IPA
INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

3

PRODUCTION AND USES OF PLATINUM GROUP METALS

CONTENTS

SUMMARY

- Major deposits of PGMs are found in South Africa, Zimbabwe, the U.S., Canada, and Russia. South Africa is the largest producer of PGMs, followed by Russia.

- PGMs are extracted either from newly-mined primary ore or from used, scrap, or by-product metal. Primary production and secondary recovery involve various different processes to form a PGM-rich concentrate which subsequently becomes the feedstock for PGM separation and purification in dedicated refineries.

- PGMs and their compounds have inherent properties —such as their unique catalytic activity, resistance to corrosion and oxidation, mechanical strength, biocompatibility, and electrical conductivity—that make them of significant benefit to society. PGMs are often superior in use to other materials and are not readily substitutable.

- Many of the applications of PGMs—from environmental protection (as components of automobile catalytic converters) to health care (as ingredients in pharmaceuticals and medical devices) to making useful chemicals and consumer products (as in fertilisers, gasoline, electronic equipment, computers, and plastics)—are shown in Table 3-2.

3.1

GEOLOGICAL OCCURRENCES

Although small quantities of PGMs occur in placer deposits, particularly in the Ural Mountains in Russia, the major commercially mined deposits have nickel-copper sulphides associated with igneous mafic and ultramafic rocks of volcanic origin which are rich in magnesium and iron. The primary silicate mineralogy is feldspathic pyroxenite containing olivine, amphibole, and norite/anorthosite. Base metal mineralogy is dominated by pentlandite (Ni,Fe)S, chalcopyrite ($CuFeS_2$), and pyrrhotite (FeS). Some typical PGM mineralogy has been described in Chapter 2.

The main deposits are in South Africa (Merensky Reef, UG2, and Platreef), Zimbabwe (Great Dyke), North America (Stillwater, Montana, USA and Sudbury, Ontario, Canada) and Russia (Norilsk-Talnakh complex). Around 60% of world primary PGMs production, including 75% of global primary platinum output, comes from South Africa; Russia produces nearly 25% of new PGMs, with palladium predominant.

The Southern African deposits generally contain a higher proportion of platinum than palladium; typically between 1.4:1 and 2.2:1. PGMs are the primary economic drivers, with relatively small co-production of copper and nickel. Conversely, the Canadian and Russian deposits are major sources of nickel and copper with comparatively small quantities of PGMs and reversed platinum to palladium ratios; typically 1:3 or 1:4. The Stillwater ores have similar PGM ratios to the other northern hemisphere deposits, but far lower base metal content. These variances in metal ratios can make substantial differences to refining process strategies and economics.

Figure 3-1: Winding gear at platinum mine in South Africa (courtesy of Impala Platinum)

3.2

PRIMARY AND SECONDARY PRODUCTION

PGMs are either extracted from newly-mined primary ore, mainly from the sources described above, or refined from secondary sources, *e.g.*, used, scrap, or by-product metals, compounds and mixtures.

Johnson Matthey estimated primary supply in 2015 of the main platinum-group metals platinum, palladium and rhodium amounted to 13.31 million troy ounces (oz). This was augmented by a further 4.46 million troy oz of platinum, palladium, and rhodium recovered from end of life consumer products—automobile catalytic converters, jewellery scrap, and old electrical equipment (Johnson Matthey, 2016). Detailed supply by region is shown in Table 3-1.

QUANTITY, '000 TROY OZ			
Location	Pt	Pd	Rh
South Africa	4,571	2,684	611
Russia	670	2,434	80
North America	318	864	23
Zimbabwe	401	320	35
Rest of the World	149	142	5
Total World Supply	6,109	6,444	754

Source: Johnson Matthey PGM Market Report November 2016.

Table 3-1: Primary Supply of Platinum, Palladium and Rhodium, 2015

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PRIMARY AND SECONDARY PRODUCTION

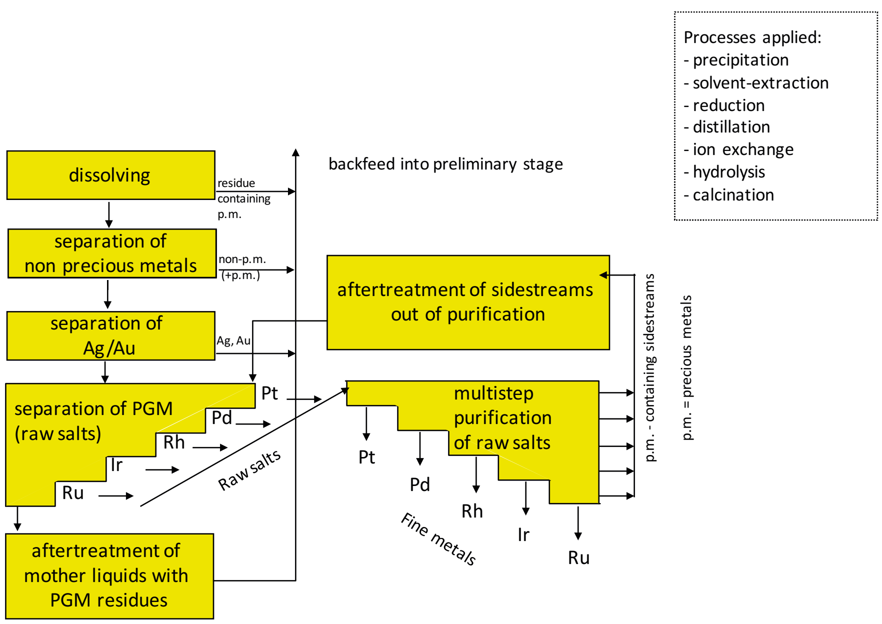
PRIMARY REFINING PROCESSES

In primary PGM production, ores from the major deposits all go through a similar series of initial process stages involving crushing, milling, and froth flotation to produce a base metal-PGM concentrate. This concentrate, containing considerable quantities of silicates and iron from the original ore, is subjected to high-temperature smelting to produce a silicate slag and a base metal-PGM sulphide matte. The slag is drawn off and the matte is processed by the injection of air to bring the iron down to low, controlled levels. In some operations, it may then be treated by slow-cooling to produce a magnetic nickel-rich phase with enhanced phase growth containing the vast majority of the PGMs which, after crushing and milling, can be recovered by magnetic separation. Alternatively, the crushed and milled converted matte may be treated hydrometallurgically to remove the base metals. In either case, a PGM-rich concentrate is produced which becomes the feedstock for PGM separation and purification in dedicated refineries. These refinery processes may be based on separations by any combination of solvent extraction, ion-exchange, distillation, or precipitation.

Figure 3-2 illustrates a typical refining process (including dissolving, separation and purification stages).

SECONDARY REFINING PROCESSES

Secondary PGM recovery is carried out by many different organisations and uses a much more diverse set of processes. Although secondary PGM recovery can be integrated into large, lower-cost base metal smelters, in many cases individual, smaller-scale processes are selected on the basis of appropriateness for the source materials. These processes can involve, for example, smelting with a metallic base metal collector, direct melting, and/or hydrometallurgical treatment, all producing concentrates which are then fed into PGM refineries.



Source: Umicore, C. Hagelueken, 2005.

Figure 3-2: Fundamental procedure for the processing of PGM concentrates

APPLICATIONS OF PGMs

PGMs have many inherent properties which make them useful, even though they are more expensive than most other materials. In many of their applications, substitutes for PGMs are either not feasible or are considerably inferior in performance. As discussed in more detail below, PGMs are of significant benefit to society, from environmental protection (as pollution control catalysts) and health care (as ingredients in pharmaceuticals and as medical treatments) to production of many useful chemicals and consumer products. Some main applications are shown in Table 3-2 and described below. Johnson Matthey has estimated demand for platinum, palladium and rhodium in 2015 at 18.98 million troy oz; 63% of this was for automobile catalytic converters, 22% for industrial and medical applications and 15% for jewellery and watches.

ENVIRONMENTAL PROTECTION

PGMs demonstrate extensive and sometimes unique catalytic activity. Their principal application in this field is the automobile catalytic converter which has been used to control pollution from motor vehicles since its introduction in the USA and Japan in the mid-1970s. As converter technology has improved, and as vehicle exhaust legislation has been tightened and extended to other countries over the past several decades, dramatic reductions in harmful emissions that can impair health have been achieved. It has been calculated that cumulative global total emissions saved by catalytic converters approach 2 billion tonnes over a 40-year period (Johnson Matthey, 2014; C Morgan, personal communication). A further beneficial consequence of the introduction of catalytic converter technologies has been the elimination of toxic lead-based gasoline additives (Johnson Matthey, 2004).

MANUFACTURE OF INDUSTRIAL AND CONSUMER PRODUCTS

When PGMs are used as industrial catalysts they often enable chemical reactions to take place at reduced temperature and pressure, resulting in energy and cost savings and reduced environmental impacts, as in the case of rhodium catalysts used in the production of plastics from propylene. PGM catalysts are also used to produce ammonia, acetic acid, silicones, chlorine, and many other chemicals which are ingredients of everyday goods such as polyester, nylon and synthetic rubber. Platinum-rhodium gauze catalyses the oxidation of ammonia to nitric acid as a precursor of ammonium nitrate fertilisers and explosives.

Platinum-rhenium catalysts are essential for reforming naphtha into high octane blending components for producing gasoline; and in fuel cells platinum and ruthenium are the catalysts for combining hydrogen and

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APPLICATIONS OF PGMs

oxygen to produce electricity for electric vehicles, standby and auxiliary power, and home heating.

Platinum and rhodium are resistant to corrosion and oxidation even at high temperature, and are used in the glass industry to contain and channel molten glass for the production of glass fibres and display glass for computers, smartphones, and TV monitors. Thin layers of platinum and ruthenium are coated onto computer hard disks to increase their data storage capacity. Palladium's electrical conductivity and durability make it useful in electronic components as capacitor electrodes, connectors, and circuits, particularly for military and aerospace applications where reliable operation is paramount.

HEALTH CARE

Platinum's mechanical strength, biocompatibility, electrical conductivity, and radio-opacity make it suitable for use inside the human body in devices such as pacemakers, defibrillators, and catheters for the treatment of heart disease; neuromodulation devices to treat Parkinson's disease and hearing loss; and in coils and catheters for the treatment of brain aneurysms. Specific compounds of platinum (the "platins") are effective in the treatment of a range of cancers. PGMs are also widely used as catalysts for the manufacture of pharmaceutical ingredients.

Figure 3-3: Platinum-chromium drug eluting stent (courtesy of Johnson Matthey, Drug Eluting Stent)

3.3

TABLE 3-2: APPLICATION OF PGMs IN PRODUCTS FOR EVERYDAY USE

Product	PGM	Applications
Automobiles	Pt, Pd, Rh Pt, Pd, Ir Pt Pt, Pd, Ru	Pollution Control Catalyst Spark Plugs Engine Control Sensors, Airbag Initiators Electronics for Engine Management Systems
Electronic Equipment	Pt, Pd, Ru, Ir	Connectors, Printed Circuits, Resistors, Capacitors, Lasers
Computers	Pt, Ru	Thin layer in hard disks to increase memory storage capacity
Jewellery	Pt, Pd, Rh	Rings, Chains, Pendants, Watch cases and straps
Glass and Ceramics	Pt, Rh	Glass Fibre, Display Glass, Optical Glass, Ceramic Glass, Tableware Decorative Patterns and Finishes
Medical & Biomedical	Pt, Pd, Rh, Ru, Ir, Os	Antitumor Drugs, Implants, Treatments for heart disease, Cancer screening
Chemical & Petroleum	Pt, Pd, Rh, Ru, Ir	Plastics, Polyester, Pharmaceutical Ingredients, High Octane Gasoline, Fertilizers and Explosives, Silicones
Aircraft Engines	Pt	Turbine Blades, Spark Plugs
Dental Restorations	Pt, Pd, Ru, Ir	Dental inlays, crowns, bridges
Fuel cells	Pt, Ru	Electric vehicles, standby and auxiliary power, domestic power and heating

Pt = platinum
Pd = palladium
Rh = rhodium
Ru = ruthenium
Ir = iridium
Os = osmium

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