

A Compact Reactor-Pump-Cell-Injection System for In-Situ / On-Line Spectroscopic Studies

Feng Gao, Li Chuanzhao and Marc Garland

Department of Chemical and Biomolecular Engineering
4 Engineering Drive 4
National University of Singapore
SINGAPORE 117576

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Abstract

Compact reaction systems for exploratory studies, over wide pressure intervals, are essential in many applications. This is particularly true for studies involving very expensive reagents and isotopes. The system was used for heterogeneous catalysis, with a chiral fixed bed reactor. The system consisted of a 25ml 2-phase stirred-tank(gas, liquid), liquid phase pump, a fixed bed reactor with small amount of catalyst, in-situ IR high pressure cell, in-line HPLC injection valves and recycle transfer lines. The potential of this new experimental setup was demonstrated using the example of asymmetric heterogeneous hydrogenation of acetophenone. Quantitative evaluation of the reagent, product by the in-situ FTIR measurement allowed simultaneous determination of reaction kinetics. The system was also use for homogeneous catalysis. A 100ml 2-phase stirred-tank was used instead of a volume of 25 in the heterogeneous catalysis. Good kinetic data were achieved. The new systems allowed easy perturbations and sample acquisition. Also, isotopic work is more easily performed.

1.0 Introduction

The synthesis of enantiomerically pure chiral compounds has gained increasing importance in the field of pharmaceutical. ¹Several methodologies have been developed to obtain pure chiral products. ² Among them, asymmetric heterogeneous catalysis is especially outstanding both in industry and academic field. Perhaps the main reason is the “multiplication of chirality”, a large amount of chiral products can be produced by using a small amount of chiral modifiers. However, progress has been restrained to two catalytic systems ^{3,4}. Hydrogenation of α -ketoesters is one of them. Most studies have focused on permutations of solvent, substrate, chiral auxillary (primarily within cinchona class of alkaloids), support material and textural properties, platinum dispersion, co-additives, temperature and pressure. ^{5,6} In term of kinetic study, most studies are carried out in CSTR system by taking samples then using different off-line analytical method. And the conversions are usually higher than that suitable for kinetic study. ⁷ Accordingly the results are not reliable and systematic.

A recycle reactor without through-flow becomes a batch reactor. This type of reactor was used by Butt et al. ⁸ Figure 1 depicts the main features of batch heterogeneous reactor. The outstanding feature is the assumption of complete uniformity of concentration and temperature through the system. This requires the conversion per pass across the catalyst be small. If the reaction volume is constant, the mole balance equation can also be written in terms of the concentration: $-r_{\text{reactant}} = -\frac{dc_{\text{reactant}}}{dt}$ and $r_{\text{product}} = \frac{dc_{\text{product}}}{dt}$. Of course very accurate analytical methods are required. The advantages of Fourier transform infrared spectrometer (FTIR) such as fast scanning and very sensitive detector make it a preferable tool for in-situ differential reaction monitoring.

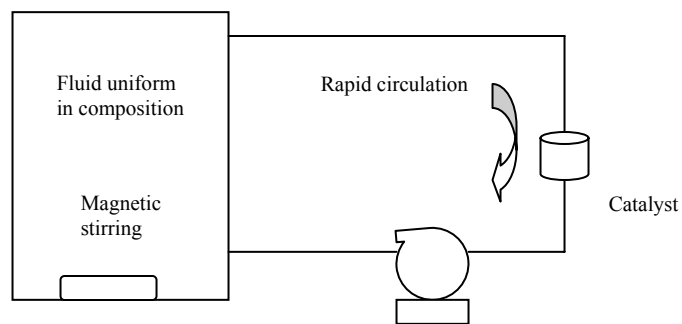
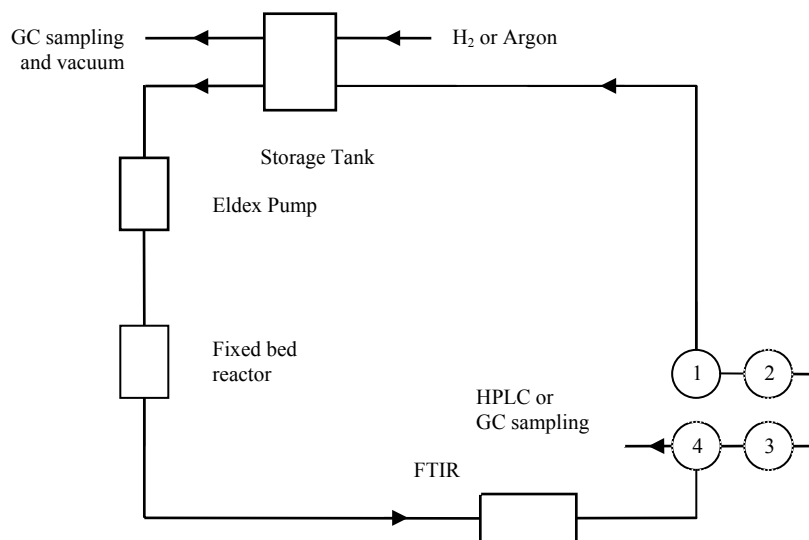


Figure 1 Batch reactor for catalytic reactions

According to Lambert-Beer's Law, the absorbance a in FTIR spectra is proportional to path length l , concentration c and absorptivity d . Therefore the mixture spectra can be regarded as linear combination of absorbance of different species. If the reference spectra with known concentration were taken for different reagent and product, the real concentration of components with time can be calculated accordingly.

2.0 Results and Discussion

A schematic diagram of the experimental system is shown in Figure 1.



Note: 1-3 Manual injectors 4. HPLC sampling and injection valve

Figure 1 Schematic diagram of the experimental system

The mass transfer in the 2-phase stirred-tank (gas, liquid) was studied. The example reaction-heterogenous asymmetric hydrogenation was operated under different circulation flow rates and different particle sizes to ensure that the kinetic study was carried out without the liquid-solid mass transfer and intraparticle diffusion problems. Low conversion circa 0.2-0.5% per pass was achieved. The designed system was proved to be suitable for heterogeneous kinetic studies.

The system was also successfully used for homogeneous hydroformylation of alkenes. Quantitative evaluation of the reagent, product by in-situ FTIR measurement allowed simultaneous determination of reaction kinetics. The new algorithm BTEM was used to recover pure component spectra.

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