TISSEMSILT UNIVERSITY

SCIENCE AND TECHNOLOGY FACULTY

SCIENCE AND TECHNOLOGY DEPARTMENT

Lecture :

Fossil Energy and Pollution

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Continuous control : 40%

Exam : 60%

Program

Chapter I : Fossil Energy

Chapter II : Fossiles Energies and the Environment

Chapter III : Carbon monoxide CO

Chapter IV : Nitrogen Oxides NO

Chapter V : Polycyclic Aromatic Hydrocarbons (PAHs)

General Introduction

A **fossil energy** is a hydrocarbon-containing material such as **coal, oil**, and **natural gas**, formed naturally in the Earth's crust from the remains of dead plants and animals that is extracted and burned as a fuel.

Fossil fuels may be burned to provide heat for use directly (such as for cooking or heating), to power engines (such as internal combustion engines in motor vehicles), or to generate electricity.

Origin

The theory that fossil energy formed from the fossilized remains of dead plants by exposure to heat and pressure in Earth's crust over millions of years was first introduced by **Andreas Libavius** "in his 1597 Alchemia and later by Mikhail Lomonosov "as early as 1757 and certainly by 1763.

Importance

Fossil fuels have been important to human development because they can be readily burned in the open atmosphere to produce heat.

Coal was burned in some early furnaces for the smelting of metal ore, while semi-solid hydrocarbons from oil seeps were also burned in ancient times, they were mostly used for waterproofing and embalming.

Commercial exploitation of petroleum began in the 19th century

Natural gas, once flared-off as an unneeded byproduct of petroleum production, is now considered a very valuable resource. Natural gas deposits are also the main source of helium.

Chapter I :   Fossil Energies

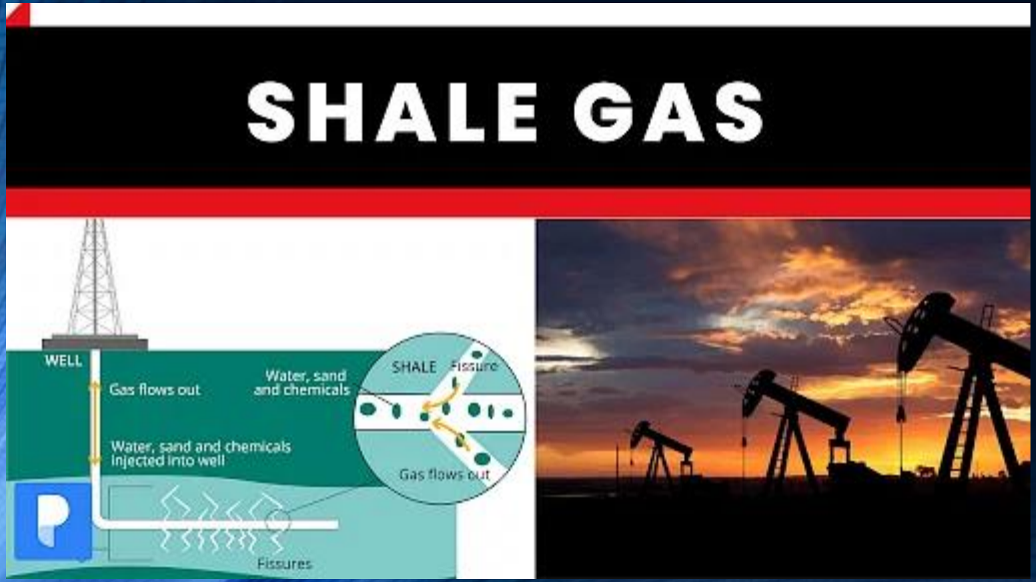
I . 1: Petroleum

I . 2: Natural Gas

I . 3: Coal Heat

I . 4: Shale Gas

Types of fossil energy



I.1: Petroleum

What is Petroleum?

Petroleum is referred to as "***Black Gold***." This name itself is an indication of its importance to humans. Crude oil is considered to be the "***mother of all commodities***" as it is used to manufacture various products such as pharmaceuticals, plastics, gasoline, synthetic fabrics, etc. Petroleum or oil has also been the world's leading source of energy since the 1950s.

Petroleum is a liquid which occurs naturally in rock formations. This consists of a complex mixture of different molecular weights of hydrocarbons, plus other organic compounds. Some petroleum-produced chemical compounds are also obtained from other fossil fuels.

Petrochemicals are produced mainly at a few manufacturing sites around the world. Petroleum is also the raw material for many industrial products, including pharmaceuticals, solvents, fertilizers, pesticides, synthetic fragrances, and plastics.

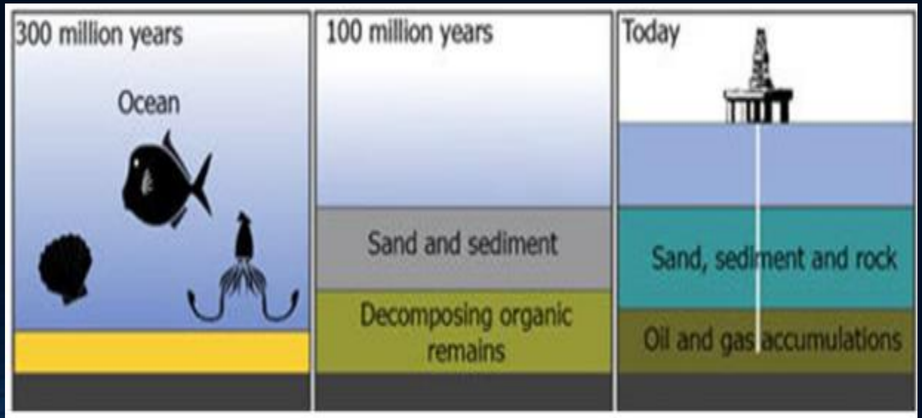
Petroleum Meaning

The word petroleum translates to ***"rock oil."*** It is derived from the Greek word "**Petra**" and the Latin word "**oleum**". When it is drilled from the ground in the liquid form, it is called crude oil. Humans have known about its existence for 4000 years. However, the first time crude oil was pumped from the ground was 2500 years ago in China and the ***world's first crude oil well was drilled in*** ***Pennsylvania, USA*** only in the year 1859.

Petroleum or mineral oil is India's next biggest source of energy after coal. It supplies heat and lighting power, machinery lubricants, and raw materials for a variety of manufacturing industries. Petroleum refineries for synthetic textiles, fertilisers and numerous chemical industries act as a "nodal industry." Most of India 's petroleum occurrences are associated with anticlines and fault traps in tertiary-age rock formations. It occurs in folding regions, anticlines, or domes, where oil is trapped in the unfolded crest.

How is Petroleum Formed?

- Petroleum is formed from the remains of dead plants and animals.
- When plants and animals die, they sink and settle on the seabed.
- Millions of years ago, these dead wildlife and vegetation decomposed and got mixed with sand and silt.
- Certain bacteria helped in the decomposition of this organic matter and caused some chemical changes,
- Matter consisting largely of carbon and hydrogen was left behind. However, as there is no sufficient oxygen at the bottom of the sea, the matter could not decompose completely.
- The partially decomposed matter remained on the seabed and eventually was covered with multiple layers of sand and silt.
- This burying took millions of years, and finally, due to high temperature and pressure, the organic matter decomposed completely and formed oil.



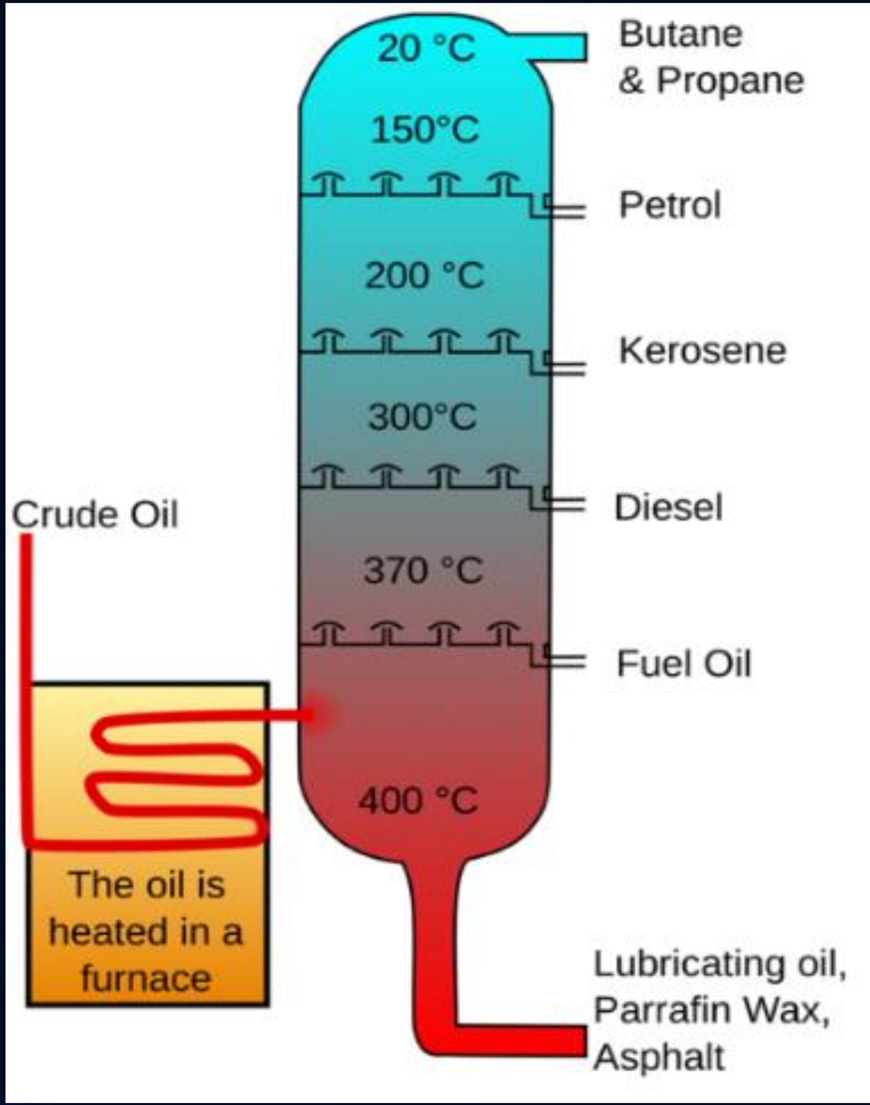
Petroleum-Refining

An oil refinery or petroleum refining is an industrial manufacturing facility where crude oil is extracted and converted into more valuable goods, such as petroleum naphtha, gasoline, jet fuel, asphalt foundation, heating oil, petroleum kerosene, and liquefied gas. Oil refineries are usually huge, vast industrial facilities with extensive pipelines running throughout, holding fluid streams in between.

- Petroleum is a mixture of many substances such as gas, petrol, diesel, kerosene, lubricating oil, paraffin wax, etc.
- As these constituents serve different purposes, it is important to separate them, or in other words, refine the crude oil. This process of separation of various constituents of petroleum is called petroleum refining.
- This is done in oil refineries. It is a three-step process.
- The first step is separation where the crude oil is separated into various components through the distillation process. The heavier constituents remain settled at the bottom whereas lighter constituents rise up as vapor, or remain liquid.
- Next, these constituents, which are still quite heavy, are converted into gas, gasoline, and diesel. Thus, the next step is conversion.
- These have certain impurities, so the last step is treating, where they are treated to obtain pure forms of various products.

The **oldest and most common way** of separating things into different components (called fractions) is to do it using the boiling temperature differences. That process is known as fractional distillation. You essentially heat up crude oil, let it spray, then condense the vapor.

New methods, in a method called conversion, use Chemical processing on certain fractions to produce others. For example, chemical processing may split lengthier chains into shorter chains. This allows a refinery to convert diesel fuel into gasoline, depending on the gasoline demand.

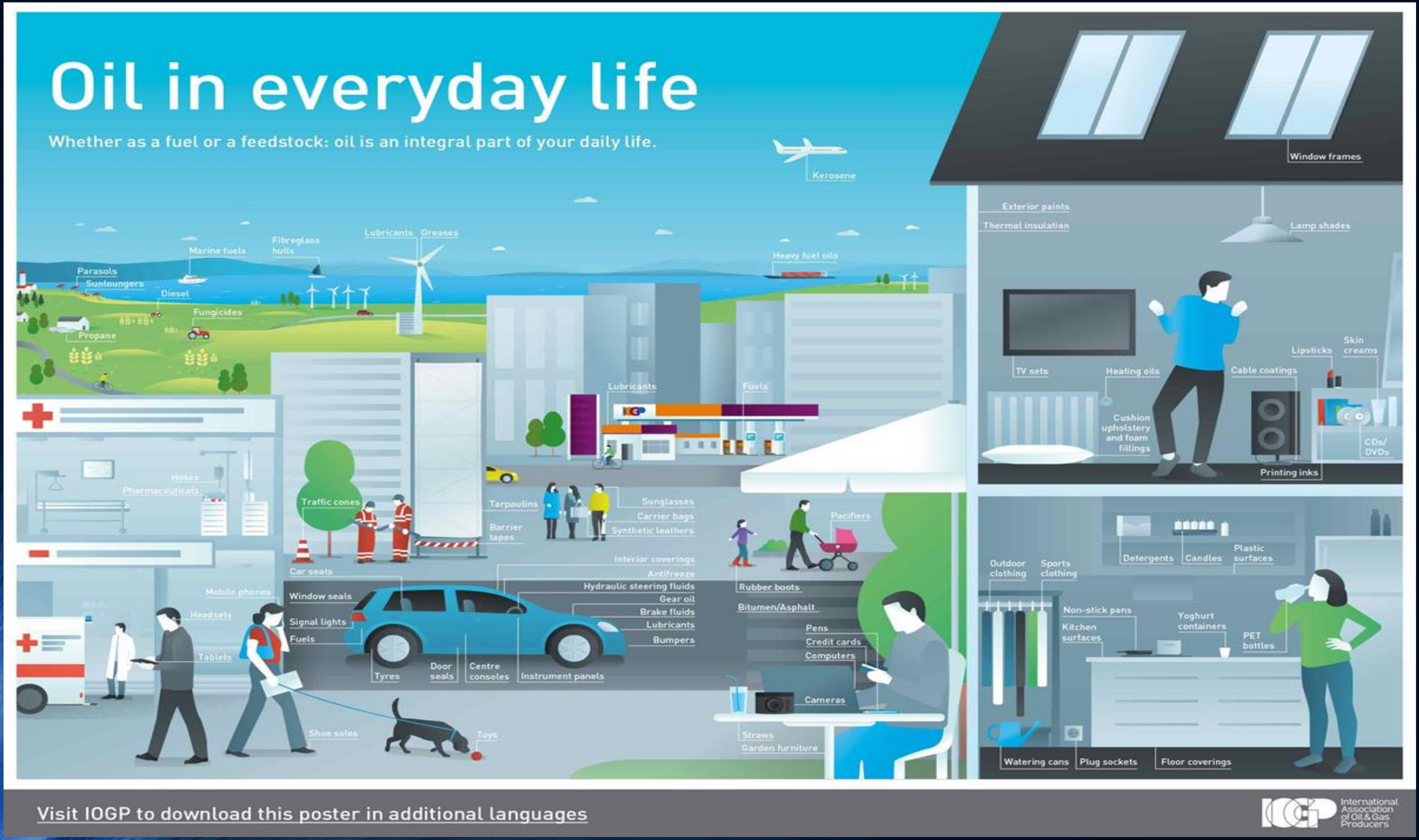


In industry, the refining process is generally called the "downstream" sector, while the "upstream" sector is known as the raw crude oil output. The word downstream is synonymous with the idea of sending oil down the supply chain of a commodity to an oil refinery to be refined into petrol. The downstream phase also includes the actual sale of petroleum products to other companies , governments or private individuals

Uses of Petroleum

- Liquefied Petroleum Gas or LPG is used in households as well as in the industry.
- Diesel and petrol are used as fuels for vehicles. Diesel is generally preferred for heavy motor vehicles.
- Petrol is also used as a solvent for dry cleaning, whereas diesel is also used to run electric generators.
- Kerosene is used as a fuel for stoves and jet planes.
- Lubricating oil reduces wear and tear and corrosion of machines.
- Paraffin wax is used to make candles, ointments, ink, crayons, etc.
- Bitumen or asphalt is mainly used to surface roads.

Uses of Petroleum



Appendix

Q1: How is petroleum refined?

Petroleum refining or oil refining is an automated procedure that removes crude oil from the earth and converts it into usable items such as liquefied petroleum gas (LPG), kerosene, asphalt foundation, jet fuel, diesel, heating oil, cooking oils, etc.

Q2: What does a petroleum refinery do?

Petroleum refineries convert crude oil into petroleum products for use as fuel for shipping, cooking, paving roads and electricity production and as feedstocks for chemical manufacturing. The refining cycle breaks down crude oil into its different components and is then gradually reconfigured into new products.

Q3: What is petroleum and its uses?

Petroleum products include aviation fuels, heating and electricity-generating fuel oils, asphalt and road tar, and feedstocks for producing the additives, plastics, and industrial materials that are in almost everything we use.

Q4: What is the chemical formula of petrol?

For petrol the basic chemical formula is CnH2n+2. This formula applies to alkanes, and because it contains different chemicals, the chemical formula for petrol can be changed.

Appendix

Q5: How is coal and petroleum formed?

Coal and petroleum are produced as a result of the destruction of the old plant life that existed millions of years ago. This dead plant matter started building up and finally developed a material called peat. Over time these materials were transformed into coal by heat and pressure from geological processes.

Q6: How is petroleum refined?

Petroleum refining or oil refining is an industrial process that extracts crude oil from the earth and converts it into useful items such as liquefied petroleum gas (LPG), kerosene, asphalt base, jet fuel, diesel, heating oil, fuel oils, etc.

Q7: What is the main purpose of petroleum refining?

Petroleum refining is mainly aimed at transforming crude oil into useful goods such as LPG, gasoline, jet fuel, diesel oil, jet fuel and fuel oils.

Q8: Where is petroleum found?

Today petroleum is found in vast underground reservoirs where there were ancient seas. Petroleum reserves can be located beneath the land, or under the ocean. They extract their crude oil using giant drilling machines.

Appendix

Q9: What are examples of petroleum products?

Petroleum products which are covered by the Oil Spill Law are commonly used for home heating and power engine energy. Types of petroleum products include kerosene, gasoline, home heating oil, and jet fuel.

Q10: How is petroleum used?

Petroleum products include transportation fuels, heating and electricity-generating fuel oils, asphalt and road oil, and feedstocks for producing the chemicals, plastics, and synthetic materials that are in almost everything we use.

https://byjus.com/chemistry/petroleum/

https://www.studyiq.com/articles/energy-resources/

I.2: Natural Gas

Natural Gas

A mixture of hydrocarbon gases that occurs naturally is called natural gas. It consists of methane, other higher alkanes, carbon dioxide, nitrogen, and hydrogen sulphide. Natural gas can be found in deep underground rock formations and in coal beds. It is found as methane clathrate or in combination with other hydrocarbon reservoirs.

Natural Gas Processes

There are two main processes that produce most natural gas: thermogenic and biogenic. Methanogenic organisms produce biogenic gas in marshes, bogs, landfills, and shallow sediments. Thermogenic gas is produced from buried organic material at higher temperatures and pressures deeper in the soil.

Natural Gas must be processed to eliminate impurities such as water. This is done to make it marketable before it may be used as fuel. Byproducts of processing include ethane, propane, butane, pentane, hydrogen sulphide, carbon dioxide, water vapour, helium, and nitrogen.

Global Distribution of Natural Gas

The USA is the largest producer accounting for 23% of the world's natural gas production in 2019. It is followed by Russia, Iran, and Qatar. Some major oil fields are mentioned below:

Country/ Continent	Region/Location
Russia	**West Siberia east of the Gulf, Urengoy, and Yamburg**
Europe	**Norway: Troll field** **Netherlands-Groningen**
North America	**USA- Marcellus Shale, Hugoton** **Canada-Elmworth** **Mexico-Cantrell**
Asia	**Arabian-Iranian basin** **Qatar-North Field** **Indonesia-North Sumatra**
Africa	**Algeria- Hassi R'Mel**

Facts About Natural Gas

- ✓ Natural gas is cleaner than other fuels. ...
- ✓ Natural gas is flexible. ...
- ✓ Natural gas is efficient. ...
- ✓ Natural gas is highly reliable. ...
- ✓ Natural gas is safe. ...
- ✓ Natural gas is affordable. ...
- ✓ Natural gas is an economic driver. ...
- ✓ Natural gas reduces demand on the electric grid.

Natural Gas Benefits

Here are the various benefits of Natural Gas described below:

- It is used for heating, cooking, and power generation.
- It's also used as car fuel and a chemical feedstock for making plastics.
- It burns completely. Hence, it is cleaner as compared to other energy sources.
- It emits 70% less carbon dioxide when compared to other fossil fuels. It does not create ashes after releasing energy.
- Natural gas was predominantly employed in the nineteenth and twentieth centuries for lighting residential and commercial areas.
- It now has a far larger range of industrial and home applications.
- Turbines are turned by it to produce wind and sun energy.
- It is a domestic fuel as well. It operates heaters, ovens, boilers, and other appliances while heating our homes.
- For cooking and heating, some families utilize compressed natural gas (CNG), which is gas that has been held under high pressure.
- For low-load cars that demand excellent fuel economy, CNG is also a reasonably priced and environmentally beneficial transportation fuel.
- Off-road trucks and trains are powered by LNG or liquefied natural gas.

Natural Gas Importance

- Currently, the manufacture of fertilisers consumes the majority of natural gas or roughly 40%.
- 10% is used for LPG, while about 30% is used to generate electricity. Production of natural gas has increased in tandem with each of these areas. Natural gas production has significantly increased, particularly since 1971.
- Nearly **10% of India's** electricity came from gas-powered power plants.
- Existing facilities are using expensive imported liquefied natural gas at less than full capacity (LNG).
- About 25% of the world's energy is provided by natural gas.

What are the advantages of using natural gas as a fuel?

Natural Gas is a cleaner fuel. It is less harmful to the environment than coal, petrol or diesel as it has less carbon dioxide emissions. It can be easily stored and transferred through pipelines. It is relatively more abundant than other fossil fuels i.e. coal and petroleum.

Natural Gas Usage Limitations

- Natural gas is a finite, non-renewable resource. It is found extremely deep within the earth.

- It is impossible to collect all in-place gas from a producible deposit due to a lack of technology

Algeria Natural Gas

Summary Table

	Million Cubic Ft (MMcf)	Global Rank
Gas Reserves	**159,054,000**	**11th** in the world
Gas Production	6,491,745	5th in the world
Gas Consumption	**1,399,216**	**26th** in the world
Yearly Surplus	+ 5,092,529	
Gas Imports	0	
Gas Exports	1,533,342	
Net Exports	**1,533,342**	

(Data shown is for 2015, the latest year with complete data in all categoreies)

FAQs

Q1: What is in a natural gas?

Methane makes up the majority of the odourless, gaseous combination of hydrocarbons known as natural gas (CH4).

Q2: What are the 4 main natural gases?

They combine to form natural gas when the proper ratios are used. Methane, ethane, butane, and propane are the first four alkanes and collectively known as the "four natural gases".

Q3: What is natural gas called?

Natural gas is a colourless, extremely flammable gaseous hydrocarbon that is mostly composed of methane and ethane. It is also known as methane gas or natural methane gas. This particular type of petroleum commonly coexists with crude oil

Q4: How is natural gas made?

Drilling is used to extract natural gas from underground rock formations. Large amounts of shale-derived natural gas are now accessible because of developments in hydraulic fracturing technology.

Q5: Is LPG a natural gas?

LPG is propane, but natural gas is methane, therefore they are not the same thing. Processing of natural gas and refining of crude oil result in the production of LPG. LPG is processed and then kept in gas cans or tanks under pressure as a liquid.

I.3: Coal Heat

What is Coal?

- Around the world, there are more than 1.06 trillion tons of coal reserves and they can be found in abundance in the Eastern United States, Russia, China, Australia and India. Coal was considered to be a type of plant; however, millions of years of geological pressure transformed this organic matter into brownish-black sedimentary rock that is now deposited all around the world.
- Coal has been used for thousands of years as one of the primary sources of fuel because of its high carbon content, which offers significant energy. However, all coal is not created equal. Some burn cleaner and hotter, while others have high moisture content that can pollute the air.

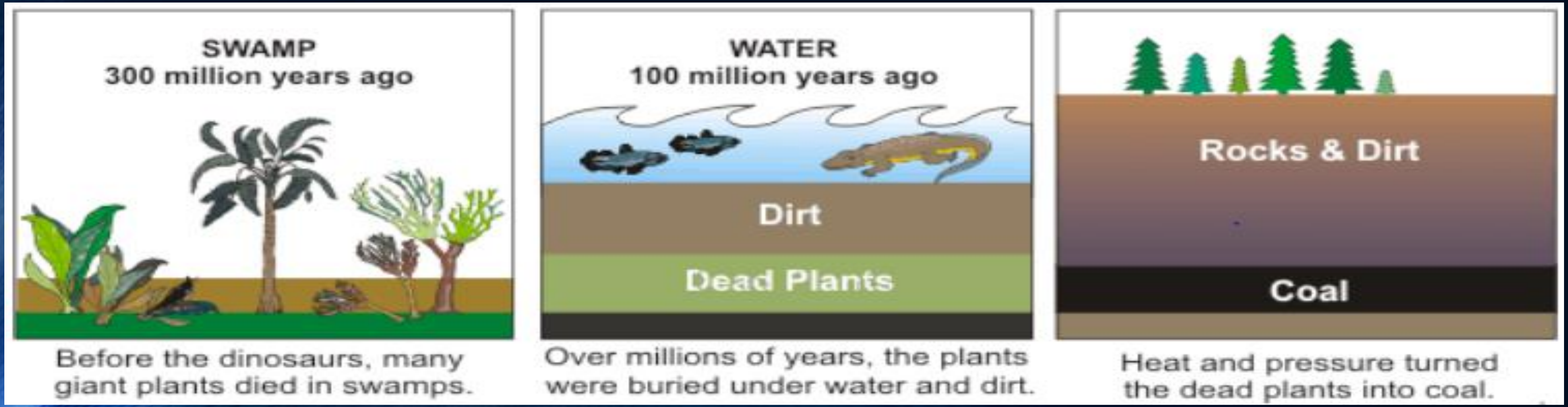


- Coal reserves are beds of coal still in the ground waiting to be mined. The United States has the world's largest known coal reserves, about 263.8 billion short tons. This is enough coal to last approximately 225 years at today's level of use.

I．3 ：How Coal Was Formed

Coal is a combustible black or brownish-black sedimentary rock composed mostly of carbon and hydrocarbons. It is the most abundant fossil fuel produced in the United States.

Coal is a nonrenewable energy source because it takes millions of years to create. The energy in coal comes from the energy stored by plants that lived hundreds of millions of years ago, when the earth was partly covered with swampy forests. For millions of years, a layer of dead plants at the bottom of the swamps was covered by layers of water and dirt, trapping the energy of the dead plants. The heat and pressure from the top layers helped the plant remains turn into what we today call coal.



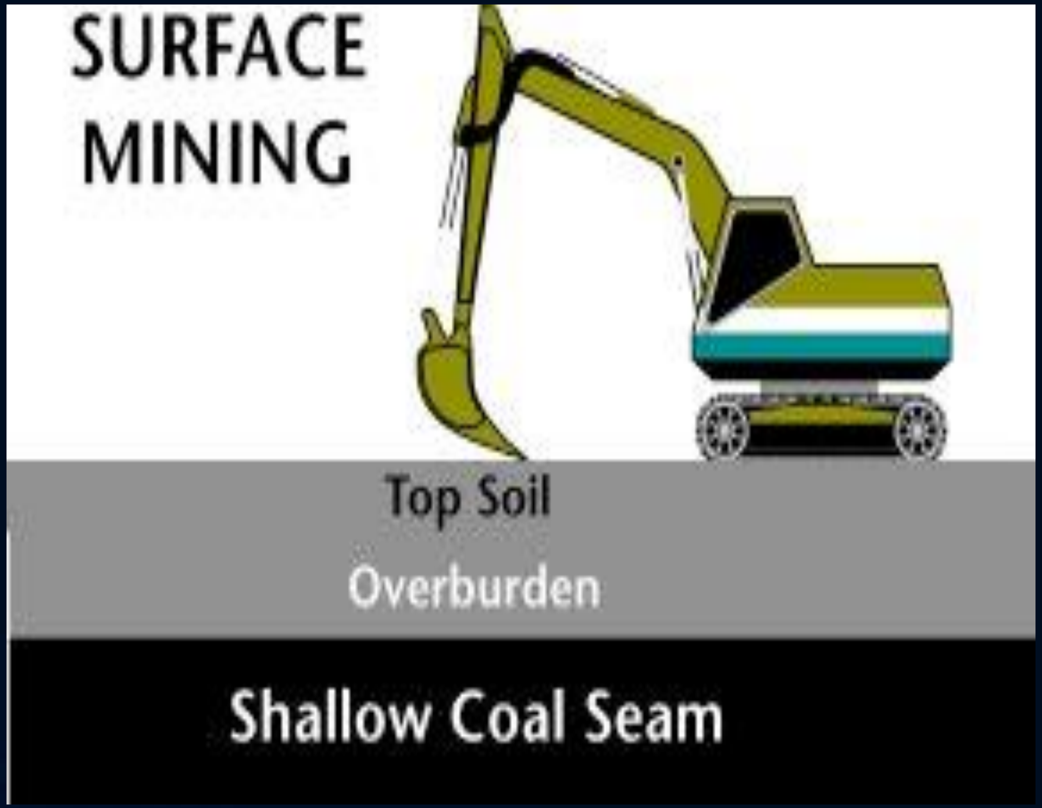
How we Get Coal

1. Mining the Coal

Coal miners use giant machines to remove coal from the ground. They use two methods: surface or underground mining.

A/ Surface mining:

is used to produce most of the. because it is less expensive than underground mining. Surface mining can be used when the coal is buried less than 200 feet underground. In surface mining, giant machines remove the top-soil and layers of rock to expose large beds of coal. Once the mining is finished, the dirt and rock are returned to the pit, the topsoil is replaced, and the area is replanted. The land can then be used for croplands, wildlife habitats, recreation, or offices or stores.



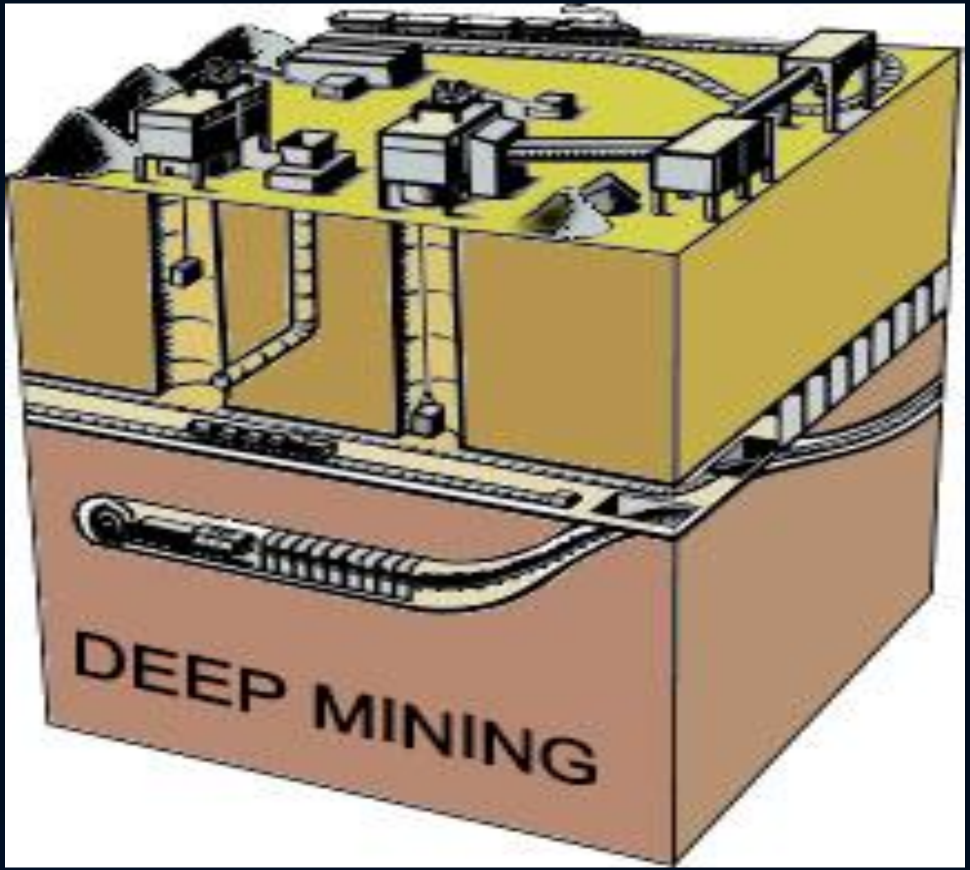
How we Get Coal

1 . Mining the Coal

B / Underground mining:

sometimes called deep mining, is used when the coal is buried several hundred feet below the surface. Some underground mines are 1,000 feet deep.

To remove coal in these underground mines, miners ride elevators down deep mine shafts where they run machines that dig out the coal



How we Get Coal

2 . Processing the Coal

After coal comes out of the ground, it typically goes on a conveyor belt to a preparation plant that is located at the mining site. The plant cleans and processes coal to remove dirt, rock, ash, sulfur, and other unwanted materials, increasing the **heating value** of the coal.

As following the important stapes

1- Crushing and breaking. Run-of-mine coal must be crushed to an acceptable top size for treatment in the preparation plant

2- Sizing. Different cleaning processes are used on different sizes of coal

3- Storage and stockpiling

4- Density separation.

5- Froth flotation.

Transporting Coal

- After coal is mined and processed, it is ready to be shipped to market. The cost of shipping coal can cost more than the cost of mining it.

- Most coal is transported by train, but coal can also be transported by barge, ship, truck, and even pipeline. About 68 percent of coal in the U.S. is transported, for at least part of its trip to market, by train. It is cheaper to transport coal on river barges, but barges cannot take coal everywhere that it needs to go. If the coal will be used near the coal mine, it can be moved by trucks and conveyors.

- Coal can also be crushed, mixed with water, and sent through a "slurry" pipeline. Sometimes, coal-fired electric power plants are built near coal mines to lower transportation costs.

Main Types of Coal

Coal is classified into four main types, or ranks (lignite, subbituminous, bituminous, anthracite), depending on the amounts and types of carbon it contains and on the amount of heat energy it can produce. The rank of a deposit of coal depends on the pressure and heat acting on the plant debris as it sank deeper and deeper over millions of years. For the most part, the higher ranks of coal contain more heat-producing energy.

- **Anthracite** – 86-97% carbon with the highest heating value
- **Bituminous** – 45-86% carbon and the most abundant coal found in the U.S.
- **Subbituminous** – 35-45% carbon and lower than average heating value
- **Lignite** – 25-35% carbon and the lowest ranking heating value

How Coal is Used

About 92 percent of the coal used for generating electricity(For example, in the United States). Except for a small amount of net exports, the rest of the coal is used, as a basic energy source in many industries, including, steel, cement and paper. The four major uses of coal are:

1/ FOR ELECTRIC POWER: Coal is used to generate almost half of all electricity produced in the United States. Besides electric utility companies, industries and businesses with their own power plants use coal to generate electricity. Power plants burn coal to make steam. The steam turns turbines which generate electricity.

2/ FOR INDUSTRY : A variety of industries use coal's heat and by-products. Separated ingredients of coal (such as methanol and ethylene) are used in making plastics, tar, synthetic fibers, fertilizers, and medicines. The concrete and paper industries also burn large amounts of coal.

3/ FOR MAKING STEEL : Coal is baked in hot furnaces to make coke, which is used to smelt iron ore into iron needed for making steel. It is the very high temperatures created from the use of coke that gives steel the strength and flexibility for products such as bridges, buildings, and automobiles.

4/ FOR EXPORT: In 2006, 49.6 million short tons, or about four percent of the coal mined, was exported to other countries from the United States. Coal is exported to many different countries, but most trade is with Canada, Brazil, the Netherlands, and Italy. More than half of coal exports are used for making steel.

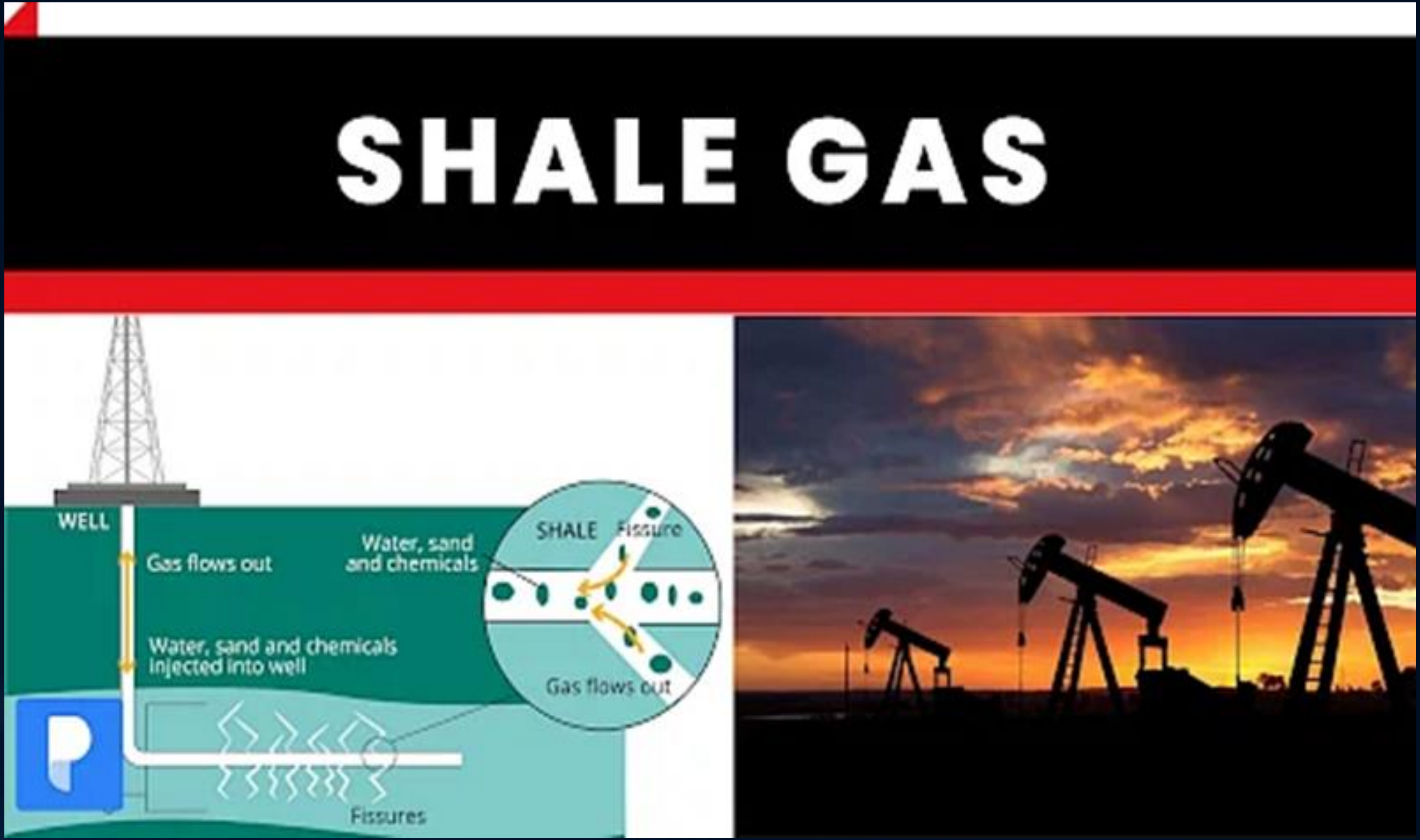
Coal exports have been generally shrinking in the past 10 years, while the amount of coal imported from other countries has been growing. In 2006, about 36.2 million short tons of coal were imported from other countries. Most of these imports (from Colombia, Venezuela, and Indonesia) were shipped to electric power producers along the U.S. coastlines. Read about a visit to a coal export facility.

World proved reserves of coal

World proved reserves of coal*

country/region	million metric tons			share of world total (%)
	anthracite and bituminous	subbituminous and lignite	total	
Canada	4,346	2,236	6,582	0.6
Mexico	1,160	51	1,211	0.1
United States	221,400	30,182	251,582	22.1
Total North America	226,906	32,469	259,375	22.8
Brazil	1,547	5,049	6,596	0.6
Colombia	4,881	–	4,881	0.4
Venezuela	731	–	731	0.1
Other South and Central American countries	1,784	24	1,808	0.2
Total South and Central America	8,943	5,073	14,016	1.2
Bulgaria	192	2,174	2,366	0.2
Czech Republic	1,103	2,573	3,676	0.3
Germany	12	36,200	36,212	3.2
Greece	–	2,876	2,876	0.3
Hungary	276	2,633	2,909	0.3
Kazakhstan	25,605	–	25,605	2.2
Poland	18,700	5,461	24,161	2.1
Romania	11	280	291	**
Russian Federation	69,634	90,730	160,364	14.1
Serbia	402	7,112	7,514	0.7
Spain	868	319	1,187	0.1
Turkey	378	10,975	11,353	1.0
Ukraine	32,039	2,336	34,375	3.0
United Kingdom	70	–	70	**
Uzbekistan	1,375	–	1,375	0.1
Other European and Eurasian countries	2,618	5,172	7,790	0.7
Total Europe and Eurasia	153,283	168,841	322,124	28.3
South Africa	9,893	–	9,893	0.9
Zimbabwe	502	–	502	**
Middle East	1,203	–	1,203	0.1
Other African countries	2,756	66	2,822	0.2
Total Africa and Middle East	14,354	66	14,420	1.3
Australia	68,310	76,508	144,818	12.7
China	230,004	14,006	244,010	21.4
India	89,782	4,987	94,769	8.3
Indonesia	17,326	8,247	25,573	2.2
Japan	340	10	350	**
Mongolia	1,170	1,350	2,520	0.2
New Zealand	825	6,750	7,575	0.7
Pakistan	207	2,857	3,064	0.3
South Korea	326	–	326	**
Thailand	–	1,063	1,063	0.1
Vietnam	3,116	244	3,360	0.3
Other Asia-Pacific countries	1,322	646	1,968	0.2
Total Asia-Pacific	412,728	116,668	529,396	46.5
Total world	816,214	323,117	1,139,331	100.0

I . 4: Shale Gas


SHALE GAS
WELL
Gas flows out
Water, sand and chemicals
Water, sand and chemicals injected into well
SHALE
Fissure
Gas flows out
Fissures

Introduction

Shale gas has drawn increasing investments as an unconventional primary resource to renovate the global energy market. Over the last decade, factors linked to supply reliability and the recent developments in horizontal drilling and hydraulic fracturing—or "fracking"—technologies have boosted the natural gas production from tight shale formations. Nevertheless, shale gas operations remain a contentious issue due to their environmental and social implications. With regard to water-related impacts, shale gas production usually requires excessive freshwater amounts and produces large volumes of damaging high-salinity wastewater. Under this scenario, zero-liquid discharge (ZLD) membrane desalination emerges as an effective wastewater management option for maintaining sustainable progress of shale gas sector, while reducing risks associated with water resources depletion and brine disposals.

What is shale gas and how much is there globally?

Shale gas is a form of natural gas (mostly methane), found underground in shale rock. It is classified as 'unconventional' because it is found is shale, a less permeable rock formation than sandstone, siltstone or limestone in which 'conventional' gas is found, and it is generally distributed over a much larger area. Shale is a fine-grained sedimentary rock, with smaller spaces or pores containing gas, and these spaces are relatively unconnected to each other. Therefore natural gas does not flow easily through shale.

Estimates of the volume of shale gas can be expressed in different way. 'Resource estimates' refer to the amount of natural gas that is believed to exist in a particular location. In some cases, technically recoverable resources can be estimated. 'Reserve estimates' refer to the amount of gas that is both technically and economically viable to extract. Reserves typically represent a small percentage of resources and can only be reliably estimated when based on detailed exploration and evaluation, including drilling. Recovery rates for shale gas are much lower than for conventional gas.

In 2015, the total amount of ‘unproved technically recoverable resources’ of shale gas was estimated at **214.6 trillion cubic metres (tcm), across 46 countries**.

The largest estimated resources are in China (31.6 tcm), followed by Argentina (22.7 tcm), **Algeria (20 tcm)**, the United States (17.6 tcm) and Canada (16.2 tcm). In Europe the largest estimated resources lie in Poland (4.1 tcm) and France (3.9 tcm), with 0.7 tcm for the United Kingdom.

Projections by the US Energy Information Administration in 2016 estimated that shale gas would account for 30 per cent of world natural gas production by 2040.

How is shale gas extracted through hydraulic fracturing ('fracking')?

Hydraulic fracturing – commonly known as fracking – is the process used to extract shale gas. Deep holes are drilled down into the shale rock, followed by horizontal drilling to access more of the gas, as shale reserves are typically distributed horizontally rather than vertically. Fracking fluids containing sand, water and chemicals are then pumped at high pressure into the drilled holes to open up fractures in the rock, enabling the trapped gas to flow into collection wells. From there it is piped away for commercial use.

Energy sector in Algeria - statistics & facts

The energy sector represents a major industrial activity and economic contributor in Algeria. The country is the leading primary energy producer in Africa, with an annual generation of roughly **six quadrillion British thermal units.** The large energy production is due to the abundance of natural resources such as oil and natural gas, which are the main energy sources used in the country. In fact, despite Algeria's ambitious renewable energy plans, clean energy sources remain largely untapped as of 2021.

According to Algeria - Country Commercial Guide:

- In terms of market size, Algeria has the tenth-largest proven natural gas reserves globally, is the world's fourth-largest gas exporter, and has the world's third-largest untapped shale gas resources. It also ranks sixteenth in proven oil reserves and exports roughly sixty percent of its total production. All the country's proven oil reserves are onshore. According to Algeria's national oil company, Sonatrach, about two-thirds of the Algerian territory remains underdeveloped or unexplored, with an estimated 100 undeveloped discoveries.
- Given pressure from European Union customers to increase its supply of gas, Sonatrach and its international partners are intensifying oil and gas exploration. Simultaneously, Algerian authorities are calling for locally manufactured products and services for small and medium-sized oil and gas service projects. As a part of this push to further develop the local oil service industry, Sonatrach encourages Algerian oil and gas services companies to conclude subcontracts and licensing agreements with international oil and gas equipment manufacturers. For large projects, however, Sonatrach continues to rely on world-class Engineering, Procurement, and Construction (EPC) contractors, who routinely work with American equipment and service providers. U.S. equipment and service suppliers should work proactively with Sonatrach to be included in its approved vendor list and become familiar with the technical specifications for upcoming EPC projects.

- Sonatrach and its subsidiaries are the leading players in Algeria's oil and gas sector. They control roughly 80 percent of hydrocarbon production in Algeria, while IOCs account for the remaining 20 percent. Sonatrach's five main divisions include E&P, midstream, downstream liquefaction and separation, downstream refineries and petrochemicals, and sales. A special unit within Sonatrach, the Division Associations' office, develops projects with IOCs. In addition, Sonatrach has multiple specialized subsidiaries, including ENAFOR (drilling and extraction), ENTP (drilling, work-over activities, and rig transfer), ENGTP (civil engineering earthworks, welding, piping, and test control), ENSP (oil well services), ENAGEO (seismic and reservoir management), and GCB (oil services and civil engineering).

- Regarding competition, Algeria's oil and gas sector includes a mix of more than two dozen IOCs working on more than 30 significant projects. These IOCs partner with various local and international oil field services companies, and the Algeria Oil and Gas Energy Resource Guide provides a comprehensive list of these companies.

Natural Gas

(million cubic meters)

	2020	2021	2022 Estimated	2023 projected
Total Local Production	85,119	104,043	108,667	112,838
Total Exports	39,459	56,556	65,330	68,802
Total Imports	0	0	0	
Imports from the U.S.	0	0	0	
Total Market Size	45,226	47,487	43,337	44,036
Exchange Rates (DA/USD)	126.78	135.06	142.63	145.52

Source: OPEC Annual Statistical Bulletin

Crude Oil
(thousand barrels/day)

	2020	2021	2022 estimated	2023 projected
Total Local Production	899	911	1,057	1,165
Total Exports	438.7	446.0	421.1	400.07
Total Imports	6	4	5	2
Imports from the U.S.	0	0	0	0
Total Market Size	460.3	465.0	635.9	716.1
Exchange Rates (DA/USD)	126.8	135.1	142.6	145.5

Source: OPEC Annual Statistical Bulletin

Chapter II :
Fossiles Energies and the Environment

II . 1 : Introduction

II . 2 : Definition of pollution and types

II . 3 : Causes of air pollution

II . 4 : Main pollutants from combustion

II . 1 : Introduction

- How have fossil fuels affect the environment ?

When fossil fuels are burned, they release nitrogen oxides into the atmosphere, which contribute to the formation of smog and acid rain. Major sources of nitrogen oxide emissions include: Cars and trucks. Coal-fired power plants.

- Fossil fuels – coal, oil and gas – are by far the largest contributor to global climate change, accounting for over 75 per cent of global greenhouse gas emissions and nearly 90 per cent of all carbon dioxide emissions. As greenhouse gas emissions blanket the Earth, they trap the sun's heat.

- Environmental Degradation and Biodiversity Loss: Fossil fuel extraction and infrastructure development often results in significant environmental degradation, habitat destruction, and biodiversity loss.

II . 2 : Definition of pollution and types

A/ Definition of pollution:

- Pollution is the introduction of harmful materials into the environment. These harmful materials are called pollutants.

- Pollution is anything that makes the earth dirty and unhealthy. Land, air, and water are all affected by pollution. Pollution takes up space on our land. Many of the things people use every day come in packages, like food, games, school supplies, and electronics.

B/ Type of pollution:

Major forms of pollution include air pollution, water pollution. and soil pollution.

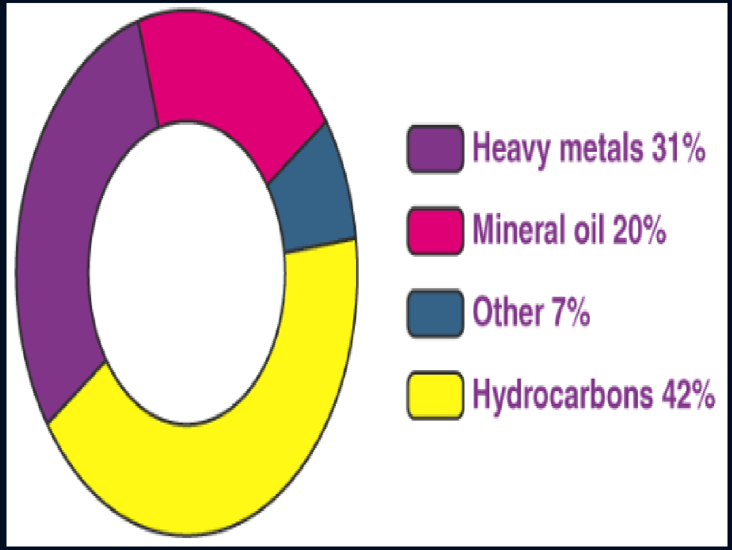
B．1: Air pollution: Air pollution is the contamination of air due to the presence of substances in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or to materials.
It is also the contamination of indoor or outdoor surrounding either by chemical activities, physical or biological agents that alters the natural features of the atmosphere. There are many different types of air pollutants, such as gases (including ammonia, carbon monoxide, sulfur dioxide, nitrous oxides, methane and chlorofluorocarbons), particulates (both organic and inorganic), and biological molecules.

Air pollution can cause diseases, allergies, and even death to humans; it can also cause harm to other living organisms such as animals and crops, and may damage the natural environment (for example, climate change, ozone depletion or habitat degradation) or built environment (for example, acid rain).Air pollution can be caused by both human activities and natural phenomena.

B . 2: water pollution (or aquatic pollution): Water pollution occurs when harmful substances—often chemicals or microorganisms—contaminate a stream, river, lake, ocean, aquifer, or other body of water, degrading water quality and rendering it toxic to humans or the environment.

The main point source of pollution to water is from sewage and waste water treatment, while for diffuse pollution, main sources are from farming and fossil fuel power plants (via the air).

Some of the most hazardous soil pollutants are xenobiotics – substances that are not naturally found in nature and are synthesized by human beings. The term ‘xenobiotic’ has Greek roots – ‘Xenos’ (foreigner), and ‘Bios’ (life). Several xenobiotics are known to be carcinogens. An illustration detailing major soil pollutants is provided below.



B .3: Soil pollution: Soil pollution refers to the contamination of soil with anomalous concentrations of toxic substances. It is a serious environmental concern since it harbours many health hazards.

II . 3 : Causes of pollution

II . 3 A: air pollution: We have listed 10 common air pollution causes along with their effects:

1. The Burning of Fossil Fuels: Most of the air pollution takes place due to the incomplete burning of fossil fuels. These include coal, oil, and gasoline to produce energy for electricity or transportation. The release of CO at a high level indicates how much fossil fuel is burned. This also emits other toxic pollutants like nitrogen oxides into the air. Inhaling air induced with pollutants due to the burning of natural gas and fossil fuel reduces the heart’s ability to pump enough oxygen. Hence causing one to suffer from various respiratory and heart illnesses. Furthermore, the nitrogen oxides are responsible for acid rain and the formation of smog.

2. Industrial Emission: Industrial activities emit several pollutants in the air that affect the air quality more than we can even imagine. Particulate matter 2.5 and 10, NO2, SO2, and CO are key pollutants that are emitted from industries that use coal and wood as their primary energy source for the production of their goods.

3. Indoor Air Pollution: Use of toxic products also called Volatile Organic Compounds (VOCs), inadequate ventilation, uneven temperature, and humidity level can cause indoor air pollution, whether you are in an office, school, or at your comfortable home. House air pollution can take place due to ignorant factors, for instance, smoking tobacco inside a room or leaving mold-infected walls untreated. The use of wood stoves or space heaters is capable of increasing the humidity level which can directly affect the health of a person in no time. Carcinogens and toxins from indoor air pollution cause 17% of deaths from lung cancer.

4. Wildfires: Climate change is not just increasing wildfire but also spiking air pollution. Burning stubble and farm residue is also a major contribution to wildfire. It causes increased PM2.5 in the air which collides with other harmful substances like chemical gas and pollen creating smog. Smog makes the air hazy and people find it difficult to breathe. Visibility also decreases as a result of this smog. Difficulty in breathing, irritation in the eyes, nose, and throat, itchiness in the respiratory tract, etc. are all symptoms of inhaling smog.

5. Microbial Decaying Process: Manufacturing, chemical, and textiles industries release a large number of CO, hydrocarbons, chemicals, and organic compounds which contaminate our environment. Bacteria and fungi play a fundamental role in the biogeochemical cycles in nature. They are the key indicators of abnormal environmental conditions. Decaying of these microorganisms present in the surroundings releases methane gas which is highly toxic. Breathing toxic gas like methane may lead to death.

6. Transportation: Cars on the roads are increasing day by day. There is no denying that vehicle pollution is the major contributor to air pollution, especially in urban cities, where car ownership rates are more as compared to rural areas. When the car burns gasoline, it emits pollutants in the air which is as harmful as smoking 10 cigarettes a day. Most Vehicle emits are: Carbon monoxide ,Hydrocarbons, Nitrogen oxide, and Particulate Matter (PM2.5 and PM10).

7. Open Burning of Garbage Waste: Exposure to open burning of garbage waste can pose serious health risks including: Cancer, Liver issues, Impairment of the immune system, Reduced reproductive functions, and Can also affect the developing nervous system.

Open air garbage burning releases toxins such as black carbon, soot, and carcinogens. It actively contributes to the greenhouse effect, and in turn to climate change. Black carbon and soot gets deposited on the ice peaks, which results in their meltdown.

8. Construction and Demolition:

A / Construction and demolition sites are a rich source of PM and other air pollutants including VOCs, etc.

B/ People living near these sites experience various health concerns like difficulty in breathing, irritation in the eyes, nose, and throat, etc.

C / The workers and personnel working on-site are exposed to these air pollutants everyday. These pollutants affect their health to a great extent as well.

D / Therefore, it becomes important to monitor the air quality at construction and demolition sites to comply with the standards.

E / It is important to maintain the air quality at these sites, so as to maintain the air quality standards and limit the excessive usage of toxin and PM generating activities.

9. Agricultural Activities: Agricultural activities have had a serious impact on the decreasing air quality. To begin with, pesticides and fertilizers are the main sources that contaminate the surrounding air. Nowadays, pesticides and fertilizers are mixed with new invasive species which are not found in nature, for quick growth of the crops and vegetation. Once they are sprayed over, the smell and the effect of the pesticides are left in the air. Some mix with water and some seeps into the ground which not only destroys the crops but also causes numerous health-related issues.

10. Use of chemical and synthetic products: Talking about air pollution, we always consider outdoor air pollution dangerous for our lives but never talk about indoor air pollution. Household products cause indoor air pollution which is 10 times more harmful than outdoor air pollution. We spend more than 90% of our lives indoors, which makes the indoor air pollution impacts more serious and concerning. Volatile Organic Compounds (VOCs) found in paints, cleaners and personal care products such as perfume and deodorants are a reason for common health issues. These are silent killers that can cause risks like asthma or other respiratory issues and lung disease are other issues caused by inhaling poor house air quality.

- Other sources include cooking, smoking, furniture, paints, hobby craft, furnaces, coal powered heaters, and many more. Indoor air pollution has caused over 4 million premature deaths per year.
- This is responsible for various lung and heart diseases in children and old people such as bronchitis, pneumonia, and aggravation of asthma.

II . 3 : B: Water pollution::

The Causes of Water Pollution:

- Industrial Waste. Industries and industrial sites across the world are a major contributor to water pollution.
- Marine Dumping.
- Sewage and Wastewater.
- Oil Leaks and Spills.
- Agriculture.
- Global Warming.
- Radioactive Waste.

II . 3 : C: Soil pollution:

The root cause of soil pollution is often one of the following:

- Agriculture (excessive/improper use of pesticides) .
- Excessive industrial activity.
- Poor management or inefficient disposal of waste.

The most commonly occurring inorganic soil contaminants are trace elements such as arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), lead (Pb), manganese (Mn), nickel (Ni), zinc (Zn), and radionuclides.

II． 4 : Main pollutants from combustion

Some of the common pollutants produced from burning the fuels, wood, natural gas, kerosene, charcoal, or tobacco are carbon monoxide, nitrogen dioxide, particles, and sulfur dioxide. Particles can have hazardous chemicals attached to them. Other pollutants that can be produced by some appliances are unburned hydrocarbons and aldehydes.

Major air pollutants include carbon monoxide (CO), ammonia (NH3), nitric oxide (NO), nitrogen dioxide (NO2), ozone (O3), particulate matter (PM), Sulphur dioxide (SO2) and volatile organic compounds (VOC)

Chapter III :
Carbon monoxide CO

III . 1 : Physical properties of carbon monoxide

III . 2 : Effects on living things

III . 3 : Main mechanisms of CO formation

III . 1 : Physical properties of carbon monoxide

Carbon Monoxide Structure

Carbon monoxide is the simplest member of the oxocarbon family. It consists of only two atoms, one carbon atom, and another oxygen atom that consists of two π-bonds. In the structure of carbon monoxide, the carbon atom is connected to an oxygen atom with a triple bond. In reality, a double bond between the two atoms is formed by the mutual sharing of electrons resulting in the two π-bonds while the third bond is formed when the oxygen atom donates a lone pair of electrons to the carbon for completing its octet and forms a σ bond. The molecule is asymmetric with a non-zero dipole moment.

Physical Properties

- The molecular mass of carbon monoxide is 28.010 g/mol with a density of 789 kg/m^3.
- It is a colourless and odourless gas.
- The melting and boiling points of carbon monoxide are -205.02 oC (68.13 K) and -191.5 oC (81.6 K), respectively.
- It is sparingly soluble in water. However, it is more soluble in chloroform, acetic acid, ethyl acetate, ethanol, benzene, etc.

Chemical Properties

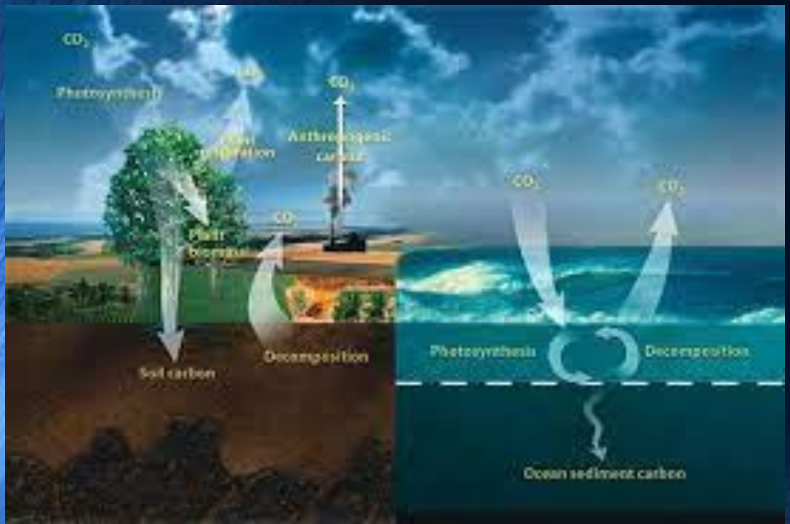
- It is a highly poisonous and flammable gas.
- High-temperature reactions between carbon monoxide and water vapour result in the production of carbon dioxide and hydrogen; this method has been used to produce hydrogen that can be combined with nitrogen to create ammonia.
- Carbon monoxide creates alkali formates with caustic alkalies, which can then be changed into either formic acid or alkali oxalates to create oxalic acid.
- Carbon monoxide reacts with some metals to produce carbonyl compounds, many of which are flammable; nickel has been purified via this reaction.
- The production of methanol begins with carbon monoxide and hydrogen, which are also used to create olefin-derived aldehydes and alcohols as well as mixtures of liquid hydrocarbons appropriate for use as fuels.

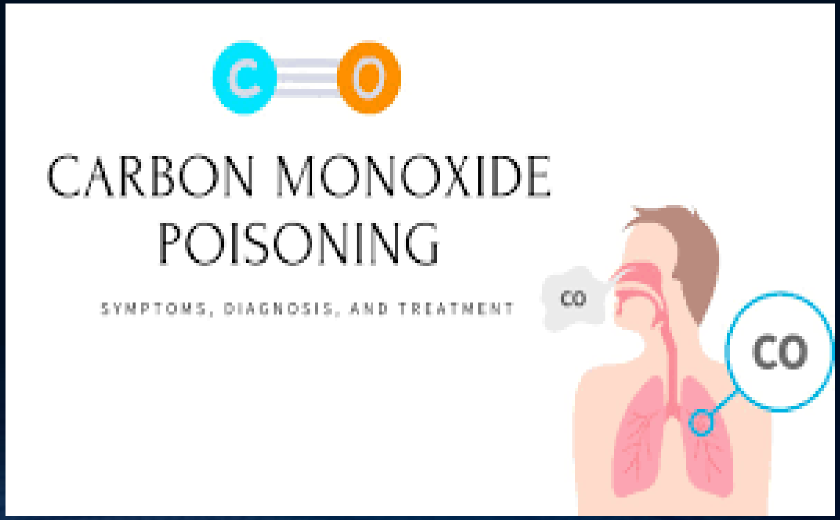
III . 2 : Effects on living things

Carbon monoxide is a poisonous gas that comes up with several harmful effects on a living system as well as the atmosphere.

- It binds to haemoglobin 200 times greater than the oxygen molecule in the blood which hampers the ability of blood to carry oxygen and results in carbon monoxide poisoning. Due to insufficient oxygen transport to the brain, lethargy, headaches, disorientation, and dizziness result as the most frequent side effects of CO exposure.

- The amount of greenhouse gases, which are associated with climate change and global warming, is affected when carbon monoxide is released into the atmosphere. When CO interacts with OH radicals in the atmosphere, OH reservoirs are depleted, making it harder to effectively control the primary emissions of GHGs like methane.



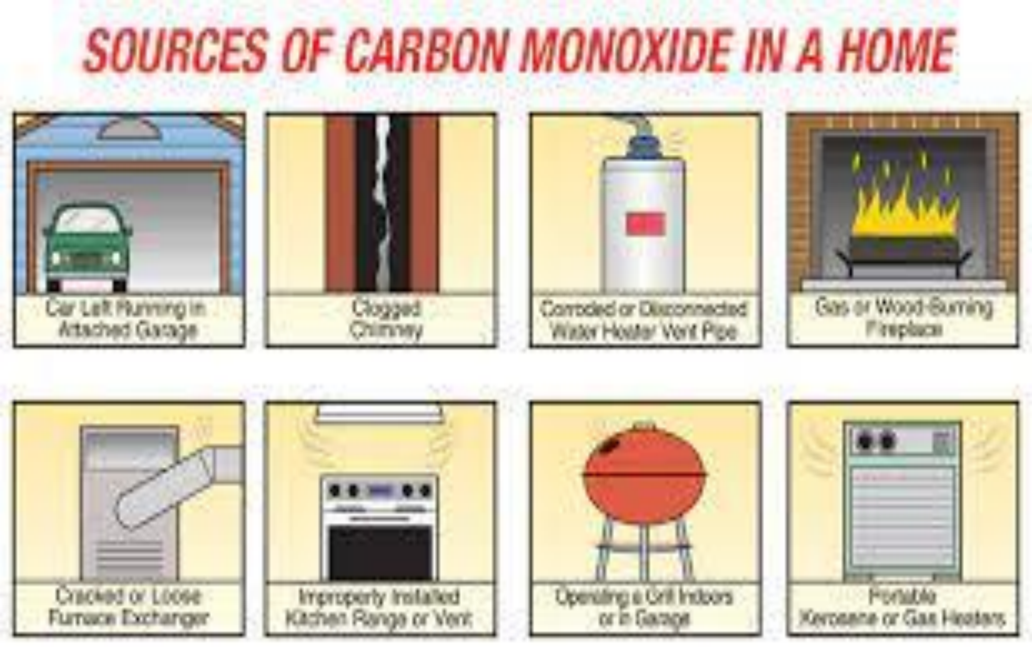


III 3 : Main mechanisms of CO formation

Carbon monoxide is produced during the incomplete combustion of carbon-containing fuels, such as natural gas, kerosene, and wood. Its production rate by gas ranges is actually greater than that for nitrogen dioxide, and indoor levels can be several times greater than those found outdoors.

Sources of Carbon Monoxide

Cars, trucks, and other machinery that burns fossil fuels are the main emitters of CO in the outdoor air. The quality of the air within the home can be impacted by a number of things, including gas stoves, unvented kerosene and gas space heaters, leaking chimneys and furnaces, and other gas appliances. The automobile exhaust from garages and even tobacco smoke generate an ample amount of carbon monoxide.



Frequently Asked Questions – FAQs

Q1: What is carbon monoxide poisoning?

A1: When high concentrations of carbon monoxide are inhaled by humans from the atmosphere, CO starts binding with the haemoglobin 200 times greater than the oxygen which causes CO build-up in the bloodstream. As a result, the ability of blood to carry oxygen is hampered which leads to lethargy, headaches, disorientation, and dizziness. The condition is called carbon monoxide poisoning.

Q2: How is carbon monoxide produced?

A2: There are several methods to produce carbon monoxide but it is mainly produced when there is not enough oxygen or heat to make carbon dioxide during the partial combustion of carbon-containing substances or incomplete combustion of natural gases like gasoline.

Q3: Why carbon monoxide is dangerous?

A3: CO is very toxic as it can form complex with haemoglobin in the red blood cells. Haemoglobin combines with oxygen to form oxyhaemoglobin. Oxyhaemoglobin (formed in lungs) is carried to different cells where it gives its oxygen. CO has stronger affinity for haemoglobin than oxygen. Due to this, the oxygen carrying capacity of blood is destroyed.. This results in suffocation and finally death.

Q4: What appliances can cause carbon monoxide?

A4: Carbon monoxide is a combustion by-product. Popular home appliances, such as gas or oil furnaces, gas refrigerators, gas clothing dryers, gas ranges, gas water heaters or space heaters, fireplaces, charcoal grills, and wood burning stoves are made.

Q5: **How does carbon monoxide affect the human body?**

A5:Carbon monoxide has positive and adverse effects on humans. Increased levels of carbon monoxide in red blood cells decrease the amount of oxygen haemoglobin carries throughout the body. The effect is that vital organs like the brain, nervous tissues, and the heart don't get enough oxygen to function properly.

Q6: **How do you get rid of carbon monoxide?**

A6:Breathing in pure oxygen is the only way to treat the CO poisoning. The procedure raises blood oxygen levels and helps keep CO out of the body. The doctor will put an oxygen mask over the mouth and nose and ask you to inhale it.

Q7: **Can you recover from carbon monoxide poisoning?**

A7: The majority of people who experience moderate carbon monoxide poisoning rapidly recover when they step into fresh air. Moderate or extreme contact of carbon monoxide induces impaired vision, confusion, unconsciousness, hallucinations, chest pain, shortness of breath, low blood pressure, and coma.

Chapter IV :
Nitrogen Oxides NO

IV . 1: Nitrogen origin

IV . 2: NO and N_2O formation reactions

IV . 3: Influence of pressure on NO emissions

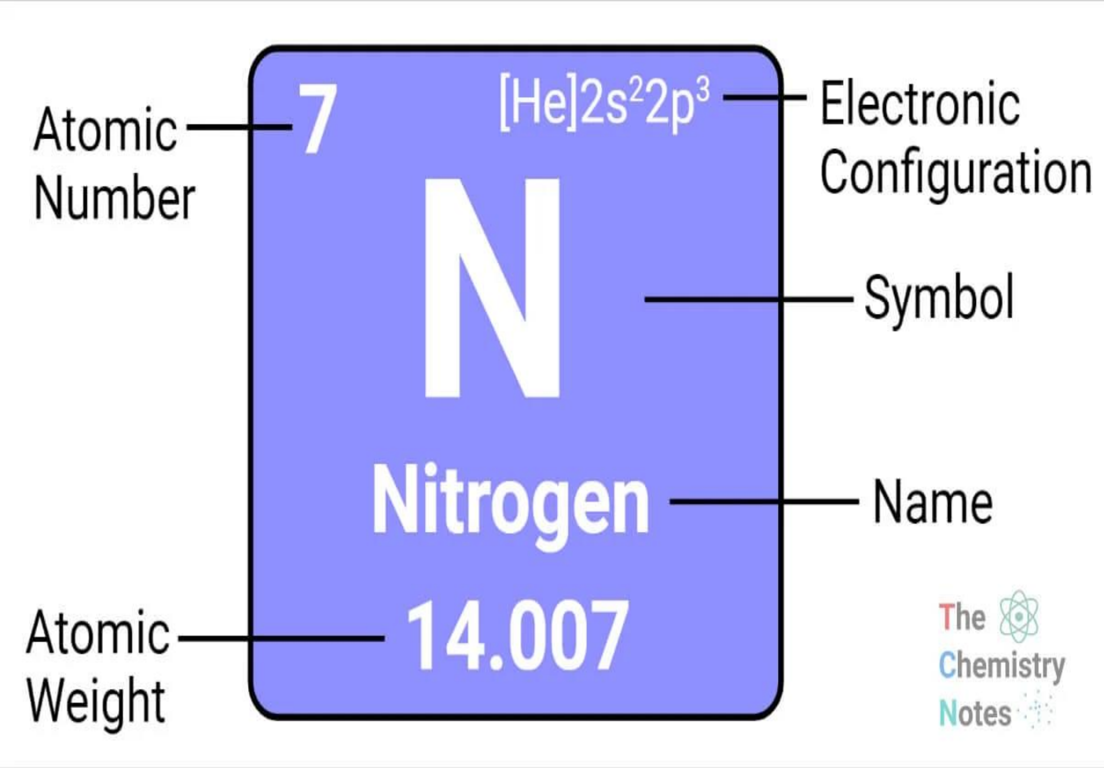
IV. 1: Nitrogen origin

A: History

From the Latin word ***nitrum***, Greek ***Nitron***, native soda; and *genes*, forming. Nitrogen was discovered by chemist and physician Daniel Rutherford in 1772. He removed oxygen and carbon dioxide from air and showed that the residual gas would not support combustion or living organisms. At the same time there were other noted scientists working on the problem of nitrogen. These included Scheele, Cavendish, Priestley, and others. They called it "burnt" or" dephlogisticated air," which meant air without oxygen.

Nitrogen (N), nonmetallic element of Group 15 [Va] of the periodic table. It is a colourless, odourless, tasteless gas that is the most plentiful element in Earth's atmosphere and is a constituent of all living matter.

Element Properties	
atomic number	7
atomic weight	14.0067
melting point	−209.86 °C (−345.8 °F)
boiling point	−195.8 °C (−320.4 °F)
density (1 atm, 0° C)	1.2506 grams/litre
usual oxidation states	−3, +3, +5
electron configuration	$1s^2 2s^2 2p^3$

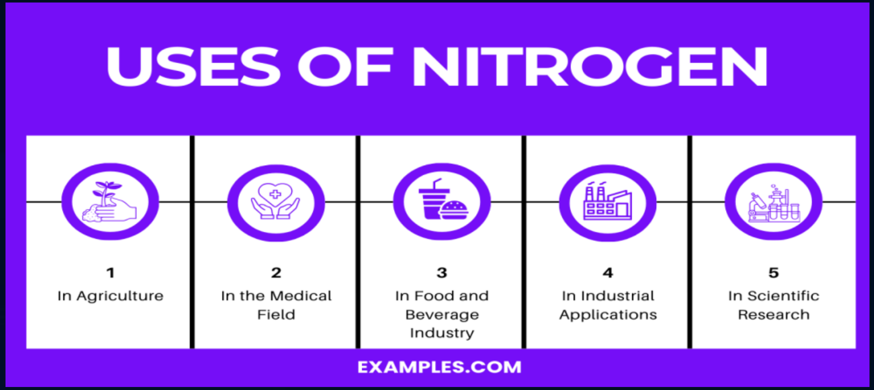


B: Sources

Nitrogen gas (N_2) makes up 78.1% of the Earth's air, by volume. The atmosphere of Mars, by comparison, is only 2.6% nitrogen. From an exhaustible source in our atmosphere, nitrogen gas can be obtained by liquefaction and fractional distillation. Nitrogen is found in all living systems as part of the makeup of biological compounds.

C: Uses

- Nitrogen is important to the chemical industry. It is used to make fertilisers, nitric acid, nylon, dyes and explosives. To make these products, nitrogen must first be reacted with hydrogen to produce ammonia. This is done by the Haber process. 150 million tonnes of ammonia are produced in this way every year.
- Nitrogen gas is also used to provide an unreactive atmosphere. It is used in this way to preserve foods, and in the electronics industry during the production of transistors and diodes. Large quantities of nitrogen are used in annealing stainless steel and other steel mill products. Annealing is a heat treatment that makes steel easier to work.
- Liquid nitrogen is often used as a refrigerant. It is used for storing sperm, eggs and other cells for medical research and reproductive technology. It is also used to rapidly freeze foods, helping them to maintain moisture, colour, flavour and texture.

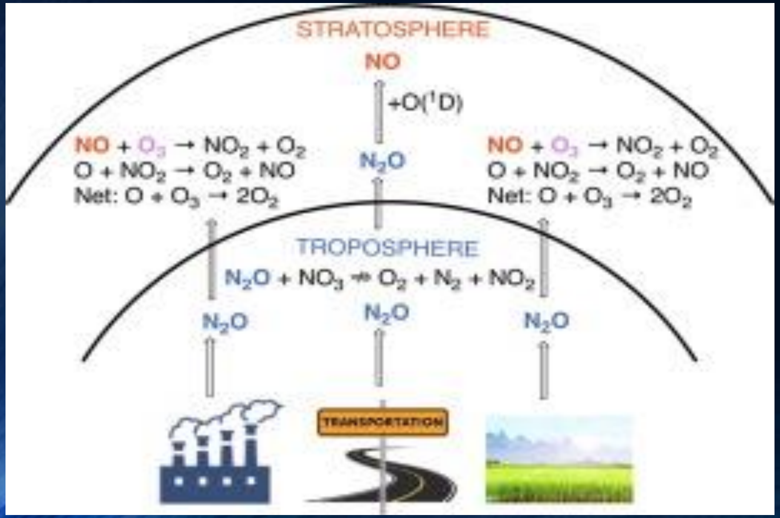


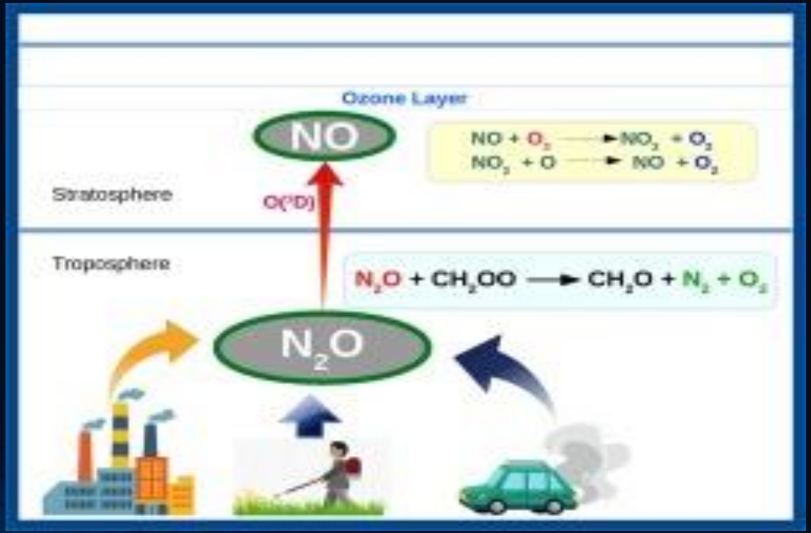
IV. 2: NO and N2O formation reactions

According to scientific publication reported by Franz Winter et all, in October 1999.

Entitled: **NO and N2O Formation during the Combustion of Wood, Straw, Malt Waste and Peat .**

The NO and N2O formation behavior of six biofuels (spruce wood, beech wood, alder wood, straw, malt waste, peat) was studied in a formation-rate unit under conditions relevant to a fluidized-bed combustor and a grate-furnace. The concentrations of CO2, CO, CH4, other hydrocarbons, NO, N2O, HCN, and NH3 were measured in the flue gas, shortly after the burning fuel particles. Most of the fuel nitrogen was released during devolatilization (66–75%). Relatively high conversions to NO were found. N2O was formed but also rapidly destroyed by the reaction: N2O + H → N2 + OH. HCN was also formed in quantities similar to NH3 even during wood combustion. The HCN/NH3 ratios seemed to depend on the fuel H/N ratios. The experimental results supported the hypothesis that the nitrogen of wood and other biofuels also exists in heterocyclic structures. With the proposed NO and N2O formation mechanism the effects of fuel nitrogen content, temperature and oxygen partial pressure can be explained.





IV. 3: Influence of pressure on NO emissions

A / Introduction

NO*x* is contained in coal combustion gas. It is a pollutant and a cause of acid rain. During the past 20-30 years, NO*x* from coal burning in the atmospheric pressure has been widely investigated in efforts to develop the technology to control these emissions. The rate of combustion was found to increase with pressure in the chemical-reaction control regime, but is less affected by pressure in the pore diffusion regime, and is invariant with pressure in gas-film diffusion control regimes. The mechanism underlying the relationship between pressure and NOx emission during coal or char combustion is not yet understood.

Deping on the literature:

- Richard et al, first studied N*x*O*y* emission from pressurized char combustion. They reported **that NO, N2O, and the total N*x*O*y* decreased with pressure**, whereas NO2 increased slightly with pressure. No explanation for this was provided in detail.
- Croiset studied NO and N2O emissions during char pressurized combustion and reported **that NO and N2O were reduced with increasing pressure**.
- Jensen et al **reported NOx reduction in coal and char pressurized combustion in real boiler**.

B/ Effect of Pressure on NO*x* Emission from Char Particle Combustion

According to previous study reporter by Shiying Lin et all in 2002

The effect of pressure on NO*x* emission during char particle combustion was examined in chemical-reaction control and diffusion control regimes. A fixed bed was used for batch testing under 0.1-1.6 MPa. It was found that with increasing pressure, NO*x* emission decreased extremely, when char combustion rate was controlled by reactant gas diffusion into the char particle at high temperature. The extent to which NO*x* was reduced in char particles strongly influenced the NO*x* emission from char pressurized combustion. Pressure increased residence time for diffusion of NO*x* throughout the char particle and consequently further increased the reduction of NO*x* in the char particle. Both pressure and temperature strongly influenced the conversion of fuel-N in char to NO*x*. When pressure was raised from 0.1 to 1.1 MPa, the conversion of fuel-N to NO*x* fell from 0.18 to 0.06 at 973 K, and from 0.68 to 0.13 at 1173 K. NO*x* emissions were lower when large char particles were combusted than when small ones were combusted. It was also observed that practically no N2O was formed in to any extent in the char particle.

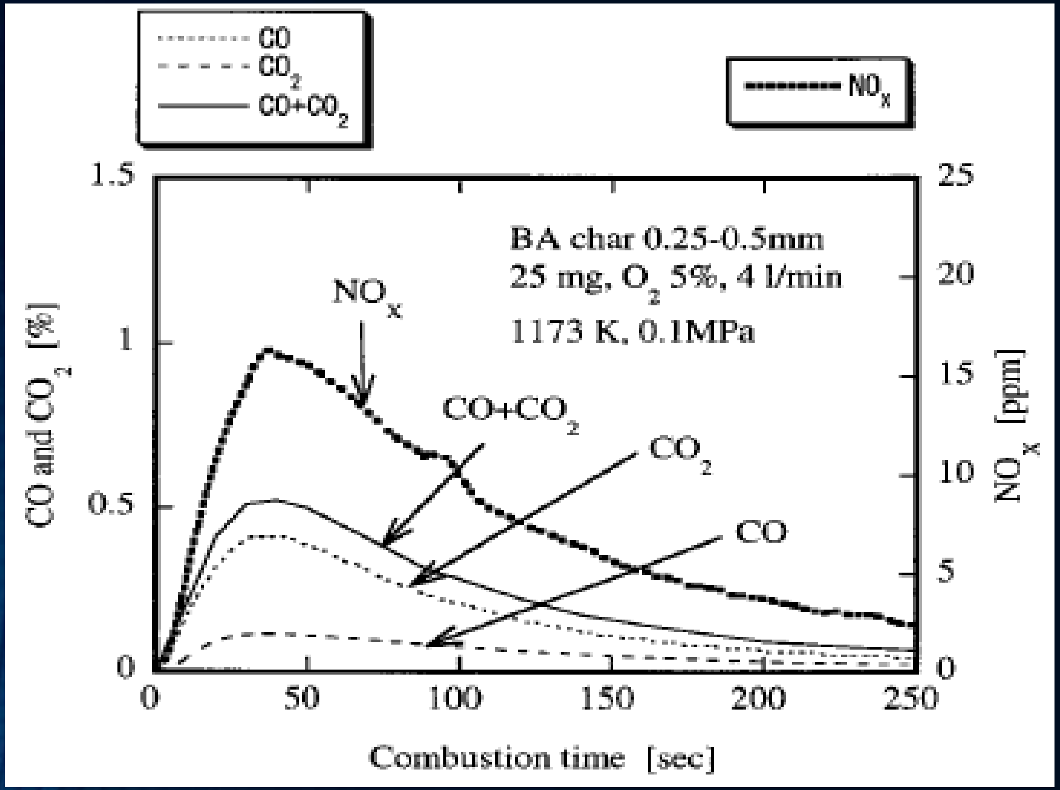


Figure 1. NO*x*, CO, and CO2 emission during pressurized char combustion (0.1 MPa).

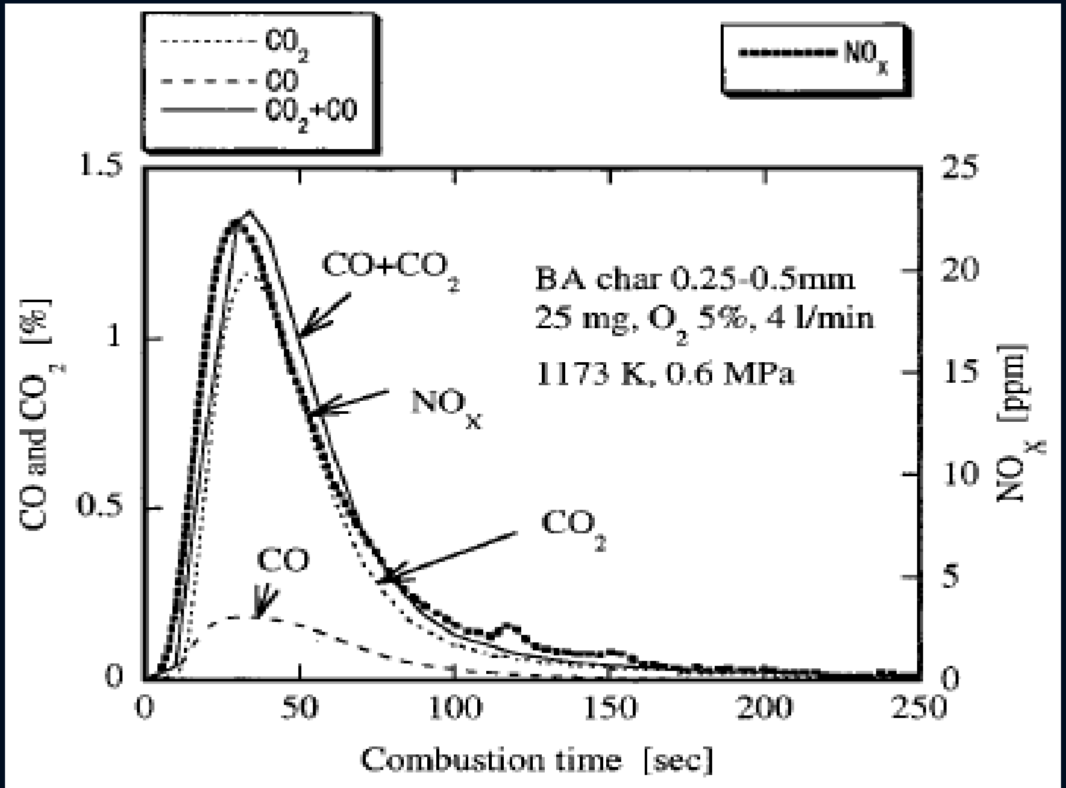


Figure 2. NO*x*, CO, and CO2 emission during pressurized char combustion (0.6 MPa).

Figures 1, 2, and 3 show the emission results of each of the gases during char combustion at pressures of 0.1, 0.6, and 1.1 MPa, respectively. O2 in supply gas was 5%, and the O2 partial pressures were 0.05, 0.3, and 0.55 MPa, corresponding to the pressure of 0.1, 0.6, and 1.1 MPa, respectively. During char combustion, CO and CO2 emissions increased with time, peaked at 40, 30, and 28 s for 0.1, 0.6, and 1.1 MPa, and then decreased with time. The peak heights of CO and CO2 emissions increased with pressure between 0.1 and 0.6 MPa (Figures 3 and 4), but did not significantly change with pressure between 0.6 and 1.1 MPa (**Figures 2 and 3**).

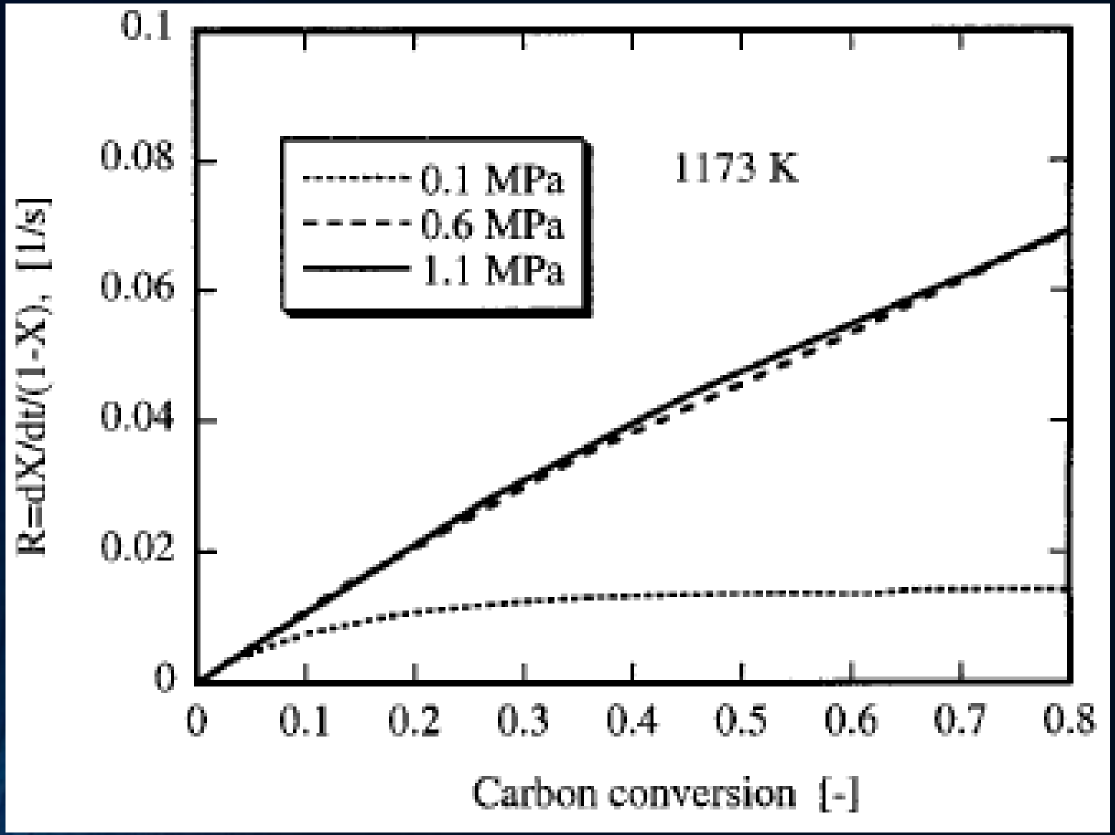


Figure 4. Rates of char combustion under various pressures.

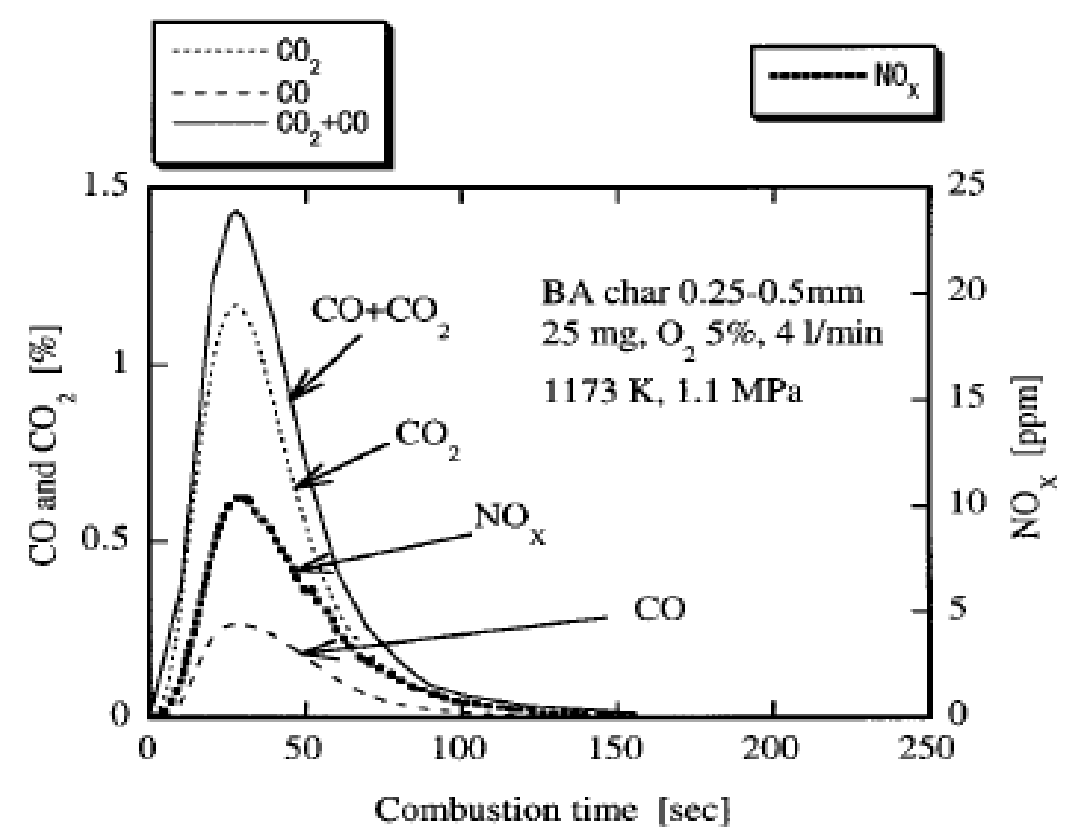


Figure 3. NO*x*, CO, and CO2 emission during pressurized char combustion (1.1 MPa).

The char combustion rates were calculated from CO and CO2 emissions as shown in **Figure 4**. The rate at 0.1 MPa was a volumetric rate, which was roughly constant during the char combustion, and the rates at 0.6 and 1.1 MPa were surface rates, which increased during char combustion. The results also showed that combustion rate tended to increase with pressure between 0.1 and 0.6 MPa but did not change between 0.6 and 1.1 MPa.

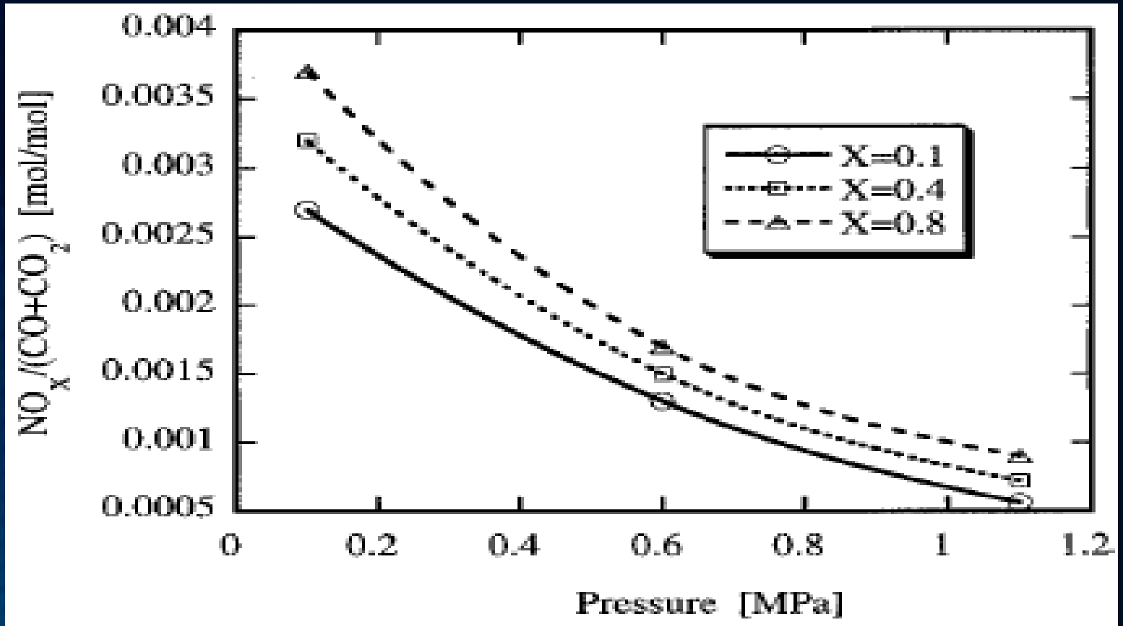


Figure 5. Variation of NO*x*/(CO + CO2) ratio with pressure

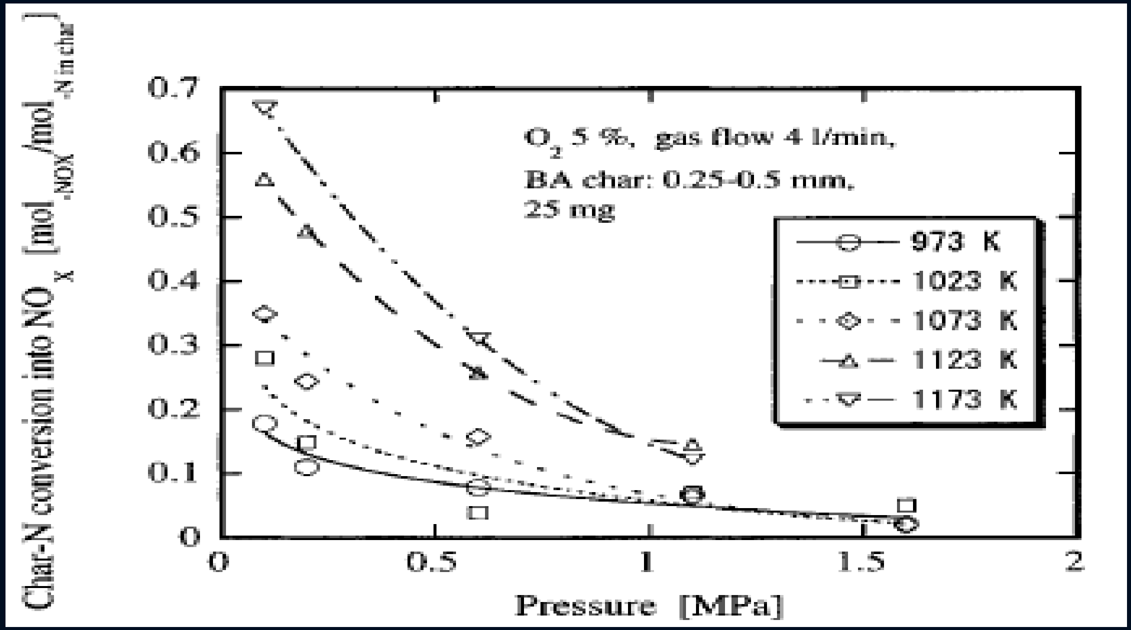


Figure 6. Effects of temperature and pressure on Nox conversion during char combustion.

By plotting the NOx/(CO + CO2) ratio vs pressure as shown in **Figure 5**, it can be seen that the NO*x*/(CO + CO2) ratio was approximately proportional with pressure *P*-0.61-*P*-.64. However, with carbon conversion, especially at high carbon conversion, the NO*x*/(CO + CO2) ratio increased in each pressure condition. **Figure 6** shows the tendency of fuel-N in char to convert to NO*x* under various temperatures and pressures. It can be seen that this tendency is strongly influenced by both temperature and pressure. Under atmospheric conditions, with temperature increasing, conversion of fuel-N to NO*x* increased. Under elevated pressure, conversion to NO*x* increased with temperature but less than it did under atmospheric conditions. Pressure strongly influenced the conversion of fuel-N to NO*x*. When pressure increased from 0.1 to 1.1 MPa, the conversion of fuel-N to NO*x* was reduced from 0.18 to 0.06 for 973 K, and from 0.68 to 0.13 for 1173 K.

Conclusion

The effect of pressure on NOx emission, as well as on N2O emission, was studied experimentally. It was found that with increasing pressure, NOx emission decreased extremely, when char combustion rate was controlled by reactant gas diffusion into the char particle at high temperatures. NOx reduction with carbon in char particles decreased the emission of NOx from char. Pressure increased the diffusion time of NOx in char, and consequently increased the reduction of NOx. Increasing the temperature increased NOx emission from char combustion, but the effect of increased temperature was weak when pressure was high. Other factors influencing NOx reduction, such as char reactivity, temperature, and particle size, can have co-effects on NOx emissions in char pressurized combustion. It was also observed that no N2O was formed in considerable in the char particle.

Chapter V :
Polycyclic Aromatic Hydrocarbons (PAHs)

V . 1: Introduction

V . 2 : Physical properties of polycyclic aromatic hydrocarbons

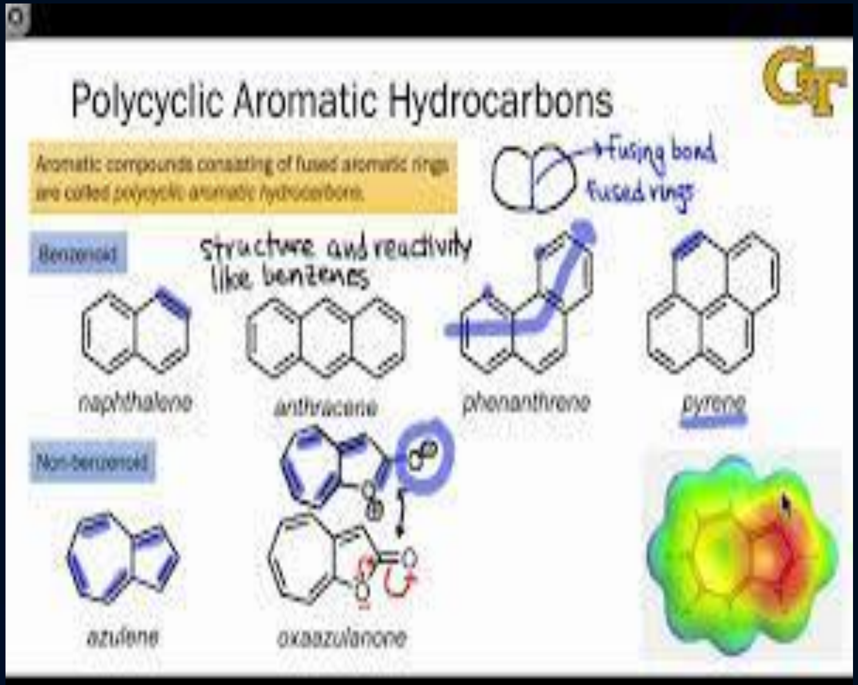
V . 3 : Mechanisms of formation of polycyclic aromatic hydrocarbons

V . 4 : Effects of polycyclic aromatic hydrocarbons on living beings

V . 1: Introduction

- Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, wood, garbage, and tobacco. PAHs can bind to or form small particles in the air. The term polycyclic aromatic hydrocarbons (PAHs) refers to a ubiquitous group of several hundred chemically-related, environmentally persistent organic compounds of various structures and varied toxicity.
- Most of them are formed by a process of thermal decomposition (pyrolysis) and subsequent recombination (pyrosynthesis) of organic molecules.
- High heat when cooking meat and other foods will form PAHs.
- Naphthalene is a manmade PAH used in the United States to make other chemicals and mothballs. Cigarette smoke contains many PAHs.

- PAHs enter the environment through various routes and are usually found as a mixture containing two or more of these compounds, e.g. soot. However, some PAHs are manufactured and these pure PAHs usually exist as colorless, white, or pale yellow solids.



PAH Exposure in People

Exposure to PAHs can occur by:

- Breathing air containing
  - Motor vehicle exhaust
  - Cigarette smoke
  - Wood smoke
  - Fumes from asphalt roads
- Consuming grilled or charred meats or foods
- Eating foods on which PAH particles have settled from the air
- In some cases, passing through the skin.

Sources

Sources of PAHs can be both natural and anthropogenic.

A : Natural sources include:

1: Forest and grass fires

2: Oil seeps

3: Volcanoes

4: Chlorophyllous plants, fungi, and bacteria

B: Anthropogenic sources of PAHs include:

1: petroleum

2: electric power generation

3: refuse incineration

4: home heating

5: production of coke, carbon black, coal tar, and asphalt

5: internal combustion engines

V . 2 : Physical and chemical properties of polycyclic aromatic hydrocarbons

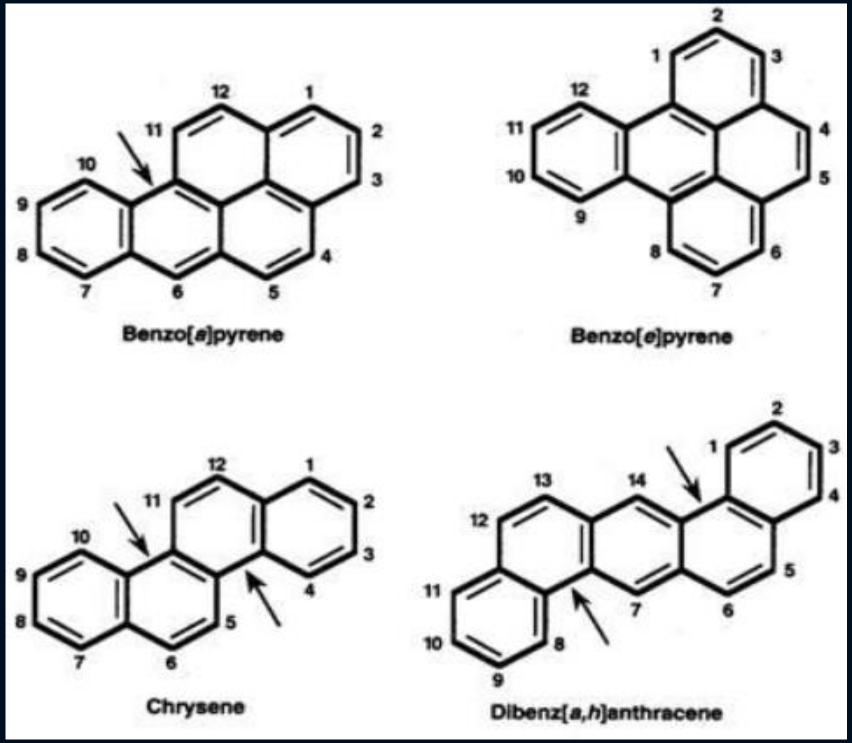
- Polycyclic aromatic hydrocarbons have two or more single or fused aromatic rings with a pair of carbon atoms shared between rings in their molecules. The term "PAH" refers to compounds consisting of only carbon and hydrogen atoms. PAHs containing up to six fused aromatic rings are often known as "small" PAHs, and those containing more than six aromatic rings are called "large" PAHs. The majority of research on PAHs has been conducted on small PAHs due to the availability of samples of various small PAHs.

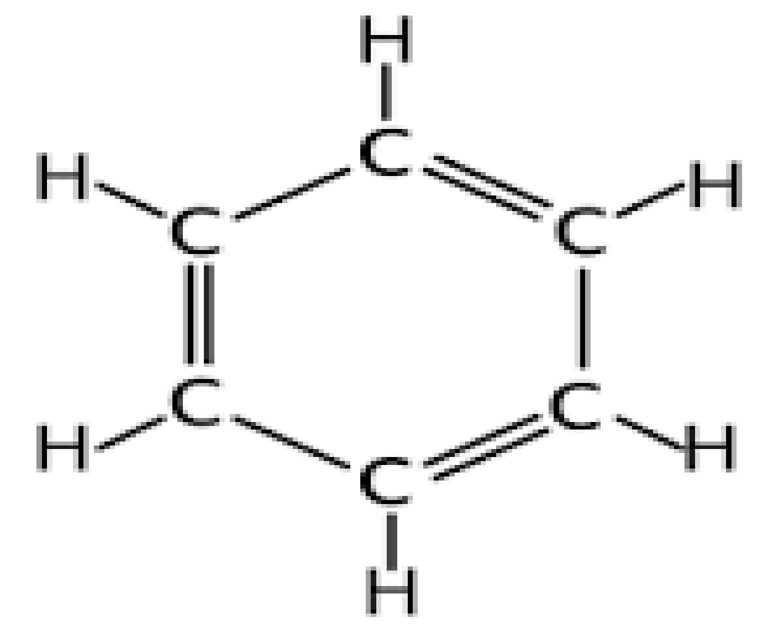
- The general characteristics of PAHs are high melting and boiling points (therefore they are solid), low vapor pressure, and very low aqueous solubility, which both tend to decrease with increasing molecular weight, whereas resistance to oxidation and reduction increases.

- PAHs are highly lipophilic and therefore very soluble in organic solvents. PAHs also manifest various functions such as light sensitivity, heat resistance, conductivity, emittability, corrosion resistance, and physiological action.

- PAHs possess very characteristic UV absorbance spectra. Each ring structure has a unique UV spectrum, thus each isomer has a different UV absorbance spectrum. This is especially useful in the identification of PAHs. Most PAHs are also fluorescent, emitting characteristic wavelengths of light when they are excited (when the molecules absorb light). Aqueous solubility decreases for each additional ring.

- The simplest PAHs, as defined by the International Union of Pure and Applied Chemistry (IUPAC), are phenanthrene and anthracene, which both contain three fused aromatic rings.
- Smaller molecules, such as benzene, are not PAHs.
- Naphthalene, which consists of two coplanar six-membered rings sharing an edge, is another aromatic hydrocarbon. By formal convention, it is not a true PAH, though is referred to as a bicyclic aromatic hydrocarbon.





- Aromatic hydrocarbons are cyclic molecules that contain carbon atoms connected with alternating double bonds that create resonance structures, where the valence electrons are delocalized. Aromatic hydrocarbons are non-polar and relatively non-reactive due to these resonance structures and make excellent solvents.

V . 3 : Mechanisms of formation of polycyclic aromatic hydrocarbons

- In nature, PAHs are produced by:

(1) Diagenesis of organic matter at low temperatures;

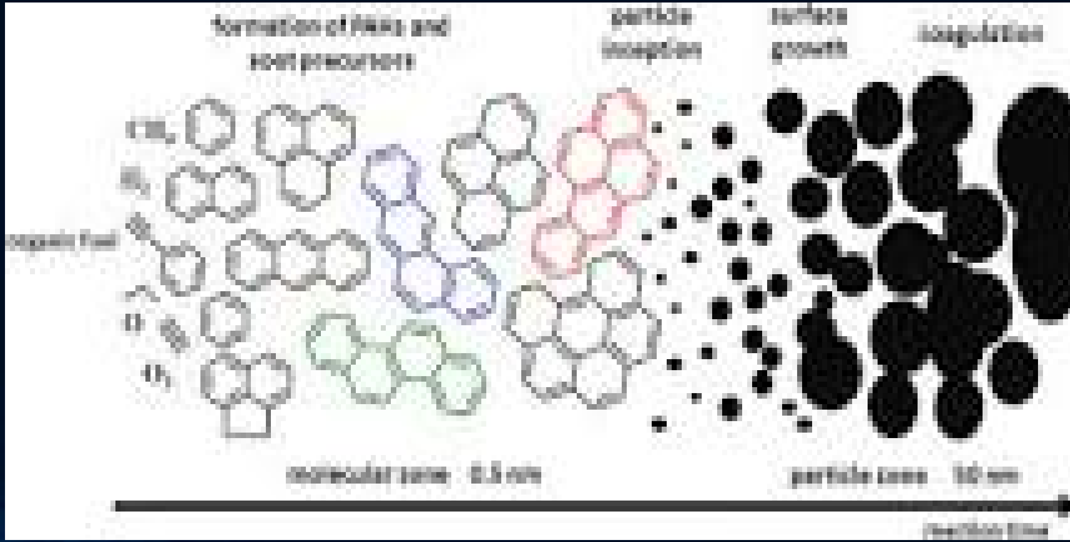
(2) During formation of petroleum and coal;

(3) Incomplete or insufficient combustion at moderate to high temperatures (pyrolysis)

(4) Biosynthesis.

- HACA - hydrogen abstraction and acetylene or carbon addition. The most classical reaction mechanism for the growth of polycyclic aromatic hydrocarbons is the hydrogen abstraction and acetylene or carbon addition (HACA). This mechanism was originally proposed by Frenklach et al.

- Polycyclic aromatic hydrocarbons (PAHs) are a class of chemicals that occur naturally in coal, crude oil, and gasoline. They result from burning coal, oil, gas, wood, garbage, and tobacco. PAHs can bind to or form small particles in the air. High heat when cooking meat and other foods will form PAHs



V . 4 : Effects of polycyclic aromatic hydrocarbons on living beings

- For Human health effects from indirect exposure to low levels of PAHs are unknown exact.
- After PAHs enter a person, the body converts PAHs into breakdown products called metabolites. The metabolites pass out of the body in the urine and feces.
- Large amounts of naphthalene in air can irritate eyes and breathing passages.
- Occupational skin exposure with liquid naphthalene and breathing its vapors may be harmful.
- Workers have become sick with blood and liver problems from large amounts of exposure.
- Scientists consider several of the PAHs and some specific mixtures to be cancer-causing chemicals.
- Polycyclic aromatic hydrocarbons affect organisms through various toxic actions. The mechanism of toxicity is considered to be interference with function of cellular membranes as well as with enzyme systems which are associated with the membrane. They have been shown to cause carcinogenic and mutagenic effects and are potent immunosuppressant's.

Although the health effects of individual PAHs are not exactly alike, these 17 PAHs have been identified as being of greatest concern with regard to potential exposure and adverse health effects on humans and are thus considered as a group (profile issued by the Agency for Toxic Substances and Disease Registry):

- Acenaphthene
- Acenaphthylene
- Anthracene
- Benz(a)anthracen
- Benzo(a)pyrene
- Benzo(e)pyrene
- Benzo(b)fluoranthen
- Benzo(ghi)perylene
- Benzo(j)fluoranthene
- Benzo(k)fluoranthene
- Chrysene
- Dibenz(ah)anthracene
- Fluoranthene
- Fluorene
- Indeno(1,2,3-cd)pyrene
- Phenanthrene
- Pyrene

Environmental Fate and Ecotoxic Effects

- PAHs are usually released into the air, or they evaporate into the air when they are released to soil or water. PAHs often adsorb to dust particles in the atmosphere, where they undergo photo oxidation in the presence of sunlight, especially when they are adsorbed to particles. This oxidation process can break down the chemicals over a period of days to weeks.
- Since PAHs are generally insoluble in water, they are generally found adsorbed on particulates and precipitated in the bottom of lakes and rivers, or solubilized in any oily matter which may contaminate water, sediments, and soil. Mixed microbial populations in sediment/water systems may degrade some PAHs over a period of weeks to months.
- The toxicity of PAHs to aquatic organisms is affected by metabolism and photo-oxidation, and they are generally more toxic in the presence of ultraviolet light. PAHs have moderate to high acute toxicity to aquatic life and birds. PAHs in soil are unlikely to exert toxic effects on terrestrial invertebrates, except when the soil is highly contaminated. Adverse effects on these organisms include tumors, adverse effects on reproduction, development, and immunity. Mammals can absorb PAHs by various routes e.g. inhalation, dermal contact, and ingestion.
- Plants can absorb PAHs from soils through their roots and translocate them to other plant parts. Uptake rates are generally governed by concentration, water solubility, and their physicochemical state as well as soil type. PAH-induced phytotoxic effects are rare, however the database on this is still limited. Certain plants contain substances that can protect against PAH effects, whereas others can synthesize PAHs that act as growth hormones.
- PAHs are moderately persistent in the environment, and can bioaccumulate. The concentrations of PAHs found in fish and shellfish are expected to be much higher than in the environment from which they were taken. Bioaccumulation has been also shown in terrestrial invertebrates, however PAH metabolism is sufficient to prevent biomagnification.

A little over six months before the "COP21" to be held in Paris, Friends of the Earth publish a brochure "Let’s leave fossil fuels in the ground!" , for the general public.

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MERCI

Bon courage