

# Uranium sorption by glutamate glucan: A modified chitosan

## Part II: Kinetic studies

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### Abstract

The kinetics of uranium sorption by glutamate glucan, a modified chitosan polymer, were studied. The effects of the particle size of sorbent, pH, metal concentration, temperature and agitation were investigated. Diffusion mechanisms were predominant in rate-controlling steps: external mass transfer seemed to have a restricted effect on kinetic behaviour, on the other hand intraparticle diffusion was the main resistance model. Metal concentration, pH and particle size of the polymer were the major parameters, showing a great effect on the rate ratio of the intraparticle diffusion model and on diffusion coefficient  $D'$ , whose value varied between 1.5 and  $36 \times 10^{15}$  m<sup>2</sup>/min.

### Introduction

Many studies have been done in the last 20 years concerning the treatment of waste water with a low metal content. Various mechanisms, including biological techniques, were investigated with the aim of treating heavy metals in solution: the use of adsorbents of biological origin, and particularly fungal biomass, demonstrates good efficiency in this field (Tsezos and Volesky, 1981). The large amount of chitin and chitosan in the cell walls of these fungi and the exclusive sorption of metal in this part of micro-organisms, suggested that these natural polymers are efficient in metal uptake (Guibal, 1990). Nowadays many studies deal with chitin and chitosan in metal removal (Muzzarelli and Zattoni, 1986, Eiden et al., 1980). The modification of these polymers (Muzzarelli et al., 1984; Muzzarelli et al., 1985) improves the efficiency of these materials in waste-water treatment, regarding sorption performances and facility of application. Various processes are possible for the modification of chitosan structure (Nishi et al., 1986;1987), Muzzarelli and co-workers (1984) proposed a simple method of synthesis of organic acid-chitosan polymers. A previous paper on this issue (Saucedo et al., 1993), used this technique to synthesise a glutamate glucan polymer and to study its properties in the uptake of uranium, and the effect of various parameters on sorption capacity was investigated. Sorption kinetics, thus, constitute a major criterion in the determination of the interest of sorption processes. The purpose of this research was to study the kinetic controlling mechanisms: a resistance external mass transfer model and a resistance intraparticle diffusion model. These models were examined according to the main sorption parameters such as temperature, agitation speed, metal concentration, pH and particle size of adsorbent.

### Theory

The kinetics can be controlled by various mechanisms and steps in adsorption phenomena. Four major rate-limiting steps are generally cited:

- Mass transfer of solute from solution to the boundary film
- Mass transfer of metal ions from boundary film to polymer surface
- Sorption of ions onto sites
- Internal diffusion of solute.

The third step is assumed to be very rapid and non-limiting in this kinetic analysis: sorption is a rapid phenomenon. The first and the second steps are external mass transfer resistance steps, depending on various parameters such as agitation and homogeneity of solution. The fourth one is an intraparticle diffusion resistance step.

#### Approach of models

The main parameters influencing metal sorption were investigated: particle size of sorbent, agitation speed, pH and metal concentration, and temperature. Each of these parameters was studied beyond the range of the 2 major resistance models: external mass transfer resistance, and intraparticle diffusion resistance, which are briefly described in this paper.

#### External mass transfer resistance model

The model used to calculate the external mass transfer rate is described by the following equation:

$$\frac{dC_t}{dt} = -B_L S (C_t - C_s) \quad (1)$$

where  $B_L$  is the external mass transfer coefficient and  $S$  the specific surface. According to complementary hypotheses such as a surface concentration of solute on the sorbent ( $C_s \rightarrow 0$ ) negligible at time  $t=0$ , and the intraparticle diffusion rate also negligible (McKay and Poots, 1980, McKay et al., 1986), Eq. (1) can be simplified to:

$$\frac{dC_t}{dt} = -B_L S C_t \quad (2)$$

according to boundary conditions and the hypothesis formulated:  $C_t \rightarrow C_0$  when  $t \rightarrow 0$ .

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