# ИНОСТРАННЫЙ ЯЗЫК

## ХИМИЧЕСКИЕ ТЕХНОЛОГИИ

***Методические указания к самостоятельным работам для студентов бакалавриата направления 18.03.01***

**САНКТ-ПЕТЕРБУРГ**
**2021**

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Санкт-Петербургский горный университет

Кафедра иностранных языков

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**ИНОСТРАННЫЙ ЯЗЫК. Химические технологии. FOREIGN LANGUAGE. Chemical technologies:** Методические указания к самостоятельным работам / Санкт-Петербургский горный университет. Сост.: *Ю.В. Борисова, Н.В. Корниенко.* СПб, 2021. 40 с.

Предлагаемый материал направлен на формирование и совершенствование навыков работы со словарем, чтения и перевода профессионально-ориентированных текстов. В методические указания включены оригинальные тексты, а также комплекс упражнений, направленных на овладение и закрепление лексического и грамматического материала и способствующих развитию речевой, языковой и профессиональной компетенций студентов. Тематика текстов и задания к ним способствуют накоплению словарного запаса, включающего в себя основные английские термины по направлению «Химическая технология». Предназначены для самостоятельной работы по английскому языку для студентов бакалавриата 2 курса.

Предназначены для студентов бакалавриата направления подготовки 18.03.01 «Химическая технология» профиля подготовки «Химическая технология природных энергоносителей и углеродных материалов» и согласованы с программой по иностранному языку для студентов неязыковых вузов.

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# ПРЕДИСЛОВИЕ

Данные Методические указания предназначены для самостоятельной работы студентов бакалавриата направления подготовки 18.03.01 «Химическая технология (Химическая технология природных энергоносителей и углеродных материалов)».

Целью данных методических указаний является развитие у студентов навыков изучающего, ознакомительного, поискового чтения студентов-бакалавров в рамках совершенствования их иноязычной профессиональной компетенции. Тематика оригинальных текстов охватывает основные вопросы в области химических технологий, а именно: процессы и устройства, главные направления, а также проблемы защиты окружающей среды при использовании химических технологий и относительно новому направлению в производстве, как «зеленая химия».

Материал методических указаний в том числе способствует овладению студентами иноязычной коммуникативно-речевой компетенцией, позволяющей будущему специалисту осуществлять профессиональную деятельность с использованием иностранного языка; формированию активного словарного запаса, который включает наиболее употребительные термины и выражения на английском языке по теме «Химические технологии».

Методические указания состоят из четырех разделов, каждый из которых включает в себя оригинальные тексты профессиональной направленности и упражнения к ним. Задания для чтения и перевода составлены на материале текстов в оригинале и сопровождаются специально разработанными лексико-грамматическими упражнениями, направленными на активизацию когнитивной деятельности обучающихся, освоение нового лексическо-грамматического материала, и способствуют развитию коммуникативных навыков в сфере профессионального общения на английском языке.

# UNIT 1. INTRODUCTION INTO CHEMICAL TECHNONOGY

**I. Read the text and answer the following questions:**

What does petrochemical industry produce?

What are the main factors the petrochemical industry is influenced by?

## FUNDAMENTALS OF PETROCHEMICAL INDUSTRY

The petrochemical industry has evolved out of oil and gas processing by adding value to low value **by-products**, which have limited use in the fuels industry. The industry now produces a remarkable range of useful products, including plastics, synthetic rubber, **solvents**, **fertilizers**, pharmaceuticals, additives, explosives and adhesives.

Petrochemical products are used in cars, packaging, household goods, medical equipment, paints, clothing and building material to name just a few of the common applications. The petrochemicals industry sources raw materials from refining and gas processing and converts these raw materials into valuable products using a variety of chemical process technologies. Furthermore, the industry continues to innovate through new technology and the ability to process different types of raw materials.

The target markets for petrochemical products are smaller and more specialized in comparison to the markets for refined products and natural gas. Although petrochemical products usually earn premium prices compared to refined products and natural gas product, marketing is more demanding. Market risks and competitive analysis therefore play an important role in lender assessment of petrochemical project finance transactions.

In terms of production volumes the industry represents approximately 10% of the total petroleum industry. Due to the product value, however, the petrochemical industry represents a larger share of the total industry, reflecting the higher value of petrochemical products compared to fuels.

The demand for chemicals and plastics is driven by global economic conditions, which are directly linked to demand for consumer goods.

The petrochemical industry has been **impacted** by the globalization and integration of the world economy. World-scale petrochemical plants built in recent years are substantially larger than those built over two decades ago. As a result, smaller, older, and less efficient units are being shut down, expanded, or, in some cases, retrofitted to produce new chemical products. The factors influencing world petrochemicals industry development are the following:

**Environment.** Increasing concerns over fossil fuel supply and consumption, with respect to their impact on health and the environment, have led to the passage of legislation globally that will affect chemical and energy production and processing for the foreseeable future.

**Technology.** Manufacturing processes introduced in recent years have resulted in raw material replacement, shifts in the ratio of co product(s) produced and costs that have led to the imbalance between supply and demand. In addition, growing environmental concerns have expedited the development and commercialization of renewably derived chemical products.

**Shale gas development.** Natural gas production from "shale" formations is one of the most rapidly growing trends in U.S. energy exploration and production. In some cases, this fast expansion has resulted in natural gas drilling and production activity in parts of the country that have seen little or no activity of this type in the recent past. Among the various technological advances, the combination of vertical **hydraulic fracturing** ("fracking") and horizontal drilling in multistage hydraulic fracturing resulted in a considerable rise in natural gas production in the United States. This new potential has caused many countries to reexamine their natural gas reserves and pursue development of their own gas plays.

**Political uncertainties.** The political situations in all parts of the world —the Middle East, Africa, the CIS, and South America and even quite sustainable markets such as the United States, the United Kingdom, and the European Union— have growing global implications for the supply and demand of petrochemicals and raw materials.

**Economic growth and demand.** The overall expansion of the population and an increase in individual purchasing power has resulted in an increase in demand for final products and greater consumption of energy in China, India, and Latin America.

**Vocabulary**

by-product – побочный продукт, отходы
solvents - растворитель
fertilizers - удобрения
additives – присадки, разбавители
feedstocks - сырье

impact - влиять
retrofit – модифицировать, модернизировать
upstream and downstream - добыча и переработка
hydraulic fracturing – гидравлический разрыв (пласта)
multistage – многоярусный, многоступенчатый

## II. Match the terms in the first column with their definitions given in the second column.

| | |
|---|---|
| by-product | a substance added to another in relatively small amounts to effect a desired change in properties |
| solvent | raw material supplied to a machine or processing plant |
| fertilizer | a substance used for sticking objects or materials together; glue. |
| additive | a liquid substance capable of dissolving or dispersing one or more other substances |
| adhesive | a secondary product derived from a production process, manufacturing process or chemical reaction; it is not the primary product or service being produced. |
| feedstock | a substance (such as manure or a chemical mixture) used to make soil more |

## III. Translate the following sentences into English

1. Нефтехимическая промышленность - отрасль тяжёлой индустрии, охватывающая производство синтетических материалов и изделий главным образом на основе продуктов переработки нефти и природных горючих газов.

2. Нефтехимическая промышленность получает сырье от переработки нефти и газа и преобразует это сырье в ценные продукты, используя различные технологии химических процессов.
3. По объемам производства нефтехимическая промышленность составляет около 10% от всей нефтяной промышленности.
4. Основными факторами, влияющими на развитие нефтехимической промышленности, являются цены на нефть, экологическая и политическая обстановка, а также покупательская способность населения.
5. Нефтехимическая промышленность подвержена существенному влиянию глобализации и интеграции в мировую экономику.
6. Производственные процессы, внедренные в последние годы, привели к замене сырья, сдвигу в соотношении производимых побочных продуктов и стоимости, что привело к дисбалансу между спросом и предложением.
7. Сочетание вертикального гидравлического разрыва пласта и горизонтального бурения с многостадийным гидравлическим разрывом привело к значительному увеличению добычи природного газа в США.

## IV. Read the text and translate it into Russian

## BASIC CHEMICALS

In the petrochemical industry, the organic chemicals produced in the largest volumes are methanol, ethylene, propylene, butadiene, benzene, toluene, and xylenes.

Ethylene, propylene, and butadiene, along with butylenes, are collectively called alkenes. Alkenes are acyclic (branched or unbranched) hydrocarbons having one carbon-to-carbon double bond (C=C), with the general molecular formula CnH2n. Because alkenes contain less than the maximum possible number of hydrogen atoms per carbon atom they belong to a class of unsaturated aliphatic hydrocarbons.

Olefins contain one or more double bonds, which make them chemically reactive. Benzene, toluene, and xylenes, commonly referred to as aromatics, are unsaturated cyclic hydrocarbons containing one or more rings. Olefins, aromatics, and methanol are precursors to a variety of chemical products and are generally referred to as primary petrochemicals.

The terms alkenes and olefins are often used interchangeably; however, this is not quite accurate. According to IUPAC (*International Union of Pure and Applied Chemistry*), alkenes include all aliphatic hydrocarbons exhibiting one and only one double bond. Olefins encompass a larger set of compounds, including alkenes. In fact, olefins include all aliphatic (both acyclic and cyclic) hydrocarbons having one or more carbon-to-carbon double bonds: alkenes, cycloalkenes, and polyenes.

Alkenes are defined by the carbon-to-carbon double bond, and it is this bond that is responsible for several specific properties of alkenes. The double bond is a shorter, and therefore stronger, bond than the analogous single bond; a greater amount of energy is required to break a double bond than to break a single bond. Another important property of double bonds is their reactivity. Double bonds are more reactive than their single bond counterparts are, and are particularly susceptible to addition reactions, including polymerization. Due to their high reactivity, alkenes are not commonly found in crude oils. For the same reason, it is not usually desirable to have alkenes in end products, as they could react, affecting the **viscosity** and other properties of the fuel. Alternatively, some products such as some varnishes or wood floor finishes purposely incorporate molecules with double bonds, so that a polymerization reaction will occur and form the desired hard film on the surface.

Many of the physical properties of alkenes are similar: they are colorless, nonpolar, and combustible. The physical state depends on molecular mass: like the corresponding saturated hydrocarbons, the simplest alkenes (ethylene, propylene, and butene) become gases at room temperature. Linear alkenes of approximately five to sixteen carbons are liquids, and higher alkenes are waxy solids. The melting point of the solids also increases with increase in molecular mass.

Alkenes generally have stronger smells than their corresponding alkanes. Ethylene has a sweet and musty odor. Like norbornene and *trans*-cyclooctene strained alkenes, in particular, are known to have strong, unpleasant odors, a fact consistent with the stronger π complexes they form with metal ions including copper.

Alkenes are produced by hydrocarbon cracking. The raw materials for alkenes are mostly natural gas condensate components (principally ethane and propane) in the US and Mideast and naphtha in Europe and Asia. Alkanes are broken apart at high temperatures, often in the presence of a zeolite catalyst, to produce a mixture of primarily aliphatic alkenes and lower molecular weight alkanes. The mixture is feedstock and temperature dependent, and separated by fractional distillation. This is mainly used for the manufacture of small alkenes (up to six carbons).

**Vocabulary**

xylene - ['zaili:n] – ксилен
olefin - олефин
unsaturated – ненасыщенный, непредельный
aliphatic – жирный, алифатический
double bond – двойная связь
cyclic hydrocarbons – циклические углеводороды
precursor – предшественник, прекурсор
susceptible – чувствительный
viscosity - вязкость
linear – нормальный, линейный
nonpolar – неполярный, аполярный
combustible – горючий, воспламеняющийся
fractional distillation – перегонка нефти

**V. Answer the following questions:**

1. What is the joint name for ethylene, propylene, and butadiene?
2. Why do alkenes belong to a class of unsaturated aliphatic hydrocarbons?
3. What is the difference between a carbon-to-carbon double bond and a single bond?
4. What kinds of hydrocarbons do olefins include?

5. What are the basic physical properties of alkenes?
6. What raw materials are mainly used for producing alkenes?

**VI. Using the dictionary find the definitions for the following terms and give the Russian equivalents to them:**

unsaturated cyclic hydrocarbons
unsaturated aliphatic hydrocarbons
susceptible to addition reactions
single bond
double bond
π complex structure
natural gas condensate components
zeolite catalyst
fractional distillation

**VII. Read the text filling the gaps with the words from the box:**

## TYPES OF CHEMICALS

**Vocabulary**

| |
|---|
| **crucial immense witnessed misleading straight chain environmentally-conscious subjected detergents fragrances monomers fertilizers feldspar biomass ethene aromatic toiletries colorants cracker macromolecules sugar** |

The chemical industry creates an _______variety of products that impinge on virtually every aspect of our lives. While many of the products from the industry, such as ______, soaps and perfumes, are purchased directly by the consumer, others are used as intermediates to make other products. For example, in Europe, 70% of chemicals manufactured are used to make products by other industries including other branches of the chemical industry itself. The industry uses a wide range of raw materials, from air and minerals to oil.

With the worldwide increasing competition, the innovations remain ______in finding new ways for the industry to satisfy its demanding and ___________ consumers.

The products of the chemical industry can be divided into three categories: basic chemicals, specialty chemicals and consumer chemicals.

**Basic chemicals**

Basic chemicals are divided into chemicals derived from oil, known as petrochemicals; polymers; basic inorganics.

***Petrochemicals*** are chemicals derived from petroleum or natural gas. They are an essential part of the chemical industry as the demand for synthetic materials grows continually and plays a major part in today's economy and society. Petrochemicals are used to manufacture thousands of different products that people use daily, including plastics, medicines, cosmetics, furniture, appliances, electronics, solar power panels, and wind turbines.

Petrochemicals are derived from hydrocarbons such as propane, ethane, butane, or other components separated from crude oil and natural gas liquids. Naphtha - a mixture of flammable liquid hydrocarbons - is also important in the production of products made from petrochemicals. After being separated in some sort of distillation process, separated hydrocarbons can be fed to a manufacturing facility known as a **cracker**. This cracker works to break chemical bonds in hydrocarbon materials which allow them to be converted into more useful chemicals for production. One major petrochemical is ethylene, used to create polyethylene - one of the most important plastics in manufacturing.

The term 'petrochemical' can be _______ as the same chemicals are increasingly being derived from sources other than oil, such as coal and ______. For example, methanol is commonly produced from oil and natural gas in the US and Europe but from coal in China. Another example is ethene, derived from oil and gas in the US and Europe but increasingly from biomass in Brazil. Basic chemicals, produced in large quantities, are mainly used within the chemical industry before becoming products for the general consumer. For example, ethanoic acid is used to make esters, much of which in turn is sold to make paints and at that point sold to the consumer. Huge quantities of ______ are transported by pipeline around Europe and used by the companies producing poly (ethene) and other polymers.

The production of chemicals from petroleum, and increasingly from coal and biomass, has ______ many technological changes. The hydrocarbons in crude oil and gas, which are mainly _______ alkanes, are first separated using their differences in boiling point. They are then converted to hydrocarbons such as branched chain alkanes, alkenes and _____ hydrocarbons. In turn, these hydrocarbons are converted into a very wide range of basic chemicals which are immediately useful (petrol, ethanol, ethane-1,2-diol) or are _______ to further reactions to produce useful end product (for example, phenol to make resins and ammonia to make fertilizers).

***Polymers*** are natural or synthetic substances composed of very large molecules, called _________ 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_______ and such man-made materials as concrete, glass, paper, plastics, and rubbers.

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 _______; 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 ______ molecules. Lignin consists of a complicated three-dimensional network of polymers. Wood resins are polymers of a simple hydrocarbon, isoprene.

Basic inorganics are relatively low cost chemicals used throughout manufacturing and agriculture. They are produced in very large amounts and include chlorine, sodium hydroxide, sulfuric and nitric acids and chemicals for fertilizers. Many emerging countries are now able to produce petrochemicals at a cheaper price than those located in the US or Europe. This has led to tough competition and producers of these chemicals worldwide have been working continuously to reduce the costs while meeting ever more stringent environmental and safety standards.

**Specialty chemicals**

This category covers a wide variety of chemicals for crop protection, paints and inks, ______ (dyes and pigments). It also includes chemicals used by such industries as textiles, paper and engineering. There has been a tendency in the US and Europe to focus on this sector rather than the basic chemicals due to specialty chemicals' profitability and safer delivery. New products are being created to meet both customer needs and new environmental regulations. An everyday example is household paints which have evolved from organic solvent-based to water-based. Another example is the latest ink developed for ink-jet printers.

**Consumer chemicals**

Consumer chemicals are sold directly to the public. They include, for example, detergents, soaps and other ______. Searching for more effective and environmentally safe detergents has increased over the last 20 years, particularly in finding surfactants capable of cleaning anything from sensitive skin to large industrial plants. Alongside with it, a lot has been done in producing a wider range of synthetic chemicals for toiletries, cosmetics and ______.

## Vocabulary

immense – огромный, обширный
detergents – моющие средства
crucial – ключевой, существенный
ethene – этен, этилен
ester – сложный эфир
witness – пережить, быть свидетелем
end-use market – рынок конечного потребления
straight chain - прямая цепь
branched chain -

fertilizers –удобрения
are subjected to further reactions – подвергаются дальнейшим реакциям
end product – конечный продукт
feldspar – полевой шпат
emerging countries – развивающиеся страны (с формирующимся рынком)
specialty chemicals - специализированные химикалии; химические продукты тонкого органического синтеза
crop protection – защита посевов, пестициды
toiletries – банные принадлежности, средства гигиены
surfactant - ПАВ

разветвленная цепь
aromatic hydrocarbons – ароматические углеводороды

**VIII. Divide the following products into three categories:**

Calcium carbonate, petrol, iodine, cellulose, sulfur, polyethylene, polypropylene, methanol, polystyrene, ammonia, polyvinyl chloride, sodium carbonate, wool, rubber, ethene, ethanoic acid.

| Petrochemicals | Polymers | Basic inorganics |
|---|---|---|
| | | |

**IX. Give the full names to the following chemical elements and compounds:**

Cl, CH□COOH, NaOH, H□SO□, HNO□, $C_2H_4$, $NH_3$, $CH_3OH$, $(C_6H_{10}O_5)n$

How to read chemical formulae

In Russian, we call each chemical element either one letter (as in the case of $H_2O$), or a whole name from the table (for example, Cl - хлор). As a rule, we name the elements consisting of 2 letters with a whole name (Ca – кальций, Na – натрий). In English, the letters that make them up pronounce all chemical elements. Moreover, the names of the letters are used in English, not in Latin! Therefore, hydrogen H is not called "ash", but [eiʧ], and copper Cu will be pronounced as separate letters C and U [si: ju:]. We shouldn’t also forget about the numbers. Thus, the formula for water $H_2O$ would sound like [eiʧ tu: ou] in English.

**X. Choose one type of the basic chemicals and describe its chemical and physical properties.**

## UNIT 2. CHEMICAL REACTORS

**I. Read the text and answer the questions:**

1. What types of chemical reactors do you know?
2. Where is a batch reactor mainly used?

3. What is the difference between batched and continuous reactors?
4. Name the types of continuous reactors.
5. What type of continuous reactors is widely used in chemical industry nowadays?
6. What is a catalyst?
7. What catalysts are used in fluid bed reactors in producing of PVC (*polyvinyl chloride*)?
8. What conditions provide plug flow?

The reactors, in which chemicals are produced, vary in size from a few $cm^3$ to the vast structures that are often depicted in photographs of industrial plants. For example, **kilns** that produce lime from **limestone** may reach over 25 meters high. The design of the reactor is determined by many factors but of particular importance are the thermodynamics and kinetics of the chemical reactions being carried out. The two main types of reactor are termed *batch* and *continuous reactors*. ***Batch reactors*** are mainly used in a laboratory. The reactants are placed in a **test-tube**, **flask** or **beaker**.

They are mixed together, often heated for the reaction to take place and cooled afterwards. The products are poured out and, if necessary, purified. This procedure is also carried out industrially, the key difference being one of size of reactor and the quantities of reactants.

Following reaction, the reactor is cleaned ready for another batch of reactants to be added. Batch reactors are usually used when a company wants to produce a range of products involving different reactants and reactor conditions. They can then use the same equipment for these reactions. Examples of processes that use batch reactors include the manufacturing of colorants and margarine.

**Continuous reactors.** An alternative to a batch process is to feed the reactants continuously into the reactor at one point, allow the reaction to take place and withdraw the products at another point. There must be an equal flow rate of reactants and products. While *continuous reactors* are rarely used in the laboratory, a water-softener can be regarded as an example of a continuous process. Hard water from the mains is passed through a tube containing an **ion-exchange resin**. Reaction occurs down the tube and soft water pours out at the exit.

Continuous reactors are normally installed when large quantities of a chemical are being produced. It is important that the reactor can operate for several months without a breakdown.

The **residence time** in the reactor is controlled by the feed rate of reactants to the reactor. For example, if a reactor has a volume of 20 $m^3$ and the **feed rate** of reactants is 40 $m^3$ $h^{-1}$ the residence time is 20 $m^3$ /40 $m^3$ $h^{-1}$ = 0.5 h. It is simple to control accurately the flow rate of reactants.

The product from a continuous reactor tends to be of a more consistent quality because the reaction parameters (e.g. residence time, temperature and pressure) are better controlled than in batch operations. They also produce less waste and require much lower storage of both raw materials and products resulting in a more efficient operation. The main disadvantage is their lack of flexibility as once the reactor has been built it is only in rare cases that it can be used to perform a different chemical reaction.

There are several types of continuous reactors that are used in chemical industry.

In a ***tubular reactor***, fluids (gases and/or liquids) flow through it at high velocities. As the reactants flow, for example along a heated pipe, they are converted to products. At high velocities, the products are unable to **diffuse** back and there is almost no **back mixing**. The conditions are referred to as **plug flow**. This reduces the occurrence of side reactions and increases the yield of the desired product.

With a constant flow rate, the conditions at any one point remain constant with time. The reaction rate is faster at the pipe inlet because the concentration of reactants is at its highest point. The reaction rate reduces as the reactants flow through the pipe due to the decrease in concentration of the reactant.

Tubular reactors are used, for example, in the steam cracking of ethane, propane and butane and naphtha to produce alkenes.

### *Fixed bed reactors*

A heterogeneous catalyst is used frequently in industry where gases flow through a solid catalyst (which is often in the form of small pellets to increase the surface area). It is often described as a fixed bed of catalyst (Figure 3).

Among the examples of their use are the manufacture of sulfuric acid (the Contact Process, with vanadium (V) oxide as catalyst), the manufacturing nitric acid and ammonia (the Haber Process, with iron as the catalyst).

The further example of a fixed bed reactor is a catalytic reforming of naphtha to produce branched chain alkanes, cycloalkanes and aromatic hydrocarbons using usually platinum or a platinum-rhenium alloy on an alumina support.

### *Fluid bed reactors*

A fluid bed reactor is sometimes used whereby the catalyst particles, which are very fine, are placed on a distributor plate. When the gaseous reactants pass through the distributor plate, the particles are carried with the gases forming a fluid. This ensures a very good mix of the reactants with the catalyst, with a high contact between the molecules of gas which provides a rapid reaction, a uniform mixture, reducing the variability of the process conditions.

One example of using fluid bed reactors is the oxychlorination of ethane to chloroethene (vinyl chloride), the feedstock for the polymer poly(chloroethene) (PVC). The catalyst is copper (II) chloride and potassium chloride deposited on the surface of alumina. This support is so fine that it acts as a fluid when gases pass through it.

Another example is the catalytic cracking of gas oil to produce alkenes (ethene and propene) and petrol with a high octane rating. In a silica-alumina catalyst fine particles of carbon are rapidly deposited on its surface and the catalyst quickly becomes ineffective. The catalyst, still in the form of a fluid, is regenerated as it passes into a second vessel where it is heated strongly in air (sometimes with added oxygen) burn off the carbon and then returned into the reaction zone and mixed with gas oil. These reactors are larger than fixed bed reactors and are more expensive to construct. However, it is easier to control the conditions to make the process more efficient.

***Continuous stirred tank reactors, CSTR***

In a CSTR, one or more reactants, for example in solution or as slurry, are introduced into a reactor equipped with an impeller (stirrer) and the products are removed continuously. The impeller stirs the reagents vigorously to ensure good mixing so that there is a uniform composition throughout. The composition at the outlet is the same as in the bulk in the reactor. These are exactly the opposite conditions to those in a tubular flow reactor where there is virtually no mixing of the reactants and the products. A steady state must be reached where the flow rate into the reactor equals the flow rate out, for otherwise the tank would empty or overflow. The residence time is calculated by dividing the volume of the tank by the average volumetric flow rate. For example, if the flow of reactants is 10 $m^3$ $h^{-1}$ and the tank volume is 1 $m^3$, the residence time is 1/10 h, i.e. 6 minutes.

A CSTR reactor is used, for example in the production of the amide intermediate formed in the process to produce methyl 2-methylpropenoate. Sulfuric acid and 2-hydroxy-2-methylpropanonitrile are fed into the tank at a temperature of 400 K. The heat generated by the reaction is removed by cooling water fed through coils and the residence time is about 15 minutes.

A variation of the CSTR is the loop reactor that is relatively simple and cheap to construct. In the diagram, only one loop is shown. However, the residence time in the reactor is adjusted by altering the length or number of the loops in the reactor.

Loop reactors are used, for example, in the manufacturing of poly (ethene) and the manufacture of poly(propene). Ethene (or propene) and the catalyst are mixed, under pressure, with a diluent, usually a hydrocarbon. A **slurry** is produced which is heated and circulated around the loops. Particles of the polymer gather at the bottom of one of the loop legs and, with some hydrocarbon **diluent**, are continuously released from the system. The diluent evaporates, leaving the solid polymer, and is then cooled to reform a liquid and passed back into the loop system, thus recirculating the hydrocarbon.

Vocabulary

kiln – сушильная печь
limestone - известняк
*batch reactor – реактор циклического действия*
continuous reactors – реактор непрерывного действия
test tube - пробирка
flask – сосуд
beaker - мензурка
ion-exchange resin – ионообменные смолы
residence time – время нахождения (*зд.:* в реакторе)
rhenium – рений (Re, 75-й элемент таблицы Менделеева)
diluents – растворитель
recirculate – повторно пропустить через систему
feed rate – периодичность загрузки реактора
diffuse – рассыпаться, распаляться
back mixing – обратная реакция
plug flow – идеальное вытеснение
slurry – суспензия, шлам
vapour – пары, испарения

**II. Match the following words and word combinations with their Russian equivalents. Make your own sentences with five of them.**

| | |
|---|---|
| diluents | действующее вещество |
| diffuse | время нахождения в реакторе |
| lack of flexibility | октановое число |
| catalytic reforming | ионообменные смолы |
| residence time | рассыпаться, рассеиваться |
| reaction rate | объемный расход |
| octane rating | ограниченная функциональность |
| ion-exchange resin | скорость протекания реакции |
| reactant | растворитель |
| volumetric flow rate | catalytic reforming |

**III. Translate the following extract into English.**

Теплообменники

Теплообменники в химической промышленности представляют собой специальные установки, проводящие регулировку температуры между теплоносителями. Устройства проводят смешение горячего и холодного агента в определенных пропорциях. В химической отрасли процесс теплопередачи связан с обменом тепловой энергией между действующими веществами. Потому, теплообменники химической промышленности востребованы в процессе синтеза различных веществ. Кожухотрубные (shell and tube) теплообменники наиболее распространены в химической промышленности. Это аппараты, предназначенные для передачи тепла между двумя автономными потоками – горячим и холодным. Процесс теплообмена заключается в движении жидкостей в разных полостях. Во время движения жидкости горячая среда предает тепло холодной через стенки теплообменных труб. Еще один тип теплообменника - конденсаторы для ректификационной колонны (distillation column). Перегретые пары из верхней части колонны поступают в конденсатор, где они охлаждаются до температуры насыщения (saturation temperature) при помощи воды и полностью конденсируются.

## UNIT 3. CHEMICAL PROCESSES

**I. Read the text and answer the questions:**

1. What is a catalyst?
2. What are the 3 types of catalysis?
3. What is an autocatalysis?
4. What is homogeneous catalysis?
5. How do heterogeneous catalysts work?
6. What are the most common examples of heterogeneous catalysis?

### CATALYSIS

**Catalysts** are integral in making plastics and many other manufactured items. Even the **human body** runs on **catalysts**. Many proteins in human **body** are actually **catalysts** called enzymes, which do everything from creating signals that move your limbs to helping digest your food. They are truly a fundamental part of life.

Catalysts are substances that speed up reactions by providing an alternative way for breaking and making bonds. The key to this alternative way is a lower activation of energy than that required for the uncatalyzed reaction.

The three types of catalysis are homogeneous, *heterogeneous and autocatalysis.*

If one of the reaction products is also a catalyst for the same or a coupled reaction, the reaction is called ***autocatalytic***. In **autocatalysis**, one of its products catalyses the reaction. One of the simplest **examples** of this is in the oxidation of a solution of ethanedioic acid (oxalic acid) by an acidified solution of potassium manganate (VII) (potassium permanganate). The reaction is very slow at room temperature.

If the catalyst exists in the same phase as the reactants, it is referred to a *homogeneous* catalyst. Acid catalysis, organometallic catalysis, and enzymatic catalysis are examples of homogeneous catalysis. Most often, homogeneous catalysis involves the introduction of an aqueous phase catalyst into an aqueous solution of reactants. In such cases, acids and bases are often very effective catalysts, as they can speed up reactions by affecting bond polarization.

An advantage of homogeneous catalysis is that the catalyst mixes into the reaction mixture, allowing a very high degree of interaction between catalyst and reactant molecules. However, unlike with heterogeneous catalysis, the homogeneous catalyst is often irrecoverable after the reaction has run to completion.

Homogeneous catalysts are used in variety of industrial applications, as they allow for an increase in reaction rate without an increase in temperature.

A *heterogeneous* catalyst exists in a different phase to the reactants and products, and is often favored in industry, being easily separated from the products, although it is often less specific and allows side reactions to occur.

The most common examples of heterogeneous catalysis in industry involve the reactions of gases being passed over the surface of a solid, often a metal, a metal oxide or a **zeolite**.

The gas molecules interact with atoms or ions on the surface of the solid. The first process usually involves the formation of very weak intermolecular bonds, a process known as **physisorption**, followed by chemical bonds being formed, a process known as **chemisorptions**.

Physisorption can be likened to a physical process such as **liquefaction**. The enthalpy changes that occur in physisorption are from -20 to -50 kJ $mol^{-1}$, which is similar to those of **enthalpy** changes when a gas condenses to form a liquid. The enthalpies of chemisorption are similar to the values found for enthalpies of reaction. They have a very wide range, just like the range for non-catalytic chemical reactions.

An example of the stepwise processes that occur in heterogeneous catalysis is the oxidation of carbon monoxide to carbon dioxide over palladium. This is a very important process in everyday life. Motor vehicles are fitted with catalytic converters. These consist of a metal casing in which there are two metals, palladium and rhodium, dispersed very finely on the surface of a ceramic support that resembles a honeycomb of holes. The converter is placed between the engine and the outlet of the exhaust pipe.

The exhaust gases normally contain carbon monoxide and unburned hydrocarbons that react with the excess oxygen to form carbon dioxide and water vapour, the reaction being catalyzed principally by the palladium:

$$2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$$

$$C_xH_y(g) + (x+y/4)O_2(g) \longrightarrow xCO_2(g) + y/2\,H_2O(g)$$

The exhaust gases also contain nitrogen (II) oxide (nitric oxide, NO), and this is removed by the reactions catalyzed principally by the rhodium:

$$2CO(g) + 2NO(g) \longrightarrow 2CO_2(g) + N_2(g)$$

The accepted mechanism for the oxidation of carbon monoxide to carbon dioxide involves the chemisorptions of both carbon monoxide molecules and oxygen molecules on the surface of the metals. The adsorbed oxygen molecules dissociate into separate atoms of oxygen. Each of these oxygen atoms can combine with a chemisorbed carbon monoxide molecule to form a carbon dioxide molecule. The carbon dioxide molecules are then desorbed from the surface of the catalyst.

Each of these steps has lower activation energy than the homogeneous reaction between the carbon monoxide and oxygen.

The removal of carbon monoxide, unburned hydrocarbons and nitrogen (II) oxide from car and lorry exhausts is very important for this mixture leads to **photochemical smog** that can cause respiratory diseases such as asthma.

Another point to consider when choosing a catalyst is that the product must not be able to absorb too strongly to its surface. Carbon dioxide does not adsorb strongly on platinum and palladium and so it is rapidly desorbed into the gas phase.

A testimony to the importance of catalysis today is the award of the Nobel Prize in Chemistry in 2007 to Gerhard Ertl for his work in elucidating, amongst other processes, the mechanism for the synthesis of ammonia (the Haber Process):

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

Ertl obtained a crucial evidence on how iron catalyses the dissociation of the nitrogen molecules and hydrogen molecules leading to the formation of ammonia.

To be successful the catalyst must allow the reaction to proceed at a suitable rate under conditions that are economically desirable, at as low a temperature and pressure as possible. It must also be long lasting. Some reactions lead to undesirable side products. For example in the cracking of gas oil, carbon is formed which is deposited on the surface of the catalyst, a zeolite, and leads to a rapid deterioration of its effectiveness. Many catalysts are prone to poisoning which occurs when an impurity attaches itself to the surface of the catalyst and prevents the adsorption of the reactants. One example is sulfur dioxide, which poisons the surface of platinum and palladium. Thus all traces of sulfur compounds must be removed from the petrol used in cars fitted with catalytic converters.

Furthermore, solid catalysts are much more effective if they are finely divided as this increases the surface area.

At high temperatures, the particles of a finely divided catalyst tend to fuse together and the powder may 'cake', a process known as *sintering*. This reduces the activity of the catalyst and steps must be taken to avoid this. One way is to add another substance, known as a *promoter*. When iron is used as the catalyst in the Haber Process, aluminium oxide is added and acts as a barrier to the fusion of the metal particles. A second promoter is added, potassium oxide that appears to cause the nitrogen atoms to be chemisorbed more readily, thus accelerating the slowest step in the reaction scheme.

The search for catalysts continues to be one of the highest priorities for the chemical industry as it seeks to run the processes at lower temperatures and pressure closer to the atmospheric one. The gains from improving catalysts are both financial and environmental, leading to lower fuel costs, for example the manufacturing of methanol and the reduction of harmful waste gases, for example the manufacture of ethanoic acid. Similarly, benzene and propene are converted into cumene in the manufacture of phenol, using a zeolite catalyst in place of aluminum chloride. This means lower temperatures and pressures are used and the effluent produced is much cleaner.

Furthermore, catalysts are sought which will favour one specific reaction over another, thus again making the process much more economic. There are benefits if a catalyst can be used rather than another chemical that takes part stoichiometrically in the reaction and cannot be recovered and reused. For example, aluminium chloride was used for many years to effect the reaction between benzene and a long chain alkene in the production of alkylbenzene sulfonates, an active surfactant in many detergents. 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.

One more similar example is manufacturing 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, and ammonium sulphate is produced as a by-product. However, 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.

Vocabulary:

zeolite - цеолит
physisorption – физическая адсорбция
chemisorptions – химическая адсорбция
liquefaction – переход в жидкое состояние
enthalpy - тепловая энергия
exhaust gases – отработанные газы
honeycomb – сетка, сотовая конструкция, решетка
photochemical smog – фотохимический смог (густой туман с дымом и копотью)
promoter – усилитель
*sintering - спекание*

## II. Find the chemical formulae of the following compounds and read them:

Polyamide, cyclohexanone, caprolactam, hydroxylamine hydrogensulfate, oxime, sulfuric acid, ammonium sulphate, alkylbenzene, ethanedioic acid, phenol.

## III.Match the terms with their definitions

| | |
|---|---|
| **enthalpy** | a kind of adsorption which involves a chemical reaction between the surface and the adsorbate. **chemisorption** |
| **physisorption** | the sum of the system's internal energy and the product of its pressure and volume. It is a convenient state function standardly used in many measurements in chemical, biological, and physical systems at a constant pressure. **enthalpy** |
| **catalysts** | a process in which the electronic structure of the atom or molecule is barely perturbed upon adsorption. **physisorption** |
| **chemisorption** | substances that speed up reactions by providing an alternative way for breaking and making bonds **Catalysts** |
| **the Haber Process** | method of directly synthesizing ammonia from hydrogen and nitrogen. **the Haber Process** |

## IV.Find information about an example of any type of catalysis and make a presentation on this topic.

## V. Read the following text

### TYPES OF CATALYSTS

Catalysts have played a huge part in the development of sustainable processes for manufacturing chemicals. There are many advantages in developing and using catalysts for industrial reactions. For example, 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. There are several types of catalysts that are widely used in chemical industry.

**Bifunctional catalysts** are able to catalyze the conversion of one compound to another, using two substances on the surface.

The most well known one is **platinum** impregnated on the surface of alumina and both the metal and the oxide play their parts in the process. The first step in the process is the dehydrogenation of alkanes to alkenes, catalysed by the metal, followed eventually by adsorption of the alkene molecules on alumina. As platinum is involved, the reforming is also called *platforming*. The hydrogen ensures that the resulting alkenes and cycloalkenes subsequently react with hydrogen to form saturated compounds.

In the industrial process, naphtha vapour is passed over platinum and rhenium, which are finely dispersed over aluminium oxide.

If a sulfur compound is allowed to pass over the surface of the catalyst, it is preferentially adsorbed by the rhenium. If sulfur compounds are not removed, the reactions occurred eventually lead to the formation of carbon which causes the activity of the catalyst to be markedly reduced. Branched alkanes have a higher octane rating than straight chain ones. Not only the alkanes but also cycloalkanes are branched. All three classes of hydrocarbon have a higher octane rating than naphtha. Besides aluminium oxide and silicon dioxide, other oxides are important catalysts. For example, in the Contact Process used for sulfuric acid manufacturing, the catalyst for the oxidation of sulfur dioxide to sulfur trioxide is vanadium (V) oxide on the surface of silica:

$$2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$$

Potassium sulfate is added as a promoter. Mixed metal oxides catalyse several important industrial processes. The surfaces contain two or more different metal atoms, $O^{2-}$ ions and -OH groups. They are particularly useful in the oxidation of hydrocarbons, where selective oxidation is required. For example, propene can be oxidized to propenal (acrolein) using a mixture of bismuth (III) and molybdenum (VI) oxides.

Without the catalyst, propene is oxidized to a large number of organic compounds, including **methanal** and ethanal, and eventually forming carbon dioxide. The oxygen atoms on the surface of molybdenum (VI) oxide are not very reactive, reacting selectively with propene and breaking the weakest bond in the alkene to form an allyl radical.

The allyl radical is then oxidized on the surface to yield propenal. It is postulated that an oxygen atom that is adsorbed at a molybdenum site oxidizes the allyl radical. Another oxygen atom, adsorbed on a bismuth site, is then transported to the reduced molybdenum site to replace oxygen. There is a compensating transport of electrons to complete the cycle.

**Homogeneous catalysts** are less frequently used in industry than heterogeneous catalysts, as, on completion of the reaction, they have to be separated from the products, a process that can be very expensive.

However, there are several important industrial processes that are catalysed homogeneously, often using an acid or base. One example is manufacturing of ethane-1, 2-diol from epoxyethane where the catalyst is a trace of acid.

In the mechanism for this reaction a hydrogen ion is added at the start, and lost at the end. The hydrogen ion functions as a catalyst.

**Ziegler-Natta catalysts** are organometallic compounds which act as catalysts for the manufacturing of poly(ethene) and poly(propene). **Ziegler-Natta catalysts belong to** an important class of chemical compounds. They are remarkable for their ability to effect the polymerization of olefins (hydrocarbons containing a double carbon–carbon bond) to polymers of high molecular weights and highly ordered (stereoregular) structures.

These catalysts were originated in the 1950s by the German chemist Karl Ziegler for the polymerization of ethylene at atmospheric pressure. Ziegler used a catalyst consisting of a mixture of titanium tetrachloride and an alkyl derivative of aluminum. Giulio Natta, an Italian chemist, extended the method to other olefins and developed further variations of the Ziegler catalyst based on his findings on the mechanism of the polymerization reaction. The Ziegler-Natta catalysts include many mixtures of halides of transition metals, especially titanium, chromium, vanadium, and zirconium, with organic derivatives of nontransition metals, particularly alkyl aluminum compounds. For their work on the production of polyalkenes, Karl Ziegler and Giulano Natta were awarded the Nobel Prize in Chemistry in 1965.

The catalysts are prepared from titanium compounds with an aluminium trialkyl which acts as a promoter. The alkyl groups used include ethyl, hexyl and octyl. The alkene monomer, for example ethene or propene, attaches itself to an empty coordination site on the titanium atom and this alkene molecule then inserts itself into the carbon-titanium bond to extend the alkyl chain. This process then continues, thereby forming a linear polymer, poly(ethene) or poly(propene).

The polymer is precipitated when the catalyst is destroyed on addition of water. Because it is linear, the polymer molecules are able to pack together closely, giving the polymer a higher melting point and density than poly(ethene) produced by radical initiation.

Not only Ziegler-Natta catalysts allow for linear polymers to be produced. Propene, for example could polymerize in three ways, even if linear, to produce either atactic, isotactic or syndiotactic polypropylene. However, this catalyst only allows the propene to be inserted in one way to produce isotactic polypropene. Better control of the polymerization is obtained using a new class of catalysts, the metallocenes.

Vocabulary

| | |
|---|---|
| atom economy – атомная эффективность<br>Bifunctional catalyst – бифункциональный катализатор<br>Conversion - конверсия<br>*Platforming – крекинг нефтепродукта (над платиновым катализатором)*<br>Dehydrogenate – дегидрировать<br>Saturated compound – насыщенное соединение<br>Secondary carbocation – вторичный карбокатион<br>Silica – (зд.) диоксид кремния<br>Finely dispersed – тонкодисперсный, мелкодисперсный<br>Promoter – ускоритель | Octane rating – октановое число<br>Methanal – метаналь, формальдегид<br>Ethanal – этаналь, уксусный альдегид<br>Metallocene – металлоцен, металлоорганическое соединение<br>Stereoregular - стереорегулярный (высокомолекулярное соединение, макромолекулы которого состоят из одинаковых по химическому составу звеньев)<br>Low-density – обладающий низкой плотностью<br>Halides of transition metals – галогениды переходных металлов |

**VI. Answer the following questions:**

1. What are the advantages of using catalysts in chemical industry?
2. What is the principle of bifunctional catalysts?
3. What is platforming?
4. What is the purpose of using rhenium in industrial processes?
5. What chemical element is used as a catalyst in the contact process to produce sulfuric acid?
6. In what industrial processes are homogeneous catalyst used?
7. What are the advantages of **Ziegler-Natta catalysts?**
8. What chemical compounds are used as **Ziegler-Natta catalysts?**

## VII. Translate the following sentences into Russian paying special attention to the passive constructions:

1. Catalysts affect the conditions that **are needed**, often reducing energy demand by lowering the temperature and pressure.
2. The branched alkene molecule **is desorbed** into the gas phase.
3. In the industrial process, naphtha vapour **is passed** over platinum and rhenium which **are** finely **dispersed** over aluminium oxide.
4. If sulfur compounds **are not removed**, the reactions occurred eventually lead to the formation of carbon which causes the activity of the catalyst to be markedly reduced.
5. Potassium sulfate **is added** as a promoter.
6. Several important industrial processes **are catalysed** by mixed metal oxides.
7. Without the catalyst, propene **is oxidised** to a large number of organic compounds including **methanal** and ethanal.
8. These catalysts **were originated** in the 1950s by the German chemist Karl Ziegler for the polymerization of ethylene at atmospheric pressure.
9. The polymer **is precipitated** when the catalyst is destroyed on addition of water.
10. Better control of the polymerization **is obtained** using a new class of catalysts, the metallocenes.

## VIII. Make questions to the words in bolds.

1. **Catalysts** have played a huge part in the development of sustainable processes for the manufacturing chemicals.
2. The most well known catalyst is **platinum** impregnated on the surface of alumina and both the metal and the oxide play their parts in the process.
3. In the Contact Process used for sulfuric acid manufacturing, **the catalyst for the oxidation of sulfur dioxide to sulfur trioxide** is vanadium (V) oxide on the surface of silica.
4. The allyl radical is then oxidized on the surface **to yield propenal.**
5. **Homogeneous catalysts** are less frequently used in industry than heterogeneous catalysts.

6. These catalysts were originated **in the 1950s** by the German chemist Karl Ziegler for the polymerization of ethylene at atmospheric pressure.

7. **Giulio Natta, an Italian chemist,** extended the method to other olefins and developed further variations of the Ziegler catalyst based on his findings on the mechanism of the polymerization reaction.

8. **For their work on the production of polyalkenes**, Karl Ziegler and Giulano Natta were awarded the Nobel Prize in Chemistry in 1965.

9. The catalysts are prepared **from titanium compounds** with an aluminium trialkyl, which acts as a promoter.

10. Better control of the polymerization is obtained using a new class of catalysts, **the metallocenes**.

## Distillation

**IX. Read and translate the text.**

**Distillation** is the process of separating the components or substances from a liquid mixture by using selective boiling and condensation. Distillation may result in essentially complete separation (nearly pure components), or it may be a partial separation that increases the concentration of selected components in the mixture. In either case, the process exploits differences in the relative volatility of the mixture's components. In industrial processes, distillation is a unit operation of practically universal importance, but it is a physical separation process, not a chemical reaction. It is exemplified when steam from a kettle becomes deposited as drops of distilled water on a cold surface.

Aristotle mentioned that pure water is made by the evaporation of seawater. Pliny the Elder described a primitive method of condensation in which the oil obtained by heating rosin is collected on wool placed in the upper part of an apparatus known as a still.

Distillation is used to separate liquids from nonvolatile solids, as in the separation of alcoholic liquors from fermented materials, or in the separation of two or more liquids having different boiling points, as in the separation of gasoline, kerosene, and lubricating oil from crude oil.

Other industrial applications include the processing of such chemical products as formaldehyde and phenol and the desalination of seawater. The distillation process appears to have been utilized by the earliest experimentalists.

**Distillation of crude oil**

A method called fractional distillation, or differential distillation, has been developed for certain applications, such as petroleum refining, because simple distillation is not efficient for separating liquids whose boiling points lie close to one another. In this operation, the vapours from a distillation are repeatedly condensed and revaporized in an insulated vertical column. The most important parts in this connection are the still heads, fractionating towers, and condensers that permit the return of some of the condensed vapour toward the still. The objective is to achieve the closest possible contact between rising vapour and descending liquid to allow only the most volatile material to proceed in the form of vapour to the receiver while returning the less volatile material as liquid toward the still. The purification of the more volatile component by contact between such countercurrent streams of vapour and liquid is referred to as rectification, or enrichment.

Crude oil is heated in a furnace (ca 650 K) and the resulting mixture fed as a vapour into a fractionating tower which can have a height of 25-100 m, handling volumes of over 40 000 $m^3$ a day. The column may contain 40-50 steel 'sieve trays' which fit horizontally across the column and are designed to ensure there is intimate mixing between the descending liquid, formed by condensation, and the rising vapour. To affect this close contact, the trays have holes in them ('the sieve') through which the vapour flows up into the liquid collecting on the trays.

Alternatively, there may be valves fitting over the holes, which lift up when the pressure of the vapour below the tray is greater than the pressure on the tray. These are considered more efficient in fractionation than sieve trays without valves.

A temperature gradient exists in the tower, with the top being cooler than the bottom. When the rising vapour reaches a tray containing liquid with the temperature below the boiling point (bp) of the vapour, it partially condenses. As some of the vapour condenses to a liquid, the dissipated latent heat then heats more liquid, and the more volatile components in the liquid evaporate joining the remaining vapour and passing up the tower. The less volatile liquid flows across the tray and down a pipe to the tray below.

This process occurs continuously in each tray, the least volatile vapour components condensing and the most volatile evaporating. This results in each tray containing products with a comparatively narrow boiling point range (a close cut). This leads to the low relative molecular mass products (low b.p.) accumulating near the top of the tower and high relative molecular mass constituents (high b.p.) collecting near the bottom.

The high boiling point residue from the crude oil is then transferred to another column and distilled under vacuum; lowering the pressure reduces the boiling point and ensures constituents distil at temperatures below their decomposition temperature. From this process, lubricating oils and waxes are obtained. The final residue from the process is bitumen.

Vocabulary

selective boiling – селективное кипячение
partial separation – частичное отделение
volatility - летучесть
desalination – деминерализация
fractional distillation – фракционная перегонка
fractionating tower – ректификационная колонна
sieve tray – ситчатая рама
valve – клапан
close cut – *зд.: погон,* выкипающий в *узких пределах*

**X. Find the English equivalents in the and make sentences with five of them:**

Происходить в результате (чего-л.), полное разделение, подтверждаться, нелетучие вещества, температура кипения, опреснение, ситчатая тарелка, рассеиваться, конечный осадок.

**XI. Answer the questions:**

1. What is distillation?
2. What is distillation used for?

3. What is the simplest example of distillation?
4. Who was the first to describe the primitive method of distillation?
5. What is fractional distillation?
6. Which industries use fractional distillation of crude oil?

**XII. Complete the sentences 1-5 with a phrase a-e**

1. Aristotle mentioned that pure water
2. Other industrial applications include the processing of such chemical products
3. A method called fractional distillation, or differential distillation,
4. The most important parts in this connection
5. When the rising vapour reaches a tray containing liquid with the temperature below the boiling point (bp) of the vapour,

*a. as formaldehyde and phenol and the desalination of seawater.*
*b. is made by the evaporation of seawater.*
*c. it partially condenses.*
*d. ,has been developed for certain applications, such as petroleum refining.*
*e. are the still heads, fractionating towers, and condensers that permit the return of some of the condensed vapour toward the still.*

**XIII. Find the examples of distillation in nature and make a presentation about it.**

## XIV.Read and translate the text.

## CRACKING

Oil, and the gases associated with it, consists of a mixture of hundreds of different hydrocarbons, containing any number of carbon atoms from one to over a hundred. Most of these are straight chain, saturated hydrocarbons that, except for burning, have relatively little direct use in the chemical industry or as fuel for cars.

Thus, the various fractions obtained from the distillation of crude oil and the associated gases have to be treated further in oil refineries to make them useful. The most valuable fractions for the chemical industry, and for producing petrol, are liquefied petroleum gas (LPG), naphtha, kerosine and gas oil. These substances are treated in several ways including cracking, isomerisation and reforming.

Petrol (gasoline) contains a mixture of hydrocarbons, with 5 to 10 carbon atoms. The mixture of C5-C10 hydrocarbons obtained directly from the distillation of crude oil contains a high proportion of straight-chain alkanes. However, if this mixture is used as petrol, it does seriously damage engines. Petrol containing a high proportion of straight chain alkanes tends to ignite in the cylinder of the car engine as the piston increases the pressure and before the cylinder reaches the optimum position.

The octane rating of petrols usually available for cars range from 95 upwards and contain a mixture of straight chain branched, cyclic and aromatic hydrocarbons, produced by the processes described below.

These processes are also used to convert staight-chain hydrocarbons to hydrocarbons, which are much more useful to make chemicals, which are then used to make a huge range of compounds from polymers to pharmaceuticals.

Cracking, as the name suggests, is a process in which large hydrocarbon molecules are broken down into smaller and more useful ones.

The cracking products, such as ethene, propene, buta-1,3-diene and C4 alkenes, are used to make many important chemicals. Others such as branched and cyclic alkanes are added to the gasoline fraction obtained from the distillation of crude oil to enhance the octane rating.

Cracking is conducted at high temperatures, by two processes:

- Steam cracking which produces high yields of alkenes
- Catalytic cracking with a catalyst employed produces high yields of branched and cyclic alkanes.

A steam cracker is one of the most technically complex and energy intensive plants in the chemical industry. It has equipment operating from 100 K to 1400 K and near vacuum to 100 atm. Though the fundamentals of the process have not changed in recent decades, the improvements continue to be made to the energy efficiency of the furnace, ensuring that the cost of production is continually reduced.

A catalyst allows lower reaction temperatures to be used. In fluidised catalytic cracking, the feedstock is gas oil, which is vaporised and passed through a zeolite, produced as a fine powder, heated to about 700-800 K in the reactor. It is so fine that it behaves like a fluid and continuously flows out of the furnace with the cracking products. The temperature, residence time and the catalyst determine the product proportions. After cracking, the catalyst is separated from the products, regenerated by burning off deposited carbon in air (900 K), and subsequently recycled.

The products of a catalytic cracking are:

- a gas of which ethene and propene are the main constituents
- a liquid which is used for petrol and contains branched- chain alkanes, cycloalkanes and aromatic hydrocarbons
- a high boiling residue used as a fuel oil

The relative proportions of the products, as noted above, can be altered by changing the catalyst and temperature. One of several zeolites can be used. For example, if the chosen zeolite contains ZSM-5, the propene yield is increased.

A variant of the process is known as hydrocracking. The cracking is carried out with hydrogen at a pressure of 80 atm and a catalyst of finely divided platinum on silica or alumina. Because excess hydrogen is present no alkenes are formed, and high proportions of branched alkanes, cycloalkanes and aromatics are produced which are essential in the formulation of high-grade 'green' petrol. The hydrogen also decreases the tendency for the hydrocarbons to form finely divided carbon on the catalyst surface. The reaction products are separated by fractionation.

Hydrocracking is also used to crack heavy gas oils (which have over 20 carbon atoms in the hydrocarbon molecule) to shorter chain molecules similar to those in naphtha, which can then be steam-cracked to form alkenes.

Isomerisation is the process in which hydrocarbon molecules are rearranged into a more useful isomer. The process is particularly useful in enhancing the octane rating of petrol, as branched alkanes burn more efficiently in a car engine than straight-chain alkanes.

An important example is the isomerisation of butane (from LPG) to 2-methylpropane (isobutane). Butane vapour is passed over a solid catalyst, aluminium chloride, on an inert solid at *ca* 300 K. The two alkanes are then separated either by distillation or by passing them through a molecular sieve, an aluminosilicate. The branched chain alkane is trapped and the straight chain passes through and is recirculated into the reactor. The 2-methylpropane is subsequently released and used to make a branched alkane, 2,2,4-trimethylpentane (iso-octane), for petrol.

Reforming is another process in which hydrocarbon molecules are rearranged into other molecules, usually with the loss of a small molecule such as hydrogen. An example is the conversion of an alkane molecule into a cycloalkane or an aromatic hydrocarbon. This is a very important process for the petroleum and chemical industries. It enables straight chain alkanes to be converted into branched-chain alkanes, cyclohexanes and aromatic hydrocarbons that are used to enhance the octane rating of petrol.

Vocabulary

consist of – состоять из
contain – содержать
liquefied petroleum gas – сжиженный углеводородный газ
molecular sieve – молекулярное сито
high proportion – высокий процент, высокое содержание
residue – осадок
residence time – время пребывания

## XV. Answer the following questions

1. What are the four processes described in the text?
2. What is the main purpose of the processes?
3. What is cracking?
4. What are the principles of steam and catalytic cracking?
5. What is the main condition for conducting cracking?
6. What are the main cracking products?
7. What is hydrocracking used for?
8. How does reforming affect the octane rating of petrol?

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# ИНОСТРАННЫЙ ЯЗЫК

## ХИМИЧЕСКИЕ ТЕХНОЛОГИИ

***Методические указания к самостоятельным работам для студентов бакалавриата направления 18.03.01***


Сост. *Ю.В. Борисова, Н.В. Корниенко*

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