Efficient Recovery of Gold and Platinum from Waste Sources Using Dithiocarbamate-modified Cellulose

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INTRODUCTION

Recovery of precious metals (PMs) like gold (Au) and platinum (Pt) from secondary sources is of considerable importance to mitigate imbalance in the supply-demand ratio as well as the toxicological effects. Most of the reported work has focused only on the extraction process of PM ions from solution, while their subsequent recovery in metallic pure and metallic form has been largely ignored. In the present study, a new approach has been explored for the selective recovery of Au and Pt from acidic solutions using bio-adsorbent, dithiocarbamate-modified cellulose (DMC), followed by subsequent recovery in elemental form.

MATERIALS AND METHODS

Preparation of DMC

DMC was synthesized according to a previously reported procedure (Nakakubo et al., 2019). The average particle size of DMC was maintained at ~200 µm in this study.

Real waste samples

An acid-leached wash solution of e-waste and an industrial effluent were used as real samples for the DMC-assisted recovery of Au and Pt, respectively. The element contents in the samples were as follows.

E-waste (mmol L^{-1}): Al, 0.148; Au, 0.039; Ba, 0.031; Cu, 141.6; Fe, 0.461; Ni, 2.561; Pb, 0.511; Zn, 4.911.

Industrial effluent (mmol L^{-1}): Co, 2.151; Cr, 0.037; K, 1.75; Pt, 1.301.

Adsorption studies

Batch adsorption experiments were carried out to investigate the adsorption properties of DMC against Au^{III} and Pt^{IV}. In a polypropylene conical tube (50 mL), the metal ion solution (10 mL) was mixed with DMC (5 mg) and then agitated at 200 rpm in a thermostatic shaker at a controlled temperature for a predetermined contact time. The adsorbent was separated via filtration using 0.45 µm nitrocellulose membrane filters and preserved for characterization and recovery experiments. ICP-AES was used for the analysis of metal content in the filtrate.

Post-adsorption recovery of Au and Pt

After adsorption, the Au^{III}-loaded and Pt^{IV}-loaded DMC were incinerated to recover the PMs in the corresponding elemental forms (i.e., Au^0 and Pt^0).

RESULTS AND DISCUSSION

It was observed that DMC possesses excellent selectivity and efficiency towards the adsorption of Au^{III} and Pt^{IV} at a wide range of pHs (1–6) and acid concentrations (up to 5.0 mol L^{-1}). The metal ions adsorption process was fast (Au^{III}: 20 min; Pt^{IV}: 30 min), and the maximum uptake capacities of DMC were evaluated as 5.07 and 2.41 mmol g^{-1} for Au^{III} and Pt^{IV}, respectively. The maximum adsorption capacities are significantly higher than most of the reported bio-adsorbents. The FTIR, XPS, XANES, and EXAFS analyses confirmed that DMC adsorbed the PMs through a complexation mechanism, followed by reduction. Furthermore, DMC was capable of the selective and quantitative extraction (> 99%) of Au and Pt from the real waste samples. The recovered Au and Pt-pellets (obtained by incineration of the PMs-loaded DMC) were pure, and the overall recovery yield was > 99% (Fig 1.; Biswas et al., 2020).

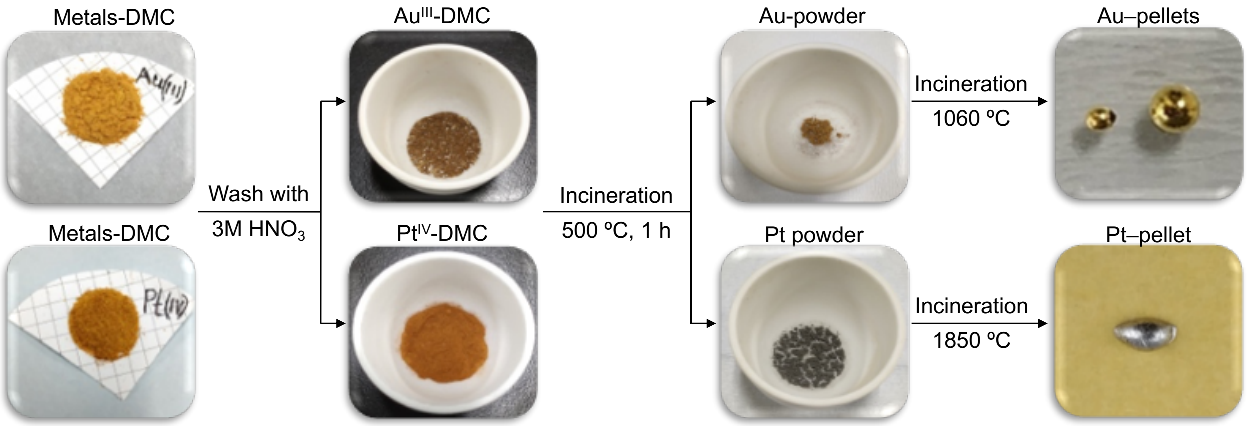

Fig 1. Schematic illustration of the recovery of pure Au^0 and Pt^0 by incineration of Au^{III}-DMC and Pt^{IV}-DMC.

CONCLUSION

Compared to the conventional adsorption-desorption-reduction approaches, the proposed technique of PM's post-adsorption recovery is straightforward, with an excellent recovery yield. Other advantages include process simplicity, high efficiency, non-utilization of cyanide or other toxic eluents, and recovery of the metals in their elemental form without any reductants. Therefore, the process can offer a sustainable pathway for resource (Au and Pt) recovery and increase valuable metals' global stock.

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