A Course in Environmentally Conscious Chemical Process Design

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Outline

- Motivation and Objectives
- Course Components
- Design Projects
- Teaching Experience and Assessment
- Related Work

Motivation

- The chemical industry is the major source of toxic pollutant release in the US (Anastas, 1994).
- Efforts to address this are shifting from remediation to prevention (“benign by design”).
- Pollution prevention is an increasingly important part of the average chemical engineer’s job responsibilities.
- Pollution prevention concepts must be incorporated into the chemical engineering curriculum
  - Materials (lectures, problems, projects) for core courses.
  - Specialized courses.

CHEG 498B Environmentally Conscious Chemical Process Design

Objectives

- To educate students on the real cost of operating processes that release pollutants.
- To provide students with strategies to minimize or reduce the environmental impact of a current process.
- To examine the design of processes using new technologies that eliminate pollution at the source.

Course Components

- Introduction to pollution prevention
- Environmental regulations
- New technology and current research
- Design projects: Comparison of conventional processes with new environmentally benign technologies

Introduction to Pollution Prevention

- The waste management hierarchy: prevention vs. remediation.
- Scientific bases for environmental challenges
- Waste audits and inventories: TRI, AIRS, BRS
- Life cycle analysis
- Industrial ecology and process integration
- Common sense “housekeeping” solutions
- Engineering modifications
- Allen and Sinclair Rosselot, *Pollution Prevention for Chemical Processes*, Wiley (1997).

Environmental Regulations

- Know your legal responsibilities.
- Impetus for the development of new technologies and pollution prevention strategies.
- Discussion driven by scenarios.
- Lynch, *A Chemical Engineer's Guide to Environmental Law and Regulation*, National Pollution Prevention Center (1995).

New Technology and Current Research

- Raise awareness of types of new technology and ongoing research
- Process Integration: Mass Exchange Networks
- Solvent substitution
  - Liquid and supercritical carbon dioxide: dry cleaning, spray painting, separations and reactions
  - Room temperature ionic liquids: reactions and separation
  - Aqueous solvents in cleaning applications

New Technology and Current Research

- Alternative raw materials or intermediates
  - Adipic acid from glucose
  - Road salt from lactose
  - Urethanes from amines and CO_2 (i.e., without phosgene and isocyanates)
- More selective catalysts and reaction systems
  - Optimal distribution of catalyst on support
  - Catalytic membrane reactions
  - Effect of mass transfer on selectivity in packed beds

Projects

- Case studies that compare designs of conventional processes to those using new benign technologies.
  - Decaffeination of coffee
  - Extraction of soybean oil
  - Production of *p*-nitroaniline
- Students develop preliminary designs.
- ASPEN PLUS simulations with costing and economic evaluation
  - Identification of environmental issues.
  - Evaluation of a variety of scenarios.
- Good framework for discussion of ethical issues concerning the value of inherently safer processes.

Project 1: Decaffeination of Coffee

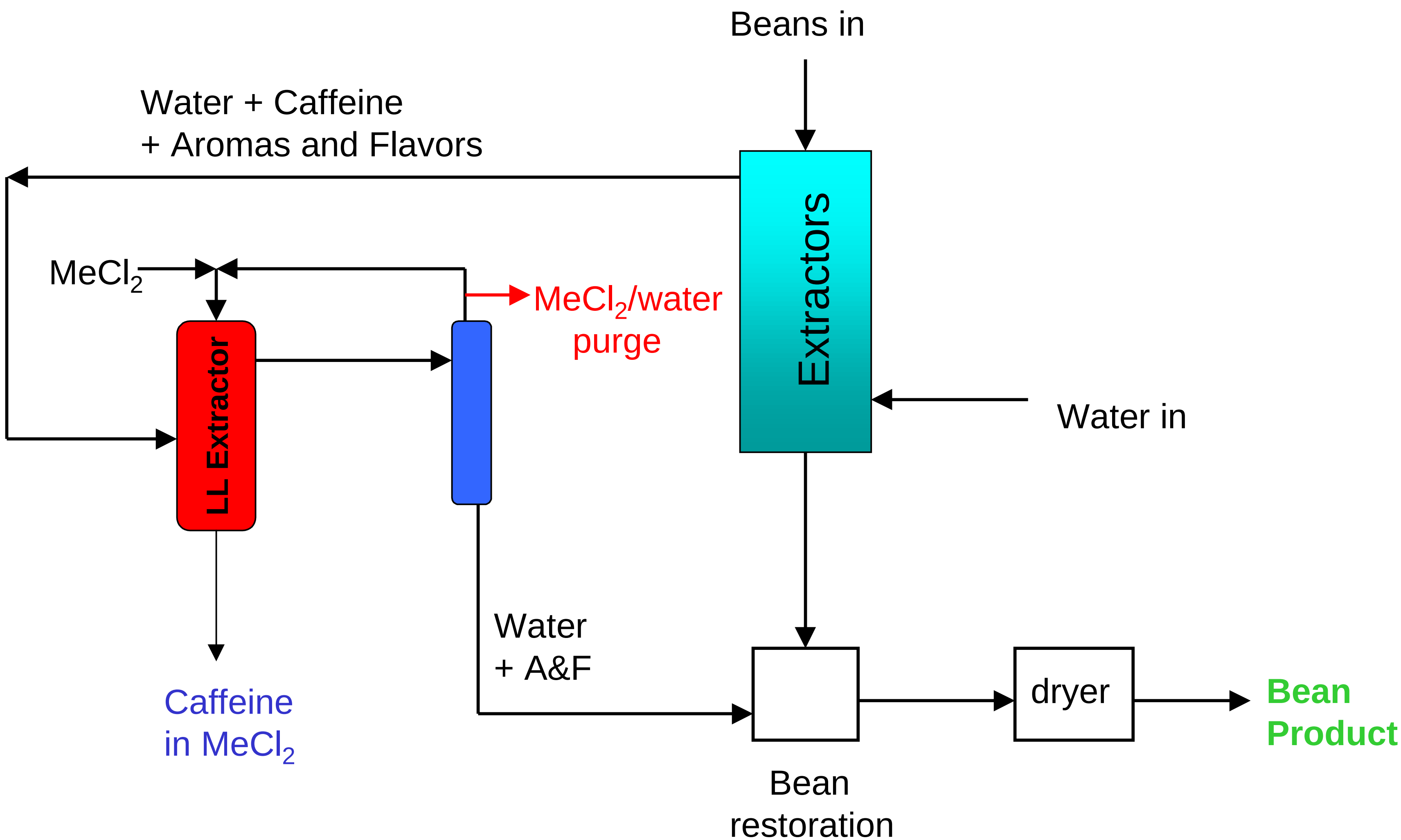
Decaffeination using supercritical carbon dioxide

vs.

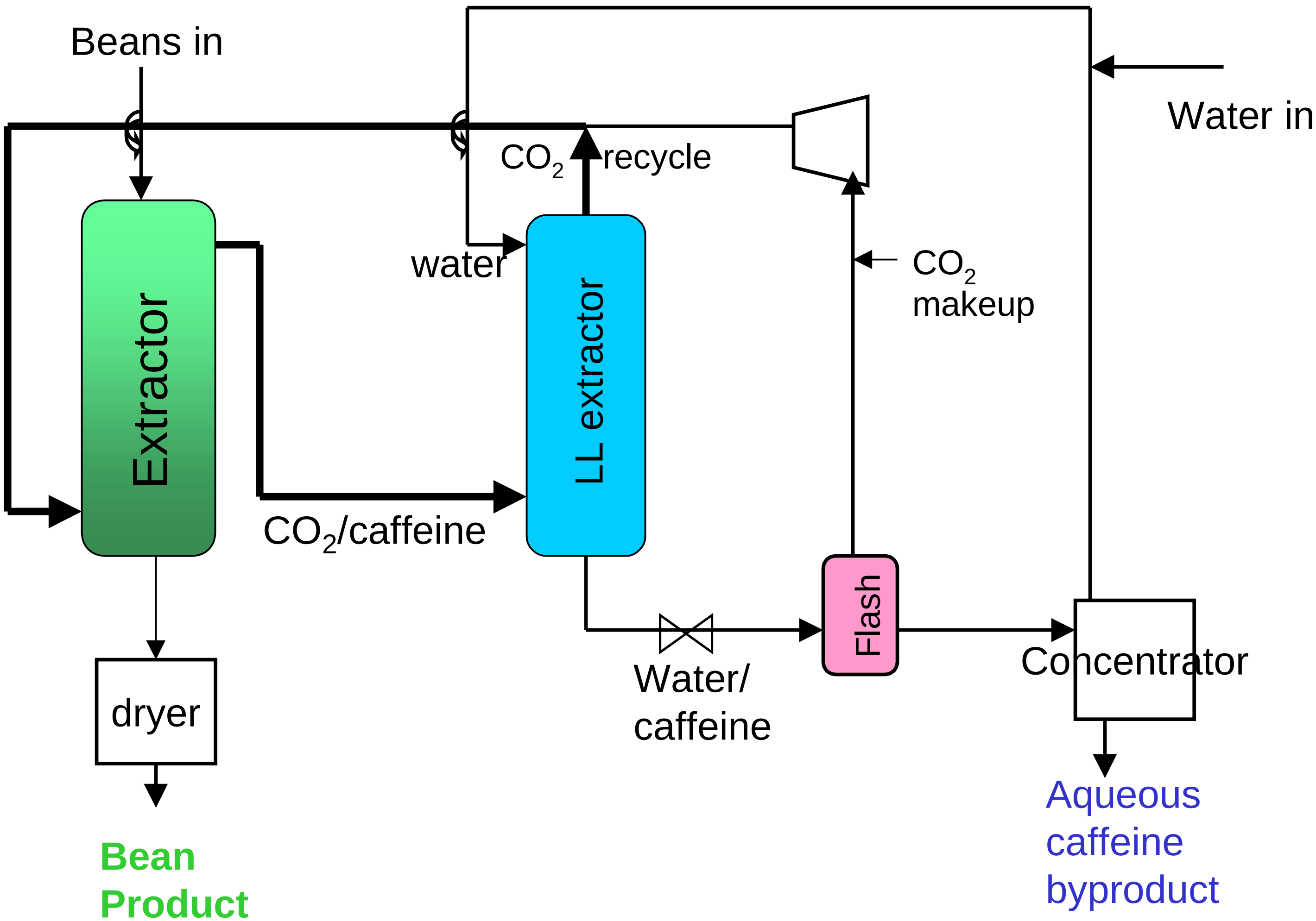
Conventional "water process" using

methylene dichloride

Caffeine Extraction - Water Process



Caffeine Extraction - Supercritical CO_2



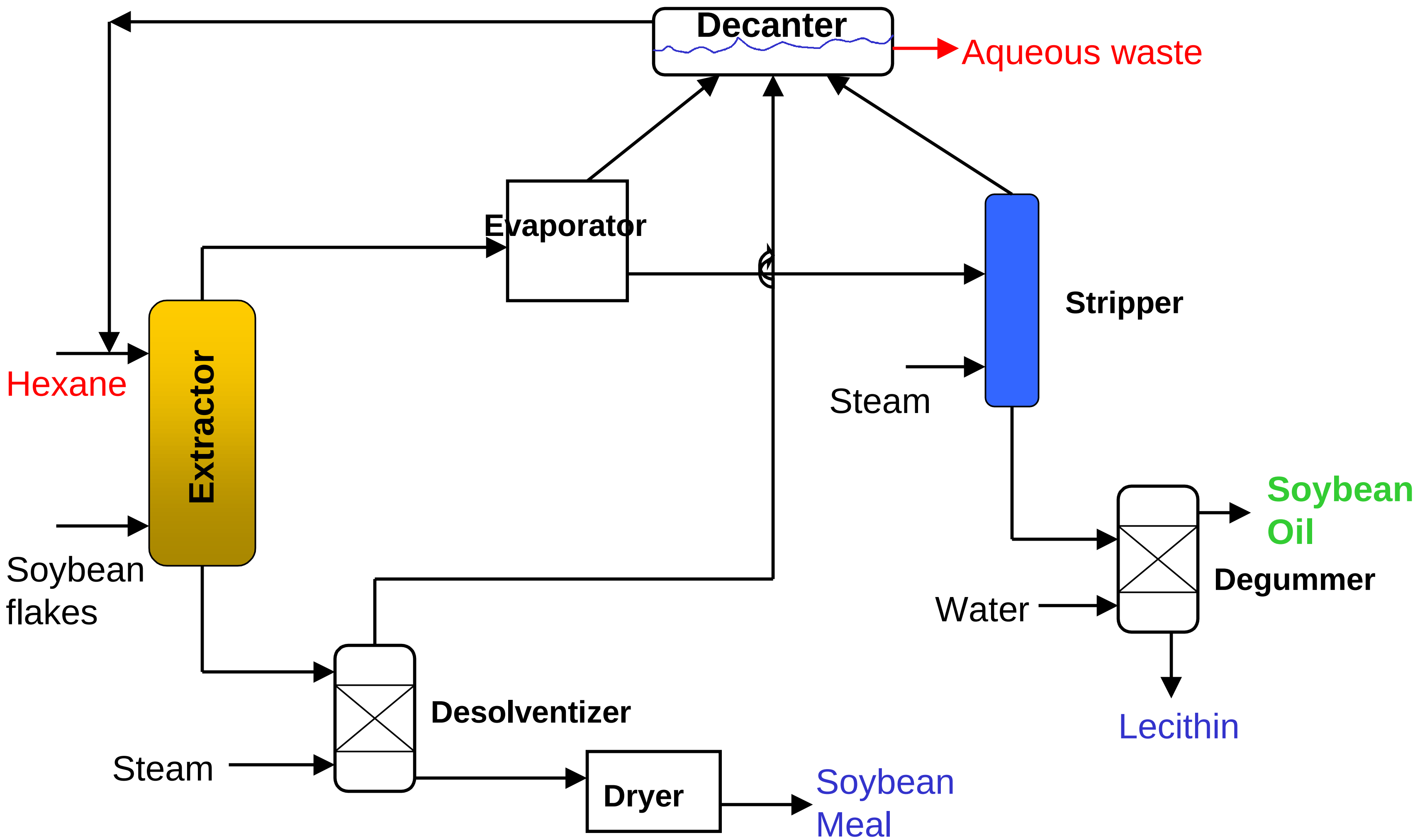
Project 2: Extraction of Soybean Oil

Extraction with supercritical CO_2

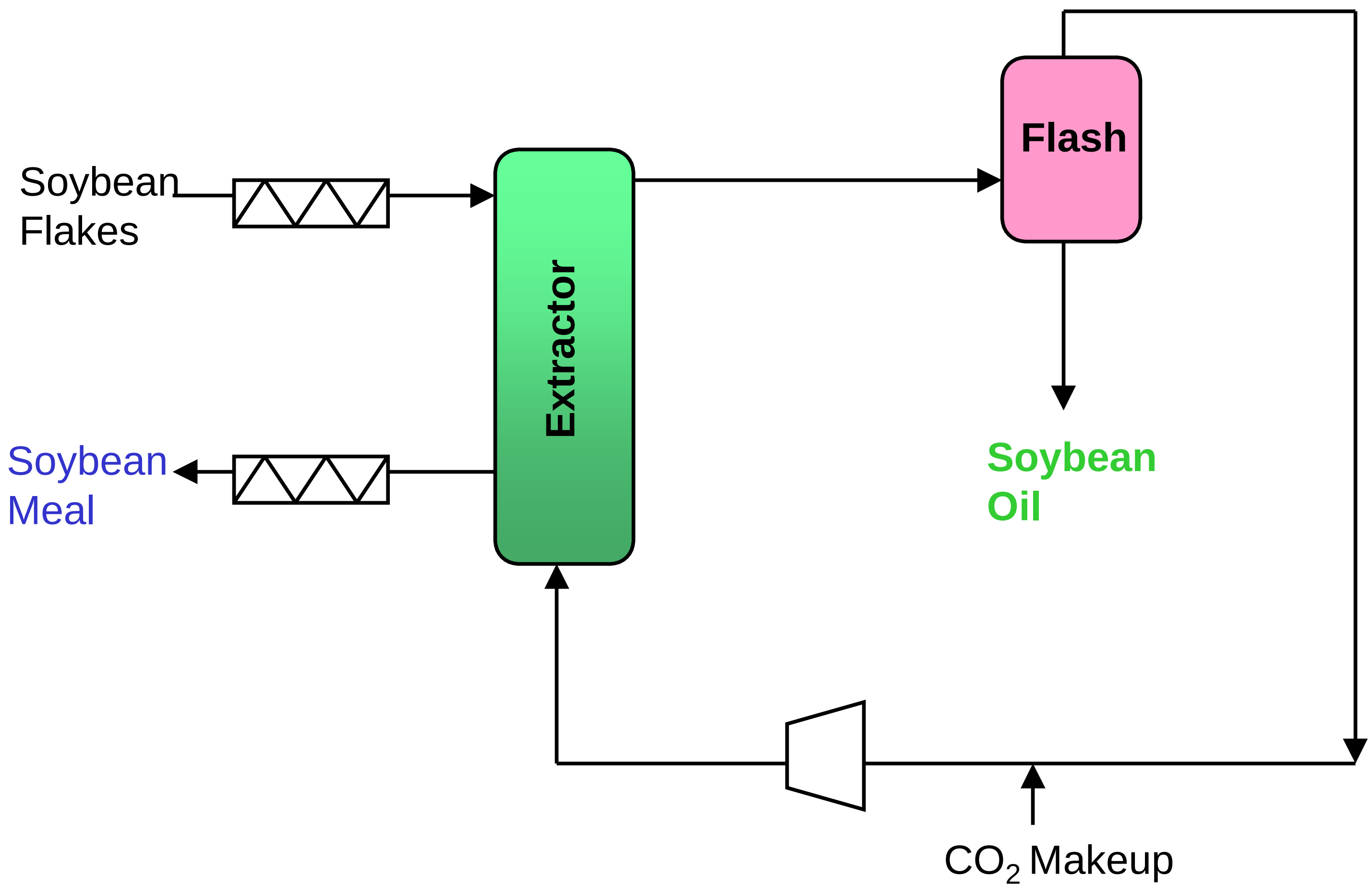
vs.

Extraction with hexane

Soybean Oil Extraction - Hexane Process



Soybean Oil Extraction - Supercritical CO_2



Project 3: Production of *p*-Nitroaniline

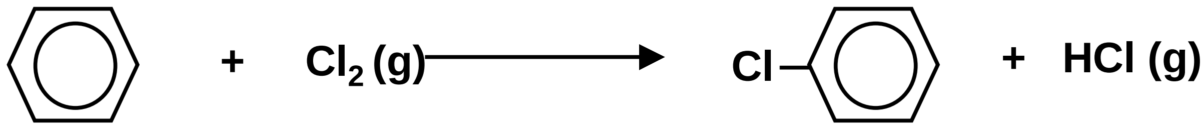
Nucleophilic aromatic substitution process

vs.

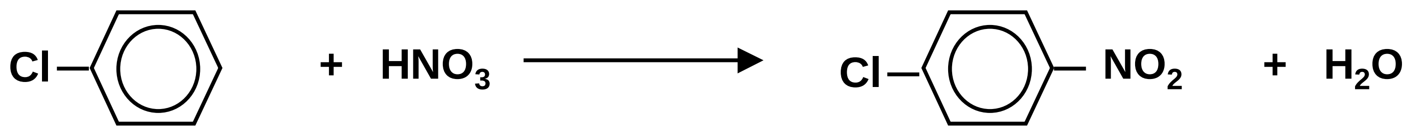
Chlorine-based process

p-Nitroaniline - Conventional Process

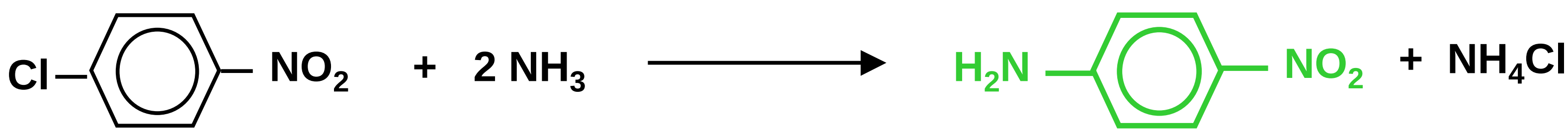
1. Chlorination of benzene



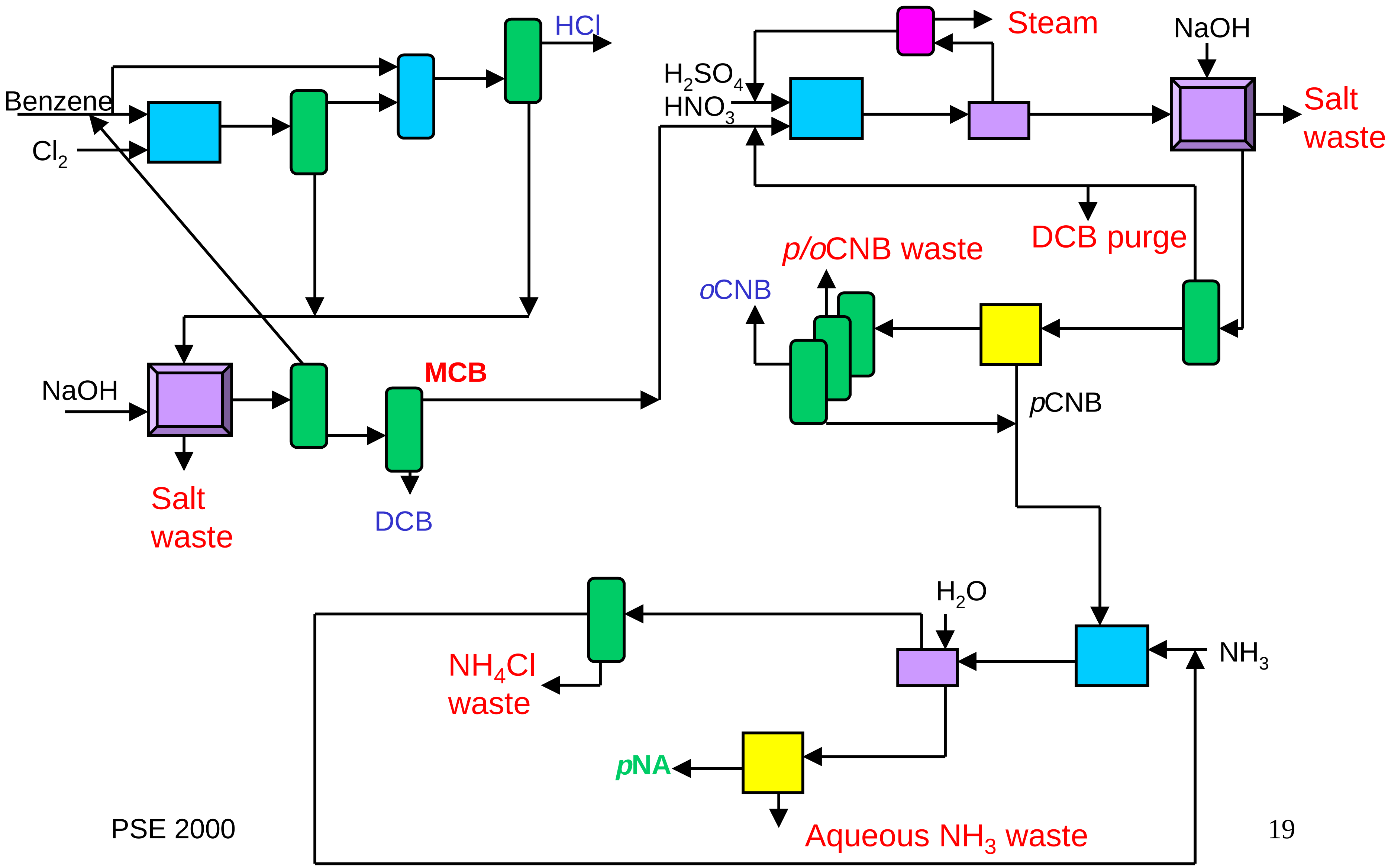
2. Nitration of chlorobenzene



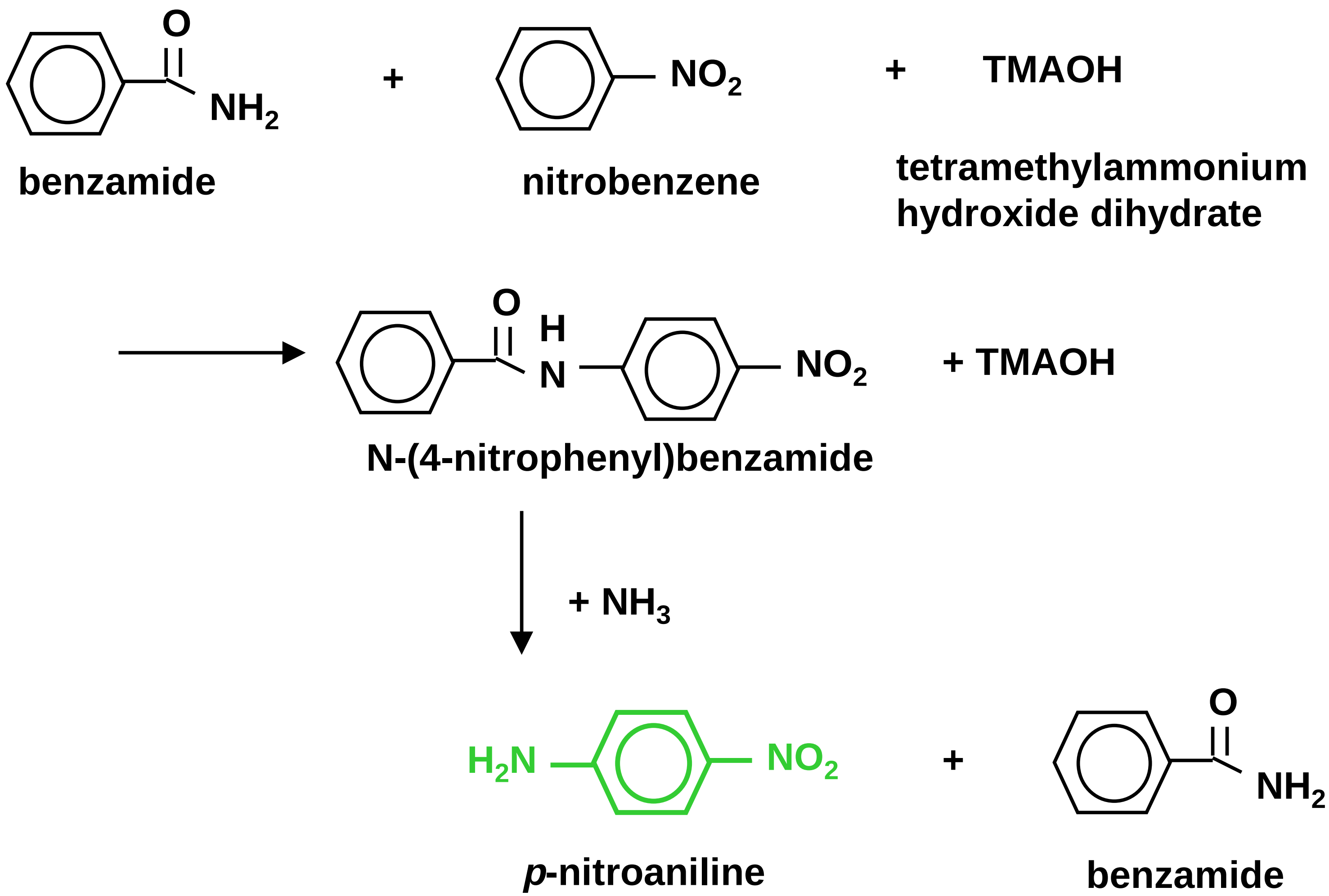
3. Ammonolysis of *p*-chloronitrobenzene



p-Nitroaniline - Conventional Process

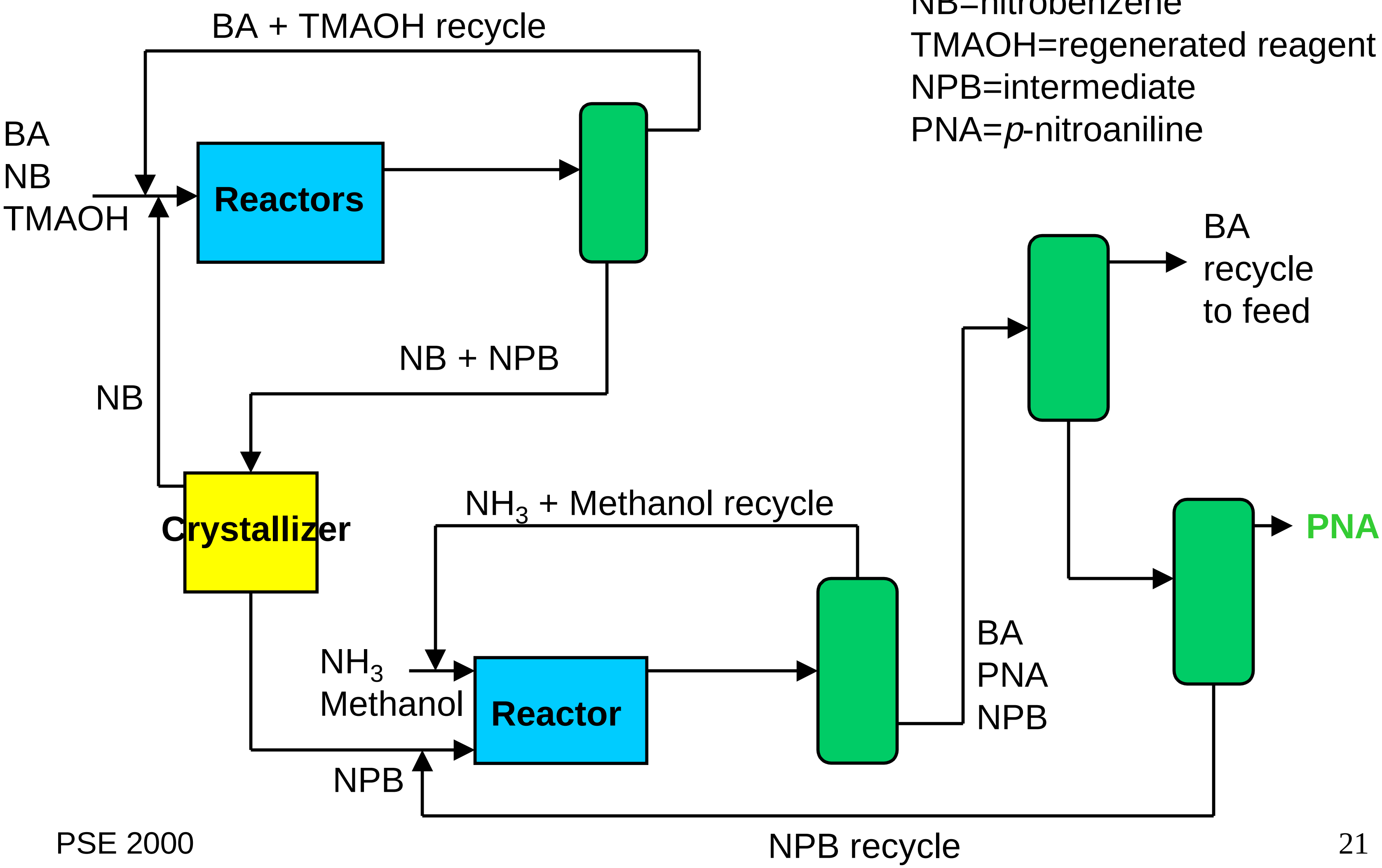


p-Nitroaniline - New Chemistry



p-Nitroaniline - New Chemistry

BA=benzamide
NB=nitrobenzene
TMAOH=regenerated reagent
NPB=intermediate
PNA=*p*-nitroaniline



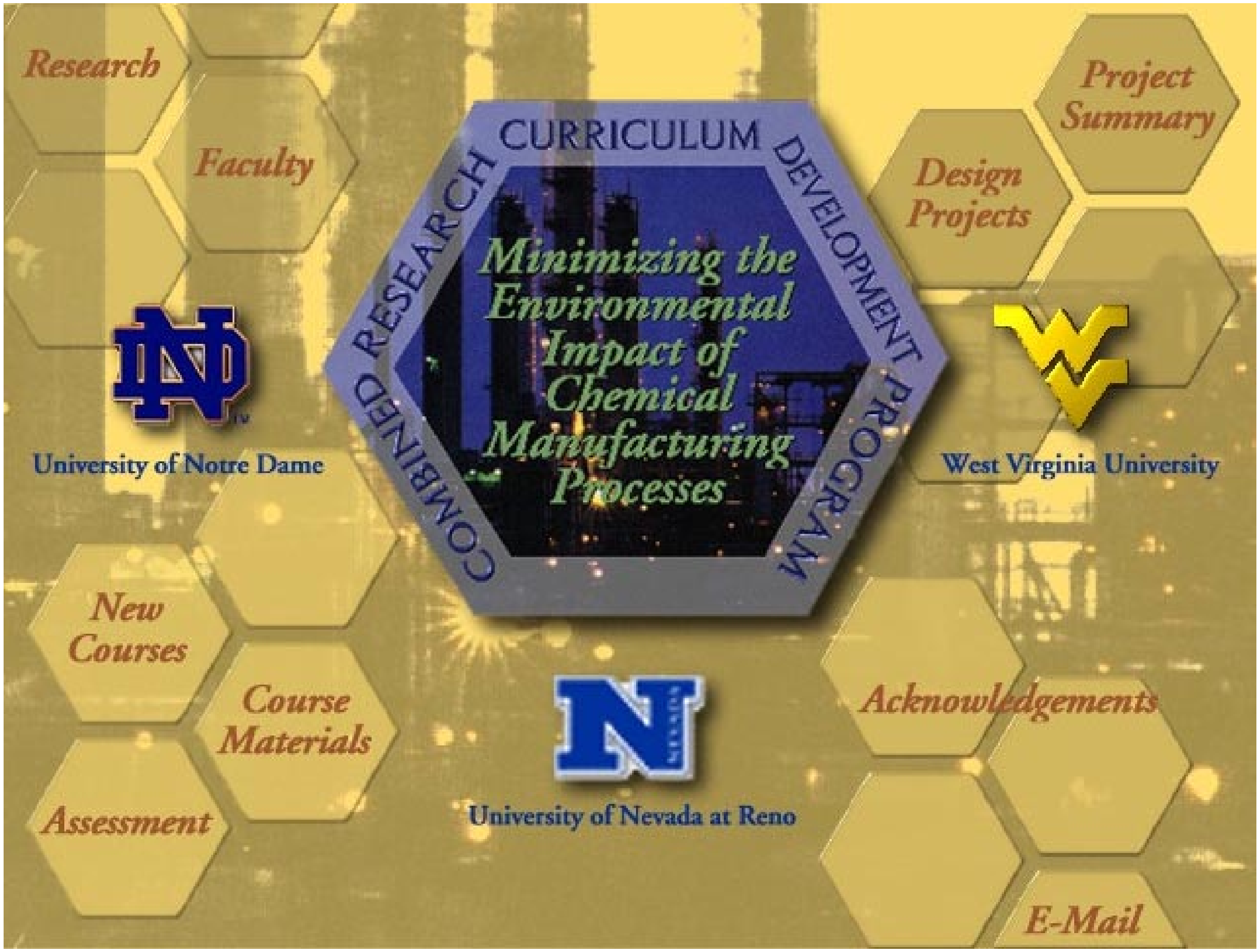
Teaching Experience

- Course taught at Notre Dame three times (JFB)
  - Spring 1997 (lecture format; seniors)
  - Spring 1998 (lecture format; juniors and seniors)
  - Fall 1999 (discussion format)
- Modified version taught at West Virginia University
  - Spring 2000
  - Professor Joseph. A. Shaeiwitz
  - Used materials from draft of new “Green Engineering” text (EPA; D. Allen)

Assessment

- Entry and exit questionnaires used.
- No significant changes in student attitudes. Students appreciated both before and after the course that industrial activity has an impact on the environment.
- Increase in student knowledge of environmental regulations.
- Increase in student awareness of pollution prevention concepts and technologies, from simple "housekeeping" solutions to use of entire new technologies.

Related Work: http://www.nd.edu/~enviro



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