



## Separation of platinum and ruthenium by a sulphoxide modified polystyrene resin in laboratory column systems



Michael Trautmann, Hans-Jürgen Holdt\*

University of Potsdam, Institute of Chemistry, Inorganic Chemistry, Karl-Liebknecht-Straße 24-25, 14476 Golm, Germany

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### ABSTRACT

The present study deals with the adsorption performance of fixed bed columns using powdered sulphoxide modified poly(styrene-co-divinylbenzene) ( $d_{10} < 13 \mu\text{m}$ ,  $d_{50} < 30 \mu\text{m}$ ,  $d_{90} < 50 \mu\text{m}$ ) for the separation of platinum and ruthenium from hydrochloric acidic solutions containing both metals ( $c_{\text{Pt}} = 20 \text{ mg/L}$ ,  $c_{\text{Ru}} = 10 \text{ mg/L}$ ). The influence of hydrochloric acid concentration, temperature, flow rate, flow direction, redox potential and bed height on the breakthrough characteristics was examined. Platinum was separately adsorbed mainly induced by hydrochloric acid concentration and redox potential keeping platinum as  $\text{Pt}^{\text{IV}}$  and ruthenium as  $\text{Ru}^{\text{III}}$ . Ruthenium was separately adsorbed to 90% essentially induced by hydrochloric acid concentration, temperature and redox potential keeping platinum as  $\text{Pt}^{\text{IV}}$  and ruthenium predominantly as  $\text{Ru}^{\text{IV}}$ . Experimental data at optimised separation conditions were fitted to different kinetic models (Thomas, Yoon–Nelson, Bohart–Adams, Wolborska) to characterise the fixed bed column behaviour. Adsorption of both metals was well described by Thomas and Yoon–Nelson model with correlation coefficients  $R^2 \geq 0.95$  whereas Bohart–Adams and Wolborska model were less suitable.

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### 1. Introduction

Handling the world energy supply is always an actual topic and becomes more and more key issue for the future of humankind. Long-term scarcity of crude oil, gas and coal associated with global environment pollution requires exploitation of renewable energy sources. The further demand of mobile devices with battery longevity leads to the development of new portable low power systems because current rechargeable batteries have reached their theoretical energy density limits. For that purpose fuel cells exhibit high efficiency and high potential for environment-friendly energy conversion leading to a significant reduction of fossil fuel use. Proton exchange membrane fuel cells (PEMFC) as well as direct liquid fuel cells (e.g. direct methanol fuel cell (DMFC), direct ethanol fuel cell (DEFC)) are prime candidates for mobile application due to their compactness and portability. According to the theoretical energy density of pressurized hydrogen (3000 Wh/L) and methanol–water mixtures (3400 Wh/L), fuel cell systems can make more energy available than Li-ion batteries ( $\sim 1300 \text{ Wh/L}$ ) achieving longer operating periods at the same volume [1]. A big drawback is the elemental necessity of significant amounts of costly platinum group metals (PGMs) as catalysts at which carbon supported

platinum and platinum–ruthenium mixtures (1:1 atomic ratio) have emerged as best among all other catalysts [2]. Both metals are rare and mining is expensive hampering the broad commercialisation of fuel cell technology. The growing demand makes development of efficient and environmentally friendly recycling processes necessary. Catalyst recycling of exhausted fuel cells lowers manufacturing costs, reduces mining of primary sources and accordingly protects the environment. The classical route is a pyrometallurgical process. After stack dismantling, the membrane electrode assembly (MEA) is separated, shredded and incinerated followed by manifold extraction, solution and precipitation steps. Unfortunately incineration holds the adverse effect of releasing aggressive and toxic hydrofluoric acid what necessitates special linings as well as laborious gas scrubber. The hydrometallurgical route offers an alternative at which both metals are leached using strong oxidising acidic solutions [3]. Ruthenium is separated via distillation as its volatile tetroxide and platinum via precipitation or solvent extraction [4]. These processes are well established but offer disadvantages. Special design and construction materials are needed for distillation because volatile ruthenium compounds are highly explosive and extremely poisonous. Precipitation of platinum may be cheap but demands large quantities of precipitating agent and generates a lot of waste. Solvent extraction requires costly amounts of toxic and/or flammable organic solvents and consumes a lot of time due to multiple extraction steps. One useful

\* Corresponding author.

E-mail address: [holdt@uni-potsdam.de](mailto:holdt@uni-potsdam.de) (H.-J. Holdt).



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