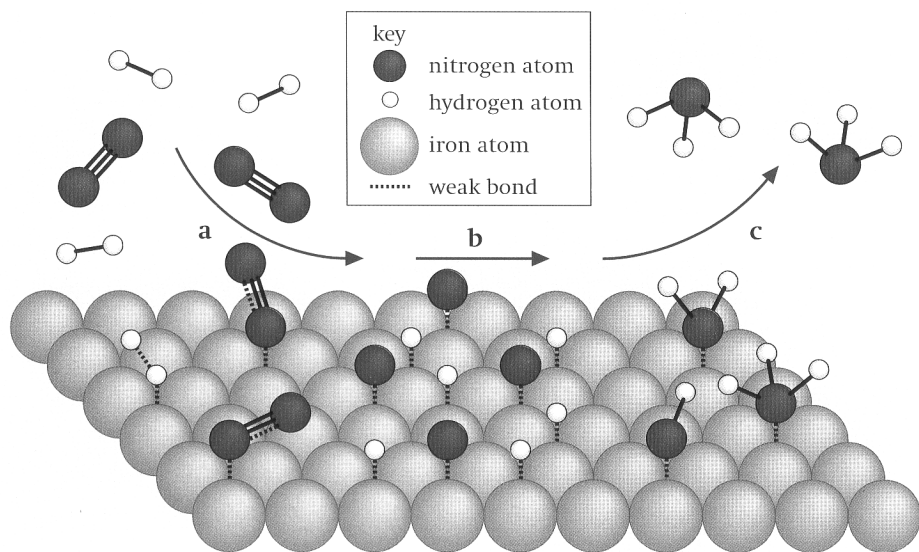


● **Figure 8.42** A scanning probe microscope (SPM) picture of oxygen on a copper surface. The diagonal rows coloured orange are copper atoms. **a** is an oxygen molecule, O_2 , adsorbed on the surface. **b** are four O^- ions. The distance between these is about 0.80 nm, which is large enough to show they are not bonded together.



a Adsorption of nitrogen and hydrogen molecules onto iron catalyst surface. Each molecule bonds weakly to iron atoms, causing bonds in the molecules to weaken.

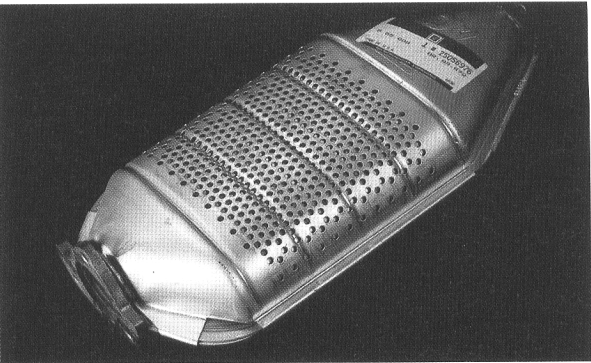
b Nitrogen and hydrogen molecules dissociate into atoms as covalent bonds break on the surface of the catalyst. Nitrogen and hydrogen atoms bond to iron atoms.

c Nitrogen and hydrogen atoms combine in steps to form ammonia molecules. Desorption of ammonia molecules readily occurs as weak bonds to iron break.

Catalytic converters

Another area where chemists have contributed to an improvement in air quality is the development of catalytic converters. It is now a legal requirement for the exhausts of all new cars sold in many

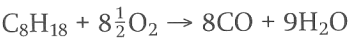
● **Figure 8.41** A possible model for the reaction pathway for the formation of ammonia from nitrogen and hydrogen by the Haber process. Heterogeneous catalysts bond to reactants which are **adsorbed** onto the catalyst atoms. Covalent bonds in the reactants are weakened and broken. New bonds form to give the product molecules which are **desorbed** from the catalyst.



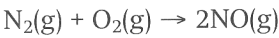
● **Figure 8.43** A three-way catalytic converter is designed to remove carbon monoxide, oxides of nitrogen and unburnt hydrocarbons from an engine's exhaust gases.

countries to be fitted with a catalytic converter. Figure 8.43 shows a modern catalytic converter.

These pollutant gases are present in the gaseous mixture produced following the combustion of petrol in the engine of the car (see table 8.11). Carbon monoxide is formed by the incomplete combustion of fuel. This will occur when there is insufficient air mixed with the fuel. An equation for the incomplete combustion of octane is:



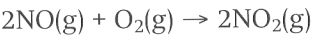
Nitrogen(II) oxide (monoxide) forms at the very high temperatures inside the engine (around 1000 °C). This high temperature provides sufficient energy for nitrogen and oxygen molecules to combine to form nitrogen(II) oxide:



SAQ 8.16

What is the source of nitrogen in the engine?

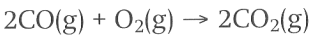
Nitrogen(II) oxide is oxidised when it mixes with air:



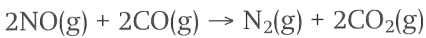
The product, nitrogen(IV) oxide, $\text{NO}_2(\text{g})$, is a brown gas; nitrogen(II) oxide, $\text{NO}(\text{g})$, is colourless.

The catalytic converter helps to promote the following reactions:

- The oxidation of carbon monoxide to carbon dioxide:



- The reduction of nitrogen monoxide back to nitrogen:



- The oxidation of hydrocarbons to water and oxygen. For example:



The catalyst can be expensive, as it is made of an alloy of platinum, rhodium and palladium. Research to reduce costs has led to oxides of transition metals like chromium being used instead. As with other examples of heterogeneous catalysis, the above reactions will involve adsorption of the reactants on the surface of the catalyst, followed by chemical reaction and then desorption of the products as gaseous molecules. Catalytic converters must be hot to start working (typically 150–240 °C). They are not effective on short journeys.

Name of gas	Formula	Origin	Effect
Carbon monoxide	CO	Incomplete combustion of hydrocarbons in petrol	Poisonous gas that combines with oxygen-carrying haemoglobin in the blood, and prevents oxygen from being carried
Nitrogen dioxide	NO ₂	Atmospheric nitrogen and oxygen combine under the high-temperature conditions of the engine to form nitrogen monoxide. This is oxidised in the atmosphere to form nitrogen dioxide	Nitrogen dioxide is involved in the formation of photochemical smog and low level ozone
Hydrocarbons	C _x H _y	Some hydrocarbons in petrol may not be combusted at all	Some hydrocarbons (for example benzene) are toxic and may cause cancer

● **Table 8.11** Pollutants in vehicle exhaust fumes.