without a catalytic converter, a car would release all of the byproducts of incomplete combustion into the atmosphere. In addition to being harmful themselves, NO_x compounds, CO, and VOCs react with sunlight to make ozone, O_3. In the lower atmosphere, ozone is a major part of photochemical smog. NO_x gases can also mix with rainwater to produce acid rain.

Catalytic converters use precious metal catalysts to change the gases coming from the engine into less harmful gases. A combination of rhodium and platinum, and sometimes palladium, is used to convert nitrogen compounds back into N_2 and O_2. This combination also converts CO into CO_2 and converts VOCs into CO_2 and water. The catalysts need O_2 from the air and temperatures above approximately 500°F to work properly. The temperatures are achieved from the normal operation of the car engine. However, until the car engine reaches the temperatures needed for the catalysts to work, CO, NO_x, and VOCs will be released into the air by the automobile.

The interior structure of a catalytic converter is usually made of a ceramic honeycomb with a surface coating of metal catalyst particles. The honeycomb has many holes for the gases to pass through and provides a large surface area for the metal to be deposited on. A large surface area is needed to maximize the reactions that occur during heterogeneous catalysis because the transformation of the gas molecules occurs at the surface of the metal.

Up to 90% of CO, NO_x, and VOCs are typically eliminated from automobile exhaust by a catalytic converter. Although catalytic converters are beneficial to our environment, they could still be improved.

▲ *The ceramic honeycomb inside a catalytic converter is coated with a metal catalyst.*

Catalysts that work at lower temperatures would reduce an automobile's emission during the first few minutes of operation. Other gases that are emitted by cars may also pose problems for the environment. Nitrous oxide, N_2O, can be formed from the incomplete reduction of NO_x in catalytic converters. Unlike the NO_x gases, N_2O can travel to the upper atmosphere, where it can destroy ozone. As a greenhouse gas, N_2O is more that 300 times more potent than CO_2.

Questions

1. Why do you think a heterogeneous catalyst is used instead of homogeneous catalyst in a catalytic converter?
2. Nitrous oxide, N_2O, actually has beneficial uses, despite its role as a greenhouse gas. Can you name a beneficial use of N_2O?