Министерство науки и высшего образования Российской Федерации

Федеральное государственное бюджетное образовательное учреждение
высшего образования
«Владимирский государственный университет
имени Александра Григорьевича и Николая Григорьевича Столетовых»

Г. Н. ЗАМАРАЕВА

МИР ХИМИЧЕСКОЙ ТЕХНОЛОГИИ

WORLD OF CHEMICAL ENGINEERING

Учебное пособие по английскому языку

Владимир 2019

УДК 811.111
ББК 81.2Англ
З-26

Рецензенты:
Кандидат филологических наук
доцент кафедры философии, истории, права и межкультурной коммуникации Владимирского филиала Финансового университета при Правительстве Российской Федерации
Н. А. Наумова

Кандидат педагогических наук
доцент кафедры английской филологии и переводоведения Государственного гуманитарно-технологического университета
О. Н. Поддубская

Издается по решению редакционно-издательского совета ВлГУ

Замараева, Г. Н.
З-26 Мир химической технологии = World of Chemical Engineering : учеб. пособие по англ. яз. / Г. Н. Замараева ; Владим. гос. ун-т им. А. Г. и Н. Г. Столетовых. – Владимир : Изд-во ВлГУ, 2019. – 136 с. – ISBN 978-5-9984-0943-1.

Цель пособия – обучение различным видам речевой деятельности на английском языке в профессиональной сфере химической технологии.

Предназначено для студентов II курса направления 18.03.01 «Химическая технология» (бакалавриат, III – IV семестры) для формирования компетенций, связанных с использованием знаний, умений и навыков владения английским языком.

Рекомендовано для формирования профессиональных компетенций в соответствии с ФГОС ВО.

Библиогр.: 15 назв.

УДК 811.111
ББК 81.2Англ

ISBN 978-5-9984-0943-1

INTRODUCTION

Те, кто изучает химические технологии, даже не подозревают, что уже знают, хоть и немного, английский язык своей профессиональной сферы. «Индустрия», «дизайн», «инженер», «лаборатория», «технология», «органический», «молярная масса», «компонент», «бакелит», «протеин», «гликоген», «эластомер» – эти и многие другие слова можно найти в английском языке, но в несколько видоизмененном виде. Остается научиться правильно произносить их.

Это пособие для тех, кто изучает английский язык одновременно с профессиональным освоением химических технологий.

В книге представлены аутентичные тексты, которые знакомят с историей химических технологий и профессией химика-технолога, с некоторыми производственными процессами и продуктами, проблемами отрасли. Упражнения помогут научиться коммуникации на английском языке, в том числе деловой, устной и письменной формах для решения задач межличностного и межкультурного взаимодействия. Практические задания необходимы для активного усвоения новой лексики и грамматики английского языка.

Тематика издания предполагает использование не только печатных, но и мультимедийных источников как в аудиторной, так и в самостоятельной работе, что позволяет существенно расширить свои знания в профессиональной сфере.

Цель пособия – расширить кругозор учащихся, подготовить студентов к чтению специальной литературы и профессиональному общению на английском языке.

Unit I
INTRODUCTION TO CHEMICAL ENGINEERING

1. Match the terms and their definitions.

1) engineer (2 definitions)	a) a person who studies chemistry or a scientist who works with chemicals or studies their reactions
2) engineering (2 definitions)	b) a person whose job is to design or build machines, engines, or electrical equipment, or things such as roads, railways or bridges, using scientific principles
3) chemist	c) a person whose job is to repair or control machines, engines or electrical equipment
4) chemistry	d) a person who has studied chemical engineering and whose job involves the design and operation of machinery used in industrial chemical processes
5) chemical (2 definitions)	e) the scientific study of the basic characteristics of substances and the ways in which they react or combine
6) chemical engineer	f) the work of an engineer or the study of this work
7) chemical engineering	g) the design and operation of machinery used in industrial chemical processes
	h) any basic substance that is used in or produced by a reaction involving changes to atoms or molecules
	i) relating to chemicals
	j) to design and build something using scientific principles

2. Complete each sentence with the appropriate form of a word or word combination from exercise 1.

1. Using basic foundations in mathematics and science, ………….. apply their technical knowledge to conceive, design and implement new processes, products and systems that make our everyday lives possible. 2. …………… requires the knowledge of physics, chemistry and maths in particular. ………………… have the knowledge of these subjects in order to design, develop new or improve existing manufacturing processes and unit operations in the petrochemicals, chemicals, oil and gas and other related industries. 3. The …………… composition of the air is not a

precondition for life but the result of it. 4. There is often more than one synthetic **route** for preparing a desired …………… 5. Mathematicians don't do experiments the way …………… or biologists or other 'natural scientists' do. 6. On the one hand, alchemy is regarded as a precursor of the modern science of ……………

3. Translate the sentences given below. Pay attention to the forms and functions of the infinitive.

1. I can only think of six of these winners who can be classified as chemical engineers. 2. Not all these students will go on to work as chemists or chemical engineers. 3. Chemists tend to focus on developing novel materials and processes. 4. Both chemistry and chemical engineering are good subjects to study. 5. The skills learnt can be applied to a variety of different jobs and roles. 6. We chemical engineers need to do even more work to achieve a better gender balance. 7. It is important to remember that chemists and chemical engineers have to work together to achieve successful outcomes. 8. The advent of digital computers has allowed laborious design calculations to be performed rapidly. 9. We must work with others to achieve our outcomes. 10. To succeed we all need to be aware of the latest technology. 11. When someone needs to fix the worlds problems they should be calling up the chemical engineers! 12. Margaret was the first woman to receive a chemical engineering doctorate from MIT. 13. This book wouldn't have been possible without John H. Perry. 14. Who knows who else could be added to this list in the future? 15. To see an idea finally go into motion is one of the most gratifying experiences. 16. Hyatt was the first to take out patents for this discovery. 17. To tell the truth, people do not understand the difference between chemists and chemical engineers. 18. Scientists are now able to copy the structure of natural polymers to produce synthetic polymers. 19. Various units or segments must be able to move. 20. Baekeland's main project was to make hard objects from phenol and formaldehyde.

4. Do you remember how to read numerals? Try to brush up.

166 laureates; since 1901; in the 1600s; the late 1800s; 29,800 applications; in 2014; compared with ~19,900; an increase of 18.6 per cent; compared with an increase of 9.4 per cent; £29,500; AUD $69,000; £22,000; earn over £50,000; earn £70,000+; 42 per cent of applicants.

5. Translate conjugate words or words with the same roots.

Apply – application – applicant, chemist – chemistry – chemical – chemicals, win – winner, engineer – engineering, recognize – recognition, science – scientist – scientific, develop – development, design – designer, operate – operator – operation, manufacture – manufacturer, equip – equipment, investigate – investigator – investigation.

6. Read and try to guess the meaning of the following words and word combinations:

clinical biochemist; public recognition; water industry; physical properties; energy industry; equipment design, factory size equipment; novel material.

7. Do you know if there are any differences between chemistry and chemical engineering?

A. Discuss with your groupmates.

B. Read the text to find out. Complete the table while reading the text.

Category	Chemistry	Chemical engineering
Recognition		
History		
Numbers		
Area of study		
Focus		
Salary		
Careers		
Place of work		
Scale		
Diversity		

Ten Differences between Chemistry and Chemical Engineering

When I talk about my work I find the **common problem** that people do not understand the difference between chemists and chemical engineers.

Both **fields** are becoming increasingly important and **deserve** greater public recognition, but they are **distinct**.

Although I now work as a chemical engineer I originally studied chemistry, and so feel I should **be well placed** to **highlight** the **key differences** and **dispel common misconceptions**.

However, this **list** is **in no way definitive** and there are huge **overlaps** in the work of chemists and chemical engineers.

Here are ten differences between chemists and chemical engineers:

1. Recognition

The most **apparent** difference between chemists and chemical engineers to me is recognition. The public **at large** understand what a chemist does (because they studied chemistry in school), but there is **a lack of** recognition of what chemical engineering is.

Perhaps the highest form of recognition for both chemists and chemical engineers would be winning a Nobel Prize. The Nobel Prize in Chemistry has been **awarded** to 166 laureates since 1901 but I can only think of six of these winners who can be classified as chemical engineers; Koichi Tanaka, Jon B. Fenn, Kurt Wuthrich, Linus Carl Pauling, William Francis Giauque and Robert H. Grubbs.

As a group we chemical engineers need to **get better at being envoys** of our work.

2. History

Chemistry and the study of it is an old profession. Records exist of the ancient civilisations **amassing** practical knowledge of chemistry involved in metallurgy, **pottery** and **dyeing**. The study of chemistry as a science began in the 1600s, with chemists like Robert Boyle working towards the formulation of Boyle's Law.

Chemical engineering emerged **in its own right in the late 1800s** with George E Davis **coining the term** 'chemical engineering'. The importance of chemical engineering increased after World War.

3. **Numbers**

There are more chemists than there are chemical engineers, perhaps explaining why chemistry is more **readily** analysing. For example; there were ~29,800 applications to study chemistry in 2014 the UK, **compared with** ~19,900 to study chemical engineering.

However there is good news for chemical engineering. **In the last year**, chemical engineering in the UK has seen an **increase of** 18.6 per cent in the number of people applying to study it, compared with an increase of 9.4 per cent for chemistry. **Obviously** not all these students will go on to work as chemists or chemical engineers, but increasing numbers of students are **a good sign** for both fields.

4. Area of study

Chemistry investigates the **background** of the science **encompassing** aspects of; organic, inorganic, analytical, physical and bio-chemistry. Chemical engineering is more multidisciplinary in its **approach** and includes all of the previous topics, as well as aspects of physics and maths such as **heat transfer**, **fluid dynamics**, equipment design etc.

5. Focus

Chemists **tend** to **focus on** developing novel materials and processes, analyzing **substances**, measuring the physical properties of substances and testing theories.

Chemical engineering focuses on **turning** these new ideas and discoveries **into** useful products that are **attainable**. Most work **falls into** the design, manufacture and operation of plants and **machinery** and the development of new materials or substances. Chemical engineers focus on making products **for profit** and **on a scale** that is **accessible** to the many.

6. **Salary**

Chemical engineers generally get paid more than chemists. The starting salary of a chemical engineer is £29,500 (AUD $69,000); the starting salary of an analytical chemist is £22,000. This does not change with **career progression**; senior analytical chemists could earn over £50,000 but **chartered** chemical engineers can earn £70,000+.

7. Careers

Both chemistry and chemical engineering are good subjects to study and the skills learnt can be applied to a variety of different jobs and roles. For chemists typical jobs within the field of chemistry include; analytical chemist, clinical biochemist, **forensic scientist**, pharmacologist, **research scientist** or toxicologist. The skills learnt in studying chemistry can also be applied to being an accountant, **environmental consultant**, **patent law**, teacher or **science writer**. Chemists can even go on to become chemical engineers (like me!).

Chemical engineers can fill a wide range of roles in a variety of disciplines including; chemical engineer in the water industry, **bioproduct engineer**, **food processing engineer** or **process engineer** in the energy industry.

8. Place of work

Chemists tend to work in laboratories performing analysis or research and development, but can also be found in offices, classrooms and **in the field**. Chemical engineers tend to work at the plant end of research, but also work in laboratories, the field and the **boardroom**.

9. **Scale**

Chemists work with relatively small amounts of materials in **glassware** or on a **laboratory bench**; e.g. developing new **drugs**. Whereas chemical engineers work on **industrial scale** reactions with factory size equipment; e.g. **scaling up** drug production.

Chemists are more likely to develop novel products; and then chemical engineers are likely to take these products and make them more efficient so they are widely available and cheap.

10. Diversity

The **bodies of** chemistry and chemical engineering have both worked hard to **promote diversity** within the fields and both have seen success. This year 42 per cent of applicants to study chemistry were **female**, a good sign for **gender equality**.

In chemical engineering one in four students applying for chemical engineering is female, the highest amount in all the engineering professions. We chemical engineers need to do even more work to achieve a better gender balance.

It is important to remember that chemists and chemical engineers have to work together to achieve successful **outcomes**. This **collaboration** is the **backbone** of our work!

https://ichemeblog.org/2014/08/01/ten-differences-between-chemistry-and-chemical-engineering-day-66/

C. Decide if the statements are true or false. Correct the false ones.

1. People usually understand the difference between chemists and chemical engineers.
2. Chemists and chemical engineers have much in common.
3. Common people can understand what chemists and chemical engineers do.
4. Chemical engineering emerged much later than chemistry.
5. Chemical engineering became important as soon as it emerged.
6. The number of chemical engineers is increasing in terms of education.
7. Chemical engineering is more multidisciplinary than chemistry.
8. Chemical engineering is based on chemistry developing novel materials and processes.
9. Chemical engineers sometimes get paid more than chemists.

10. Chemical engineers have more career opportunities than chemists.
11. Chemists and chemical engineers can get job at the same places.
12. Chemical engineers work with small amounts of materials while developing new products.
13. Chemists and chemical engineers are successful thanks to their collaboration.

D. Read the text again and make a summary. Use the patterns that follow:

The text *is about* / *devoted to* / *related to* / *deals with* …
This is of great interest for those who study …
The author draws our attention to the fact that …
There are some good and interesting examples illustrating …
To sum up / *In conclusion* I'd like to say that …

E. Make a presentation to explain differences between chemists and chemical engineers.

F. Make a presentation to introduce chemical engineering as a separate field.

8. Complete the text with the words from the box:

optimization, chemistry, physical chemistry, chemical, mathematics, physical, physics, modeling

Chemical engineering, the development of processes and the design and operation of plants in which materials undergo changes in their … or … state. Applied throughout the **process industries**, it is founded on the principles of …, …, and ….

The laws of … … and physics govern the practicability and efficiency of chemical engineering operations. Energy changes, deriving from thermodynamic considerations, are particularly important. Mathematics is a basic tool in optimization and modeling. … means arranging materials, facilities, and energy to yield as productive and economical an operation as possible. … is the construction of theoretical mathematical prototypes of complex process systems, commonly with the aid of computers.

Written by Carl Hanson

9. Match the English words and word combinations in A with their Russian equivalents in B.

A. 1) date from; 2) large-scale; 3) continuous production; 4) increase in demand; 5) public concern; 6) transition; 7) from a craft to a science-based industry; 8) demand for; 9) chemical technologist; 10) petroleum industry; 11) separation process; 12) meet a challenge; 13) mechanical engineer; 14) plant item; 15) concept of unit operations; 16) unit process; 17) common characteristics; 18) process engineering; 19) restricted outlook; 20) based on existing practice; 21) mass transfer; 22) heat transfer; 23) fluid flow; 24) laborious design calculations; 25) plant layout; 26) environmental factors.

B. а) увеличение/повышение спроса; б) крупномасштабный; в) вести начало от; г) обеспокоенность общества; д) переход; е) непрерывное/массовое производство; ж) востребованность, спрос на; з) от ремесла к наукоемкой промышленности; и) на основе существующей практики; к) перерабатывающий завод, установка по переработке; л) принимать вызов; м) заводское оборудование, часть установки; н) инженер-машиностроитель; о) нефтеперерабатывающая промышленность; п) процесс разделения; р) химик-технолог; с) факторы внешней/ окружающей среды; т) понятие типовой операции; у) общие характеристики; ф) единичный/типовой процесс; х) технологическая схема процесса; ц) трудоемкие проектные расчеты; ч) ограниченный взгляд; ш) поток жидкости/текучей среды; щ) теплопередача; э) перенос массы/массопередача.

10. Translate the sentences given below. Pay attention to the infinitive constructions.

1. Chemists are more likely to develop novel products; and then chemical engineers are likely to take these products and make them more efficient. 2. The mould seemed to be empty. 3. The human body is estimated to have 100,000 different proteins. 4. Wallace Hume Carothers is considered to be the father of synthetic polymer science. 5. They appear to be flexible and act as rubber and plastic materials.

11. Read the text and answer the questions:

1. *How old is chemical engineering?*
2. *What processes can be considered the beginning of chemical engineering?*
3. *When did modern chemical engineering emerge?*
4. *What problems does chemical engineering solve?*
5. *What caused the transition from a craft to a science-based industry?*
6. *What was the result of the transition from a craft to a science-based industry?*
7. *What was a challenge for the traditional chemists and mechanical engineers?*
8. *What was the role the first textbook on chemical engineering? When was it published?*
9. *What examples of unit operations are given in the text?*
10. *What does the complexity arise from?*
11. *What examples of unit processes are provided by the author? Do they have common characteristics?*
12. *What is the disadvantage of the unit approach?*
13. *What laws do the fundamental phenomena involved in the various unit operations depend on?*
14. *What has led to the development of chemical engineering science in its own right?*
15. *What has allowed laborious design calculations to be performed rapidly?*
16. *What different parameters can cause variations in industrial processes?*

History

Chemical engineering is as old as the **process industries**. Its **heritage** dates from the **fermentation** and **evaporation** processes **operated** by early civilizations. Modern chemical engineering **emerged** with the development of large-scale, chemical-manufacturing operations in the second half of the 19th century. Throughout its development as an independent discipline, chemical engineering has been directed toward solving problems of designing and operating large plants for continuous production.

Manufacture of chemicals in the mid-19th century consisted of modest craft operations. Increase in demand, public concern at the emission of **noxious effluents**, and competition between **rival** processes provided the **incentives** for greater efficiency. This led to the emergence of **combines** with resources for larger operations and caused the transition from a **craft** to a **science-based industry**. The result was a demand for chemists with knowledge of manufacturing processes, known as industrial chemists or chemical technologists. The term chemical engineer was in general use by about 1900. The demand for plants capable of operating physical separation processes continuously at high levels of efficiency was a **challenge** that could not be met by the traditional chemist or mechanical engineer.

A **landmark** in the development of chemical engineering was the publication in 1901 of the first textbook on the subject, by George E. Davis, a British chemical consultant. This concentrated on the design of plant items for specific operations. The notion of a processing plant encompassing a number of operations, such as mixing, evaporation, and filtration, and of these operations being essentially similar, whatever the product, led to the concept of unit operations. This was first **enunciated** by the American chemical engineer Arthur D. Little in 1915 and formed the basis for a classification of chemical engineering that dominated the subject for the next 40 years. The number of unit operations – the building blocks of a chemical plant – is not large. The complexity arises from the variety of conditions under which the unit operations are conducted.

In the same way that a complex plant can be divided into basic unit operations, so chemical reactions involved in the process industries can be classified into certain groups, or unit processes (*e. g.* polymerizations, **esterifications**, and **nitrations**), having common characteristics. This classification into unit processes brought rationalization to the study of process engineering.

The unit approach suffered from the disadvantage **inherent in** such classifications: a restricted outlook based on existing practice. Since World War II, closer examination of the fundamental phenomena involved in the various unit operations has shown these to depend on the basic laws of **mass transfer**, **heat transfer**, and **fluid flow**. This has given unity to the diverse unit operations and has led to the development of chemical engineering science in its own right; as a result, many applications have been found in fields outside the traditional chemical industry.

Study of the fundamental phenomena upon which chemical engineering is based has necessitated their description in mathematical form and has led to more sophisticated mathematical techniques. The advent of digital computers has allowed laborious design calculations to be performed rapidly, opening the way to accurate optimization of industrial processes. Variations due to different parameters, such as energy source used, **plant layout**, and environmental factors, can be predicted accurately and quickly so that the best combination can be chosen.

https://www.britannica.com/technology/chemical-engineering.

12. Read the text again and make a summary.

13. Complete the table with the information provided in this text as wel as in ex. 11 on this unit:

Dates / period	**Steps / discoveries / inventions / …**
early civilizations	
early 1800s	
1888	
mid-19^{th} century	
by about 1900	
1901	
1915	
20^{th} century	

Chemical engineering, which in most general terms is applied chemistry, existed even in early civilizations. Chemical engineering is the newest of the four big engineering professions, which are civil, mechanical, and electrical. Chemical engineering dates back to Ancient Greece where they distilled alcoholic beverages, as did the Chinese, who had learned to distill alcohol from rice by 800 BC. Aristotle, the Greek philosopher of the fourth century BC, wrote about the process of obtaining fresh water by evaporating water from the sea.

Chemical engineering evolved from two main roots. The earlier was industrial chemistry, in which the work of the chemical engineer emerged from what was previously done by a team of chemists and a mechanical engineer. The other main root came around because of the great innovations from the US, which consisted of a connected approach to unit operations. These were physical separations such as distillations, absorption, and extraction in which the principles of mass transfer, fluid dynamics, and heat transfer were combined in equipment design. The foundations of the modern field of chemical engineering were laid out during the Renaissance, when experimentation and the questioning of accepted scientific theories became widespread. This period saw the development of many new chemical processes, such as those for sulfuric acid (for fertilizers and textile treatment) and alkali (for soap). The atomic theories of John Dalton and Amedeo Avogadro, developed in the early 1800s, became an important theoretical underpinning for both chemistry and chemical engineering.

With the birth of large scale manufacturing in the mid-nineteenth century, modern chemical engineering began to take shape. Chemical manufacturers were soon required to seek out chemists who also had knowledge of manufacturing processes. These early chemical engineers were called chemical technicians or industrial chemists. The first course in chemical engineering was taught tin 1888 at the Massachusetts Institute of Technology, and by 1900 chemical engineer had become a widely used job title.

In the twentieth century chemical engineers were employed in increasing numbers to design new and more efficient ways to process chemicals and chemical products. In the US, chemical engineers were especially important in the development of petroleum-based fuels for the automotive industry. The achievements of chemical engineers – from large-scale production of plastics, antibodies (including penicillin), and synthetic rubbers to the development of high-octane gasoline – have gratefully affected our daily lives.

http://coolreferat.com/Chemical_Engineering_Essay_Research_Paper_Chemical_EngineeringScopeChemical.

14. Make a presentation to introduce history of chemical engineering. Use the information of the texts in ex. 11 and 13.

Vocabulary

1)	accessible	➢ доступный
2)	amass	➢ накапливать
3)	apparent	➢ очевидный, наглядный
4)	apply	➢ применять, подавать заявление
5)	approach	➢ подход
6)	at large	➢ в целом, в общих чертах
7)	attainable	➢ доступный
8)	award	➢ присуждать, вручать
9)	backbone	➢ основа, основополагающий элемент
10)	background	➢ теоретическая основа
11)	be well placed	➢ находиться в выгодном положении, иметь все возможности
12)	bioproduct engineer	➢ инженер-биотехнолог
13)	boardroom	➢ администрация, руководство компании, правление
14)	body of	➢ группа (людей), комплекс
15)	career progression	➢ карьерный рост, продвижение по карьерной лестнице
16)	challenge	➢ сложная и интересная задача, сложная проблема
17)	chartered	➢ привилегированный, дипломированный, член профессионального объединения
18)	coin the term	➢ ввести термин
19)	collaboration	➢ сотрудничество, взаимодействие
20)	combine	➢ комбинат, объединение, концерн
21)	common misconception	➢ распространенное заблуждение
22)	common problem	➢ типичная проблема
23)	craft	➢ ремесло, ручная работа
24)	definitive	➢ окончательный, исчерпывающий
25)	deserve	➢ заслуживать
26)	dispel	➢ развеять
27)	distinct	➢ различный, несхожий
28)	drugs	➢ лекарственные препараты, медикаменты
29)	dyeing	➢ окраска тканей, красильное дело
30)	emerge	➢ появляться

31)	encompass	➢ охватывать, включать
32)	enunciate	➢ объявлять, провозглашать
33)	environmental consultant	➢ консультант-эколог
34)	envoy	➢ представитель
35)	esterification	➢ эстерификация
36)	evaporation	➢ испарение, выпаривание
37)	fall into	➢ разделяться на, относиться к
38)	female	➢ женщина, женского пола
39)	fermentation	➢ брожение, ферментация
40)	field	➢ сфера деятельности
41)	fluid dynamics	➢ гидродинамика, динамика жидкостей и газов
42)	fluid flow	➢ поток текучей среды, гидродинамика
43)	food processing engineer	➢ инженер-технолог пищевой промышленности
44)	for profit	➢ с целью извлечения прибыли
45)	forensic scientist	➢ судебный эксперт, криминалист
46)	gender equality	➢ равенство полов
47)	get better at	➢ продвинуться в, совершенствоваться в
48)	get paid	➢ получать зарплату
49)	glassware	➢ лабораторная посуда
50)	heat transfer	➢ теплообмен, теплоотдача
51)	heritage	➢ наследие, происхождение
52)	highlight	➢ останавливаться на
53)	in its own right	➢ самостоятельный, отдельный
54)	in no way	➢ ни в коем случае, никоим образом
55)	in the field	➢ в производственных условиях
56)	in the last year	➢ за последний год
57)	in the late 1800s	➢ в конце XIX века
58)	incentive	➢ стимул, мотивация
59)	increase of	➢ возрастание/увеличение (в размере…, на …)
60)	industrial scale	➢ промышленный/производственный масштаб
61)	inherent in	➢ характерный для
62)	key differences	➢ основные отличия
63)	laboratory bench	➢ лабораторный стол, лабораторный/ испытательный стенд

64)	lack of	➢ недостаток
65)	landmark	➢ поворотный момент, важная веха
66)	list	➢ список, перечень
67)	machinery	➢ оборудование, станки
68)	mass transfer	➢ массообмен, массопередача
69)	modest	➢ скромный, незатейливый, простейший
70)	nitration	➢ нитрование
71)	noxious effluents	➢ отравленные сточные воды
72)	numbers	➢ цифры
73)	obviously	➢ очевидно, безусловно
74)	on a scale	➢ в масштабах
75)	one in four	➢ каждый четвертый
76)	operate	➢ обслуживать, эксплуатировать
77)	outcomes	➢ конечные результаты, перспективы
78)	overlap	➢ совпадение
79)	patent law	➢ закон о патентах
80)	plant layout	➢ план завода, технологическая схема процесса
81)	pottery	➢ гончарное производство
82)	precondition	➢ предварительные / исходные условия
83)	precursor	➢ предшественник
84)	process engineer	➢ инженер-технолог, инженер по организации производства
85)	process industry	➢ перерабатывающая промышленность
86)	promote diversity	➢ стимулировать / поддерживать разнообразие
87)	readily	➢ с готовностью, охотно
88)	research scientist	➢ научный сотрудник
89)	rival	➢ конкурентоспособный
90)	route	➢ вариант, метод
91)	salary	➢ зарплата
92)	scale up	➢ увеличивать, расширять масштабы
93)	science writer	➢ автор научных публикаций
94)	science-based industry	➢ наукоемкая отрасль промышленности
95)	turn smth into	➢ воплощать / превращать в
96)	variety	➢ разнообразие, многогранность

Unit II
OBJECTS AND MATERIALS OF CHEMICAL ENGINEERING

1. Read the text and learn how to read chemical formulas.

Symbols, Formulas and Equations

Each of the 107 presently known chemical elements has a symbol. This symbol is usually **derived from** the name of the element. The symbol of oxygen is O, of hydrogen is H, of helium is He, of copper is Cu, of sodium is Na, of plutonium is Pu. Groups of symbols are called formulas. They are used to designate compounds. The formula for water is H_2O, for carbon dioxide CO_2, for sulphuric acid H_2SO_4. These symbols and formulas are used to indicate chemical reactions. For example:

$2H_2O \rightarrow 2H_2 + O_2$ (Statement: Water decomposes to form hydrogen and oxygen)

The symbols of chemical elements are read according to the names of English alphabet letters.

The sign "+" is read as *plus*, *and*, *together*, *with*, *react with*.

The sign "–" indicates one relation and isn't read at all.

The sign "=" is read as *give*, *form* or *produce*.

The sign "→" is read as *give*, *pass over to* or *lead to*.

The sign "⇆"is read as *forms and is formed from*.

$2H_2O$ – a figure before an element signifies the number of molecules; *two molecules of water*.

$2H_2 + O_2 \rightarrow 2H_2O$

Two molecules of H two plus O two give two molecules of H two O or Two two-atom molecules of hydrogen react with one two-atom molecule of oxygen and produce two molecules of water.

$N_2 + 3H_2 \leftrightarrows 2NH_3$

N two plus three molecules of H two form and are formed from two molecules of NH three or one two-atom molecule of nitrogen plus three two-atom molecules of hydrogen form and are formed from two molecules of ammonia.

$Na_2CO_3 + CaSO_4 \rightarrow Na_2SO_4 + CaCO_3$

Na two CO three plus CaSO four form Na two SO four plus CaCO three or the sodium (Na) and the calcium (Ca) switch places. The sodium combines with the sulphate radical (SO_4), forming sodium sulphate (Na_2SO_4) which dissolves in water. The calcium combines with the carbonate radical

(CO_3), forming calcium carbonate ($CaCO_3$). Calcium carbonate does not dissolve in water and so settles to the bottom of the solution.

https://studopedia.su/11_129612_How-to-read-chemical-formulas.html.

2. Try to read some chemical formulae.

OH, NHCOCH, H_2O, NH_3, N_2, Na_2CO_3, $CaSO_4$, $N_2 + 3H_2 \leftrightarrows 2NH_3$, $Na_2CO_3 + CaSO_4 \rightarrow Na_2SO_4 + CaCO_3$, CH_2

3. Translate conjugate words or words with the same roots:

bond – bonding; nature – natural; branch – branched; synthetic – synthesized – synthesis; part – partial; combine – combination; react – reaction – reactant, solid – solidify, rubber – rubbery, resist – resistant – resistance; elastic – elasticity.

4. Read and try to guess the meaning of the following words and word combinations:

organic chemical industry, molar mass, polypeptides, glucose polymers, monosaccharide, polysaccharide, component, Bakelite, car tail lights, colloid chemistry, corrosion, genetic information.

5. Match the English words and word combinations in A with their Russian equivalents in B.

A. 1) latex; 2) textiles fiber; 3) synthetic rubber; 4) giant molecule; 5) addition polymer; 6) condensation polymer; 7) natural polymer; 8) protein; 9) nucleic acid; 10) cellulose; 11) basic food; 12) straight chain polymer; 13) branched chains; 14) food additives; 15) organic compound; 16) commercial use; 17) plastic food wrap; 18) industrial wastewater; 19) amino acid; 20) peptide bond.

B. а) текстильное волокно; б) пищевая пленка; в) конденсационный полимер; полимер, полученный поликонденсацией мономеров; г) природный полимер; д) пищевые добавки; е) синтетический каучук; ж) промышленные сточные воды; з) нуклеиновая кислота, полинуклеотид; и) промышленное применение; к) аминокарбоновая кислота; л) основной продукт питания; м) макромолекула; н) белок; о) полимер, полученный ступенчатой полимеризацией; п) полимер с линейной решеткой; р) разветвленная цепь; с) органическое соединение; т) клетчатка; у) пептидная связь; ф) млечный сок.

6. Translate the sentences. Pay attention to the Participles.

1. Polymers are giant molecules with molar masses ranging from thousands to millions. 2. The organic chemical industry is devoted to the production of synthetic polymers. 3. The small molecules used to synthesize polymers are called monomers. 4. Synthetic polymers can be classified as addition polymers, formed from monomer units directly joined together. 5. The resulting structure is not elastic. 6. Natural rubber is an addition polymer made up of thousands of **isoprene** monomer repeating units. 7. Polymers are large molecules composed of repeated chemical units. 8. By adding dyes to the starting materials the objects became available in different colors. 9. After **setting** the liquid **aside**, it **solidified** into a material that seemed **rubbery** and even bounced. 10. Polymers could be formed by employing already known organic reactions. 11. Generally speaking, we use polymers in our everyday life. 12. Strictly speaking, every chemical reaction is reversible. 13. While working in the laboratory we made experiments. 14. If used this method will help us to increase the output. 15. The problem is being solved. 16. Having been translated into many languages the book became very popular.

7. Read the text and answer the questions:

1) *What are polymers?*
2) *What are monomers?*
3) *Which of the synthetic polymers are mentioned in the text?*
4) *What types of synthetic polymers are mentioned in the text?*
5) *Where can natural polymers be found?*
6) *Which of the natural polymers are described in the text?*

Natural Polymers

The word "polymer" means "many parts" (from the Greek *poly*-, meaning "many" and *meros*-, meaning "parts"). Polymers are giant molecules with molar masses ranging from thousands to millions. Approximately 80 per cent of the organic chemical industry is devoted to the production of synthetic polymers, such as plastics, textiles fibers, and synthetic rubbers. A polymer is synthesized by chemically joining together many small molecules into one giant molecule. The small molecules used to synthesize polymers are called monomers. Synthetic polymers can be classified as addition polymers, formed from monomer units directly joined together, or condensation polymers, formed from monomer units combining such that a small molecule, usually water, is produced during each reaction.

Polymers are widely found in nature. The human body contains many natural polymers, such as proteins and nucleic acids. Cellulose, another natural polymer, is the main structural component of plants. Most natural polymers are condensation polymers, and in their formation from monomers water is a **by-product**.

Starch is a condensation polymer made up of hundreds of glucose monomers, which **split out** water molecules as they chemically **combine**. Starch is a member of the basic food group **carbohydrates** and is found in cereal grains and potatoes. It **is** also **referred to as** a polysaccharide, because it is a polymer of the monosaccharide glucose. Starch molecules include two types of glucose polymers, amylose and amylopectin, **the latter** being the major starch component in most plants, **making up** about three-fourths of the total starch in wheat flour[1]. Amylose is a straight chain polymer with an average of about 200 glucose units per molecule.

A typical amylopectin molecule has about 1,000 glucose molecules arranged into branched chains with a branch occurring every 24 to 30 glucose units. Complete hydrolysis of amylopectin **yields** glucose; partial hydrolysis produces mixtures called dextrins, which are used as food additives and in **mucilage**, **paste**, and **finishes** for paper and **fabrics**.

Glycogen is an energy reserve in animals, just as starch is in plants. Glycogen is similar in structure to amylopectin, but in a glycogen molecule a branch is found every 12 glucose units. Glycogen is stored in the liver and skeletal muscle tissues.

Cellulose is the most **abundant** organic compound on Earth, and its **purest** natural form is **cotton**. The woody parts of trees, the paper we make from them, and the supporting material in plants and leaves are also mainly cellulose. Like amylose, it is a polymer made from glucose monomers. The difference between cellulose and amylose lies in the **bonding** between the glucose units. The bonding angles around the oxygen atoms connecting the glucose rings are each 180° in cellulose, and 120° in amylose. This **subtle** structural difference is the reason we cannot **digest** cellulose. Human beings do not have the necessary **enzymes** to **break down** cellulose to glucose. On the other hand, termites, a few species of cockroaches[2], and ruminant

[1] wheat flour – пшеничная мука
[2] cockroach – таракан

mammals[3] such as cows, sheep, goats, and camels, are able to digest cellulose.

Chitin, a polysaccharide similar to cellulose, is Earth's second most abundant polysaccharide (after cellulose). It is present in the cell walls of fungi[4] and is the fundamental substance in the exoskeletons[5] of crustaceans[6], insects, and spiders. The structure of chitin is identical to that of cellulose, except for the replacement of the OH group on the C-2 carbon of each of the glucose units with an – $NHCOCH_3$ group. The principal source of chitin is shellfish[7] waste. Commercial uses of chitin waste include the making of **edible** plastic food wrap and cleaning up of industrial wastewater.

All proteins are condensation polymers of amino acids. An **immense** number of proteins exists in nature. For example, the human body is estimated to have 100,000 different proteins. What is amazing is that all of these proteins are **derived from** only twenty amino acids. In the condensation reaction whereby two amino acids become linked, one molecule of water forming from the **carboxylic acid** of one amino acid and the amine group of the other **is eliminated**. The result is a peptide bond; hence, proteins are **polypeptides** containing from approximately fifty to thousands of amino acid **residues**.

The **primary structure** of a protein is the **sequence** of the amino acid units in the protein. The **secondary structure** is the shape that the **backbone** of the molecule (the chain containing peptide bonds) assumes. The two most common secondary structures are the α**-helix** and the β-**pleated sheet**. An α-helix is held together by the intramolecular **hydrogen bonds** that form between the N-H group of one amino acid and the oxygen atom in the third amino acid down the chain from it.

The α-helix is the basic structural unit of hair and wool, which are **bundles** of polypeptides called α-keratins. The helical structure **imparts** some elasticity to hair and wool. The polypeptides in silk, on the other hand, are β-keratins with the β-sheet structure, in which several protein chains are joined side-to-side by intermolecular hydrogen bonds. The resulting structure is not elastic.

[3] ruminant mammals – жвачные млекопитающие
[4] fungi – грибы, плесень
[5] exoskeleton – панцирь
[6] crustaceans – ракообразные
[7] shellfish – моллюски

Nucleic acids are condensation polymers. Each monomer unit in these polymers is composed of one of two simple sugars, one phosphoric acid group, and one of a group of **heterocyclic nitrogen compounds** that behave chemically as **bases**. Nucleic acids are of two types: deoxyribonucleic acid (DNA), the storehouse[8] of genetic information, and ribonucleic acid (RNA), which transfers genetic information from cell DNA to cytoplasm, where protein synthesis takes place. The monomers used to make DNA and RNA are called nucleotides. DNA nucleotides are made up of a phosphate group, a **deoxyribose** sugar, and one of four different bases: **adenine**, **cytosine**, **guanine**, or **thymine**. The nucleotides that polymerize to produce RNA differ from DNA nucleotides in two ways: they contain ribose sugar in place of deoxyribose sugar and **uracil** instead of thymine.

Natural rubber is an addition polymer made up of thousands of **isoprene** monomer repeating units. It is obtained from the *Hevea brasiliensis* tree in the form of latex. The difference between natural rubber and another natural polymer, gutta-percha (the material used to cover golf balls), is the geometric form of the polyisoprene molecules. The CH_2 groups joined by double bonds in natural rubber are all on the same sides of the double bonds (the *cis* configuration), whereas those in gutta-percha are on opposite sides of the double bonds (the *trans* configuration). This single structural difference changes the elasticity of natural rubber to the **brittle hardness** of gutta-percha.

http://www.chemistryexplained.com/Pl-Pr/Polymers-Natural.html.

8. Read the text again and find nouns which mean the following:

1) a condensation polymer made up of hundreds of glucose monomers;
2) an energy reserve in animals, just as starch is in plants;
3) the most abundant organic compound on Earth;
4) Earth's second most abundant polysaccharide;
5) the basic structural unit of hair and wool;
6) an addition polymer made up of thousands of isoprene monomer repeating units.

[8] storehouse – хранилище, кладовая, сокровищница

9. Read the text and make a summary of text "Natural Polymers" (ex. 7).

10. Read the text. What new information on natural polymers have you got?

Naturally Occurring Polymers

This group consists of naturally occurring polymers and chemical modifications of these polymers. Cellulose, starch, lignin, chitin, and various polysaccharides are included in this group.

These materials and their derivatives offer a wide range of properties and applications. Natural polymers tend to be readily biodegradable, although the rate of degradation is generally inversely proportional to the extent of chemical modification.

Naturally occurring polymers exist in plants or animals.

Natural polymers are made up of carbon, hydrogen, nitrogen and oxygen.

Examples of naturally occurring polymers are

(a) Protein: in muscles, skin, silk, hair, wool and fur

(b) Carbohydrates: in starch and cellulose

(c) Natural rubber: in latex

Proteins are formed by the polymerization or monomers known as amino acids:

amino acids	polymerization	protein
(monomers)	→	(polymer)

Carbohydrates such as starch and cellulose consist of monomers known as glucose joined together chemically.

glucose	polymerization	carbohydrates
(monomers)	→	(polymer)

Natural rubber found in latex consists of monomers known as isoprene (2 – methylbuta – 1, 3 – diene) joined together chemically.

Natural rubber comprises the molecules of the monomer 2-methyl-1,3-butadiene, also called isopropene, joined together to form a long chain.

https://ru.scribd.com/doc/19255206/Synthetic-Polymers.

11. Read the text and complete the table.

Categories of polymers	Properties	Examples	Application

Synthetic Polymers

Synthetic polymer is a polymer that is manufactured in industry from chemical substances through the polymerisation process. Through research, scientists are now able to copy the structure of natural polymers to produce synthetic polymers.

The raw materials for the manufacture of synthetic polymers are **distillates** of petroleum.

However, most of them can be classified in at least three main categories: thermoplastics, fibres and elastomers.

Thermoplastics. This is a polymer which, when subjected to heat, becomes soft so they can be **moulded** into various shapes.

The properties of plastics. They are light, strong, and **inert to** chemicals such as acids and **alkali** and are **insulators** of electricity and heat.

The examples of plastics are polyethylene (PE), polyvinylchloride (PVC), polypropylene (PP), polystyrene, Perspex and Bakelite.

Synthetic fibres are long chained polymers that withstand stretching.

The examples of synthetic fibres are nylon and Terylene. Nylon is used to make ropes, fishing lines, stocking, clothing and parachutes. Terylene is used to make clothing, sleeping bags and fishing nets. Clothes made from Terylene do not crease easily.

Elastomer is a polymer that can regain its original shape after being stretched or pressed.

Both natural rubber and synthetic rubber are examples of elastomer. Examples of synthetic rubbers are neoprene and styrene-butadiene rubber (SBR). SBR is used to make car tyres.

The two types of polymerization are:

– polymerisation by addition;

– polymerisation by condensation.

Polymerisation by addition involves monomers with $>C = C<$ bonding, where the monomers join together to make a long chain without losing any simple molecules from it. Examples of polymers produced through this process are polythene, PVC perspex and other plastics.

Polymerisation by condensation involves the elimination of small molecules like water, methanol, ammonia or hydrogen chloride during the process. Examples of products of this process are terylene and nylon-66.

Synthetic Polymer & Their Uses in Daily Life

Synthetic Polymer	Uses
Neoprene	Shoe soles, hoses, radiator hoses, wetsuits
Polyvinyl chloride or PVC (polychloroethene)	Raincoat, pipes, to insulate electric wires
Polyamide (nylon)	Parachutes, carpet, ropes, form-fitting skiwear, hosiery
Polypropene	Plastics, bottles, plastic tables and chairs
Teflon (polytetrafluoroethene or PTFE)	To make non-stick pots and pans
Polyester	Filters, conveyor belts, sleeping bag insulation
Polyethylene terephthalate (PET, PETE)	Soft drink bottles, peanut butter jars, salad dressing bottles
Polythene (polyethylene)	Plastic bags, containers and cups
Perspex (polymethyl2-methylpropene)	Airplane window panes, lenses, car lamp covers
Polystyrene	Styrofoam® cups, grocery store meat trays, cafeteria trays

Synthetic polymers have been used widely to replace natural materials such as metals, wood, cotton, animal skin and natural rubber because of the following advantages:

- strong and light;
- cheap;
- able to resist corrosion;
- inert to chemical reactions;
- easily moulded or shaped and be coloured;
- can be made to have special properties.

https://ru.scribd.com/doc/19255206/Synthetic-Polymers.

12. Read the text again and decide if the statements are true or false.

1) Scientists are now able to develop new structures to produce synthetic polymers.

2) Petroleum is the raw material for the manufacture of synthetic polymers.

3) Most distillates can be classified in three main categories: thermoplastics, fibres and elastomers.

4) Plastics and synthetic fibres are made through polymerisation by addition.

5) Synthetic polymers can't replace natural materials in terms of their advantages.

13. Read the text and answer the questions that follow.

Synthetic Polymers

Polymers are large molecules composed of repeated chemical units. The smallest repeating unit is called a mer. The term polymer is derived from the Greek words *poly* and *mers* meaning "many parts". Linear polymers are like ropes. For a polymer chain of 10,000 units (a typical length), a standard half-inch-thick rope would be about 128 meters (140 yards) long to represent the length-to-thickness ratio. Polymers are synthesized naturally and artificially to perform a wide variety of specialized tasks.

Physical Properties of Polymers

The properties of polymers are dependent on many factors including inter- and intrachain bonding, the nature of the backbone, processing events, presence/absence of additives including other polymers, chain size and geometry, and molecular weight distribution.

While most materials have melting/freezing and boiling/condensing points, polymers do not boil because the energy necessary to put a polymer into the vapor state is greater than the bond energies of the atoms that hold the polymer together, thus they degrade prior to boiling. In order for a polymer to be flexible, its various units or segments must be able to move. The glass transition temperature (T_g) is the temperature where polymer units or segments can move but the entire chain cannot. Most vinyl polymers have T_g values below room temperature so that they appear to be flexible and act as rubber and plastic materials. Most condensation polymers have T_g values above room temperature and are used as hard plastics and fibers. The temperature where entire chain movement occurs is called the melting point (T_m) and is greater than the T_g.

Many polymers are themselves brittle at room temperature. For these polymers to become more **pliable**, additives called **plasticizers** that allow segmental mobility, and consequently segmental flexibility, are added. For synthetic polymers such as polyvinyl chloride (PVC) and polystyrene, plasticizers are added that allow the polymers to be flexible.

The inflexible regions of a polymer, such as crystalline regions, are often referred to as "hard" regions. **Conversely**, the flexible regions of a polymer, where segmental mobility occurs, are referred to as "soft" regions. This combination of hard and soft can be illustrated with so-called segmented polyurethanes. The urethane portion of such polymers is involved in hydrogen bonding and is considered "hard", while the polyether portion, flexible at room temperature, is considered "soft". These segmented polyurethanes are sold under a number of trade names including Spandex.

1) *What are polymers?*
2) *What is the origin of the word?*
3) *What are the properties of polymers dependent on?*
4) *Do polymers boil? Why? Why not?*
5) *Can a polymer be flexible?*
6) *What is the melting point for polymers?*
7) *What allows the polymers to be flexible?*
8) *What regions of a polymer are called "hard"? "soft"?*

14. Read the text and complete the table. The first one has been done for you as an example. If there is a lack of information use the Internet to find it.

Polymer	Developer	Place	Date	Properties	Application
Vulcanized rubber	*Charles Goodyear*	*USA*	*1844*	*temperature stable*	*shoe soles, tires etc.*

History of Synthetic Polymers

While polymers form the basis of life, the history of synthetic polymers is relatively recent. Some of the key polymers that have been developed since the early days of polymer science include:

Vulcanized rubber. In the mid-1800s, American scientist Charles Goodyear began working with rubber to try to make it more **temperature**

stable. After many unsuccessful attempts, he accidentally allowed a mixture of **sulfur** and pre-rubber to touch a hot stove. The rubber did not melt but only charred a little. By 1844 Goodyear had been given a patent for a process he called "vulcanization" after the Roman god of fire, Vulcan. Vulcanization is the **crosslinking** reaction between the rubber chains and the sulfur.

Bakelite. After years of work in his chemistry lab in Yonkers, New York, Leo Baekeland announced in 1907 the synthesis of the first truly synthetic polymeric material, later dubbed "Bakelite". It was generally recognized by leading organic chemists of the nineteenth century that phenol would condense with formaldehyde, but because they did not understand the principles of the reaction, they produced useless **crosslinked** materials. Baekeland's main project was to make hard objects from phenol and formaldehyde and then dissolve the product to reform it again in a desired shape. He **circumvented** the problem by placing the reactants directly in a **mold** of the desired shape and then allowing the reactants to form a hard, **clear solid** – Bakelite. It could be worked (i.e., cut, **drill**ed, and **sanded**), was **resistant to** acids and **organic liquids**, was stable at high temperatures, and did not break down when exposed to electrical charge. By adding dyes to the starting materials the objects became available in different colors. Bakelite was used to make bowling balls, phonograph records, telephone housings, cookware, and billiard balls. Bakelite also acted as a **binder** for textiles, **sawdust**, and paper, forming a wide range of composites including **Formica laminates**. Many of these combinations are still in use in the twenty-first century.

Neoprene. Chemist and Catholic priest Julius A. Nieuwland did extensive work in the 1920s on acetylene. He found that acetylene could be made to add to itself forming dimers and trimers. Arnold Collins, a chemist at the Dupont Company in the lab of Wallace Carothers, continued work on the project and in 1930 ran the reaction described by Nieuwland, purifying the reaction mixture. He found a small amount of material that was not vinylacetylene or divinylacetylene. After **setting** the liquid **aside**, it **solidified** into a material that seemed **rubbery** and even bounced. This new rubber was given the name Neoprene. Neoprene has outstanding resistance to gasoline, ozone, and oil in contrast to natural rubber and is used in a variety of applications including electrical **cable jacketing**, window **gaskets**, **shoe soles**, **industrial hose**, and **heavy-duty drive belts**.

Nylon. In the early 1930s Wallace Carothers and his team of chemists at Dupont were investigating synthetic fibers in order to find a synthetic alternative to silk. One promising candidate was formed from the reaction of **adipic acid** with hexamethylenediamine and was called fiber 66 because each monomer-containing unit had six carbons. It formed a strong, elastic, largely insoluble fiber with a relatively high melting temperature. DuPont chose this material for production. Such polyamides were given the name "nylons"; thus was born nylon 6,6.

Polyvinyl chloride. While PVC was initially formed by German chemist Eugen Baumann in 1872, scientists at B. F. Goodrich discovered in 1926 how to make sheets and **adhesives** from it, starting the "vinyl age". PVC's many applications include water pipes and joints, building materials, food packaging, wire insulation, and medical components.

Polystyrene. While polystyrene was probably first formed by German apothecary Eduard Simon in 1839, it was almost 100 years later, in 1930, that the German chemical company I. G. Fraben placed polystyrene on the market. Polystyrene-molded parts **became common place** by 1935. Applications of polystyrene include loose-fill packaging "peanuts", shape-molded packaging, and **disposable utensils**.

Polyacrylonitrile. Rohm and Haas Company bought out Plexiglas (polyacrylonitrile; also known as acrylic and as a fiber sold under trade names such as Orlon) from a British firm in 1935 and began production of clear plastic parts and goods, including replacements for glass in camera lenses, aircraft windows, clock faces, and car tail lights.

Polyvinyl butyral. The polymer polyvinyl butyral (PVB) was first used in automotive safety glass in 1938 to prevent **flying glass** resulting from automobile accidents and continues to be utilized in the twenty-first century for this purpose.

Other important synthetic polymers. World War II helped shape the future of polymers. Wartime demands and **shortages** encouraged scientists to seek **substitutes** and materials that **exceeded** currently available materials. During and after the war new materials were developed, **spurred** by needs in the electronics, medical, communications, food, aerospace, and other industries. The **aromatic nylons** (armids) Kevlar (capable of stopping a speeding bullet and used as **tire cord**) and Nomex (used in constructing **fire-resistant garments**) were developed. Polycarbonates sold under the trade names of Merlon and Lexon were developed that substituted for glass in many automotive products such as tail lights. Other key developments included polytetrafluoroethylene, a slick material also known as Teflon; polysiloxanes, also known as silicones, which have an extremely wide temperature-use range and were a component of the soles of the shoes that first touched the moon; and polyester fibers and plastics such as polyethylene terephthalate (PET), used in carbonated drink bottles.

Even with this early commercial activity, little was actually known about polymers. German chemist Herman Staudinger studied the polymerization of isoprene (a five-carbon hydrocarbon containing a double bond that is obtained as a product of the degradation of natural rubber by heating) as early as 1910. Intrigued by the difference between this synthetic material and natural rubber he began to study giant molecules. Many of his fellow scientists told him there was no such thing as giant molecules and that he was wasting his time. By 1920 he published a summary of his studies and correctly proposed linear structures for polystyrene and polyoxymethylene. X-ray studies were used to support the concept of macromolecules.

Wallace Hume Carothers is considered to be the father of synthetic polymer science. In 1927 the DuPont Company began a program of fundamental research in the areas of colloid chemistry, catalysis, organic synthesis, and polymer formation. Carothers, then a Harvard instructor, was persuaded to join the DuPont group. Carothers looked at the construction of giant molecules from small molecules to form synthetic polymers. His intention was to prepare molecules of known structure through the use of known organic chemistry and to "investigate how the properties of these substances depended on constitution". Over the course of his career, Carothers filed for over fifty patents and was involved in the discovery of nylon and the synthetic rubber neoprene.

From his studies Carothers established several concepts. First, polymers could be formed by employing already known organic reactions but with reactants that had more than one reactive group per molecule. Second, the forces that bring together the individual polymer units are the same as those that hold together the starting materials: namely, primary covalent bonds. Much of the polymer chemistry names and ideas that **permeate** polymer science were standardized through his efforts.

15. Make a summary on the text of History of Synthetic Polymers.

16. Make a presentation to introduce natural or synthetic polymers.

17. Read and translate the sentences. Pay attention to the Participial Constructions.

1. You will find the reaction completed. 2. We saw the chemical plant being built. 3. We had the detail moulded. 4. They want their students completing the experiment. 5. We heard Wallace Carothers and his team of chemists at Dupont investigating synthetic fibers. 6. Neoprene is considered having outstanding resistance to gasoline, ozone, and oil. 7. Leo Baekeland was reported having synthesized the first truly synthetic polymeric material. 8. The history of synthetic polymers is relatively recent, some of the key polymers having been developed since the early days of polymer science. 9. PVC initially formed by German chemist Eugen Baumann in 1872, scientists at B. F. Goodrich discovered in 1926 how to make sheets and **adhesives** from it.

Vocabulary

1)	abundant	➢ распространенный
2)	adenine	➢ аденин
3)	adhesive	➢ вяжущее вещество, адгезивное средство
4)	adipic acid	➢ адипиновая кислота
5)	alkali	➢ основание, щелочь
6)	aromatic nylons	➢ ароматический найлон
7)	backbone	➢ цепь, главная цепь
8)	base	➢ основание
9)	be eliminated	➢ исключаться, ликвидироваться, устраняться
10)	be referred to as	➢ называться
11)	become common place	➢ становиться общепринятым/обыденным, входить во всеобщее употребление
12)	binder	➢ вяжущий, связующее вещество
13)	bonding	➢ соединение
14)	break down	➢ расщеплять
15)	brittle	➢ хрупкий
16)	bundle	➢ связка, пучок

17)	by-product	➢ побочный продукт
18)	cable jacketing	➢ изоляция кабеля
19)	carbohydrates	➢ углеводы
20)	carboxylic acid	➢ карбоновая кислота
21)	circumvent	➢ преодолеть
22)	clear	➢ бесцветный, непигментированный
23)	combine	➢ соединяться, присоединяться
24)	conversely	➢ с другой стороны, в то же время
25)	cotton	➢ хлопок
26)	crosslinked	➢ поперечно сшитый
27)	crosslinking	➢ сшивание, вулканизация, образование поперечных межмолекулярных связей
28)	cytosine	➢ цитозин
29)	deoxyribose	➢ дезоксирибоза
30)	derived from	➢ производный от, происходить от
31)	digest	➢ переваривать, усваивать
32)	dimer	➢ димер
33)	disposable utensils	➢ одноразовая посуда
34)	distillates	➢ дистилляты
35)	drill	➢ сверлить
36)	edible	➢ съедобный
37)	enzyme	➢ фермент
38)	exceed	➢ превосходить
39)	fabric	➢ ткань
40)	finishes	➢ покрытия
41)	fire-resistant garments	➢ огнеупорная / негорючая одежда
42)	flying glass	➢ разбитое стекло
43)	formica	➢ жаростойкий пластик
44)	gasket	➢ уплотнитель
45)	glycogen	➢ гликоген, полисахарид
46)	guanine	➢ аминооксипурин, гуанин
47)	hardness	➢ жесткость
48)	heavy-duty drive belt	➢ ремень передачи большой мощности
49)	helix	➢ спираль

50) heterocyclic ➢ гетероциклический
51) hydrogen bonds ➢ водородные связи
52) immense ➢ огромный
53) impart ➢ придавать, давать
54) industrial hose ➢ промышленный рукав
55) inert to ➢ инертный по отношению к
56) insulators ➢ изолятор
57) isoprene ➢ изопрен, метилбутадиен
58) laminate ➢ слоистый материал
59) make up ➢ составлять
60) mold ➢ пресс-форма
61) mould ➢ отливать под давлением, прессовать
62) mucilage ➢ клей с низкой адгезионной прочностью
63) nitrogen compound ➢ соединение азота, азотистое соединение
64) organic liquid ➢ органическая жидкость
65) paste ➢ паста
66) permeate ➢ лежать в основе
67) plasticizer ➢ пластификатор
68) pleated sheet ➢ складка
69) pliable ➢ пластичный
70) primary structure ➢ первичная структура
71) purest ➢ без примеси, беспримесный, чистый
72) residues ➢ остатки
73) resistant to ➢ устройчивый к
74) rubbery ➢ эластичный, упругий, резиноподобный
75) sand ➢ шлифовать
76) sawdust ➢ древесные опилки, древесная мука
77) secondary structure ➢ вторичная структура
78) sequence ➢ последовательность
79) set aside ➢ выделять, отводить
80) shoe sole ➢ подошва обуви
81) shortage ➢ нехватка, перебои, дефицит
82) solid ➢ твердое тело
83) solidify ➢ отвердевать

84)	split out	➢ отщеплять
85)	spur	➢ побуждать, подстегнуть
86)	starch	➢ крахмал
87)	substitute	➢ замена, заменитель
88)	subtle	➢ незначительный
89)	sulfur	➢ сера
90)	temperature stable	➢ термостабильный
91)	the latter	➢ последний из двух
92)	thymine	➢ тимин
93)	tire cord	➢ шинный корд
94)	trimers	➢ тример, трехзвенный полимер
95)	uracil	➢ урацил
96)	vulcanized rubber	➢ резина (вулканизированная)
97)	yield	➢ дать, произвести

Unit III
CHEMICAL ENGINEERING PROCESSES AND EQUIPMENT

1. Read and try to guess the meaning of the following words and word combinations:

pesticides, washing soda, portland cement, agrochemicals, pharmaceutical, corrosion resistant equipment, pressures, distillation, adsorption, filtration, empirical data, fundamental principles.

2. Translate conjugate words or words with the same roots:

extrude – extruder – extrusion – extruded – extrudate, heat – heater – heating – heat-softened

3. Match the English words and word combinations in A with their Russian equivalents in B.

A. 1) industrial chemicals; 2) ceramic products; 3) corrosion resistant equipment; 4) meet required specifications; 5) a variety of techniques; 6) insure safe operation; 7) research and development laboratory; 8) research facilities; 9) production plant.

B. а) устойчивое к коррозии оборудование; б) обеспечить безопасную эксплуатацию; в) керамические изделия; г) научно-исследовательская база; д) промышленное предприятие; е) научно-исследовательская лаборатория; ж) различные методики; з) химические вещества промышленного назначения; и) соответствовать необходимым нормативам.

4. Read the text. Make a list of all the chemicals mentioned in the text. Give their Russian equivalents.

Technology

As accepted by chemical engineers, the chemical industry involves the use of chemical processes such as chemical reactions and **refining methods** to produce a wide variety of solid, liquid, and gaseous materials. Most of these products are used in manufacture of other items, although a smaller number are used directly by consumers. **Solvents**, pesticides, **lye**, washing soda, and portland cement are a few examples of product used by consumers. The industry includes manufacturers of inorganic- and organic-industrial chemicals, ceramic products, **petrochemicals**, agrochemicals, polymers and rubber (elastomers), **oleochemicals** (oils, fats, and **waxes**), **explosives**, **fragrances** and **flavors**. Examples of these products are shown in the Table below.

Product Type	Examples
inorganic industrial	ammonia, nitrogen, sodium hydroxide, sulfuric acid
organic industrial	acrylonitrile, phenol, ethylene oxide, urea
ceramic products	silica brick, frit
petrochemicals	benzene, ethylene, styrene
agrochemicals	fertilizers, insecticides, herbicides
polymers	polyethylene, Bakelite, polyester
elastomers	polyisoprene, neoprene, polyurethane
oleochemicals	lard, soybean oil, stearic acid
explosives	nitroglycerin, ammonium nitrate, nitrocellulose
fragrances and flavors	benzyl benzoate, coumarin, vanillin

Although the pharmaceutical industry is often considered a chemical industry, it has many different characteristics that put it in a separate category. Other closely related industries include petroleum, glass, paint, ink, **sealant**, adhesive, and food processing manufacturers.

Chemical processes such as chemical reactions are used in **chemical plants** to form new substances in various types of **reaction vessels**. In many cases the reactions are conducted in special corrosion resistant equipment **at elevated temperatures** and pressures with the use of **catalysts**. The products of these reactions are separated using a variety of techniques including distillation especially **fractional distillation**, **precipitation**, **crystallization**, adsorption, filtration, sublimation, and drying. The processes and product are usually tested during and after manufacture by **dedicated** instruments and **on-site quality control laboratories** to insure safe operation and to assure that the product will meet required specifications. The products are packaged and delivered by many methods, including **pipelines**, **tank-cars**, and **tank-trucks** (for both solids and liquids), cylinders, drums, bottles, and boxes. Chemical companies often have a research and development laboratory for developing and testing products and processes. These facilities may include **pilot plants**, and such research facilities may be located at a site separate from the production plant(s).

https://www.chemeurope.com/en/encyclopedia/Chemical_industry.html.

5. Read the text again and decide if the statements are true or false.

1) Chemical reactions and refining methods are chemical processes.

2) Chemical reactions and refining methods produced by the chemical industry are mostly used directly by consumers.

3) The industry includes manufacturers of great variety of chemicals.

4) The pharmaceutical industry is a chemical industry.

5) Petroleum, glass, paint, ink, **sealant**, adhesive, and food processing manufacturers are closely related to the chemical industry.

6) When new substances are formed in reaction vessels they are separated by distillation and then tested.

7) The packaged products can be delivered by trucks.

8) Pilot plants are used for research and development at production sites.

6. Translate the sentences. Pay attention to the Gerund.

1. Chemical companies often have a research and development laboratory for developing and testing products and processes. 2. A chemical process is a method intended to be used in manufacturing. 3. A chemical process is a method or means of somehow changing one or more chemicals. 4. In addition to chemical plants for producing chemicals, chemical processes with similar technology and equipment are also used in **oil refining** and other **refineries**, natural gas processing, polymer and pharmaceutical manufacturing, and water and wastewater treatment. 5. The dyeing of a fibre is a mass-transfer problem. 6. It can then be shaped by extrusion, **molding**, or **pressing**. 7. They are commonly used in food packaging. 8. Blow molding is a process used **in conjunction with** extrusion or injection molding. 9. Casting can make thick sheet. 10. The next step in the process is mixing and reacting the products.

7. Read the text. Three sentences have been removed from the text. Choose from the sentences A – D those which best fit each gap. There is one extra sentence which you do not need to use.

A. *Block flow diagrams show the units as blocks and the streams flowing between them as connecting lines with arrowheads to show direction of flow.*

B. *The rest of the article will cover the engineering type of chemical process.*

C. *Chemical engineering unit operations consist of five classes.*

D. *More than one chemical plant may use the same chemical process, each plant perhaps at differently scaled capacities.*

Chemical Process

In a "scientific" sense, a chemical process is a method or means of somehow changing one or more chemicals or **chemical compounds**. Such a chemical process can occur by itself or be caused by somebody. Such a chemical process commonly involves a chemical reaction of some sort. In an "engineering" sense, a chemical process is a method intended to be used in manufacturing or on an industrial scale to change the composition of chemical(s) or material(s), usually using technology similar or related to that used in chemical plants or the chemical industry.

Neither of these definitions is exact in the sense that one can always tell definitively what a chemical process is and what is not; they are practical definitions. There is also significant overlap in these two definition variations. Because of the inexactness of the definition, chemists and other scientists use the term "chemical process" only in a general sense or in the engineering sense. However, in the "process (engineering)" sense, the term "chemical process" is used extensively. 1. _________________

Although this type of chemical process may sometimes involve only one step, often multiple steps, referred to as unit operations, are involved. In a plant, each of the unit operations commonly occur in individual vessels or sections of the plant called units. Often, one or more chemical reactions are involved, but other ways of changing chemical (or material) composition may be used, such as mixing or separation processes. The process steps may be **sequential** in time or sequential in space along a stream of flowing or moving material. For a given amount of a **feed (input) material** or **product (output) material**, an expected amount of material can be determined at key steps in the process from **empirical data** and **material balance calculations**. These amounts can be **scaled up or down** to suit the desired capacity or operation of a particular chemical plant built for such a process. 2. ________

Such chemical processes can be illustrated generally as **block flow diagram**s or in more detail as **process flow diagrams**. 3. ____________

In addition to chemical plants for producing chemicals, chemical processes with similar technology and equipment are also used in **oil refining** and other **refineries**, natural gas processing, polymer and pharmaceutical manufacturing, and water and wastewater treatment.

https://www.chemeurope.com/en/encyclopedia/Chemical_process.html.

8. Read the text again and answer the questions:

1. *What is a chemical process?*
2. *Does the author state that the definitions of a chemical process given in the text are exact?*
3. *What type of chemical process is covered in the article?*
4. *Where do unit operations commonly occur?*
5. *Are chemical reactions combined with other ways of changing chemical (or material) composition?*
6. *How can chemical processes be illustrated generally or in more detail?*
7. *Where are chemical processes also used?*

9. Read the text and answer the questions that follow.

Unit Operation

In chemical engineering and related fields, a unit operation is a basic step in a process. For example in milk processing, homogenization, pasteurization, chilling, and packaging are each unit operations which are connected to create the overall process. A process may have many unit operations to obtain the desired product.

Historically, the different chemical industries were regarded as different industrial processes and with different principles. In 1923 William H. Walker, Warren K. Lewis and William H. McAdams wrote the book *The Principles of Chemical Engineering* and explained the variety of chemical industries have processes which follow the same physical laws. They summed-up these similar processes into unit operations. Each unit operation follows the same physical laws and may be used in all chemical industries. The unit operations form the fundamental principles of chemical engineering.

Chemical engineering unit operations consist of five classes:

1. Fluid flow processes, including fluids transportation, filtration, solids fluidization
2. Heat transfer processes, including evaporation, condensation
3. Mass transfer processes, including gas absorption, distillation, extraction, adsorption, drying
4. Thermodynamic processes, including gas liquefaction, refrigeration
5. Mechanical processes, including solids transportation, crushing and pulverization, screening and sieving

Chemical engineering unit operations also fall in the following categories:

- Combination (mixing)
- Separation (distillation)
- Reaction (chemical reaction)

Chemical engineering unit operations and chemical engineering unit processing form the main principles of all kinds of chemical industries and are the foundation of designs of chemical plants, factories, and equipment used.

https://www.chemeurope.com/en/encyclopedia/Unit_operation.html.

1. What is a unit operation in chemical engineering and related fields?

2. What did William H. Walker et al explain in the book "The Principles of Chemical Engineering"?

3. What fundamental transport processes are most unit operations based upon?

4. What classes do chemical engineering unit operations consist of?

5. What do chemical engineering unit operations and chemical engineering unit processing form?

10. Read and say in what industries chemical engineers are found.

Branches of Chemical Engineering

The fundamental principles of chemical engineering underlie the operation of processes extending well beyond the boundaries of the chemical industry and chemical engineers are employed in a range of operations outside traditional areas. Plastics, polymers and synthetic fibres involve chemical-reaction engineering problems in their manufacture, with fluid flow and heat transfer considerations dominating their fabrication. The dyeing of a fibre is a mass-transfer problem. Pulp and paper manufacture involve considerations of fluid flow and heat transfer. While the scale and materials are different, these again are found in modern continuous production of foodstuffs. The pharmaceuticals industry presents chemical engineering problems, the solutions of which have been essential to the availability of modern drugs. The nuclear industry makes similar demands on the chemical engineer, particularly for fuel manufacture and reprocessing. Chemical engineers are involved in many sectors of the metals processing industry, which extends from steel manufacture to separation of rare metals.

Further applications of chemical engineering are found in the fuel industries. In the second half of the 20th century, considerable numbers of chemical engineers have been involved in space exploration, from the design of **fuel cells** to the manufacture of propellants. Looking to the future, it is probable that chemical engineering will provide the solution to at least two of the world's major problems: supply of adequate fresh water in all regions through desalination of seawater and environmental control through prevention of pollution.

https://www.britannica.com/technology/chemical-engineering.

11. Read and try to guess the meaning of the following words and word combinations:

polyurethanes, mattress, insulation; phenol formaldehyde, thermoplastic; extrusion; polyethylene; polypropylene; polyvinyl chloride; granules.

12. Match the English words and word combinations in A with their Russian equivalents in B.

A. 1) boat hull; 2) bath tub; 3) shower stall; 4) engine blade; 5) electrical appliances; 6) electrical circuit boards and switches; 7) milk jug; 8) carbonated soft drink; 9) packaging film; 10) agricultural film; 11) instrument panel; 12) finished product; 13) conveyor belt; 14) meat mincer; 15) coated paper; 16) three-dimensional; 17) reproducibility; 18) molten plastic.

B. а) лопасть двигателя; б) мясорубка; в) молочный кувшин; г) готовый продукт, конечная продукция; д) воспроизводимость; е) сельскохозяйственная пленка; ж) мелованная бумага; з) расплавленный пластик; и) корпус лодки; к) газированный безалкогольный напиток; л) ванна; м) пленка для упаковки; н) электрооборудование; о) лента конвейера; п) приборная панель; р) объемный; с) душевая кабина; т) электрические щиты и выключатели.

13. Read the text and complete the chart with the necessary information according to the example.

Types of Plastics and Their Applications			
Thermoset			
Properties:		Properties:	
polyurethane	matrasses		
	cushions		
	insulation		

The Basics of Plastic Manufacturing.
The Two Plastic Types, Based on Processing

A Thermoset is a polymer that **solidifies** or "**sets**" **irreversibly** when heated or **cured**. Similar to the relationship between a raw and a cooked egg, a cooked egg cannot **revert** back to its original form once heated, and a **thermoset polymer** can't be softened once "set". Thermosets are valued for their **durability** and **strength** and are used extensively in automobiles and construction including applications such as adhesives, inks, and **coatings**. The most common thermoset is the rubber truck and automobile tire. Some examples of thermoset plastics and their product applications are:

Polyurethanes:
- Mattresses
- Cushions
- Insulation

Unsaturated Polyesters:
- Boat hulls
- Bath tubs and shower stalls
- Furniture

Epoxies:
- Adhesive glues
- Coating for electrical devices
- Helicopter and jet engine blades

Phenol Formaldehyde:

- **Oriented strand board**
- **Plywood**
- Electrical appliances
- Electrical circuit boards and switches

A Thermoplastic is a polymer in which the molecules are held together by weak secondary **bonding force**s that soften when exposed to heat and return to its original condition when cooled back down to room temperature. When a thermoplastic is softened by heat, it can then be shaped by extrusion, **molding**, or **pressing**. Ice cubes are common household items which exemplify the thermoplastic principle. Ice will melt when heated but readily solidifies when cooled. Like a polymer, this process may be repeated numerous times. Thermoplastics offer **versatility** and a wide range of applications. They are commonly used in food packaging because they can be rapidly and economically formed into any shape needed to fulfill the packaging function. Examples include milk jugs and carbonated soft drink bottles. Other examples of thermoplastics are:

Polyethylene:

- Packaging
- Electrical insulation
- Milk and water bottles
- Packaging film
- **House wrap**
- Agricultural film

Polypropylene:

- Carpet fibers
- Automotive bumpers
- Microwave containers
- **External prostheses**

Polyvinyl Chloride (PVC):

- **Sheathing** for electrical cables
- Floor and wall coverings
- **Siding**
- Automobile instrument panels

14. Read the text and make flowcharts to illustrate processing methods described in the text.

Thermoplastic and Thermoset Processing Methods

There are a variety of different **processing methods** used to **convert** polymers into finished products. Some include:

Extrusion. This continuous process is used to produce films, sheet, profiles, tubes, and pipes. Plastic material as granules, **pellets**, or powder, is first loaded into a **hopper** and then **fed** into a long **heated chamber** through which it is moved by the action of a continuously **revolving screw**. The chamber is a cylinder and is referred to as an extruder. Extruders can have one or two revolving screws. The plastic is melted by the mechanical work of the screw and the heat from the extruder wall. At the end of the heated chamber, the molten plastic is forced out through a small opening called a **die** to form the shape of the finished product. As the plastic is extruded from the die, it is fed onto a conveyor belt for cooling or onto **rollers** for cooling or by **immersion** in water for cooling. The operation's principle is the same as that of a meat mincer but with added heaters in the wall of the extruder and cooling of the product. Examples of extruded products include lawn edging[9], pipe, film, coated paper, insulation on electrical wires, gutter and down spouting[10], plastic lumber[11] and window trim[12]. Thermoplastics are processed by continuous extrusion. Thermoset elastomer can be extruded into weatherstripping[13] by adding catalysts to the rubber material as it is **fed into** the extruder.

Calendering. This continuous process is an extension of film extrusion. The still warm **extrudate** is chilled on polished, cold rolls to create sheet from 0.005 inches thick to 0.500 inches thick. The thickness is well maintained and surface made smooth by the polished rollers. Calendering is used for high output and the ability to deal with low **melt strength**. Heavy polyethylene films used for construction vapor and liquid barriers are calendered. High volume PVC films are typically made using calendars.

Film Blowing. This process continuously extrudes vertically a ring of semi-molten polymer in an upward direction, like a fountain. A bubble of

---

[9] lawn edging – бордюрная лента для сада

[10] spouting – система самотечных трубопроводов

[11] lumber – брус

[12] window trim – оконные наличники

[13] weatherstripping – уплотнитель

air is maintained that stretches the plastic axially and radially into a tube many times the diameter of the ring. The diameter of the tube depends on the plastic being processed and the processing conditions. The tube is cooled by air and is **nipped** and **wound** continuously as a **flattened tube**. The tube can be processed to form saleable[14] bags or **slit** to form rolls of film with thicknesses of 0.0003 to 0.005 inches thick. Multiple layers of different resins can be used to make the tube.

Injection Molding. This process can produce **intricate** three-dimensional parts of high quality and great reproducibility. It is **predominately** used for thermoplastics but some thermosets and elastomers are also processed by injection molding. In injection molding plastic material is fed into a hopper, which feeds into an extruder. An **extruder screw** pushes the plastic through the heating chamber in which the material is then melted. At the end of the extruder the molten plastic is forced at high pressure into a **closed cold mold**. The high pressure is needed to be sure the mold is completely filled. Once the plastic cools to a solid, the mold opens and the finished product is **ejected**. This process is used to make such items as butter tubs, yogurt containers, bottle caps, toys, fittings, and lawn chairs. Special catalysts can be added to create the thermoset plastic products during the processing, such as cured silicone rubber parts. Injection molding is a **discontinuous** process as the parts are formed in molds and must be cooled or cured before being removed. The economics are determined by how many parts can be made per cycle and how short the cycles can be.

Blow Molding. Blow molding is a process used **in conjunction with** extrusion or injection molding. In one form, extrusion blow molding, the die forms a continuous semi-molten tube of thermoplastic material. A chilled mold is **clamped** around the tube and compressed air is then blown into the tube to conform the tube to the interior of the mold and to solidify the stretched tube. Overall, the goal is to produce a **uniform melt**, form it into a tube with the desired **cross section** and blow it into the exact shape of the product. This process is used to manufacture **hollow** plastic products and its principal advantage is its ability to produce hollow shapes without having to join two or more separately injection molded parts. This method is used to make items such as commercial drums and milk bottles. Another blow molding technique is to injection mold an intermediate shape called a **preform** and then to heat the preform and blow the heat-softened plastic

[14] saleable – пользующийся спросом

into the final shape in a chilled mold. This is the process to make carbonated soft drink bottles.

Expanded Bead Blowing. This process begins with a measured volume of **beads of plastic** being placed into a mold. The beads contain a **blowing agent** or gas, usually pentane, dissolved in the plastic. The closed mold is heated to soften the plastic and the gas expands or blowing agent generates gas. The result is fused closed cell structure of foamed plastic that **conforms to a shape**, such as **expanded polystyrene** cups. **Styrofoam**™ expanded polystyrene thermal insulation board is made in a continuous extrusion process using expanded bead blowing.

Rotational Molding. Rotational molding consists of a mold mounted on a machine capable of rotating on two axes simultaneously. Solid or liquid resin is placed within the mold and heat is applied. Rotation distributes the plastic into a uniform coating on the inside of the mold then the mold is cooled until the plastic part cools and hardens. This process is used to make hollow configurations. Common rotationally molded products include shipping drums, storage tanks and some consumer furniture and toys.

Compression Molding. This process has a prepared volume of plastic placed into a **mold cavity** and then a second mold or **plug** is applied to **squeeze** the plastic into the desired shape. The plastic can be a semi-cured thermoset, such as an automobile tire, or a thermoplastic or a mat of thermoset resin and long glass fibers, such as for a boat hull. Compression molding can be automated or require considerable hand labor. Transfer molding is a refinement of compression molding. Transfer molding is used to **encapsulate** parts, such as for semi-conductor manufacturing.

The formation of plywood or oriented strand board using thermoset adhesives is a variant of compression molding. The wood veneer[15] or strands[16] are coated with catalyzed thermoset phenol formaldehyde resin and compressed and heated to cause the thermoset plastic to form into a rigid, non-melting adhesive.

Casting. This process is the low pressure, often just pouring, addition of liquid resins to a mold. Catalyzed thermoset plastics can be formed into intricate shapes by casting. Molten polymethyl methacrylate thermoplastic can be cast into slabs[17] to form windows for commercial aquariums. Casting can make thick sheet, 0.500 inches to many inches thick.

---

[15] wood veneer – древесная фанера

[16] strands – кабель

[17] slabs – листовая заготовка

Thermoforming. Films of thermoplastic are heated to soften the film, and then the soft film is pulled by vacuum or pushed by pressure to conform to a mold or pressed with a plug into a mold. Parts are thermoformed either from cut pieces for thick sheet, over 0.100 inches, or from rolls of thin sheet. The finished parts are cut from the sheet and the scrap sheet [18]material recycled for manufacture of new sheet. The process can be automated for high volume production of clamshell food containers or can be a simple hand labor process to make individual craft items.

https://plastics.americanchemistry.com/How-Plastics-Are-Made/.

15. Get ready to summarize the text of ex. 13.

16. Make a presentation on Thermoplastic and Thermoset Processing Methods.

17. Read the text and say what the major process steps are. Draw a flowchart to illustrate the sequence of these steps.

What Are the Different Types of Chemical Plant Equipment?

Chemical plant equipment used for chemical processing includes a wide range of machines, tanks, and other parts. From the time **raw materials** enter a process, they are stored, moved, and processed in a great number of ways. One way to look at important chemical plant equipment is to move through the major process steps.

Raw materials may be delivered by boat, truck or rail, as liquids and solids. They are often stored in tanks for bulk materials, and warehouse storage may be used for bags or drums. Materials eventually enter the process through feeder tanks that store enough products to supply the reaction steps, or bagged chemicals may be added by hand.

The next step in the process is mixing and reacting the products. Mixing tanks with large **agitator paddles** or **air jets** can mix solids and liquids. **Tower reactors** move liquids and gases in the same or opposite directions to provide chemical reactions. Reactors can be heated to melt raw materials or provide temperatures needed for chemical reactions to occur. Heat may be provided by electricity, requiring electrical **heating coils**, or with steam provided by a separate **steam plant**. Some processes are performed at low temperatures and need cooling systems to maintain proper temperatures.

[18] scrap sheet – бракованный лист

Once the reaction or multiple reactions have occurred, the next type of chemical plant equipment is **separation** and **purification**. In many processes, the desired product is mixed with raw materials or other chemicals used in the reaction. These products may be removed using tanks that separate liquids and gases or by towers that extract the desired product by mixing the stream with water or **solvents**. The final product may be dried in large tanks called **spray towers**, where the liquid is sprayed into drops that allow the liquid to evaporate, creating a dry final product.

Products may need to be dried in large rotating drums, called **kilns**, which remove water or solvents to create the final product. Liquids may need to be heated or cooled prior to **shipping**, and are stored in tanks that provide the needed temperatures. Dry products may be placed in bags or other containers, requiring a **packaging plant** to be installed that loads the bags from **bulk storage**.

A review of chemical plant equipment should also include the systems that support the operation of the plant. Chemical plants often require a large cooling capacity, and cooling towers may be used to provide cool water for plant use. Air compressors provide pressurized air for process and instrumentation needs. Instruments control everything by monitoring plant conditions and operating **control valves**, and may be powered by electricity or compressed air. Refrigeration systems may be needed for process cooling or for storage of temperature-sensitive products.

Another type of chemical plant equipment is used to move product through the plant. Pumps move liquids and liquid/solid mixtures through the various process steps, and load finished product onto rail cars, ships and trucks. Some solids can be mixed with air and moved through piping like a liquid, saving time and handling of bags or containers. **Valves** can start and stop movement of product in and out of reactors or tanks, or change the direction of flow to different reactors or storage tanks.

Conveyors using continuous belts move **bulk or loose solids** from place to place, and in or out of storage buildings or tanks. Groups of storage tanks called **tank farm**s store products awaiting transportation or use in another plant. Warehouses store bags, containers, or drums of finished product for shipping, and can be temperature-controlled. There is normally a loading dock attached to a warehouse, and motorized loaders called **fork trucks** can pick up **pallets** or containers and place them in transport trucks.

https://www.wisegeek.com/what-are-the-different-types-of-chemical-plant-equipment.htm.

18. What kinds of tanks, plants and towers are mentioned in the text? Read the text again and complete the word combinations with words from the text.

1) feeder 2) tanks 3)	1) steam 2) plants 3)	1) spray 2) towers 3)

19. Complete the passage with words and word combinations from the box.

Enter, mixed, moved, processed, boat, truck, rail, liquids, solids, tanks, bags, drums, containers, feeder tanks, agitator paddles, mixing, tower reactors

Raw materials are delivered by …, …, … as … and … They are stored in …, …, …, or other … Eventually they … a process through … …. They are … with air jets or … … in … tanks and … by … to provide chemical reactions. They are … in different ways.

20. Read the text again and complete the table.

Types of Chemical Plant Equipment	Functions

21. Get ready to summarize the text on different types of chemical plant equipment.

22. Make a presentation on different types of chemical plant equipment.

Vocabulary

1) aforementioned	➢ вышеупомянутый
2) agitator paddle	➢ лопасть мешалки
3) air jet	➢ форсунка
4) at elevated temperatures	➢ при повышенной температуре
5) bagged chemicals	➢ химические вещества, упакованные в мешок
6) beads of plastic	➢ гранулы/шарики пластика
7) block flow diagram	➢ технологическая блок-схема
8) blow molding	➢ литье с раздувом
9) blowing agent	➢ вспенивающее вещество
10) bonding forces	➢ сила химической связи
11) bulk or loose solids	➢ порошок
12) bulk storage	➢ хранение насыпью (без тары)
13) calendering	➢ каландрирование, вальцевание
14) casting	➢ литье
15) catalysts	➢ катализатор, отвердитель
16) chemical compound	➢ химическое соединение
17) chemical plants	➢ химическая технологическая установка; химическое оборудование; химический завод
18) clamp	➢ фиксировать
19) closed cold mold	➢ матрица для холодного прессования
20) coatings	➢ покрытия
21) compression molding	➢ прессование в форме; прямое прессование
22) conform to a shape	➢ соответствовать форме
23) control valves	➢ регулирующий клапан
24) convert	➢ изменять, преобразовывать
25) cooling systems	➢ система охлаждения
26) cross section	➢ поперечное сечение
27) crystallization	➢ кристаллизация, отвердевание
28) cure	➢ отверждать
29) dedicated	➢ специализированный
30) die	➢ головка экструдера
31) discontinuous	➢ прерываемый

32) durability ➢ износоустойчивость, долговечность
33) eject ➢ извлекать
34) empirical data ➢ эмпирические / опытные данные
35) encapsulate ➢ компоновать
36) epoxy ➢ эпоксидная смола
37) expanded polystyrene ➢ вспененный / газонаполненный полистирол
38) explosives ➢ взрывчатые вещества
39) external prostheses ➢ эктопротез
40) extrudate ➢ экструдат, экструдируемая заготовка
41) extruder screw ➢ шнек экструдера
42) feed – fed ➢ подавать
43) feed (input) material ➢ загружаемый (исходный) материал
44) feed into ➢ вводить
45) film blowing ➢ получение плёнки экструзией с раздувкой
46) flattened tube ➢ сплющенная трубка
47) flavors ➢ вкусовая добавка
48) fork truck ➢ вилочный автопогрузчик
49) fractional distillation ➢ фракционная перегонка, ректификация
50) fragrances ➢ ароматические добавки, отдушка
51) fuel cell ➢ топливный элемент
52) heated chamber ➢ нагревательная камера
53) heating coil ➢ нагревательный элемент
54) hollow ➢ полый, пустотелый
55) hopper ➢ загрузочный люк
56) house wrap ➢ ветрозащитная пленка
57) immersion ➢ погружение
58) in conjunction with ➢ наряду с
59) injection molding ➢ литьевое прессование
60) intricate ➢ замысловатый, сложный
61) irreversibly ➢ необратимо
62) kiln ➢ камерная сушилка
63) loading dock ➢ погрузочно-разгрузочная платформа
64) lye ➢ щелочь
65) material balance calculations ➢ расчет материального баланса
66) melt strength ➢ прочность расплава

67) mold cavity	➢ гнездо пресс-формы
68) molding	➢ литье под давлением
69) motorized loaders	➢ механизированное погрузочное устройство
70) nipped	➢ сжатый
71) oil refining	➢ перегонка нефти, очистка нефти и нефтепродуктов
72) oleochemicals	➢ продукты переработки масел
73) on-site	➢ выездной, на месте эксплуатации
74) oriented strand board	➢ ориентированно-стружечная плита
75) packaging plant	➢ установка для упаковки
76) pallet	➢ грузовой поддон
77) pellet	➢ шарик, гранула
78) petrochemicals	➢ нефтепродукты, продукты нефтепереработки
79) pilot plants	➢ экспериментальная установка
80) pipeline	➢ трубопровод
81) plant equipment	➢ заводское оборудование
82) plug	➢ вставка
83) plywood	➢ фанера
84) precipitation	➢ высаживание, осаждение
85) predominately	➢ преимущественно, в основном
86) preform	➢ преформа, заготовка
87) pressing	➢ прессование
88) process flow diagrams	➢ схема технологического процесса
89) processing method	➢ способ обработки, технологический метод
90) product (output) material	➢ исходящий материал
91) purification	➢ очистка
92) quality control laboratory	➢ лаборатория контроля качества
93) rail car	➢ железнодорожный вагон
94) raw materials	➢ сырье, заготовка, исходный материал
95) reaction vessels	➢ химический реактор
96) refinery	➢ очистка, переработка
97) refining method	➢ метод очистки
98) revert	➢ возвращаться (в прежнее состояние)
99) revolve	➢ вращаться

100) rollers	➢ роликовый конвейер
101) rotating drums	➢ вращающийся барабан
102) rotational molding	➢ центробежное формование
103) scale down	➢ снижать, уменьшать
104) scale up	➢ повышать, увеличивать
105) screw	➢ червяк (экструдера)
106) sealant	➢ герметик, заполнитель
107) separation	➢ разделение
108) sequential	➢ последовательный, поэтапный
109) set	➢ *зд*. затвердевать
110) sheathing	➢ изоляционный материал, обмотка
111) shipping	➢ транспортировка груза, перевозка
112) siding	➢ обшивка, облицовка
113) slit	➢ разрезать
114) solidify	➢ отверждаться
115) solvent	➢ растворитель
116) specifications	➢ технические условия
117) spray tower	➢ колонна с распылительным орошением
118) squeeze	➢ формовать, выпрессовывать
119) steam plant	➢ парогенератор
120) strength	➢ прочность
121) styrofoam	➢ пенополистирол
122) tank farm	➢ хранилище, склад готовой продукции, резервуарный парк горючего
123) tank-cars	➢ цистерна, автоцистерна, железнодорожная цистерна
124) tank-trucks	➢ бензовоз
125) temperature-sensitive product	➢ термочувствительный продукт
126) thermoset polymer	➢ термореактивный полимер
127) uniform melt	➢ однородный сплав
128) unsaturated polyester	➢ ненасыщенный полиэфир
129) valve	➢ клапан
130) versatility	➢ универсальность, многофункциональность
131) waxes	➢ воск, парафин
132) wind (wound, wound)	➢ крутиться

Unit IV
ENVIRONMENTAL PROBLEMS AND CHEMICAL ENGINEERING

1. Read and try to guess the meaning of the following words and word combinations:

living organisms, future generations; green chemistry; human health; plastic ingredient; governments strictly control; artificially created; toxic materials; permanent harm; metabolism; natural hormone levels; serious problems; label products; biofiltration; chemical reactors design; composting.

2. Translate conjugate words or words with the same roots:

pollute – pollution – polluted; degrade – degradable – biodegradable; sustainable – sustainability; produce – producer – product – production.

3. Match the English words and word combinations in A with their Russian equivalents in B.

A. 1) few decades; 2) growing concerns; 3) impact of industry; 4) a hole in the ozone layer; 5) streams and rivers; 6) directly attributable; 7) cause problems; 8) lie outside; 9) direct influence; 10) enormous investment; 11) many of the public; 12) the very consumers; 13) significant changes; 14) reduce the impact on the environment; 15) sustainable development; 16) meets the needs; 17) present a risk.

B. а) экоустойчивое развитие; б) представлять угрозу; в) существенные изменения; г) огромные капиталовложения; д) создавать проблемы; е) дыра в озоновом слое; ж) несколько десятилетий; з) ручьи и реки; и) находиться за пределами; к) многие люди, широкая общественность; л) снизить влияние на окружающую среду; м) отвечать потребностям; н) именно потребители; о) непосредственное влияние; п) непосредственно вызванный; р) растущая озабоченность; с) влияние промышленности.

4. Combine words from A with words from B to make word partnerships.

A	B
acid	gases
global	layer
greenhouse	rain
polluted city	generation
ozone	problems
power	environment
major	the needs
significant	generations
future	chemistry
green	development
meet	atmosphere
process	changes

5. Read the text and answer the questions that follow.

Green Chemistry

The last few decades of the 20th century **witnessed** growing concerns over the impact of industry on the global environment. These concerns included acid rain, increasing levels of greenhouse gases, **fertilizers** in streams and rivers, polluted city atmospheres, and a hole in the ozone layer. Some of these are directly attributable to power generation and transport, which have caused major problems and lie outside the direct influence of the chemical industry.

However, in spite of an enormous investment over the last 50 years to ensure that the production of chemicals does not have a **malign effect** on the environment, many of the public, the very consumers of the products, still associate the chemical industry with the worst sorts of pollution.

There is no doubt that there are still mistakes and these are generally **well publicised** in the media but overall there have been significant changes in the operation of the chemical industry that are designed to reduce the impact on the environment.

The acceptance that the chemical industry must not **adversely affect** the environment for future generations has been the **driving force behind** the development of *green chemistry*. This is not a separate branch of chemistry, but an approach that **permeates** every stage of process development.

The **aspiration** can be summed up in one word: ***sustainability***. Sustainable development and manufacture meets the needs of the present without compromising the ability of future generations to meet their own needs. The problems it aims to address are:

- the **depletion** of **finite** oil, gas and mineral resources
- the production of **waste**, some of it harmful to living organisms
- reagents and processes that present a risk to human health and the environment
- products, which when **disposed of**, do not degrade easily.

http://www.essentialchemicalindustry.org/processes/green-chemistry.html.

1. *When did impact of industry on global environment become growing concern?*
2. *What did these concerns include?*
3. *Are they directly influenced by the chemical industry?*
4. *Do many people associate the chemical industry with the worst pollution?*
5. *What makes it possible to develop green chemistry?*
6. *How is green chemistry related to chemistry?*
7. *What does sustainability mean and what problems does it address?*

6. Read the text and make a list of problems resulted from the use of synthetic polymers.

The Effect of the Uses of Synthetic Polymers to Our Environment

The use of synthetic polymers, however results in environmental problems.

Most polymers are not biodegradable. Polymers cannot be decomposed biologically or naturally by bacteria or fungi as in the case of other garbage. Thus, the disposal of polymers has resulted in environmental pollution because they remain in the environment forever.

Discarded plastic items may cause blockage of drainage systems and rivers thus causing flash floods[19].

Plastic containers and bottles **strewn around** become good breeding places[20] for mosquitoes which cause dengue fever[21] or malaria.

[19] flash floods – ливневые паводки
[20] breeding place – место размножения
[21] dengue fever – лихорадка денге

Small plastic items that are thrown into the rivers, lakes and seas are something swallowed[22] by aquatic animals. These animals may die from choking[23].

The open burning of plastics gives rise to poisonous and acidic gases like carbon monoxide, hydrogen chloride and hydrogen cyanide. These are harmful to the environment as they cause acid rain.

Burning of plastics can also produce carbon dioxide, too much of this gas in the atmosphere leads to the "green house effect".

The main source of raw materials for the making of synthetic polymers is petroleum. Petroleum is a non-renewable resource.

This problem can be overcome by the following ways:

Recycling polymers: Plastics can be decomposed by heating them without oxygen at 700 °C. This process is called pyrolysis. The products of this process are then recycled into new products.

Inventing biodegradable polymers: Such polymers should be mixed with substances that can be decomposed by bacteria (to become biodegradable) or light (to become photodegradable).

https://ru.scribd.com/doc/19255206/Synthetic-Polymers.

7. Read the text again and decide if the statements are true or false. Correct the false ones.

1) Polymers cause environmental pollution as they are not biodegradable.
2) Discarded plastic items may cause flooding.
3) Plastic containers and bottles strewn around can cause dengue fever[24], or malaria.
4) Aquatic animals may die from swallowed plastic items.
5) The open burning of plastics causes acid rain and leads to the "green house effect".
6) Synthetic polymers are made from petroleum.
7) Polymers can be recycled but they can’t be biodegradable.

[22] swallow – глотать
[23] choking – удушье
[24] dengue fever – лихорадка денге

8. Read the text and fill in the table.

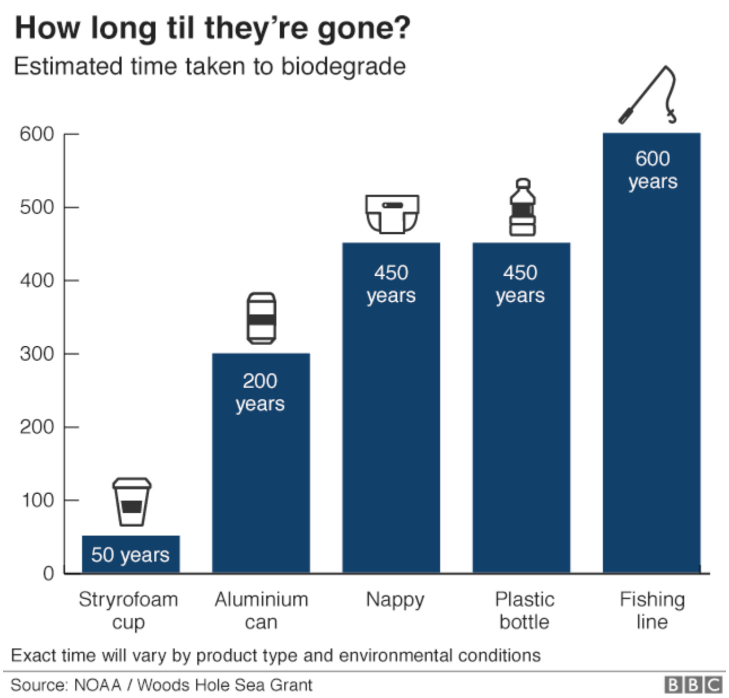
Plastic Disadvantages	Negative Effects of Plastic

Plastic Disadvantages – Negative Effects of Plastic

Today, you can hardly look around you and not spot some item that is made entirely from plastic or has some plastic ingredient. This only proves that from its **inception** up to now plastic has managed to become popular building material of millions of useful items, but it is not perfect. Plastic has several disadvantages that **prevent it from** becoming universal building block of modern human civilization, and because of that many governments strictly control its use and create complex law that govern its creation, recycling and environmental impact of waste plastic and chemicals that are used in its creation.

Here are some of the biggest disadvantages of plastic:

Durability. Plastic is light, **moldable**, **sturdy**, and can have countless forms, but one of the most known features is its durability. Plastic is artificially created polymer compound which can survive many centuries before nature is able to degrade it (some degrade into basic ingredients and some only divide into very small pieces). This **troublesome** ability of plastic doesn't have great **immediate** impact on our environment, but its continuous **dumping** into seas and land will eventually create problems for future generations. Even with all this durability, plastic products are not **indestructible** and it cannot be used as a basic building block for everything we need.



Environmental Harm. Ever increasing plastic production since 1950s managed to **saturate** world with waste plastic product that can cause big effects on our environment. **Decomposing** of plastic product can last from 400 to 1000 years with newer "degradable" compounds, but before that degradation can happen waste plastic will continue to **clog** our **waterways**, oceans, forests, and other **natural habitats** that are filled with animals who **mistake** dangerous plastic **for** food. Chemical dangers are also high, because both creation and recycling of plastic produce toxic materials of many kinds.

Chemical Risk. Not only that creation and recycling of plastic can cause serious environmental risk, but some of the **additives** that are **infused** in plastic can cause permanent harm to our metabolism. Chemicals such as phthalates and BPA are widely used as an additive that prevents degrading of plastic structure, but they also interfere with our **natural hormone levels** which can cause serious problems to both males and females (lower testosterone levels in men, and premature girl puberty).

Choking Hazard. Plastic is one of the most popular building materials for small items. This is most evident in toy industry, where vast majority of children toys is manufactured with plastic. These toys and small plastic objects of many uses can easily get into children's hands (especially babies and toddlers) that unknowingly put them in their mouth. To prevent these serious accidents, governments have **implemented** detailed **set of rules** which force manufacturers to clearly label their plastic products and warn users of the possible chocking potential. Another problematic plastic product that can cause serious injuries or death are plastic bags (grocery or trash bags)who can sometimes end up wrapped around children faces, disrupting their breathing.

http://www.historyofplastic.com/plastic-facts/disadvantages-of-plastic/.

9. Read the text again and get ready with its summary.

10. Read the text and fill in the table with some important steps in plastic recycling

When	**What**	**Where**
1972		
1980s and 1990s		
2008		

History of Plastic Recycling

Plastic is one of the most popular building materials of modern human culture, but its widespread use brought us many problems and caused environmental dangers of unprecedented scale. Since its mass adoption in the 1950s, **discarded** plastic products have filled **landfills** and contained seas and earth with materials that will not break down for centuries and centuries. To **combat this problem**, governments of many countries around the world formed rules for recycling plastic, established industrial processes for transforming discarded plastic into useful materials, and educated communities to the benefits of recycling all around the world.

One of the largest recycling efforts of the 20th century happened of course during wars when governments demanded of their people to donate their unused metals, tires and even nylon, but the **notion** of recycling plastic came only after the environmental revolutions of 1960s. During those years people really started noticing the impact of plastic waste on environment, and started **laying groundwork** for future recycling efforts. First plastic waste recycling mill in the world was created in Conshohocken, Pennsylvania in 1972, **marking the beginning** for all future recycling plants. **As years went by**, government programs and eco-friendly communities slowly started to educate **regular people** into habit of recycling and forcing manufacturers to start producing easier to recycle plastic. Their efforts came to life during 1980s and 1990s with the adoption of PETE and HDPE plastic, which were designed with recycling in mind. These recyclable plastic products were introduced by Plastic Bottle Institute of the Society of the Plastics Industry and clearly marked on their containers by logo of triangle made of arrows.

The process of recycling plastic is not as simple as recycling paper, glass and metals, because the greater number of steps involved for extracting dyes, fillers and other additives that can be found in "virgin" plastic. First step in their recycling is sorting by the type of resin that is in their structure (seven basic types) and in some cases additionally sorted by color. After that, plastic is chopped into small pieces, cleaned to remove debris and small residue, melted down and compressed into pellets named **nurdles**. These small pellets are then transported to plastic processing plants where they are introduced into manufacturing process.

Because of the complicated recycling process and unwillingness of people to properly dispose of their unwanted plastic, recycling rates of plastic **lag far behind of** other items such as paper, glass and metal. In 2008 only 6.5 % (2.2 million tons) of post-consumer plastic waste was recycled, 7.7 % (2.6 million tons) was burned for energy and 85.5 % (28.9 million tons) went to landfills.

http://www.historyofplastic.com/plastic-history/history-of-plastic-recycling/.

11. Read the text again and find English equivalents for the following words and word combinations:

распространенный; экологическая угроза; беспрецедентный масштаб; повсеместное использование; пластиковое изделие; преимущества переработки; сдавать/жертвовать; влияние пластиковых отходов на окружающую среду; фабрика по переработке пластиковых отходов; пластмассовые изделия, пригодные для вторичного использования; простые смертные.

12. What do you know about plastic recycling in your city / region? Try to find out if there are any plastic waste recycling plants in your region. What can you do to improve the environmental situation in your city / region?

13. Read the text to find out if plastics have any advantages.

Sustainability

Plastics help us to do more with less in many ways. Because they're durable, lightweight, and versatile, plastics can help reduce waste and consume less energy. American Chemistry Council's (ACC) Plastics Division supports sustainability initiatives that are conducted in accordance with principles that conserve resources and minimize the environmental and health impacts of plastics and plastic products.

Plastics Help Lower Energy Use and Greenhouse Gas Emissions. By allowing manufacturers and consumers to do more with less, using plastics can help reduce energy use and greenhouse gas emissions throughout the life of a product or package. A recent European study found that replacing plastics with other materials would require the use of 57 per cent more energy and result in a 61 per cent increase in greenhouse gas emissions.

Efficient Packaging. Much of the packaging we use in the United States is made from plastics. In addition to increasing the shelf life of foods and beverages, plastics help reduce our environmental foot print by lowering energy use and greenhouse gas emissions. A recent life cycle study found that replacing all plastic packaging in the United States with alternatives would increase energy use by 80 per cent and greenhouse gas emissions by 130 per cent.

Home Energy Savings: Adding It All Up. Many plastic building products promote the efficient use of energy and other resources. A one-year study found that the use of plastic building and construction materials saved 467.2 trillion BTU of energy over alternative construction materials. That's enough energy saved over the course of a year to meet the average annual energy needs of 4.6 million U.S. households. From roofing, walls, windows and more – architects and designers rely on plastics to help maximize energy efficiency.

Lighter, More Fuel Efficient Vehicles. Reducing vehicle weight can have a significant effect on fuel efficiency and emissions. For every 10-percent weight reduction achieved, a vehicle's fuel economy can improve by six to eight percent. Automotive components designed in plastic and plastic-metal hybrids have achieved significant weight savings over some conventional designs. Today's plastics typically make up 50 per cent of a vehicle's volume, but only 10 per cent of its weight. The growing use of carbon fiber-reinforced plastics could one day improve fuel efficiency by about 35 per cent.

https://plastics.americanchemistry.com/Sustainability/.

14. Now you know at least a little about advantages and disadvantages of plastic. What do you think of them? Discuss with your groupmates.

15. Read the text. Then make a summary on the current role of chemical engineering in solving environmental problems.

The Current Role of Chemical Engineering in Solving Environmental Problems

Chemical Engineering (CE) has demonstrated to be a powerful tool to have **comprehensive solutions** to a wide range of environmental problems. Classical disciplines of CE have been extensively applied to typical and emerging environmental technologies such as **wastewater treatment**, **anaerobic digestion**, biofiltration, etc. Among them, it is important to highlight these CE classical topics: chemical reactors design, kinetics, simulation, control, modeling and especially, heat and mass balances.

Through these CE fundamentals, a lot of environmental processes have been described and designed. However, environmental science and technology is **evolving** so fast that some processes still need a CE approach.

In my opinion, **waste biological treatment** is the topic where more CE approaches are needed. From composting, which is a **robust** and well implemented technology, and where most of the decisions are based on "**rules of thumb**" criteria, to **solid-state fermentation**, the new paradigm of **circular economy** to convert wastes into new bioproducts, there are only first approaches to use the CE paradigms.

Water and wastewater treatment are one or two steps forward. Complex models are being presented and analyzed, and some of them implemented at full-scale. Today, researchers are focusing these emerging studies not on the treatment of these wastewaters, but on the recovery of their compounds. A paradigmatic research trend is the recovery of phosphorous, which has important and relevant advances. In this same trend, the transformation of wastewater into bioplastics is another top research line, although the behavior of these biodegradable plastics needs further research.

Considering the three main pollutant sources, gaseous emissions have been, without any doubt, the topic of many studies related to the use of CE tools to provide reliable and consistent information about their **abatement** and transformation. From chemical processes (**scrubbers**) to more complex biological processes (biofiltration and **biotrickling filters**, especially), researchers have an extensive collection of realistic studies to treat and model this equipment. Microbiology has been easily incorporated to these biological treatments, giving **consistency** to the models developed.

Another important emerging trend is the use of nanotechnology to solve environmental problems. This multidisciplinary approach has a lot of problems to be published: is this a nanotechnology or and environmental paper? The answer to this question is: it is both. CE is, by definition, a multidisciplinary approach to real problems.

After these brief considerations about the state-of-the-art of the three main issues considered in environmental problems: liquid, gas and solid, two main topics appear as major questions in deciding technologies for environmental treatments and involving all the stakeholders (some of them are not familiar with the research field): **Life Cycle Assessment** (LCA) and Circular Economy. Additionally, issues such as circular economy and food-energy-water-waste **nexus** could be systematically analyzed using LCA tools (both attributional and consequential).

LCA is a developed version of the typical CE mass and heat balances of a technology or product (or even more than this, "from cradle to grave") to define the **environmental impacts** that are often expressed as some pollution categories. Being a powerful tool, and recommended for making decisions, scientific papers such consider that this analysis, to be consistent and reliable, need the use of realistic data. This is not what happens sometimes, and it is the role of scientists to enlarge the databases of environmental processes to have concluding results. An enormous field of research is awaiting.

The second and most **transversal** is the relatively recent term of "circular economy". It is somewhat surprising that practically everybody understands what circular economy is about. This term (recent but previously known with other names) is related to the need of closing cycles, especially when dealing with energy and materials. Being a fashionable term, one wonders if the composting and anaerobic digestion studies performed 30 years ago do not deserve to be considered circular economy.

In this framework, it is relatively easy to deduce the general areas where CE principles can be used for the complete solution of environmental problems:

(1) Apply CE consolidated paradigms: among them, mass and heat balances should be the first ones.

(2) Multidisciplinary: most environmental problems do not have a unique solution. Biological treatments do no discard the help of other physico-chemical treatments.

(3) Do not think on disposal, think on recovery: a typical example of this problem is the use of adsorption to "remove" pollutants from water. And then, what? You have not removed anything, it is only a pollutant transport.

(4) When possible, try to do an approximation using LCA principles. If built with realistic data, it will give you clues about if your proposal is as good as you think.

(5) When possible (and when not), estimate the **economic viability** of your proposal.

In summary, CE tools are a powerful tool to explain, interpret and model environmental problems, from the mere technological point of view to more complex LCA and circular economy analyses.

https://www.frontiersin.org/articles/10.3389/fceng.2019.00001/full.

16. Read the text again and find English equivalents for the following words and word combinations:

мощный инструмент; широкий спектр экологических проблем; природоохранные технологии; проект химического реактора; моделирование; тепловой и материальный баланс; преобразовать отходы; водоподготовка и водоочистка; шаг вперед; воплощать в полном объеме; возобновление соединений; хрестоматийные направления исследования; значимые успехи; подобным образом; надлежащая информация; направление исследований; источник загрязнения; выбросы газа; богатая коллекция практических исследований; физико-химические способы очистки

17. Make a presentation on environmental problems related to chemical engineering and their solving.

Vocabulary

1) abatement	➢ сокращение
2) additive	➢ добавка
3) adversely affect	➢ оказывать вредное влияние
4) anaerobic digestion	➢ анаэробная обработка
5) as years went by	➢ с годами
6) aspiration	➢ цель
7) circular economy	➢ безотходная экономика
8) clog	➢ засорять
9) combat this problem	➢ справиться с проблемой
10) comprehensive solutions	➢ радикальное решение
11) consistency	➢ постоянство, стабильность
12) decomposing	➢ разрушение, разложение
13) depletion	➢ истощение
14) discarded	➢ использованный

15) dispose of	➢ выбрасывать
16) driving force behind	➢ двигатель чего-нибудь
17) dumping	➢ сброс (отходов)
18) evolve	➢ развиваться, эволюционировать
19) fertilizers	➢ удобрения
20) finite	➢ конечный, исчерпаемый
21) immediate	➢ мгновенный, прямой
22) implement	➢ вводить в действие, внедрить, претворить в жизнь
23) inception	➢ возникновение
24) indestructible	➢ неразрушаемый
25) infuse	➢ вводить
26) lag far behind	➢ заметно отставать от
27) landfills	➢ свалка
28) lay groundwork	➢ закладывать фундамент
29) malign effect	➢ негативное, вредное влияние
30) mark the beginning	➢ положить начало
31) mistake for	➢ ошибочно принимать за
32) moldable	➢ пластичный
33) natural habitats	➢ естественная среда обитания
34) natural hormone levels	➢ естественный гормональный уровень
35) notion	➢ намерение
36) nurdle	➢ пластиковая гранула
37) permeates	➢ преодолевать, проходить сквозь
38) polymer compound	➢ полимерная композиция
39) prevent from	➢ лишать возможности, мешать
40) robust	➢ разумный, функциональный
41) rules of thumb	➢ проверенное правило, практическое правило
42) saturate	➢ заполнить
43) set of rules	➢ свод правил, инструкция
44) solid-state fermentation	➢ твердофазная ферментация
45) strewn around	➢ разбросанный
46) sturdy	➢ прочный
47) sustainability	➢ экологичность, разумное использование ресурсов

48) transversal	➢ сквозной
49) troublesome	➢ причиняющий массу беспокойства
50) waste	➢ отходы производства, сточные воды
51) waste biological treatment	➢ биологическая обработка отходов
52) wastewater treatment	➢ очистка сточных вод
53) waterways	➢ водоем
54) well publicised	➢ получивший широкую огласку
55) witness	➢ быть временем совершения чего-либо
56) scrubbers	➢ очиститель
57) biotrickling filter	➢ биофильтр
58) consistency	➢ стабильность
59) Life Cycle Assessment	➢ оценка жизненного цикла
60) nexus	➢ связь, цепь
61) environmental impact	➢ неблагоприятное воздействие на окружающую среду
62) economic viability	➢ экономическая эффективность, рентабельность

Unit V
PROFESSIONAL ETHICS. PROFESSIONAL COMPETENCIES

1. What do you think ethics is? Do you think ethics is necessary in any professional field?

2. Read and discuss.

1. Is ethics given any attention at universities and in companies? What does it result in according to the author?
2. What does engineering ethics combine?
3. Are serious incidents always caused by technical problems?
4. What presents potential ethical dilemmas now?
5. How is ethics best taught and learnt?

How to Think about Ethics

Ethics is **referenced** in many engineering curricula, yet few universities require chemical engineering students to attend a formal ethics course. And although ethics **underpins** consistent achievement of safety, environmental, and business outcomes, many corporate training classes mention the subject only briefly. We continue to see **failures**, workplace deaths, and product-related deaths and injuries, and hear of large firms being fined or **prosecuted** for not self-reporting safety or environmental issues.

"Ethics" is defined by the Oxford Dictionary as "the moral principles that govern a person's or a group's behavior". Good ethics could also be described as the appropriate execution of an engineer's professional responsibility. Harris **et al** describe engineering ethics as an **amalgam** of complex concepts: professionalism, standards, risk management, **liability**, competence, truth, societal protection, trust, reliability, honesty, cost/benefit, attitude, organisation, **obligation**, **whistleblowing**, regulation, and the law. Ethics is sometimes clearly black and white and easy to understand; often, though, ethics comes in many shades of gray.

What kinds of chemical engineering mistakes might result in fatalities? An incorrect calculation or an unrealistic assumption? Could you lose your job over using the wrong safety factor in a design? Perhaps. However, the underlying causes of many serious incidents are not technical, and may have little or nothing to do with technology. For example:

– You do what your boss tells you to do, even if it is against your better engineering judgment.

– You tell your boss about a condition that could be dangerous under certain conditions, and when your boss says everything is fine, you remain silent and do not revisit the subject.

– You act contrary to a legal hold order and destroy evidence related to **pending litigation**, because you are afraid that you will lose your job, or worse yet be prosecuted for something you have written.

The underlying issues often involve conflicts that arise in the execution of engineering work; money and time are often at the root of the conflict. Serious incidents are frequently the result of ignoring **common sense**.

As the profession continues to expand, many chemical engineers are in areas of practice where the rules are not always clearly laid out and the lines are not always bright. New fields and new research areas, such as nanotechnology, structural biology, genetics, and **tissue engineering**, are exciting and **full of promise**. However, they present potential ethical dilemmas for which we not only do not have answers, but we do not even know the questions.

The issues around ethics can sometimes be double-sided – you can be "damned if you do and damned if you don't". These situations require you to search deep within yourself to decide on the best path, as there may be no good way out. The secret is to not land in this position in the first place. That avoidance takes clear thinking, good analysis, and **forethought**. ... You will not become an expert in ethics by reading this article, but it will help you become better prepared. Since each situation is unique, ethics is best taught through case studies.

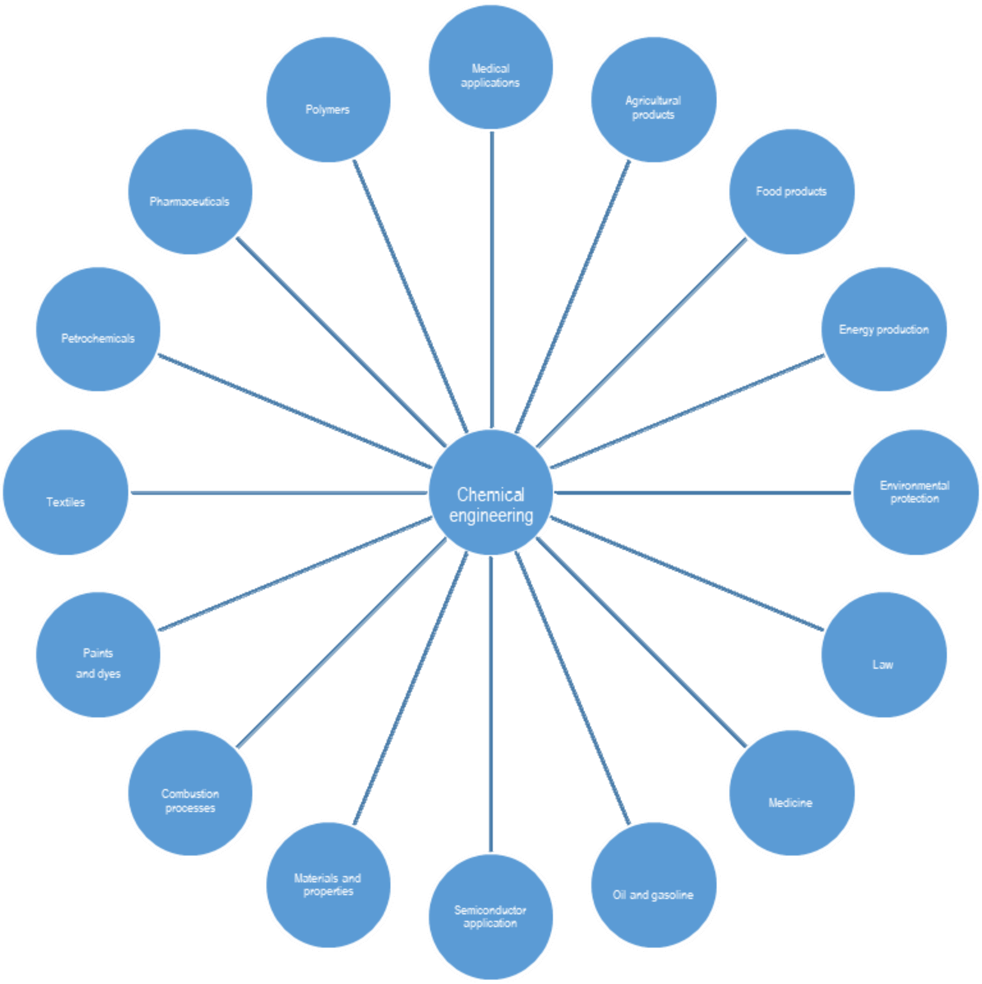
https://www.researchgate.net/publication/312158637_How_to_Think_About_Ethics_The_Chemical_Engineer_UK_Institution_of_Chemical_Engineers_November_2017_pp_44-53.

3. Read the text and say why chemical engineering ethics is so important nowadays?

The Impact of Chemical Engineering

Chemical engineering creatively combines the three basic physical sciences – chemistry, physics, and biology – along with mathematics to **address the world's needs** by creating new technology and solving problems in existing technology. The use of all three basic sciences and mathematics makes chemical engineering **extremely versatile**, since nearly all physical phenomena can be described by the combination of these four sciences. Because of this versatility, chemical engineers make valuable contributions in a very broad spectrum of fields from food processing to semiconductor fabrication and from energy production to artificial organ development.

The American Institute of Chemical Engineers (AIChE) has suggested the following definition: [Chemical engineers] use science and mathematics, especially chemistry, biochemistry, applied mathematics and engineering principles, to take laboratory or conceptual ideas and turn them into value added products in a cost effective, safe (including environmental) and cutting edge process. From the development of smaller, faster computer chips to innovations in recycling, treating disease, cleaning water, and generating energy, the processes and products that chemical engineers have helped create touch every aspect of our lives. Chemical engineers discover, develop, and implement creative solutions to the world's problems and new ways to benefit humankind.



4. Read the text again and find English equivalents for the following words and word combinations:

основополагающие естественные науки; наряду с; создавать новую технологию; решать проблемы существующей технологии; физические явления; вносить ценный вклад в; широкий спектр сфер деятельности; пищевая промышленность; изготовление полупроводников; выработка электроэнергии; разработка искуственного органа; концептуальная идея; продукт с высокой добавленной стоимостью; передовой процесс; приносить пользу человечеству.

5. Read and discuss AIChE Code of Ethics. Answer the questions that follow.

Ethical Considerations in Solving Problems

Each of the major engineering societies expresses its **commitment to** ethical standards in the form of an **ethical code**. Among those societies is the American Institute of Chemical Engineers (AIChE), which has the adopted the following code:

AIChE Code of Ethics
Board Approved November 2015

The Board of Directors of the American Institute of Chemical Engineers adopted this Code of Ethics **to** which it expects that the professional conduct of its members shall **conform**, and to which every applicant **attests** by signing his or her **membership application**. Members of the American Institute of Chemical Engineers shall **uphold** and advance the **integrity**, honor and **dignity** of the engineering profession by: being honest and **impartial** and **serving with fidelity** their employers, their clients, and the public; **striving** to increase the competence and prestige of the engineering profession; and using their knowledge and skill for the **enhancement of human welfare**. To achieve these goals members shall:

1. Hold **paramount** the safety, health and welfare of the public and protect the environment in performance of their professional duties.
2. Formally advise their employers or clients (and consider further **disclosure**, if **warranted**) if they **perceive** that a **consequence** of their duties will adversely affect the present or future health or safety of their colleagues or the public.
3. **Accept responsibility** for their actions, **seek and heed critical review** of their work and offer **objective criticism** of the work of others.

4. **Issue statements** or present information only in an objective and truthful manner.
5. **Act in professional matters** for each employer or client as **faithful** agents or trustees, **avoiding conflicts of interest** and never **breaching confidentiality**.
6. Treat all colleagues and co-workers fairly and respectfully, recognizing their unique contributions and capabilities by **fostering** an environment of equity, **diversity and inclusion**.
7. Perform professional services only in areas of their competence.
8. Build their professional reputations on the **merits** of their services.
9. Continue their professional development throughout their careers, and provide opportunities for the professional development of those under their supervision.
10. Never tolerate **harassment**.
11. Conduct themselves in a fair, honorable and respectful manner.

It is clear from this code that, in all plans and considerations associated with solving problems, chemical engineers have the responsibility to promote safety, to protect the environment, to treat others with respect and fairness, and to act ethically. These responsibilities are borne by each individual engineer and by companies (which are, after all, just collections of people).

Safety. Every company must be concerned about the safety of its own employees and of the public affected by its operations. This responsibility **stems** primarily **from** concern about people, but **safety lapses** can also expose a company to substantial **financial liabilities**, including lost productivity. Thus, many companies maintain a strong culture of safety for their employees, supported by frequent training sessions, posted reminders throughout their facilities, associated rewards and punishments, and an attempt to encourage honest employee feedback from personnel at all company levels. In addition, engineering companies must be **vigilant** in protecting the community surrounding its operation and protecting the customers using its products. Thus, all reasonable practices should be consistently implemented to promote the safety of these groups of people, and any potential safety risks should be promptly reported to supervisors who can take steps to reduce those dangers.

Protecting the Environment. Chemical engineers have an important responsibility to protect the environment. This is particularly true today with our increasing world population and its greater use of technology. Local and global environmental issues have the potential to impact the very **viability** of our way of life. The needs of developing countries are particularly critical, since we cannot afford for them to pass through the same pollution-intensive pathways once followed by the world's most developed nations. Chemical engineers have the skills and experience needed to address today's pressing problems and to make possible a better tomorrow.

Avoiding Harassment. All professionals, including chemical engineers, are morally obligated to treat their associates with respect, independent of race, gender, and lifestyle. That respect should be manifest in all interpersonal interactions. In addition, all decisions **pertaining to** advancement, salary, and other recognition should be fair and based on professional performance, again without regard to race, gender, and lifestyle. In addition, chemical engineers should be prepared to defend the rights and fair treatment of their colleagues.

Ethical Practice. Observing the AIChE Code of Ethics summarized above requires that individual professionals and companies are truthful and responsible in all aspects of their professional service. While most engineers and companies uphold their ethical responsibilities, there have been notable exceptions. The line between ethical and unethical behavior is sometimes **blurred**, and decisions can be quite difficult, especially under the influence of pressure by management to take a particular path. Each engineer has the responsibility to aggressively pursue an ethical path and to help others to do the same. The consequences of unethical behavior can be disastrous personally and collectively, while the consequence of ethical choices (even hard ones) ultimately is a clear conscience. You should make the decision now to always practice your profession in an ethical manner.

https://kupdf.net/download/introduction-to-chemical-engineering-tools-for-today-and-tomorrow_5af6afb2e2b6f5ad671d83d9_pdf.

1. *Do you agree to all the points of the Code? Which of them do you agree? Why? Why not?*
2. *Have you ever heard of such a code of ethics in Russia?*

3. Is it important for companies to have a written code of ethics? Why?

4. Is it more important for some companies / industries than others to have a code of ethics?

6. Read the text and say if the skills mentioned in the text are related to code of ethics in this or that way.

Ten Skills Chemical Engineers Should Be Talking about

Within our profession it is easy to find lists of the skills chemical engineers 'should' have: we are solution focused; we are good with numbers; we are practical.

However, none of these skills sound very exciting.

Interestingly, it is the 'skills' which we aren't so good at and stereotypical engineering 'memes' which, arguably, we are more famous for.

I think we need to set the record straight and create an image of our skills which better reflects what we do in the twenty-first century.

Even our employers have a role – they are the ones with the power to present a picture of the modern engineer through their job specifications and approach to recruitment advertising.

So, here it is – a list of ten skills and values I know chemical engineers (and other scientists and engineers) have that we should be shouting about.

1. Creative. It is easy to present engineers and scientists as a bit 'dull' and 'geeky'. This is perhaps the biggest misconception of them all. However, if engineers and scientists were not creative there would be no new inventions, products or discoveries. Creativity is in everything that chemical engineers do.

2. Problem solvers. Being able to solve problems should be the most highly sought skill in the world and it is something that chemical engineers have to do every day. The ability to identify problems itself is an important skill, but chemical engineers have been trained to have the know-how to evaluate the possible options and then implement the best solution.

3. Team players. No one works alone. In the past scientific breakthroughs were often delivered by one researcher, however I challenge you to find a recently published journal article (that is not a review piece) with only one author. They are extremely rare. This is the case in all lines of work; we must work with others to achieve our outcomes. Chemical engineers are specialists at doing so; we often work with large teams of people both within and outside of our field.

4. Life-long learners. Being a chemical engineer (or scientist) involves a life-long quest of learning. In this profession we constantly learn new ideas and try to better ourselves by completing new courses and further education. As a measure of this ability to learn IChemE offers chartership to those chemical engineers who strive to better themselves, chemical engineers never stop learning.

5. Organised. Many people think being organised is dull, but without this skill nothing gets done. The ability to organise work (for example by using a list like this one!) helps chemical engineers to work more efficiently and prioritise what needs to be done. Being organised makes everything run more economically.

6. Inquisitive. Being able to ask questions is important. But being able to ask the right questions is a huge asset. Engineers and scientists are analysts at heart; we work by constantly reviewing and analysing our work allowing us to highlight the gaps and identify what needs to change.

Being an expert isn't about knowing all the answers, but instead being able to ask the right questions and then using your skills to work out the answers.

7. Computer savvy. Our increasing reliance on the digital world means that to succeed we all need to be aware of the latest technology. Computing is an important part of chemical engineering and all chemical engineers are trained to be numerate, IT literate and develop new technologies.

8. Leaders. Chemical engineers are trained to make important decisions; this makes us ideally placed to become good leaders. Many chemical engineers go on to have successful careers in the boardroom (find a list of them here). Being a good leader isn't about being the loudest or about knowing all the answers, but is reliant on your ability to work with others, being confident of your own abilities and having a sense of humour and positive attitude (when things go right or wrong!).

9. Detail orientated. Paying attention to the details is crucial to be a successful chemical engineer. A good example of this is process safety, as chemical engineers we are responsible to ensure that accidents do not happen, failure is not acceptable as discussed in my blog ‘when 99.9 per cent just isn’t good enough’. Being detail orientated means that chemical engineers are able to focus on the smaller issues without losing sight of the bigger picture.

10. Calm under pressure. Sadly most of the news coverage of chemical engineers in the mainstream media comes from when we are called in to fix something that has gone wrong (e.g. deep water horizon). But this just demonstrates perhaps the most important skill of a chemical engineer, we are calm under pressure.

When someone needs to fix the world's problems they should be calling up the chemical engineers!

In the UK an estimated 32.6 per cent of chemical engineering graduates go on to work in a different profession. However, when you look at a list of skills like this it points out what a valuable commodity chemical engineers are and that chemical engineering attracts such high calibre students that they are actively recruited by other professions.

And let’s not forget communication… I didn't put communication into my top ten because it is one of the main themes for my presidential year. It's an area we need to get much better at.

Chemical engineers can be great communicators, but we often focus on the other areas which we considered more important. But it is a waste of all our good work if we don't communicate it.

As we strive to achieve excellence in chemical engineering, we should be telling everyone about our progress and achievements.

https://ichemeblog.org/2014/09/18/ten-skills-chemical-engineers-should-be-talking-about-day-114/.

7. Read the text again and put the ten skills in the order of their importance from 1 being the most important. Can you add any other skills to the list? Discuss with your partner.

8. There is another opinion on skills required for chemical engineers. Read and compare with the previous list of skills. Do they have anything in common? How do they differ?

What Skills are Required for Chemical Engineers?

Science. Using scientific rules and methods to solve problems.

Critical Thinking. Using logic and reasoning to identify the strengths and weaknesses of alternative solutions, conclusions or approaches to problems.

Complex Problem Solving. Identifying complex problems and reviewing related information to develop and evaluate options and implement solutions.

Judgment and Decision Making. Considering the relative costs and benefits of potential actions to choose the most appropriate one.

Systems Analysis. Determining how a system should work and how changes in conditions, operations, and the environment will affect outcomes.

Mathematics. Using mathematics to solve problems.

Reading Comprehension. Understanding written sentences and paragraphs in work related documents.

Active Learning. Understanding the implications of new information for both current and future problem-solving and decision-making.

Systems Evaluation. Identifying measures or indicators of system performance and the actions needed to improve or correct performance, relative to the goals of the system.

Speaking. Talking to others to convey information effectively.

Operations Analysis. Analyzing needs and product requirements to create a design.

Active Listening. Giving full attention to what other people are saying, taking time to understand the points being made, asking questions as appropriate, and not interrupting at inappropriate times.

Writing. Communicating effectively in writing as appropriate for the needs of the audience.

Monitoring. Monitoring/Assessing performance of yourself, other individuals, or organizations to make improvements or take corrective action.

Time Management. Managing one's own time and the time of others.

Troubleshooting. Determining causes of operating errors and deciding what to do about it.

Operation Monitoring. Watching gauges, dials, or other indicators to make sure a machine is working properly.

Coordination. Adjusting actions in relation to others' actions.

Persuasion. Persuading others to change their minds or behavior.

Social Perceptiveness. Being aware of others' reactions and understanding why they react as they do.

Instructing. Teaching others how to do something.

Learning Strategies. Selecting and using training/instructional methods and procedures appropriate for the situation when learning or teaching new things.

Management of Personnel Resources. Motivating, developing, and directing people as they work, identifying the best people for the job.

Quality Control Analysis. Conducting tests and inspections of products, services, or processes to evaluate quality or performance.

Technology Design. Generating or adapting equipment and technology to serve user needs.

Negotiation. Bringing others together and trying to reconcile differences.

Service Orientation. Actively looking for ways to help people.

Management of Financial Resources. Determining how money will be spent to get the work done, and accounting for these expenditures.

Management of Material Resources. Obtaining and seeing to the appropriate use of equipment, facilities, and materials needed to do certain work.

https://www.mymajors.com/career/chemical-engineer/skills/.

9. Make a presentation on chemical engineers skills.

Vocabulary

1) accept responsibility	➢ брать на себя ответственность
2) act in professional matters	➢ действовать в профессиональных ➢ вопросах
3) address the world's needs	➢ служить интересам человечества
4) adversely affect	➢ негативно отразиться на
5) amalgam	➢ смесь, сплав, соединение
6) attest to	➢ подтверждать, свидетельствовать
7) avoid conflicts of interest	➢ избегать конфликта интересов
8) blurred	➢ расплывчатый, нечеткий
9) breach confidentiality	➢ нарушать конфиденциальность
10) code of ethics, ethical code	➢ моральный кодекс
11) commitment to	➢ приверженность идее
12) common sense	➢ здравый смысл
13) conform	➢ соответствовать
14) consequence	➢ последствие
15) critical review	➢ критический анализ
16) dignity	➢ достоинство
17) disclosure	➢ сообщаемая информация
18) diversity and inclusion	➢ личностное многообразие и учёт индивидуальных особенностей
19) enhancement of human welfare	➢ повышение благосостояния человечества
20) et al.	➢ и др.
21) extremely versatile	➢ исключительно разносторонний
22) failure	➢ выход из строя, отказ в работе
23) faithful	➢ заслуживающий доверия, надежный
24) financial liabilities	➢ финансовые обязательства
25) forethought	➢ продуманность, заблаговременный анализ
26) foster	➢ поддерживать
27) full of promise	➢ многообещающий
28) harassment	➢ оскорбление, притеснение
29) impartial	➢ беспристрастный
30) integrity	➢ профессиональная этика
31) issue statements	➢ официально сообщать

32) liability	➢ ответственность
33) membership application	➢ заявление / заявка на участие
34) merits	➢ заслуги, показатели
35) objective criticism	➢ объективная критика
36) obligation	➢ долг, обязанность
37) paramount	➢ первостепенный, важнейший
38) pending litigation	➢ текущие судебные разбирательства
39) perceive	➢ осознавать
40) pertaining to	➢ связанный с
41) prosecute	➢ преследовать в судебном порядке, предъявлять иск
42) reference	➢ ссылаться, рассматривать
43) safety laps	➢ обеспечение безопасности работ, техника безопасности
44) seek and heed	➢ просить и обращать внимание
45) serve with fidelity	➢ работать добросовестно
46) stem from	➢ исходить, проистекать
47) strive	➢ стремиться
48) tissue engineering	➢ тканевая инженерия
49) underpin	➢ лежать в основе
50) uphold	➢ сохранять, поддерживать
51) viability	➢ эффективность, целесообразность
52) vigilant	➢ бдительный
53) warranted	➢ обоснованный
54) whistleblowing	➢ политика корпоративного информирования

Unit VI
CAREER OPPORTUNITIES

1. Discuss with your groupmated advantages and disadvantages of your future career. Try to prove your opinion.

1. Do you think that profession of engineer is prestigious nowadays?
2. Is this profession much wanted?
3. Is it difficult to find a good job in the field of chemical engineering?
4. Is there a shortage of good quality graduate engineers in our city?
5. Are chemical engineers well paid?
6. Is this career more suitable for men or women?
7. Does this profession require much time or efforts for education?
8. Does it require any special traits of character?
9. Does the career of engineer in the field of medical equipment require permanent self-education?

2. Read and fill in the table to support you in introducing your future career in more or less detailed way.

Chemical engineering	is	
	turns	
	combines	
Reasons to study	know-how	
	soft skills	
	job opportunities	
Study course	is made up of	
	includes	
	changes	
Graduates	have a focus in	
Chemical engineers	turn ideas into practical devices to	
	use	
	build & operate	
	research and develop, design & control	
Chemical engineers	can work in	

What is Chemical Engineering?

Chemical engineering is the design, development, production, transformation, transportion, operation and management of the industrial processes that turn raw materials into valuable products. It is a multi-disciplinary branch of engineering that combines natural and experimental sciences (such as chemistry and physics), along with life sciences (such as biology, microbiology and biochemistry) plus mathematics and economics.

Three Reasons to Study Chemical Engineering

Chemical engineers have the knowledge to save the world: chemical engineers develop products making life easier and better for others. The products you will develop as a chemical engineer are part of everyday life, e.g. pharmaceuticals, fuels, plastics and vehicles. You can even help decrease starvation, diseases and poverty with your products.

Development of soft skills: the work of chemical engineers is challenging and covers a rather comprehensive body of knowledge. You will be trained to think logically, creatively and in an innovative way as well as to communicate and work well with others to solve problems.

Good job opportunites: because of their expertise in developing products commercially, e.g. by reducing costs and the time required to finalise processes, chemical engineers can generally expect high salaries when entering the labour market.

How to Study Chemical Engineering?

Courses in chemical engineering are made up of lectures, tutorials, seminars, computer practice sessions, practical laboratory work and both individual and group work. Site visits and classes by industry professionals may also form part of the course. Many courses include work placements and a year in industry to equip graduates for tools to succeed in the industry.

Because chemical engineering is a developing study subject, the curriculum changes and adapts with it.

What Kind of Job Can I Get by Studying Chemical Engineering?

Graduates with a degree in chemical engineering typically have a focus in one of the two sub-areas, but will need both to successfully do their jobs.

What do Chemical Engineers Do?

Chemical or process engineers turn great ideas discovered in laboratories into practical devices and processes that:

- improve our quality of life;
- protect the environment;
- ensure products and services we purchase are cheaper and of better quality;
- that industry increases competitiveness, thereby protecting and creating jobs and wealth for communities.

Chemical engineers do this using a combination of biology, biochemistry and/or chemistry with math (as well as a bit of economics and finance) to predict how these ideas will work on a larger-scale outside the laboratory in the real world, and then building and operating the equipment needed to bring these ideas to life. For example, chemical engineers have helped do this by performing "research and development" or by "design and operation" of processes that:

- manufacture pharmaceuticals, making them cheaper and safe for people to use;
- refine oil into petrol, keeping petrol prices low and improving petrol quality so it doesn't pollute the air;
- generate electricity in the most efficient fashion to preserve our natural resources and protect the environment;
- create renewable fuels and energy sources to replace coal, petrol and gas;
- produce safe drinking water from rivers, groundwater or the sea for city, rural and remote aboriginal communities;
- safely treat toxic hazardous industrial wastes so their disposal does not harm the environment;
- help the wine industry make premium wines for export more consistently and at lower cost;
- improve mining techniques, so they minimise environmental damage and cost less.

Chemical engineering is very "multi-disciplinary": its principles are widely applied to a diverse range of everyday things that people do, and in almost every product and service we use. In fact almost everything that you see and touch around you has, at one time or another, been created by a process invented, designed and/or operated by a chemical engineer.

Chemical engineers have the opportunity to enjoy a diverse career, and there are a range of different jobs from which to choose. You can work in a laboratory, in an office, in the outdoors or on an industrial plant, or combination of all of these in the one job. Some industries and careers that chemical engineers are involved in include:

- biotechnology & pharmaceutical industries;
- wine-making;
- food production (e.g. beer, milk, cheese);
- petrochemicals (e.g. gold, rare earths, oil refining, natural gas, plastics);
- industrial chemicals (e.g. detergents & soaps, chlorine, explosives);
- mining and minerals processing (e.g. iron ore, steel manufacture, aluminium);
- environmental engineering (i.e. air pollution control, water and waste-water treatment, waste disposal, resource management);
- semi-conductors & microelectronics (many chemical engineers work in these areas);
- nanotechnology (an emerging scientific area utilising very small particles for diverse applications);
- management consulting (i.e. engineering business and financial management).

Many chemical engineers go on to manage companies, or even start their own business.

https://chemeng.adelaide.edu.au/programs/chemical/about/.

3. Make a summary of the text of ex. 2. Get ready for the presentation.

4. Read the text and answer the questions that follow.

Nature of Work

Chemical engineers work in manufacturing, pharmaceuticals, healthcare, design and construction, pulp and paper, petrochemicals, food processing, specialty chemicals, polymers, biotechnology, and environmental health and safety industries, among others.

It is the smallest of the four major engineering disciplines (the others in order of size are electrical, mechanical and civil). Because chemical engineers are rigorously trained in not only chemistry but also physics, mathematical and other physical and natural sciences, such as biology or geology, they are among the most versatile of all engineers, with many specialties and job roles and employed by many different industries. The largest share of chemical engineers, however, is involved in manufacturing industries, transforming raw materials into desired products.

Chemical engineers rely on their knowledge of mathematics and science, particularly chemistry to overcome technical problems safely and economically. They use and apply their engineering knowledge to solve any technical challenges they may encounter. Their expertise is also applied in the areas of law, education, publishing, finance and medicine, as well as in many other fields that require technical training.

Chemical engineers also construct the synthetic fibers that make our clothes more comfortable and water-resistant. They develop methods for mass-producing drugs, making them more affordable, and they create safer, more efficient methods of refining petroleum products, making energy and chemical sources more productive and cost effective. Chemical engineers also develop solutions to environmental problems, such as pollution control and remediation.

Chemical engineers face many of the same challenges that other professionals face, and they meet these challenges by applying their technical knowledge, communication and teamwork and hard work. Chemical engineers are employed in many industries, representing a diverse range of products, employers, and services. Chemical engineers affect or control, at some stage, the materials of production of almost every article manufactured on an industrial scale.

Associations. Chemical Engineers are represented in the US by the AIChE, which has over 70,000 members, and was founded in 1908. The American Institute of Chemical Engineers (AIChE) is a nonprofit organization providing leadership to the chemical engineering profession. Representing 58,000 members in industry, academia, and government, AIChE provides forums to advance the theory and practice of the profession, upholds high professional standards and ethics, and supports excellence in education. Institute members range from undergraduate students to entry-level engineers, to chief executive officers of major corporations.

In other countries, chemical engineers are represented by national organizations, such as the Canadian Society for Chemical Engineers and the Institution of Chemical Engineers in Britain.

Requirements and Education. A bachelor's degree in chemical engineering is generally considered the minimum educational requirement for entering the field. For some jobs a master's or Ph. D. is necessary, especially for positions in research, teaching, and administration. The proportion of chemical engineers who have their master's and doctorate degrees, has been much higher over the years than electrical, civil or mechanical engineers.

High school students interested in chemical engineering should take math and science courses offered by their schools. Computer science classes are also recommended. For college students, a chemical engineering program approved by the Accreditation Board for Engineering and Technology and the American Institute of Chemical Engineers is required. There are about 145 accredited undergraduate programs in chemical engineering in the US, offering bachelor's degrees. Some engineering programs last five or six years, and often include work experience at nearby industries.

A typical engineering curriculum includes basic sciences (advanced mathematics, physics, chemistry, and some life sciences) and engineering sciences. Necessary communications courses include English, speech, technical writing, computer languages, and both manual and computer-generated graphics. Students can major in chemical engineering with a specialty in a specific area, such as biomedical engineering.

Chemical engineers must be licensed in order to work for the public sector. All fifty states and Washington D. C. have specific licensing requirements, which include graduation from an accredited engineering program, passing a written exam, and having at least four years of engineering experience. About one-third of all chemical engineers are licensed. Those who are not are called registered engineers.

Important personal qualities for the chemical engineer are accuracy, objectivity, and perseverance. Chemical engineers should be inquisitive, open-minded, creative, and flexible, with problem-solving ability. To be competitive in the job market, a master of chemistry, a variety of science knowledge, and computer literacy, are essential. Practical experience gained through research projects, part-time, or co-op work, while not a requirement, are a big advantage in setting one away from the competition.

http://coolreferat.com/Chemical_Engineering_Essay_Research_Paper_Chemical_EngineeringScopeChemical.

1. *Where do chemical engineers work?*
2. *Why are chemical engineers among the most versatile of all engineers?*
3. *What helps chemical engineers overcome technical problems safely and economically?*

4. Where is their knowledge and expertise applied?
5. What can chemical engineers do?
6. How do chemical engineers meet the challenges?
7. Where are chemical engineers employed?
8. What chemical engineers' associations are mentioned in the text? Are there any in Russia?
9. What education is required to work in chemical engineering?
10. What subjects do typically students study to enter chemical engineering field?
11. Do graduates have to be licensed? What about Russia?
12. What personal qualities are important for a chemical engineer? What else should be characteristic for a chemical engineer?

5. Get ready to speak on your future career.

6. Job application is often followed by an interview. Read about some interesting question you could come across. How would you answer these questions?

Top Interview Questions Big Companies Ask

Cracking some of these questions will make you feel as proud as a peacock!

If you are one of those people, who like to stay updated with all the latest advancements in technical companies, learning about some interesting and hard job interview questions that these companies ask their candidates can be quite interesting.

There is always something special about the Fortune 500 Companies where everyone wants to go and work. They are known for their tough job interviews that make candidates think out of the box.

1. Tesla. Interview Questions in Tesla.

"You are standing on the surface of the Earth. You walk one mile south, one mile west, and one mile north. You end up exactly where you started. Where are you? "

This is one of the favorite questions posed by Elon Musk in interviews as stated in his biography, *Tesla, SpaceX, and the Quest for a Fantastic Future.* He likes to ask this question to test the intelligence of the candidate he’s interviewing.

So, if you are aiming to get selected by a company like Tesla, you will need to be prepared to prove your wit and acumen by thinking of a creative answer to this question.

Tesla is a great company to work with so even if they ask a few tough job interview questions, tackling them would take you a long way.

"Describe how you would change the culture of the company".

This is another interesting question that candidates are asked when they go for an interview at Tesla. This question aims at testing the ability of an individual to use their technical expertise in bringing about a change within their organization.

It also tests how candidates can mix their technical and soft skills to come up with a solution. Hence, to qualify in a Tesla interview, candidates need to be quick-witted and open in their approach towards problem-solving.

Only then, they can come up with answers that will impress the interviewers. Getting through the hard job interview of Tesla is not easy, but once you do it, you will be proud!

2. Microsoft. Interview Questions Asked at Microsoft.

"What did you think about Microsoft's decision to launch Office products on the iPhone?" – Senior Business Planner candidate.

This question was asked to a Senior Business Planner candidate to assess if the applicant will be open about expanding the business to a competitor's domain. Therefore, when you go for a job interview at Microsoft, you must be prepared to take on such questions.

Moreover, it would be a good idea to read about the company's business expansion policies over the last decade to be sure that you can tackle their tough job interview questions with full understanding and ease.

"Why are manholes round?" – Software Development Engineer candidate.

With this question it can be seen that Microsoft asks a question to candidates to see how they apply their theoretical knowledge in practical situations. In order to work and be successful in a company like Microsoft, candidates need to be street smart along with being book smart.

Missing out on one aspect might make it difficult for them to deal with the challenges that are posed to them on a daily basis.

3. Apple. Interview Questions Apple.

"Describe an interesting problem and how you solved it". – Software Engineering candidate.

Apple is a technical giant that is popular for asking the most challenging and the trickiest questions from applicants. They are known for their hard job interview questions that keep the candidates stunned at times.

That said, it can potentially be one of the most exciting workplaces if you are interested in this domain. Therefore, getting a job at a company like Apple is not a cakewalk.

Apple is known to ask the perfect blend of technical interview questions as well as insane puzzles that take all the mental faculties and creativity of a candidate to come up with a job-worthy answer. This is a relatively easy-looking question until you actually start thinking about a problem good enough to talk about.

This question is designed for a candidate to showcase his/her problem-thinking and problem-solving capabilities.

4. Google. Interview Questions Google.

"If you wanted to bring your dog to work, but one of your team members was allergic to dogs, what would you do?" – Associate Account Strategist, December 2014.

Google is yet another industry giant that is well-known for its challenging interview questions in hard job interviews that are difficult to crack. This technology giant has a reputation that precedes itself when it comes to presenting potential job applicants with brainteasers that might leave them mind-boggled.

When you go for a job interview, it is natural to expect to be asked questions related to your job or the position you are vying for. However, not for Google!

This company certainly knows how to challenge job applicants with tough job interview questions to see how the candidates perform under pressure. Although most questions asked by Google will require you to think and answer quantitatively, this is one problem-solving question that might require you to tackle a problem of your allergic colleague on the spot.

In addition to some brain-stumping puzzles, you can also expect plenty of short and concise questions from this company that calls for nothing but your honesty such as "Why Google?"

Conclusion.

These questions are just the tip of the iceberg when it comes to technical interview questions asked in big technology companies. So, if you aim to work in one of these companies one day, you must start thinking of some creative solutions to these questions.

These questions can open up your mind and thought process even if you don't plan to work in such companies. So, having knowledge about such questions is always effective.

https://interestingengineering.com/top-interview-questions-big-companies-ask.

SUPPLEMENTARY READING

Text 1
What if Chemical Engineers didn't Exist?

Can you imagine a life without chemical engineers? We can't!

No food to feed the world! Fritz Haber was the inventor of the all-renowned Haber Process, where nitrogen from the air is mixed with hydrogen under high temperature and pressure, to produce Ammonia. Now ammonia stinks, but, thanks to this process, more than half of the world's population is being fed with good food. This process produces nitrogen fertilizers and is used by most of the food industries. Now, this process was invented by Fritz Haber, but, it was Carl Bosch, who took it an industrial scale and then began mass production of the fertilizers. Imagine if the process wasn't introduced on an industrial scale; we would probably be eating only fish now.

No clean water. We can drink clean water today, with the help of the cleaning process invented by Chemical Engineers. Purifying water has several steps to it and being able to change the sea water into something edible, wouldn't have been possible without the thinking of Chemical Engineers. Today, even contaminated sewage waters can be turned into pure, drinkable water. Even, desalination, a process where salts and unwanted minerals are removed to purify the water and make it suitable for drinking and other purposes. Desalination is a way that majorly contributes to purifying water and is being used in over 120 countries, including United Arab Emirates, India, Greece and Saudi Arabia.

Recycling wouldn't have been possible! Recycling things like aluminum, paper and plastics and reusing them have become possible, thanks to the innovators. Recycling aluminum was developed in the 1960s and today, aluminum has become one of the most recycled materials. With this, starting from cans to cars is being recycled today, and has mainly helped in reducing the consumption of bauxite and crude oil and has also contributed in reducing the air pollution.

Recycling paper and plastics has also become possible with the help of Chemical Engineers. Plastic is something we use in our everyday lives and is non-biodegradable. Therefore, to save energy and the environment, Engineers have come up with a process, which reprocesses the plastic to be reused again. This not only saves energy, but, even helps environmentally.

Batteries? What are they? This is something that every technology needs, especially the long-lasting ones. Without it, you probably wouldn't have been able to read this article. Lewis Urry, a Chemical Engineer, invented the alkaline and the lithium battery, while working for the all-known battery company, Eveready. Today, 80 % of the dry-cell batteries are based on his invention. This is the technology era and it definitely wouldn't have been possible without Urry's work and methods. Eveready produced batteries since the 1800s, but, the batteries that were produced before Urry's invention, wouldn't have been able to power any of the gadgets that we use today. Urry's invention brought long-lasting, cost-effective batteries and basically is one of the major inventions, which made portable electronics a reality.

Ozone layer probably wouldn't have been depleted. CFCs, also knows as Chloro-Fluro Carbon, wouldn't exist today. It's a coolant used in refrigerators, air conditioners and as propellants in aerosol. This invention, however, has caused a lot of harm to the ozone layer, thereby exposing the earth to ultraviolet radiation. Thomas Midgley was a Mechanical Engineer and a Chemist, so if you combine the worst subjects of these two, one may get Chemical Engineer, which Midgley was arguably. Apparently, the first CFC was highly stable and had no harmful effects on animals, humans and plants. Due to its non-inflammability and volatility, the product was a huge success commercially and was used in refrigerators and air conditioners. However, people were too late to realize its long-term harmful effects and the fact that, it was due to CFCs that the ozone layer was being majorly affected. The damage became known in the 1980s and that's when the Montreal Accord came into play, which eventually phased-out the use of CFCs.

We would be breathing lead! Unfortunately, Midgley didn't stop at CFCs. Before CFCs, Midgley produced TEL, tetraethyl lead, which was used in early cars to reduce 'engine knocking'. TEL caused birth defects, polluted the environment and affected people in many ways physically and mentally. However, the use of it was soon to be outlawed and replaced by the great innovation of Vladimir Haensel. He invented the platforming process, which allowed oil to have a higher octane rating and at the same time caused less air pollution, unlike TEL. Haensel had the idea in mind, which is reforming the naphthas, but, the process required a catalyst. Then, he discovered the use of platinum as a catalyst, which was a stable and facilitated the process accordingly. Although, the surface eventually gets piled up with coke, today's refining processes, allows the platinum catalyst to regenerate up to 400 times before being recycled. This great invention, allowed petrol to have a higher octane rating, without any use of harmful chemicals and also benefitted the environment. It cuts off harmful emissions and produces hydrocarbon like benzene, which is mainly used in the production of plastics. Haensel contributed to the production of catalytic converters and thanks to that, we are breathing air instead of lead today!

https://gineersnow.com/engineering/chemical/what-if-chemical-engineers-didnt-exist.

Text 2

Famous Chemical Engineers Who Changed the World

George Edward Davis. Known as the father of the discipline *Chemical Engineering*, George Davis gave the first 12 ‘Chemical Engineering’ lectures in the University of Manchester Institute of Science and Technology. The lectures were the core of the discipline, which defined and explained what Chemical Engineering basically is. He even wrote the book, *A Handbook Of Chemical Engineering, Volume I and II*, which explained the basic industrial operations done on a much larger scale.

Arthur D. Little. We all know Arthur D. Little is the famous international consultancy firm, but, the man behind it is a famed Chemical Engineer. Arthur D. Little was a drop-out, who laid the foundations for unit operations. This was applied to all the basic industrial processes and basically helped in defining the discipline.

John H. Perry. Perry's Chemical Engineer's Handbook wouldn't have been possible without John H. Perry, who edited the first Handbook published in 1934. John was a chemical engineer and also a Ph.D. holder in Physical chemistry. He is more known for his handbook, which contains all the important properties and knowledge required by Professors and Chemical Engineers.

Robert Samuel Langer, Jr. Robert Langer is known as the father of Tissue Engineering and has over 1,100 issued and pending patents. He is known for his contributions to medicine and biotechnology and has invented new technologies, especially in the drug delivery systems. He is the most cited engineer and currently the David H. Koch Insititute Professor at MIT.

Thomas H. Chilton. Known as the father of modern Chemical Engineering Practices, Chilton and Allan P. Colburn developed what is known as the Chilton-Colburn analogy. This analogy is widely known and used in courses like mass and heat transfer. He worked as a Chemical Engineer at DuPont for 35 years and contributed to understanding the chemical phenomena behind heat and momentum.

Elmer L. Gaden, Jr. Elmer was the father of Biochemical Engineering, who served 25 years of his career in academics. He is known for his dissertation topic, which was based on penicillin production. It basically explained Chemical Engineers the processes and fundamentals behind the penicillin production. He spent 25 years of his career in Columbia University, where the first biochemical engineering program was established.

Carl Bosch. Although, Haber process was invented by Fritz Haber, the process was further scaled up to the industrial level, thanks to Carl Bosch. This process enables the production of synthetic fertilizers and today contributes to half of the world's food production. He is a recipient of the Nobel Prize in Chemistry, 1931.

Margaret Hutchinson Rousseau. In 1937, Margaret became the first women to ever receive a doctorate in Chemical Engineering from MIT. She is mainly known for producing the first commercial penicillin plant and also contributed to creating processes, which produced high-octane gasoline. She was also the first female member of the American Institute of Chemical Engineers (AIChE).

Vladimir Haensel. Holding nearly 150 patents and more than 400 foreign patent, Vladimir is famous for inventing the platforming process. This is a process where platinum is used as a catalyst to produce clean, low-cost gasoline, containing a higher energy content. This process has also helped in the removal of lead from gasoline and is also a role model for different catalytic reforming processes. Vladimir worked in the University of Massachusetts Amherst as a Professor in Chemical Engineering from 1980-till his death.

Fritz Haber. Although, his contribution is mostly in the field of Chemistry, without his invention, two-thirds of the world’s food production would have been impossible. His very well-known Haber Process, is the process where nitrogen is converted to Ammonia, under high temperature and pressure. The process was further applied to industrial-scale by Carl Bosch. For this process, Fritz Haber received a Nobel Prize in Chemistry in 1918

https://engineeringwondersblog.wordpress.com/2017/11/04/famous-chemical-engineers-who-changed-the-world/.

Text 3
No, People Didn't Invent Polymers

You may think that polymers are so common that they grow on trees... Well, you're right. When we say that polymers are everywhere, we mean it. In fact polymers have been in nature from the beginning. All living things – plants, animals, and people – are made of polymers. There are lots of polymers in the sea. Let's start with plants.

Polymers in Plants. Plants are made of a polymer called cellulose. This is the tough stuff that wood and stems – and Paul's tree house! – are made from. Cellulose is also what makes fibers like cotton and hemp that we can twist into threads and weave into clothing. And many plants also make starch. Potatoes, corn, rice, and grains all have a lot of starch. Starch is also a polymer.

Even though starch and cellulose are both made from the same sugar (glucose), they act very differently (because the glucose molecules are joined together differently). Starch will dissolve in water, but cellulose won't. So we make food from starches and we build things and make clothing out of cellulose.

Starch is all twisted up in a tight blob, with lots of branches and ends sticking out all over. Starch is really just a compact way to store a lot of glucose in a small space. Our bodies break the starch down into glucose, which can be used for energy so you can run and jump and play and think.

Plants use cellulose for strength. The cellulose chains are all stretched out, and like to stay tight right next to each other, like raw spaghetti that's all stuck together. That's why cellulose can hold up the tallest trees! And wooden houses too! Cotton is mostly cellulose – those stretched-out chains make great fibers.

The cellulose in vegetables and grains is the fiber in our foods. We can't digest it, but it's good for us because it helps keep our insides clean.

Cellulose and starches are both made from sugars – so they're called polysaccharides (meaning "many sugars").

Another useful natural polymer produced by plants is rubber. It has been harvested from trees in Central and South America for hundreds of years. In the last couple hundred years people have figured out ways to make it stronger and more durable. And scientists have been very successful in inventing their own versions of rubber for different purposes.

Polymers in People – and all kinds of animals, too...

Protein. You know they say "You are what you eat". Well, one natural polymer that we eat a lot of is also one we are made of – PROTEIN! Protein also forms some of the things you wear – namely leather, silk, and wool. Protein is a natural polymer formed from molecules called amino acids. Chicken nuggets and hamburgers have a lot of protein (but the bun has a lot of starch!). Protein is the main thing in skin, organs, muscles, hair and fingernails. The most common protein in your body, collagen, is used for support and structure. It's in-between all the cells in your body, all around your organs, even in your teeth and bones.

Feathers and fur, hair and fingernails (even animal hooves), are all made of the protein keratin. Wool is made from sheep hair, and is great for clothing and fabric. Wool is warm and sometimes a little itchy, but it's still widely used. You'll find it everywhere from hats to skirts to the inside of a piano... and of course in sweaters. In fact many kinds of animal hair besides wool have been used to make clothing. Angora rabbits have extra light, soft, fluffy fur. Cashmere is a wool that comes from special goats, and is very soft and long-wearing. Alpacas and llamas also produce wool that's soft and warm.

Silk. Another great protein is silk – a sort of fiber made by special caterpillars. This stuff has been used for thousands of years to make beautiful fabric for clothing. And though people have made their own version of silk called nylon, there's still nothing out there quite like silk. Spider silk is incredibly strong for its weight, and scientists have been working hard to mimic this fiber, too.

Enzymes. A special group of proteins that work inside the body are enzymes. Each enzyme is a specific little glob of a protein that does a specific job in the body, and does it really really fast. Without enzymes, these jobs either just wouldn't happen, or would go way too slowly to make life possible! Some enzymes even make other enzymes. The enzymes all work together to keep everything in your body going, like processing your food into energy so you can chase your little brother around.

Chitin (sounds "like kite-inn"). What do lobsters and giant cockroaches and mushrooms have in common? Chitin!

Chitin is the strong waterproof stuff that crustaceans like crabs and shrimp and all kinds of bugs make to form their protective outer shells. It's even found in the cell walls of mushrooms (weird, huh?!). The neat thing about chitin is that its structure is a lot like cellulose. One might think it would be a protein since it's made by animals (mostly), but it's more like the tough stuff in plants. Scientists have found a way to purify the chitin into an off-white powder that can be useful to farmers, doctors, and even in food as a thickening agent. To learn more about polymers in the sea, click here to visit the Polyquarium.

https://pslc.ws/macrog/kidsmac/natural.htm.

Text 4
Polymer

Written by
The Editors of Encyclopaedia Britannica

Polymer, any of a class of natural or synthetic substances composed of very large molecules, called macromolecules, that are multiples of simpler chemical units called monomers. Polymers make up many of the materials in living organisms, including, for example, proteins, cellulose and nucleic acids. Moreover, they constitute the basis of such minerals as diamond, quartz and feldspar and such man-made materials as concrete, glass, paper, plastics and rubbers.

The word *polymer* designates an unspecified number of monomer units. When the number of monomers is very large, the compound is sometimes called a high polymer. Polymers are not restricted to monomers of the same chemical composition or molecular weight and structure. Some natural polymers are composed of one kind of monomer. Most natural and synthetic polymers, however, are made up of two or more different types of monomers; such polymers are known as copolymers.

Organic polymers play a crucial role in living things, providing basic structural materials and participating in vital life processes. For example, the solid parts of all plants are made up of polymers. These include cellulose, lignin, and various resins. Cellulose is a polysaccharide, a polymer that is composed of sugar molecules. Lignin consists of a complicated three-dimensional network of polymers. Wood resins are polymers of a simple hydrocarbon, isoprene. Another familiar isoprene polymer is rubber.

Other important natural polymers include the proteins, which are polymers of amino acids, and the nucleic acids, which are polymers of nucleotides – complex molecules composed of nitrogen-containing bases, sugars, and phosphoric acid. The nucleic acids carry genetic information in the cell. Starches, important sources of food energy derived from plants, are natural polymers composed of glucose.

Many inorganic polymers also are found in nature, including diamond and graphite. Both are composed of carbon. In diamond, carbon atoms are linked in a three-dimensional network that gives the material its hardness. In graphite, used as a lubricant and in pencil "leads", the carbon atoms link in planes that can slide across one another.

Synthetic polymers are produced in different types of reactions. Many simple hydrocarbons, such as ethylene and propylene, can be transformed into polymers by adding one monomer after another to the growing chain. Polyethylene, composed of repeating ethylene monomers, is an addition polymer. It may have as many as 10,000 monomers joined in long coiled chains. Polyethylene is crystalline, translucent, and thermoplastic – i.e., it softens when heated. It is used for coatings, packaging, molded parts, and the manufacture of bottles and containers. Polypropylene is also crystalline and thermoplastic but is harder than polyethylene. Its molecules may consist of from 50,000 to 200,000 monomers. This compound is used in the textile industry and to make molded objects.

Other addition polymers include polybutadiene, polyisoprene, and polychloroprene, which are all important in the manufacture of synthetic rubbers. Some polymers, such as polystyrene, are glassy and transparent at room temperature, as well as being thermoplastic. Polystyrene can be coloured any shade and is used in the manufacture of toys and other plastic objects.

If one hydrogen atom in ethylene is replaced by a chlorine atom, vinyl chloride is produced. This polymerizes to polyvinyl chloride (PVC), a colourless, hard, tough, thermoplastic material that can be manufactured in a number of forms, including foams, films, and fibres. Vinyl acetate, produced by the reaction of ethylene and acetic acid, polymerizes to amorphous, soft resins used as coatings and adhesives. It copolymerizes with vinyl chloride to produce a large family of thermoplastic materials.

Many important polymers have oxygen or nitrogen atoms, along with those of carbon, in the backbone chain. Among such macromolecular materials with oxygen atoms are polyacetals. The simplest polyacetal is polyformaldehyde. It has a high melting point and is crystalline and resistant to abrasion and the action of solvents. Acetal resins are more like metal than are any other plastics and are used in the manufacture of machine parts such as gears and bearings.

A linear polymer characterized by a repetition of ester groups along the backbone chain is called a polyester. Open-chain polyesters are colourless, crystalline, thermoplastic materials. Those with high molecular weights (10,000 to 15,000 molecules) are employed in the manufacture of films, molded objects, and fibres such as Dacron.

The polyamides include the naturally occurring proteins casein, found in milk, and zein, found in corn (maize), from which plastics, fibres, adhesives, and coatings are made. Among the synthetic polyamides are the urea-formaldehyde resins, which are thermosetting. They are used to produce molded objects and as adhesives and coatings for textiles and paper. Also important are the polyamide resins known as nylons. They are strong, resistant to heat and abrasion, noncombustible, and nontoxic, and they can be coloured. Their best-known use is as textile fibres, but they have many other applications.

Another important family of synthetic organic polymers is formed of linear repetitions of the urethane group. Polyurethanes are employed in making elastomeric fibres known as spandex and in the production of coating bases and soft and rigid foams.

A different class of polymers are the mixed organic-inorganic compounds. The most important representatives of this polymer family are the silicones. Their backbone consists of alternating silicon and oxygen atoms with organic groups attached to each of the silicon atoms. Silicones with low molecular weight are oils and greases. Higher-molecular-weight species are versatile elastic materials that remain soft and rubbery at very low temperatures. They are also relatively stable at high temperatures.

https://www.britannica.com/science/polymer.

Text 5
Basic Polymer Science

A polymer is generally described in terms of a single repeat unit, such as the following example.

The number of repeat units in a chain is called the degree of polymerization (DP) or chain length. Thus, a poly (propylene) chain 5,000 units long would have a DP of 5,000 and an "n" value of 5,000. Because most polymer mixtures contain chains of varying lengths, the chain length is often referred to in terms of average chain length or average DP.

At either end of the polymer chain are end groups. (Because the chain is often thousands of units long, the end groups are usually omitted.) For (poly)propylene the repeating carbons (C-C-C-C-C-C-C) form the polymer backbone and represent the atoms that connect the chain together. In vinyl polymers, so called because they are generally derived from substituted vinyl reactants or monomers, the polymer backbone is composed of only carbon atoms.

Condensation polymer backbones include non-carbon atoms. For example, polyesters have oxygen atoms and nylons have nitrogen atoms in the backbone in addition to carbon atoms.

Unsymmetrical reactants, such as substituted vinyl monomers, react almost exclusively to give what are called "head-to-tail" products where the substituents occur on alternative carbon atoms:

Copolymers are polymers derived from two different monomers (M and N). Saran, a component of Saran Wrap, is one example.

Some linear chains have extensions (beyond the substitution) coming off the polymer backbone. These extensions are called branches and influence a polymer's properties. Branches may be long or short, frequent or infrequent. For example, so-called low density polyethylene (LDPE) has between forty and one hundred short branches for every 1,000 ethylene units, whereas high density polyethylene (HDPE) has only one to six short branches for every 1,000 ethylene units (Figure 11). Branching discourages the chains from fitting close together so that the structure will be **amorphous** with relatively large amounts of empty space. Regular structures with little or no branching allow the polymer chains to fit close together, forming a crystalline structure. Crystalline structures are generally stronger, more brittle, of higher density, more resistant to chemical penetration and degradation, less soluble, and have higher melting points. For example, HDPE has a density of 0.97 gram per milliliter and a melting point of about 130 °C (266 °F), whereas LDPE has a density of about 0.92 gram per milliliter and a melting point of about 100 °C (212 °F).

Polymer chains can be connected to one another chemically or physically, much like a knot can connect two pieces of string. These connections are called crosslinks and cause the connected chains to act as a single unit

Some materials can have only a few crosslinks, such as permanent press materials where the fabric contour is locked into place with crosslinks. Others materials such as Bakelite and ebonite are heavily crosslinked; these are hard, brittle, non-flexible materials.

http://www.chemistryexplained.com/Pl-Pr/Polymers-Synthetic.html.

Text 6
Types of Synthetic Polymers

Elastomers. Elastomers are polymers possessing chemical and/or physical crosslinks. These crosslinks allow the stretched, deformed segments to return to their original locations after the force is removed. The "use" temperature must be above the T_g to allow ready chain slippage as the rubbery material is flexed and extended. The forces between the chains should be minimal to allow easy movement of these chain segments. Finally, the chains must be present in an amorphous, disorganized fashion. As force is applied and the material distorts or elongates, the randomly oriented chains are forced to align and take more ordered positions with the chains, forming crystalline regions that resist ready movement. As the force is removed the material has a tendency to return to its original disorganized state and therefore its pre-stretched shape. The formation of the crystalline regions as the material is stretched gives the material a greater tensile strength (i.e. an increased force is necessary for further elongation) at high extensions. Crosslinked vinyl polymers are ideal materials to be used in elastomers: the attractive forces between chains is low and their T_g is below room temperature.

Thermosets and thermoplastics. Thermosets are materials that have sufficient crosslinking present so that they are prevented from being soluble and melting when heated. Such materials are therefore difficult to recycle. Thermoplastics are materials that melt on heating and generally contain little or no crosslinking. They can be recycled more easily through heating and reforming. Linear polymers are thermoplastic materials.

Fibers. Fibers require materials with a high tensile strength and high modulus (high force required for elongation). This requires polymers with strong forces between the chains and chains that are symmetrical to allow for good crystalline formation. Condensation polymers exhibit these properties and so are most utilized as fibers. Fibers are normally linear and drawn (pulled) in one direction, producing higher mechanical properties in that direction. If the fiber is to be ironed, its T_g should be above 200 ^oC. Branching and crosslinking are undesirable since they inhibit crystalline formation. Even so, some crosslinking may be present to maintain a given orientation, such as desired in permanent press clothing. While most fibers are made from condensation polymers, new treatments allow some fibers to be made from olefinic materials such as polypropylene.

Plastics. Plastics require properties that are intermediate between elastomers and fibers. Engineering plastics can be readily machined, cut, and drilled. Condensation polymers are typically engineering plastics while vinyl polymers are typically plastics.

Coatings. Coatings and adhesives are generally derived from polymers that are considered to be plastics, although there are major groups that do not. For instance, silicone rubbers are elastomers that can be used as adhesives. Coatings, or coverings, are generally highly viscous (low flowing) materials. Coatings protect surfaces from the degradative effects of oils, oxidative chemical agents, extreme temperatures, rain, snow and ionizing radiation. Coatings must adhere to the surface they are applied to. Coatings are typically a mixture of a liquid (vehicle or binder/adhesive) and one or more colorants (pigments). Coatings often also contain a number of so-called additives that can furnish added protection against ionizing radiation, increase the rate of drying and/or curing (crosslinking) and prevent microorganism growth. Coatings are specially formulated for specific purposes and locations and can be divided into five groups:

- oil paints consist of a suspension of pigment (colorant) in a drying oil such as linseed oil;
- oil varnishes consist of a polymer, either natural or synthetic, dissolved in a drying oil together with the necessary additives such as catalyst that promotes crosslinking of the drying oil;
- enamels are oil varnishes with pigment added;
- lacquers are polymer solutions to which pigments have been added;
- latex paints are polymer latexes, often poly(methyl methacrylate) and polyacrylonitrile, to which pigments have been added. They account for well over one half of the commercial paint used.

Hardening or drying consists of removal of solvent (evaporation) and/or crosslinking of a drying oil that contains C = C units.

Adhesives. In contrast to coatings that must adhere to only one surface, adhesives are used to join two surfaces together. Adhesion for both adhesives and coatings can occur through a number of mechanisms including physical interlocking, chemical adhesion where primary bonding occurs between the adhesive and the surfaces being joined, secondary bonding where hydrogen bonding or polar bonding occurs and viscosity adhesion where movement is restricted because of the viscous nature of the adhesive material. Adhesives can be divided according to the type of delivery of the adhesive or by the type of polymer:

- solvent-based adhesives like model airplane glue contain a volatile solvent that dissolves part of the plastic and when dry forms a solvent weld;
- pressure-sensitive adhesives like those used on Post-It-Notes often contain the same adhesive material used in more permanent adhesives like Scotch Tape except in lesser amounts;
- reactive adhesives are short chained polymers or monomers that solidify through polymerization or crosslinking after application;
- plywood is formed from the impregnation of thin sheets of wood with resin that dries after the sheets are pressed together. Phenolic thermosets such as those developed by Bakelite are often used as the resins for plywood;
- adhesives made from cyanoacrylates are among the best known adhesives, sold under trade names such as Super Glue and Crazy Glue. Monomers such as butyl-alpha-cyanoacrylate polymerize spontaneously in the presence of moisture. The presence of the cyano and acrylate groups, both quite polar, makes this a particularly good adhesive; it is used in surgery and for mechanical assemblies.

Sealants and caulks. Sealants and caulks provide a barrier to the passage of gases, liquids, and solids; maintain pressure differences; and moderate mechanical and thermal shock. While adhesives are used for "load transfer" and require high tensile and shear strengths, sealants act as insulators and shock attenuators and do not require high tensile and shear strengths.

Films and sheeting. Films are two-dimensional forms of plastic, thick enough to be coherent, but thin enough to be flexed, creased, or folded without cracking. Most films are produced from materials from the elastomeric and plastic categories. Sheeting is a two-dimensional form of plastic that is thicker (generally greater than 250 micrometers) than film and is generally not easily flexed, creased, or folded without cracking.

Composites. Composites are materials that contain strong fibers or reinforcement embedded in a continuous phase called a matrix. They are found in jet fighters such as stealth fighters and bombers, in the "reusable" space shuttle, in graphite golf clubs, in synthetic human body parts, and for many years in marine craft (fibrous glass).

Laminates. The combination of an adhesive and an adherent is a laminate, a type of composite. Commercial laminates are produced on a large scale with wood as the adherent and phenolic, urea, epoxy, resorcinol or polyester resins as the adhesive. Plywood is an example of a laminate.

Laminates of paper or textile include Formica and Micarta. Laminates of phenolic, nylon or silicone resins with cotton, asbestos, paper or glass textiles are used as mechanical, electrical and general purpose structural materials.

Conductive polymers. Most polymers are nonconductive and polymers such as polyethylene, polypropylene and polytetrafluoroethylene (Teflon) are used as insulators. Even so, some polymers have been found to conduct electricity. An example is polyacetylene; oxidation with chlorine, bromine, or iodine vapor makes polyacetylene film 10^9 (1,000,000,000) times more conductive than the non-treated film. This treatment with a halogen is called "doping". Other polymers including polyaniline, polythiophene, and polypyrrole have been found to be conducting after doping and these materials are now being used in a variety of applications. Doped polyaniline is employed as a conductor and as an electromagnetic shielding for electronic circuits. Polythiophene derivatives are used in field-effect transistors. Polypyrrole is used in microwave-absorbing "stealth" screen coatings and in sensing devices. Poly(phenylene vinylidene) derivatives are used in the production of electroluminescent displays.

http://www.chemistryexplained.com/Pl-Pr/Polymers-Synthetic.html.

Text 7
Polyesters

Polyesters are long chain synthetic **polymers** that have ester linkages. Polyester materials are used as fibers, plastics, and films; in composites and elastomers; and as coatings. They are truly versatile materials.

In the late 1920s American chemist Wallace Carothers and his research group at DuPont began to investigate the formation of polymers from the reaction of **aliphatic** diacids (having two acid groups) with diols (having two alcohol groups), in search of materials that would give them fibers. At first they were able to form only syrupy mixtures. But the Carothers group did make polyester fibers. They investigated a wide array of dialcohols, diacids, and w-hydroxy acids for use as starting points. Some of the polyesters that they achieved were solids, but they had rather low melting points and thus were not useful as fiber materials. The lack of success was due to the fact that the researchers had used only aliphatic diacids. In order to form long polymer chains, the reactive groups of the reactants must be present in approximately equal amounts. This is easily achieved via the use of amines and the subsequent formation of amine salts. (Diols do not easily form salts.) Carothers's group understood the principle of "driving" an equilibrium reaction and so sought to remove water from their amine salt mixtures, thus forcing the reaction toward **ester** formation. For this they developed a so-called molecular still, which involved heating the mixture and applying a vacuum coupled with a "cold-finger" that allowed evacuated water to condense and be removed from the reaction system. Even with this understanding and lots of hard work, they achieved polymer chains with fewer than 100 repeat units.

The DuPont research team turned from the synthesis of polyesters to tackle, more successfully, the synthesis of polyamides. The experience with polyesters was put to use in the making of polyamides.

Initial polyester formation actually occurred much earlier and is attributed to Gay Lussac and Théophile-Jules Pelouze in 1833 and Jöns Jakob Berzelius in 1847. They did not realize what they had discovered, however, and so moved on to other work.

Glyptal polyesters were first produced in 1901 by heating glycerol and phthalic anhydride. Because the secondary hydroxyl is less active than the terminal, primary hydroxyl in glycerol, the initial product formed is a linear polyester. A cross-linked product is produced by further heating through reaction the third alcohol.

Related compounds, alkyds, were synthesized by Kienle in the 1920s from trifunctional alcohols and dicarboxylic acids. Unsaturated oils (alcohols and anhydrides containing double bonds) were also reacted with phthalic anhydride, yielding polyesters that contained a double bond, which could be further reacted to produce cross-linked products. The extent of cross-linking or "drying" depends on the amount of unsaturated oil present.

Today, the term alkyd is often used to describe all polyesters produced from the reaction of a diacid or anhydride and a diol or triol resulting in a product that contains a double bond that can be further reacted, giving a cross-linked product. These polyesters are called unsaturated polyesters. They are mainly used in the production of reinforced plastics (composites) and nonreinforced filled products for the marine, automotive, and other industries.

These glyptal and alkyd polyesters are useful as coating materials but not for fiber or plastic production. The first commercially available polyesters were made by GE in the 1920s. Called Glyptals™, they were used as sealing waxes. Out of the Glyptal™ research came alkyd paints. Although these reactions had low fractional conversions, they formed high molecular weight materials because they had functionalities (i.e. a number of reactive groups on a single reactant) greater than 2, resulting in cross-linking.

The heat resistance of Carothers's polyesters was not sufficient to withstand the temperature of the hot ironing process. Expanding on the work of Carothers and his coworkers on polyesters, Whinfield and Dickson, in England, overcame the problems of the Carothers group by using aromatic acids, especially terephthalic. This classic reaction, which produces plastics and fibers are sold under a variety of tradenames, including Dacron, Fortrel, Trevira, and Terylene, and films sold under a variety of trade names. All new plants now use pure acid for this reaction.

Methyl alcohol, or methanol, is lower boiling than water (65 °C compared with 100 °C) and is thus more easily removed, allowing the reaction to be forced toward polymer formation more easily. Although this polyacryl ester, produced by Whinfield and Dickson, polyethylene terephthalate or PET, met the specifications for a useful synthetic fiber, because of inferior molding machines and inadequate plastic technology, it was not possible to use it in injection molds. Until more recently PET was not a widely used plastic or film material.

Although aromatic polyesters had been successfully synthesized from the reaction of ethylene glycol with various **aromatic** diacids (almost always terephthalic acid or its ester), commercialization of polyester synthesis awaited an inexpensive source of aromatic diacids. In 1953 an inexpensive process for the separation of the various xylene isomers by crystallization was discovered. The availability of inexpensive xylene isomers enabled the formation of terephthalic acid through the air oxidation of the p-xylene isomer. Du Pont, in 1953, produced polyester fibers from melt spinning, but it was not until the 1970s that these polyester fibers became commercially available.

In 2000 about 3,900 million pounds of polyester fiber were used in the United States, making it the largest single fiber group material. As with nylon, polyester fibers are comparable to and/or surpass common natural fibers such as cotton and wool in heat stability, wash-and-wear properties, and wrinkle resistance. Textiles blended from polyester, cotton, and wool (in varying combinations) can also be made to be "permanent press" and wrinkle resistant. The fibers are typically formed from melt or solvent spinning. Chemical and physical modification can generate fibers of differing fiber appearances from the same basic fiber material. Self-crimping textiles are made by combining materials that have differing shrinkage properties. Different shaped dyes produce materials with varying contours and properties, including hollow fibers.

Along with the famous polyester suits and slacks, polyester fibers are widely used in undergarments, permanent press shirts, tire cord, and felts.

Because the ease of processing and fabricating polyesters is related to the number of methylene groups ($–CH_2–$) in the repeat units, scientists turned to the use of diols with additional methylene units. Whereas PET is difficult to mold because of its high melting point, T_m 240 °C, poly butylene terephthalate or PBT, because of its two additional methylene units in the diol-derived portion, is lower melting with a T_g of about 170 °C. PET also crystallizes relatively slowly, so extra care must be exercised to insure that PET molded products become fully crystallized. Otherwise, the partially crystallized portions will be preferred sites for cracking, crazing, shrinkage, and so on.

By comparison, PBT melts at a lower temperature (as noted above), crystallizes more rapidly, and is often employed as a molding compound. PBT has properties that represent a balance between those of nylons and acetals. It is characterized by low moisture absorption, good fatigue resistance, good solvent resistance, extremely good self-lubrication, and good maintenance of its physical properties even at relatively high use temperatures. Fiber-reinforced PBT molding compound is sold under the trade-name Celanex. Another PBT molding compound was first sold under the tradename Valox. Today, there are many PBT molding compounds available.

In 2000 worldwide production of PET was 30 million tons. The manufacture of PET textiles is increasing at 5 percent a year, of PET bottles at 10 percent a year. China produces the most polyesters. PET is now used extensively as bottling material for soft drinks instead of glass because it is shatterproof and lightweight. Carbon dioxide permeability decreases with increasing film thickness and crystallinity. Glass has better CO_2

impermeability than PET in these respects. Therefore, to achieveoptimal crystallinity, partially crystalline PET is employed in the stretch blow molding process, carried out to promote further crystalline formation. It is also used for molded automobile parts. Over 500,000 tons of polyester engineering plastics are produced annually in the United States.

Polydihydroxymethylcyclohexyl terephthalate was introduced by Eastman Kodak as Kodel in 1958. Here, the insertion of the cyclohexyl moiety gives a more **hydrophobic** material (in comparison to PET and PBT) as well as a more moldable product that can very readily be injected-molded. The polymer's sole raw material is dimethyl terephthalate. Reduction of dimethyl terephthalate yields the dialcohol, cyclohexanedimethanol. Kodel, along with its blends and mixtures, is often extruded into film and sheeting for packaging. Kodel-type materials are used to package hardware and other heavy items; they are also blow-molded to produce packaging for shampoos, liquid detergents, and so on.

Du Pont and Shell have developed a new polyester, polytrimethylene terephthalate, or PTT, with the trademarks Sorona (Du Pont) and Corterra (Shell). It is structurally similar to polyethylene terephthalate, PET, except that 1,3-propanediol (PDO) is used as a reactant in place of ethylene glycol. The extra methylene (CH_2) in PTT allows the fiber to be more easily colored, giving a material that is also softer to the touch and with greater stretch for textile use. Further, PTT offers good wear and stain resistance for carpet use. The ready availability of the monomer PDO is a major consideration, with current efforts underway to create PDO from the fermentation of sugar through the use of biocatalysts for this conversion. Corterra and Lycra blends have already been successfully marketed. Corterra is also targeted for use as a resin and film.

Du Pont first introduced microfibers in 1989. Microfibers have diameters that are less than typical fibers; they are about half the diameter of fine silk fiber, one-quarter the diameter of fine wool, and one hundred times finer than human hair. Denier, the weight in grams of 9,000-meter length of a fiber, is the term used to define the diameter or fineness of a fiber. Microfibers have a denier that is 0.9 denier or less. In comparison, nylon stockings are knit from 10- to 15- denier fiber.

Microfibers allow a fabric to be woven that is lightweight and strong. They can be tightly woven so that wind, rain, and cold do not easily penetrate. Rainwear manufactures use microfibers for this reason. They also have the ability to allow perspiration to pass through them. In addition, microfibers are very flexible because their small fibers can easily slide back and forth on one another. The first fabric made from microfiber was Ultrasuade, in which short polyester microfibers were imbedded into a polyurethane base. Today, microfibers are manufactured primarily from polyesters, nylon and acrylic fibers. They are used under various tradenames to make a variety of products, such as clothing, hosiery, bedding and scarves.

Charles E. Carraher Jr.
http://www.chemistryexplained.com/Pl-Pr/Polyesters.html.

Text 8
Facts about Plastic

Every piece of plastic that was ever produced still exists.

Fathers of the modern plastic industry were chemists Leo Baekeland, Alexander Parkes, Jacques E. Brandenberger, Chemist Roy Plunkett and Daniel Fox.

First plastic compounds were made by processing naturally created rubber plants. This process was abandoned after chemist managed to create recipes for fully synthetic plastic.

The word "plastic" was introduced in 1925, approximately 100 years after first chemist started working with natural rubber.

Before WWII the most popular plastic was Bakelite and its close cousin Catalin. They were used everywhere, from children toys to the parts for large WWII bombers.

One of the last truly important plastic compounds that were discovered is Kevlar (1965)!

In 2010 31 million tons of plastic waste was generated only in United States – 14 million tons in containers and packaging, 11 million tons as durable goods and appliances, and almost 7 million tons as non-durable goods (plates, cups, cheap kitchenware, etc.).

Eight percent of United States plastic waste is recycled, but category of bags, sacks and wraps has larger recycling rate of almost 12 %.

In the year 2002 only 360 million of bottles was recycled, out of 9.1 billion bottles that were disposed.

Over 15 million plastic bottles are used in Great Britain every day, but only around 2.5 % of European plastic bottles are recycled.

Plastic bottles are made from two types of plastic – 23 % of them are made from Polyethylene terephthalate (PET, also used for food packaging, cosmetics) and 62 % of them are made from High-density polyethylene (HDPE, also used for milk, detergents, shampoos, bottled water, juices).

Buried plastic materials can last for minimum of 700 years.

Over 4 million plastic bottles is used by American every hour!

Plastic represents 8 % of total American waste weight and 20 % of its volume.

1050 milk jugs can be recycled into one 6-foot plastic park bench.

Standard weight of one PET 2 liter bottle was reduced by 28 % between 1970s and now (it went from 67 to 48 grams).

U. S. annually creates over 9 billion plastic bottles. Around two thirds end up in landfills or incinerators.

The largest plastic recycling facility in the U. S. is Wellman Inc, located in South Carolina. It annually process over 2.5 billion plastic bottles, turning them into polyester fiber compound known as Fortrel EcoSpun.

Small plastic cup can take 50 to 80 years to decompose.

11 % of household waste is plastic, and 40 % of it is plastic bottles.

Plastic bags, bottles, and other garbage that end up in the ocean kill around 1 million sea creatures every year.

Plastic bags are one of the most common plastic items that are manufactured today – over 300 per person, per year.

Recycling plastic is much more energy efficient than incinerating it.

9 – 15 billion of plastic shopping bags are used each year in Canada alone. On average, one of those bags is used for five minutes before it is discarded.

Plastic waste can travel large distances over air and sea. Canadian plastic shopping bags are found as far as Scotland.

In 2009 2.45 billion of PET and HDPE bottles were recycled.

Recycling one single plastic bottle saves enough energy to ring 60-watt light bulb for six hours!

http://www.historyofplastic.com/plastic-facts/facts-about-plastic/.

Text 9
Plastics Today

Uta Scholten, of the German Plastics Museum Association in Dusseldorf says: "Most people today don’t know there was a time before plastics". This was a time when a soccer ball still was made of leather, not foamed PU, and a surfboard was made of wood not PE.

Today yogurt tubes are made of PS, CDs of PC, shoes of PU, waste baskets of PP, computer keyboards of ABS (a copolymer of acrylonitrile, butadiene and styrene), and soda bottles of PET poly(ethylene terephthalate). These materials, called plastics in English, were given the name Kunststoffe by the German chemist Dr. Ernst Richard Escales in 1910, later also referred to as Plastik in a critical way. But over the last few years they have shaken off their image as cheap or inferior substitutes. "These days, plastics have a high-quality image", says Dirk Ziems, manager of a market research institute in Köln, Germany. "The elegant appearance of the iPod cannot be topped, and the functionality of modern athletic clothing will not be surpassed soon".

Plastics in architecture, fashion and design. The Swiss architects Jacques Herzog and Pierre de Meuron gave the Allianz Arena in Munich an inflatable covering made of EFTE (ethylene – tetrafluoroethylene copolymer) plastic that can be illuminated in white, blue and red, the colors of Munich's two professional soccer teams.

The Allianz Arena consists of 66,500 square meters of EFTE film, 0.2 mm thick, cut into rhombus-shaped cushions. Fans inflate the cushions, which have an estimated service life of 25 years. Karsten Moritz from Rosenheim who engineered the arena's plastic facade is convinced that film skins give architects new opportunities, especially when combined with sophisticated technologies, such as liquid crystal layers that can be laminated with film, or the special effects created when light hits the edges of the film.

Fashion is another field with its sight set on plastics. Fashion guru Karl Lagerfeld surprised an interviewer by naming not *velvet* or silk as his favorite material, but plastics.

According to the local newspaper of San Francisco, the Chronicle, "Plastic furniture has become the focal point in some of the most elegantly designed rooms". The Prada Store in Beverly Hills, designed by Rem Kohlhaas, has wall coverings made of spongy, translucent PU mats. Spaces for items on display are simply cut out as needed. "No other material can be so lightweight and luminescent", says the designer.

Plastics in aircraft engineering. Jets have to be safe and airlines need planes that can fly economically. Consequently, the percentage of plastics integrated in jet planes is rising steadily. The development of the giant Airbus 380 has taken the use of plastics to a new level. For the first time in civil aviation, fiber composites were used to build wing boxes, which are the heart of any jet. Compared to a conventional aluminum structure, fiber composites help to reduce the total weight by 1.5 tons, which reduces fuel consumption while increasing payload and range. In comparison with the new jumbo jet, the proportion of plastics in an older Boeing is less than 5 % of the total weight. The A380 brings the figure up to 20 %, and in the Boeing 787, plastics make up more than half of the material used.

Plastics as a Commodity. For commodity manufacturers, plastic has become the material of choice for getting ahead of the competition. With its brightly colored iMac models, Apple proved that computers don't have to be gray boxes. However, the greater the demands imposed by industry on plastics, the more expensive their manufacturing becomes. For this reason industry is called on to develop corresponding methods that make the cost of manufacturing equal to or less than that of metallic materials.

From Bayer MaterialScience, modified and abridged.

Text 10
The Basics of Plastic Manufacturing

The term "plastics" includes materials composed of various elements such as carbon, hydrogen, oxygen, nitrogen, chlorine, and sulfur. Plastics typically have high molecular weight, meaning each molecule can have thousands of atoms bound together. Naturally occurring materials, such as wood, horn and rosin, are also composed of molecules of high molecular weight. The manufactured or synthetic plastics are often designed to mimic the properties of natural materials. Plastics, also called polymers, are produced by the conversion of natural products or by the synthesis from primary chemicals generally coming from oil, natural gas, or coal.

Most plastics are based on the carbon atom. Silicones, which are based on the silicon atom, are an exception. The carbon atom can link to other atoms with up to four chemical bonds. When all of the bonds are to other carbon atoms, diamonds or graphite or carbon black soot may result. For plastics the carbon atoms are also connected to the aforementioned hydrogen, oxygen, nitrogen, chlorine or sulfur. When the connections of atoms result in long chains, like pearls on a string of pearls, the polymer is called a thermoplastic. Thermoplastics are characterized by being meltable. The thermoplastics all have repeat units, the smallest section of the chain that is identical. We call these repeat units unit cells. The vast majority of plastics, about 92 %, are thermoplastics.

The groups of atoms that are used to make unit cells are called monomers. For some plastics, such as polyethylene, the repeat unit can be just one carbon atom and two hydrogen atoms. For other plastics, such as nylons, the repeat unit can involve 38 or more atoms. When we combine monomers, we generate polymers or plastics. Raw materials form monomers that can be or are used to form unit cells. Monomers are used to form polymers or plastics

When the connection of the carbon atoms forms two and three-dimensional networks instead of one-dimension chains, the polymer will be a thermoset plastic. Thermoset plastics are characterized by not being meltable. Thermoset plastics, such as epoxy adhesives or unsaturated polyester boat hulls and bathtubs or the phenolic adhesives used to make plywood, are created by the user mixing two chemicals and immediately using the mixture before the plastic "sets up" or cures.

The formation of the repeat units for thermoplastics usually begins with the formation of small carbon-based molecules that can be combined to form monomers. The monomers, in turn, are joined together by chemical polymerization mechanisms to form polymers. The raw material formation may begin by separating the hydrocarbon chemicals from natural gas, petroleum, or coal into pure streams of chemicals. Some are then processed in a "cracking process". Here, in the presence of a catalyst, raw materials molecules are converted into monomers such as ethylene (ethene) C_2H_4, propylene (propene) C_3H_6, and butene C_4H_8 and others. All of these monomers contain double bonds between carbon atoms such that the carbon atoms can subsequently react to form polymers.

Other raw material chemicals are isolated from petroleum, such as benzene and xylenes. These chemicals are reacted with others to form the monomers for polystyrene, nylons, and polyesters. The raw materials have been changed into monomers and no longer contain the petroleum fractions. Still other raw materials can be obtained from renewable resources, such as cellulose from wood to make cellulose butyrate. For the polymerization step to work efficiently, the monomers must be very pure. All manufacturers purify raw materials and monomers, capturing unused raw materials for reuse and byproducts for proper disposition.

Monomers are then chemically bonded into chains called polymers. There are two basic mechanisms for polymerization: addition reactions and condensation reactions. For addition reactions a special catalyst is added, frequently peroxide, that causes one monomer to link to the next and that to the next and so on. Catalysts do not cause reactions to occur, but cause the reactions to happen more rapidly. Addition polymerization, used for polyethylene and polystyrene and polyvinyl chloride among others, creates no byproducts. The reactions can be done in the gaseous phase dispersed in liquids. The second polymerization mechanism, condensation polymerization, uses catalysts to have all monomers react with any adjacent monomer. The reaction results in two monomers forming dimers (two unit cells) plus a byproduct. Dimers can combine to form tetramers (four unit cells) and so on. For condensation polymerization the byproducts must be removed for the chemical reaction to produce useful products. Some byproducts are water, which is treated and disposed. Other byproducts are raw materials and recycled for reuse within the process. The removal of byproducts is conducted so that valuable recycled raw materials are not lost to the environment or exposed to populations. Condensation reactions are typically done in a mass of molten polymer. Polyesters and nylons are made by condensation polymerization.

Different combinations of monomers can yield plastic resins with different properties and characteristics. When all monomers are the same, the polymer is called a homopolymer. When more than one monomer is used, the polymer is called a copolymer. Plastic milk jugs are an example of homopolymer HDPE. Milk is satisfactorily packaged in the less expensive homopolymer HDPE. Laundry detergent bottles are an example of copolymer HDPE. The aggressive nature of the detergent makes a copolymer the right choice for best service function. Each monomer yields a plastic resin with specific properties and characteristics. Combinations of monomers produce copolymers with further property variations. So, within each polymer type, such as nylons, polyesters, polyethylenes, etc, manufacturers can custom make plastics that have specific features. Polyethylenes can be made to be rigid or flexible. Polyesters can be made to be low temperature melting adhesives or high temperature resistant automobile parts. The resulting thermoplastic polymers may be melted to form many different kinds of plastic products with application in many major markets. The variability of the plastic either within plastic family types or among family types permits a plastic to be tailored to a specific design and performance requirements. This is why certain plastics are best suited for some applications while others are best suited for entirely different applications. No one plastic is best for all needs.

Some examples of material properties in plastic product applications are:
- hot-filled packaging used for products such as ketchup;
- chemical-resistant packaging used for products such as bleach;
- impact strength of car bumpers.

https://plastics.americanchemistry.com/How-Plastics-Are-Made/.

Text 11
The Structure of Polymers

As we have discussed, polymers can be homopolymers or copolymers. If the long chains show a continuous link of carbon-to-carbon atoms, the structure is called homogeneous. The long chain is called the backbone. Polypropylene, polybutylene, polystyrene and polymethylpentene are examples of polymers with homogeneous carbon structure in the backbone. If the chains of carbon atoms are intermittently interrupted by oxygen or nitrogen, the structure is called heterogeneous. Polyesters, nylons, and polycarbonates are examples of polymers with heterogeneous structure. Heterogeneous polymers as a class tend to be less chemically durable than homogeneous polymers although examples to the contrary are numerous.

Different elements can be attached to the carbon-to-carbon backbone. Polyvinyl chloride (PVC) contains attached chlorine atoms. Teflon contains attached fluorine atoms.

How the links in thermoplastics are arranged can also change the structure and properties of plastics. Some plastics are assembled from monomers such that there is intentional randomness in the occurrence of attached elements and chemical groups. Others have the attached groups occur in very predictable order. Plastics will, if the structure allows, form crystals. Some plastics easily and rapidly form crystals, such as HDPE (high density polyethylene). HDPE can appear hazy from the crystals and exhibits stiffness and strength. Other plastics are constructed such that they cannot fit together to form crystals, such as low density polyethylene, LDPE. An amorphous plastic typically is clear in appearance. By adjusting the spatial arrangement of atoms on the backbone chains, the plastics manufacturer can change the performance properties of the plastic.

The chemical structure of the backbone, the use of copolymers, and the chemical binding of different elements and compounds to a backbone, and the use of crystallizability can change the processing, aesthetic, and performance properties of plastics. The plastics can also be altered by the inclusion of additives.

Additives

When plastics emerge from reactors, they may have the desired properties for a commercial product or not. The inclusion of additives may impart to plastics specific properties. Some polymers incorporate additive during manufacture. Other polymers include additives during processing into their finished parts. Additives are incorporated into polymers to alter and improve basic mechanical, physical or chemical properties. Additives are also used to protect the polymer from the degrading effects of light, heat, or bacteria; to change such polymer processing properties such as melt flow; to provide product color; and to provide special characteristics such as improved surface appearance, reduced friction, and flame retardancy.

Types of Additives

– Antioxidants: for plastic processing and outside application where weathering resistance is needed
– Colorants: for colored plastic parts
– Foaming agents: for expanded polystyrene cups and building board and for polyurethane carpet underlayment
– Plasticizers: used in wire insulation, flooring, gutters, and some films
– Lubricants: used for making fibers
– Anti-stats: to reduce dust collection by static electricity attraction
– Antimicrobials: used for shower curtains and wall coverings
– Flame retardants: to improve the safety of wire and cable coverings and cultured marble

https://plastics.americanchemistry.com/How-Plastics-Are-Made/.

Text 12
Primary Industrial Equipment of Chemical Production and Its Selection

Chemical industry involves a great amount of all sorts of industrial equipment which can be divided into the following classes:

- apparatuses;
- machines;
- transport facilities

Apparatus is an engineering installation which has working volume and equipped with technological process power and instrumentation control and monitoring facilities.

Machine is an engineering installation in which technological process behavior is accompanied with introduction of mechanical energy in the working volume by means of equipment actuators.

Working volume (reaction space) is a place of technological process behavior.

The second type of reactors has maximum high production capacity and is less sophisticated in design, including technological process control and monitoring facilities, but allows to get a very limited number of types of final products.

Moreover, depending on its purpose all chemical equipment is divided into:

1. *Universal equipment* – this equipment is used at enterprises as it is, without being retrofitted. It is called general-purpose equipment or, otherwise, all-factory equipment. It includes:

- aggressive media pumps (for more details see pumps);
- mixers, dryers, centrifuges and separators (for more details see centrifuges);
- compressors (for more details see compressors);
- fans (for more details see fans and gas compression);
- filters, dust catching and gas treating systems (for more details see filters and gas treatment);
- delivery facilities.

2. *Special-purpose equipment* is equipment which is used in one technological oft different changes. It includes:

- heat exchange assemblies (for more details see heat-exchange equipment);
- rectification (spacer liquid mixtures) columns;
- absorption apparatuses.

3. *Dedicated equipment* is equipment which is used only for performance of one production process. It includes:

- calenders and calendaring machines (for more details see roller machines, calenders);
- vulcanization presses (for more details see pressure equipment);
- granulators;
- shaft chlorinators;
- freeze-driers.

Moreover process equipment is also divided into:

1. *Basic equipment* is machines, installations and apparatuses in which different technological operations and processes take place (physical-chemical, chemical, and so on), resulting in production of any final product (or products).

Basic industrial equipment for chemical production includes the following apparatuses:

- reaction-type – contact devices, reactors, shaft converters, converters (ammonia production) and other devices;
- machines and apparatuses for performance of physical and chemical operations and processes – heat-exchanging and evaporating apparatuses, saturation towers, extractors, absorbers, roll mills, dryers, presses, calenders and so on.

2. *Auxiliary equipment* is various reservoirs, tanks and storages. Auxiliary equipment is designed for performance of additional production processes. So auxiliary equipment provides storage and delivery of the following substances:

- fluids;
- liquidized gases;
- vapors;
- loose materials.

Thus auxiliary equipment includes tanks capable to store and transport various types of substances and materials:

- reservoirs;
- gas holders;
- bunkers;
- silos.

It should be noted that any product (or products), as a rule, are obtained not on a single, but on a number of equipment which represent one integrated technological process. In addition, the change of chemical composition or physical form takes place in each piece of this equipment and, correspondingly, all machines and apparatuses which make up one piece of equipment will operate under its individual operating conditions. For normal technological process behavior each of these machines should maximally correspond to the product being processed under such parameters, as size, form and intrinsic property.

It follows that the type of machine or apparatuses is selected according to the aggregate state, chemical properties, temperature, thermal effect and pressure of substances being a part in the technological process.

Equipment Classification by Process Category

Equipment of each manufacturing enterprise can be divided into dedicated and general industrial equipment. Dedicated equipment is typical for specific production and cannot be used in other technological processes. General industry equipment has universal nature and it is installed at all enterprises regardless of sector affiliation.

Processing equipment provides behavior of various technological processes in manufacturing industries. By type of process that takes place thanks to process equipment operation the latter are subdivided into classes:

- equipment implementing mechanical processes;
- equipment implementing hydromechanical processes;
- equipment implementing thermal processes;
- equipment implementing mass-exchanging processes;
- equipment implementing chemical processes.

Each individual class of process equipment is subdivided into groups in accordance with functional purpose. Groups that include certain technological apparatuses are commonly subdivided into types.

Classes of process equipment are subdivided into groups of apparatuses in accordance with their functional purpose. The term "classification" implies distribution of equipment by groups in accordance with purpose, nature and organization of technological processes, performance (power), control methods (manual, automatic, combined). Chemical production processing equipment is dedicated equipment and intended for implementation of successive chain of technological processes starting from preparation of incoming fresh raw materials to final product fabrication:

- mechanical equipment used for preparation of fresh raw materials for processing – crushing-grinding (crushers, mills), screening (sifting machines, separators, sieves, sorters), as well as feeders, dispensers;
- hydromechanical equipment for purification of fresh raw materials against impurities, using different densities of its components. Hydromechanical processes: centrifuges, separators, sedimentation reservoirs, cyclones, hydrocyclones, filters, scrubber;
- equipment for air and electromechanical cleaning – cyclones, scrubbers, direct-action filters, electrical, catalytic, etc.;
- thermal processes: heat pipes and furnaces, plasmatrons, regenerative and open-type heat exchangers, crystallization and evaporation apparatuses; Thermal (heat) equipment – dryers, regenerative heat exchangers, plasmatrons, recuperators, regenerators;

- mass exchange processes: adsorbers, dryers, apparatuses for diffusion and baromembrane processes, desalinization and dissolution equipment, ion-exchange apparatuses, rectifiers, extractors, dissolvers, neutralizers, membrane equipment, and others;
- chemical processes: furnaces for implementation of chemical processes and chemical reactors.

The above-listed groups of equipment make it possible to decontaminate fresh raw materials, bring it to homogeneous state by mechanical, physical and chemical properties for further treatment. Final product is obtained in the next group of process equipment under generalized term "chemical reactor". Depending on the nature of processes that take place in them, the reactors can be of cold and hot type.

Chemical reactions which proceed under natural conditions are carried out in cold reactors. If high temperatures or catalysts are required in order to obtain a product, then furnaces, autoclaves and special vessels are used as reactors. In its turn, groups of equipment are distributed into types (by mode of operation, type of drive, etc.), and those in its turn – into standard sizes (by overall dimensions, power, efficiency).

For accompanying technological processes auxiliary equipment is intended – it provides collection and storage of by-products, delivery and accumulation of fresh raw materials and final product (reservoirs, gas holders, bunkers, etc.). According to the method of influence on raw materials chemical reactors are divided into apparatuses and machines. Apparatus is called a facility inside of which operation zone (chemical reactions space) locates, where technological process proceeds without involvement of mechanical devices. If normal process flow requires additional mechanisms (agitators, rippers and so on), apparatus becomes a machine.

Description and Classification of Machines

Depending on the technological process structure and final product range, chemical reactors are subdivided into apparatuses and machines of continuous or periodic action.

Apparatuses and machines of periodic action make it possible to manufacture different types of products close in composition (for example, polymers) using the same equipment. Change-over of such reactors requires minimal consumption of time and means. Manufacturing flexibility is a major advantage of intermittent action equipment.

According to principle of technological process structure the machines are commonly divided into equipment of continuous and intermittent action.

- In intermittent action machines different technological process stages proceed within one working volume, but with different time intervals. The key advantage of such equipment is degree of flexibility, i.e. ability to quickly change-over from one type of product to another without degrading its quality.
- In continuous action machines different technological process stages proceed within different working volumes, but at one and the same time interval. The key advantage of such equipment is relatively low metal and power intensity, simplicity of design and high performance.

According to automation level the machines are commonly divided into the following types:

- ordinary machines (operates under operator's control) with simple (manual) control which entirely depends on operator’s experience, knowledge and skill;
- semi-automatic machines (they perform basic operations thanks to installed program, while operator's functions include loading/unloading, control and adjustment); semi-automats are the equipment with several programmed functions or operating modes, for the selection of which the operator is responsible;
- automatic machines (all operations after loading and activation are carried out independently according to the installed program); automats provide full cycle of product manufacture (starting from loading of raw materials to issue of final product), and if they go beyond programmed range of parameters the technological process is interrupted on its own;
- adapting machines (perform logical operations taking into account various conditions). More advanced systems of equipment control can take into account changing conditions of technological process behavior and independently correct operation in accordance with the current situation.

https://ence-gmbh.ru/en/tech_chemical_processing_equipment/.

Text 13
Green Chemistry

In the early 1990s the term *green chemistry* was introduced by the Environmental Protection Agency, an agency of the US Government. The EPA produced a set of 12 principles to guide the chemical industry and in this unit some of these principles will be explained, using wherever possible examples taken from subsequent units dealing with the manufacture of chemicals. These examples illustrate how the search for ways of meeting these principles is a continuing activity. In many instances, changes which reduce the environmental impact of a process also lead to an increase in the profitability of the process. For example, if a new catalyst is developed that reduces the operating temperature and pressure for the process, less energy is consumed which is good both for the environment and for the company.

Prevention. Manufacturers try to generate as little waste as possible, through reaction choice, process design and recycling. Industry aims to use chemical reactions and processes that make the most effective use of available resources and generate the smallest possible amount of waste material. But can prevention be assessed quantitatively?

One way of measuring the efficiency of a process is to calculate the *yield*, which compares the expected product quantity with the actual amount obtained (although some potential product may be 'lost' as a result of competing reactions).

An example is the manufacture of phenol. It used to be made from benzene using sulfuric acid and sodium hydroxide in a multi-stage process, which, overall, can be expressed as

$$C_6H_6 + H_2SO_4 + 2NaOH \longrightarrow C_6H_5OH + Na_2SO_3 + 2H_2O.$$

The chemical equation shows that 1 mol of benzene (78 g) should yield 1 mol of phenol (94 g). In practice, the quantity of phenol produced is found to be about 77 g, giving a yield of 82 %, which may be regarded as quite good (yield % = mass produced / mass expected × 100 %).

However, the calculation obscures the fact that the reaction also generates 1 mol (126 g) of sodium sulfite for each mole of phenol produced. This may be acceptable if there is enough demand for sodium sulfite, but if not, it presents a serious problem of waste management and adds significantly to costs, meaning that this may not be the most suitable reaction for manufacturing phenol.

Atom economy. As an alternative measure to yield, the concept of atom economy is used, considered to be one of the key ideas behind the concepts of green chemistry. This expresses the proportion of reactant atoms that end up in a useful product, measuring the number of atoms of the starting materials that end up as products that are wanted and the number that end up as waste. Atom economy is defined as

$$\text{Atom economy \%} = \frac{\text{Relative molecular mass of desired products}}{\text{Relative molecular mass of all reactants}} \cdot 100\%$$

The nearer the value is to 100, the less the waste will be.

This calculation gives an atom economy of only 37 % for the manufacture of phenol by the old process (assuming sodium sulfite is waste), a clear indicator that it was wise to develop an alternative process.

The manufacture of phenol is generally from benzene and propene, again in consecutive processes which can be expressed, overall, as

$$C_6H_6 + CH_3CH{=}CH_2 + O_2 \longrightarrow C_6H_5OH + CH_3COCH_3.$$

The co-product is propanone which is a valuable chemical and so the atom economy for this process can be regarded as 100 %.

Some reactions that have 100 % atom economy have poor yields and so it is necessary to consider both measures of efficiency, yield and atom economy. Atom economy is determined in the planning stage, by calculation, while yield can only be found experimentally.

In organic chemistry, some types of reaction have inherently better atom economies. Addition, condensation and rearrangement reactions will generally have higher atom economies than either elimination or substitution. For example the addition of chlorine to ethene, to form 1,2-dichloroethane (an important reaction in the manufacture of poly(chloroethene) (PVC)) has an atom economy of 100 %:

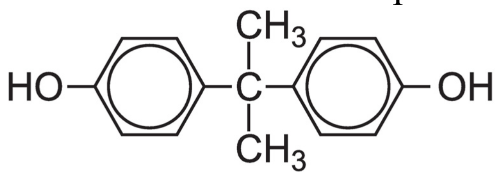
$$H_2C{=}CH_2 + Cl_2 \longrightarrow ClCH_2CH_2Cl.$$

However if the product is hydrolyzed, the atom economy falls:

$$ClCH_2CH_2Cl + 2H_2O \longrightarrow HOCH_2CH_2OH + 2HCl.$$

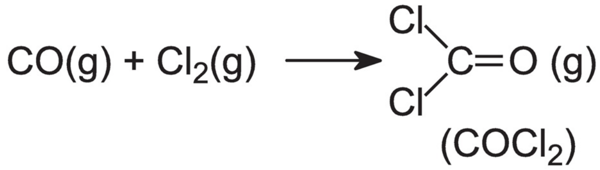
The first is an addition reaction; the latter is a substitution reaction.

Less hazardous chemical synthesis. The family of polycarbonates contains very important polymers which are used where high optical properties combined with strength are needed. The polycarbonate most used is manufactured from bisphenol A, whose structure is

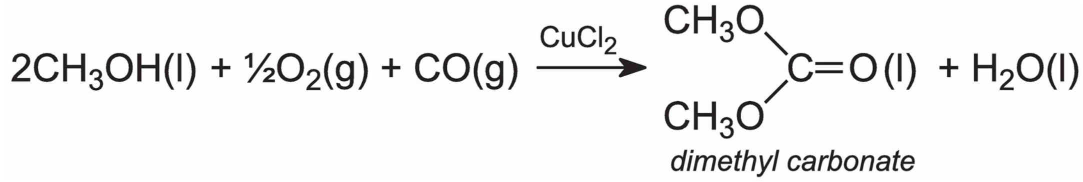


The polycarbonate is manufactured by a condensation reaction between bisphenol A and either carbonyl chloride or diphenyl carbonate.

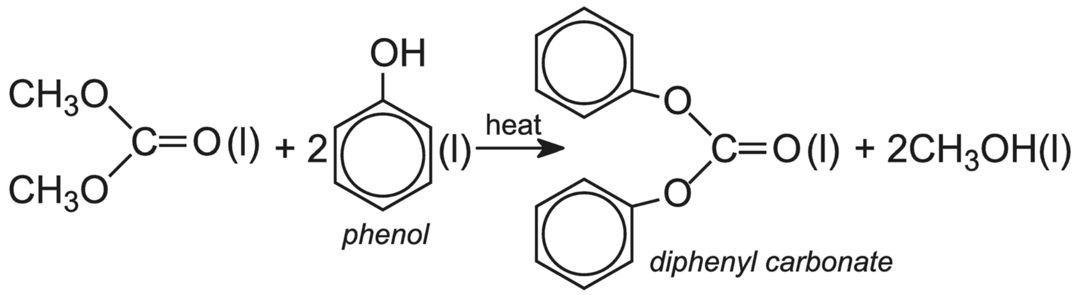
Carbonyl chloride is a very poisonous gas, manufactured from other hazardous gases, carbon monoxide and chlorine:



On the other hand, diphenyl carbonate is produced from dimethyl carbonate, which is readily manufactured from methanol, carbon monoxide and oxygen in the liquid phase, in presence of copper(II) chloride, $CuCl_2$:

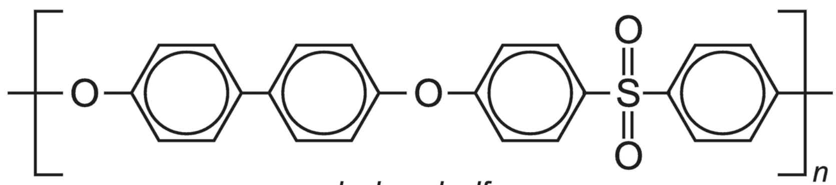


Dimethyl carbonate, when heated with phenol in the liquid phase, forms the diphenyl carbonate:



Overall, the process for the production of polycarbonate that uses diphenyl carbonate is less hazardous than that using carbonyl chloride.

Designing safer chemicals. Underlying the concept of green chemistry is the desire to produce chemicals that are as useful as possible whilst also being both safe for us to use and safe for the environment. Safety refers to both flammability and toxicity. For example, polymers have been developed which are much less flammable than the more well known polymers but also retain properties such as toughness. They must be able to absorb severe impacts without cracking and breaking. One such polymer is polyphenylsulfone which has the formula:



polyphenylsulfone

It is also important that chemicals that are produced are safe for the environment. Some products are specifically intended to be spread on soil, used in water, sprayed in the air or ingested by people; others, like washing detergents, may end up in water courses or in household waste for landfill. In both these cases, the material should degrade to harmless products. Detergents used to be based on the sodium salts of alkylbenzene sulfonic acids, and the alkyl group was branched. These were not degraded naturally in sewage works and caused foaming which made the sewage difficult to manage. Now these compounds have been replaced with sodium salts of linear alkylbenzene sulfonic acids, which are readily degraded. Their production is not simple and it took much research to develop it.

Another development to help the environment was the replacement of the compounds added to detergents to remove magnesium and calcium ions from hard water, known as builders. Sodium phosphates were used for this purpose but these caused considerable problems leading to eutrophication of water courses. Now zeolites (aluminosilicates) are used which are benign.

Further examples are the pyrethoid pesticides which have the duel benefits of breaking down in sunlight in 2 – 3 days and have much lower acute toxicity to humans than phosphorus, or chlorine-based pesticides.

Safer solvents. Reactions that occur in the gas phase are preferable as they avoid the use of solvents to bring the reactants together. Examples include the manufacture of ammonia, the manufacture of methanol and the manufacture of ethene.

Some reactions use water as a solvent, for example in the manufacture of inorganic compounds such as hydrogen peroxide, phosphoric acid, sodium carbonate, and organic compounds such as ethane-1,2-diol and ethanol. Water is not a harmful solvent but it is a precious resource and it is important to ensure that it is not wasted.

In the manufacture of ethanoic acid, the product itself is used as the solvent. However, other reactions use organic solvents which readily evaporate into the atmosphere unless great care is used to contain them. Wherever possible alternative solvents are used which are not harmful, one example being the development of water-borne paints, which are replacing paints that use volatile organic compounds such as the hydrocarbons which are harmful to the atmosphere. Supercritical (liquid) carbon dioxide is widely used as a solvent in the extraction of caffeine from coffee beans and in the latest drycleaning equipment it replaces chlorinated solvents such as perchloroethene, C_2Cl_4.

Energy efficiency and use of waste materials. All manufacturing processes need energy to convert raw materials into useful products. In the chemical industry it is used to heat reactants and in processes such as distillation, product drying, electrolysis, and treatment of waste.

At present, the energy used still relies mainly on fossil fuels, but even so the use of these can be reduced in several ways.

Maintenance and recovery	Good insulation and well-maintained equipment will reduce heat loss, and any waste heat can be used for warming offices and producing hot water rather than being lost to the atmosphere. In some cases this heat may be shared with a local community by piping hot water from the site.
Reaction choice and conditions	Reactions and catalysts that operate at lower temperatures may be chosen. Most reactions based on biosynthesis work at relatively low temperatures; however this may need balancing with the extra energy often needed for product separation.
Combined heat and power (CHP)	Manufacturing sites often generate their own electricity, rather than buying from the grid. This is more efficient as it eliminates transmission losses, and the excess heat released during the generation process can be used on site for many different purposes from pre-heating reactants to keeping offices warm.

Waste often has energy content, and it may be possible to convert this to a useful fuel. Waste solvents from the manufacture of paints, varnishes, adhesives, inks, cleaning fluids and so on are made into a liquid fuel for use by the cement-making industry. A solid fuel is also made from shredded carpets, packaging, furniture, plastics and paper, most of which would otherwise be destined for landfill.

Old vehicle tyres can no longer be sent to landfill in the EU. Many are shredded and used as a fuel by the cement industry. A single plant may consume as many as 250,000 tyres annually.

All fuels of this type must meet strict criteria before use to prevent the production of harmful combustion products, and constant monitoring is essential to ensure the emissions remain within legal requirements.

Traditional processes are being overhauled and more energy efficient ones substituted. Catalysts are being developed so that a process can be run at lower temperatures and pressures (high temperatures and pressures are very energy consuming.

Similarly, the development of molecular sieves means that processes such as the purification of ethanol can be carried out at ambient temperatures instead of by distillation.

Some industries co-operate to make better use of energy. For example, the production of ammonia generates both waste heat and carbon dioxide, both derived from fossil fuel. One UK manufacturer pipes these to large commercial tomato greenhouses, greatly extending the season during which the plants may be grown economically. As well as saving fuel for heating greenhouses, fewer tomatoes need to be imported (saving 'air miles') and the time between picking and purchase is shorter, giving consumers fresher produce.

This use of waste carbon dioxide has recently been enhanced in Iceland in a particularly exciting development. The country is one of the pioneers in building power stations based on geothermal power. In geothermal power stations super-heated steam generated deep underground when water comes into contact with heated rock or magma from the earth's mantle is extracted through a series of boreholes and piped into a turbine, where the steam is used to generate electricity.

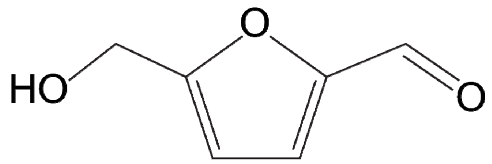
Small amounts of carbon dioxide and other gases such as hydrogen sulphide are emitted from the geothermal areas. In one area in Iceland, the gases from a power plant are piped to an adjacent installation where carbon dioxide is separated from other non-condensable gases and used as an input to a process, where hydrogen and carbon dioxide are passed over a solid catalyst under high pressure to produce renewable methanol. The hydrogen is made by electrolysis of water using electricity from hydro and geothermal power sources. This green methanol can be blended directly with standard petrol or can be used in esterification of vegetable oil or animal fats to produce biodiesel (Fatty Acid Methyl Ester).

Renewable feedstocks. There are many developments aiming to reduce the dependence of the chemical industry on oil. These are discussed in detail in units devoted to biotechnology, biofuels and biorefineries.

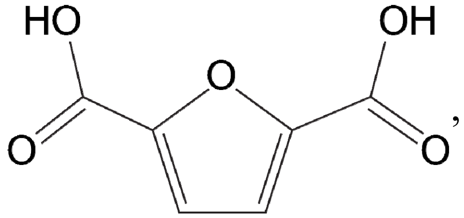
Renewable resources are theoretically inexhaustible, and the range of materials being manufactured from such sources continues to grow. Examples on this website describe the production of a variety of compounds including the production of:

- surfactants are made which are readily biodegradable, and in some cases are manufactured from renewable plant-derived resources such as carbohydrates (sucrose, glucose) or plant oils.
- polyols, from soya, which are used to make polyurethanes.
- ethene from bioethanol, and which is used to make bio-based poly(ethene).

- propene is being produced by a variety of ways from materials produced in turn from biodegradable resources, The propene is used to manufacture bio-based poly(propene).
- 1,4-dimethylbenzene (para-xylene), from bio-based ethene, can be used to make polyesters.
- a wide range of chemicals can be produced in chemocatalytic (bioforming) reactions, for example, hydroxymethylfurfural, HMF:



This can be oxidised to a dicarboxylic acid



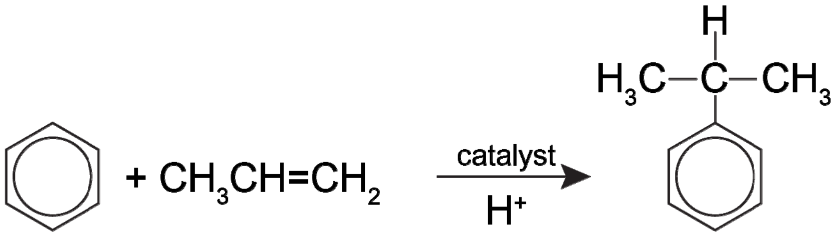
which can be used in place of benzene-1,4-dicarboxylic acid (terephthalic acid) and co-polymerised with a diol to make a polyester with similar properties to polyethylene terephthalate (PET).

Catalysis. Catalysts have played a huge part in the development of more sustainable processes for the manufacture of chemicals. There are many advantages in developing and using catalysts for industrial reactions, some important ones being:

- they affect the conditions that are needed, often reducing energy demand by lowering the temperature and pressure used
- they enable alternative reactions to be used which have better atom economy and thus reduce waste
- it is possible to control reaction pathways more precisely, reducing unwanted side products and making it easier to separate and purify the required product.

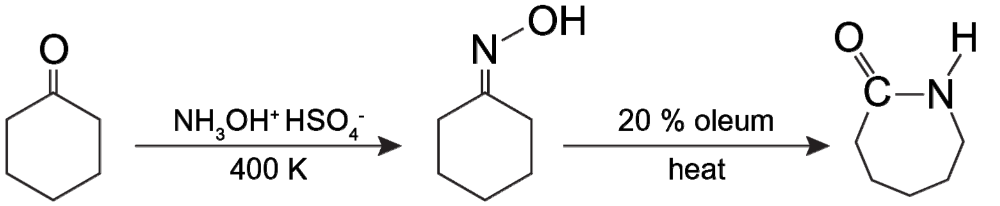
Attention is drawn in the twelve principles to the benefits of catalysts compared to stoichiometric reagents which are necessary for the reaction to take place but which cannot be recovered. For example, aluminium chloride was used for many years in the production of alkylbenzene sulfonates, an active surfactant in many detergents. The aluminium chloride was needed to effect the reaction between benzene and a long chain alkene. The aluminium chloride could not be recycled and became waste as aluminium hydroxide and oxide. Now a solid zeolite catalyst with acid groups is used and can be reused time and time again with no waste products.

Similarly, benzene and propene are converted into cumene in the manufacture of phenol. This reaction needs an acid catalyst, such as aluminium chloride. A solid zeolite with acid groups, such as ZMS-5 is now the favoured catalyst:



The zeolite is more environmentally friendly as the effluent is much cleaner and lower temperatures and pressures can be used.

Another similar example is in the manufacture of one of the most important polymers used to make fabrics, polyamide 6 (sometimes known as nylon 6). In this process cyclohexanone is converted into caprolactam via the oxime (produced by the reaction of the ketone with hydroxylamine hydrogensulfate). The oxime is isomerised by sulfuric acid to caprolactam, the released sulfuric acid is converted to ammonium sulfate.



However, again a zeolite catalyst, with acidic sites, is now being used to effect the rearrangement. The zeolite is regenerated and saves the use and subsequent waste of sulfuric acid.

Another example is the removal of chlorine from effluents in sewage, which is usually present as the chlorate(I) (hypochlorite) ion. The ions are present because chlorination remains the most common form of waste water disinfection. However, this can lead to chlorination of residual organic material in the sewage, leading to chlorinated-organic compounds, which may be carcinogenic or harmful to the aquatic species.

One way of doing this is to reduce the hypochlorite ion to a chloride ion by adding solutions of nickel, iron or cobalt ions to the waste stream in stirred or agitated tanks. Another is to react the sewage with sulfur dioxide or a salt that will react with water to form it. Sulfur dioxide reduces the hypochlorite ion to chloride. However, it is not easy to handle and any escape can be very harmful.

A new process, known as HYDECAT (the Hypochlorite Decomposition Catalysis) uses very finely divided nickel dispersed on an inert solid. These pellets are on beds through which the effluent passes.

There is large surface area of the metal exposed to the effluent and the nickel leads to the reduction of the hypochlorite ion to the chloride ion and oxygen gas. The overall reaction is

$$2OCl^- \longrightarrow 2Cl^- + O_2$$

During the reaction the hypochlorite ion is adsorbed onto the catalyst surface where it is broken down to give a chloride ion with the oxygen atom, remaining on the catalyst surface, combining with an adjacent oxygen atom to form an oxygen molecule. The adsorbed oxygen atom can also oxidise harmful chlorinated-organic compounds. The catalyst can be readily regenerated.

The Hydecat process was originally designed to remove hypochlorite byproduct from waste streams generated during chlorination processes where sodium hydroxide scrubbers are used to remove excess chlorine, for example in the production of chloroethene (vinyl chloride), titanium dioxide (by the chloride route) and chlorofluorocarbons.

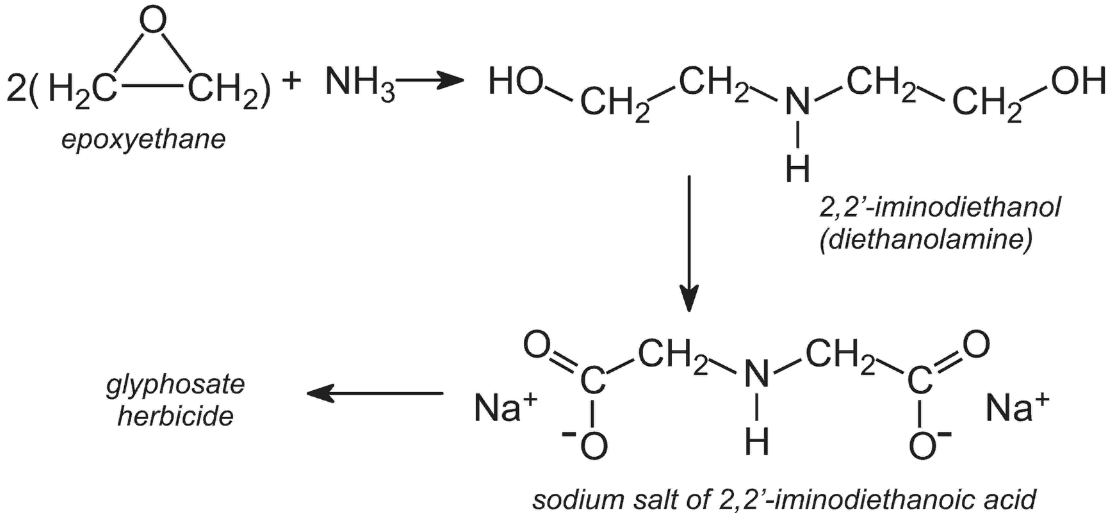
Design for degradation. Among the best known materials that are being produced intentionally for a limited life are degradable plastics. The new generation of surfactants, the alkylbenzene sulfonates have also been designed for rapid degradation.

Inherently safer chemistry for accident prevention. The impact of chemicals on human health and the environment can be the result of

- routine or accidental emissions during production;
- the use and disposal of a product.

It is not in the interest of any industry to waste resources or endanger its workforce, and this is as much an incentive to reduce emissions as are the legal requirements placed upon manufacturers. Some processes of necessity need the handling of dangerous materials but wherever possible industry is attempting to make this safer. One way is to alter the reagents used. For example, one process used in the manufacture of the most widely used herbicide, glyphosate (sold as Roundup), uses the sodium salt of 2,2'-iminodiethanoic acid as one of the intermediates. This is made in a series of reactions from ammonia, methanal (formaldehyde) and hydrogen cyanide. Although hydrogen cyanide is a very useful reagent, it is extremely toxic. A recent innovation has been the introduction of a new route to the sodium salt.

The starting materials are ammonia and epoxyethane, which, on reacting, form 2,2'-iminodiethanol, often named diethanolamine. This is then converted to the sodium salt of 2,2'-iminodiethanoic acid:



Thus in the event of an accident, the consequences would not be as serious, and clean-up would be simpler.

A manufacturing site will also generate waste in the form of unwanted material from the production processes; this may include solvents for reaction, extraction, purification and waste treatment. Solvents can often be recycled or, where this is not feasible, may be used as fuel substitutes (see above). Other waste may ultimately end up in landfill, and this is when the nature of the waste is important.

Many products are disposed of when they reach the end of their useful life. The ideal would be for all such waste to be recycled, rather than it ending up in landfill, though this is more dependent on the willingness of consumers to take responsibility. Products that are likely to go to landfill should be designed so they degrade rapidly and safely.

Cradle to grave. This unit has concentrated mostly on the changes that are being made to industrial production processes to make them more consonant with the principles of green chemistry. However a consideration of the environmental impact of a product from the time it is made until it is no longer required also requires a more detailed account of recycling and the degradation of disposed material (particularly plastics).

http://www.essentialchemicalindustry.org/processes/green-chemistry.html.

CONCLUSION

Эта книга – своеобразный вводный курс в химическую технологию на английском языке, предшествующий традиционным русскоязычным курсам, объясняющим массоперенос, теплообмен и другие физические явления применительно к химической технологии. Издание адресовано студентам, решившим изучать химическую технологию. Цель пособия – не только развить навыки чтения, говорения и письма на английском языке, но и помочь в освоении сложной программы, объединяющей в себе физику, химию, математику и другие науки.

Информация о комплексной природе химической технологии, материалах и технических процессах отрасли, экологических проблемах, связанных с химическим производством, о профессиональной этике и компетенциях, необходимых для профессионального роста, представленная в учебном пособии на английском языке, формирует основу профессионального общения с зарубежными партнерами.

Для того чтобы не утратить обретенные знания и навыки, надо продолжить увлекательное путешествие в мир английского языка. Книги, видео, сайты, социальные сети помогут учащимся двигаться дальше, поэтому никогда не следует останавливаться на достигнутом результате.

REFERENCES

1. AIChE Code of Ethics [Электронный ресурс]. – URL: https://www.aiche.org/about/code-ethics (дата обращения: 13.05.2018).
2. Grubbe, Deborah L. How to Think About Ethics / Deborah L. Grubbe. – Rugby : UK Institution of Chemical Engineers, 2017 (дата обращения: 13.05.2018).
3. Encyclopaedia Britannica [Электронный ресурс]. – URL: https://corporate.britannica.com/about/ (дата обращения: 13.05.2018).
4. History of Plastic [Электронный ресурс]. – URL: http://www.historyofplastic.com/ (дата обращения: 13.05.2018).
5. Polymers [Электронный ресурс]. – URL: https://www.toppr.com/ guides/chemistry/polymers/ (дата обращения: 13.05.2018).
6. Preliminary Chemical Engineering Plant Design [Электронный ресурс]. – URL: https://kupdf.net/download/preliminary-chemical-engineering-plant-design_5b061cc0e2b6f5a04ae0275e_pdf (дата обраще-ния: 13.05.2018).
7. Reinoso Oswaldo. Introduction to Chemical Engineering Tools for Today and Tomorrow [Электронный ресурс]. – URL: https:// kupdf.net/download/introduction-to-chemical-engineering-tools-for-today-and-tomorrow_5af6afb2e2b6f5ad671d83d9_pdf (дата обращения: 13.05.2018).
8. Sánchez, A. (2019) The Current Role of Chemical Engineering in Solving Environmental Problems. Frontiers in Chemical Engineering [Электронный ресурс]. – URL: http://www.researchgate.net/publication/ 336807322_The_Current_Role_of_Chemical_Engineering_in_Solving_Environ mental_Problems (дата обращения: 13.05.2018).
9. Science History Institute [Электронный ресурс]. – URL: https://www.sciencehistory.org/about-us (дата обращения: 13.05.2018).
10. Seven Charts That Explain the Plastic Pollution Problem [Электронный ресурс]. – URL: https://www.bbc.com/news/science-environment-42264788 (дата обращения: 13.05.2018).
11. Synthetic Polymers [Электронный ресурс]. – URL: https://ru. scribd.com/doc/19255206/Synthetic-Polymers (дата обращения: 13.05.2018).
12. Synthetic Polymers. Quizlet [Электронный ресурс]. – URL: https://quizlet.com/205295972/synthetic-polymers-flash-cards/ (дата обращения: 13.05.2018).
13. The Environmental Chemical Engineering [Электронный ресурс]. – URL: https://www.frontiersin.org/journals/chemical-engineering/sections/ environmental-chemical-engineering#about (дата обращения: 13.05.2018).
14. The Essential Chemical Industry – Online [Электронный ресурс]. – URL: http://www.essentialchemicalindustry.org/ (дата обра-щения: 13.05.2018).
15. Visual Encyclopedia of Chemical Engineering Equipment [Электронный ресурс]. – URL: http://encyclopedia.che.engin.umich.edu/ (дата обращения: 13.05.2018).

ОГЛАВЛЕНИЕ

Учебное издание

ЗАМАРАЕВА Галина Николаевна

МИР ХИМИЧЕСКОЙ ТЕХНОЛОГИИ

WORLD OF CHEMICAL ENGINEERING

Учебное пособие по английскому языку

Редактор Е. С. Глазкова
Технический редактор С. Ш. Абдуллаева
Корректор Н. В. Пустовойтова
Корректор иностранного языка О. А. Селиверстова
Компьютерная верстка П. А. Некрасова
Выпускающий редактор А. А. Амирсейидова

Подписано в печать 25.12.19.
Формат 60×84/16. Усл. печ. л. 7,91. Тираж 50 экз.
Заказ
Издательство
Владимирского государственного университета
имени Александра Григорьевича и Николая Григорьевича Столетовых.
600000, г. Владимир, ул. Горького 87.