Experiment 3
Study of Sucrose Inversion using catalytic reactor

CHEN3010/ CHEN5040 - Chemical Reaction Engineering - S1 2024

> **!** Prelab Module
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> Prelab module for experiment 3 Can be accessed here.

1 Objective

The aim of this experiment is to demonstrate the principles of packed bed catalysis. We will study the sucrose inversion reaction using two different catalyts. For each catalyst, conversion and effectiveness factor will be reported.

2 Theory

The hydrolysis reaction results in fructose and glucose as products.

$$C_{12}H_{22}O_{11} + H_2O \rightleftharpoons C_6H_{12}O_6 + C_6H_{12}O_6 \tag{1}$$

$$\text{Sucrose} + \text{water} \rightleftharpoons \text{fructose} + \text{glucose}$$

The sucrose inversion reaction is acid catalysed. Homogeneous catalysis in an aqueous solution of sucrose would ultimately require the separation of the products of the reaction from the acid catalyst. A more practical way of conducting this reaction is by "immobilisation" of the catalyst. A cationic exchange resin in the protonated form is in fact no more than an immobilised acid, where the anion is covalently bonded to the 3-D structure of the resin and the cation H+ is ionically bonded to this group.

Sucrose inversion is a reaction with very high activation energy, approx. 15950 cal/mol (66.67 kJ/mol) for Amberlite IR 120 particles with an average diameter of 0.715mm [1]. This reaction is therefore very

[1] Reed, E. and J. Dranoff; "Ion Exchange Resin Catalysis of Sucrose Inversion in Fixed Beds", I&EC Fundamentals, 3, pg.304-307 (1964).

sensitive to temperature. The reaction is controlled by the transport kinetics (diffusional control), i.e. by the diffusion of sucrose inside the particle and of the products towards the outside.

The reaction will be carried out in a fixed bed catalytic reactor. Two catalysts are proposed: a strong cationic exchange resin and an immobilised enzyme, invertase, the activity of which is specific to the catalysis of this reaction. The reactors' steady state conversion is followed either manually or by an automated analytical technique known as FIA (Flow Injection Analysis). The accompanying laboratory manual ("PC-0054962-Armfield-Manual-CEU-Issue 13.pdf") details experimental data analysis, and procedure to obtain conversion, and effectiveness factor from the absorbance data.

3 Experimental procedure

The experiment will be carried out in the Armfield CEU catalytic reactor.

Begin by familiarising yourself with the experimental set-up. Explanation of the workings of the reactor and product analysis is given in the Operation section of the laboratory manual[2]. A virtual tour is also provided that describes the setup in detail. Follow the experimental procedure given on page 56-57 of the laboratory manual.

4 Data analysis

Having recorded the absorbance of the contents of the reactor over the period of the reaction, the absorbance measurements must now be translated into concentration. The calculations required for converting the absorbance data into concentration are given in the instruction manual.

5 Tasks

Prepare a report based on your interpretation of experimental data. The report should consider the following:

1. For catalysts with spherical symmetry and first order kinetics, show that the effectiveness factor, η is given by
$$\eta = \frac{3}{\phi}\left[\frac{1}{tanh\phi} - \frac{1}{\phi}\right]$$
2. **Data analysis**: Prepare a calibration curve (linking absorbance to concentration) using the data obtained for standards. Calculate the conversion in both the columns For the two datasets given, perform data analysis in Excel to calculate the effectiveness factors for the two columns. Present relevant calculations.

[2]Laboratory manual "PC-0054962-Armfield-Manual-CEU-Issue 13.pdf"