University of Mosul
collage of Science
Department of Forensic

جامعة الموصل
كلية العلوم
قسم الادلة الجنائية

# مدخل لمواد الوقود ومسرعات الحرائق

# Fuel and fire accelerators

كورس للأدلة الجنائية – المرحلة الاولى

2024-2023

**اعداد:**

**م.د. حامد عبدالله صالح**

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# Fuel and fire accelerators

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## fuel

A **fuel** is any material that can be made to react with other substances so that it releases energy as thermal energy or to be used for work. The concept was originally applied solely to those materials capable of releasing chemical energy but has since also been applied to other sources of heat energy, such as nuclear energy (via nuclear fission and nuclear fusion).

The heat energy released by reactions of fuels can be converted into mechanical energy via a heat engine. Other times, the heat itself is valued for warmth, cooking, or industrial processes, as well as the illumination that accompanies combustion. Fuels are also used in the cells of organisms in a process known as cellular respiration, where organic molecules are oxidized to release usable energy. Hydrocarbons and related organic molecules are by far the most common source of fuel used by humans, but other substances, including radioactive metals, are also utilized.

Fuels are contrasted with other substances or devices storing potential energy, such as those that directly release electrical energy (such as batteries and capacitors) or mechanical energy (such as flywheels, springs, compressed air, or water in a reservoir).

## History

The first known use of fuel was the combustion of firewood by *Homo erectus* nearly two million years ago. Throughout most of human history only fuels derived from plants or animal fat were used by humans. Charcoal, a wood derivative, has been used since at least 6,000 BCE for melting metals. It was only supplanted by coke, derived from coal, as European forests started to become depleted around the 18th century. Charcoal briquettes are now commonly used as a fuel for barbecue cooking.(1)

Firewood was one of the first fuels used by humans.[1]

Crude oil was distilled by Persian chemists, with clear descriptions given in Arabic handbooks such as those of Muhammad ibn Zakarīya Rāzi.[2] He described the process of distilling crude oil/petroleum into kerosene, as well as other hydrocarbon compounds, in his *Kitab al-Asrar* (*Book of Secrets*). Kerosene was also produced during the same period from oil shale and bitumen by heating the rock to extract the oil, which was then distilled. Rāzi also gave the first description of a kerosene lamp using crude mineral oil, referring to it as the "naffatah".[3]

## Chemical

Chemical fuels are substances that release energy by reacting with substances around them, most notably by the process of combustion.

Chemical fuels are divided in two ways. First, by their physical properties, as a solid, liquid or gas. Secondly, on the basis of their occurrence: *primary (natural fuel)* and *secondary (artificial fuel)*. Thus, a general classification of chemical fuels is:

**General types of chemical fuels**

| | **Primary (natural)** | **Secondary (artificial)** |
|---|---|---|
| **Solid fuels** | wood, coal, peat, dung, etc. | coke, charcoal |
| **Liquid fuels** | petroleum | diesel, gasoline, kerosene, LPG, coal tar, naphtha, ethanol |
| **Gaseous fuels** | natural gas | hydrogen, propane, methane, coal gas, water gas, blast furnace gas, coke oven gas, CNG |

## Solid fuel

Solid fuel refers to various types of solid material that are used as fuel to produce energy and provide heating, usually released through combustion. Solid fuels include wood, charcoal, peat, coal, hexamine fuel tablets, and pellets made from wood (see wood pellets), corn, wheat, rye and other grains. Solid-fuel rocket technology also uses solid fuel (see solid propellants). Solid fuels have been used by humanity for many years to create fire. Coal was the fuel source which enabled the industrial revolution, from firing furnaces, to running steam engines. Wood was also extensively used to run steam locomotives. Both peat and coal are still used in electricity generation today. The use of some solid fuels (e.g. coal) is restricted or prohibited in some urban areas, due to unsafe levels of toxic emissions. The use of other solid fuels as wood is decreasing as heating technology and the availability of good quality fuel improves. In some areas, smokeless coal is often the only solid fuel used. In Ireland, peat briquettes are used as smokeless fuel. They are also used to start a coal fire.

Coal is a solid fuel

## Liquid fuels

Liquid fuels are combustible or energy-generating molecules that can be harnessed to create mechanical energy, usually producing kinetic energy. They must also take the shape of their container; the fumes of liquid fuels are flammable, not the fluids.

Most liquid fuels in widespread use are derived from the fossilized remains of dead plants and animals by exposure to heat and pressure inside the Earth's crust. However, there are several types, such as hydrogen fuel (for automotive uses), ethanol, jet fuel and bio-diesel, which are all categorized as liquid fuels. Emulsified fuels of oil in water, such as orimulsion, have been developed as a way to make heavy oil fractions usable as liquid fuels. Many liquid fuels play a primary role in transportation and the economy.

Some common properties of liquid fuels are that they are easy to transport and can be handled easily. They are also relatively easy to use for all engineering applications and in home use. Fuels like kerosene are rationed in some countries, for example in government-subsidized shops in India for home use.

Conventional diesel is similar to gasoline in that it is a mixture of aliphatic hydrocarbons extracted from petroleum. Kerosene is used in kerosene lamps and as a fuel for cooking, heating, and small engines. Natural gas, composed chiefly of methane, can only exist as a liquid at very low temperatures (regardless of pressure), which limits its direct use as a liquid fuel in most applications. LP gas is a mixture of propane and butane, both of which are easily compressible gases under standard atmospheric conditions. It offers many of the advantages of compressed natural gas (CNG) but is denser than air, does not burn as cleanly, and is much more easily compressed. Commonly used for cooking and space heating, LP gas and compressed propane are seeing increased use in motorized vehicles. Propane is the third most commonly used motor fuel globally.

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Locomotive diesel Gasoline Kerosene Petroleum based motor oil Residual fuel oil or Bunker C oil

## Fuel gas

Fuel gas is any one of a number of fuels that are gaseous under ordinary conditions. Many fuel gases are composed of hydrocarbons (such as methane or propane), hydrogen, carbon monoxide, or mixtures thereof. Such gases are sources of potential heat energy or light energy that can be readily transmitted and distributed through pipes from the point of origin directly to the place of consumption. Fuel gas is contrasted with liquid fuels and from solid fuels, though some fuel gases are liquefied for storage or transport. While their gaseous nature can be advantageous, avoiding the difficulty of transporting solid fuel and the dangers of spillage inherent in liquid fuels, it can also be dangerous. It is possible for a fuel gas to be undetected and collect in certain areas, leading to the risk of a gas explosion. For this reason, odorizers are added to most fuel gases so that they may be detected by a distinct smell. The most common type of fuel gas in current use is natural gas.

## Fuel measurement

## flash point

The **flash point** of a material is the "lowest liquid temperature at which, under certain standardized conditions, a liquid gives off vapours in a quantity such as to be capable of forming an ignitable vapour/air mixture". (EN 60079-10-1)

The flash point is sometimes confused with the autoignition temperature, the temperature that causes spontaneous ignition. The fire point is the lowest temperature at which the vapors keep burning after the ignition source is removed. It is higher than the flash point, because at the flash point vapor may not be produced fast enough to sustain combustion.[1] Neither flash point nor fire point depends directly on the ignition source temperature, but ignition source temperature is far higher than either the flash or fire point, and can increase the temperature of fuel above the usual ambient temperature to facilitate ignition.

## Fuels

The flash point is a descriptive characteristic that is used to distinguish between flammable fuels, such as petrol (also known as gasoline), and combustible fuels, such as diesel.

It is also used to characterize the fire hazards of fuels. Fuels which have a flash point less than 37.8 °C (100.0 °F) are called flammable, whereas fuels having a flash point above that temperature are called combustible.[2]

Methods for determining the flash point of a liquid are specified in many standards. For example, testing by the Pensky-Martens closed cup method is detailed in ASTM D93, IP34, ISO 2719, DIN 51758, JIS K2265 and AFNOR M07-019. Determination of flash point by the Small Scale closed cup method is detailed in ASTM D3828 and D3278, EN ISO 3679 and 3680, and IP 523 and 524.

## Examples

| Fuel | Flash point | Autoignition temperature |
|---|---|---|
| Ethanol (70%) | 16.6 °C (61.9 °F)[5] | 363 °C (685 °F)[5] |
| Coleman fuel (White Gas) | −4 °C (25 °F)[6] | 215 °C (419 °F)[6] |
| Petrol (gasoline) | −43 °C (−45 °F)[7] | 280 °C (536 °F)[8] |
| Diesel (2-D) | >52 °C (126 °F)[7] | 210 °C (410 °F)[8] |
| Jet fuel (A/A-1) | >38 °C (100 °F) | 210 °C (410 °F) |
| Kerosene | >38 °C (100 °F)[9] | 210 °C (410 °F)[9] |
| Vegetable oil (canola) | 327 °C (621 °F) | 424 °C (795 °F)[10] |
| Biodiesel | >130 °C (266 °F) | |

Coleman fuel*Historically called *white gas*, it is a liquid petroleum fuel (100% light hydrotreated distillate).[1] White gas was originally simply additive-free gasoline. This formulation is now rarely found. Coleman fuel, and other white gases, contain additives for inhibiting rust, ease of lighting, and fast burning. It is also cleaner than the original white gas.[2

Gasoline (petrol) is a fuel used in a spark-ignition engine. The fuel is mixed with air within its flammable limits and heated by compression and subject to Boyle's Law above its flash point, then ignited by the spark plug. To ignite, the fuel must have a low flash point, but in order to avoid preignition caused by residual heat in a hot combustion chamber, the fuel must have a high autoignition temperature.

Diesel fuel flash points vary between 52 and 96 °C (126 and 205 °F). Diesel is suitable for use in a compression-ignition engine. Air is compressed until it heats above the autoignition temperature of the fuel, which is then injected as a high-pressure spray, keeping the fuel-air mix within flammable limits. A diesel-fueled engine has no ignition source (such as the spark plugs in a gasoline engine), so diesel fuel can have a high flash point, but must have a low autoignition temperature.

Jet fuel flash points also vary with the composition of the fuel. Both Jet A and Jet A-1 have flash points between 38 and 66 °C (100 and 151 °F), close to that of off-the-shelf kerosene. Yet both Jet B and JP-4 have flash points between −23 and −1 °C (−9 and 30 °F).

## Pour point

**he pour point of a liquid is the temperature below which the liquid loses its flow characteristics. It is defined as the minimum temperature in which the oil has the ability to pour down from a beaker.[1][2] In crude oil a high pour point is generally associated with a high paraffin content, typically found in crude deriving from a larger proportion of plant material.**

## Cloud point

**In liquids, the cloud point is the temperature below which a transparent solution undergoes either a liquid-liquid phase separation to form an emulsion or a liquid-solid phase transition to form either a stable sol or a suspension that settles a precipitate. In the petroleum industry, cloud point refers to the temperature below which paraffin wax in diesel or biowax in biodiesels forms a cloudy appearance. The presence of solidified waxes thickens the oil and clogs fuel filters and injectors in engines.[1] The wax also accumulates on cold surfaces (producing, for example, pipeline or heat exchanger fouling) and forms an emulsion or sol with water. Therefore, cloud point indicates the tendency of the oil to plug filters or small orifices at cold operating temperatures.[2]**

**An everyday example of cloud point can be seen in olive oil stored in cold weather. Olive oil begins to solidify (via liquid-solid phase separation) at around 4 °C, whereas winter temperatures in temperate countries can often be colder than 0 °C. In these conditions, olive oil begins to develop white, waxy clumps/spheres of solidified oil that sink to the bottom of the container.[3]**

**In crude or heavy oils, cloud point is synonymous with wax appearance temperature (WAT) and wax precipitation temperature (WPT).**

## Viscosity

### What Is Viscosity?

Suppose you have a cup of water and a cup of syrup. When you pour the liquids from these cups, you notice a distinct difference in how each liquid flows. The water pours out quickly and easily while the syrup pours more slowly. This difference is due to a difference in their viscosities.

**Viscosity is a measure of a fluid's resistance to flow. It can also be thought of as a measure of a fluid's thickness or its resistance to objects passing through it. The greater the resistance to flow, the higher the viscosity, so in the previous example, the syrup has a higher viscosity than water.**

### What Causes Viscosity?

**Viscosity is caused by internal friction between the molecules in a fluid**. Think of a flowing fluid as consisting of **layers** moving in relation to each other. These layers rub against each other, and the greater the friction, the slower the flow (or the more force required to achieve flow). This **friction** is caused by intermolecular forces which impacts the internal resistance of a fluid

**Many factors can affect a substance's viscosity**; among these is temperature. Recall that temperature is a measure of the average kinetic energy per molecule in a substance. A higher average kinetic energy – temperature increase – per molecule results in faster-moving molecules and the resulting viscosity decreases. If you warm syrup up in a microwave, for example, you might notice that it flows more easily.

**The viscosity of liquids is different from gas**. When dealing with this less contained state of matter, a higher temperature actually causes them to "thicken," and their viscosity increases with temperature. This is because for gasses at low temperatures, the molecules rarely collide or interact with each other, while at higher temperatures there are many more collisions. As a result, the gasses' resistance to flow increases. Looking at the viscosity of gasses can be very useful when dealing with atmospheric science and weather predictions; the atmosphere can be described by flow rate of various layers with viscous forces.

The shape of the molecules in a fluid can also affect the viscosity. Rounder molecules can roll past each other more easily than molecules with branches and less uniform shapes. (Imagine pouring a bucket of marbles out versus pouring a bunch of jacks.)

## Wax

### Chemistry

**Waxes are organic compounds that characteristically consist of long aliphatic alkyl chains, although aromatic compounds may also be present. Natural waxes may contain unsaturated bonds and include various functional groups such as fatty acids, primary and secondary alcohols, ketones, aldehydes and fatty acid esters. Synthetic waxes often consist of homologous series of long-chain aliphatic hydrocarbons (alkanes or paraffins) that lack functional groups.[1]**

## Crude oil assay

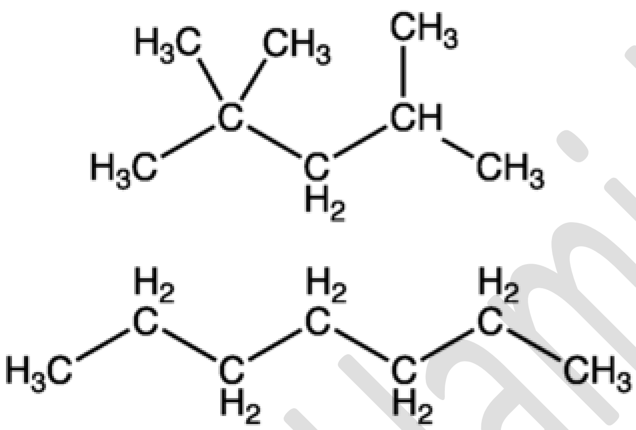
A crude oil assay is the chemical evaluation of crude oil feedstocks by petroleum testing laboratories. Each crude oil type has unique molecular and chemical characteristics. No two crude oil types are identical and there are crucial differences in crude oil quality. The results of crude oil assay testing provide extensive detailed hydrocarbon analysis data for refiners, oil traders and producers. Assay data help refineries determine if a crude oil feedstock is compatible for a particular petroleum refinery or if the crude oil could cause yield, quality, production, environmental and other problems.[1]

The assay can be an inspection assay or comprehensive assay. Testing can include crude oil characterization of whole crude oils and the various boiling range fractions produced from physical or simulated distillation by various procedures. Information obtained from the petroleum assay is used for detailed refinery engineering and client marketing purposes. Feedstock assay data are an important tool in the refining process.

## Octane rating

An octane rating, or octane number, is a standard measure of a fuel's ability to withstand compression in an internal combustion engine without undergoing pre-ignition. The higher the octane number, the more compression the fuel can withstand before detonating. Octane rating does not relate directly to the power output or the energy content of the fuel per unit mass or volume, but simply indicates gasoline's resistance to detonating under pressure without a spark.

Whether or not a higher octane fuel improves or impairs an engine's performance depends on the design of the engine. In broad terms, fuels with a higher octane rating are used in higher-compression gasoline engines, which may yield higher power for these engines. The added power in such cases comes from the way the engine is designed to compress the air/fuel mixture, and not directly from the rating of the gasoline.[1]




**2,2,4-Trimethylpentane (iso-octane) (upper) by definition is assigned the octane rating of 100, whereas *n*-heptane (lower) is assigned the octane rating of 0.**

Octanes are a family of hydrocarbons that are typical components of gasoline. They are colorless liquids that boil around 125 °C (260 °F). One member of the octane family, iso-octane, is used as a reference standard to benchmark the tendency of gasoline or LPG fuels to resist self-ignition.

## Cetane number

## Chemical relevance

Cetane is the hydrocarbon with chemical formulas $C_{16}H_{34}$ and specifically the structural formula $CH_3(CH_2)_{14}CH_3$. Also named n-hexadecane, it is an unbranched saturated alkane. Cetane ignites with a short delay under compression, and is assigned a cetane number of 100. Alpha-methylnaphthalene, which has a long delay period, was assigned a cetane number of 0, but has been replaced as a reference fuel by 2,3,4,5,6,7,8-heptamethylnonane, which is assigned a cetane number of 15.[2] All other hydrocarbons in diesel fuel are indexed to cetane as to how rapidly they ignite under compression, i.e. diesel engine conditions. Since hundreds of components comprise diesel fuel, the overall cetane number of that fuel is the average cetane quality of all the components. High-cetane components have a disproportionate influence, hence the use of high-cetane additives.

Cetane number (cetane rating) is an indicator of the combustion speed of diesel fuel and compression needed for ignition. It plays a similar role for diesel as octane rating does for gasoline. The CN is an important factor in determining the quality of diesel fuel, but not the only one; other measurements of diesel fuel's quality include (but are not limited to) energy content, density, lubricity, cold-flow properties and sulphur content.[1]

## Definition

The cetane number (or CN) of a fuel is defined by finding a blend of cetane and isocetane with the same ignition delay. Cetane has a cetane number defined to be 100, while isocetane's measured cetane number is 15, replacing the former reference fuel alpha-methylnaphthalene, which was assigned a cetane number of 0. Once the blend is known, the cetane number is calculated as a volume-weighted average, rounded to the nearest whole number, of cetane's 100 and heptamethylnonane's 15.[2]

cetane number = % *n*-cetane + 0.15(% heptamethylnonane)[2]

Cetane number is an inverse function of a fuel's ignition delay, the time period between the start of ignition and the first identifiable pressure increase during combustion of the fuel. In a particular diesel engine, higher cetane fuels will have shorter ignition delay periods than lower cetane fuels. Cetane numbers are only used for the relatively light distillate diesel oils..

Typ Generally, diesel engines operate well with a CN from 48 to 50. Fuels with lower cetane number have longer ignition delays, requiring more time for the fuel combustion process to be completed. Hence, higher speed diesel engines operate more effectively with higher cetane number fuels.

## Additives

Alkyl nitrates (principally 2-ethylhexyl nitrate[11]) and di-*tert*-butyl peroxide are used as additives to raise the cetane number.

### Density

Density (volumetric mass density or specific mass) **is a substance's mass per unit of volume. The symbol most often used for density is *ρ*** (the lower case Greek letter rho), although the **Latin letter *D* can also be used**. **Mathematically, density is defined as mass divided by volume:**

From the equation for density ($\rho = m/V$), mass density has any unit that is *mass divided by volume*. As there are many units of mass and volume covering many different magnitudes there are a large number of units for mass density in use. The SI unit of kilogram per cubic metre ($kg/m^3$) and the cgs unit of gram per cubic centimetre ($g/cm^3$) are probably the most commonly used units for density. One $g/cm^3$ is equal to 1000 $kg/m^3$. One cubic centimetre (abbreviation cc) is equal to one milliliter. In industry, other larger or smaller units of mass and or volume are often more practical and US customary units may be used.

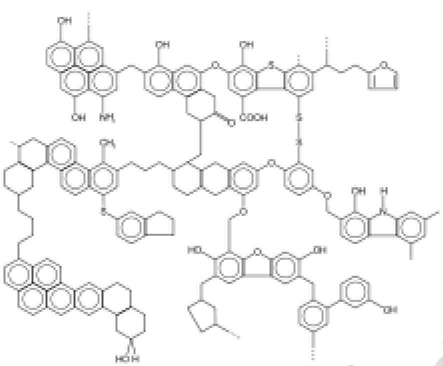
**where *ρ* is the density, *m* is the mass, and *V* is the volume. In some cases (for instance, in the United States oil and gas industry), density is loosely defined as its weight per unit volume,**[

# Coal

**Coal** is a combustible black or brownish-black sedimentary rock, formed as rock strata called coal seams. Coal is mostly carbon with variable amounts of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen.[1] Coal is a type of fossil fuel, formed when dead plant matter decays into peat and is converted into coal by the heat and pressure of deep burial over millions of years.[2] Vast deposits of coal originate in former wetlands called coal forests that covered much of the Earth's tropical land areas during the late Carboniferous (Pennsylvanian) and Permian times.[3][4]

Coal is used primarily as a fuel. While coal has been known and used for thousands of years, its usage was limited until the Industrial Revolution.

## Formation



Example chemical structure of coal

The conversion of dead vegetation into coal is called coalification. At various times in the geologic past, the Earth had dense forests[21] in low-lying wetland areas. In these wetlands, the process of coalification began when dead plant matter was protected from biodegradation and oxidation, usually by mud or acidic water, and was converted into peat. This trapped the carbon in immense peat bogs that were eventually deeply buried by sediments. Then, over millions of years, the heat and pressure of deep burial caused the loss of water, methane and carbon dioxide and increased the proportion of carbon.[19] The grade of coal produced depended on the maximum pressure and temperature reached, with lignite (also called "brown coal") produced under relatively mild conditions, and sub-bituminous coal, bituminous coal, or anthracite coal (also called "hard coal" or "black coal") produced in turn with increasing temperature and pressure.[2][22]

## Types of coal

As geological processes apply pressure to dead biotic material over time, under suitable conditions, its metamorphic grade or rank increases successively into:

1-Peat, a precursor of coal

2-Lignite, or brown coal, the lowest rank of coal, most harmful to health when burned,[6] used almost exclusively as fuel for electric power generatio Jet, a compact form of lignite, sometimes polished; used as an ornamental stone since the Upper Palaeolithic

3-Sub-bituminous coal, whose properties range between those of lignite and those of bituminous coal, is used primarily as fuel for steam-electric power generation.

4-Bituminous coal, a dense sedimentary rock, usually black, but sometimes dark brown, often with well-defined bands of bright and dull material. It is used primarily as fuel in steam-electric power generation and to make coke. Known as steam coal in the UK, and historically used to raise steam in steam locomotives and ships

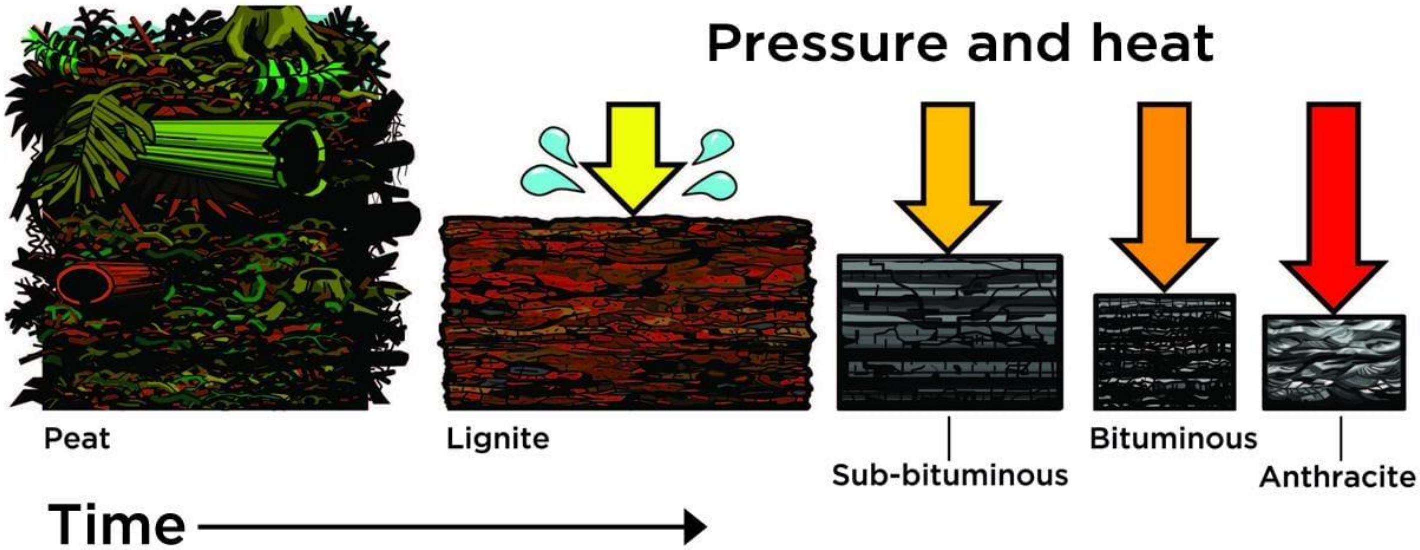
5-Anthracite coal, the highest rank of coal, is a harder, glossy black coal used primarily for residential and commercial space heating.

6-Graphite is difficult to ignite and not commonly used as fuel; it is most used in pencils, or powdered for lubrication.

7-Cannel coal (sometimes called "candle coal") is a variety of fine-grained, high-rank coal with significant hydrogen content, which consists primarily of liptinite.

There are several international standards for coal.[49] The classification of coal is generally based on the content of volatiles. However the most important distinction is between thermal coal (also known as steam coal), which is burnt to generate electricity via steam; and metallurgical coal (also known as coking coal), which is burnt at high temperature to make steel.

Hilt's law is a geological observation that (within a small area) the deeper the coal is found, the higher its rank (or grade). It applies if the thermal gradient is entirely vertical; however, metamorphism may cause lateral changes of rank, irrespective of depth.




## Composition of coal

The composition of coal is reported either as a proximate analysis (moisture, volatile matter, fixed carbon, and ash) or an ultimate analysis (ash, carbon, hydrogen, nitrogen, oxygen, and sulfur). The "volatile matter" does not exist by itself (except for some adsorbed methane) but designates the volatile compounds that are produced and driven off by heating the coal. A typical bituminous coal may have an ultimate analysis on a dry, ash-free basis of 84.4% carbon, 5.4% hydrogen, 6.7% oxygen, 1.7% nitrogen, and 1.8% sulfur, on a weight basis.[40]

The composition of ash, given in terms of oxides, varies:[40]

| Ash composition, weight percent | |
|---|---|
| $SiO_2$ | 20–40 |
| $Al_2O_3$ | 10–35 |
| $Fe_2O_3$ | 5–35 |
| CaO | 1–20 |
| MgO | 0.3–4 |
| $TiO_2$ | 0.5–2.5 |
| $Na_2O$ & $K_2O$ | 1–4 |
| $SO_3$ | 0.1–12[74] |

**Other minor components include:**

**Average content**

| Substance | Content |
|---|---|
| Mercury (Hg) | 0.10±0.01 ppm[75] |
| Arsenic (As) | 1.4–71 ppm[76] |
| Selenium (Se) | 3 ppm[77] |

### Coking coal and use of coke to smelt iron

Coke oven at a smokeless fuel plant in Wales, United Kingdom

## Gasification of coal

Coal gasification, as part of an integrated gasification combined cycle (IGCC) coal-fired power station, is used to produce syngas, a mixture of carbon monoxide (CO) and hydrogen ($H_2$) gas to fire gas turbines to produce electricity. Syngas can also be converted into transportation fuels, such as gasoline and diesel, through the Fischer–Tropsch process; alternatively, syngas can be converted into methanol, which can be blended into fuel directly or converted to gasoline via the methanol to gasoline process.[84] Gasification combined with Fischer–Tropsch technology was used by the Sasol chemical company of South Africa to make chemicals and motor vehicle fuels from coal.[85]

During gasification, the coal is mixed with oxygen and steam while also being heated and pressurized. During the reaction, oxygen and water molecules oxidize the coal into carbon monoxide (CO), while also releasing hydrogen gas ($H_2$). This used to be done in underground coal mines, and also to make town gas, which was piped to customers to burn for illumination, heating, and cooking.

$3C\ (\textit{as Coal}) + O_2 + H_2O \rightarrow H_2 + 3CO$

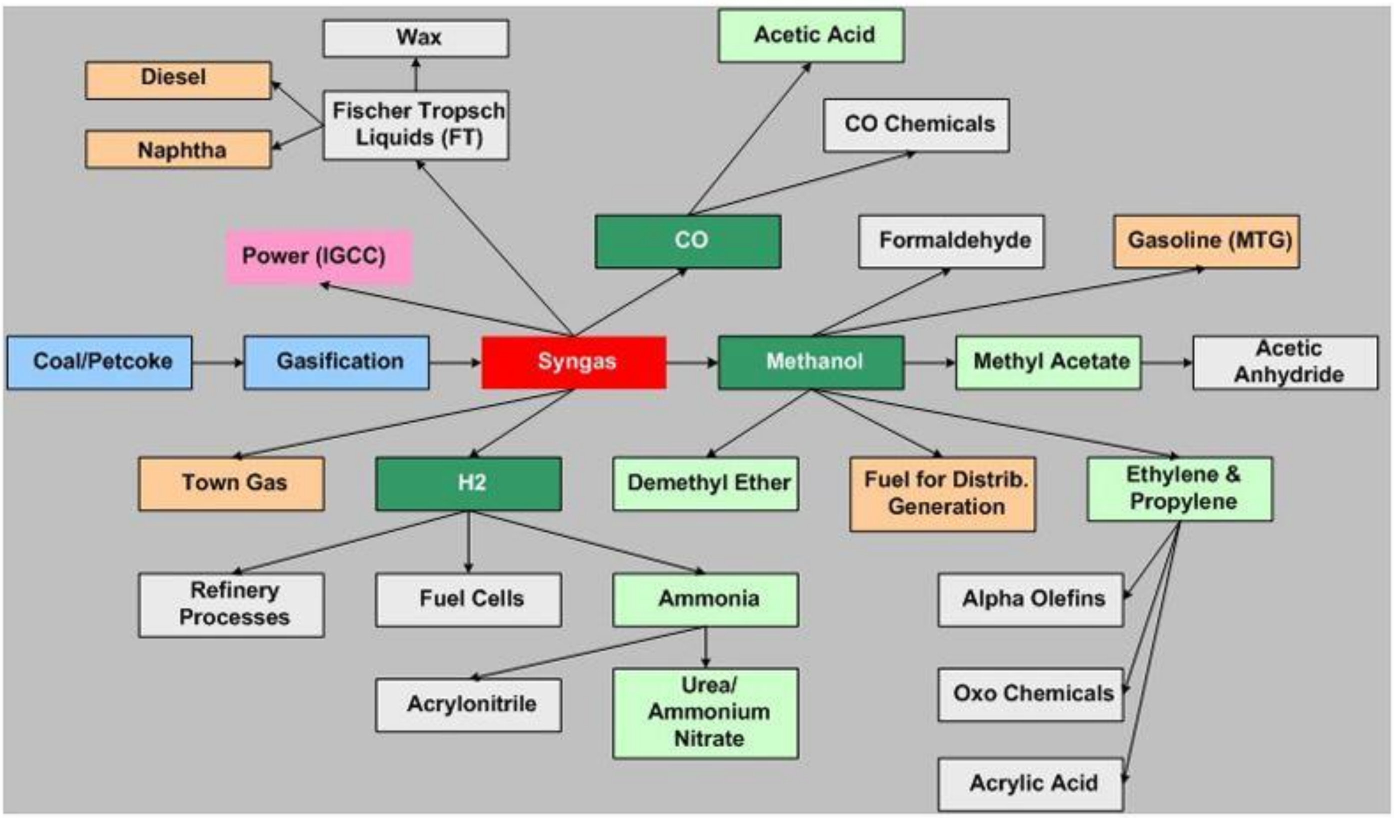
If the refiner wants to produce gasoline, the syngas is routed into a Fischer–Tropsch reaction. This is known as indirect coal liquefaction. If hydrogen is the desired end-product, however, the syngas is fed into the water gas shift reaction, where more hydrogen is liberated:

$CO + H_2O \rightarrow CO_2 + H_2$

## Liquefaction of coal

Coal can be converted directly into synthetic fuels equivalent to gasoline or diesel by hydrogenation or carbonization.[86] Coal liquefaction emits more carbon dioxide than liquid fuel production from crude oil.

### Production of chemicals



## Production of chemicals from coal

Chemicals have been produced from coal since the 1950s. Coal can be used as a feedstock in the production of a wide range of chemical fertilizers and other chemical products. The main route to these products was coal gasification to produce syngas. Primary chemicals that are produced directly from the syngas include methanol, hydrogen and carbon monoxide, which are the chemical building blocks from which a whole spectrum of derivative chemicals are manufactured, including olefins, acetic acid, formaldehyde, ammonia, urea and others. The versatility of syngas as a precursor to primary chemicals and high-value derivative products provides the option of using coal to produce a wide range of commodities. In the 21st century, however, the use of coal bed methane is becoming more important.[90]

Because the slate of chemical products that can be made via coal gasification can in general also use feedstocks derived from natural gas and petroleum, the chemical industry tends to use whatever feedstocks are most cost-effective. Therefore, interest in using coal tended to increase for higher oil and natural gas prices and during periods of high global economic growth that might have strained oil and gas production.

Coal to chemical processes require substantial quantities of water.[91] Much coal to chemical production is in China[92][93] where coal dependent provinces such as Shanxi are struggling to control its pollution.[94]

## Energy density

The energy density of coal is roughly 24 megajoules per kilogram[95] (approximately 6.7 kilowatt-hours per kg). For a coal power plant with a 40% efficiency, it takes an estimated 325 kg (717 lb) of coal to power a 100 W lightbulb for one year.[96]

27.6% of world energy was supplied by coal in 2017 and Asia used almost three-quarters of it.[97]

## Petroleum

**Petroleum**, also known as **crude oil**, or simply **oil**, is a naturally occurring yellowish-black liquid mixture of mainly hydrocarbons,[1] and is found in geological formations. The name *petroleum* covers both naturally occurring unprocessed crude oil and petroleum products that consist of refined crude oil.

Petroleum is primarily recovered by oil drilling. Drilling is carried out after studies of structural geology, sedimentary basin analysis, and reservoir characterisation. Unconventional reserves such as oil sands and oil shale exist.

Once extracted, oil is refined and separated, most easily by distillation, into innumerable products for direct use or use in manufacturing. Products include fuels such as petrol (gasoline), diesel, kerosene and jet fuel; asphalt and lubricants; chemical reagents used to make plastics; solvents, textiles, refrigerants, paint, synthetic rubber, fertilizers, pesticides, pharmaceuticals, and thousands of others. Petroleum is used in manufacturing a vast variety of materials essential for modern life,[2] and it is estimated that the world consumes about 100 million barrels (16 million cubic metres) each day.

## Composition

Petroleum includes not only crude oil, but all liquid, gaseous and solid hydrocarbons. Under surface pressure and temperature conditions, lighter hydrocarbons methane, ethane, propane and butane exist as gases, while pentane and heavier hydrocarbons are in the form of liquids or solids. However, in an underground oil reservoir the proportions of gas, liquid, and solid depend on subsurface conditions and on the phase diagram of the petroleum mixture.[58] Some of the components of oil will mix with water: the water associated fraction of the oil.

The proportion of light hydrocarbons in the petroleum mixture varies among different oil fields, ranging from as much as 97 percent by weight in the lighter oils to as little as 50 percent in the heavier oils and bitumens.[*citation needed*]

The exact molecular composition of crude oil varies widely from formation to formation but the proportion of chemical elements varies over fairly narrow limits as follows:[62]

| Composition by weight | |
|---|---|
| **Element** | **Percent range** |
| Carbon | 83 to 85% |
| Hydrogen | 10 to 14% |
| Nitrogen | 0.1 to 2% |
| Oxygen | 0.05 to 1.5% |
| Sulfur | 0.05 to 6.0% |
| Metals | < 0.1% |

Four different types of hydrocarbon appear in crude oil. The relative percentage of each varies from oil to oil, determining the properties of each oil.[58]

| Composition by weight | | |
|---|---|---|
| **Hydrocarbon** | **Average** | **Range** |
| Alkanes (paraffins) | 30% | 15 to 60% |
| Naphthenes | 49% | 30 to 60% |
| Aromatics | 15% | 3 to 30% |
| Asphaltics | 6% | remainder |

## Oil refinery

An **oil refinery** or **petroleum refinery** is an industrial process plant where petroleum (crude oil) is transformed and refined into products such as gasoline (petrol), diesel fuel, asphalt base, fuel oils, heating oil, kerosene, liquefied petroleum gas and petroleum naphtha.[1][2][3] Petrochemical feedstock like ethylene and propylene can also be produced directly by cracking crude oil without the need of using refined products of crude oil such as naphtha.[4][5] The crude oil feedstock has typically been processed by an oil production plant.

Oil refineries are typically large, sprawling industrial complexes with extensive piping running throughout, carrying streams of fluids between large chemical processing units, such as distillation columns. In many ways, oil refineries use much of the technology and can be thought of, as types of chemical plants. Oil refineries are an essential part of the petroleum industry's downstream sector.[7]

## Major products

Petroleum products are materials derived from crude oil (petroleum) as it is processed in oil refineries. The majority of petroleum is converted to petroleum products, which includes several classes of fuels.[31]

Petroleum products are usually grouped into four categories: light distillates (LPG, gasoline, naphtha), middle distillates (kerosene, jet fuel, diesel), heavy distillates, and residuum (heavy fuel oil, lubricating oils, wax, asphalt). This classification is based on the way crude oil is distilled and separated into fractions.[2]

- Gaseous fuel such as liquified petroleum gas and propane, stored and shipped in liquid form under pressure.
- Lubricants (produces light machine oils, motor oils, and greases, adding viscosity stabilizers as required), usually shipped in bulk to an offsite packaging plant.
- Paraffin wax, used in the candle industry, among others. May be shipped in bulk to a site to prepare as packaged blocks. Used for wax emulsions, candles, matches, rust protection, vapor barriers, construction board, and packaging of frozen foods.

- Sulfur (or sulfuric acid), byproducts of sulfur removal from petroleum which may have up to a couple of percent sulfur as organic sulfur-containing compounds. Sulfur and sulfuric acid are useful industrial materials. Sulfuric acid is usually prepared and shipped as the acid precursor oleum.
- Bulk tar shipping for offsite unit packaging for use in tar-and-gravel roofing.
- Asphalt used as a binder for gravel to form asphalt concrete, which is used for paving roads, lots, etc. An asphalt unit prepares bulk asphalt for shipment.
- Petroleum coke, used in specialty carbon products like electrodes or as solid fuel.
- Petrochemicals are organic compounds that are the ingredients for the chemical industry, ranging from polymers and pharmaceuticals,
- Gasoline
- Naphtha
- Kerosene and related jet aircraft fuels
- Diesel fuel and fuel oils
- Heat
- Electricity

Over 6,000 items are made from petroleum waste by-products, including fertilizer, floor coverings, perfume, insecticide, petroleum jelly, soap, vitamin capsules.[33]



motor oil

Sulph

Pile of asphalt-covered aggregate for formation into asphalt concrete

## Refinery equipment's of crude oil

1- **Crude Oil Distillation Unit (CDU)**: is the first processing unit in virtually all oil refineries. The CDU distills the incoming crude oil into various fractions of different boiling ranges, each of which are then processed further in the other refinery processing units. The CDU is often referred to as the atmospheric distillation unit because it operates at slightly above atmospheric pressure. The products of CDU include gasoline, kerosene, light diesel oil, heavy diesel oil, heavy oil…etc.

## Application of CDU

1. Widely used in oil refinery field.

2. Gasoline, diesel, kerosene can be obtained in this process.

3. The different components are collected and utilized separately.

**2-Vacuum Distillation Unit (VDU)**:

further distills the residue oil from the bottom of the crude oil distillation unit. The vacuum distillation is performed at a pressure well below atmospheric pressure. The vacuum distillation unit is widely used to separate substance that decomposed, oxidized or polymerized at a temperature far below the boiling point at CDU condition.

**Application of VDU:**

1. Widely used in oil refinery field.

2. PCC's VDU have a high separate efficiency.

3. The heavies are further separated to obtain a product of pure purity, so as to increase product yield.

**3-Diesel Hydrotreating Unit (DHT):** uses hydrogen to desulfurize the naphtha fraction from the crude oil distillation or other units within the refinery.

**Application of DHT:**

1. Remove impurities and polluted elements from diesel fraction with a high efficiency

2. PCC's DHT can increase the performance of diesel product

3. The production process of diesel can be more environmental friendly by using our unit.

4-Semi-regenerative Reforming (SRR): With the help of heating, hydrotreating and catalyst, semi-regenerative reforming is a process which is used to convert petroleum refinery naphtha distilled from crude oil (typically having low octane ratings) into high-octane liquid products called reformates, which are premium blending stocks for high-octane gasoline. Compared with other regenerative reforming types, semi-regenerative reforming has advantages includes low investment, low operating fee…etc. Semi regenerative reforming can also be applied in various production scales.

**Application of SRR:**

1. Widely used in petrochemical industry.

2. In the hydrogenation, heating, high pressure conditions for light gasoline fractions or naphtha can be processed to be re-gasoline.

3. High-octane petrol is produced by using SRR.

4. Large amount of aromatics will also be produced.

**5-Fluid Catalytic Cracking Unit (FCC)**: FCC is one of the most important conversions processes used in oil refinery process. The purpose of FCC unit is to transfer heavy crude oil into light oil. Under the action of heat and catalyst, upgrades the heavier, higher-boiling fractions from the crude oil distillation by converting them into lighter and lower boiling, more valuable products like cracking gas, gasoline and diesel oil etc.

**Application of FCC:**

1. Many products includes ethylene, petrol, diesel, Heavy diesel, slurry oil… etc. could be obtained by using FCC.

2. PCC's FCC has a high catalytic efficiency.

3. One of the main methods of secondary processing of oil, in the role of high temperature and catalyst to make heavy oil cracking reaction, into crack gas, gasoline, and diesel.

**6-Sulfur Recovery Unit (SRU)**: SRU is widely used to recover sulfur-containing, poisonous acidic gas in oil refinery process. The most commonly used process in sulfur recovery practice is Claus Process, which is to burn the incoming gas with oxygen, refrigerate the burnt gas and recover sulfur from the burnt gas. SRU converts sulfur gas such as $H_2S$ into elemental sulfur, so as to convert waste into treasure and protect the environment.

**Application of SRU:**

1. Separate sulfur from sulfur-containing oil

2. Recover the wasted material efficiently

3. This unit can reach rather high sulfur purity

**7-Isomerization Unit:** converts linear molecules such as normal pentane into higher-octane branched molecules for blending into the end-product gasoline. Also used to convert linear normal butane into isobutane for use in the alkylation unit.

**Application of Isomerization Unit:**

1. a key equipment in producing clean gasoline

2. an important method for oil refinery factory to increase light fraction octane number.

**Fuel gas**

**Fuel gas** is one of a number of fuels that under ordinary conditions are gaseous. Most fuel gases are composed of hydrocarbons (such as methane and propane), hydrogen, carbon monoxide, or mixtures thereof. Such gases are sources of energy that can be readily transmitted and distributed through pipes.

Fuel gas is contrasted with liquid fuels and solid fuels, although some fuel gases are liquefied for storage or transport (for example, autogas and liquified petroleum gas). While their gaseous nature has advantages, avoiding the difficulty of transporting solid fuel and the dangers of spillage inherent in liquid fuels, it also has limitations. It is possible for a fuel gas to be undetected and cause a gas explosion. For this reason, odorizers are added to most fuel gases. The most common type of fuel gas in current use is natural gas.

**Coal gas** is a flammable gaseous fuel made from coal and supplied to the user via a piped distribution system. It is produced when coal is heated strongly in the absence of air. **Town gas** is a more general term referring to manufactured gaseous fuels produced for sale to consumers and municipalities.[1]

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**Components of Gaseous fuels-**

Gaseous fuels have two components:

- **Combustible Gaseous Fuels**: Combustible fuels are composed of gases like Carbon Monoxide (CO), Hydrogen (H). Methane(CH), Ethane (C, H). Propane (C, H), Butane (C, H) etc.
- **Non-combustible Gaseous Fuels**: Non-combustible gaseous fuel materials are Carbon-dioxide (CO) and Nitrogen (N).

**Classification of Gaseous Fuels-**

**Gaseous fuels can be classified on the basis of their Availability and Calorific Value and they are-**

**1-On the basis of Availability-**

On the basis of availability, gaseous fuels are of the following two types:

1. Natural gaseous fuels
2. Artificial gaseous fuels

**1. Natural Gaseous Fuel-**

**Natural gaseous fuels are gaseous fuels which are found in nature freely and used in their original form in which they exist in nature. Such natural gases are propene and butene etc. Which are found with petroleum and coal underneath the earth's surface.**

**2. Artificial Gaseous Fuel-**

**Artificial gaseous fuels are gaseous fuels which are produced in the artificial form in industrial establishments under various processes in their original form or as by-products.**

**For example- Water-gas, blast furnaces, gas coke-oven gas etc.**

## 2-On the basis of calorific value-

**On the basis of calorific value, the gaseous fuels are of the following two types-**

1. **High calorific value gaseous fuels**
2. **Low calorific value gaseous fuels**

**1. High calorific value gaseous fuels–**

**Among the high calorific value gaseous fuels, coke gas, coke oven gas and natural gas are prominent fuel gases which emit high heat during combustion.**

**2. Low calorific value gaseous fuels–**

**Among the low calorific value gaseous fuels, blast furnace gas, producer gas etc, are prominent fuel gases which emit comparatively low heat during combustion.**

## Examples of Gaseous Fuels-

**Details of main gaseous fuels or Types of gaseous fuels or gaseous fuels examples are given below:**

1. **Natural Gas**
2. **Liquified Petroleum Gas Fuel**
3. **Coke-oven gas and coal gas**
4. **Water gas or Blue gas**
5. **Blast furnace gas**
6. **Producer gas**
7. **Acetylene gas**
8. **Sewer gas**
9. **Biogas**
10. **Oil gas**

## Let’s deal with types or examples of these gaseous fuels one by one-

**1. Natural Gas-**

Natural gas is obtained in its natural form beneath the earth’s surface at a high pressure of 30 to 200 atmospheric pressure where it is available in abundance.

Natural gas is taken out by digging deep wells (about 3 to 4 km) by means of pipelines. It is then treated to reduce moisture in it and sent to the place of use through pipes.

Natural gas is also obtained from coal mines but it is not used in commercial form.

Natural gas is colourless and odourless. Normally it is free from sulphur, clean and pure. It is non-toxic too. It is lighter than air and its specific gravity is 0.57 to 0.7. Its thermal value is 26 to 35 MJ/m.

Natural gas which is obtained along with petroleum is also known as oil gas. Natural gas having heavy hydrocarbon splits up at high temperature and produce soot.

**2. Liquified Petroleum Gas Fuel-**

It is a liquified mixture of hydro-carbon stored under pressure. The composition of this gas consists of ethylene, propane, propylene, butane, Isobutane and butylene.

From the commercial point of view, it is classified as propane, propane-butane mixture and butane. Its transportation, storage and uses are very simple.

It is colourless, odourless and non-toxic in nature. It is obtained by refining the gas available with petroleum. These gases are used for domestic purposes, industrial purposes and commercially for making artificial gas.

It is also being used in I.C. Engines. Its storage is done in tankers or cylinders (over the earth or below the earth).

**3. Coke-oven gas and coal gas-**

When coke coal is heated in a coke oven, coke is obtained as the basic product and coke-oven gas is obtained as a by-product. When coal is heated in horizontal or vertical retorts, coal gas is produced as a basic product. Coal gas is also called illuminating gas.

Both these gases are similar. They are obtained by fractional distillation of bituminous coal at a high temperature (about 990°C). These gases are mostly used in steel furnaces, power production and heating purpose in industries.

The main elements of these gases are methane and hydrogen. Their percentage depends upon the type of coal, method of coke making, temperature and time, the quantity of oil used on coal, air infiltrations and some other reasons.

So before using any gas its sample should be tested to know its composition. In India mostly, coke-oven gas is used. About 290 $m^3$ of coke oven gas can be produced per 1000 kg of coal.

Its specific density is 0.45 to 0.49 kg/m and its calorific value is 14 to 22 MJ/m. Coal gas has a higher calorific value than coke-oven gas.

**4. Water gas or Blue gas-**

This gas is produced by passing steam over a contest fuel having a high percentage of carbon. Basically, it is a mixture of 40% CO, 40% of $H_2$ and remaining $CO_2$, and $N_2$.

Its calorific value is 10 to 11.3 MJ/ $m^{3.}$ This gas has a low calorific value, so it is not useful from an industrial point of view. To improve its calorific value, it is mixed with oil gas.

The mixture of water gas and oil gas is called carburated water gas. It contains about 35% CO, and 35% $H_2$. 20% $CH_4$(Methane), $C_2H_4$(Athelyno) etc. and 10% $CO_2$, and $N_2$.

Then its calorific value increases up to 19 $MJ/m^3$. These gases are used in the manufacture of chemical products like ammonia methanol and in forge welding. It is a good gas fuel for domestic purposes.

**5. Blast furnace gas-**

It is a byproduct of a blast furnace. It has dust and toxic materials mixed with it which must be removed before using the gas.

The composition of this gas contains about 28% carbon monoxide (CO), 11% carbon dioxide ($CO_2$), 58% nitrogen ($N_2$), 2.9% Hydrogen ($H_2$) and 0.2% Methane ($CH_4$).

This gas contains non-combustible gases like $CO_2$ and $N_2$ in excess. So its calorific value is low (about 2.5 to 3.5 MJ/$m^3$).

It is used within the plant itself for various purposes like heating air for the blast furnace, heating coke ovens, heating boiler tubes, and gas engine power plants. It is also used in an industrial furnace.

**6. Producer gas-**

It is produced by the partial oxidation of coal, coke or peat when they are burnt with an insufficient quantity of air. The process is carried out in specially designed retorts.

It has a low heating value and in general, is suitable for large installations. This gas is mostly used in ceramic kilns, glass-making furnaces, coke furnaces etc. It is also used in steel plants and stationary I.C. engines.

**7. Acetylene gas-**

This gas is obtained by the action of calcium carbide with water. It is a hydrocarbon. 0It can also be prepared by carbon electric arc.

In this method, acetylene is produced in an atmosphere of hydrogen by igniting an electric area between carbon electrodes. In low-pressure generators, it is produced at up to 10 kPa pressure and in medium-pressure generators, it is produced at up to 150 kPa pressure.

Acetylene gas generators have a production capacity of 0.8 to 8 $m^3$/hour.

This gas is colourless and has a pleasing smell. When burnt in the air it gives a sharp flame at 300°C. This gas prepares an explosive mixture with air and produces numerous amounts of heat.

This gas can be prepared at the place of use or it may be produced at a production place at high pressure of about 1500 kPa and then filled in cylinders.

It is then carried to the place of use in cylinders. This gas is not stable at high pressure so it is dissolved in acetone and kept in cylinders.

This gas is mostly used in oxy-acetylene welding and cutting processes. During welding, its flame burns at about 3100°C, which is not possible to obtain by any other gas.

When liquifying at 0°C temperature and 48 atmospheric pressure liquid acetylene produces which is an explosive. This gas is also used for lumination.

It is also used in other Industrial jobs like the production of vegetable oil, benzene, acetic acid, oxalic acid etc. It is also used in the manufacturing of highly poisonous "Hydro cynic acid".

**8. Sewer Gas-**

It is obtained from sewage disposal waste in which fermentation and decay occur. It consists mainly marsh gas and is collected at large disposal plants.

It works as a fuel for gas engines which in turn drive the plant pumps and agitators.

**9. Biogas-**

It is produced by animal dung stored in biogas plants by mixing with water in a ratio of 4: 5. Due to the fermentation process the gas is formed.

It contains 55% methane and 45% carbon dioxide and Its calorific value is 19 MJ/m.

**10. Oil gas-**

This gas is produced by cracking of kerosene oil in hot iron retorts. It can also be produced by the gasification of oils. It is obtained by flowing steam-oil mixture over the hot coal.

The calorific value of this gas depends upon the calorific value of cracked oil. This gas is mostly used in laboratories as fuel.

## Combustion

Combustion, or burning,[1] is a high-temperature exothermic redox chemical reaction between a fuel (the reductant) and an oxidant, usually atmospheric oxygen, that produces oxidized, often gaseous products, in a mixture termed as smoke. Combustion does not always result in fire, because a flame is only visible when substances undergoing combustion vaporize, but when it does, a flame is a characteristic indicator of the reaction. While activation energy must be supplied to initiate combustion (e.g., using a lit match to light a fire), the heat from a flame may provide enough energy to make the reaction self-sustaining.

### Combustion management

Since combustibles are undesirable in the off gas, while the presence of unreacted oxygen there presents minimal safety and environmental concerns, the first principle of combustion management is to provide more oxygen than is theoretically needed to ensure that all the fuel burns. For methane ($CH_4$) combustion, for example, slightly more than two molecules of oxygen are required.

The second principle of combustion management, however, is to not use too much oxygen. The correct amount of oxygen requires three types of measurement: first, active control of air and fuel flow; second, offgas oxygen measurement; and third, measurement of offgas combustibles.

### Reaction mechanism

Combustion of hydrocarbons is thought to be initiated by hydrogen atom abstraction (not proton abstraction) from the fuel to oxygen, to give a hydroperoxide radical (HOO). This reacts further to give hydroperoxides, which break up to give hydroxyl radicals.

The rate of combustion is the amount of a material that undergoes combustion over a period of time. It can be expressed in grams per second (g/s) or kilograms per second (kg/s).

### Kinetic modelling

The kinetic modelling may be explored for insight into the reaction mechanisms of thermal decomposition in the combustion of different materials by using for instance Thermogravimetric analysis.[49]

### Air–fuel ratio

Air–fuel ratio (AFR) is the mass ratio of air to a solid, liquid, or gaseous fuel present in a combustion process. The combustion may take place in a controlled manner such as in an internal combustion engine or industrial furnace, or may result in an explosion (e.g., a dust explosion, gas or vapor explosion or in a thermobaric weapon).

The air–fuel ratio determines whether a mixture is combustible at all, how much energy is being released, and how much unwanted pollutants are produced in the reaction. Typically a range of fuel to air ratios exists, outside of which ignition will not occur. These are known as the lower and upper explosive limits.

In an internal combustion engine or industrial furnace, the air–fuel ratio is an important measure for anti-pollution and performance-tuning reasons. If exactly enough air is provided to completely burn all of the fuel, the ratio is known as the stoichiometric mixture, often abbreviated to stoich. Ratios lower than stoichiometric (where the fuel is in excess) are considered "rich". Rich mixtures are less efficient, but may produce more power and burn cooler.

## Mixture

Mixture is the predominant word that appears in training texts, operation manuals, and maintenance manuals in the aviation world.

Air–fuel ratio is the ratio between the *mass* of air and the mass of fuel in the fuel–air mix at any given moment. The mass is the mass of all constituents that compose the fuel and air, whether combustible or not.

The air-fuel ratio of 12:1 is considered as the maximum output ratio, whereas the air-fuel ratio of 16:1 is considered as the maximum fuel economy ratio.

## Fuel–air ratio (FAR)

Fuel–air ratio is commonly used in the gas turbine industry as well as in government studies of internal combustion engine, and refers to the ratio of fuel to the air.

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