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Guest Editorial

Platinum Group Metals for a Greener Future

Clustered together in the centre of the Periodic Table lie six remarkable elements, six metals without which the world would be a completely different place. Think about the food you eat, your computer, your car, your mobile phone or even the clothes you wear. At some stage during their production one or more of these six rare metals has been utilised, whether as a catalyst or perhaps in the end product itself. The platinum group metals (pgms) play an essential role in our modern lifestyles.

Platinum, palladium, rhodium, ruthenium, iridium and osmium are rare, expensive and have a unique combination of incredibly useful properties. For example, high thermal stability, corrosion and oxidation resistance and the ability to catalyse a broad range of chemical reactions make them indispensable in processes such as petroleum refining, nitric acid, bulk chemical production and glass manufacture. They are also to be found in a diverse range of products such as the hard disk drives in computers and data storage centres, the airbag in your car or the jet engine that carries you to your holiday destination. Apart from their chemical properties the pgms and platinum and palladium in particular have found favour in both the jewellery and investment markets. Platinum has for many years been marketed as a premium jewellery metal, rarer and more precious even than gold.

Science and Industrial Applications

But it is not for the pgms' aesthetic or investment value that this collection of papers has been collated, rather to highlight the fascinating science of these incredible metals and their wide range of industrial uses. This special edition of the *Johnson Matthey Technology Review* will examine both the fundamental properties of these metals and their use in a variety of applications and fields.

The pgms are rare elements, occurring in economic quantities in only a few geographical locations. Demand is generally price inelastic, meaning that consumption volumes are often relatively insensitive to underlying metal prices (1). Importantly, the pgms are widely recovered and recycled; for example, through the recovery of catalytic convertors from end of life vehicles or through a closed-loop system where the catalyst that is installed in a chemical plant is recovered, sent for refining and ultimately reused. Sustainability not only of the metals themselves but also with regard to their end uses is why the pgms are so important, as described in two of the articles – European projects BIORECOVER and PLATIRUS.

The use of platinum, palladium and rhodium is dominated by the automotive sector where for several decades they have been a vital component in emission control catalysts. These three metals have been fundamental in removing carbon monoxide, hydrocarbons and nitrogen oxides from gasoline and diesel engine exhausts to dramatically improve air quality across the world, as detailed in several publications by one of our authors, Martyn Twigg, who in his long career was at the forefront of autocatalyst development (2–4).

In this special edition, Twigg and Emeritus Reader John Burgess from the University of Leicester, UK, have written a two-part commemoration of the late Professor Bob Gillard, discussing his remarkable life, work and contribution to the understanding of transition metal chemistry, particularly the chemistry of rhodium and other platinum group metal complexes.

The use of pgms by the chemical industry is of vital importance to a huge range of bulk and speciality products. One example of this is the oxidation of ammonia to produce nitric acid which has used platinum and rhodium in catalyst gauze for over 100 years (5). The latest work in this field will be discussed by Ashcroft in this special edition. Interestingly, the use of pgm for chemical catalysts has remained one of the more

robust areas of demand during the coronavirus disease (COVID-19) pandemic. Nitric acid is used to manufacture both fertilisers for global crop production and explosives for the mining industry, which are essential for the supply of metals such as nickel and platinum and will be central to the future electrification of the automotive fleet.

The minor pgms ruthenium, iridium and osmium can often appear somewhat neglected despite their use in a huge number of applications. Iridium is prized for its high melting point which makes it ideal for use in crucibles to produce high purity metal oxide single crystals, used in medical scanners, light-emitting diode production and surface acoustic wave filters, amongst others. The behaviour and properties of iridium are the subject of two papers in this edition. Osmium is perhaps the least known of the metals given its more limited applications. However, Arblaster has remedied that with a paper discussing the thermodynamic properties of the densest element in the Periodic Table.

The Most Useful Elements

The pgms are among the most invaluable elements discovered. To sum up all their useful properties in one key attribute is that they enable the world to be a more sustainable place. Globally we are starting to undergo a monumental change in energy use and production, away from reliance on fossil fuels towards a cleaner, greener, more sustainable model (6). The move to hydrogen as an energy source is vital in the move to a net zero economy, a key example of which is the fuel cell vehicle. Johnson Matthey actually provided the platinum to William Grove when he demonstrated the first fuel cell in 1839 (7). Aside from the use of pgm in the catalyst of the vehicle itself, the production of hydrogen of suitable purity makes use of one of the key properties of palladium. Palladium has an intrinsic selectivity for hydrogen, which makes it an ideal choice for purification membrane technology. In this issue, Faizal *et al*. discuss the use of palladium in this vital application for the growing hydrogen economy.

The pgms: six of the rarest elements in the Periodic Table that have and continue to change the world around us. Metals that are driving forward sustainable technology and the move towards net zero, metals that will help drive the clean energy revolution, provide food to billions and facilitate communication and data sharing and storage across the globe to enable a more connected society.

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