Is Chemical Engineering Right for You?

Professor David Graves
Dept. of Chemical and Biomolecular Engineering
University of California, Berkeley
My Background

- Bachelor's degree in Chemical Engineering (ChE): University of Arizona (Tucson)

- Work for 2 years at Chevron: Process Control Engineer

- Masters of Science ChE: University of Arizona (research on coal combustion)

- PhD (doctorate) ChE: University of Minnesota (research on plasmas for semiconductor processing)

- Professor at UC Berkeley ChE department (since 1986...)
What is Chemical Engineering?

Easiest definition: any industrial or applied chemical process involves chemical engineering....

How do you take a process from a test tube to a large scale factory?
What is Chemical Engineering?

In fact, any system that involves chemical transformation is relevant to the field of chemical engineering.
Where do Chemical Engineers work?

Everywhere and anywhere!
### Starting Salaries, Bachelors Degree Recipients

#### 15 top-earning degrees

<table>
<thead>
<tr>
<th>Rank</th>
<th>Field</th>
<th>Current Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Petroleum engineering</td>
<td>$83,121</td>
</tr>
<tr>
<td>2</td>
<td>Chemical engineering</td>
<td>$64,902</td>
</tr>
<tr>
<td>3</td>
<td>Mining engineering</td>
<td>$64,404</td>
</tr>
<tr>
<td>4</td>
<td>Computer engineering</td>
<td>$61,738</td>
</tr>
<tr>
<td>5</td>
<td>Computer science</td>
<td>$61,407</td>
</tr>
<tr>
<td>6</td>
<td>Electrical engineering</td>
<td>$60,125</td>
</tr>
<tr>
<td>7</td>
<td>Mechanical engineering</td>
<td>$58,766</td>
</tr>
<tr>
<td>8</td>
<td>Industrial engineering</td>
<td>$58,358</td>
</tr>
<tr>
<td>9</td>
<td>Systems engineering</td>
<td>$57,438</td>
</tr>
<tr>
<td>10</td>
<td>Engineering technology</td>
<td>$56,447</td>
</tr>
<tr>
<td>11</td>
<td>Actuarial science</td>
<td>$56,320</td>
</tr>
<tr>
<td>12</td>
<td>Aeronautical engineering</td>
<td>$56,311</td>
</tr>
<tr>
<td>13</td>
<td>Agricultural engineering</td>
<td>$54,352</td>
</tr>
<tr>
<td>14</td>
<td>Biomedical engineering</td>
<td>$54,158</td>
</tr>
<tr>
<td>15</td>
<td>Construction management</td>
<td>$53,199</td>
</tr>
</tbody>
</table>

#### Current Average

<table>
<thead>
<tr>
<th>Discipline</th>
<th>Current Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accounting</td>
<td>$48,085</td>
</tr>
<tr>
<td>Business Administration/Mgmt.</td>
<td>$45,915</td>
</tr>
<tr>
<td>Economics</td>
<td>$50,507</td>
</tr>
<tr>
<td>Finance</td>
<td>$48,547</td>
</tr>
<tr>
<td>Marketing/ Marketing Mgmt.</td>
<td>$42,053</td>
</tr>
<tr>
<td>Computer Science</td>
<td>$60,416</td>
</tr>
<tr>
<td>Information Sciences &amp; Systems</td>
<td>$52,418</td>
</tr>
<tr>
<td>Chemical Engineering</td>
<td>$63,165</td>
</tr>
<tr>
<td>Civil Engineering</td>
<td>$51,632</td>
</tr>
<tr>
<td>Electrical/Electronics Engineering</td>
<td>$56,910</td>
</tr>
<tr>
<td>Mechanical Engineering</td>
<td>$57,009</td>
</tr>
<tr>
<td>English</td>
<td>$34,327</td>
</tr>
<tr>
<td>Psychology</td>
<td>$33,564</td>
</tr>
<tr>
<td>Sociology</td>
<td>$34,796</td>
</tr>
</tbody>
</table>

All data are for the bachelor's degree level.

Source: Summer 2008 Salary Survey, National Association of Colleges and Employers. Reprinted with the permission of the National Association of Colleges and Employers, copyright holder. All rights reserved.
Berkeley Data

• From UC Berkeley Career Center “What can I do with a major in…” survey

• 2008-2009 salaries for BS awardees:
  - ChemE average salary: $63.3k (8% grad school bound)
  - Chemistry: $35.3k (34% grad school bound)
  - Chemical Biology: $41.2k (28% grad school bound)
Chemical Plant Design and Processing
Large scale processes →

marrying chemistry with physics and thermodynamics
Chemical Industry (CI) and Chemical Processing Industry (CPI)

- Chemicals, including petrochemicals (CI)
- Plastic materials, synthetic resins, and nonvulcanizable elastomers (CI)
- Man-made fibers (CI)
- Drugs and cosmetics (CI)
- Soap, glycerin, cleaning, polishing, and related products (CI)
- Paints, varnishes, pigments and allied products (CI)
- Fertilizers and agricultural chemicals (CI)
- Petroleum refining and coal products (CPI)
- Rubber products (CPI)
- Leather tanning and finishing (CPI)
- Foods and beverages (CPI)
- Fats and oils (CPI)
- Wood, pulp, paper and board (CPI)
- Stone, clay, glass and ceramics (CPI)
- Lime and cement (CPI)
- Metallurgical and metal products (non-ferrous) (CPI)
- Explosives and ammunition (CPI)
- Other chemically processed products - including semiconductors and related products (CPI)
Advanced Materials:
Extreme Conditions, Advanced Performance

- Nanotechnology—tiny, tiny!
- High performance materials: polymers (plastics)
- Electronic/photonic material applications: IC ‘chips’ for computers; solar cells; light emitting diodes...
Biotechnology
Environmental Safety & Health
Design & Construction
Semiconductor Electronics: Integrated Circuits
Energy/Fuels
What is Chemical Engineering Like?

Chemically engineering students learn how to apply the principles of *physics*, *chemistry* and even *biology* to analyze and design processes.

This usually means first formulating, then solving math problems – often using computers.
What do ChEs Do?

 Mostly solve math problems related to things like chemical reactors...

**Fundamental Concepts**
- Species Balances
- Stoichiometry
- Chemical Kinetics
- Transport Phenomena (Transport Limitations)
- Global Reaction Rate Expressions

**Design Decisions**
- Mode of Operation
- Reactor Configuration

**Reactor Design Equations**
- Energy Balance (Temperature Effect)
- Momentum Balance (Pressure Effect)

**Solver**

**Design Formulation (Solution)**
Early Sources of Agricultural Nitrogen: Fertilizer

• 1840’s saw introduction into Europe and North America of guano (solidified bird excrement) and sodium nitrate (NaNO₃)
  - about 40 times higher nitrogen content than barnyard manure
• Second half of 19th century: development of alternatives required, especially in Britain and Germany
  - NH₃ recovery from coal coking
  - high temperature synthesis of cyanimide (CaCN₂)
  - fixation of atmospheric N₂ from electric discharge, forming NO first, then reacting with water to form nitric acid
NH$_3$ Manufacture

- Basic laboratory synthesis of NH$_3$ from N$_2$ and H$_2$ demonstrated by Fritz Haber in 1909 (Germany)
- German chemical company BASF developed commercial process by 1913. Lead engineer: Carl Bosch
- Haber received Nobel prize (chemistry) in 1918
- Bosch received Nobel prize (chemistry) in 1932
- Haber-Bosch NH$_3$ manufacturing process has become an extremely important source of agricultural fertilizer
- *Estimates are that about 2 billion people depend directly on this process, and that future increases in population in land-poor, developing nations will depend very heavily on it.*
NH₃ Manufacture

• Many features of NH₃ manufacture characteristic of modern developments in industrial chemical technology:
  - catalytic process
  - energy intensive
  - high pressure (common but not ubiquitous)
  - continuous process
  - heavily instrumented
  - many challenges in materials and equipment overcome

• Since 1913, many improvements made, but basic features of technology remain
Reactions for NH₃ Manufacture

CH₄(g) + H₂O(g) → CO(g) + 3H₂(g)  
(Ni catalyst, 400 psig, 1450 F)  
Primary reformer

CH₄(g) + air (g) → CO(g) + 2H₂(g) + 2 N₂  
(Ni catalyst, 1 atm; 1730 F)  
Secondary reformer

CO(g) + H₂O(g) → CO₂(g) + H₂(g)  
(FeO₂/Cr₂O₃ catalyst, 1 atm, 400°C)  
Water-gas shift; Shift converter

CO(g) + 3H₂ → CH₄(g) + H₂O(g)  
CO₂(g) + 4H₂ → CH₄(g) + 2H₂O(g)  
(Ni catalyst; 315 C)  
Methanation; Methanator

3/2 H₂(g) + 1/2 N₂(g) → NH₃(g)  
100-150 atm; 450 C; promoted Fe catalyst  
NH₃ converter
Schematic of NH₃ Manufacture

natural gas → desulfurization → Primary reforming → Secondary reforming

- Steam: 0.56 H₂, 0.23 N₂, 0.12 CO
- Air: 0.005 CH₄, 0.08 CO₂

Methanation
- 0.001 CO₂, 0.003 CO

Compression & ammonia synthesis
- 0.74 H₂, 0.24 N₂, 0.008 CH₄, 0.003 Ar

CO₂ removal
- CO₂

Shift conversion
- CO₂

ammonia

Inerts (CH₄, Ar)
Schematic of NH₃ Plant

- Natural Gas
- Sulfur Removal
- Primary Reformer
- Fuel
- Furnace
- Secondary Reformer
- Air
- CO₂ Absorber
- Carbonate Regenerator
- CO₂
- Condensate
- Ammonia Converter
- Purge
- Methanator
- CO₂ Condensate
- Recycle
- NH₃ Product

Symbols:
- Compressor
- Cooler
- Pump
NH₃ conversion is exothermic, releasing heat. Reactor temperature must be controlled to balance thermodynamic and kinetic requirements. Walls are too thick for external heat exchange.

Feed is split into two parts and is introduced into converter reactor to cool converter walls and to limit reaction temperature. Quench feed is introduced at various locations within the converter to cool, or ‘quench’ the reaction.

Scheme heats the incoming feed, keeps the reactor temperature at optimum level and cools thick converter walls without external heat exchange.
Graves Group: Plasma Biomedicine

Video courtesy of Dr. Jim Barthel
Section Head, Endoscopic Oncology
Medical Director, Endoscopic Oncology Area
Moffitt Cancer Center & Research Institute
Tampa, Florida

Tissue ablation and coagulation
(http://www.erbe-med.de/)
Graves Group: Plasma Biomedicine

Dental: root canal treatment

(a)  (b)


Cancer treatment


Also: Killing bacteria, wound healing, dermatology, others…
Graves Group: Undergraduate Researchers!

1. Plasma device characterization (Dustin Chen)
2. Hand-held plasma device for school class projects (Connor Galleher)
3. Analysis of plasma treated water (Stephenie Zhang)
4. Electrochemical probe analysis of plasma treated water (Leo Kao)
5. Cell viability assay for characterization of plasma devices (Phillip Tu)
6. Plasma-assisted pretreatment of lignocellulosic materials (Pritha Hait)
7. Math modeling plasma-aided wound healing (Marat Orzov)

(~ 10 hours per week)
What are the Options After Getting a ChE Degree Besides Industry?

Law school – for example, patent law is a good option for ChEs.

Medical school – ChE is good training in hard work!

Business school – get an MBA degree after working in industry.

Graduate school – get a Masters or PhD (doctorate) in Engineering then maybe become a Professor!!