**HACETTEPE UNIVERSITY**
**DEPARTMENT OF CHEMICAL ENGINEERING**

**Course Title:**

CHE 529 Mass Transfer With Chemical Reaction

Course Instructor: Prof. Dr. Erdoğan Alper

Date: Autumn Semesters

Credits: (3 – 0 – 3)

Prerequisities: Graduate standing

**Catalog Description:**

Introduction to "Mass Transfer with Chemical Reaction Operations". Unified Treatment of Gas – Liquid, Liquid – Liquid and Gas – Liquid – Solid Systems. Theory of Mass Transfer Accompanied by Irreversible and Reversible Reaction of General Order: Regimes of Mass Transfer. Complex Reactions. Simultaneous Absorption and Reaction of Two Gases. Reaction in Both Phases. Desorption With Reaction. Non – isothermal Behavior and Steady – State Multiplicity. Models for Simulation of Fluid – Fluid Contactors and Use of Laboratory – Scale Experiments. Types of Contactors, Their Relative Merits and Hydrodynamic Data. Case Studies from Process Industries (e.g. Sweetening of Natural and Refinery Gases by Chemical Solvents, Carbon Dioxide Capture from Power Plants).

**Textbooks:**

1. P. V. Danckwerts, P. V., "Gas – Liquid Reactions", McGraw – Hill Co., New York (1970).

2. Doraiswamy, L. K. and Sharma, M. M., "Heterogenous Reactions: Analysis, Examples and Reactor Design: Vol.2", Wiley, New York (1984)

**References:**

1. Astarita, G., Savage, D. and Bisio, A., "Gas Treating With Chemical Solvents", Wiley, New York (1983).

2. Alper, E. (Ed.), "Mass Transfer with Chemical Reaction in Multiphase Systems: Vol.1 and 2", Sijthoof and Noordhoof, The Hague (1983).

3. Selected references from recent periodicals.

**Course Objective:**

The phenomenon of mass transfer with chemical reaction takes place whenever one phase is brought into contact with one or more other phases not in chemical equilibrium with it. This phenomenon has industrial, biotechnological and physiological importance. In Chemical Engineering, it is encountered in both "separation processes" and "reaction engineering"; both of these areas are covered adequately in other courses but interactions are often neglected. This course attempts to fill this gap and the main emphasis is given to quantify the effects of chemical reactions on the mass transfer rate. Special attention is devoted to gas – liquid systems not only that this area has been developed better than others but also involves important applications since chemical solvents are often employed to increase the capacity and the selectivity in gas absorption.

The subject has also a practical importance for large-scale industries, such as bulk and/or selective removal of hydrogen sulphide, carbon dioxide (and carbonyl sulphide) in natural and refinery gases sweetening as well as bulk removal of carbon dioxide in hydrogen production and carbon dioxide capture from power plants.

**Weekly Breakdown of Course Material:**

Week 1: Introduction

1. Examples of industrial importance
2. Principles involved in mathematical lay – out and in unified treatment of multiphase systems

Week 2: Review of interphase mass transfer models

1 .Mathematical description of interfaces

2. Film and surface renewal models

Week 3: Effect of Chemical Reactions

1. Enhancement factor concept

2. Analytical solutions for linear kinetics and for infinitely fast reactions

Week 4: Irreversible reactions of general order

1. General treatment

2. Mass Transfer regimes:

   (a) Very slow reactions
   (b) Slow reactions
   (c) Pseudo – $m^{th}$ order reactions
   (d) Fast pseudo – $m^{th}$ order reactions or diffusional falsification regime
   (e) Transition regime
   (f) Instantaneous reaction regime or diffusional control

Week 5: Continuation and extension to reversible reactions

Week 6: Absorption of a gas into a solution containing two reactants

Week 7: Simultaneous absorption of two gases

1. Basic concepts and selectivity
2. Uncoupled mass transfer
3. Coupled mass transfer and effects of a possible "shift reaction"

Week 8: Reaction in both phases, complex reactions, desorption with reaction

Week 9: Non – isothermal behavior and steady – state multiplicity

Week 10: Models for simulation and design of gas – liquid absorbers

1. Microscopic and macroscopic models
2. Laboratory – scale absorbers and their use in design
   (a) "point" model
   (b) "complete" model

Week 11: Mass transfer with reaction in fluid – fluid – solid systems

1. Classical and pseudo – homogeneous models
2. Analogy and differences in two and three phase systems

Week 12: Slurry reactors

1. Solid as a reactant and its application in flue gas desulfurization
2. Finely powdered catalysts

Week 13: Types of contactors and their relative merits

Week 14: Case Studies from industries

1. Acid gas removal by chemical solvents
   (a) $CO_2$ and $H_2S$ removal by amine solvents
   (b) Flue gas desulfurization by limestone – water slurry
2. Carbon dioxide capture from power plant gases

Week 15: Detailed design and simulation of an absorber – desorber cycle for natural gas sweetening using also Simulation Programs (such as HYSYS)