Cairo University
Faculty of Engineering
Chemical Engineering Department

جامعة القاهرة

Introduction to Chemical Engineering (Chem.E)

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v12

Outline

1. Introduction
2. What is a Chemical Engineer ?
3. Where Do Chemical Engineers Work ?
4. What is Special about Chem.E ?
5. Process Flowsheets as a Chemical Engineering Language
6. Chemical Engineers Past Achievements
7. Chemical Engineers Engagement in Future Achievements
8. The Building Blocks of Chem.E Education
9. Concluding Remarks

1. Introduction

- Chemical engineering is one of the big four branches of engineering: civil, mechanical, electrical and chemical
- Chemical engineering is one of the most dynamic progressive fields of engineering
- Chemical engineering is well established in Egypt (see next slide)
- Chemical engineers are very well recognized all-over the world

Chemical Engineering Departments in Egypt

- Cairo University: 1942
- Alexandria University: 1946
- Military Technical College: 1962
- Menya University: 1978
- 10th of Ramadan Technical Institute: 1990
- Al Sherook Academy: 1998
- British University in Egypt (BUE): 2006
- Badr University in Cairo (BUC): 2016

2. What is a Chemical Engineer?

A good way to answer this question is to show the difference between the scope of work مجال عمل of “Chemists” and “Chemical Engineers”.

The following illustrative example will show:

- The link between the two fields
- The applied tools by chemists and chemical engineers

Illustrative Example مثال توضيحي

A chemist working in the Research and Development (R&D) Department قسم البحوث والتطوير in a chemical company discovered a process for producing a new valuable substance “C”. The reaction he applied is as follows:

A + B → C + un-reacted A + un-reacted B

The work of the chemist in the Lab may be illustrated as follows:

The Chemist and Her/His Laboratory Apparatus

الكيميائي يُؤَّهَل بدراسة العلوم الكيميائية في كليات العلوم ويكتسب مهارات تخليق المواد الكيميائية وتحليلها في معامل متخصصة.

يعتمد التقدم العلمي للأمم علي العلوم الأساسية الأربعة:

- الرياضيات
- العلوم البيولوجية
- العلوم الفيزيائية
- العلوم الكيميائية

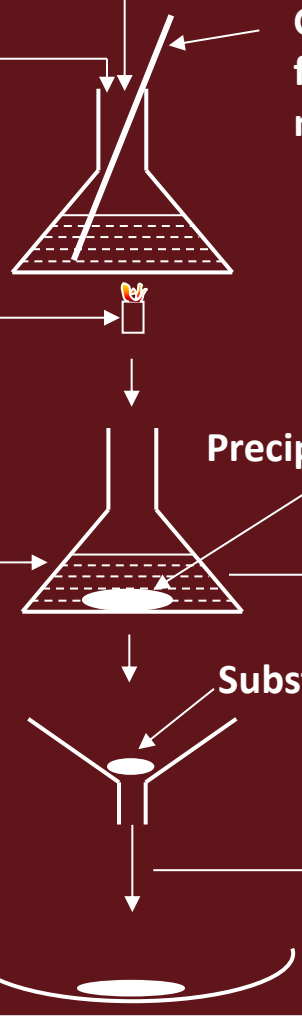
ويتلازم التقدم العلمي للأمم مع تقدمها في العلوم الإنسانية والاجتماعية.

All photos in this presentation are taken from photo galleries available on the web.

Process Description as Done in the Laboratory

توصيف العمليات كما تجري في المعامل الكيميائية

Inputs	Description of Work in the Lab	Outputs
10 ml A 10 ml B RAW MATERIALS	Glass rod for mixing	
Heat energy source		
Tap water for Cooling	Precipitated C	Used tap water for cooling to sink
	Substance C Filtration	Filtrate as waste to Sink
	Drying	PRODUCT: one gram of C



From Laboratory-Scale to Industrial-Scale

الانتقال من مستوي المعمل الي مستوي الصناعة

After a lot of discussions and studies (?), the company decided to build a chemical plant to produce substance C with a production capacity of 1 ton/day.

Laboratory scale production: 1 gm/day

Industrial scale production: 1,000,000 gm/day

Scale-up factor: 1,000,000

قرار الشركة أن تنتج طن يوميا من المادة C يعني أنها قررت الانتقال من مستوي الإنتاج المعملي الي مستوي الإنتاج الصناعي، وسوف نري متطلبات تنفيذ هذا القرار

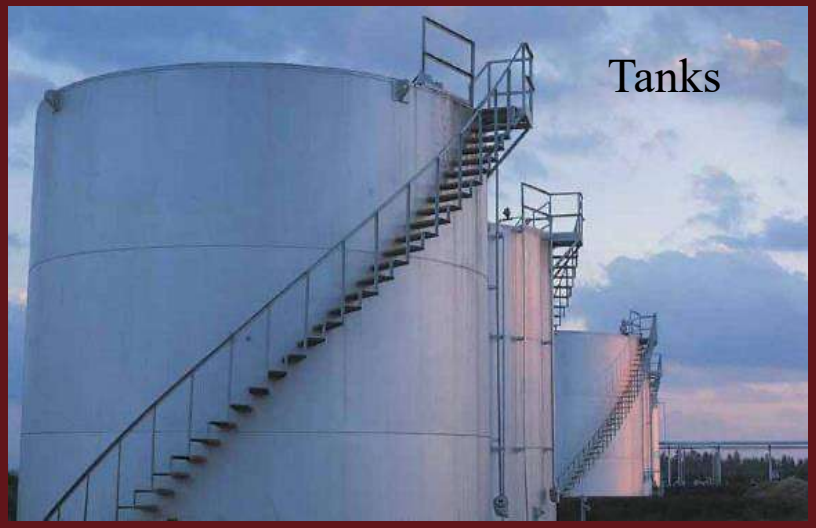
Storage of Liquid Raw Materials

تخزين المواد السائلة

Laboratory-Scale

In the Laboratory

Industrial-Scale



In the Chemical Process Plant

Chemical Engineering Study Courses:

- **Fluid Mechanics**
- **Vessel Design**

في المعمل يستخدم الكيميائي زجاجات لتخزين الكيماويات السائلة. في المصنع يستخدم المهندس الكيميائي خزانات ذات تصميم يناسب كل مادة كيميائية يلزم تخزينها

Liquid Transport

نقل المواد السائلة

Laboratory-Scale

In the Laboratory

Industrial-Scale

In the Chemical Process Plant

Chemical Engineering Study Courses:

- **Fluid Mechanics**
- **Materials Handling**

في المعمل يستخدم الكيميائي "ماصة" لنقل الكيماويات السائلة، في المصنع يستخدم المهندس الكيميائي "طلمبات" ذات تصميم يناسب كل مادة كيميائية يلزم نقلها من مكان الي مكان في المصنع

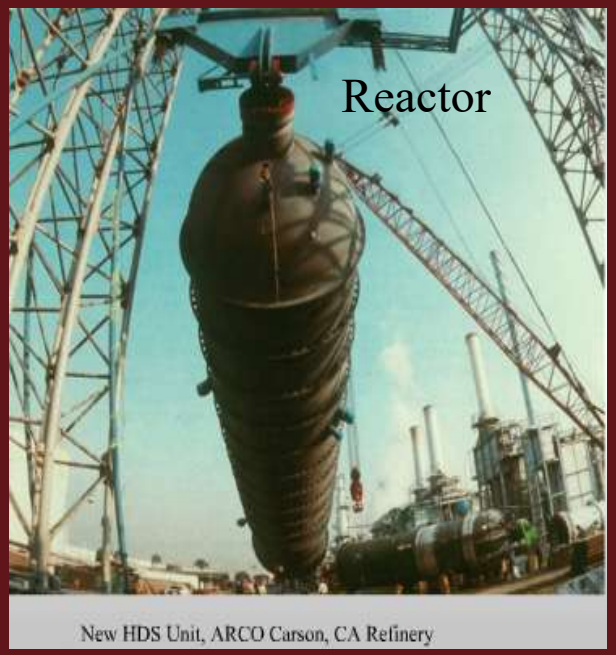
Chemical Reactors

المفاعلات الكيميائية

Laboratory-Scale

In the Laboratory

Industrial-Scale



In the Chemical Process Plant

Chemical Engineering Study Courses:

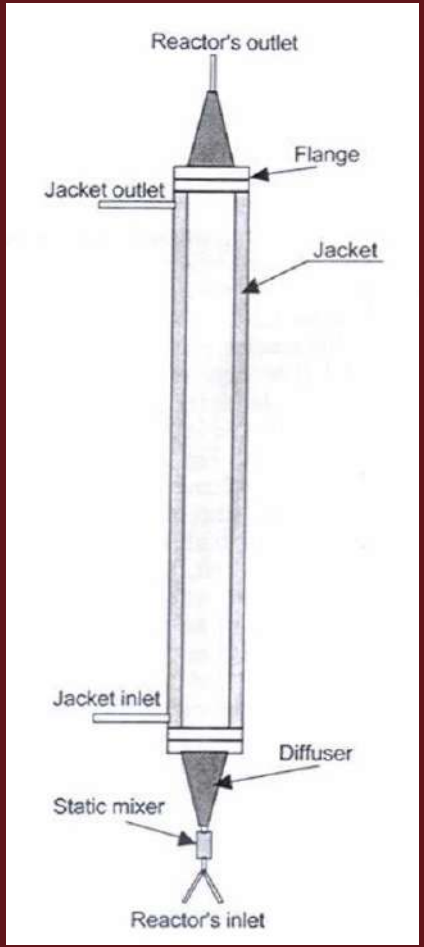
- **Reactor Design**
- **Organic Technology**

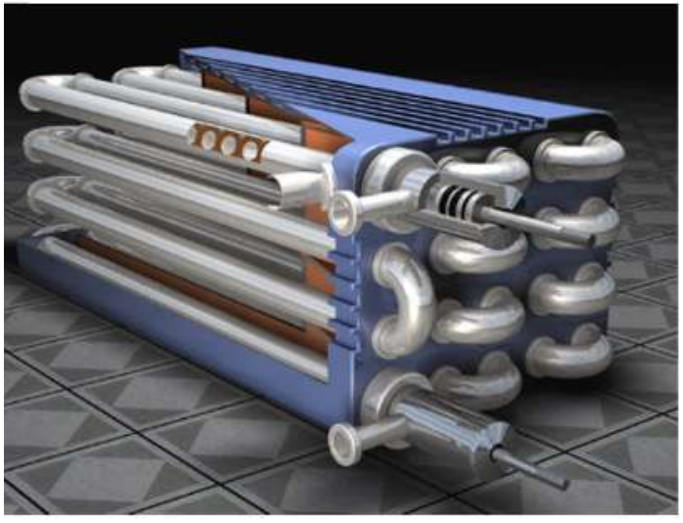
في المعمل يستخدم الكيميائي "إناء زجاجي" لإجراء التفاعل الكيميائي ، في المصنع يستخدم المهندس الكيميائي "مفاعلات كيميائية" لإجراء التفاعلات

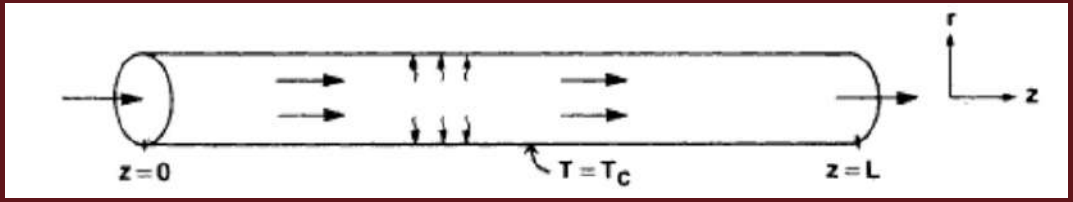
Chemical Reactors

المفاعلات الكيميائية

Tubular reactors as one example of chemical engineeres creative design work







Mixing of Liquids

خلط المواد السائلة

Laboratory-Scale

In the Laboratory

Industrial-Scale

In the Chemical Process Plant

Chemical Engineering Study Courses

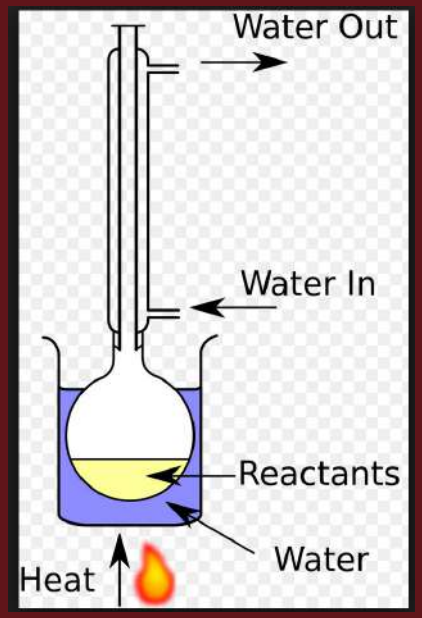
- **Unit Operations**
- **Electrical Engineering**

في المعمل يستخدم الكيميائي "قضيب زجاجي" لتقليب المواد ، في المصنع يستخدم المهندس الكيميائي "خلاطات" ذات تصميم يناسب نوعية المواد التي يود خلطها

Cooling and Heating

التبريد والتسخين

Laboratory-Scale



In the Laboratory

Industrial-Scale

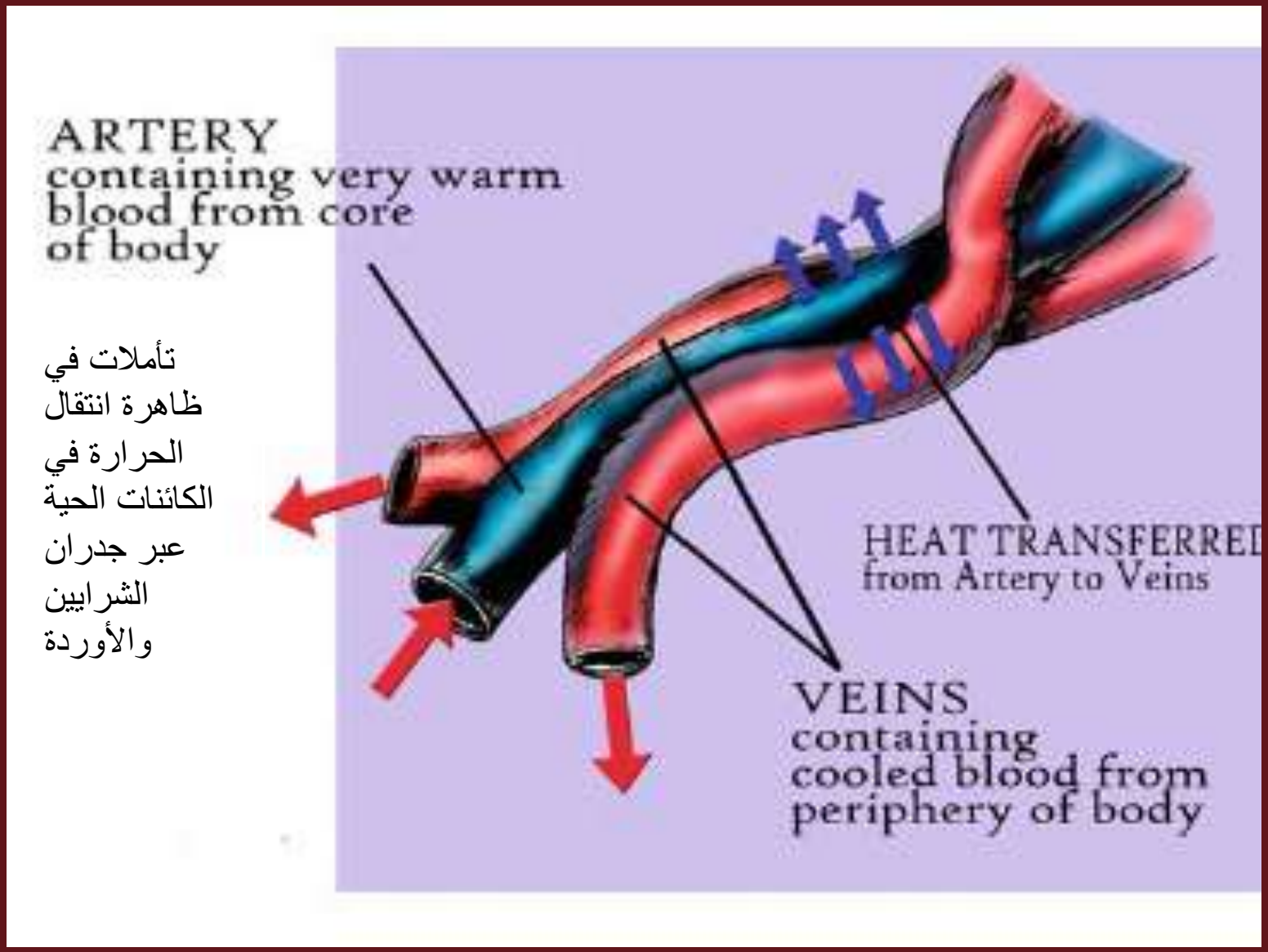
In the Chemical Process Plant

Chemical Engineering Study Courses

- **Heat Transfer**

في المعمل يستخدم الكيميائي أجهزة زجاجية للتبريد والتسخين، في المصنع يستخدم المهندس الكيميائي ؛مبادلات حرارية" ذات تصميم يحقق أعلي كفاءة في انتقال الحرارة

Side Note: understand what counter-current heat transfer means, from Dolphins!



تأملات في
ظاهرة انتقال
الحرارة في
الكائنات الحية
عبر جدران
الشرايين
والأوردة

Filtration
الترشيح

Laboratory-Scale

In the Laboratory

Industrial-Scale

In the Chemical Process Plant

Chemical Engineering Study Courses:

- **Unit Operations**
- **Mechanical Engineering**

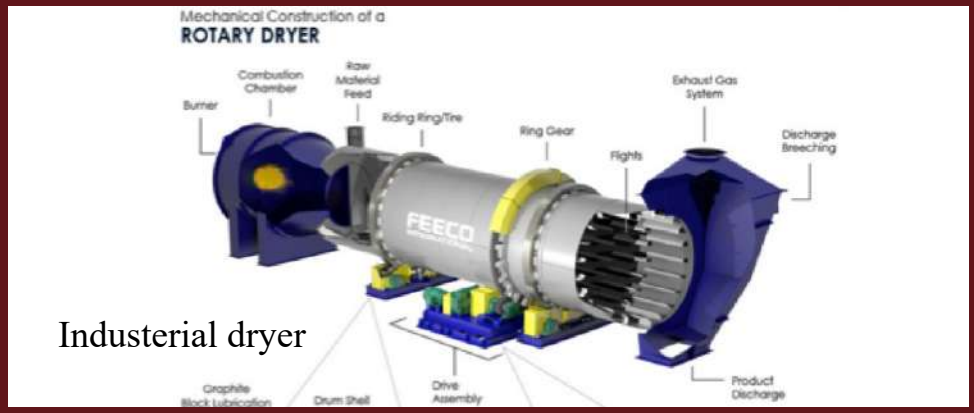
في المعمل يستخدم الكيميائي قمع زجاجي وورقة ترشيح لفصل المادة الصلبة العالقة عن السائل، في المصنع يستخدم المهندس الكيميائي معدات ذات تصميم خاص لإجراء عملية الترشيح

Drying
التجفيف

Laboratory-Scale

Industrial-Scale

In the Laboratory



Industerial dryer

In the Chemical Process Plant

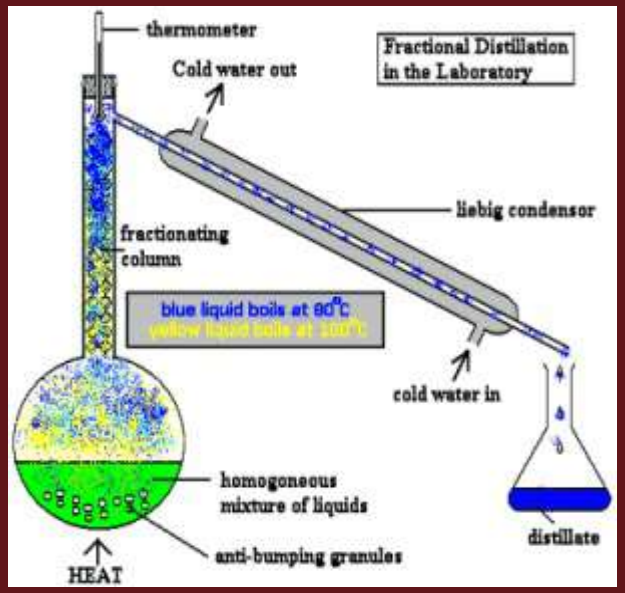
Chemical Engineering Study Courses:

- **Drying (UO)**
- **Mechanical Engineering**
- **Heat Transfer**

في المعمل يستخدم الكيميائي "زجاجة ساعة" ومجفف معملي لإجراء عملية التجفيف، في المصنع يستخدم المهندس الكيميائي معدات ذات تصميم خاص لتجفيف المواد الصلبة

Distillation
التقطير

Laboratory-Scale



In the Laboratory

Industrial-Scale

In the Chemical Process Plant

Chemical Engineering Study Courses:

- **Distillation (UO)**
- **Heat Transfer**
- **Vessel Design**

في المعمل يستخدم الكيميائي جهاز التقطير الزجاجي لتقطير السوائل، في المصنع يستخدم المهندس الكيميائي "أبراج التقطير" لتقطير سوائل مثل زيت البترول

يضطلع المهندسون الكيميائيون بمسؤوليات هامة في تصميم المصانع وإنشائها وتشغيلها

معمل الكيميائي

مصنع المهندس الكيميائي

3. Where Chemical Engineers Work ?

المجال الأهم لعمل المهندس الكيميائي هو تصميم وإنشاء وتشغيل المصانع الكيميائية التي تطورت الآن لتشمل المصانع البيوكيميائية ، والتي هي مكونة من وحدات متتالية لتخزين المواد الخام وتحضيرها للدخول في العمليات الصناعية، ونقلها وخلطها ،واجراء التفاعلات فيما بينها ، واجراء عمليات الفصل بين المنتجات وتخزينها.

أمثلة المواد الخام: زيت البترول، الغاز الطبيعي، خامات تعدينية، محاصيل زراعية
أمثلة المنتجات: مواد بلاستيكية، مواد الصباغة، منظفات صناعية، مواد دوائية، مواد تدخل في الصناعات الالكترونية، مواد تدخل في صناعة السيارات

Where Chemical Engineers Work?

Conventional Fields	New Fields
• Chemical Process Industries • Petroleum Refineries • Petrochemical Industry • Pharmaceutical Industry • Pulp and Paper Industry • Detergents and Cosmetics Industry • Cement, Ceramics and Glass Industry • Paints, Pigments and Ink Industry • Polymers and Composites • Rubber and Rubber Products Industry	• Biotechnology Industry • Nanotechnology • Specialty Chemicals • Recycling Industries • Electronics Industries • Water Industry • Renewable Energy

Major Products of Chemical Industries and their Area of Application

Group of Product	Areas
Plastics and Polymers	Agricultural water management, packaging, automobiles, telecommunications, health and hygiene, education
Synthetic rubber	Transportation Industry, Textile, Industrial equipment lining
Synthetic fiber	Non-oven and woven fibre in automobile , hosiery, textile
Soap and Synthetic detergents	Health and hygiene domestic as well as industrial
Industrial chemicals	Drugs & pharmaceuticals, pesticides, explosives, surface loading, dyes, lube additives, adhesive oil field, antioxidants, chemicals, metal extraction, printing ink, paints
Sugar & Alcohol	Food, Alcoholic Brewages, Chemical Feed Stock, Ethoxylate, biofuel
Pulp & Paper	Writing & Printing Paper, Culture Paper, News Printing Paper, Tissue Paper, Packaging Paper
Fertiliser	Agriculture, Chemical industry(ammonia and urea)
Agrochemicals	Pesticides
Mineral acids	Chemical industry- organic and inorganic

4. What is Special about Chemical Engineering?

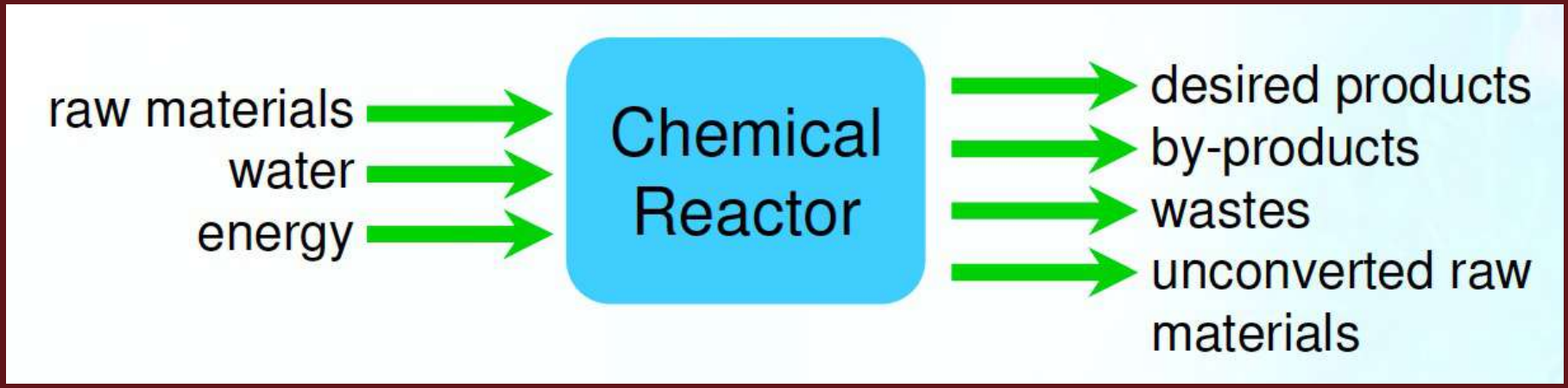
الهندسة الكيميائية هي المجال الهندسي المعني بتحقيق قيمة مضافة added value

"بتحويل" المواد الخام والطاقة الي منتجات ذات قيمة عالية

كلمة السر هي:

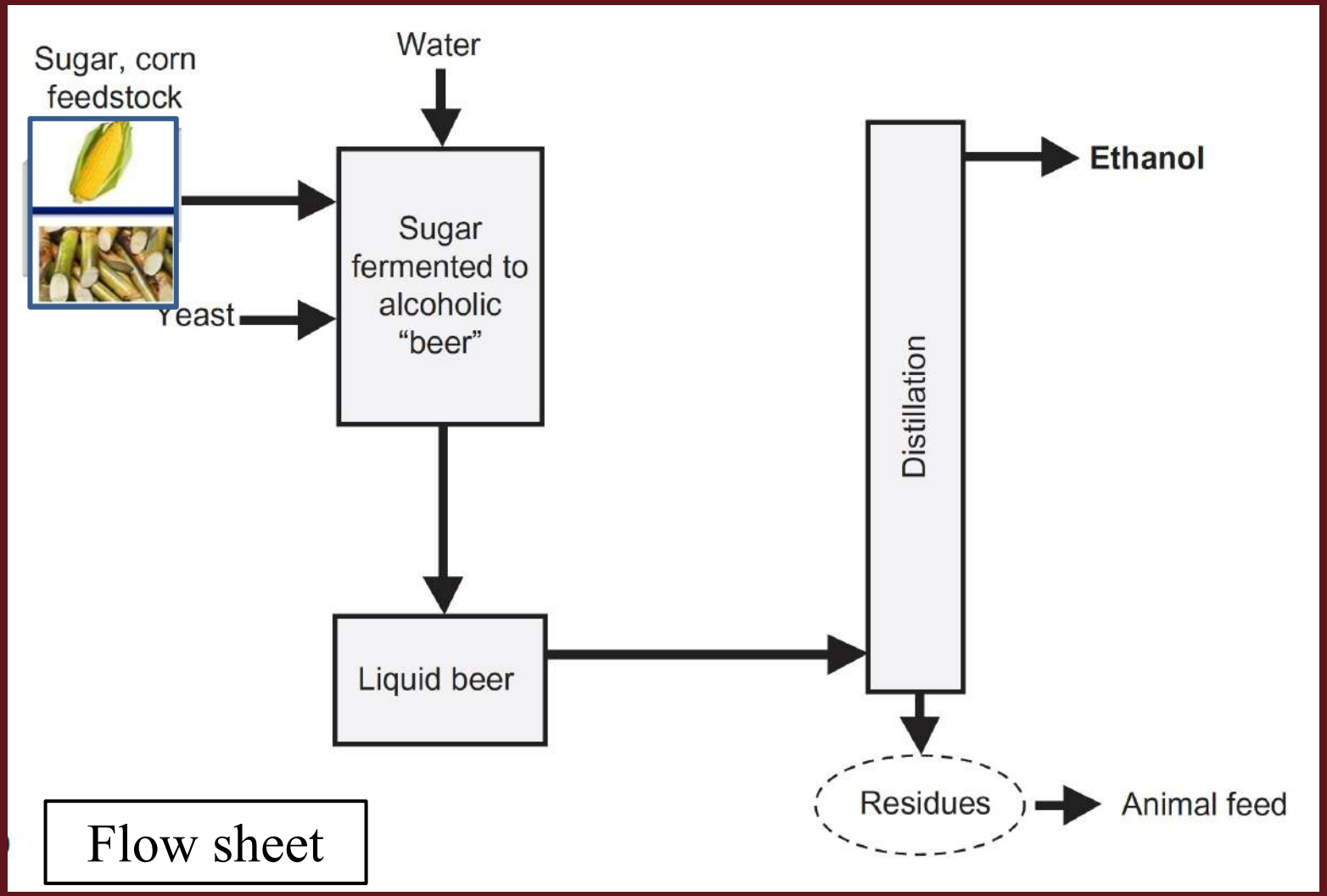
CONVERSION

Chemical Engineers "CONVERT" Petroleum and Natural Gas to Hundreds of Synthetic Products



Example: Chemical Engineers "CONVERT" Sugar Crops to Ethanol Which is Used as Liquid Fuel

تحويل المحاصيل السكرية الي إيثانول عن طريق التخمير والتقطير



Flow sheet

(Cont'd) What is Special about Chemical Engineering?

The process industry consists of firms that "add value by mixing, separating, forming and/or chemical reactions by either batch of continuous mode"

كلمة السر هي:

VALUE CHAIN

The Chemical Industery Value Chain

Refined Chemicals & Consumer Products (≈ 30000)

Plastics, pharmaceuticals, dyes, solvents, fertilizers, fibres, dispensers, cosmetics,

Intermediate Products (≈ 300)

Methanol, vinyl chloride, styrene, urea, formaldehyde, ethylene oxide, acetic acid, acrylonitrile, cyclohexane, acrylic acid

Basic Products (≈ 20)

Ethylene, propene, butadiene, benzene, synthesis-gas, actylene, ammonia, sulfuric acid, sodium hydroxide, chlorine

Raw Materials (≈ 10)

Petroleum, natural gas, coal, biomass

Rock, salt, phosphate, sulfur, air, water

B2C

B2B

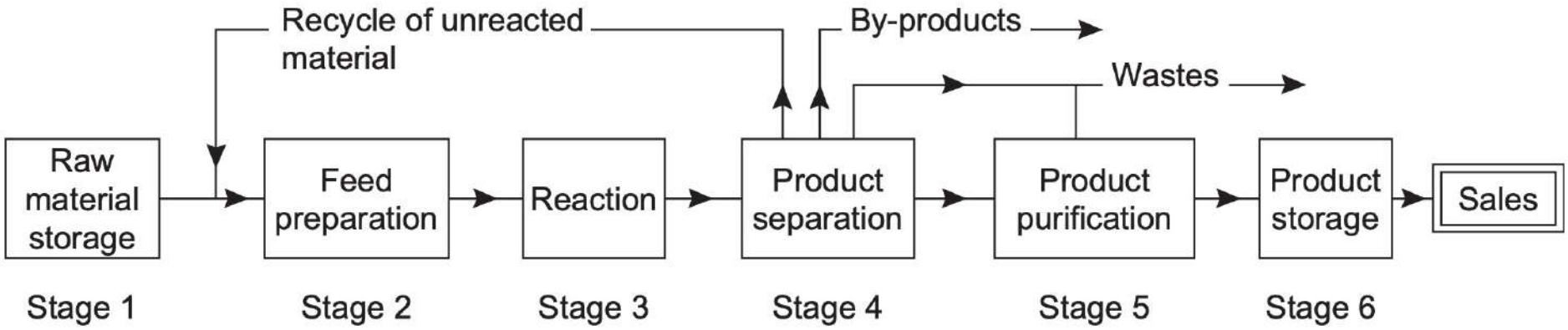
Consumer products (~ 30,000)

Intermediate Products (~ 300)

Basic Products (~ 20)

Raw Materials (~ 10)

5. Process Flow Sheets as a Chemical Engineering Language



The basic components of a typical chemical process are shown in the figure, in which each block represents a stage in the overall process for producing a product from the raw materials. Chemical engineering design is concerned with the selection and arrangement of the stages and the selection, specification, and design of the equipment required to perform the function of each stage.

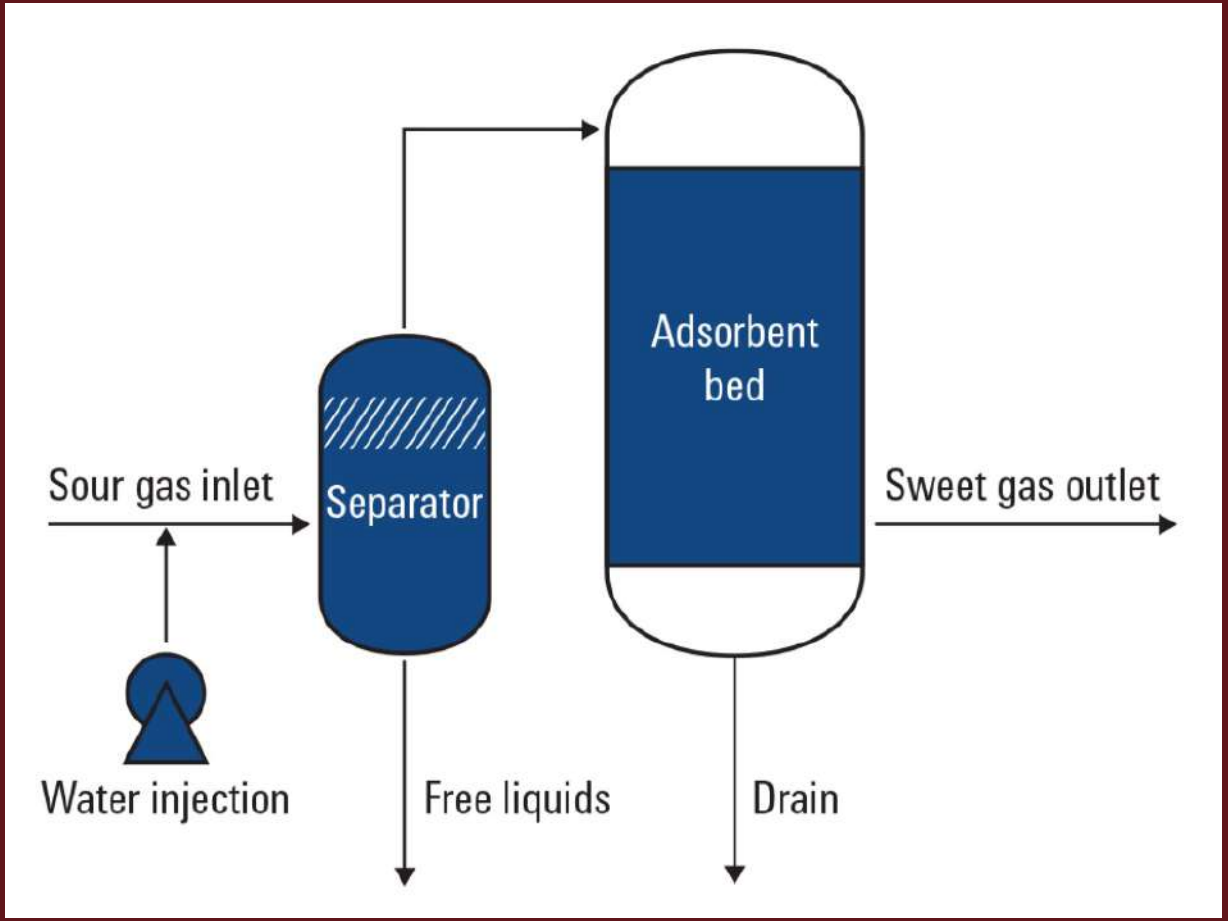
The World as We See: Thousands of Boxes!!

This box could be a human being or a cow, a water treatment plant or a cement factory. Chemical engineers see it as a process which contain inside multiple processes. Our work is to understand each sub-process as far as its inputs, outputs and what is happening inside and to optimize the overall process design.

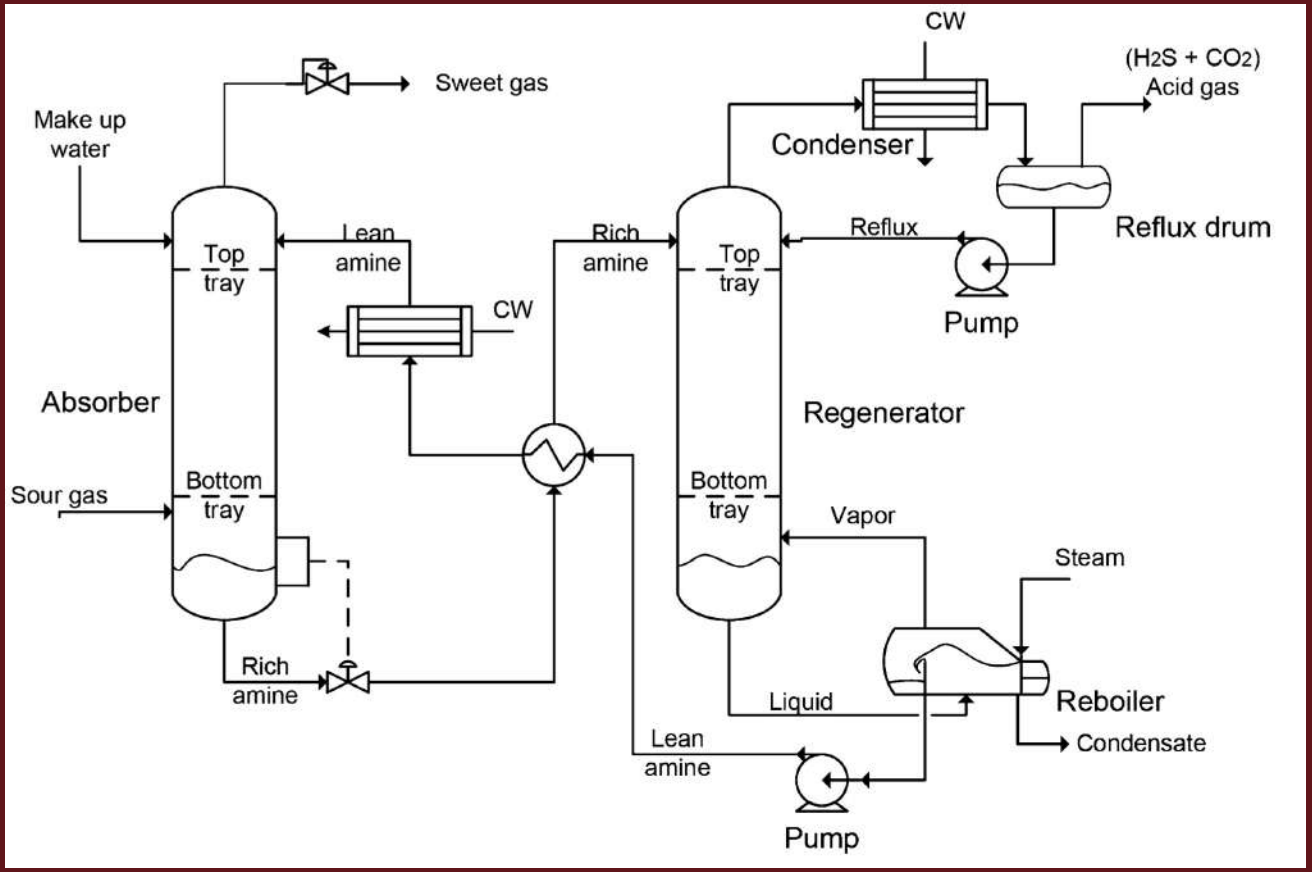
Example 1: Natural Gas Purification Process using Granular Iron Oxide-Based Hydrogen Sulfide Adsorbents

Hydrogen sulfide (H2S) is an environmentally hazardous, corrosive, and toxic gas, mostly generated in gas and oil industry.

For small-scale natural gas processing sites, the use of regenerable iron oxide adsorbent to adsorb H2S from natural gas is an economical and effective method.

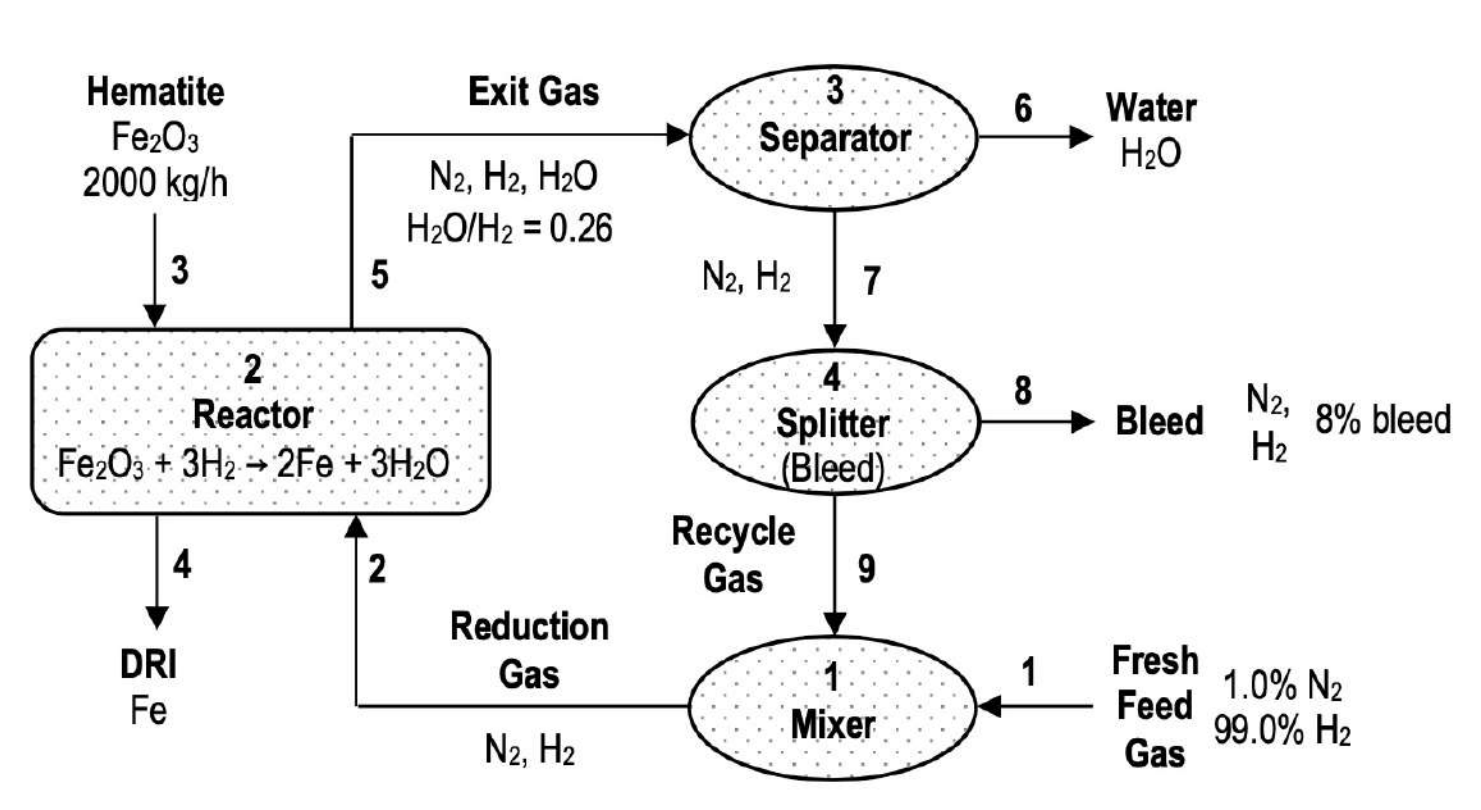


Example 2: Removal of H_2S from Sour Gas by Amine Extraction



Amine solution is used in the absorber to absorb hydrogin sulfide and carbon dioxide to produce a sweetened gas stream. In the regenerator, the rich amine is stripped to produce a lean amine straem (back to the absorber) and a concentrated H_2S and CO_2 straem. Sulfur is recoverd from this stream by a process called Claus process.

Example 3: Direct Iron Reduction Process



Direct Iron Reduction (DIR) simplified flowsheet showing four unit operations: Reactor, water separator, splitter and mixer. The reduction gas is obtained by mixing recycle gas with fresh gas of high H2 concentration.

Example 4: Recycling of PET Botteles

PET is a clear, strong, and lightweight plastic that is widely used for packaging foods and beverages, especially convenience-sized soft drinks, juices and water.

Baled PET bottles: 1.33–1.34 kg

Bale opening

Pre-washing/ delabelling → By-products, e.g. PVC/LDPE; & solid waste.

Process efficiency $\eta \approx 75\%$

Sorting (machine/labour) → By-products, e.g. green/ blue bottles

Chopping

Chemicals, water

Washing

Effluent treatment → Solid waste & waste water

Float separation → By-products, e.g. PE, PVC; & solid waste

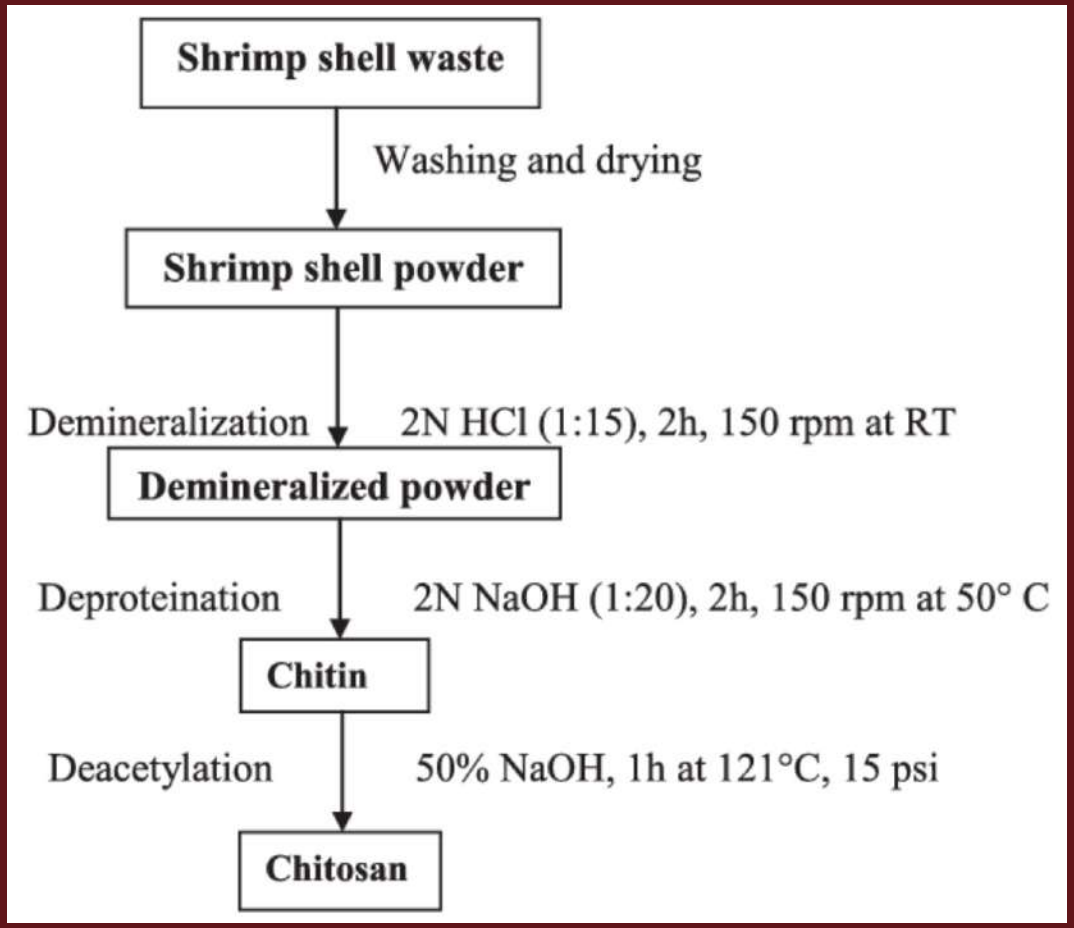
Rinsing

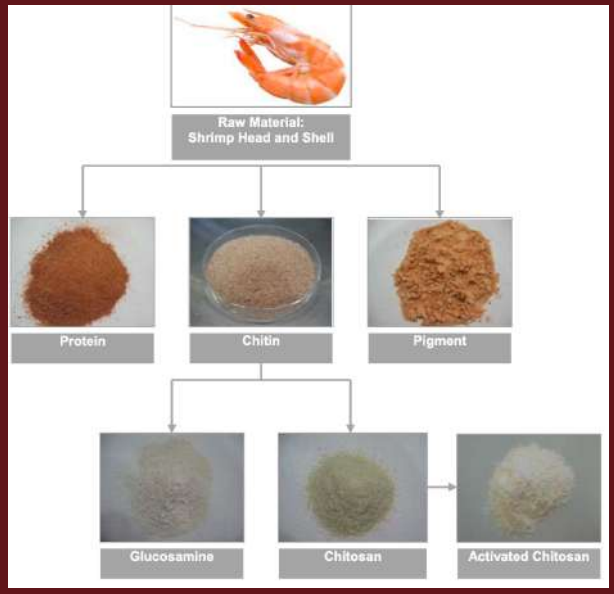
Drying

Recycled PET flakes: 1 kg

Total by-products	0.09–0.14 kg
Solid waste to MSWI or landfilling (loss)	0.25–0.19 kg

Example 5: Extraction of Chitin and Chitosan from Shrimp Shell Waste





Through enzymatic or chemical deacetylation, chitin can be converted to its most well-known derivative, chitosan. The main natural sources of chitin are shrimp and crab shells, which are an abundant byproduct of the food-processing industry, that provides large quantities of this biopolymer to be used in biomedical applications.

Chitin is the most abundant amino-polysaccharide polymer occurring in nature. It is the building material that gives strength to the skeletons of crustaceans, insects, and the cell walls of fungi.

6. Chemical Engineers Past Achievements

(six examples)

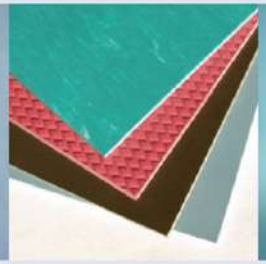
1. Chemical fertilizers العلاقة مع الغذاء
2. Synthetic fibers العلاقة مع الكساء
3. Mass production of plastics
4. Biotechnology of food production
5. Synthetic Rubber
6. New materials production

Next slide

Our civilization is built on plastics. In 2014 alone, industry generated 311 million metric tons, an amount expected to triple by 2050, according to the World Economic Forum.

NYLON BRISTLE TOOTHBRUSH

In 1937, Wallace H. Carothers, at DuPont de Nemours, developed polyamide 6.6, better known as nylon. Used a year later to replace boar hairs, this synthetic fiber marked a turning point in the history of toothbrushes.



PVC FLOORING

In 1949, manufacturing company Gerland used PVC for the first time to make a floor covering.

DISPOSABLE DIAPER

Designed in the 1950s by Procter & Gamble, the plastic disposable diaper went on sale 10 years later.

UPRIGHT VACUUM CLEANER

The first upright vacuum cleaner manufactured entirely from nylon was sold by Moulinex in 1961.

PLASTIC BOTTLE

In 1968, Vittel took the revolutionary step of producing its first plastic bottle. It weighed 36 g compared with 300 g for a glass bottle and contained 1.5 liters of water.

BANK CARD

Traditional bank cards were revolutionized by the arrival of the microchip invented by Roland Moreno. This small PVC or polypropylene card was to become an essential payment method.

DISPOSABLE RAZOR

After the Bic© ballpoint pen, in 1975, Marcel Bich invented the disposable plastic razor. Several million of these are still sold every day throughout the world.

6.7%

PS, PS-E

Eyeglass frames, plastic cups, egg trays (PS); packaging, building insulation (PS-E), etc.

7.4%

PET

Bottles for water, soft drinks, juices, cleaners, etc.

7.5%

PUR

Building insulation, pillows and mattresses, insulating foams for fridges, etc.

10%

PVC

Window frames, profiles, floor and wall covering, pipes, cable insulation, garden hoses, inflatable pools, etc.

12.3%

PE-HD, PE-MD

Toys, (PE-HD, PEMD), milk bottles, shampoo bottles, pipes, houseware (PE-HD), etc.

PE-LD, PE-LLD

Reusable bags, trays and containers, agricultural film (PE-LD), food packaging film (PE-LLD), etc.

PP

Food packaging, sweet and snack wrappers, hinged caps, microwave-proof containers, pipes, automotive parts, bank notes, etc.

OTHERS

Hub caps (ABS); optical fibers (PBT); eyeglass lenses, roofing sheets (PC); Touch screens (PMMA); cable coating in telecommunications (PTFE); and many others in aerospace, medical implants, surgical devices, membranes, valves & seals, protective coatings, etc.

7. Chemical Engineers Engagement in Future Achievements (three examples)

1. Utility Storage of Renewable Energy:

Lithium-ion batteries will likely be the dominant technology for the next five to 10 years, and continuing improvements will result in batteries that can store four to eight hours of energy – long enough, for example, to shift solar-generated power to the evening peak in demand.

2. Bioplastics for Circular Economy:

Less than 15% of produced plastics is recycled. Much of the rest is incinerated, sits in landfills or is abandoned in the environment – where, being resistant to microbial digestion, it can persist for hundreds of years. Biodegradable plastics can ease these problems, contributing to the goal of a "circular" plastic economy in which plastics derive from and are converted back to biomass.

3. Development of Smarter Fertilizers:

Slow-release fertilizers can reduce environmental contamination. It is based on new formulations which deliver nourishment to the plant on demand.

8. The Main Building Blocks of Chemical Engineering Education

Chemical Engineering Courses:
- Unit Operations
- Reactor design
- Chemical Engineering Thermodynamics
- Process and Plant Design
- Process control and Instrumentation

Other Engineering Courses:
- Civil
- Mechanical
- Electrical

Technology Courses:
- Inorganic technology (e.g Chemical Fertilizers)
- Organic Technology (e.g Solvents and Plastics)
- Petroleum and Petrochemicals Technology
- High Temperature technology (e.g Glass industry)

Other Disciplines:
- Humanities
- Economics

Core of Basic Sciences:
Mathematics +Physics+ Chemistry

9. Concluding Remarks

- يعمل المهندسون الكيميائيون في مجالات متعددة لتحويل الخامات الطبيعية الي منتجات وسيطة، ولتحويل المنتجات الوسيطة الي منتجات نهائية
- تكمن عبقرية الهندسة الكيميائية في كلمة "التحويل" هذه. نحن "محولون"، نغير بالمعرفة والخبرة الهندسية كينونة الأشياء، نحول الغاز الطبيعي الي أسمدة كيميائية ومواد بلاستيكية ومنظفات صناعية، ونحول الماء والهواء الي سماد نترات الأمونيوم، نطبق مفهوم سلاسل القيمة لتحقيق أعلي قيمة مضافة ممكنة.
- تعتمد الصناعات الهامة علي إنجازات الهندسة الكيمائية ، أمثلة: الصناعات الهندسية ، الصناعات الدوائية، الأجهزة الطبية ، الصناعات الالكترونية، صناعة المنسوجات ، الصناعات الغذائية
- تتعاظم أهمية الهندسة الكيميائية في بحثها عن حلول عملية لمشاكل العالم في مواجهة ندرة المياه والطاقة والغذاء وفي مواجهة مشاكل الاحتباس الحراري وتغير المناخ