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Kinetic study of the effect of carrier and stripping agent concentrations on the facilitated transport of cobalt through bulk liquid membranes

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Abstract

Heavy metal contamination of industrial effluents and waste waters is a very important environmental problem. Heavy metals tend to accumulate in living organisms causing various diseases and disorders. So the search for extraction techniques to remove those heavy metals are of increasing interest. Liquid membranes have shown great potential in this way, especially in cases where solute concentrations are relatively low and other techniques cannot be applied efficiently. A kinetic study of the effect of carrier and counter ion concentrations on the transport of cobalt(II) through bulk liquid membrane containing di-2-ethylhexyl phosphoric acid (D2EHPA), as mobile carrier, in kerosene and protons (H_2SO_4), as counter ions, in the product phase is carried out is this paper. The transport kinetic was analysed by means of a kinetic model involving two consecutive irreversible first order reactions. The rate constants of the extraction and stripping reactions were determined for all experimental conditions studied. Maximum transport fluxes of cobalt(II) through the bulk liquid membrane were also calculated.

Keywords: Membrane processes; Bulk liquid membranes; Cobalt; D2EHPA; Kinetic

1. Introduction

Heavy metal contamination exists in the vast majority of industrial effluents and waste waters, such as mining effluents, etching or pickling baths, dilute leaching solutions generated during hydrometallurgy, electroplating rinse liquors, etc. As heavy metals are not biodegradable they tend to accumulate in living organisms causing various diseases and disorders. So extraction techniques for the removal and recovery of heavy metals are of increasing interest with a variety of processes being studied.

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Cobalt is one of the heavy metals associated to those industrial activities. The permissible limits of cobalt in the irrigation water and livestock watering are 0.05 and 1.0 $mg \cdot dm^{-3}$ respectively [1]. The effects of acute cobalt poisoning in humans are very serious, among them are asthma like allergy, damage to the heart, causing heart failure, and damage to the thyroid and liver. Cobalt may also cause genetic changes in living cells.

Several methods has been described for cobalt removal from wastewater during last years, including chemical precipitation [2], adsorption on activated carbon [3,4], biosorption by algae [5] ion exchange [6–9], pressure driven membrane processes [10] and combined methods (sorption or complexation plus pressure driven membranes processes) [11–13]. Recently, the use of liquid membranes for the removal of cobalt from aqueous solutions have been described [14–18]. Liquid membranes have shown great potential, especially in cases where solute concentrations are relatively low and other techniques cannot be applied efficiently, since they combine the processes of extraction and stripping in a single unit operation [19]. The extraction chemistry is basically the same as that found in liquid–liquid extraction, but the transport is governed by kinetic rather than equilibrium parameters, that is, it is governed by a non-equilibrium mass transfer.

Metal ion extraction in the liquid membrane system, can be facilitated by carrier mediated transport, in which an ion exchange reagent is incorporated in the membrane phase to carry the diffusing specie across the membrane to the product phase, a process that is usually accompanied by the transport of other chemical specie from the product to the feed phase (facilitated counter transport). This coupled transport mechanism is interesting because it offers the possibility of transporting a component against its own concentration gradient [20].

The kinetic of the effect of carrier and counter ion concentrations on the transport of cobalt(II) ions through bulk liquid membrane containing di-2-ethylhexyl phosphoric acid (D2EHPA), as mobile carrier, in kerosene and protons (H_2SO_4), as counter ions, in the product phase is studied in this paper.

1.1. Theory

The facilitated transport of Co(II) ions through a liquid membrane using D2EHPA as carrier and H^+ as counter ions is illustrated in Fig. 1. The carrier diffuses from the bulk membrane phase to the feed membrane interface, where cobalt(II) ions are exchanged for protons. Due to the high interfacial reactivity of D2EHPA [21], a dimerized molecule undergoes acid dissociation [22] and reaction with cobalt(II), according to the equation:

$$Co^{+2}(aq) + 2(HR)_2(org) \Leftrightarrow CoR_2(HR)_2(org) + 2H^+$$

The cobalt(II) carrier complex formed diffuses through the membrane to the

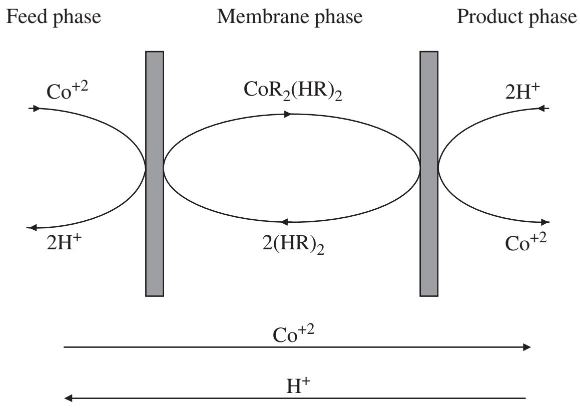

Fig. 1. Diagram of the facilitated transport of Co(II) ions using D2EHPA as carrier and H^+ as counter ions.