Hydrometallurgy 154 (2015) 56–62

Contents lists available at ScienceDirect

Hydrometallurgy

journal homepage: www.elsevier.com/locate/hydromet

Recovery of palladium, platinum, rhodium and ruthenium from catalyst materials using microwave-assisted leaching and cloud point extraction

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ARTICLE INFO

Article history:
Received 17 September 2014
Received in revised form 16 March 2015
Accepted 21 March 2015
Available online 24 March 2015

Keywords:
Platinum group elements
Recycling
Hydrometallurgy
Microwave-assisted leaching
Cloud point extraction

ABSTRACT

The recovery of Pd, Pt, Rh and Ru from an automotive catalyst and from an alumina-supported Ru catalyst was studied. Microwave-assisted leaching of Pd, Pt, Rh and Ru was combined with cloud point extraction to obtain an environmentally friendly recycling method. A series of leaching experiments with HCl, HNO_3 and *aqua regia* at five different temperatures (90–210 °C) was performed in a microwave oven. *Aqua regia* and HCl were able to leach >90% of Pd, Pt, Rh and Ru at temperatures above 150 °C. At 120 °C slightly lower recoveries were observed, but also the leaching of the matrix elements was decreased. A cloud point extraction (CPE) method was applied to the samples obtained after HCl leaching at 120 °C. The method was first optimized to a suitable concentration level of Pd, Pt, Rh and Ru (>1 mg L^{-1}) by using a factorial design. Then, the appropriately diluted leach solutions (1 M HCl) were extracted and the recoveries of 91 ± 6% for Pd, 91 ± 5% for Pt, 85 ± 6% for Rh and 66 ± 11% for Ru were achieved. Simultaneously, the concentrations of the matrix elements (Al, Ce, Zr) were reduced by over 95%.

1. Introduction

Palladium, platinum, rhodium and ruthenium, together with iridium and osmium, are called platinum group elements (PGEs). These elements have a wide variety of applications in automobile, chemical, electrical, and medical industries (Cowley, 2013). For example, Pd, Pt and Rh are most commonly used in catalytic converters of automobiles. PGEs, especially Pt, are also used in jewelry. The abundance of PGEs in the earth's crust is low and their primary sources are geographically concentrated in certain locations (e.g., South Africa, Russia, North America and Zimbabwe) (Mudd, 2012). For example, in year 2012 South Africa was the biggest supplier of Pt and Rh, whereas Russia was the biggest supplier of Pd (Cowley, 2013). High demand of PGEs during the last decades, together with environmental, social, economic and political aspects related to their production, have led to discussion on the availability of PGEs in the future (Glaister and Mudd, 2010; Gordon et al., 2006; Mudd, 2012; Yang, 2009).

Due to their various applications, PGEs are available in many secondary sources (e.g., in spent catalyst materials). High economic value of the PGEs, together with their high concentration levels in the secondary sources, when compared to the primary sources, makes the recovery of PGEs in spent materials feasible (Hagelüken, 2007, 2012; Jha et al., 2013). PGEs can be recovered from spent catalyst materials using pyrometallurgical and hydrometallurgical methods. In pyrometallurgical processing, the catalyst materials are smelted in a high temperature (usually above 1500 °C) in the presence of suitable fluxes to form a liquid slag, from which the PGEs are collected to a collector metal (e.g., Cu or Fe) (Benson et al., 2000; Willner et al., 2014). In hydrometallurgical methods, the PGEs are leached from the catalyst materials using suitable reagents, for example acid or cyanide solutions (Jha et al., 2013). Hydrometallurgical methods can be applied for the PGE recovery either directly, after pyrometallurgical processing or after other pretreatment methods (e.g., thermal pretreatment or dissolution of base metals in sulfuric acid) (Jha et al., 2013). After initial leaching/dissolution of the PGEs, further refining can be used to separate the PGEs from base metals or from each other. For example, precipitation, extraction methods or ion-exchange can be applied for these purposes (Barakat and Mahmoud, 2004; Gupta and Singh, 2013; Jafarifar et al., 2005; Lee et al., 2010; Marinho et al., 2010; Mhaske and Dhadke, 2001; Nikoloski and Ang, 2014; Shams et al., 2004).

In industrial scale, pyrometallurgical methods are commonly used (Crundwell et al., 2011). These methods are effective, but slow and highly energy consuming. Hydrometallurgical methods, on the other hand, consume less energy, but often result to lower recovery efficiencies and tend to produce large amounts of waste solutions (Hagelüken, 2007; Rumpold and Antrekowitsch, 2012). Recently, many studies have targeted to develop environmentally friendly recovery methods for the PGEs. A lot of effort has been put to improve the leaching efficiency of these valuable metals in hydrometallurgical treatment of spent catalysts (Jimenez de Aberasturi et al., 2011; Kizilaslan et al., 2009; Nogueira et al., 2014; Rumpold and Antrekowitsch, 2012;

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http://dx.doi.org/10.1016/j.hydromet.2015.03.014
0304-386X/