Cairo University
Faculty of Science
Chemistry Department

Studies on the Treatment and Mathematical Modelling of Pure Beryllium Concentrate from Egyptian Beryl Mineralization via Flow Through Bed Reactors

A Thesis Submitted to

Faculty of Science

Cairo University

By

MOHAMMED DEMERDASH HASHEM MOHAMMED

(B.Sc. 2000 and M.Sc. 2006)

For the Degree of

Doctor of Philosophy in Science

(Chemistry)

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Publication from this thesis

The following articles have been published and prepared from the present thesis:

A-Published articles:

[1] Othman, S.H.; Shabaan, M.; M., Demerdash, M.; Saleh, M. Experimental and Theoretical Investigation of Sorption Kinetics of Beryllium on Amberlite-IR-120 Sorbent, Journal of Nuclear material, 2009, 392, P 427-433.

[2] Sameh H.Othman, Mahmoud M. Saleh, M. Demerdash, Bahgat E. El-Anadouli, Mathematical Model: Retention of Beryllium on Flow-Through Fixed Bed Reactor of Amb-IR-120, Journal of Chem. Eng. 156, 2010, P 157-164

B-Submitted article:

[1] Experimental Validation for Mathematical Model Describing Beryllium Retention on Flow-Through Fixed Bed Reactor of Amb-IR-120.

ABSTRACT

Experimental and theoretical studies of the sorption kinetics of beryllium cation from its solution on amberlite IR-120 (Amb-IR-120) sorbent was achieved at batch and flow systems. In the batch process, the kinetics and resin uptake at different conditions were studied. The dependence of the sorption kinetic parameters on the temperature of the solution has been investigated. The pH of solution and agitation speed had dramatic effects on the uptake of Be by Amb-IR-120. It was found that pH in the range of 3–3.5 and agitation speed of 150 rpm are proper conditions of Be sorption at the present experimental set. The fit of experimental data with the homogeneous diffusion model (HDM) equations demonstrated the possibility of using this model for adequate description of the beryllium sorption kinetics on the Amb-IR-120 sorbent. Two stages of adsorption with different controlling processes were proposed. Liquid film diffusion controls the process at the early stage of the adsorption followed by matrix diffusion which controls the process in the final stage. Two different equations were used to express each stage.

In the flow system a mathematical model was proposed to simulate the beryllium uptake within a fixed porous flow through reactor. The effects of various structural, kinetic and hydraulic parameters on the behavior of the flow reactor were studied. These include linear velocity of the fluid, packing density, void fraction and adsorption coefficient. The proposed mathematical model is solved analytically and its predictions were compared with experimental results. The mathematical model was experimentally validated using different sets of experiments at different values of linear velocity, bed thickness, initial concentration and pH of the feeding solution. Analyses of the respective experimental results in accordance with predictions of the theoretical model give a satisfactory agreement at the present set of the investigated parameters.

TABLE OF CONTENTS

Chapter (3)
EXPERIMENTAL

Chapter (4)
RESULTS AND DISCUSSION OF THE BATCH PROCESS

Chapter (5)
MATHEMATICAL SIMULATION OF ADSORPTION

Chapter (6)

VALIDATION OF THE MODEL PREDICTION

Chapter (7)

BERYLLIUM REFINING FROM ZDB BERYL SOLUTION

LIST OF TABLES

LIST OF FIGURES

List of Symbols

C_o	initial concentration of sorbing species, mole L^{-1}
C_e	equilibrium concentration of sorbing species, mole L^{-1}
C	concentration of Be^{2+}, mole/L^{-1}
D_{FD}	diffusion coefficient in liquid phase, m^2 s^{-1}
D_{MD}	diffusion coefficient in solid phase, m^2 s^{-1}
dz	the differential unit length, m
E_a	activation energy, kJ/mol
k	pseudo first order rate constant, min^{-1}
k_l	Lagergren sorption rate constant, min^{-1}
k_a	absorption coefficient, kg/m^3
k_r	pseudo first order rate constant at the rapid step, min^{-1}
k_s	pseudo first order rate constant at the slow step, min^{-1}
k_{FD}	liquid film diffusion constant
k_{MD}	matrix diffusion constant
L	the height of the column, m
m	the weight of the resin, kg
q(t)	amount of solute sorbed at time t, mol kg^{-1} (resin).
q_e	amount of solute sorbed at equilibrium, mg g^{-1}
q_{max}	max concentration of Be obtained at equilibrium mol kg^{-1} (resin)
Q	accumulated beryllium overall the column, mol
R	gas constant, 82.06 (cm^3 atm)/(mol/K)
r	radius of the cross section of the column, m
r_p	average resin particle radius, m
X	fractional attainment of equilibrium or extent of solid conversion
T	absolute temperature, K
t	time, min
U	uptake percent
V	volume of bed, ml
V_b	band volume, ml
Z	the bed thickness, m
Z_b	the height of the sorption band, m
	stoichiometric coefficients

n, y constants characteristic of chemisorption given by Elovich equation

α, a

Greek letters

ρ the packing density, kg/m^3

ε the void fraction, dimensionless

μ linear velocity of fluid, m/s

β the solid-liquid partition coefficient, kg/m^3

Ψ main column parameter, m^{-1}

δ liquid film thickness, m

ϕ the conversion ratio

List of Abbreviations

AAS	Atomic absorption spectrometer
Amb	Amberlite IR-120
CCM	Constant capacitance model
CEM	Chemical equilibrium model
DEHPA	Di ethyl hexyl phosphoric acid
ED	Eastern Desert of Egypt
EDTA	Ethylenediamine tetraacetic acid
FD	Film diffusion mode
HDM	Homogeneous Diffusion Model
MD	Matrix diffusion mode
MCM	Mesoporous molecular sieve
SCM	Shrinking Core model
TBP	Tributylphosphate
TOPO	Tri-n-octylphosphine oxide
XAD	Styrene-divinylbenzene copolymer
ZDB	Zabara-Um Debaa belt