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TRƯỜNG ĐẠI HỌC BÁCH KHOA HÀ NỘI
50 NĂM XÂY DỰNG VÀ PHÁT TRIỂN

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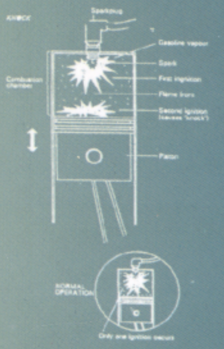

TIẾNG ANH DÀNH CHO SINH VIÊN NGÀNH HÓA DẦU

ENGLISH FOR STUDENTS OF PETROCHEMICAL TECHNOLOGY

NHÀ XUẤT BẢN KHOA HỌC VÀ KỸ THUẬT

TRƯỜNG ĐẠI HỌC BÁCH KHOA HÀ NỘI
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Phạm Thanh Huyền

TIẾNG ANH DÀNH CHO SINH VIÊN NGÀNH HOÁ DẦU

(Bài giảng cho sinh viên)

NHÀ XUẤT BẢN KHOA HỌC VÀ KỸ THUẬT
HÀ NỘI

HANOI UNIVERSITY OF TECHNOLOGY
FACULTY OF CHEMICAL TECHNOLOGY

Pham Thanh Huyen

ENGLISH FOR STUDENTS OF PETROCHEMICAL TECHNOLOGY

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LỜI NÓI ĐẦU

Bài giảng "Tiếng Anh dành cho sinh viên ngành Hoá dầu" được biên soạn dựa trên các tài liệu tiếng Anh chuyên ngành của các tác giả người Mỹ và Anh. Hy vọng bài giảng này sẽ cung cấp cho bạn đọc, đặc biệt là sinh viên chuyên ngành Hóa dầu, một số vốn từ và thành ngữ tiếng Anh thường được sử dụng trong chuyên ngành Công nghệ Lọc - Hoá dầu.

Tác giả xin chân thành cảm ơn các đồng nghiệp, bạn bè, người thân, đặc biệt là các cựu sinh viên ngành Công nghệ Hoá dầu đã động viên, giúp đỡ và cung cấp nguồn tài liệu vô cùng phong phú và đa dạng trong quá trình hoàn thành tập bài giảng này.

Chắc chắn trong quá trình biên soạn, bài giảng không thể tránh khỏi các thiếu sót, rất mong nhận được các ý kiến đóng góp của độc giả để bài giảng được hoàn thiện hơn.

PREFACE

The textbook "English for students of Petrochemical Technology" was written based on the specialist books of American and English authors. I hope that this textbook will provide readers, especially students of petrochemical technology, some special words and phrases commonly used in the Refining and Petrochemical Technology.

I wish to acknowledge the cooperation and assistance I received from my colleagues, my friends, my family and my former students for their encouragement and their document support in completing this work.

I also hope to receive the suggestion and the criticism of readers to make this textbook better.

Pham Thanh Huyen, Ph.D

CONTENT

UNIT 1. CRUDE OIL

Section A. READING COMPREHENSION

Crude oil (petroleum) is a naturally occurring brown to black flammable liquid. Crude oils are principally found in oil reservoirs associated with sedimentary rocks beneath the earth's surface. Although exactly how crude oils originated is not established, it is generally agreed that crude oils derived from marine animal and plant debris subjected to high temperatures and pressures. It is also suspected that the transformation may have been catalyzed by rock constituents. Regardless of their origins, all crude oils are mainly constituted of hydrocarbons mixed with variable amounts of sulfur, nitrogen, and oxygen compounds.

Metals in the forms of inorganic salts or organometallic compound are present in the crude mixture in trace amounts. The ratio of the different constituents in crude oils, however, varies appreciably from one reservoir to another.

Normally, crude oils are not used directly as fuels or as feedstocks for the production of chemicals. This is due to the complex nature of the crude oil mixture and the presence of some impurities that are corrosive or poisonous to processing catalysts.

Crude oils are refined to separate the mixture into simpler fraction that can be used as fuels, lubricants or as intermediate feedstock to the petrochemical industries. A general knowledge of this composite mixture is essential for establishing a processing strategy.

PROPERTIES OF CRUDE OILS

Crude oils differ appreciably in their properties according to origin and the ratio of the different components in the mixture. Lighter crudes generally yield more valuable light and middle distillates and are sold at higher prices. Crudes containing a high percent of impurities, such as sulfur compounds, are less desirable than low-sulfur crudes because of their corrosivity and the extra treating cost. Corrosivity of crude oils is a function of many parameters among which are the type of sulfur compounds and their decomposition temperatures, the total acid number, the type of carboxylic and naphthenic acids in the crude and their decomposition temperatures. It was found that naphthenic acids begin to decompose at 600°F. Refinery experience has shown that above 750°F there is no naphthenic acid corrosion. For a refiner, it is necessary to establish certain criteria to relate one crude to another to be able to assess crude quality and choose the best processing scheme. The following are some of the important tests used to determine the properties of crude oils.

Density, Specific Gravity and API Gravity

Density is defined as the mass of unit volume of a material at a specific temperature. A more useful unit used by the petroleum industry is specific gravity, which is the ratio of the weight of a given volume of a material to the weight of the same volume of water measured at the same temperature.

Specific gravity is used to calculate the mass of crude oils and its products. Usually, crude oils and their liquid products are first measured on a volume basis, then changed to the corresponding masses using the specific gravity.

The API (American Petroleum Institute) gravity is another way to express the relative masses of crude oils. A low API gravity indicates a heavier crude oil or a petroleum product, while a higher API gravity means a lighter crude or product. Specific gravities of crude oils roughly range from 0.82 for lighter crudes to over 1.0 for heavier crudes.

Salt Content

The salt content expressed in milligrams of sodium chloride per liter oil (or in pounds/barrel) indicates the amount of salt dissolved in water. Water in crudes is mainly present in an emulsified form. A high salt content in a crude oil presents serious corrosion problems during the refining process. In addition, high salt content is a major cause of plugging heat exchangers and heater pipes. A salt content higher than 10 lb/1,000 barrels (expressed as NaCl) requires desalting.

Sulfur Content

Determining the sulfur content in crudes is important because the amount of sulfur indicates the type of treatment required for the distillates. To determine sulfur content, a weighed crude sample (or fraction) is burned in an air stream. All sulfur compounds are oxidized to sulfur dioxide, which is further oxidized to sulfur trioxide and finally titrated with a standard alkali.

Identifying sulfur compounds in crude oils and their products is of little use to a refiner because all sulfur compounds can easily be hydrodesulfurized to hydrogen sulfide and the corresponding hydrocarbon. The sulfur content of crudes, however, is important and is usually considered when determining commercial values.

Pour Point

The pour point of a crude oil or product is the lowest temperature at which an oil is observed to flow under the conditions of the test. Pour point data indicates the amount of long-chain paraffins (petroleum wax) found in a crude oil. Paraffinic crudes usually have higher wax content than other crude types. Handling and transporting crude oils and heavy fuels is difficult at temperatures below their pour points. Often, chemical additives known as pour point depressants are used to improve the flow properties of the fuel. Long-chain n-paraffins ranging from 16-60 carbon atoms in particular, are responsible for near-ambient temperature precipitation. In middle distillates, less than 1% wax can be sufficient to cause solidification of the fuel.

Ash Content

This test indicates the amount of metallic constituents in a crude oil. The ash left after completely burning an oil sample usually consists of stable metallic salts, metal oxides, and silicon oxide. The ash could be further analyzed for individual elements using spectroscopic techniques.

CRUDE OIL CLASSIFICATION

Appreciable property differences appear between crude oils as a result variable ratios of the crude oil components. For a refiner dealing with crudes of different origins, a simple criterion may be established to group crudes with similar characteristics. Crude oils can be arbitrarily classified into three or four groups depending on the relative ratio of the hydrocarbon classes that predominates in the mixture. The following describes three types of crudes:

1. Paraffinic-the ratio of paraffinic hydrocarbons is high compared to aromatics and naphthenes.

2. Naphthenic-the ratios of naphthenic and aromatic hydrocarbons are relatively higher than in paraffinic crudes.

3. Asphaltic-These crudes contain relatively a large amount of polynuclear aromatics, a high asphaltene content, and relatively less paraffins than paraffinic crudes.

COMPREHENSION

1. What are the main constituents of crude oil mixture?
2. List some important properties of crude oil.
3. Define the density, the pour point of crude oil.
4. How to determine the sulfur content of a crude oil?
5. What does ash consist of?
6. Compare the paraffinic, naphthenic and asphaltic crudes.

Section B. REVIEW EXERSISES

I. Fill in the blanks in the sentences below with the correct prepositions

1. Table salt is *composed* _____ two elements, sodium and chlorine
2. Water is *essential* ________ all life.
3. One meter is approximately *equal* ________ a yard.
4. Oxygen, fuel, and heat are all *necessary* _______ combustion.
5. Iron *combines* _____ oxygen to form rust.
6. The IUPAC rules for naming halocarbons are *based* ____ the name of the parent hydrocarbon.
7. The branch of chemistry that *deals* _____ carbon compounds is called organic chemistry.

8. Coal consists largely ___ condensed ring compounds of very high molecular mass. These compounds have a very high proportion of carbon compared ____ hydrogen.

9. Coal is chemically *similar* ___ both natural gas and crude oil.

II. Choose the one that should be corrected

1. A carbon-carbon double bond is the most reaction part of an alkene.
A B C D

2. A substance is a form of matter that have a definite composition and
A B C
distinct properties
D

3. A physical property can be measured and observe without changing
A B C D
the composition or identity of a substance.

4. A molecular may contain atoms of the same element or atoms of
A B
two or more elements joined in a fixed ratio.
C D

5. An electrolyte does not conduct electricity when dissolved in water.
A B C D

6. For a chemical reaction to take, reactant particles must collide.
A B C D

7. Molecular hydrogen is a colorless, odorness and nonpoisonous gas.
A B C D

8. Most simplest aromatic compounds are named as derivatives of benzene.
A B C
D

9. The mixture of CO and H_2 gas producted in this reaction is commonly
A B C
known as water gas.
D

10. Many of the solid inorganic and organic compounds that are used in
A B
the laboratory were purity by fractional crystallization.
C D

III. Choose the correct word or phrase that best keeps the meaning of its definition or synonym underlined in each sentence below

1. A mixture is a combination of two or more substances in which the substances retain their ***distinct*** identities

A. similar B. useful C. worthy D. separate

2. The number of positively charged protons in the nucleus of an atom remains the same during ordinary chemical ***changes***.

A. reaction B. exchange C. action D. equation

3. Beyond 4°C, thermal expansion ***predominates*** and the density of water decreases with increasing temperature.

A. is inferior B. prevails C. affects D. influences

4. The dependence of the solubility of a solid on temperature ***varies*** considerably

A. is the same B. increases C. is different D. decreases

5. Hydrogen is the most ***abundant*** element in the universe.

A. plentiful B. toxic C. inert D. poisonous

6. The hydrocarbons are compounds composed ***entirely*** of carbon and hydrogen.

A. mostly B. completely C. mainly D. nearly

7. Other than ***combustion***, alkanes undergo few reactions.

A. addition B. substitution C. burning D. reduction

IV. Match the words in column A with their synonym in column B

A		B	
1.	crude oil	a.	under
2.	fraction	b.	confirm
3.	occur	c.	petroleum

4.	beneath	d.	broken and detached fragments
5.	originate	e.	expose to
6.	establish	f.	cut
7.	debris	g.	to bring into existence
8	subject to	h	appear

UNIT 2. DOWNSTREAM OF PRODUCTION

Section A. READING COMPREHENSION

Crude oil often contains water, inorganic salts, suspended solids, and water-soluble trace metals. As a first step in the refining process, to reduce corrosion, plugging, and fouling of equipment and to prevent poisoning the catalysts in processing units, these contaminants must be removed by desalting (dehydration). Then, the oil is pumped via the crude train to the first column in the refinery system. Crude oil is combustible, of course, and it is sometimes asked why crude isn't burned as fuel without the expense of refining it. There are two basic reasons. First, modern engines will not run on crude oil. Secondly, most crudes contain the lighter hydrocarbons, and as a result they are so highly inflammable that they must be handled by very experienced men. Only fuel oils with a flashpoint above 65°C are safe enough for ordinary use. To ensure a high flashpoint, therefore, the more volatile parts of the crude must be removed by refining.

Crude oil is a mixture of hydrocarbon molecules, which are organic compounds of carbon and hydrogen atoms that may include from one to 60 carbon atoms. Hydrocarbons containing up to four carbon atoms are usually gases, those with 5 to 19 carbon atoms are usually liquids, and those with 20 or more are solids. The refining process uses chemicals, catalysts, heat, and pressure to separate and combine the basic types of hydrocarbon molecules naturally found in crude oil into groups of similar molecules (called 'cuts' or 'fractions'). The refining process also rearranges their structures and bonding patterns into different hydrocarbon molecules and compounds. Therefore it is the type of hydrocarbon (paraffinic, naphthenic, or aromatic) rather than its specific chemical compounds that is significant in the refining process.

The distillation process by which fractions are separated from a mixture is known as 'fractionation'. In most modern refineries, the crude is processed through several CDUs, so that the various cuts can be produced to very precise specifications. Multi-stage distillation also ensures that straight-run fractions are free of impurities.

SPECIAL WORDS AND EXPRESSIONS

downstream	This word describes a stage in the industry which follows other stages. The word '*upstream*' refers to a stage which precedes others. Drilling is upstream of refining; refining is downstream of drilling.
tank farm	area containing tanks.
crude train	the pumps, valves, pipes and various vessels leading from the tank farm into the first refinery unit.
column	tall vertical separation vessel.
combustible	capable of being burned. Cars are powered by internal combustion engines.
inflammable	capable of catching fire easily and of burning very rapidly. Native English speakers use the word 'flammable' to mean the same thing. Therefore, both FLAMMABLE and INFLAMMABLE indicate the need for safe handling due to the risk of fire.
flashpoint	the lowest temperature at which vapors above a combustible substance will ignite (catch fire) in air when exposed to a flame.
volatile	vaporizable at a relatively low temperature.
distillation	process of first driving gas or vapor from a liquid by heating, then collecting the gas or vapor by condensation (i.e., reduction to a denser form by cooling; e.g., condensation of steam to water).
CDUs	crude distillation units.

straight-run fractions	fractions which require no further treatment after they have been distilled from the crude.
impurities	Notice how the word is built up: 'pure', opposite 'impure', 'impurity', 'impurities' .

COMPREHENSION

a. Why does their lighter-hydrocarbons content make crudes highly flammable?

b. What's the difference between 'flammable' and 'inflammable'?

c. What is the relation of high flashpoint to safety? What is the relation of low flashpoint to danger?

d. How might a liquid's low flashpoint and high volatility combine to cause a risky situation? In such a situation, what would be the minimum required to cause an explosion?

e. Name three impurities in wellhead crude.

f. How does the internal combustion engine get its name?

TRUE OR FALSE? Say whether these are true or false. Correct the false ones.

a. Temperatures in the lower part of the fractionating tower are lower than those near the top.

b. The higher the flashpoint of a fuel, the safer it is to handle.

c. Volatility describes the capacity of a liquid to condense at a relatively low temperature.

d. If two different hydrocarbons boil in the same temperature range, they're part of the same cut.

e. There are fewer different hydrocarbons in the highest section of the column than there are in the middle.

Section B. STRUCTURE PRACTICE

1. Comparison of Adjectives

'The higher the flashpoint of a fuel, the safer it is to handle'

The idea above could also be expressed like this: As the flashpoint of a fuel increases, its safety increases.

Example: As the specific gravity of a crude increases, its lighter-hydrocarbons content decreases. (the greater/the lower)

→ *The greater* the specific gravity of a crude, *the lower* its lighter-hydrocarbons content.

Notice particularly that in the example sentence no verb is required.

Now rewrite the following using the words in brackets

a. As the molecular weight of a hydrocarbon decreases, its boiling point decreases. (the lower / the lower)

b. As the water depth increases, the difficulty of pipe-laying increases. (the deeper / the more difficult)

c. As height increases in the column, the temperature decreases. (the higher / the lower)

2. Passive Voice

Example: People sometimes ask why crude isn't burned as fuel without the expense of refining it.

→ It is sometimes asked why crude isn't bummed as fuel without the expense of refining it.

Now change the following sentences to passive voice

a. People sometimes say that oil is black gold.

b. People no longer believe that oil will last forever.

c. People think that North Sea oil will begin to run out by the mid-1990s.

d. In the oil business people accept that practical experience is often more important than formal education.

3. Reported Speech

In the first example, notice the change from 'said' to 'told'. In the second, notice the change from 'your' to 'my'.

Examples:

- 'Get some burners in', Brian said to Jeff. → Brian told Jeff to get some burners in.

- 'Get your hands out of your pockets', he told me. → He told me to get my hands out of my pockets.

- 'Don't be late again', Barry told the roughneck. → Barry told the roughneck not to be late again.

Change the following to reported speech.

a. 'Take this report to the super,' he ordered the roustabout.

b. 'Don't take your eyes off the panel,' he warned me.

c. 'Hand that core to me,' Tom said to George.

d. 'Don't touch that valve without my permission,' Brian said to the new operator.

Section C. WRITING PRACTICE

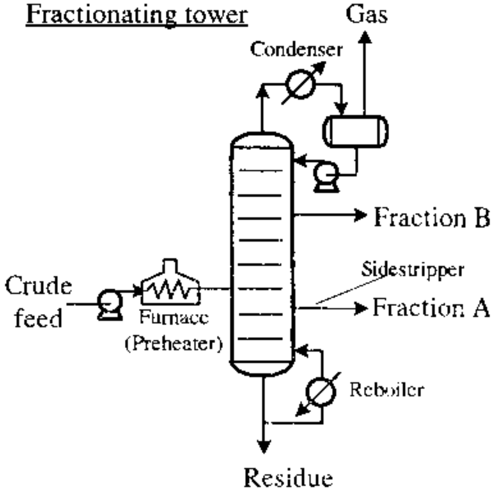
Flow Descriptions from Diagrams

a. The sentences making up the paragraph below are out of order. Write them out correctly by referring to the diagram of the tower

b. When you have finished, cover up your work and rewrite the description by heart.

Fractionation

The most volatile of all may leave the column as gas, without condensing out. Here, all the hydrocarbons except the heaviest form a mixture of vapors. By being pumped through a preheater, the crude feed is first heated to about 300°C. As these rise in the column, they separate out by condensing at different temperatures in the various



Fractionating tower

trays. Because these processes in the CDU are continuous, the liquid cuts from the various trays are piped out via the sidestrippers as the crude feed is being pumped in. So, going up in the column, the least volatile vapors condense back into liquids first. From the preheater, the hot feed is pumped into a section of the fractionating tower about a quarter or a third of the way up from the bottom.

UNIT 3. REFINING PROCESSES

Section A. READING COMPREHENSION

Read the following passage.

The primary refining processes are the distillation of the feedstock into its basic fractions and then the redistillation of most of these, in separate towers, into highly-concentrated intermediates. In a simple refinery, the split would probably consist of these six basic cuts: petroleum gas (refinery gas and LPG), gasoline, naphtha, kerosene, gas oil, residue.

The secondary processes are designed (1) to remove any impurities from the distilled fractions, and (2) to convert some of the distilled hydrocarbons into different molecular forms. Conversion processes can produce hydrocarbons which do not exist in reservoir crude.

(1) All crudes contain organic sulfur compounds (e.g. H_2S, mercaptans) which will be carried over from the column into the resulting gases, distillates and residue. The higher the density of a crude, the greater its sulfur content. This can vary from about 0.05% by weight, as in some Pennsylvanian crudes, to about 2% wt in an average Middle East crude, and to 5% or more in heavy Nigerian or Mexican crudes. Sour cuts are corrosive and possess an extremely objectionable odour. The secondary refining process for the treatment of toxic, corrosive and evil-smelling sulfur-compound impurities is known as 'sweetening'.

(2) In conversion processes, the structures of natural hydrocarbon molecules are changed. Because the simple distillation of crude oil

produces amounts and types of products that are not consistent with those required by the marketplace, subsequent refinery processes change the product mix by altering the molecular structure of the hydrocarbons. One of the ways of accomplishing this change is through "cracking," a process that breaks or cracks the heavier, higher boiling-point petroleum fractions into more valuable products such as gasoline, fuel oil, and gas oils. The two basic types of cracking are thermal cracking, using heat and pressure, and catalytic cracking. The oldest of all the conversion processes is thermal cracking, which has been in use since the 1880s.

SPECIAL WORDS AND EXPRESSIONS

feedstock	petroleum-based substance used in the production of other substances.
intermediates	oil products used as feedstocks.
split	the way a crude is divided into cuts.
refinery gas	methane and ethane produced from crude and re-circulated in the refinery for use as fuel.
LPG	liquefied petroleum gas (butane and propane). LPG can be bottled and used as camping gas in cigarette lighters, for industrial fuel supplies, etc.
gasoline	volatile flammable liquid hydrocarbon mixture used as a fuel, especially for internal combustion engines. In the UK, outside of the petroleum industry, the same fuel is referred to as 'petrol'
kerosene	flammable hydrocarbon oil used as a fuel, especially in oil lamps, space heaters, etc. In the UK, outside of the petroleum industry, kerosene is referred to as 'paraffin'.
gas oil	This is the fraction which is generally refined into diesel oil and other heavy fuels.
to convert	to change the chemical and/or physical properties of.
organic	consisting of compounds formed from organisms, i.e., from plant and/or animal life.
mercaptans	group of sulfur compounds, highly corrosive and bad-smelling.

distillates	liquid products condensed from vapour during distillation.
sour	containing sulfur compounds; e.g., sour gas, sour crude, etc. The opposite (i.e., containing little or no sulfur) is 'sweet'; e.g., sweet gas, sweet fraction, etc.
objectionable odour	bad / evil smell.
catalyst	substance which assists or speeds up a chemical change but is not changed chemically itself.

COMPREHENSION

a. Why isn't residue from the CDU referred to as a distillate?

b. Is fractionation a conversion process? If not, why not?

c. API barrel = 42 U.S. gallons. One U.S. gal = 3.785 liters. What is the approximate weight of the sulfur content in a barrel of average Middle East crude?

d. What's the difference between' gasoline' and 'petrol' ?

e. Which is denser, gas-oil or kerosene? Why?

f. If the feedstock is changed from Nigerian crude to Middle East crude, what will happen to the split?

g. There is no such thing as a naphtha molecule. Why not?

h. Why do cracked hydrocarbons have a lower boiling point than the cuts they are produced from?

i. Why can't methane be used as a feedstock in cracking?

TRUE OR FALSE? Say whether these are true or false. Correct the false ones.

a. The proportions of the primary products contained in a feedstock mixture are the same as those produced by distillation of the mixture.

b. The proportions of the primary products contained in a feedstock mixture are the same as those produced by cracking the mixture.

c. In the chemical change which it assists or speeds up, a catalyst can be physically changed.

d. Cracking produces a mixture which contains hydrocarbons not present in crude oil.

e. CDUs produce various mixtures which together contain the same hydrocarbons as those present in the feedstock.

Section B. STRUCTURE PRACTICE

1. Compound adiectives

Expressions such as the one below are common in technical English:

evil-smelling sulfur-compound impurities

The expression can be re-phrased like this: *These are impurities which contain sulfur compounds and smell evil.*

Re-phrase the following in the same way:

a. large-diameter pipeline.

b. stainless steel non-return valve.

c. low-pressure catalytic cracking unit.

d. man-made petroleum-based chemical intermediates.

e. low-boiling-point hydrocarbon components.

f. volatile flammable liquid hydrocarbon mixture.

g. low hydrogen-to-carbon ratio.

h. two-carbon-atom molecules.

i. fluid-transmitting capacity.

j. horizontal gas-oil separator.

k. high-wax-content crudes.

2. Reported Speech: Questions

E.g. 'Why is that valve open?' Brian asked Jeff. → *Brian asked Jeff why that valve was open.* Notice, first, the change from 'is' to 'was'. Secondly, notice that the converted verb has moved from the question-position to the statement-position, so the reported form does not end in a question mark.

E.g. 'Where is your helmet?' he asked me. → *He asked me where my helmet was.*

'Can you manage by yourself?' Barry asked Tom → *Barry asked Tom if he could manage by himself.*

Convert the following to reported speech.

a) "How long is it going to take you to do it?" he wanted to know.

b) "How are things going, Jeff?' Brian asked.

c) 'Will you check out the rundown to the header?' Brian asked Jeff.

d) 'Are you ready to receive residue?' he asked the panel man.

e) 'Why don't you follow my instructions?' the super angrily asked Tom.

f) 'What time is it?' he wanted to know.

3. Choose the right word

Catalytic cracking

Catalytic cracking breaks *(1)*....... (complex/ simpler) hydrocarbons into *(2)*....... (complex/ simpler) molecules in order to *(3)*....... (increase/decrease) the quality and quantity of lighter, more desirable products and *(4)*....... (increase/decrease) the amount of residuals. This process rearranges the *(5)*.......(molecular/molecule) structure of hydrocarbon compounds to convert heavy hydrocarbon feedstock into lighter fractions such as kerosene, gasoline, LPG, heating oil, and petrochemical feedstock.

Catalytic cracking is similar to thermal cracking except that catalysts facilitate the *(6)*....... (convert/conversion) of the heavier molecules into lighter products. Use of a catalyst (a material that *(7)*.......(retards/assists) a chemical reaction but does not take part in it) in the cracking reaction increases the yield of improved-quality products under *(8)*....... (much less/less much) severe operating conditions than *(9)*....... (on/at/in) thermal cracking. Typical temperatures are from 850°-950° F at much lower pressures of 10-20 psi. The catalysts *(10)*....... (are used/used/use) in refinery cracking units are typically solid materials (zeolite, aluminum hydrosilicate, treated bentonite clay, bauxite, and silica-alumina) that come in the form of powders, beads, pellets...

There are three basic functions in the catalytic cracking process:

Reaction: Feedstock reacts with catalyst and cracks into different hydrocarbons;

Regeneration: Catalyst is reactivated by burning off coke; and

Fractionation: Cracked hydrocarbon stream is separated into various products.

Section C. WRITING PRACTICE

Flow Descriptions from Diagrams.

a. The sentences making up the paragraph below are out of order. Write them out correctly by referring to the diagram.

b. When you have finished, cover up your work and rewrite the description by heart.

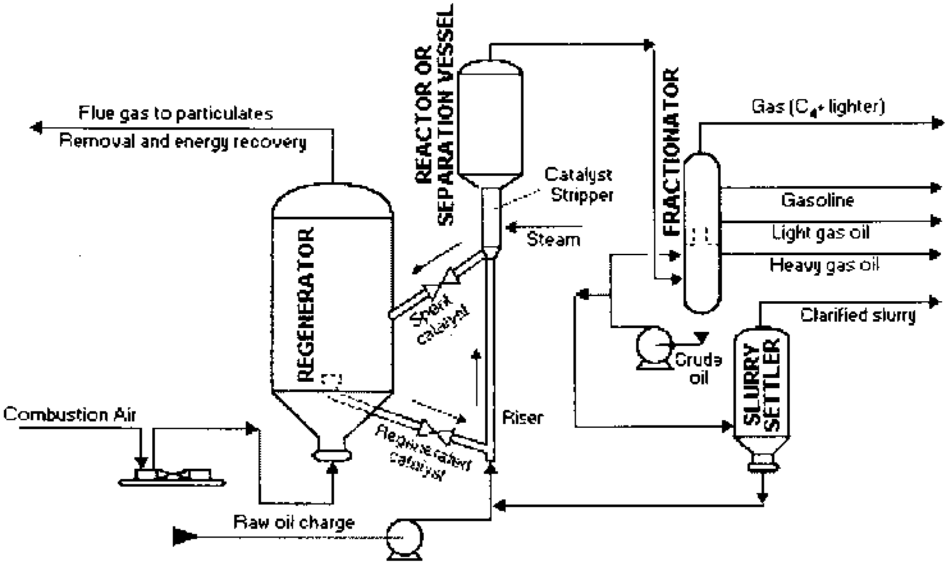
Fluid-bed Catalytic Cracking

(1) It is mixed with hot air to burn off the carbon which was deposited on it in the cracking process. *(2)* Typical products are fuel gas, LPG, gasoline, and light and medium gas oil. *(3)* The feedstock is then preheated and pumped to the reactor. *(4)* As the catalyst re-circulates from the reactor to the regenerator and back, the cracked mixture flows to a fractionation column. *(5)* Here, spent catalyst flows continuously to the regenerator while cracking is taking place. *(6)* At the same time, via the furnace-reactor line, regenerated catalyst is mixed with it and both are carried to the reactor. *(7)* From a unit upstream a suitable cut is selected and pumped to the catalytic cracking unit.

Section D. FURTHER READING

THERMAL CRACKING

The first thermal cracking process was developed around 1913.



Distillate fuels and heavy oils were heated under pressure in large drums until they cracked into smaller molecules with better antiknock characteristics. However, this method produced large amounts of solid, unwanted coke. This early process has evolved into the following applications of thermal cracking: visbreaking, steam cracking, and coking.

Visbreaking Process. Visbreaking, a mild form of thermal cracking, significantly lowers the viscosity of heavy crude-oil residue without affecting the boiling point range. Residual from the atmospheric distillation tower is heated (800°-950° F) at atmospheric pressure and mildly cracked in a heater. It is then quenched with cool gas oil to control overcracking, and flashed in a distillation tower. Visbreaking is used to reduce the pour point of waxy residues and reduce the viscosity of residues used for blending with lighter fuel oils. Middle distillates may also be produced, depending on product demand. The thermally cracked residue tar, which accumulates in the bottom of the fractionation tower, is vacuum flashed in a stripper and the distillate recycled.

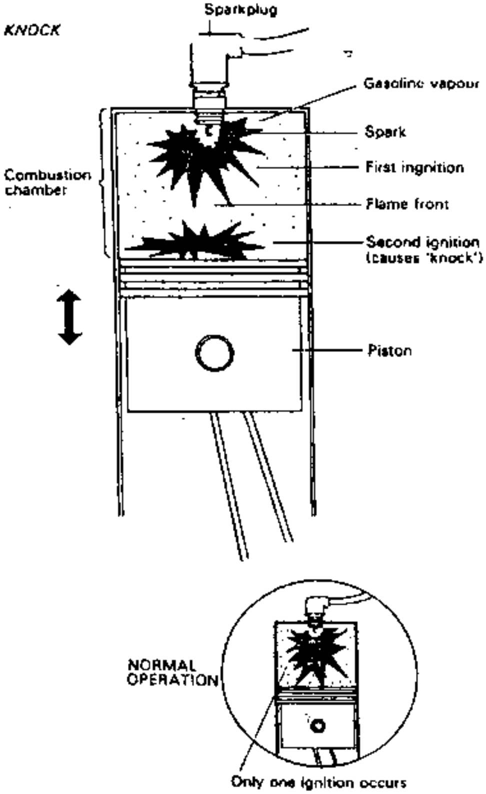
Steam Cracking Process. Steam cracking is a petrochemical process sometimes used in refineries to produce olefinic raw materials (e.g., ethylene) from various feedstock for petrochemicals manufacture. The feedstock range from ethane to vacuum gas oil, with heavier feeds giving higher yields of by-products such as naphtha. The most common feeds are ethane, butane, and naphtha. Steam cracking is carried out at temperatures of 1,500°-1,600° F, and at pressures slightly above atmospheric. Naphtha produced from steam cracking contains benzene, which is extracted prior to hydrotreating. Residual from steam cracking is sometimes blended into heavy fuels.

Coking Processes. Coking is a severe method of thermal cracking used to upgrade heavy residuals into lighter products or distillates. Coking produces straight-run gasoline (coker naphtha) and various middle-distillate fractions used as catalytic cracking feedstock. The process so completely reduces hydrogen that the residue is a form of carbon called "coke." The two most common processes are delayed coking and continuous (contact or fluid) coking. Three typical types of coke are obtained (sponge coke, honeycomb coke, and needle coke) depending upon the reaction mechanism, time, temperature, and the crude feedstock.

UNIT 4. FINISHING PROCESSES

Section A. READING COMPREHENSION

The diagram above illustrates 'knock', which is the noise produced by the abnormal ignition of *motor spirit* vapour in the combustion chamber of an engine. For smooth engine performance ignition should occur *throughout* the chamber *instantaneously,* but it sometimes occurs in two stages and knock then results. The antiknock properties of a fuel are measured by octane number (or 'octane rating'), from a system developed by Graham Edgar in 1926. The higher the octane rating of a gasoline, the better its antiknock properties



There are basically two methods for the *upgrading* of low-octane-number gasoline: (1) reforming, a conversion process by which hydrocarbons are actually re-formed into different molecular shapes, and (2) the use of antiknock *additives,* such as tetraethyl lead *(TEL)* or tetramethyl lead *(TML).* Straight-run naphtha, for example, has a very low octane rating of about 40. By catalytic reforming, this can be increased to 95 or more, and the *reformate* can then be blended with a light gasoline cut to give a fuel of just the right volatility and octane number. *Besides* being used to improve gasoline yields, naphtha is important as a feedstock in the production of petrochemical intermediates. Two of the most valuable of these are the gases ethylene (C_2H_4) and propylene (C_3H_6), essential in the manufacture of a wide range of synthetic materials. Ethylene and propylene can also be cracked from *wide-cut* light distillate feedstock (LDF).

Alkylation and *isomerization* are specific reforming processes for the production of high-grade gasoline components. Alkylation combines low-molecular-weight olefins (primarily a mixture of propylene and butylene) with isobutene in the presence of a catalyst, either sulfuric acid or hydrofluoric acid. The product is called alkylate and is composed of a mixture of high-octane, branched-chain paraffinic hydrocarbons. Alkylate is a premium blending stock because it has exceptional antiknock properties and is clean burning. The octane number of the alkylate depends mainly upon the kind of olefins used and upon operating conditions.

Isomerization is a reaction that catalytically converts straight-chain hydrocarbon molecules into branched-chain molecules of substantially higher octane number. The reaction rearranges the carbon skeleton of a molecule without adding or removing anything from the original material. In isomerization, the catalysts are platinum (Pt) or aluminum chloride ($AlCl_3$)

Caustic washing and *hydrodesulphurization* are finishing processes designed to remove H_2S and mercaptan impurities. Scrubbing with caustic soda (sodium hydroxide, NaOH) is the most widely-used process for H_2S removal, mainly because it *simultaneously* removes other impurities such as carbon dioxide (CO_2) and *fatty acids*.

SPECIAL WORDS AND EXPRESSIONS

motor spirit	gasoline.
throughout	in every part of.
instantaneously	in the same instant.
upgrading	improving the quality of.
additives	chemicals added to other substances.
TEL	$Pb(C_2H_5)_4$
TML	$Pb(CH_3)_4$
reformate	product of a reforming process. Compare this word with 'distillate' .
besides	in addition to.
wide-cut	relatively wide boiling range.
isomerization	process to form isomers. An isomer of a compound contains the same number of atoms of the same elements, but differs in structural arrangement and chemical properties.
hydrodesulphurization	Notice how the word is built up: sulphur → sulphurize (add sulphur to) → desulphurize (remove sulphur from) → desulphurization (removal of sulphur) →

	hydrodesulphurization (removal of sulphur in the presence of hydrogen).
simultaneously	at the same time.
fatty acids	Fatty-acid molecules are long-chain CH_2 groups, ending in -COOH.

COMPREHENSION

a. How might a refiner use butane in the production of iso-octane?

b. What are colour additives? Why are they used in gasolines?

c. What is the difference between cracking and reforming?

d. Define (i) distillates, (ii) reformates, (iii) crackates.

e. Why might ethylene and propylene be cracked from LDF rather than from naphtha?

f. What is the difference between caustic washing and hydrodesulphurization?

g. Explain what happens when ignition doesn't take place instantaneously throughout the combustion chamber.

h. What's the chemical difference between 2-star and 3-star petrol?

i. Explain what is meant by (i) a catalytic desulphurization process, and (ii) a deisobutanizer.

j. Describe briefly the reforming process that takes place in a 'platformer' (*plat-* = Pt).

Choose from these words to complete the paragraph below:

widely-used, maximum, spirit, ratio, catalytic, distillates, primary, gasoline, rating, feed, straight-run, raised, boiling.

One of the most important processes nowadays for the production of motor *(1)*.... is *(2)* .... cracking. The *(3)*.... is a *(4)*.... cut *(5)*... from about 70°C to a *(6)*.... of 190°C, the octane *(7)*.... of which is *(8)*.... in the cracking process from 40 to 95-100. Since the mid-1940s, this has been the most *(9)*.... process for the production of *(10)*.... from heavy *(11)*.... . It is also, therefore, the *(12)*.... method for increasing the *(13)*.... of light to heavy products from crude oil.

STRUCTURE PRACTICE

1. Reported Speech

Examples:

- Dick asked Jeff if he could have a quick word with him.

→ 'Can I have a quick word with you?' Dick asked Jeff.

- Dick told Jeff to keep an eye on Ralph for him

→ 'Keep an eye on Ralph for me, Jeff,' Dick said.

Convert the following from reported speech to direct speech.

a. Ralph asked Jeff which way the sweetener was.

b. Ralph told Jeff that he would be right behind him.

c. Jeff asked Dick what was up then.

d. Brian told the panel man to let him know what the PVT readings were then.

e. Tom asked the floorman why he wasn't wearing his safety boots and helmet.

f. Tom asked the floorman if he knew who the boss was.

g. Mason asked Smith if he could tell him the difference between 'porosity' and 'permeability'.

h. Smith told Mason that he was sorry but that he didn't know what the difference was.

i. Jack told Frank that he knew they needed the scrubber spares but that they couldn't do anything until the weather cleared.

j. Frank told Chris to stay away from the hatch until he got there and to make sure the crew were wearing muffs.

2. Chemical Symbols

$AlCl_3$ = aluminum chloride

$NaOH$ = sodium hydroxide

The list below contains some of the other chemical symbols. Write them out in words and say what elements each is composed of.

H_2S CH_4 H_2O Fe_3O_4 CO_2

$Pb(C_2H_5)_4$ $Pb(CH_3)_4$ HF C_2H_6 $CaCO_3$.

3. Sentences with should

'For smooth engine performance, ignition *should occur* throughout the chamber instantaneously...' (Section A)

Example: Why should ignition occur throughout the chamber instantaneously?

→ Ignition should occur throughout the chamber instantaneously to give smooth engine performance.

Answer the following in the same way.

a. Why should a trainee work with an experienced operator?

b. Why should operators wear muffs at the pig receiver?

c. Why should nobody smoke on the refinery floor?

d. Why should toxic-chemicals containers carry warnings?

Now consider what *may* happen if someone *doesn't* do what he *should* do.

Example: A trainee should work with an experienced operator. If he doesn't, he may cause a serious accident.

In the same way, write two sentences for each of the other four questions in the exercise above.

4. Passive Voice

'By catalytic cracking, this *can be increased* to 95 or more, and the reformate *can then be blended* ... .' (Section A)

Put the verbs in brackets into the same passive form.

a. Wide-cut LDF (also crack) to form ethylene and propylene.

b. Alkylation (think of) as the opposite of cracking.

c. Low-octane-number gasoline (upgrade) by reforming.

d. Naphtha (use) as a feedstock for petrochemical intermediates.

e. Methane (produce) from other sources besides oil.

WRITING PRACTICE

Cracking of naphtha

The cut between gasoline and kerosine is naphtha. Naphtha is a straw-coloured liquid. Like the other crude-oil fractions, it's a group of hydrocarbons. Each hydrocarbon molecule in the naphtha group contains between 6 and 10 carbon atoms and a number of hydrogen atoms. One of these naphtha-cut hydrocarbons is called heptane. The chemical symbol for heptane is C_7H_{16}. In other words, 7 carbon atoms combine with 16 hydrogen atoms to form one molecule of heptane. Heptane is a liquid hydrocarbon in the naphtha cut. When naphtha is cracked, the heptane in it is also cracked. It's cracked into gaseous fragments.

The fragments which result from the cracking of heptane are the gases ethylene and propylene. But ethylene and propylene gas are only two of the fragments produced from naphtha. Because there are other hydrocarbons in naphtha in addition to heptane. And when these are cracked, other fragments result. Some are gases, others are liquids

For the petrochemicals industry, however, ethylene and propylene gas are the most important fragments which result from the cracking of heptane molecules in naphtha

1. Now do this exercise based on the text above

a. Describe naphtha.

b. Define heptane

c. What are 'gaseous fragments'?

d. What are C_2-C_5 hydrocarbons?

e. Name three naphtha-cut hydrocarbons.

2. Write a similar text for hexane and the cracking of hexane:

Naphtha contains a group of hydrocarbons. One of these is the hydrocarbon known as hexane. ….

FURTHER READING

HYDROCRACKING

Description

Hydrocracking is a two-stage process combining catalytic cracking and hydrogenation, wherein heavier feedstocks are cracked in the presence of hydrogen to produce more desirable products. The process employs high pressure, high temperature, a catalyst, and hydrogen. Hydrocracking is used for feedstocks that are difficult to process by either catalytic cracking or reforming, since these feedstocks are characterized usually by a high polycyclic aromatic content and/or high concentrations of the two principal catalyst poisons, sulfur and nitrogen compounds.

The hydrocracking process largely depends on the nature of the feedstock and the relative rates of the two competing reactions, hydrogenation and cracking. Heavy aromatic feedstock is converted into lighter products under a wide range of very high pressures (1,000-2,000 psi) and fairly high temperatures (750°-1,500° F), in the presence of hydrogen and special catalysts. When the feedstock has a high paraffinic content, the primary function of hydrogen is to prevent the formation of polycyclic aromatic compounds. Another important role of hydrogen in the hydrocracking process is to reduce tar formation and prevent buildup of coke on the catalyst. Hydrogenation also serves to convert sulfur and nitrogen compounds present in the feedstock to hydrogen sulfide and ammonia.

Hydrocracking produces relatively large amounts of isobutane for alkylation feedstock. Hydrocracking also performs isomerization for pour-point control and smoke-point control, both of which are important in high-quality jet fuel.

Hydrocracking Process

In the first stage, preheated feedstock is mixed with recycled hydrogen and sent to the first-stage reactor, where catalysts convert sulfur and nitrogen compounds to hydrogen sulfide and ammonia. Limited hydrocracking also occurs.

After the hydrocarbon leaves the first stage, it is cooled and liquefied and run through a hydrocarbon separator. The hydrogen is recycled to the feedstock. The liquid is charged to a fractionator. Depending on the products desired (gasoline components, jet fuel, and gas oil), the fractionator is run to cut out some portion of the first stage reactor outturn. Kerosene-range material can be taken as a separate side-draw product or included in the fractionator bottoms with the gas oil.

The fractionator bottoms are again mixed with a hydrogen stream and charged to the second stage. Since this material has already been subjected to some hydrogenation, cracking, and reforming in the first stage, the operations of the second stage are more severe (higher temperatures and pressures). Like the outturn of the first stage, the second stage product is separated from the hydrogen and charged to the fractionator.

UNIT 5. REFINERY PRODUCTS

Section A. READING COMPREHENSION

Read the following passage

The fuels refined from crude oil can be divided into two general types: (l) fuels that are exploded, when vapourised with air, to provide primary moving power, and (2) those fuels that are either burned directly for heat and light or are converted into secondary energy sources such as electricity. The *former* type includes the *aviation* fuels (*Avgas, Avtag, Avtur*), industrial and *domestic* gases (LPG), motor spirits, DERV, and refinery gases. Fuels of the *latter* type include the ordinary kerosines and the various grades of fuel oils.

In the 1860s, when modern refinery practices began, the main products from *raw* petroleum were lamp kerosine and residue for use as a lubricant. Nowadays however, as we have already seen, about 88% of all crude oil ends up as fuel of one kind or another. Considering only the *finite* nature of fossil fuels, many people feel that far too much oil is being burned needlessly.

Of the remaining 12%, just over half is refined into petroleum-chemicals intermediates. These are used as feedstocks in the manufacture of synthetic materials *(fibres,* rubbers, plastics, etc.), *fertilizers, insecticides,* and even *protein* for animal feeds. For example, CH_2=CH-Cl is vinyl chloride produced by cracking ethylene dichloride, which is a compound made by reacting ethylene and chlorine. In the catalytic conversion process known as *'polymerization',* vinyl chloride becomes the well-known oil-based plastic, PVC (polyvinyl chloride).

About 5% of the average barrel of crude is used in the production of a wide range of lubricating oils and greases, waxes, *solvents,* and *asphalt* for roads and *weatherproofing.* Finally, there are commercial markets for the *by-products* of many refinery processes. Examples of these are pure sulphur, important in other areas of industry, and the platinum in some spent catalysts.

SPECIAL WORDS AND EXPRESSIONS

former	first in a preceding group of two.
aviation	concerning aeroplanes and flying
Avgas	aviation gasoline, used in piston-engined aeroplanes
Avtag	aviation turbine gasoline. In the USA, this is referred to as 'JP 4'.
Avtur	aviation turbine kerosine. In the UK, this is also referred to as 'ATK'.
domestic	for use in the home.
DERV	diesel engine road vehicle (fuel).
latter	last in a preceding group of two.
raw	unprocessed; in the natural state.
finite	having a definite end; limited.
should be conserved	should be protected from being wasted; should be saved.
fibres	Cotton and wool are natural fibres
fertilizers	chemicals which are added to the soil to help plant grow better.

insecticides	poisons to kill insects.
protein	basic chemical substance of all living things. Fish, meat and soya beans are foods which are rich in protein.
polymerization	In this process, single molecules combine to form much larger molecules. PVC is the polymer of vinyl chloride.
solvents	compounds which dissolve other substances.
asphalt	ie., bitumen, the heaviest cut of all. In the UK, 'asphalt' generally refers to the mixture of crushed rock and bitumen used in the construction of, e.g., road.
weatherproofing	protection against the weather, e.g., weatherproofing of roof tiles so that the rain is kept *out.*
byproducts	products in addition to the main product.

COMPREHENSION

a. Describe the five general types of products refined from crude oil.

b. Why should oil be conserved?

c. Explain the difference between (i) Avgas and Avtur, (ii) asphalt and bitumen.

d. Oil as a fuel indirectly helps the world's food supply when it is used, for example, to power farm tractors. Discuss the ways in which at least three non-fuel uses of oil can do the same.

e. Define 'fossil fuels'. Why are they described as being 'finite'?

f. Use the following to describe briefly how polyvinyl chloride is produced: crude → distillation → naphtha → cracking → ethylene → ethylene + chlorine → ethylene dichloride → cracking → vinyl chloride → polymerization → PVC.

g. Which process is the source of commercial sulphur in oil refineries?

h. How are alkylation and polymerization similar? How do they differ?

i. From 1500 tonnes of crude feed at the average large refinery, about how many tonnes end up as fuel?

j. Has the number of refinery products increased or decreased over the years? Why? How do you think the product split may change in, say, ten *years* from now? Give reasons for your answer.

TRUE OR FALSE?

Say whether these are true or false. Correct the false ones

a. The product of a polymerization process has a higher molecular weight than the feed.

b. The first refinery products were in the lower-boiling-point range.

c. Aviation fuels are in the lower-boiling-point range.

d. DERV is a secondary source of energy.

e. Insecticides improve farm yields by protecting plants from destruction during their growing period.

Section B. FURTHER READING

MAJOR REFINERY PRODUCTS

Gasoline. The most important refinery product is motor gasoline, a blend of hydrocarbons with. boiling ranges from ambient temperatures to about 400 °F. The important qualities for gasoline are octane number (antiknock), volatility (starting and vapor lock), and vapor pressure (environmental control). Additives are often used to enhance performance and provide protection against oxidation and rust formation.

Kerosene. Kerosene is a refined middle-distillate petroleum product that finds considerable use as a jet fuel and around the world in cooking and space heating. When used as a jet fuel, some of the critical qualities are freeze point, flash point, and smoke point. Commercial jet fuel has a boiling range of about 375°-525° F, and military jet fuel 130°-550° F. Kerosene, with less-critical specifications, is used for lighting, heating, solvents, and blending into diesel fuel.

Liquified Petroleum Gas (LPG). LPG, which consists principally of propane and butane, is produced for use as fuel and is an intermediate material in the manufacture of petrochemicals. The important specifications for proper performance include vapor pressure and control of contaminants.

Distillate Fuels. Diesel fuels and domestic heating oils have boiling ranges of about 400°-700° F. The desirable qualities required for distillate fuels include controlled flash and pour points, clean burning, no deposit formation in storage tanks, and a proper diesel fuel cetane rating for good starting and combustion.

Residual Fuels. Many marine vessels, power plants, commercial buildings and industrial facilities use residual fuels or combinations of residual and distillate fuels for heating and processing. The two most critical specifications of residual fuels are viscosity and low sulfur content for environmental control.

Coke and Asphalt. Coke is almost pure carbon with a variety of uses from electrodes to charcoal briquets. Asphalt, used for roads and roofing materials, must be inert to most chemicals and weather conditions.

Solvents. A variety of products, whose boiling points and hydrocarbon composition are closely controlled, are produced for use as solvents. These include benzene, toluene, and xylene.

Petrochemicals. Many products derived from crude oil refining, such as ethylene, propylene, butylene, and isobutylene, are primarily intended for use as petrochemical feedstock in the production of plastics, synthetic fibers, synthetic rubbers, and other products.

Lubricants. Special refining processes produce lubricating oil base stocks. Additives such as demulsifiers, antioxidants, and viscosity improvers are blended into the base stocks to provide the characteristics required for motor oils, industrial greases, lubricants, and cutting oils. The most critical quality for lubricating-oil base stock is a high viscosity index, which provides for greater consistency under varying temperatures.

COMMON REFINERY CHEMICALS.

Leaded Gasoline Additives. Tetraethyl lead (TEL) and tetramethyl lead (TML) are additives formerly used to improve gasoline octane ratings but are no longer in common use except in aviation gasoline.

Oxygenates. Ethyl tertiary butyl ether (ETBE), methyl tertiary butyl ether (MTBE), tertiary amyl methyl ether (TAME), and other oxygenates improve gasoline octane ratings and reduce carbon monoxide emissions.

Caustics. Caustics are added to desalting water to neutralize acids and reduce corrosion. They are also added to desalted crude in order to reduce the amount of corrosive chlorides in the tower overheads. They are used in some refinery treating processes to remove contaminants from hydrocarbon streams.

Sulfuric Acid and Hydrofluoric Acid. Sulfuric acid and hydrofluoric acid are used primarily as catalysts in alkylation processes. Sulfuric acid is also used in some treatment processes.

From the text above, write an abstract of 150 words about major and common refinery products.

Section C. STRUCTURE PRACTICE

1. Reported Speech

In the following examples notice particularly that both Past Simple and Present Perfect are converted to Past Perfect. Notice also that if a verb is already in the Past Perfect, it doesn't change.

Examples:

- 'Those are the only other products I've ever heard about,' Michael said to Miller.

→ Michael said to Miller that those were the only other products he had ever heard about.

- 'It is actually possible that the chicken I ate on Tuesday had been raised on an oil-based product?' Michael asked Miller.

→ Michael asked Miller if it was actually possible that the chicken he had eaten on Tuesday had been raised on an oil-based product.

Convert the following to reported speech.

a. 'Call in when you've started,' Brian told Jeff.

b. 'Has the operator phoned in to say why he didn't show up?' Frank asked Jack.

c. 'Bob, if you haven't finished the job by the end of this tour, I'll ask Paul's crew to do it,' Barry said.

d. 'I read in the changeover report that Bob's crew hadn't finished the job,' Paul said.

2. Passive Voice

Example:

Safety instruction (should obey) → Safety instructions *should be obeyed.*

Put the verbs in brackets into the same passive form.

a. Toxic-chemicals containers (should mark and lock away).

b. Trainees (should accompany) at all times by experienced personnel

c. Fire extinguishers (should place) at locations which are easy to reach and clearly marked by signs and notices.

d. Muffs (should wear) by all personnel involved in pigging operations and other high-noise work.

Now consider what may happen if action which should be taken isn't taken.

Example: Oil should be conserved. If it isn't conserved, the world may run into serious energy problems in a few years' time.

Write a mini-paragraph like that for each of the five sentences you wrote in the exercise above.

3. British and American Forms

(British) aluminium = (American) aluminum

These differences are not very great, and there is only a small number of them, but both forms should be learned in order to avoid confusion.

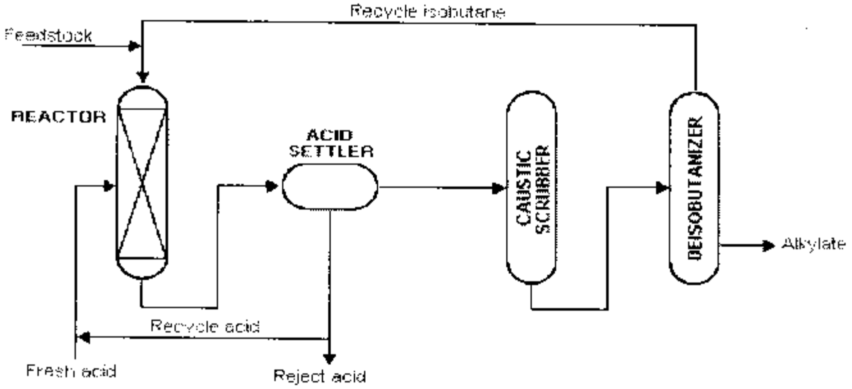
British	American
petrol	gasoline
petrol	gas (for a car)
motor spirit	gas, gasoline
litre	liter
gramme	gram
metre	meter
ATK	Avtur
DERV	diesel

British	American
Avtag	JP 4
bottoms up	lag time
vapour	vapor
paraffin (for space heaters)	kerosine
bitumen	asphalt (for weatherproofing)
polymerisation	polymerization
safety helmet	hard hat
bloody (e.g., bloody bad job)	damn

flammable	inflammable
helicopter	chopper

hydrodesulphurization	hydrodesulfurization
green, inexperience worker	boll weevil

Section D. WRITING PRACTICE

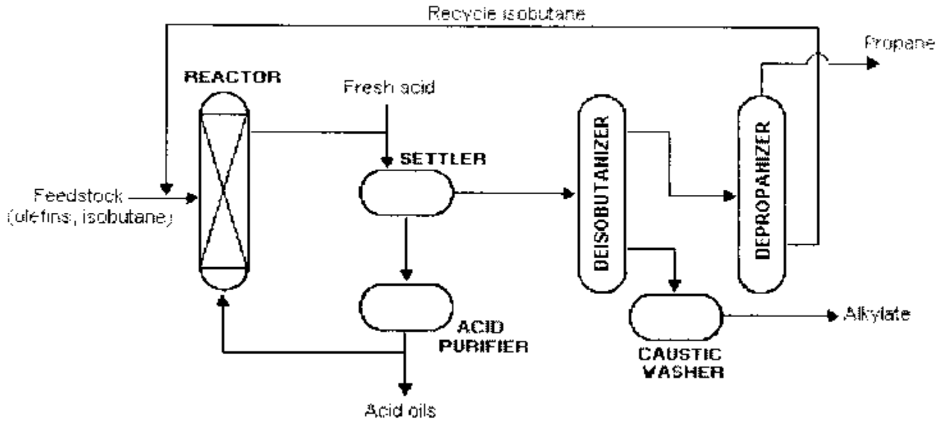


Sulfuric acid alkylation process

In cascade type sulfuric acid (H_2SO_4) alkylation units, the feedstock (propylene, butylene, amylene, and fresh isobutane) enters the reactor and contacts the concentrated sulfuric acid catalyst (in concentrations of 85% to 95% for good operation and to minimize corrosion). The reactor is divided into zones, with olefins fed through distributors to each zone, and the sulfuric acid and isobutanes flowing over baffles from zone to zone.

The reactor effluent is separated into hydrocarbon and acid phases in a settler, and the acid is returned to the reactor. The hydrocarbon phase is hot-water washed with caustic for pH control before being successively depropanized, deisobutanized, and debutanized. The alkylate obtained from the deisobutanizer can then go directly to motor-fuel blending or be rerun to produce aviation-grade blending stock. The isobutane is recycled to the feed.

Using the flow diagram below, write a description of the Hydrofluoric Acid Alkylation Process.



UNIT 6. HYDROTREATING AND CATALYTIC REFORMING

Section A. READING COMPREHENSION

1. INTRODUCTION

1.1. What is Catalytic Reforming ?

In simple terms, reforming is a chemical modification that converts a charge material into a higher- octane product called reformate. Octane is a number, or rating, that measures a fuel's anti-knock properties. The feedstock that is converted in the reforming process is usually naphtha. Naphtha, which consists of hydrocarbon molecules, is a product of crude oil distillation. Naphtha contains paraffins and naphthenes, like hexane and methylcyclohexane.

When heat and pressure are applied to naphtha, the structure of the naphtha's hydrocarbon molecules is rearranged, or reformed. As a result, the paraffins and naphthenes are converted into aromatic hydrocarbons such as toluene. These aromatics have a higher octane number, which makes them more suitable for high-compression engines.

Through experimentation and research, scientists learned that, in addition to using heat and pressure, the reforming process could be improved by using a catalyst. The catalyst would produce higher octanes and better yields at lower temperatures and pressures.

A catalyst is a substance that allows a reaction to occur without being significantly affected by the reaction. Different types of catalysts can be used in the reforming process. In many refineries, the reforming catalyst is in the form of small beads that contain platinum. Platinum is a precious metal, and several million dollars worth of it may be used in a catalytic reforming unit. As a result, a main concern, during the catalytic reforming process is safeguarding the catalyst.

1.2. Major Sections of a Catalytic Reforming Unit

The process is divided into two main sections: the pretreating section and the reforming section.

The feed material for a catalytic reforming unit is often a straight-run naphtha. It may contain sulfur, and it may also contain traces of arsenic, lead, or other contaminants that would poison the catalyst and inhibit the reforming process.

In the pretreating section, the feed material is pretreated. Pretreatment consists of removing the contaminants, especially sulfur, by a process called hydrotreating. During pretreatment, the main process is the use of hydrogen to remove sulfur. Therefore, this process may also be referred to as hydrodesulfurization or by the abbreviation "HDS".

The hydrotreating unit consists of two subsections: the reaction section and the separation section. In the reaction section, reactions occur that help decontaminate the feed. The product of these reactions is a mixture of gases and desulfurized naphtha. In the separation section, the gases are separated from the liquid and removed.

The reforming unit also has a reaction section and a separation section. In the reaction section, the reactions that occur reform the feed into higher-octane hydrocarbons. Byproducts of these reactions include gases and lighter hydrocarbons. In the separation section, the lighter byproducts are separated from the heavier products.

During the reforming process, the lighter byproducts are either removed from the unit and sent elsewhere in the refinery or recycled back to the reaction section or to the hydrotreating unit. The heavier material is the reformate, or finished product. Although most of the reformate ends up as blending stocks for motor fuels, some of it is processed into products such as benzene, toluene and xylene, which are feedstocks for petrochemicals.

Although hydrotreating and catalytic reforming are separate units, they are often operated together.

2. PROCESS REACTIONS

Hydrotreating and catalytic reforming consist of a series of process reactions. These reactions decontaminate the feed and cause the octane number of the Naphtha charge to increase.

2.1. Hydrotreating Reactions

The primary goal of hydrotreating is to remove contaminants, especially sulfur, from the feed. Reforming catalysts are very sensitive to contaminants, and an expensive platinum catalyst can be damaged by even a small amount of sulfur. Other contaminants that are removed include nitrogen, arsenic, lead, and other trace metals.

During hydrotreating, hydrogen is added to the feed material. Then the mixture of hydrogen and feed material is exposed to heat and pressure and passed through a reactor over a hydrotreating catalyst. This process initiates a series of hydrotreating reactions.

2.1.1. Hydrodesulfurization

The main hydrotreating reaction is the removal of sulfur. In an ideal reaction, the combining characteristics, or valences, of hydrogen and sulfur cause the hydrogen molecules to attach themselves to sulfur molecules in a 2:1 ratio. For example, reaction of hydrogen with a sulfur-contaminated feed molecule produces hydrogen sulfide (H_2S) gas, which is separated from the liquid and removed before catalytic reforming occurs. A reaction in which hydrogen is used to remove sulfur is called hydrodesulfurization, or HDS.

In an actual reaction of this type, large quantities of hydrogen are added to the feed material to ensure that all of the sulfur is reacted and removed.

2.1.2. Denitrification

Another contaminant that is removed during hydrotreating is nitrogen. The reaction that removes nitrogen is called denitrification, or denitrogenation. In the presence of hydrogen, nitrogen is pulled away from the hydrocarbon molecule. Hydrogen attaches to nitrogen in a 3: 1 ratio. The result of this bonding is the compound ammonia (NH_3).

2.1.3. Metal Adsorption

During hydrotreating, some of the trace metals in the feed attach themselves to the hydrotreating catalyst. This adhesion, or adsorption, of trace metals to the catalysts decontaminates the feed. The trace metals that stick to the hydrotreating catalyst are not passed onto the reforming catalyst. The reforming catalyst, which often contains platinum, is a much more expensive and valuable material than the hydrotreating catalyst.

2.2. Reforming Reactions

In the reforming unit, the naphtha is converted into higher-octane reformate. The reactions that take place are based on some of the same chemical principles as the hydrotreating reactions. For example, during reforming, hydrogen is again mixed with the feed material. The mixture of hydrogen and feed material is exposed to heat and pressure and passed over a reforming catalyst.

2.2.1. Dehydrogenation

The most common reaction that occurs during catalytic reforming is dehydrogenation, which is the removal of hydrogen. This reaction converts a naphthene into an aromatic. One of the naphthenes found in the feedstock is methylcyclohexane (MCH). Through dehydrogenation, MCH is reformed into toluene and hydrogen. The hydrogen is an important byproduct; it is used to protect the reforming catalyst.

2.2.2. Isomerization

Another reaction that occurs during reforming is isomerization, which is the conversion of a paraffin to an isoparaffin. For example, normal hexane (n-C_6H_{14}) is reformed to isohexane (iso-C_6H_{14})

2.2.3 Cyclization

Dehydrogenation and isomerization increase the octane number of the naphtha to approximately 88 to 90. To increase it even more, a third reaction, called cyclization, is needed. Cyclization converts a paraffin into a naphthene. Cyclization requires a higher reactor temperature than the first two reactions. For example, normal heptane (n- C7) is converted to methylcylohexane (MCH) and hydrogen. Normal heptane is a paraffin found in the feedstock. It is a straight-chain hydrocarbon, but, during the reaction, it is reformed into a cyclic hydrocarbon (thus the name "cyclization").

The product of one reforming reaction often becomes the reactant for another reaction. For example, the methylcyclohexane produced by the cyclization of normal heptane is a napthene that can then be converted to an aromatic by the dehydrogenation reaction.

2.2.4 Hydrocracking

The extra heat that is needed for the cyclization reaction also causes a reaction called hydrocracking. Hydrocracking is the breaking down of hydrocarbon molecules into smaller molecules in the presence of hydrogen at high temperature and pressure.

There are, in fact, two hydrocracking reactions. One reaction cracks napthenes into paraffins, and the other breaks longer paraffins into smaller paraffins. The following reaction illustrates the first reaction

$$+ 2\,H_2 \rightarrow C_4H_{10} + C_2H_6$$

In this example, the napthene compound cyclohexane (CYC6), in the presence of hydrogen, cracks into the paraffins butane (C4) and ethane (C2). The hydrogen is used up during the reaction.

The reaction below illustrates the second reaction.

$$C_9H_{20} + H_2 \rightarrow C_6H_{14} + C_3H_8$$

In this example, nonane (C9) is cracked and immediately saturated with hydrogen. The result is hexane (C6) and propane (C3). Some of these smaller paraffins can go on to reform into aromatics.

The two hydrocracking reactions can occur in stages, that is, the product of the first reaction may become the reactant for the second. Hydrocracking is an unavoidable reaction that occurs during reforming. In some ways, it is a favorable reaction, since it increases octane numbers. On the whole, however, hydrocracking is considered an unfavorable reaction. One reason it is considered unfavorable is that the catalytic reforming process is more efficient when aromatics are produced than when paraffins are produced. Another reason is that hydrocracking consumes some of the valuable hydrogen that is produced by other reactions.

Although hydrocracking is regarded as an adverse reaction, the overall result of the four reforming reactions is favorable. A low-octane, straight-run naphtha is converted to high-octane reformate, which can be used for motor fuels or petrochemical feedstocks.

2.3. Reforming Catalysts

One of the main ingredients in the reforming process is the catalyst that helps the reactions occur. A typical reforming catalyst consists of a base material, such as alumina, that contains metal sites and acid sites. Different kinds of catalyst metals can be used, but a common type is a combination of platinum and rhenium. The acid sites are generally made up of chloride.

The different sites on a catalyst promote different reactions. In general, the metal sites promote dehydrogenation and cyclization, and the acid sites promote hydrocracking and isomerization.

2.4. Catalyst Protection

Reforming reactions involve hydrocarbons, so carbon deposits build up on the catalyst over time as reforming occurs. These deposits, called coke, can eventually deactivate the catalyst. If coke deposits cover the catalyst, the catalyst will be unable to promote the reforming reactions.

Coking of the catalyst is minimized if the process reactions occur in an atmosphere that is rich with hydrogen. Both dehydrogenation and cyclization yield hydrogen. If some of this hydrogen is recycled back through the process, more hydrogen will be available to react with carbon atoms. With an abundance of hydrogen, the carbon atoms are more likely to attach to hydrogen than to the catalyst.

Recycling hydrogen to a process helps to protect the catalyst in another way: by minimizing the adverse effects of the hydrocracking reactions. Hydrocracking steals hydrogen from the reforming process. However, when hydrogen is continuously recycled, there is enough in supply to keep the catalyst well protected.

The hydrogen that is produced during reforming can also be put to good use in other hydrogen-consuming processes. For example, this hydrogen can be fed to the hydrotreating unit to combine with sulfur and remove catalyst contaminants from the feed.

COMPREHENSION

1. Define the octane number.
2. What is the feedstock for a catalytic reforming ?
3. What is the main purpose of hydrotreating ?
4. Name some contaminants that can poison the reforming catalysts.
5. Which reactions are used to decontaminate these compounds?
6. What is the role of metal sites and acid sites on reforming catalyst?
7. What are the main reactions of reforming process?
8. What are the adverse reactions in reforming process?
9. Why does the reforming have to be carried out in hydrogen atmosphere?
10. What are the main products of catalytic reforming? And what are they used for?

Choose from these words to complete 'the paragraph below':

source, octane, composed, "reformed", boils, branched, chemicals, number

Naphtha, the distillation cut which (1).............. between 70 and 200^{0}C (C_5-C_{10}) is (2)............... primarily of alkanes and cycloalkanes with a small fraction of aromatics. This low octane feedstock must be (3)............... to make high (4)......... gasoline. In naphtha reforming, normal alkanes and cycloalkanes are converted to (5)............. alkanes and aromatics in order to improve the octane (6)............ . Thus reforming is also a primary (7)............. of aromatics for (8).............. .

Section B. EXERCISES

I. Fill in the blanks in the sentences below with the correct prepositions

1. Natural gas is composed ___ about 80% methane, 10% ethane, 4% propane, and 2% butane.
2. The remaining 4% consists ___ nitrogen and higher molecular mass hydrocarbons
3. When heat and pressure are applied ___ naphtha, the structure of the naphtha's hydrocarbon molecules is rearranged
4. The reactions that take place in the reforming unit are based __ some of the same chemical principles as the hydrotreating reactions.
5. Methylcyclohexane can be converted ___ an aromatic by the dehydrogenation reaction.

II. Match the following words or phrases with their definitions.

1.	charge material (n)	a.	a little perforated ball
2.	safeguard (v)	b.	denitrification
3.	trace (n)	c.	secondary product made in the manufacture of something else
4.	contaminant (n)	d.	of great value or worth
5.	inhibit (v)	e.	component
6.	hydrodesulfurization (n)	f.	pollutant
7.	Byproduct (n)	g.	protect
8.	blend (v)	h.	restrain or prevent
9.	precious (a)	i.	change in form, character, or function

10.	convert (v)	j.	mix
11.	bead (n)	k.	(feed material) feedstock
12.	ingredient (n)	l	process in which hydrogen is used to remove sulfur
13	denitrogenation (n)	m	a very small quantity

III. Choose the one that should be corrected

1. A catalyst is a substance that allows a reaction occur without being
A B C
significantly affected by the reaction
D

2. During the reforming process, the lighter byproducts are either removed
A B
from the unit and recycled back to the reaction section.
C D

3. Hydrocracking is the breaking down of hydrocarbon molecules into
A B C
smaller moleculars in the presence of hydrogen at high temperature
D
and pressure

4. Coking of the catalyst is minimizes if the process reactions occur in
A B
an atmosphere that is rich with hydrogen
C D

5. The product of one reforming reaction often become the reactant for
A B C
another reaction
D

IV. Fill in the blanks in the sentences below with the correct words or phrases

1. A reaction in which hydrogen is used to remove sulfur is called ________

   A. hydrogenation B. dehydrogenation

   C. hydrodesulfurization C. hydrocyclization

2. A ________is a substance that allows a reaction to occur without being significantly affected by the reaction

   A. catalyze B. catalyst C. catalytic D. catalysis

3. Reforming is a chemical modification that converts a charge material into a _________called reformate

   A. higher- octane product B. lower-octane product

   C. product higher octane D. product lower-octane

4. Another reaction that occurs during reforming is isomerization, which is the conversion of a paraffin to an _______.

   A. isoparaffin B. olefin C. aromatic D. iso-olefin

5. The hydrogen that is produced during reforming can also be put to good use in other ______________.

   A. processes hydrogen-consuming B. processes consuming hydrogen

   C. hydrogen-consume processes D. hydrogen-consuming processes

V. Choose the correct word or phrase that best keeps the meaning of its definition or synonym underlined in each sentence below

1. In alkenes and alkynes, addition reactions ***occur*** at the double or triple bonds.

   A. take place B. occupy C. contain D. convert

2. The ***properties*** of ethane are similar to methane.

   A. structures B. bonds C. characteristics D. reactions

3. Reforming is a chemical modification that converts a ***charge material*** into a higher- octane product called reformate.

   A. starting material B. paraffin C. molecules D. intermediate

4. Octane is a ***number*** that measures a fuel's anti-knock properties.

   A. compound B. rating C. paraffin D. product

5. Dehydrogenation and isomerization increase the octane number of

the naphtha to approximately 88 to 90.

A. exactly B. completely C. relatively D. about

6. Hydrocracking is a(n) *unavoidable* reaction that occurs during reforming.

A. necessary B. inevitable C. unnecessary D. usable

UNIT 7. ZEOLITES

Section A. READING COMPREHENSION

Zeolites are crystalline aluminosilicates primarily of group I and II elements. Their chemical composition can be represented by the *empirical* formula: .

$$M_{2/n}O.Al_2O_3.xSiO_2.yH_2O.$$

where x is equal to 2 or more and n is the valence of the cation M. The maximum value of x for naturally occurring zeolites is 10.

Structurally, zeolites form an *infinite* three-dimensional network of AlO_4 and SiO_4 tetrahedra linked to each other by shared oxygens. The structure can be visualized hypothetically as being derived from SiO_2 units jointed in a three-dimensional network. The replacement of tetravalent silicon atoms by trivalent aluminum atoms results in the formation of an ionic site in the *vicinity* of the aluminum atom. A cation is necessarily introduced into the structure for preservation of electrical neutrality. The cations introduced are usually readily exchangeable resulting in typical zeolitic properties. Utilizing the *concept* that tetracoordinated aluminum atoms cannot share the same oxygen, x should always be ≥ 2.

The three-dimensional framework consists of channels and interconnected *voids* or cages. The cations and water molecules occupy the void spaces in the structure. When the zeolite is hydrated, the cations are highly mobile and can be replaced by ion exchange to varying degrees depending on the particular zeolite structure and the exchanging cation.

The intracrystalline zeolitic water can be *removed* by thermal treatment, usually reversibly. For many zeolites the structure remains *intact* and the intracrystalline channels and voids become *vacant* except for the remaining cations. In many cases, the positions of the cations change as a function of the degree of hydration.

The synthetic routes for producing zeolites and molecular sieves usually result in final products containing substantial amounts of alkali metal ions or organic templates. Although some reactions have been shown to be catalyzed by these materials, these reactions are relatively few and none are believed to be commercial. Most industrial reactions conducted over molecular sieves are acid catalyzed reactions. It is necessary to modify the zeolites to introduce the acid catalytic sites. It is also frequently necessary to *modify* the as synthesized zeolite so as to improve the thermal and chemical stability. The zeolite molecular sieve can be suitably modified by treatment in one or more of the following ways: cation exchange, thermal and hydrothermal treatment, and chemical modification.

Molecular sieve zeolite catalysts have found application in the areas of refinery fuels processing, production of chemicals and environmental pollution control.

COMPREHENSION

1. What are zeolites ?
2. How does an ionic site form in the structure of zeolites?
3. Why is a cation introduced into the structure of zeolite ?
4. Describe the three-dimensional framework of zeolite.
5. How can intracrystalline zeolitic water take away?
6. What are the applications of molecular sieve zeolite catalysts?

Section B. EXERCISES

I. Match the following words or phrases (in column A) with their definitions (in column B)

A	B
1. empirical (a)	a. endless
2. vicinity (n)	b. a general notion

3.	infinite (a)	c.	untouched
4.	void (n)	d.	based on observation or experience
5.	concept (n)	e.	change the form or quality of
6.	vacant (a)	f.	surrounding place
7.	intact (a)	g.	take off or take away
8.	remove (v)	h.	an empty space
9.	modify (v)	i.	not filled or occupied/ empty

II. Choose the one that should be corrected.

1. The synthesis X and Y type zeolites have framework structures
A
similar to that of the natural mineral faujasite although they are
B C D
distinct species with characteristic properties.

2. The basic building block is a truncated octahedron (sodalite cage)
A B
consisting a three-dimensional structure of AlO_4^- and SiO_4 tetrahedra.
C D

3. Mordenite is one of the more silica rich zeolite minerals with a
A B C
SiO_2/Al_2O_3 ratio of about 10.
D

4. For catalyst purposes, the cation sites that exist inside the supercage
A B
or close to the walls of the supercages are probably the most
C D
important.

5. The adsorption properties of molecule sieve zeolites were studied by
A B C D
McBain.

III. Fill in the blanks in the sentences below with the correct words or phrases

1. Catalysis involving ________ was reported a few years later.

   A. zeolite molecular sieves B. molecular sieve zeolites

   C. molecules sieve zeolites D. molecular zeolite sieves

2. This review will _______ industrial uses of molecular sieve catalysts.

   A. concentrate on B. concentrated on

   C. concentrates on D. concentrate

3. Zeolites _________the large-pore X, Y, and mordenite materials and the smaller-pore ZSM-5 and ZSM-11 types and erionite.

   A. are divide into B. is divided into

   C. are dividing into D. are divided into

4. In the late 1960s, __________of shape selective catalysts were revealed.

   A. commercial applications B. commercially applications

   C. commercial apply D. applications commercial

5 Molecular sieve zeolite catalysts have found application in the areas of refinery fuels processing, production of________, and environmental pollution control.

   A. chemist B. chemistry C. chemical D. chemicals

UNIT 8. PHYSICAL AND CHEMICAL ADSORPTION

Section A. READING COMPREHENSION

Physical adsorption is the result of a relatively weak *interaction* between the solid surface and the gas - a physical attraction. Physical attractive forces involve relatively weak van der Waals forces and low heats of adsorption usually not exceeding 80 kJ/mole. Physical adsorption does not *affect* the structure or *texture* of the adsorbent, and desorption takes place as conditions are *reversed*.

Chemical adsorption is a much stronger interaction than physical adsorption with heats of adsorption up to 800 kJ/mole. But heat of adsorption values less than 80 kJ/mole do not necessarily rule out chemisorption. During the chemisorption process the adsorbing gas or vapor molecule *splits* into atoms, radicals,. or ions which form a chemical bond with the adsorption site. This interaction involves the sharing of electrons between the gas and the solid surface and may be regarded as the formation of a surface compound.

The fact that the chemisorptive gas or vapor molecule may split during the adsorption process creates complications not present in physisorption, particularly as chemisorption pertains to the determination of active surface area. One complication is the stoichiometry factor *Fs* which is required in chemisorption data reduction methods. This factor is obtained from the ratio of the atoms of molecules in the balanced chemical equation between the active gas and active surface or, simply put, it is the number of surface atoms interacting with one adsorptive molecule. The stoichiometry factor in simple cases can be determined empirically by performing both a chemisorption surface area and a BET surface area analysis on the pure metal.

As an example, a hydrogen gas molecule (H_2) *dissociates* into two atoms and each atom chemisorbs onto an atom of platinum; the stoichiometry factor pertaining to this adsorptive-adsorbent pair is 2. However, the adsorption of carbon monoxide on platinum is one molecule of carbon monoxide to one atom of platinum. Therefore the stoichiometry factor is 1. The situation becomes more complicated in cases where the chemisorptive molecule is adsorbed differently depending on surface structure. An example of this is carbon monoxide on a Pd/SiO_2 catalyst where either a bridged Pd-(CO)-Pd bond or linear Pd=C=O bond may result.

Unlike physical adsorption, chemisorption is difficult to reverse by vacuum alone. In fact, when sufficient energy is applied to remove the adsorbed molecules, atoms of the surface material may be carried away with them. For example, when oxygen is chemisorbed on charcoal, the application of heat and vacuum results in desorption of carbon monoxide.

Physical adsorption takes place on all surfaces *provided* temperature and pressure conditions are favorable. Chemisorption, on the other hand, is *localized* and *occurs* only on certain surfaces or surface sites. Meaningful examination of the energies and sites involved can be achieved only if these sites are *cleansed* of previously adsorbed molecules. Thus, before a chemisorption analysis can proceed, removal from the active sites of any existing atmospheric contamination must be achieved.

Under *proper* conditions physical adsorption results in adsorbed molecules forming multiple layers. Chemical adsorption occurs only if the adsorptive makes direct contact with the surface; therefore it is a single-layer process. But physical and chemical adsorption processes are not *exclusive*. A layer of molecules may be adsorbed physically on top of an underlying chemisorbed layer, or physical adsorption may occur on nonactive sites of a substrate while chemisorption is occurring on the active sites.

Physical adsorption diminishes rapidly with temperature *elevation*; chemisorption, on the other hand, is *enhanced* by high temperature. Furthermore, the same surface can display physical adsorption at one temperature and chemisorption at a higher temperature. For example, at liquid nitrogen temperature (77 K) nitrogen gas is adsorbed physically on iron but at 800 K, an energy level too high for physical adsorption bonds, nitrogen is adsorbed chemically to form iron nitride.

Many molecules must be activated before they will react according to present theories. Activation energy is a measure of the energy which must be supplied to them to *bring about* reaction. In some cases the activation energy requirement is such that reaction will proceed only at a measurable rate above a certain temperature. Other reaction *proceeds* rapidly at low temperature, hydrogen on platinum being an example of a chemisorption reaction where the activation energy approaches zero.

COMPREHENSION

1. What are the main differences between physical and chemical adsorption?

2. What is the influence of temperature on physical and chemical adsorption ?

Section B. EXERCISES

I. Match the following words or phrases (in column A) with their definitions (in column B)

A		B	
1.	*affect (v)*	a.	happen, take place
2.	*interact (v)*	b.	influence
3.	*texture (n)*	c.	not including/ except for
4.	*split (v)*	d.	restrict or assign to a particular place
5.	*dissociate (v)*	e.	break into parts
6.	*reverse (v)*	f.	make clean
7.	*localize (v)*	g.	act on each other
8.	*occur (v)*	h.	disconnect, separate
9.	*cleanse (v)*	i.	the arrangement of small constituent parts
10.	*exclusive (a)*	j.	bring to a higher position
11.	*elevate (v)*	k.	turn the other way round or up or inside out

II. Choose the correct word or phrase that best keeps the meaning of its definition or synonym underlined in each sentence below

1. Physical adsorption takes place on all surfaces ***provided*** temperature and pressure conditions are favorable

   A. supplied B. if C. when D. how

2. Under ***proper*** conditions physical adsorption results in adsorbed molecules forming multiple layers.

   A. atmospheric B. reaction C. reduction D. suitable

3. Chemisorption is ***enhanced*** by high temperature

   A. improved B. done C. occurred D. happened

4. Activation energy is a measure of the energy which must be supplied

to them to *bring about* reaction.

A. increase B. supply C. cause to happen D. decrease

5. Other reaction *proceeds* rapidly at low temperature

A. goes on B. decreases C. diminishes D. lowers

III. Choose the one that should be corrected and explain why

1. Physical adsorption does not affect on the structure or texture of the
A B C
adsorbent.
D

2. Chemical adsorption is a much strong interaction than physical
A B
adsorption with heats of adsorption up to 800 kJ/mole
C D

3. Physical adsorption take place on all surfaces provided temperature
A B
and pressure conditions are favorable.
C D

4. When sufficient energy is applied to remove the adsorbed molecules,
A B C
atoms of the surface material may carried away with them
D

5. Many molecules must be activated before they will react according
A B C D
present theories

UNIT 9. VINYL CHLORIDE

Section I. READING COMPREHENSION

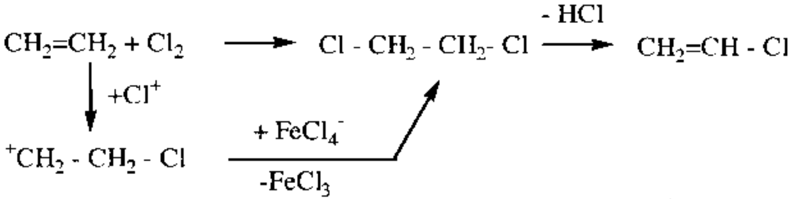
Vinyl chloride is the monomer for the production of polyvinylchloride (PVC). About 8 to 10 million tons are produced annually worldwide. Most of it is produced by oxychlorination of ethylene. The overall reaction is

$$4CH_2{=}CH_2 + 2\ Cl_2 + O_2 \rightarrow 4\ CH_2{=}CH\text{-}Cl + 2\ H_2O$$

However, this equation does not describe the real sequence of *classical addition* and *elimination* reactions.

The first step is the addition of chlorine to ethylene with $FeCl_3$, $CuCl_2$ or $SbCl_3$ as catalysts at 40-70^{0}C and 5 bar. According to the classical mechanism the catalyst polarizes the chlorine. The *positively* charged chlorine attacks the olefin to form a carbenium ion intermediate.

$$Cl_2 + FeCl_3 \rightleftharpoons Cl^+ + FeCl_4^-$$



Hydrochloric acid is eliminated in the vinyl chloride forming step. It can be used as the chlorine source in the presence of oxygen and copper (II) chloride. The $CuCl_2$ is the actual chlorinating agent. It is *reduced* to Cu(I) chloride, which is then *reoxidized* by oxygen.

$$CH_2{=}CH_2 + 2\ CuCl_2 \rightarrow Cl\text{-}CH_2\text{–}CH_2\text{-}Cl + 2\ CuCl$$

$$2\ CuCl + 1/2\ O_2 \rightarrow CuO.CuCl_2$$

$$CuO.CuCl_2 + 2\ HCl \rightarrow 2\ CuCl_2 + H_2O$$

No free chlorine is involved. The process operates typically at 230^{0}C and 0.2 - 0.4 MPa. The reaction is *exothermic* and the processes used by different manufacturers usually vary in the reactor design and the methods to control the *evolution* of heat.

In *modern* processes the dehydrochlorination of dichloroethane to vinyl chloride is achieved by thermal cracking in a purely thermal radical chain process at 500-600°C and 2.5 - 3.5 MPa. Catalytic dehydrochlorination on pumice or charcoal at 430-530°C and 2.5 MPa is less important.

The classical conversion of dichloroethane to vinyl chloride with alkali hydroxides in liquid phase is rarely used today.

Since chlorine is rather *expensive*, all three steps, chlorination, oxychlorination and dehydrochlorination, are integrated in one process and balanced in such a way that no chlorine is lost. The principle set-up is illustrated in figure 1.

The first industrial processes for the manufacture of vinyl chloride were based on acetylene as the feedstock. HCl was added to acetylene at 140-200°C in the *presence* of $HgCl_2$ as the catalyst.

$$HC{\equiv}CH \quad + HCl \xrightarrow{HgCl_2} CH_2{=}CH\text{-}Cl$$

The reaction is straightforward and proceeds with high conversions (96%) of acetylene and high selectivities (98%) for vinyl chloride. Nevertheless, ethylene has replaced acetylene as the starting material, since it is significantly *cheaper*.

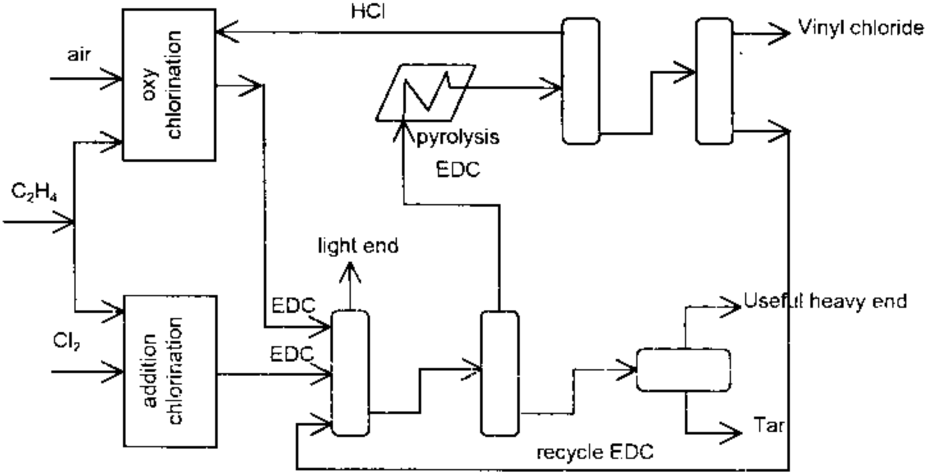


Fig.1 *Industrial process for the manufacture of vinyl chloride by combined chlorination and oxychlorination.*

COMPREHENSION

1. What is the major application of vinyl chloride ?
2. Name the main starting materials to produce VC.
3. Summarize the reaction conditions of oxychlorination of ethylene.
4. Why is ethylene widely used as a feedstock for the production of VC ?

Section B. EXERCISES

1. Match the words in column A with their antonyms in column B

	A		B
1.	*classical*	a.	oxidize
2.	*addition*	b.	absorption
3.	*positive*	c.	modern
4.	*reduce*	d.	cheap
5.	*exothermic*	e.	negative
6.	*evolution*	f.	absence
7.	*expensive*	g.	endothermic
8.	*presence*	h.	elimination

II. Choose the correct word or phrase that best keeps the meaning of its definition or synonym underlined in each sentence below

1. Vinyl chloride is the monomer for the ***production*** of polyvinylchloride.

   A. manufacture B. reaction C. addition D. elimination

2. The classical conversion of dichloroethane to vinyl chloride with alkali hydroxides in liquid phase is ***rarely*** used today.

   A. commonly B. usually C. not often D. sometimes

3. Chlorine is ***rather*** expensive.

   A. not B. very C. quite D. completely

4. The reaction is ***straightforward*** and proceeds with high conversions (96%) of acetylene and high selectivities (98%) for vinyl chloride.

   A. difficult B. uncomplicated C. easy D. complicated

Section C. WRITING PRACTICE

1. Use the flow diagram in fig. 1, write a description of the production of VC.

2. Write a description of the physical and chemical properties of VC (Find the reference in Ullmann's encyclopedia of industrial chemistry).

UNIT 10. SAFETY

Section A. READING COMPREHENSION

Read the following passage

The winning, production, transport and refining of oil can be hazardous. The first thing which should be taken into consideration is the terrible flammability of petroleum and petroleum products. All hydrocarbons that boil at less than 250°C are volatile; ie., at normal temperatures they will produce, or exist as, vapour. Together with air, this vapour can easily form a mixture which is explosive within the limits of proportion: just one spark, in the wrong place at the wrong time, and lives may be lost. For this reason, oil companies provide detailed safety *regulations* concerning the use of lights, smoking materials, *welding* equipment, etc., and employees who do not obey these regulations run the added risk of being *dismissed.*

Petroleum is frequently won under physical conditions which can endanger the workers involved. The workers who are most *vulnerable* are those who are inexperienced or untrained, but even *old hands* may be seriously injured in a moment of carelessness. Oily and muddy floors, fast-moving items of equipment, high-powered tools and sudden overhead hazards all demand *constant alertness,* especially in the extreme conditions of such places as Siberia or the North Sea. *Extremes* must also be considered relative to the upper working limits of machinery such as power units, pumps and *compressors.* A few years ago, in an oil-producing country in the Middle East, eight members of a workover crew were killed instantly when the gas-compression unit they were preparing to overhaul suddenly blew up. Accidents such as this are very rare, however, and in general the petroleum industry has an excellent safety record. This is due entirely to careful training and to the discipline that most companies insist on.

Three out of every four injuries suffered in the oil industry are caused by falling, e.g., on wet or grease walkways, from *masts,* ladders, *scaffolding,* etc. Many other accidents involve burns, most frequently from non-oil-product sources. Temperatures higher than 1000°C in some conversion processes and lower than -160°C (in the *liquefaction* of natural gas) are not uncommon. In addition to these hazards there are toxic chemicals and gases, caustics, strong acids, and in some cases even *radioactive* materials. There should be signs and notices to give warning of these dangers, to instruct workers in safe procedure, and to give information about what should be done in case of emergency.

SPECIAL WORDS AND EXPRESSIONS

regulations	rules which must be obeyed .
welding	joining metallic parts by heating; e.g., oxyacetylene welding, electric-arc welding etc.
dismissed	discharged from his job or position; fired. In many oil companies, employees who disobey safety regulations can be fired without notice, ie., given one or two weeks' pay and told to leave.
vulnerable	capable of being injured easily.
old hands	experienced personnel.
constant	continuous; unchanging; not decreasing.
alertness	being aware of possible danger and being ready to meet it.
extremes	extreme conditions.
compressors	machines designed to apply pressure to gases in order to reduce their volume. Gases are highly compressible; liquids are not.
workover	repairs to a production unit. A workover rig is a special rig for repairing wells after a period of production.
to overhaul	to replace or repair damaged or worn-out parts of existing machinery.

blew up exploded.

discipline system of punishment (e.g., dismissal) to ensure that regulations are obeyed.

masts A 'mast' is the tower-like part of a rig .

scaffolding temporary platforms at height for workers to stand or sit on while doing a job.

liquefaction liquid → liquefy → liquefaction . Liquefied natural gas consists mainly of methane and is commonly referred to as LNG, which should not be confused with NGL (natural gas liquids, ie., ethane and heavier cuts).

radioactive sending out alpha, beta or gamma rays. Uranium (U) is a radioactive element. Gamma-ray and neutron-gamma ray equipment is used to log boreholes.

COMPREHENSION

a. Explain the relation between accidents and the following: (i) oily floors (ii) fast-moving items of equipment, (iii) sudden overhead hazards.

b. Which *added* risk is run by employees who disobey safety regulations? What is the *primary* risk?

c. Why is a boll weevil more vulnerable than an old hand?

d. When floormen aren't very busy, certain safety regulations are more likely to be broken than at other times. How?

e. Why must workers be more alert in such places as (i) Alaska, (ii) the North Sea?

f. Define 'limits of proportion'

g. What is the relation between safety and (i) discipline, (ii) signs, notices and warnings (iii) protective clothing?

h. What is the difference between NGL and LNG?

i. Safety procedures are designed to protect not only you, but the crew members you work with as well. How?

j. Discuss this statement: 'The basis of safe procedure is clear communication.'

Choose from these words to complete 'the paragraph below':

flammable, dismissal, non-sparking, discipline, movements, disobey, fighting, hazards, permitted, handy, safe, masks, intoxication, vessel, authorised, forbidden, regulation.

SAFETY ON THE REFINERY FLOOR

Fire, explosion and *(1)*.... are the main refinery *(2)*.... , and *(3)*.... is therefore important in ensuring that safety *(4)*.... are obeyed. Refinery workers who *(5)*.... may be subject to *(6)*.... or loss of pay. In most areas of the refinery floor, cigarettes, matches, lighters and tobacco are *(7)*.... , and before any special work is done the supervisor may insist on the use of *(8)*.... tools. No worker is *(9)*.... to enter a *(10)*.... if the in-lines have not been isolated or blocked off. Entry to operating units is limited to *(11)*..... personnel, and for this reason a record is kept of the *(12)*.... of all operators. In areas where there is toxic or *(13)*.... gas, gas *(14)*.... must be worn even when the area has been declared *(15)*.... by a chemist. Fire-*(16)*... equipment should always be *(17)*.... , and wherever possible no operator should be allowed to work alone.

Section B. STRUCTURE PRACTICE

1. Sentences with should

Examples:

You (wear) your gloves. → You *should have worn* your gloves.

He (work) with someone experienced. → He *should have worked* with someone experienced.

Do the following in the same way.

a. You (close) that valve as soon as the order came through.

b. Before he started to climb the scaffolding, he (put on) his safety belt.

c. You (mark) the container 'toxic'.

d. You (clean up) that spilled can of dope.

e. You (check) the compass heading before you kicked off.

Now consider what might/could/would not have happened if someone had actually done what he should have done.

Example:

You should have worn your gloves. If you had worn them, you wouldn't have burned your hands so badly .

Write a mini-paragraph like that for each of the other five sentences in the exercise above.

2. Passive Voice

Examples:

Nobody should waste oil. (conserve) → Oil *should be conserved.*

Nobody should give instructions that are not clear. (clearly) → Instructions *should be given* clearly.

Use the words in brackets to rewrite the following.

a. Nobody should disobey safety regulations (obey)

b. Nobody should position fire extinguishers where they can't be reached quickly and easily. (handy)

c. Nobody should permit welding when gas is being vented. (forbid)

d. Nobody should allow trainees to work alone. (accompany)

e. Nobody should leave fire doors open. (keep closed)

f. Nobody should keep first-aid equipment locked away (open and clearly-marked cupboard)

g. Nobody should ignore safety notices. (not ignore)

h. Nobody should leave work areas messy or dirty. (tidy and clean)

i. Nobody should leave tools lying around where other may trip over them. (not leave)

Section C. WRITING PRACTICE

SIGNS & WARNINGS

A sign which says 'Keep Away' indicates that a certain area should not be approached by unauthorised personnel. A notice such as this might be found, for example, near equipment which is faulty and has become hazardous, or in front of scaffolding where there is a danger of objects falling from a height.

Now write similar paragraphs for the safety notices below.

KEEP AWAY

MIGHT YOUR HEAD

HAND OFF

RADIOACTIVE SOURCE

CORROSIVE

Section D. FURTHER READING

HEALTH AND SAFETY CONSIDERATIONS IN CATALYTIC CRACKING

Fire Prevention and Protection. Liquid hydrocarbons in the catalyst or entering the heated combustion air stream should be controlled to avoid exothermic reactions. Because of the presence of heaters in catalytic cracking units, the possibility exists for fire due to a leak or vapor release. Fire protection including concrete or other insulation on columns and supports, or fixed water spray or fog systems where insulation is not feasible and in areas where firewater hose streams cannot reach, should be considered.

In some processes, caution must be taken to prevent explosive concentrations of catalyst dust during recharge or disposal. When unloading any coked catalyst, the possibility exists for iron sulfide fires. Iron sulfide will ignite spontaneously when exposed to air and therefore must be wetted with water to prevent it from igniting vapors. Coked catalyst may be either cooled below 120° F before it is dumped from the reactor, or dumped into containers that have been purged and inerted with nitrogen and then cooled before further handling.

Safety. Regular sampling and testing of the feedstock, product, and recycle streams should be performed to assure that the cracking process is working as intended and that no contaminants have entered the process stream. Corrosives or deposits in the feedstock can foul gas compressors. Inspections of critical equipment including pumps, compressors, furnaces, and heat exchangers should be conducted as needed. When processing sour crude, corrosion may be expected where temperatures are below 900° F.

Corrosion takes place where both liquid and vapor phases exist, and at areas subject to local cooling such as nozzles and platform supports.

When processing high-nitrogen feedstock, exposure to ammonia and cyanide may occur, subjecting carbon steel equipment in the FCC overhead system to corrosion, cracking, or hydrogen blistering. These effects may be minimized by water wash or corrosion inhibitors. Water wash may also be used to protect overhead condensers in the main column subjected to fouling from ammonium hydrosulfide. Inspections should include checking for leaks due to erosion or other malfunctions such as catalyst buildup on the expanders, coking in the overhead feeder lines from feedstock residues, and other unusual operating conditions.

Health. Because the catalytic cracker is a closed system, there is normally little opportunity for exposure to hazardous substances during normal operations. The possibility exists of exposure to extremely hot (700°F) hydrocarbon liquids or vapors during process sampling or if a leak or release occurs. In addition, exposure to hydrogen sulfide and/or carbon monoxide gas may occur during a release of product or vapor.

Catalyst regeneration involves steam stripping and decoking, and produces fluid waste streams that may contain varying amounts of hydrocarbon, phenol, ammonia, hydrogen sulfide, mercaptan, and other materials depending upon the feedstock, crudes, and processes. Inadvertent formation of nickel carbonyl may occur in cracking processes using nickel catalysts, with resultant potential for hazardous exposures. Safe work practices and/or the use of appropriate personal protective equipment may be needed for exposures to chemicals and other hazards such as noise and heat; during process sampling, inspection, maintenance and turnaround activities; and when handling spent catalyst, recharging catalyst, or if leaks or releases occur.

SPECIAL WORDS AND EXPRESSIONS

UNIT 1

beneath	ở dưới
crude oil	dầu thô

debris	mảnh vỡ, mảnh vụn
establish	xác minh, thiết lập
fraction	phân đoạn
occur	xuất hiện, tìm thấy
originate	có nguồn gốc từ, bắt nguồn từ
subject to	đưa vào, bắt phải chịu

UNIT 2

CDUs	tháp chưng cất dầu thô (crude distillation units.)
column	tháp tách, cột tách
combustible	có khả năng cháy
crude train	hệ thống vận chuyển dầu (gồm bơm, van, ống và thùng chứa) từ khu vực đặt bể chứa tới thiết bị lọc dầu
distillation	sự chưng cất, quá trình chưng cất
downstream	hạ nguồn, giai đoạn sau
flashpoint	điểm chớp cháy
impurities	tạp chất
inflammable, flammable	có khả năng bắt cháy dễ dàng
straight-run fractions	phân đoạn chưng cất trực tiếp
tank farm	khu vực đặt bể chứa
upstream	thượng nguồn, giai đoạn trước
volatile	dễ bay hơi

UNIT 3

blended	pha trộn
catalyst	xúc tác
distillates	sản phẩm chưng cất
feedstock	nguyên liệu

gas oil	(phân đoạn) gasoil
gasoline	(phân đoạn) xăng
intermediates	sản phẩm trung gian
kerosene	(phân đoạn) kerosen
LPG	khí hoá lỏng (liquefied petroleum gas)
mercaptans	mecaptan (RSH)
objectionable odour	mùi khó chịu
organic	(thuộc về) hữu cơ
primary	đầu tiên, thứ nhất, sơ cấp
refinery gas	khí lọc dầu
sour	chua
split	phân tách, phân chia
synthetic	tổng hợp, nhân tạo
to convert	chuyển hoá
yield	hiệu suất

UNIT 4

additives	phụ gia
besides	ngoài, ngoài ra
fatty acids	axit béo
hydrodesulphurization	quá trình hydro desulfua hoá (tách lưu huỳnh với sự có mặt của hydro
instantaneously	ngay lập tức, tức thời
isomerization	quá trình đồng phân hoá
motor spirit	xăng
reformate	sản phẩm reforming
simultaneously	đồng thời
TEL $Pb(C_2H_5)_4$	tetra etyl chì
throughout	ở khắp nơi, suốt
TML $Pb(CH_3)_4$	tetra metyl chì

upgrading	nâng cao chất lượng, nâng cấp
wide-cut	phân đoạn có khoảng nhiệt độ sôi tương đối rộng

UNIT 5

asphalt	nhựa đường, phân đoạn asphan
Avgas	xăng máy bay (sử dụng cho các máy bay dùng động cơ piston)
aviation	(thuộc về) hàng không
Avtag	xăng máy bay turbin
Avtur	kerosen máy bay turbin
byproducts	sản phẩm phụ
DERV	phương tiện chạy bằng động cơ diesel (diesel engine road vehicle)
domestic	trong nhà, trong gia đình
fertilizers	phân bón
fibres	sợi
finite	có giới hạn, hạn chế
former	cái trước
insecticides	thuốc trừ sâu
latter	cái sau
polymerization	quá trình trùng hợp
raw	thô, chưa xử lý
should be conserved	cần được bảo tồn, giữ gìn
solvents	dung môi
weatherroofing	bảo vệ, chống lại thời tiết

UNIT 6

bead	hạt
charge material	nguyên liệu đầu
contaminant	chất gây ô nhiễm, tạp chất, chất bẩn

denitrogenation	quá trình denitơ hoá (tách các hợp chất có chứa nitơ)
ingredient	thành phần
inhibit	ức chế
precious	quý
safeguard	bảo vệ
trace	vết

UNIT 7

concept	khái niệm
empirical	theo kinh nghiệm
infinite	vô hạn
intact	không bị ảnh hưởng, không bị chạm đến
outline	vẽ, phác thảo, vạch ra kế hoạch
remove	tách
vacant	rỗng, bỏ không
vicinity	vùng phụ cận, vùng lân cận
void	chỗ trống, khoảng trống

UNIT 8

affect	ảnh hưởng đến, tác động đến
cleanse	tẩy, rửa, làm sạch
dissociate	phân ly, phân tách
elevate	nâng lên cao, đưa lên cao
exclusive	loại trừ, không bao gồm
interact	tương tác, ảnh hưởng lẫn nhau
localize	định vị
occur	xảy ra
reverse	đảo ngược lại, ngược lại
texture	kết cấu

UNIT 9

addition	cộng hợp
classical	cổ điển, kinh điển
evolution	sự phát ra, sự tách ra
exothermic	toả nhiệt
expensive	đắt
positive	dương, dương tính
presence	sự có mặt
reduce	khử, giảm

UNIT 10

alertness	sự tỉnh táo, sự cảnh giác
blew up	nổ tung
compressors	máy nén
constant	liên tục, không đổi, không giảm
discipline	hệ thống kỷ luật
dismissed	đuổi việc, sa thải
extremes	điều kiện khắc nghiệt
liquefaction	hoá lỏng
masts	tháp trụ
old hands	người có kinh nghiệm
radioactive	phóng xạ
regulations	quy định, quy tắc, điều lệ
scaffolding	giàn giáo
to overhaul	đại tu (thay thế, sửa chữa các bộ phận bị hỏng)
vulnerable	dễ bị thương
welding	kỹ thuật hàn
workover	sửa chữa

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TIẾNG ANH DÀNH CHO SINH VIÊN NGÀNH HÓA DẦU

(Bài giảng cho sinh viên)

Tác giả: Phạm Thanh Huyền

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