A Course in

NONCATALYTIC HETEROGENEOUS REACTION SYSTEMS

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A NEW GRADUATE COURSE dealing with noncatalytic heterogeneous reaction systems has been developed at West Virginia University. This course was started orginally as a seminar course to supplement the first year graduate course in chemical reaction engineering. Traditionally, the courses in chemical engineering kinetics deal mostly with the homogeneous systems, and the catalytic heterogenous systems. However, many of the reactor design problems encountered by the students involve noncatalytic heterogeneous reactions. There are a large number of solid-fluid reactions which must be treated differently because the properties and reactives of solid reactants change continuously as the reaction progresses. Some of these reactions are: combustion reaction of all the carbonaceous materials, gasification reactioin pyrolysis reaction, calcination reactions, roasting of ores, reduction of matallic oxides, ion-exchange reactions, removal of gaseous acid pollutants by solid alkali and by scrubbing with an alkali slurry, fluorination of uranium oxides, etc.

It is the goal of this course to systematically organize the material to present a unified treatment of noncatalytic heterogeneous reaction systems in light of developing mechanistic as well as phenomenological models useful for design purposes. The approach taken here is to provide analysis of practical problems involving reactions on a single particle and to develop convincing and realistic yet sufficiently simple, models necessary to describe the phenomena. The deficiencies and limitations of each model are then presented carefully. These models together with reactor flow models and heat and mass transfer characteristics in a multiparticle system are combined to present integral reactor design, stressing the current state of knowledge and uncertainties in the supporting data.

The students, who have had courses in chemical reaction engineering, thermodynamics and transport phenomena, can choose to elect this course. Since no specific text book is assigned, in order to give some perspective to the course objectives, Figure 1 presents an overall flow sheet of the course illustrating interrelations and sequences of the subject matter to be introduced. A more detailed outline of the course content and the pertinent reference are presented in Table I.

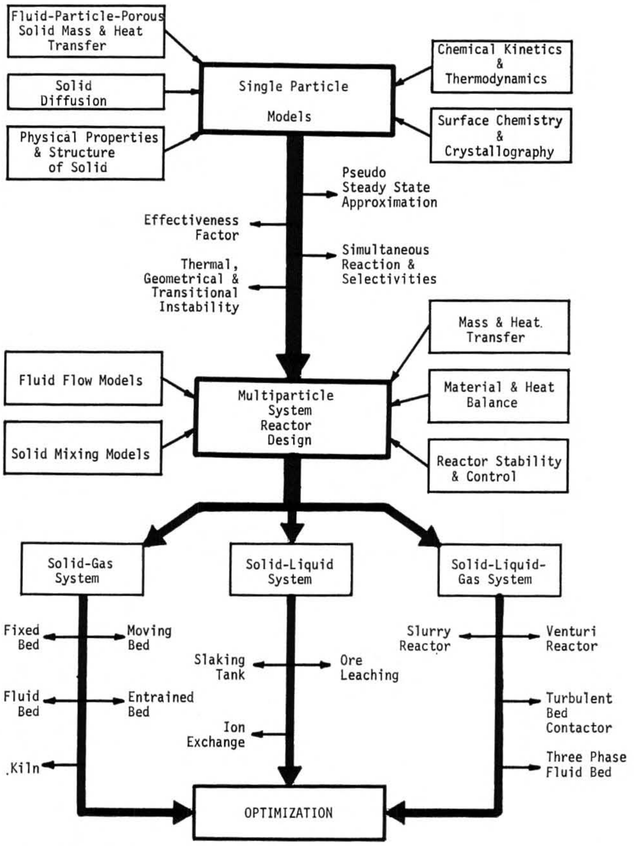
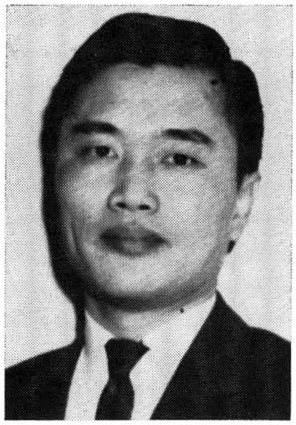


Fig. 1.—Overall flowsheet of noncatalytic heterogeneous reaction systems course.

Depending on the solid properties and structure, such as porosity and crystallization characteristics, as well as on the diffusional effects, one may observe the solid reactant undergo changes in various ways. Figure 2 shows a microscopic representation of a few typical cases



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illustrating the ways a particle reacts with a fluid reactant. Single particle models describing these phenomena are also shown. Figure 3 is a schematic diagram showing the effects of temperature on apparent overall rate reaction. In Figure 4, a schematic illustration of rate-controlling steps is shown. The understanding of chemical and physical phenomena on a single

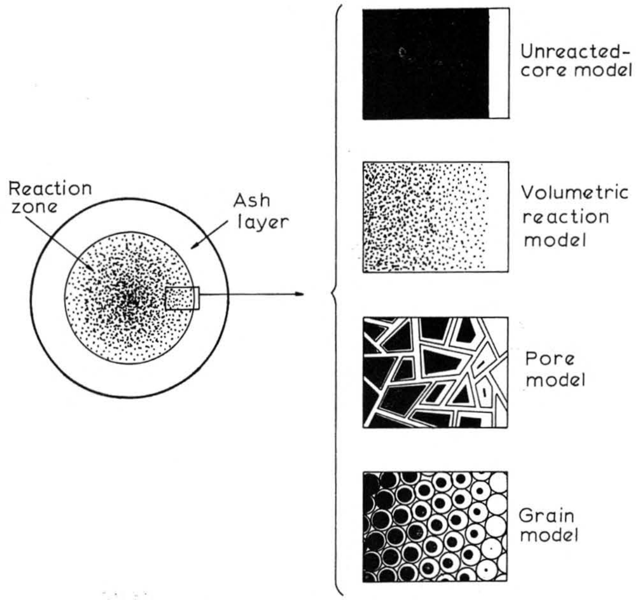

Fig. 2.—Single particle fluid-solid reaction models.

particle paves the way to the subsequent development of multiparticle system analysis. The information of single particle phenomena is thus combined together with the reactor flow models and material and heat balance to develop design criteria for an integral noncatalytic heterogeneous reactor.

Design of reactors for treating solid, liquid, or gaseous pollutants is of vital significance in coping with today's environmental problems. Processes such as fluidized bed incineration of solid waste, sulfur dioxide removal from PF boilers by limestone injection and by wet scrubbing with liquor containing limestone, neutralization of acid mine drainage, etc., which are of particular significance to ecology are discussed. Also biological reactors for treating primary effluents are included in discussion. In addition, gasification and liquefaction of fossil fuels for production of natural gas and petroleum substitutes to meet the national need for clean energy are presented in detail. These processes and topics of current interest to society and to the students are emphasized. Reactor design and process problems associated with these processes are discussed to encourage further research in these areas.

Finally, optimum reactor design and selection of a proper reactor to achieve the maximum selectivity of the products are discussed.

It is hoped that this course on noncatalytic heterogeneous reaction systems based on both mechanistic and phenomenological approaches

This course presents a unified treatment of the subject in light of developing mechanistic and phenomenological models useful for design purposes.

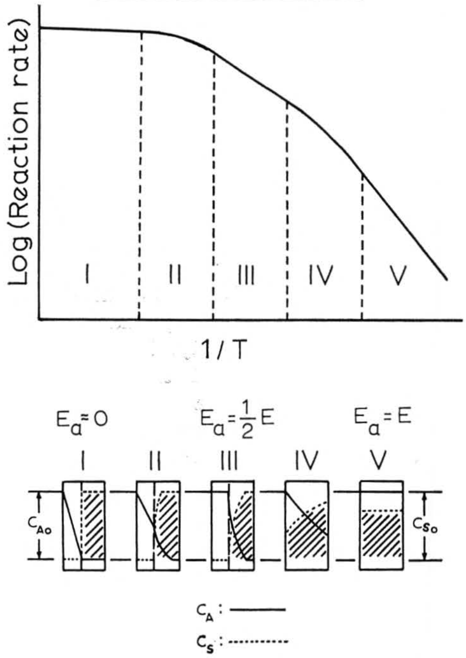

Fig. 3.—Schematic diagram showing three temperature zones of solid-gas reaction systems and concentration profiles in the solid.

will lead eventually to a unified and coherent discipline for treating this important but complex class of chemical reaction systems.

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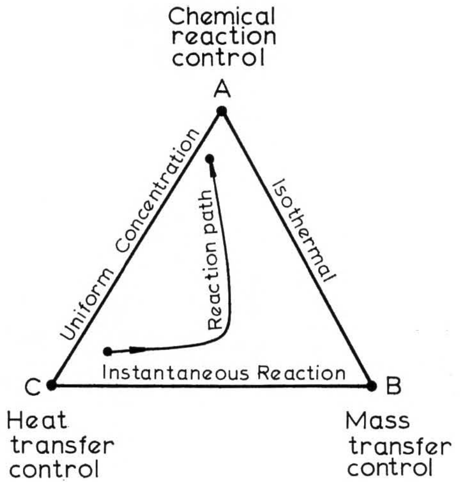

Fig. 4.—Schematic representation of rate-controlling steps.

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purpose. The physics of turbulent motions are recalled from previous discussions and are placed on a more concise and, whenever possible, quantitative basis. Turbulent intensity, correlations, Fourier decomposition and the turbulent energy spectrum are introduced for this purpose. Finally the well known quantitative results of the Universal Equilibrium theory are introduced to define characteristic length and velocity scales for this range. Scalar transport in turbulent flows is now discussed in terms of large and small scale motions and comparisons with experiments are given for stratified and dispersed systems. The course is completed with a brief discussion of interfacial turbulence.

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