Chemical Engineering, the Chemical Engineering Curriculum & Careers for Chemical Engineers

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What is chemical engineering?

- *Chemical Engineering* originated with the need to transform raw materials into useful products through chemical reactions.
- The reactions where discovered by chemists starting in the 1600’s but by the end of the 1800’s, there was a need to produce large quantities of an ever increasing number of materials.
- The “scale-up” of a laboratory reaction (~grams) to a profitable commercial process $10^6$ grams) is usually not a matter of just making bigger laboratory equipment (flasks, beaker and Bunsen burners).
More about chemical engineers

• *Chemical engineers* use the principles of engineering analysis and knowledge of chemistry to design, build and operate processes that provide society with items such as:

• petroleum fuels, toothpaste, low fat chips, paint, plastic for athletic shoes or carpeting, insecticides, pharmaceuticals, computer chips, etc.
Chemical Works, Wilton, Tesside
INDUSTRIAL RADIAL FAN

1000 Gallon reactor—on its side!

http://www.arnoldeqp.com/2312.htm

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SHANGHAI OIL REFINERY

http://www.luboil.com/brief/brief.html

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Fluidized bed Catalytic Cracking unit

http://www.luboil.com/brief/brief.html

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SHANGHAI OIL REFINERY

http://www.luboil.com/brief/brief.html

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Seal Sand
Dramatic picture of a refinery
More about the future of chemical engineering

• In the future we might expect: replacement bones, tendons, skin and other organs, superconducting integrated circuits, ceramic and plastic automobiles, nonmetallic bridges and building structures and clothes that don’t get dirty!!
Artificial knee

http://www.mayohealth.org/mayo/9701/htm/knee_rep.htm#ww5r111
Heart-Lung Machine

http://www.steeledesigns.com/gallery3.html

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Transdermal glucose monitor

Brain Cancer implantable “patch”

http://www.guilfordpharm.com/fs_products_f.htm
Defining chemical engineering

- The special role of chemical engineers is their ability to analyze, design and operate processes where
  - chemical (i.e. reactions)
  - physical (phase change)
  - biological

- transformations of matter occur.
Defining chemical engineering

• Most all of the products of the world are made of materials that are in a different form from the raw materials from which they were made.

• Chemical engineers must be able to deal with matter from atomic up to process scales.

• This requires a strong understanding of chemistry and the ability to apply physical laws over very broad range of length scales.
Primary characteristics of chemical engineers that makes them unique.

• Chemical engineers understand matter in terms of its fundamental nature,
  – i.e., molecules,
  – can describe molecules or groups of molecules quantitatively

• And can answer the important questions necessary to bridge the gap from molecular sizes up to the dimensions of everyday life.
Another way to think of it

– A thread that is worth pursuing is our understanding of "structure" and "patterns" at scales from molecular to macroscales.
– Different structure can make huge differences in properties.
Graphite Structure

- Picture from
- John Carroll University - Chemistry
• Picture from
• John Carroll University
  - Chemistry

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Local Composition Enhancement

Bulk = 1 mol%

(Pc)

Local Composition (mol%)

Pressure (bar)

acetone
methanol
ethanol
n-octane

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(Kim and Johnston, 1987)
Reaction Kinetics -- J. F. Brennecke
Local Composition Enhancement

33°C
44.4°C

Bulk Mole Fraction = 0.01

PRESSURE (bar)

LOCAL MOLE FRACTION

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Crystal Growth -- Microstructural Engineering
(P. J. McGinn)

YBa$_2$Cu$_3$O$_7$ superconductor directionally solidified to achieve a highly textured microstructure. Controlling the solidification conditions produces aligned plate-like grains.
Structure of flowing fluids

Interfacial waves generated by a shearing gas flow
A. E. Miller,
H. -C. Chang
A. E. Miller,
We can do one chemical engineering problem today

– If I asked how you how far it was to Chicago you would not answer, 5 Kg!
– Your answer would involve length, ~ 100 miles or
– 5,702,400 inches!
– I can use this idea that quantities must have the correct dimensions to do some other comparisons
Cooking !!

-- A cooking time scale for the interior of something is

- \( t \sim \frac{C_p l^2 \rho}{k} \)

- in this equation \( k \) is the thermal conductivity, \( \rho \) is the density, \( C_p \) is the heat capacity and \( l \) is the length scale of the object.
Cooking!!

- The surface time scale can be the chemical reaction time scale. The exterior cooking could be a chemical reaction time scale for dehydrolysis (removal of water from sugars and starches). If we have

• \[ \text{Rate} = K \times C \]

- where \( C \) is the concentration for a first order reaction and \( K \) is the first order rate constant, we can construct a dimensionless group (i.e. ratio of important effects) that will tell us how to cook something.
Cooking (continued)

• The (interior to exterior) cooking ratio is:

\[
\frac{KC_p l^2 \rho}{k}
\]

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More cooking equations

- **How can I use this to decide how to cook different items?**

- As the object grows larger, it will take longer for the inside to get cooked. To avoid burning the outside, we need to alter the value of $K$ to keep the ratio roughly the same. This can be done by reducing the temperature because we expect that $K$ will follow Arhenius kinetics as

  $$K = A \exp\left[-\frac{E_a}{RT}\right]$$
Still more cooking equations

– $K = A \exp[-E_a/RT]$
– Where $E_a$ is the activation energy, $A$ is a constant that depends on the reaction, $R$ is the gas constant in appropriate units and $T$ is absolute temperature.
– From this expression we find that we can reduce the temperature and the reaction (outside cooking) rate will go down!!
– Thus, we would expect this equation in every cookbook!!
Other problems solved by chemical engineers

• "The American Institute of Chemical Engineers (AIChE) has identified the 10 most outstanding achievements of chemical engineering as being:

• 1. production of fissionable isotopes,
• 2. production of synthetic ammonia,
• 3. production of petrochemicals,
• 4. production of chemical fertilizers,
• 5. commercial-scale production of antibiotics,
• 6. establishment of the plastics industry,
• 7. establishment of the synthetic fibers industry
• 8. establishment of the synthetic rubber industry,
• 9. development of high-octane gasoline,
• 10. electrolytic production of aluminum.
Accomplishments

• "Chemical engineering is also involved in a major way in nuclear energy, medicine, materials science, food production, space, undersea exploration, and, above all, in energy production and the development of new sources of energy."
What do chemical engineers study to become chemical engineers?

• 1. Basic sciences
  – Mathematics (5 courses)
  – Physics (3 courses)
  – Chemistry (7 courses + labs)

• 2. Engineering sciences
  – Thermodynamics
    • Heat -- work conversion
    • phase equilibria
  – Transport Phenomena
  – Heat transfer, fluid mechanics, mass transfer
  – Numerical Analysis
What do chemical engineers study to become chemical engineers?

• 3. Engineering Design

  – Chemical Reaction Engineering
  – Separation Processes
  – Process Control
  – Process Design
What do chemical engineers do?

• Opportunities in *traditional* fields:
  – Petroleum and Chemical Industries
  – Graduate/Professional school
  – Food processing companies
  – Consumer product companies
  – Pharmaceutical companies
  – Electronic devices manufacturing
Opportunities in nontraditional fields

• Non-traditional fields that have an inherent chemical engineering component
  – see examples above
Opportunities in nontraditional fields

• Business analysis
  – Predicting oil/commodity prices
  – How much should Wal-Mart charge for VCR's ??
  – Financial analysis of new technologies
  – Investment Banking

• Favorite Quotes:
  – "A financial person can never intimidate an engineer with numbers, but an engineer can always intimidate a financial person with technology" (paraphrased from Roger Regelbrugge, CEO of G. S. Industries)
  – “Sufficiently advanced technology is indistinguishable from magic!” (Engineers at Shell Development Corp.)
Opportunities in nontraditional fields

• Political advising
  – A broadly-based science education is ideal for understanding important environmental issues that the world faces!!
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  – Real Estate Pricing
• Political advising
  – A broadly-based science education is ideal for understanding important environmental issues that the world faces !!
• To summarize

– The ability of chemical engineers to deal with chemical nature of materials from molecular to macroscopic length scales makes them unique.
– These skills can be used in a number of areas outside of the chemical processing industries
– The inherent breadth of the curriculum and our focus on understanding why, allows our graduates to make major impacts in a diverse range of fields where the ability to analyze problems quantitatively is important!