BUSINESS

Worth its weight in platinum

Booming mineral prices leave car makers scrambling to eke more catalytic performance out of precious metals. **Jeff Tollefson** reports.

Lovers may adore platinum's silvery sheen in their favourite jewellery — but at least they can switch to gold or silver if the price isn't right. Chemical engineers wish they had the same option.

Thanks to their role in catalytic converters, platinum, palladium and rhodium have all become crucial bulwarks in the fight against air pollution. Platinum and palladium can catalyse reactions that convert hydrocarbons and carbon monoxide into carbon dioxide and water vapour. Rhodium catalyses another reaction, converting nitrogen oxides into nitrogen and oxygen. These reactions are at the heart of the three-way catalytic converters now fitted on almost all cars in the developed world and on an increasing share of those in India, China and elsewhere.

Although materials such as gold and nickel can perform similar tricks at lower temperatures, only these platinum-group metals can do the job at the high pressures and temperatures of 900 °C or more that are found in vehicle exhaust systems. With demand from the global automobile industry pushing prices ever higher and no alternative catalysts on the immediate horizon, car manufacturers are now locked in a race to make each ingot go that a little bit further.

"From a scientific standpoint, the three-way catalytic converter is really a done deal. It's now an engineering feat to bring the volume of metals down," says Johannes Schwank, a chemical engineer at the University of Michigan in Ann Arbor.

Chemical engineers are working on the problem at the molecular level, trying to make the catalyst layers even thinner and diluting them with cheaper alloys. Equally important is the design of the underlying structure to which the catalysts are applied — although the location of the catalytic converter and engine design can also play parts. The competition is taking place largely beyond the academic eye in industrial labs around the world.

Catalytic converters were first put into use in the 1970s after the world's first regulations on car emissions came into effect in California. Automobile firms in the United States developed the technology based on advances in surface chemistry made during the previous decade.

General Motors, Ford and Chrysler were all involved in the development of the catalytic converter, which Schwank regards as one of the greatest achievements in the history of chemical engineering. He compares the hydrocarbon, carbon monoxide and nitrogen oxide molecules in the converters to helicopters trying to land on the roof of a hospital; the electrochemical properties of platinum, palladium and rhodium provide an ideal landing pad. Other elements might not allow them to land at all, or might "hold them hostage" after their arrival, he says. "The strength of the bonds is just about right to carry out the reactions, but not so strong that the reaction agents won't have a chance to leave."

JOHNSON MATTHEY PLATINUM 2004

Catalytic-converter production in Shanghai: global demand for the units is surging.

At first, car makers relied on platinum for this function, but eventually switched to its sister metal, palladium, at one-third of the price. When palladium prices spiked in 2000, they went back to platinum, but the cycle has now repeated itself. Platinum prices are approaching US$1,500 per troy ounce (this historic measure of precious metals is the equivalent of about 31 grams); palladium costs less than $400.

The recent march of car makers back to palladium has helped to moderate the price of platinum, as has slower demand from jewellers, according to Johnson Matthey, a leading catalyst-making firm based in London. However, platinum performs better than palladium in diesel exhaust systems.

Global platinum supplies stood at more than 7.6 million troy ounces in 2006, 66% of which was used in autocatalysts, according to Johnson Matthey. Those figures include the recovery of 855,000 troy ounces of platinum from recycled autocatalysts, which provided 11% of overall global demand. South Africa supplied 78% of the world's new platinum in 2006 and is home to the only mines in which platinum is a primary product. For the decade ending in 2006, platinum production increased by more than one-third — but demand for autocatalysts more than doubled.

Platinum and palladium can play off each other, but manufacturers have to pay whatever the market demands for rhodium, for which there is no alternative. Posted at around $6,500 per troy ounce — almost eight times the price of gold — rhodium is one of the most expensive elements on Earth. A staggering 87% of the world supply goes into autocatalysts.

Jeremy Coombes, an analyst for Johnson Matthey, says that the amounts of the metals used in each catalyst depend on the size of the car, the kind of fuel being used and the local air regulations, and can range from 1–2 grams for

a small car in a lightly regulated environment to 12–15 grams for a big truck in the United States. That translates to anywhere from $25 to a few hundred dollars per vehicle, he says: a significant amount for the likes of Toyota, which sold 2.5 million vehicles last year.

Autocatalysts often use honeycomb-like structures to create vast surface areas — equivalent to perhaps a couple of football pitches in each converter — in which reactions can take place. The catalysts are layered as thinly as possible, often by dipping a ceramic structure into a solution of the metal. The gradual agglomeration of metal particles under intense heat, eventually reducing the surface area and catalyst efficiency, is one of catalyst designers' main challenges.

Nissan announced in August that it has deployed a new fabrication method that uses nanotechnology to reduce agglomeration. The company claimed the technique would halve the use of precious metals in its catalytic converters. Mazda said last month that it can now embed nanoparticles made of platinum-group metals into ceramic spheres, cutting use "by 70–90% with the same level of purifying efficiency". But no public data are available to verify these claims.

Although few see prospects for replacing platinum-group metals in catalytic converters, researchers are searching hard for alternatives in applications that use low-temperature catalysis. Designers of fuel cells, which catalyse hydrogen and oxygen to produce electricity and water vapour, are eagerly seeking cheaper alternatives to platinum. And Schwank says that nickel has shown promise as a catalyst for onboard fuel reforming, a technique for generating hydrogen from fossil fuels for use in fuel cells.

"There is simply not enough platinum and rhodium."

And although advances in catalyst design are likely to further reduce the amount of platinum, palladium or rhodium needed in each vehicle, those gains might not be enough. Global automobile production has risen from 56 million vehicles in 2000 to more than 66 million last year and it shows no signs of slowing, according to the consulting firm Global Insight in Waltham, Massachusetts.

"There is simply not enough platinum and rhodium going round on this planet to satisfy the collective demand of automotive emission-control systems and all of these other areas," Schwank says. Supply is sure to follow demand upwards in years to come, but few analysts expect it to get out in front, and pull prices down. That will leave new technologies that need the platinum-group metals, such as fuel cells, paying a heavy price for autocatalysts' insatiable appetite for them. ■

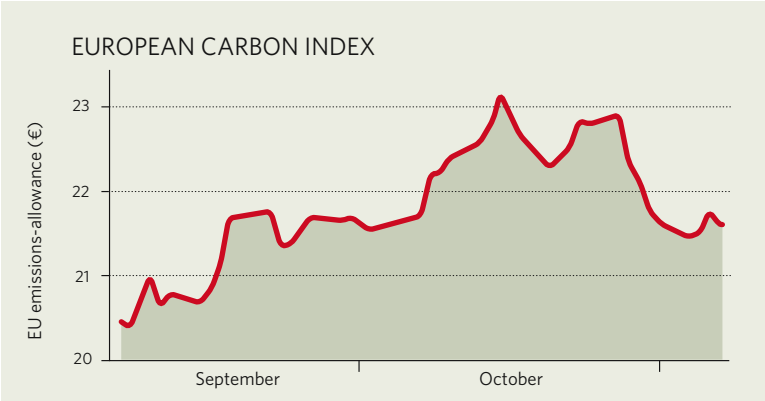
IN BRIEF

PULLBACK FROM PROTEINS Genomics company Celera in Rockville, Maryland, has confirmed that it has laid off as many as half of its 50-odd proteomics researchers over the past six months. "The business is shifting from discovery into development, and that's throughout the organization," says David Shipley, a spokesman for the company, who declined to specify the exact number of departures. He added that the cuts at the company, which employs 540 people, were confined to proteomics. The announcement came as Celera reported its first-ever profitable quarter, and on the heels of its October acquisitions of two firms in the San Francisco Bay area — Berkeley HeartLab and Atria Genetics.

TAG TEAM Ford and Daimler joined forces to buy the automotive fuel-cell division of Ballard Power Systems of British Columbia, Canada, in a deal worth $228 million. Ballard is one of the leading developers of fuel cells, which burn hydrogen and remain a long way from commercialization: some analysts estimate that costs need to come down a hundred-fold to make them competitive with internal-combustion engines. But the move by the two big rival car companies was seen by motor-industry analysts as a significant step toward the eventual adaptation of fuel cells into the mainstream motor industry.

FLU DRUG FALL Chugai, the Japanese distributor of Tamiflu, has said that it will halve the amount of the drug it is preparing to sell this winter in response to the precipitous drop in demand, brought about by reports earlier this year associating it with teenage suicide (see *Nature* 446, 358–359 and 481; 2007). In March, the government issued a safety warning against prescribing the drug for teenagers. The fall is a serious blow to Tokyo-based Chugai and to Roche, its parent company based in Basel, Switzerland, which makes the drug. Japan has in the past accounted for up to 70% of Tamiflu's global sales.

MARKET WATCH



The price of carbon allowances for the European Union's emissions-trading scheme for 2008 to 2012 increased moderately in late summer and early autumn, but has dropped slightly since mid-October. The trend is being driven, analysts say, by rising prices for oil and natural gas, which makes it profitable for energy utilities to switch to coal, which is cheaper but more carbon dioxide-intensive.

A 'carbon credit' to emit one extra tonne of CO_2 during 2008, for example, last week cost €22 (US$32) at the European Energy Exchange in Leipzig, Germany — up from €18 in late-August.

Price volatility for the allowances is likely to become more pronounced in the winter, market watchers say, when trade volumes at Europe's five carbon exchanges tend to peak. And some of them expect the price to rise further.

"A price of €25–30 is not unrealistic in the near future," says Stefan Kleeberg, a carbon-market analyst with the 3C Group near Frankfurt, Germany.

Prices on the carbon-credit market could also rise as a result of delays in the certification of clean-development projects in poorer nations, says Kleeberg. Shares in the leading British carbon-trading specialist EcoSecurities slumped by almost half last week after the company announced that some 30 million tonnes of carbon credits that had been anticipated by 2012 would probably not materialize.

The price trend comes against a backdrop of continued growth in global carbon emissions, according to the International Energy Agency's latest World Energy Outlook, released on 7 November. ■

Quirin Schiermeier