ChE211.1: Introduction to Chemical Engineering

Chemical Engineering Brief History, Definitions and Career Opportunities

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Learning Objectives

- Overview of how Chemical Engineering evolved as a discipline
- Introduction to Unit Operations
- Understand the difference between chemical process and chemical product engineering
- Learn about the diverse roles Chemical Engineers play in the 21 century

Brief history

- Chemical engineering
  - Had undergone many changes since inception the future will trace itself back to concepts we do not foresee now.
  - However, at any given time, is a profession and is a collection of facts, assumptions, and design art with the collection continuously changing.
- Note:
  - Before 18th century, industrial chemicals were mainly produced through batch processing.
  - During industrial revolution (1700-1800), production shifted from batch to continuous processing.
- We look at the brief history from 3 perspectives
  - principles, education and professional body.

Brief History (Chemical engineering principles 1/4)

- 1805: John Dalton published Atomic Weights, allowing chemical equations to be balanced and the basis for chemical engineering mass balances.
- 1824: Sadi Carnot was the first to study the thermodynamics of combustion reactions.
- 1850: Rudolf Clausius applied the principles developed by Carnot to chemical systems at the atomic to molecular scale.
- 1873-1876: Josiah Willard Gibbs developed a mathematical-based, graphical methodology, for the study of chemical systems using the thermodynamics of Clausius.

Brief History (Chemical engineering principles 2/4)

- 1882: Hermann von Helmholtz showed that measure of chemical affinity is determined by the measure of the free energy of the reaction process.
- 1883: Osborne Reynolds defines the dimensionless group for fluid flow, leading to practical scale-up and understanding of flow, heat and mass transfer
- 1898-1915: Industrial chemistry and descriptions, largely nonquantitative, of processes used in industry.
- 1915-1925: The unit-operation concept, chiefly the application of physics, took hold and was the central educational theme.

Brief History (Chemical engineering principles 3/4)

- 1925-1935: Unit operations were still the dominant theme, but more emphasis was being put on material and energy balances.
- 1935-1945: Applied thermodynamics and process control assumed importance, but the development does not imply necessarily less emphasis on unit operations.
- 1945-1955: Applied chemical kinetics and process design came to the fore. Unit operations losing its uniqueness as it was consolidated into other concepts.

Brief History (Chemical engineering principles 4/4)

- 1955-: More emphasis placed on engineering science.
  - From 1970 the focus is shifting gradually towards chemical product design and development rather than production process. These products are usually critically dependent on structure and design at the molecular level for their usefulness and require manufacturing processes that can precisely control their chemical composition and structure. Three broad products in this category are:
    - ✓ Micro-structured products (e.g. paints, Ice-cream, Snack food, foods, medicines)
    - ✓ Devices involving chemical reactions and/or separations (e.g. medical devices, Glucose sensor, Water purifier)
    - ✓ Specialty chemicals (e.g. polymers, catalysts, biofuels, copolymers)

Brief History (Chemical engineering education)

- 1882: a course in "Chemical Technology“ offered at University College London.
- 1885: a course in "chemical engineering" offered at Central College (now Imperial College), London.
- 1888: a new curriculum at Massachusetts Institute of Technology (MIT) started: Course X, Chemical Engineering.
- 1969: University of Ife (now Obafemi Awolowo University), Ile-Ife started ChE and graduated the first set of Nigeria-trained chemical engineers in 1973
- 1976: University of Lagos, Lagos produced its first graduates
- 1977: Ahmadu Bello University, Zaria produced its first graduates
- 2022: About 33 Nigerian universities offer ChE degrees.

Brief History (ChE Professional Bodies)

- 1908: the American Institute of Chemical Engineers (AIChE) was founded.
- 1922: the UK Institution of Chemical Engineers (IChemE) was founded.
- 1968: the Nigerian Society of Chemical Engineers (NSChE) was formed by a small group of graduate chemical engineers in Lagos and was formally incorporated on the 3rd of December 1981.
  - 1957 - The first Nigerian chemical engineer graduated from the University of Manchester, United Kingdom.

What is Chemical Engineering? (1/4)

- Chemical engineering has been defined by many people in a so many ways, depending to some extent on when it was stated.

- All the definitions agreed that it is a branch of engineering and that it requires a good knowledge of physics, chemistry and mathematics.

What is Chemical Engineering? (2/4)

- Some specific definitions:
  - the beautiful bride of engineering, science, medicine, social science and management science.
  - turning the principles of bench-scale chemistry reactions ideas into the safe, efficient and reliable equipment required to make money.
  - the design, construction and operation of plant in which materials undergo chemical or physical change(s).
  - the branch of engineering that applies physical sciences (physics and chemistry), life sciences (biology, microbiology and biochemistry), together with applied mathematics and economics to produce, transform, transport, and properly use chemicals, materials and energy.

What is Chemical Engineering? (3/4)

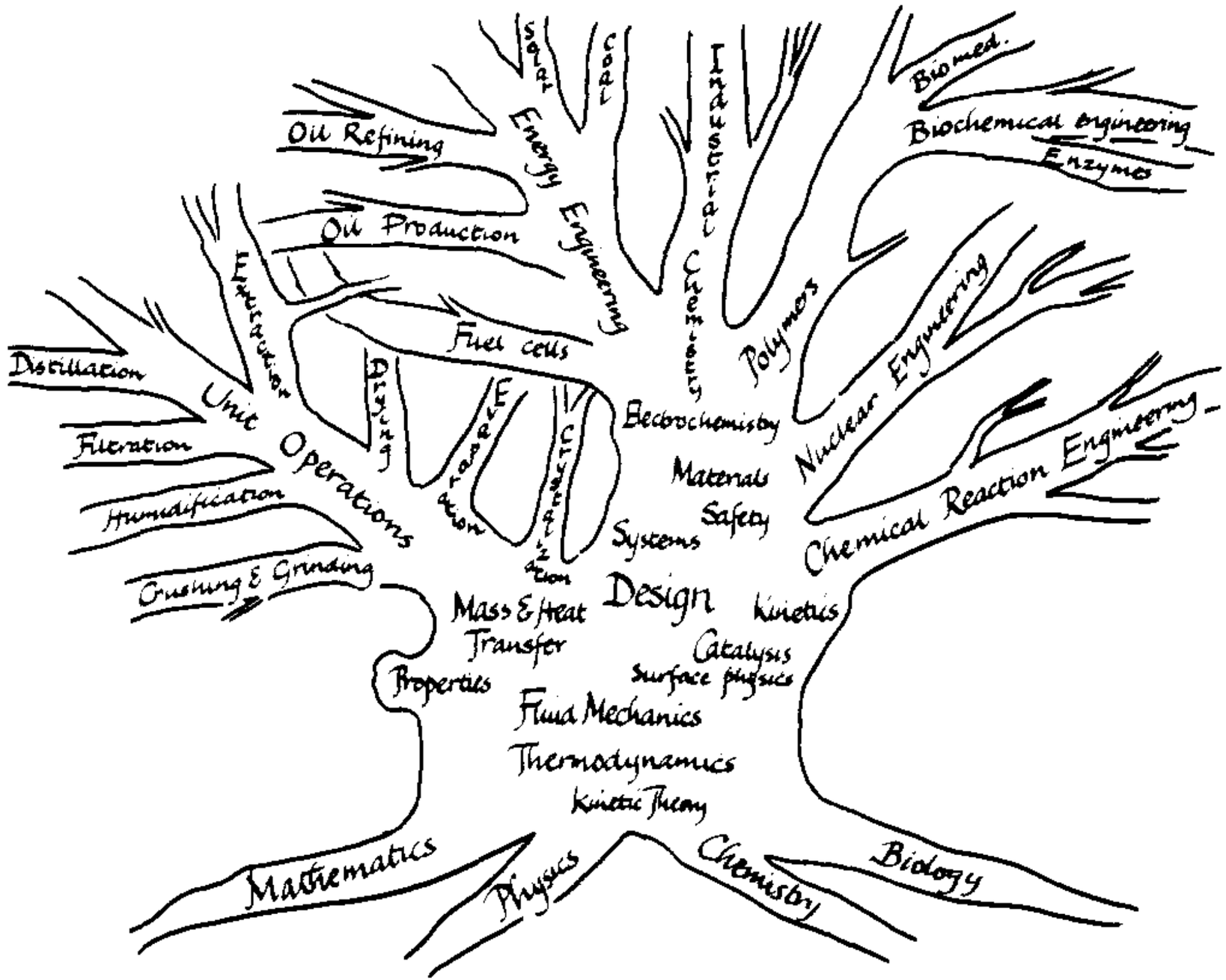
- Clearly a chemical engineer is neither a "chemist who builds things", nor an "engineer who makes chemicals".
  - All engineers use mathematics, physics, and the engineering art to solve technical problems in a safe and economical manner.
  - In addition, chemical engineer alone utilizes the knowledge of chemistry and life sciences to solve a wide range of problems.

What is Chemical Engineering? (4/4)

- Summary
  - Chemical engineers develop and design large-scale processes that convert chemicals, raw materials, living cells, microorganisms and energy into more useful forms and products. They are also involved in waste management and research.
- **Assignment: Discuss four differences between chemistry and chemical engineering**

Branches of Chemical Engineering

ChE grows from the four tap roots of mathematics, physics, chemistry, and biology through the trunk of thermodynamics, fluid mechanics, heat transfer, mass transfer, and chemical kinetics and branches into the unit operations, chemical reaction engineering, energy, materials, and the various industrial processes.



Source: Aris, R. 1977. Ind. Eng. Chem., Fundam.. 16(1), 1-5

Unit Operations (1/2)

- Early chemical engineers recognized commonalities between elements of chemical processes despite their use in different industries.
  - Thus the numerous processes for making different chemicals can be broken down into relatively few types of single process steps called “Unit Operations”.
- Unit Operations can broadly be divided into reactive (chemical reaction occur) and non-reactive operations (physical processes).
  - Examples of Reactive Unit Operations are: batch reactors, continuous stirred tank reactors, packed bed reactors and fluidized bed reactors
  - Examples of non-reactive Unit Operations are distillation columns, absorption columns, filtration devices, crystallizers, dryers, centrifuges, mixers, pumps, compressors, heat exchangers, refrigerators, holding tanks.

Unit Operations (2/2)

- Each type of Unit Operation is governed by one or more physical law(s).
- The laws governing an individual Unit Operation are always the same, regardless of the context of the unit operation.
- By modularizing complex chemical processes into relatively well understood Unit Operations, the design and operation of chemical plants became much more predictable.
- In summary, unit operation reduces chemical engineering to a series of production processes

Chemical Engineering and the Society

- Chemical engineers use the principles of engineering analysis and knowledge of chemistry and biology to design, build and operate processes that caters for the needs of a society ranging from housing to good health. Typical examples are:
  - **housing**: production of cements, iron rods, plastics, paints, ceramic tiles, carpets
  - **health**: production of toothpaste, drugs, soaps and detergent
  - **Food availability**: production of fertilizer, insecticides and pesticides
  - **transportation** and **communication**: production of metals, petrochemicals, gasoline, computer chips and paper.

Assignment: Discuss 4 other contributions of chemical engineering to society

Chemical Engineering in the 21 Century

- Blends **process** and **product engineering** to address practical problems that are rooted in chemistry, such as:
  - Chemistry of energy – make renewable energy affordable
  - Chemistry of life – new tools for diagnosis and management of human and crop diseases
  - Chemistry of the environment – sustainable use of the earth's physical resources
  - Innovations in understanding and engineering chemical reactions and/or separations

Chemical Engineering in Practice (1/4)

Petroleum Refinery

Liquified Natural Gas Plant

Chemical Engineering in Practice (2/4)

Fertilizer Plant

Cement Plant

Chemical Engineering in Practice (3/4)

Sugar Mill

Water Purifier