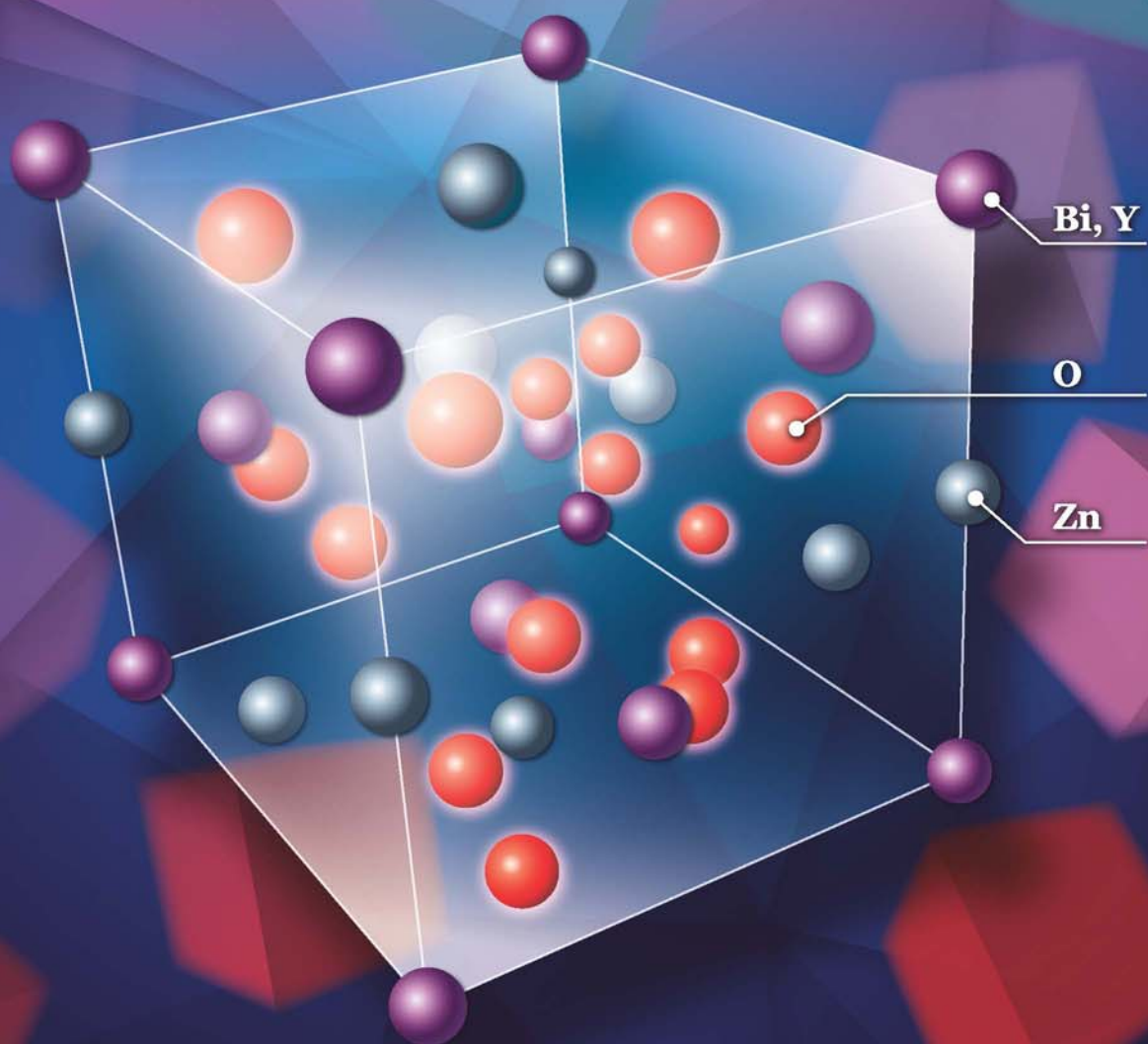


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A 1-dodecanethiol-based phase transfer protocol for the highly efficient extraction of noble metal ions from aqueous phase

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ABSTRACT

A 1-dodecanethiol-based phase-transfer protocol is developed for the extraction of noble metal ions from aqueous solution to a hydrocarbon phase, which calls for first mixing the aqueous metal ion solution with an ethanolic solution of 1-dodecanethiol, and then extracting the coordination compounds formed between noble metal ions and 1-dodecanethiol into a non-polar organic solvent. A number of characterization techniques, including inductively coupled plasma atomic emission spectroscopy, Fourier transform infrared spectroscopy, and thermogravimetric analysis demonstrate that this protocol could be applied to extract a wide variety of noble metal ions from water to dichloromethane with an efficiency of >96%, and has high selectivity for the separation of the noble metal ions from other transition metals. It is therefore an attractive alternative for the extraction of noble metals from water, soil, or waste printed circuit boards.

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Introduction

Noble metals, *e.g.*, gold, silver, rhodium and palladium, have been extensively used in many applications such as catalysis, electronics, optical, anti-corrosion materials and jewelry (Duan and Wang, 2013; Kowli et al., 2011; Lam et al., 2008; Roduner, 2006; Fontàs et al., 2002; Fricker, 1996), because of their unique chemical and physical properties (Swain et al., 2010). These applications have increased the demand for noble metals, whereas the natural resources are scarce (Swain et al., 2010; Lam et al., 2008; Begeerow et al., 1997). Therefore, it is necessary to develop various methods for recycling and separation of noble metals from diverse secondary resources (Ahamed et al., 2013; Cieszyńska and Wiśniewski, 2012). Solvent extraction (also called liquid–liquid extraction) is considered to be one of the most effective techniques for recycling of noble metal ions from their metal aqueous solutions (Cieszyńska and Wiśniewski, 2010; Regel-Rosocka et al., 2007). Indeed, liquid–liquid extraction for noble metal ions has been known and used for many

years. The examples include electrostatic interaction based extraction of gold(III) ions from an aqueous solution to a hydrocarbon phase (toluene) by means of a chemical agent, such as tetraoctylammonium bromide (Brust et al., 1994, 1995), Cyanex 301 based extraction of Ag(I) ions from aqueous HNO₃ solution to hexane (Shi et al., 2005, 2006), ionic liquid-based extraction of noble metal ions (Ag(I), Pd(II), and Au(III)) from their aqueous solutions (Lee, 2012), selective extraction of Pd(II) from hydrochloric acid solutions to toluene with phosphonium extractants (Cieszyńska and Wiśniewski, 2011), and separation and recovery of gold(III) from base metal ions using melamine–formaldehyde–thiourea chelating resin (Aydin et al., 2008). However, these methods usually make use of complex ligands to facilitate the metal ion extraction, and have only been applied to specific systems. Therefore, a universal and facile approach to extract ions for a sufficiently wide spectrum of noble metals is still lacking and poses significant challenges.

In the present work, we demonstrate a general phase transfer protocol, which is based on 1-dodecanethiol (DDT), for the highly

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efficient extraction of noble metal ions from aqueous phase to a non-polar organic medium. This protocol involves mixing the aqueous solution of noble metal ions with an ethanolic solution of DDT, and extracting the coordinating compounds formed between metal ions and DDT into dichloromethane. A number of characterization techniques, including inductively coupled plasma atomic emission spectroscopy (ICP-AES), Fourier transform infrared spectroscopy (FT-IR), and thermogravimetric analysis (TGA) were used to characterize the coordinating compounds formed between noble metal ions and DDT, and to address the following critical issues: (1) the transfer efficiency of noble metal ions; (2) the transfer mechanism of this DDT-based protocol; and (3) the selectivity of this phase transfer protocol for the extraction of noble metal ions.

1. Experimental section

1.1. Chemicals

Silver nitrate (AgNO_3 , ACS reagent, $\geq 99.0\%$), gold(III) chloride trihydrate ($\text{HAuCl}_4 \cdot 3\text{H}_2\text{O}$, ACS reagent, $\geq 49.0\%$ Au basis), ruthenium(III) chloride trihydrate ($\text{RuCl}_3 \cdot 3\text{H}_2\text{O}$, technical grade), rhodium(III) chloride (RhCl_3 , 98%), sodium tetrachloropalladate(II) (Na_2PdCl_4 , 98%), iron(III) chloride (FeCl_3 , 97%), zinc sulfate heptahydrate ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$, $\geq 99.0\%$), and osmium(III) chloride (OsCl_3 , 99.9% trace metals basis) were purchased from Sigma-Aldrich (St. Louis, USA). DDT (98.0%) was from J&K Chemical (Bei Jing, China). Ethanol ($>99.7\%$) and dichloromethane ($>99.5\%$) were purchased from Beijing Chemical Works (Bei Jing, China). Deionized water was distilled by a Milli-Q Ultrapure-water purification system. All glassware and Teflon-coated magnetic stirring bars were cleaned with aqua regia, followed by copious rinsing with deionized water before drying in an oven.

1.2. Phase transfer of noble metal ions from aqueous phase to dichloromethane

In a typical experiment, 50 mL of 1 mmol/L aqueous metal salt solution of Ag(I), Au(III), Os(III), Rh(III), Pd(II), or Ru(III) was mixed with 50 mL of ethanol containing 1 mL of DDT. After 5 min of vigorous stirring, 50 mL of dichloromethane was added and stirring was continued for 10 min. Phase transfer of metal ions from water to dichloromethane would then occur quickly and completely, as evident by the complete color bleaching of the aqueous phase. Assuming complete transfer of the metal ions from water, the metal ion concentration in dichloromethane would be 1 mmol/L. The metal ions in dichloromethane were separated from the aqueous phase, and collected for further characterization. The aqueous phase remaining was analyzed by ICP-AES to determine the transfer efficiency of the different kinds of noble metal ions.

1.3. Characterization

Concentrations of the initial and final metal ions in aqueous phases were analyzed with ICP-AES (Optima 5300DV, Perkin Elmer, Waltham, Massachusetts, USA) to determine the transfer efficiency of noble metal ions from aqueous phase to dichloromethane. The interaction between DDT and noble metal ions was confirmed by FT-IR spectra recorded on a Alpha-T spectrometer (Bruker, Ettlingen, Germany) using a

KBr pellet technique. TGA was carried out on a SAT449F3 Jupiter instrument (Netzsch, Sleib, Germany) from room temperature to 1073 K at a heating rate of 5 K/min under N_2 atmosphere with a flow rate of 20 mL/min. The sample (4 mg) was heated in a standard platinum sample pan.

2. Results and discussion

2.1. Extraction of noble metal ions by phase transfer

The phase transfer of noble metal ions has not only been widely used as an important step for the synthesis of metal nanomaterials (Yang et al., 2011), but is also of great interest for applications in environmental remediation, such as the extraction of heavy metals from water and soil (Roundhill, 2001). If an aqueous solution of noble metal salt was directly contacted with dichloromethane containing DDT, the noble metal ions would not be transferred to the dichloromethane phase. Prolonged agitation only resulted in a turbid mixture, but no ion transfer took place after the mixture was settled down into two immiscible layers in a separating funnel. As the interaction between metal ions and DDT could only occur at the interface between water and dichloromethane, the failure to transfer the metal ions might be the result of poor contact between the two phases because of their lack of mutual solubility. However, the transfer of noble metal ions could take place using ethanol as an intermediate solvent, based on the fact that water and ethanol are completely miscible and maximum contact between the noble metal ions and DDT would be ensured. The phase transfer photographs of Ag(I), Pd(II), Ru(III), Rh(III), and Au(III) noble metal ions are exhibited in Fig. 1, which display the complete bleaching of the upper aqueous phase (the density of dichloromethane is greater than water), implying the successful transfer of these noble metal ions from the aqueous phase to dichloromethane.

The transfer efficiency (TE) and the distribution ratio (DR) in two phases after transfer could be calculated using the following equations:

$$\text{TE} = \left(\frac{[\text{M}^{n+}]_i - [\text{M}^{n+}]_f}{[\text{M}^{n+}]_i} \right) \times 100\% \quad (1)$$

$$\text{DR} = \text{TE} / (100 - \text{TE}) \quad (2)$$

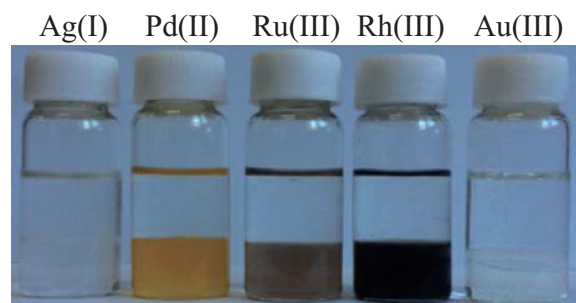


Fig. 1 – Photographs showing the successful transfer of Ag(I), Pd(II), Ru(III), Rh(III) and Au(III) metal ions from the aqueous phase to dichloromethane.

where, $[M^{n+}]_i$ (mg/L) and $[M^{n+}]_f$ (mg/L) are the initial and final noble metal ion concentrations in the aqueous phase, respectively. Analyses by ICP-AES indicated that the phase transfer efficiencies for a wide variety of noble metal ions were higher than 96%, as shown by Table 1.

2.2. Mechanism of DDT-based phase transfer

Analogous to the interaction of dodecylamine and metal ions (Yang et al., 2009), it is speculated that a metal complex between noble metal ions and DDT was formed in the process, which could be more easily extracted by dichloromethane. This was verified by the FT-IR spectra of a number of compounds recovered from the organic layer after phase transfer (Fig. 2). As shown in Fig. 2, line a for the FT-IR spectrum of pure DDT, the bands at 2918 cm^{-1} , 2843 cm^{-1} and 1471 cm^{-1} are attributed to the stretching vibrations and bending vibration of C–H (Zalakain et al., 2013; Zhao et al., 2007), respectively, while the bands at 2550 cm^{-1} , 2670 cm^{-1} and 721 cm^{-1} could be assigned to the stretching vibrations of S–H (He et al., 2001; Yee et al., 1999) and S–C (Seoudi et al., 2011). In comparison with that of pure DDT, the S–H stretching vibrations were observed to disappear, while other characteristic FT-IR peaks remained in the metal ion-DDT complexes, demonstrating that there was a strong coordination interaction between the S–H bond in DDT and noble metal ions. After coordinating with noble metal ions, the non-polar tail of DDT enabled the compounds to dissolve easily in dichloromethane, a non-polar organic solvent.

We took the Pd(II)–DDT system as a typical example to investigate the coordination number of the complex formed between DDT and noble metal ions. Phase transfer of Pd(II) ions with different molar ratios of DDT and Pd(II) was performed, and the transfer efficiencies at different DDT/Pd(II) molar ratios were calculated and demonstrated in Fig. 3a. The results showed that the TE increases proportionally with the increase of the DDT/Pd(II) molar ratio at low DDT/Pd(II) molar ratios. However, it was maximum and constant at DDT/Pd(II) molar ratio of 2 or higher, showing that the coordination number in the Pd(II)–DDT complex is 2. Based on the above analysis, the chemical structure of the

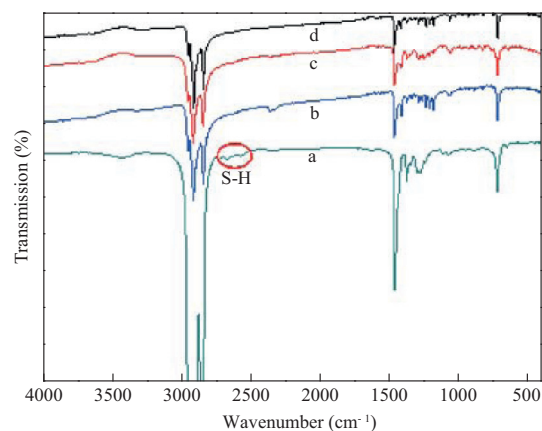


Fig. 2 – FT-IR spectra of pure DDT (line a), Au(III)–DDT complexes (line b), Pd(II)–DDT complexes (line c), and Ag(I)–DDT complexes (line d).

Pd(II)–DDT complex might be schematically illustrated as shown in the insert of Fig. 3a. This formation of a complex between DDT and Pd(II) ions was also supported by TGA results. The TG profile of Pd(II)–DDT at the heating rate of 5 K/min is depicted in Fig. 3b. The first weight loss (5.1 wt.%) that appeared at temperatures below 120 °C could be attributed to the elimination of physically absorbed water (Fu et al., 2013; Moon et al., 2005). With the increase of the temperature from 270 to 300 °C, a remarkable weight loss of 68.5 wt.% was observed, corresponding to the release of DDT ligands. The weight was maintained at temperatures higher than 300 °C, and the residue at the end of heating in nitrogen gas was only pure palladium salt.

Based on the above analysis, the process of DDT-based phase transfer of noble metal ions from aqueous solution to dichloromethane could be summarized by the scheme in Fig. 4. The ethanol was used to facilitate the transfer of noble metal ions. After the ethanol–aqueous metal salt solution mixture had been stirred for 5 min, the initially transparent aqueous solution turned turbid. This is an indication that DDT had been successfully coordinated with the noble metal ions. The extraction of DDT–metal ion complexes to the organic layer, as indicated by the vivid transfer of color from the aqueous solution to dichloromethane, occurred quickly and completely, leaving a colorless aqueous phase behind.

Although in principle, the transfer mechanism using DDT as transfer agent is analogous to that using dodecylamine as transfer agent (Yang et al., 2009), the interaction between noble metal ions and the –SH group in DDT might be different from that between metal ions and –NH₂ in dodecylamine, which could lead to different results in terms of transfer efficiency and selectivity. In addition, the DDT- and dodecylamine-based phase transfer methods might be combined to give a protocol with high selectivity for the extraction of given metal ions.

2.3. Selectivity of DDT-based phase transfer for noble metal ions

The selectivity of DDT-based phase transfer for the extraction of noble metal ions was again demonstrated using the Pd(II)–

Table 1 – Efficiencies of DDT-based phase transfer of noble metal ions from water to dichloromethane.

Metal salt	C^a (mg/L)	C^b (mg/L)	TE (%)	DR	Relative standard deviation (%)
Ag(I)	107.87	0.04	99.96	2499.00	2.76
Pd(II)	106.42	0.09	99.92	1249.00	1.69
Ru(III)	101.07	3.47	96.57	28.15	0.16
Au(III)	196.97	0.80	99.59	242.90	0.13
Rh(III)	102.91	0.72	99.30	141.86	0.12
Ir(III)	192.22	2.95	98.47	64.36	3.99
Os(III)	190.20	6.75	96.45	27.17	0.95

TE: transfer efficiency; DR: distribution ratio.

^a Concentration of aqueous noble metal salt solution before phase transfer.

^b Concentration of aqueous noble metal salt solution after phase transfer.

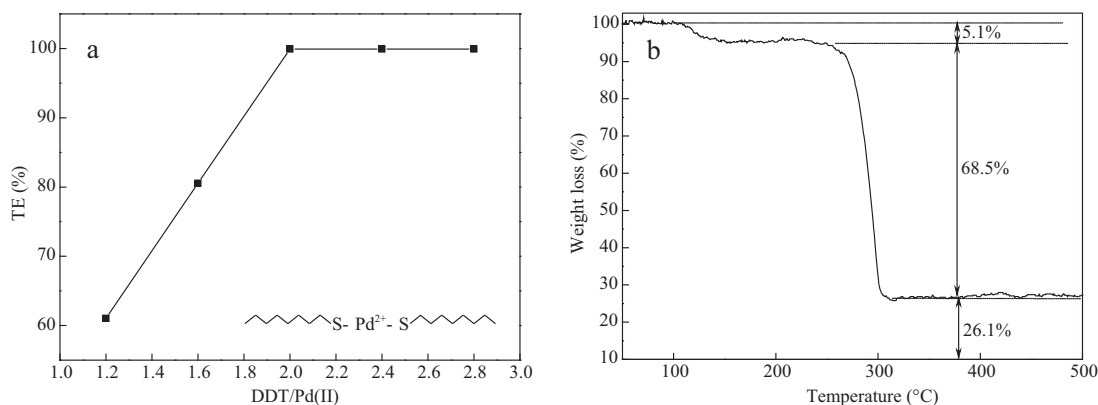


Fig. 3 – (a) The phase transfer efficiency of Pd(II) ions with the different DDT/Pd(II) molar ratios; (b) TG profile of Pd(II)–DDT complex at the heating rate of 5 K/min. Insert is the scheme of the proposed chemical structure of Pd(II)–DDT coordination compound.

DDT system. In a typical experiment, 50 mL of an aqueous mixture containing Pd(II), Fe(III), and Zn(II) ions (1 mmol/L for each) was mixed with 50 mL of ethanolic DDT solution. The molar ratio of DDT to metal ions (Pd(II), Fe(III), or Zn(II)) was controlled at 2/1. After 5 min of vigorous stirring, 50 mL of dichloromethane was added and stirring was continued for 10 min, followed by the collection of the organic layer after complete separation of the two phases. The transfer efficiencies of Pd(II), Fe(III), and Zn(II) from aqueous solution to dichloromethane were determined by analyzing the metal concentration in the aqueous phase before and after transfer

using ICP-AES. As summarized in Table 2, the TE for Pd(II) ions (99.49%) was much higher than that for Fe(III) and Zn(II) metal ions (13.18% and 6.50%, respectively), suggesting high selectivity for the separation of noble metal ions from other transition metals. In addition to the high selectivity for extracting noble metal ions, the other advantages of this protocol, *e.g.*, good ion uptake by the complexing agent, which allows for fast binding with the metal ion, and the preference of the metal complex formed for the organic phase over the aqueous phase, may find significant applications in environmental remediation, *e.g.*, extraction of noble metals from water, soil, or waste printed circuit boards.

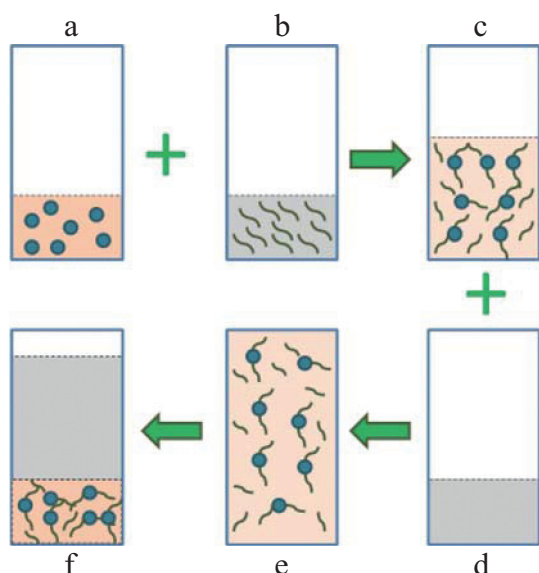


Fig. 4 – Schematic for the ethanol mediated phase-transfer of noble metal ions from aqueous solution to a hydrocarbon phase: (a) aqueous metal salt solution; (b) ethanolic 1-dodecanethiol solution; (c) mixture of aqueous metal salt solution and ethanolic 1-dodecanethiol solution; (d) dichloromethane; (e) mixture of dichloromethane and ethanol-aqueous metal salt solution; and (f) phase-transfer of noble metal ions to dichloromethane.

3. Conclusions

In summary, a 1-dodecanethiol-based phase-transfer protocol has been developed for the extraction of noble metal ions from the aqueous solution to a hydrocarbon phase, which calls for first mixing the aqueous metal ion solution with an ethanolic solution of 1-dodecanethiol, and then extracting the coordination compounds formed between the noble metal ions and 1-dodecanethiol into a non-polar organic solvent. This protocol could be applied to extract a wide variety of noble metal ions from water to dichloromethane with an efficiency of >96%, and

Table 2 – Efficiencies of DDT-based phase transfer of Pd(II) noble metal, Fe(III) and Zn(II) transition metal ions from water to dichloromethane.

Metal salt	C ^a (mg/L)	C ^b (mg/L)	TE (%)	DR	Relative standard deviation (%)
Pd(II)	106.42	0.54	99.49	195.08	1.62
Fe(III)	55.85	48.49	13.18	0.15	0.94
Zn(II)	65.39	52.98	6.50	0.07	0.64

^a Concentration of aqueous noble metal salt solution before phase transfer.

^b Concentration of aqueous noble metal salt solution after phase transfer.

had high selectivity for the separation of noble metal ions from other transition metals. Thus, this approach represents a simple and flexible route for the extraction and recovery of noble metal ions. By further optimizing the phase transfer parameters, *e.g.*, the molar ratio of 1-dodecanethiol and metal ions, the organic solvent systems, and operational conditions, *etc.*, this protocol may find significant applications in environmental remediation, *e.g.*, extraction of noble metals from water, soil, or waste printed circuit boards.

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REFERENCES

- Ahamed, M.E.H., Mbianda, X.Y., Mulaba-Bafubiandi, A.F., Marjanovic, L., 2013. Selective extraction of gold(III) from metal chloride mixtures using ethylenediamine N-(2-(1-imidazolyl)ethyl) chitosan ion-imprinted polymer. *Hydrometallurgy* 140, 1–13.
- Aydin, A., Imamoglu, M., Gulfen, M., 2008. Separation and recovery of gold(III) from base metal ions using melamine–formaldehyde–thiourea chelating resin. *J. Appl. Polym. Sci.* 107 (2), 1201–1206.
- Begerow, J., Turfeld, M., Dunemann, L., 1997. Determination of physiological noble metals in human urine using liquid–liquid extraction and Zeeman electrothermal atomic absorption spectrometry. *Anal. Chim. Acta.* 340 (1–3), 277–283.
- Brust, M., Walker, M., Bethell, D., Schiffrin, D.J., Whyman, R., 1994. Synthesis of thiol-derivatised gold nanoparticles in a two-phase liquid–liquid system. *J. Chem. Soc. Chem. Commun.* (7), 801–802.
- Brust, M., Fink, J., Bethell, D., Schiffrin, D.J., Kiely, C., 1995. Synthesis and reactions of functionalised gold nanoparticles. *J. Chem. Soc. Chem. Commun.* (16), 1655–1656.
- Cieszynska, A., Wiśniewski, M., 2010. Extraction of palladium(II) from chloride solutions with Cyphos®1L 101/toluene mixtures as novel extractant. *Sep. Purif. Technol.* 73 (2), 202–207.
- Cieszynska, A., Wiśniewski, M., 2011. Selective extraction of palladium(II) from hydrochloric acid solutions with phosphonium extractants. *Sep. Purif. Technol.* 80 (2), 385–389.
- Cieszynska, A., Wiśniewski, M., 2012. Extractive recovery of palladium(II) from hydrochloric acid solutions with cyphos®1L 104. *Hydrometallurgy* 113–114, 79–85.
- Duan, S., Wang, R., 2013. Bimetallic nanostructures with magnetic and noble metals and their physicochemical applications. *Prog. Nat. Sci.* 23 (2), 113–126.
- Fontàs, C., Salvadó, V., Hidalgo, M., 2002. Separation and concentration of Pd, Pt, and Rh from automotive catalytic converters by combining two hollow-fiber liquid membrane systems. *Ind. Eng. Chem. Res.* 41 (6), 1616–1620.
- Fricker, S.P., 1996. Medical uses of gold compounds: past, present and future. *Gold Bull.* 29 (2), 53–60.
- Fu, G., Tao, L., Zhang, M., Chen, Y., Tang, Y., Lin, J., et al., 2013. One-pot, water-based and high-yield synthesis of tetrahedral palladium nanocrystal decorated graphene. *Nanoscale* 5 (17), 8007–8014.
- He, S., Yao, J., Xie, S., Gao, H., Pang, S., 2001. Superlattices of silver nanoparticles passivated by mercaptan. *J. Phys. D. Appl. Phys.* 34 (24), 3425–3429.
- Kowligi, K.N.K., Koper, G.J.M., Picken, S.J., Lafont, U., Zhang, L., Norder, B., 2011. Synthesis of magnetic noble metal (nano)-particles. *Langmuir* 27 (12), 7783–7787.
- Lam, K.F., Fong, C.M., Yeung, K.L., Mckaya, G., 2008. Selective adsorption of gold from complex mixtures using mesoporous adsorbents. *Chem. Eng. J.* 145 (2), 185–195.
- Lee, J.-M., 2012. Extraction of noble metal ions from aqueous solution by ionic liquids fluid. *Fluid Phase Equilib.* 319, 30–36.
- Moon, K.S., Dong, H., Maric, R., Pothukuchi, S., Hunt, A., Li, Y., et al., 2005. Thermal behavior of silver nanoparticles for low-temperature interconnect applications. *J. Electron. Mater.* 34 (2), 168–175.
- Regel-Rosocka, M., Wisniewski, M., Borowiak-Resterna, A., 2007. Selective extraction of palladium(II) from hydrochloric acid solutions with pyridinecarboxamides and Acorga®CLX50. *Sep. Purif. Technol.* 53 (3), 337–341.
- Roduner, E., 2006. Size matters: why nanomaterials are different. *Chem. Soc. Rev.* 35 (7), 583–592.
- Roundhill, D.M., 2001. *Extraction of Metals from Soils and Waters*. Kluwer–Academic/Plenum.
- Seoudi, R., Shabaka, A., Sayed, Z.A.E., Anis, B., 2011. Effect of stabilizing agent on the morphology and optical properties of silver nanoparticles. *Phys. E.* 44 (2), 440–447.
- Shi, H., Fu, X., Zhou, X., Hu, Z., 2005. Preparation of organic fluid containing Ag nanoparticles with extractant cyanex 301. *J. Dispers. Sci. Technol.* 26 (3), 315–319.
- Shi, H., Fu, X., Zhou, X., Hu, Z., 2006. Preparation of organic fluids with high loading concentration of Ag₂S nanoparticles using the extractant cyanex 301. *J. Mater. Chem.* 16 (21), 2097–2101.
- Swain, B., Jeong, J., Kim, S., Lee, J.C., 2010. Separation of platinum and palladium from chloride solution by solvent extraction using alamine. *Hydrometallurgy* 104 (1), 1–7.
- Yang, J., Sargent, E.H., Kelley, S.O., Ying, J.Y., 2009. A general phase-transfer protocol for metal ions and its application in nanocrystal synthesis. *Nat. Mater.* 8 (8), 683–689.
- Yang, J., Lee, J.Y., Ying, J.Y., 2011. Phase transfer and its applications in nanotechnology. *Chem. Soc. Rev.* 40 (3), 1672–1696.
- Yee, C., Scotti, M., Ulman, A., White, H., Rafailovich, M., Sokolov, J., 1999. One-phase synthesis of thiol-functionalized platinum nanoparticles. *Langmuir* 15 (13), 4314–4316.
- Zalakain, I., Politakos, N., Angel Ramos, J., Fernandez, R., Etxeberria, H., Mondragon, I., et al., 2013. Synthesis and incorporation of dodecanethiol capped silver nanoparticles into poly(styrene-*b*-isoprene-*b*-styrene) block copolymer and their influence in the morphology. *Colloids Surf. A* 436, 170–177.
- Zhao, K., Dai, J., Zhuang, J., Li, J., Yang, W., 2007. Highly efficient transfer of water-soluble ZnS:Mn²⁺ nanocrystal into organic phase by 1-dodecanethiol. *Colloids Surf. A* 296 (1–3), 154–157.



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