wonders of chemistry

The jeans that eat pollution

You may have heard of catalytic converters, but I bet you haven't heard about catalytic clothing. It is still in the early stages of development, but imagine if our clothes could purify the air we breathe...

Exam links

This 'Wonders of chemistry' is relevant to the following A-level topics:
- pollution
- catalysis
- atmospheric chemistry

Catalytic converters in cars turn harmful gases produced during combustion into less harmful gases that are then released. So why do we need catalytic clothing?

Catalytic converters are not 100% efficient and pollutants do escape. It is these pollutants that catalysts on our clothes would break down, forming soluble products that would be washed away when cleaned.

Anti-acid rain

Developments in catalytic clothing have targeted NO_x pollutants (see Chemistry Review, Vol. 9, No. 4, pp. 2–6), due to their significant role in the formation of acid rain:

$$\underset{\text{Nitrogen dioxide}}{2NO_2} + \underset{\text{Water}}{H_2O} \rightarrow \underset{\text{Nitrous acid}}{HNO_2} + \underset{\text{Nitric acid}}{HNO_3}$$

Another cause for concern is their role in the formation of low-level ozone (O_3, see Chemistry Review, Vol. 20, No. 2, pp. 7–9). **Volatile organic compounds (VOCs)** are released by unburnt fuels. Once in the atmosphere, unburnt hydrocarbons and NO_2 react together to form low-level ozone, a serious respiratory irritant.

Catalysts (see Chemistry Review, Vol. 20, No. 3, pp. 27–31) are substances that increase the rate of a chemical reaction without being used up in the process. They provide alternative pathways for reactions to proceed, lowering the **activation energy**. To produce jeans that can have a catalytic effect on the compounds in the air, we need to incorporate a catalyst into the fabric.

Wash-in catalysts

Nano-sized titanium(IV) oxide (titanium dioxide, TiO_2) photocatalysts can be packaged into shells that are attracted to, and consequently bind onto, our clothes during a wash cycle. Nanoparticles range in size from 0.1 nm to 100 nm, and due to their size possess a huge surface area to volume ratio — making them excellent catalysts.

Photocatalytic TiO_2 absorbs sunlight, causing valence electrons to move to higher energy states. These excited electrons react with water in the air, forming hydroxyl radicals

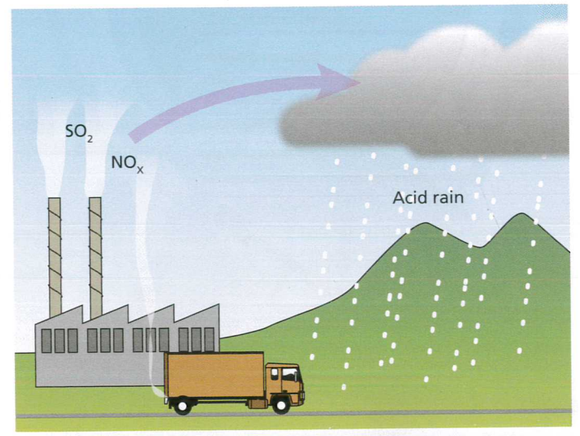

Figure 1 Acid rain formation. Emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NO_x) react in the atmosphere with oxygen and water to form acids such as sulfuric acid (H_2SO_4) and nitric acid (HNO_3). Solutions of these acids can fall to the ground as acid rain

(•OH) and oxide anions. The radicals react with the NO_x gases, generating soluble nitrates that are less harmful. The same type of technology is already used in certain paving slabs that have TiO_2 incorporated into them (see Chemistry Review, Vol. 11, No. 2, pp. 22–23), which reduce the NO_x levels in city streets.

These photocatalysts will hopefully soon be integrated into washing powders, enabling us to make garments we already own catalytic.

Photocatalysts could be integrated into washing powders

Worn and loved the world over, jeans have been targeted to host this technology. It has been calculated that 1 m^2 of fabric can remove 0.5 g of NO_x pollutants per day. Just imagine how much would be removed if every pair of jeans worn was catalytic.

Glossary

Activation energy The minimum kinetic energy that a molecular collision must possess if the molecules are to react.

NO_x (nitrogen oxides) A mixture of nitrogen oxides, such as nitrogen oxide (nitric oxide, NO) and nitrogen dioxide (NO_2), is collectively termed NO_x. Usually emitted as NO (by combustion of fossil fuels or naturally by lightning), the two species are easily interconverted by the reaction of O_3 with NO to form NO_2 and the photolysis of NO_2 by sunlight to reform NO.

Volatile organic compounds (VOCs) Organic (carbon-containing) chemicals that vaporise easily at room temperature. VOCs are present as gases at trace levels in the atmosphere. Examples include methane, ethane and propane.

Convincing customers

But would people want to act as the host for such a reaction? The catalysts trigger the reaction in the surrounding air, so people nearby would benefit from our actions. Could this be the world's first altruistic clothing? As chemists, we should not be afraid of convincing others about our ideas. Let's promote this chemistry as something exciting and amazing. We need to change what we can and spread the message, because frankly, it's utter 'jeanius'.

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