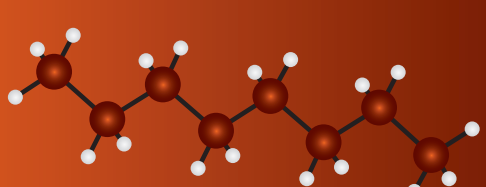
P1 PETROCHEMICALS

WHAT IS PETROLEUM?

CHEMICAL INDUSTRIES
RESOURCE PACK

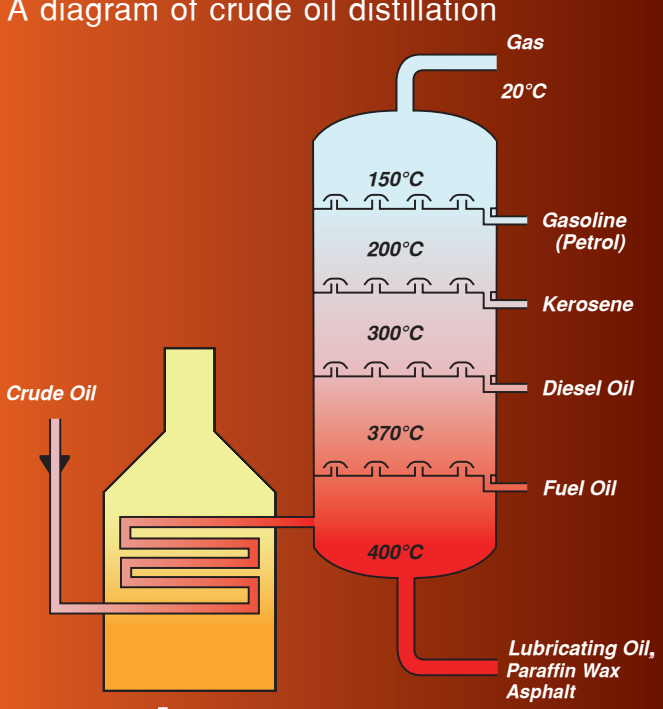
Arial photograph of Sasolburg

Two representations of octane, a hydrocarbon found in petroleum



Source: Wikimedia Commons

A diagram of crude oil distillation



Petroleum

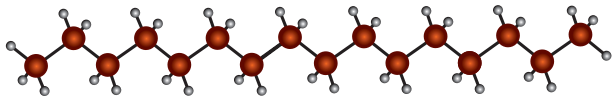
Petroleum is a mixture of several different hydrocarbons; the most commonly found molecules are alkanes (linear or branched), cycloalkanes, aromatic hydrocarbons, or more complicated chemicals like asphaltenes. Each petroleum variety has a unique mix of molecules which defines its physical and chemical properties, like colour and viscosity.

The alkanes, also known as paraffins, are saturated hydrocarbons with straight or branched chains which contain only carbon and hydrogen and have the general formula C_nH_{2n+2}. They generally have from 5 to 40 carbon atoms per molecule, although trace amounts of shorter or longer molecules may be present in the mixture.

The alkanes from pentane (C_5H_{12}) to octane (C_8H_{18}) are refined into petrol; the ones from nonane (C_9H_{20}) to hexadecane ($C_{16}H_{34}$) into diesel fuel and kerosene (primary component of many types of jet fuel); and the ones from hexadecane upwards into fuel oil and lubricating oil. At the heavier end of the range, paraffin wax is an alkane with approximately 25 carbon atoms, while asphalt has 35 carbon atoms or more. These are usually cracked (split) by modern refineries into more valuable products.

The shortest molecules, those with four or fewer carbon atoms, are in a gaseous state at room temperature. They are the petroleum gases.

Depending on demand and the cost of recovery, these gases are either flared off, sold as liquefied petroleum gas under pressure, or used to power the refinery's own burners. During the winter, butane (C_4H_{10}) is blended into the gasoline pool in large quantities because butane's high vapour pressure assists with cold starts. Liquefied at pressures slightly above atmospheric, butane is best known for powering cigarette lighters, but it is also a main fuel source in many developing countries. Propane can be liquefied under modest pressure and is consumed in just about every application relying on petroleum for energy, from cooking to heating to transportation.

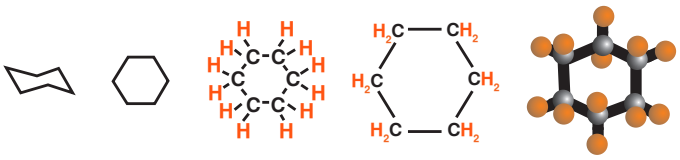


A ball and stick model of hexadecane

Source: Wikimedia Commons

Petroleum chemistry

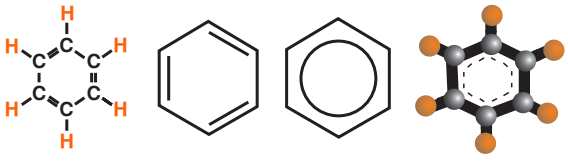
The cycloalkanes, also known as naphthenes, are saturated hydrocarbons which have one or more carbon rings to which hydrogen atoms are attached according to the formula C_nH_{2n}. Cycloalkanes have similar properties to alkanes but have higher boiling points.



Different representations of cyclohexane

Source: Wikimedia Commons

The aromatic hydrocarbons are unsaturated hydrocarbons which have one or more planar six-carbon rings called benzene rings, to which hydrogen atoms are attached with the formula C_nH_n. They tend to burn with a sooty flame and many have a sweet aroma. Some are carcinogenic (causes cancer). Benzene, C_6H_6, is also known as benzol or cyclohexa-1,3,5-triene.



Different representations of benzene

Source: Wikimedia Commons

These different molecules are separated by fractional distillation at an oil refinery to produce petrol, jet fuel, kerosene, and other hydrocarbons. For example, 2,2,4-trimethylpentane (iso-octane), widely used in petrol, has a chemical formula of C_8H_{18} and reacts with oxygen exothermically to form carbon dioxide and water.

$$2C_8H_{18}(\ell) + 25O_2(g) \rightarrow 16CO_2(g) + 18H_2O(g)$$

Incomplete combustion of petrol or gasoline results in production of toxic by-products. Too little oxygen results in the formation of carbon monoxide.

$$2C_8H_{18}(\ell) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$$

Due to the high temperatures and high pressures involved, exhaust gases from petrol combustion in car engines usually include nitrogen oxides which are responsible for the creation of photochemical smog. Nitrogen oxides are formed by nitrogen and oxygen in the air reacting together under high temperatures as found in the exhausts of fossil fuel-burning engines in cars, trucks and in coal-fired power plants.

Oil rig

Source: Petroleum Agency of South Africa

DID YOU KNOW?

Photochemical smog is air pollution produced by the action of light on oxygen, nitrogen oxides and unburned fuel from car exhausts to form ozone and other pollutants.

3D-hydrocarbon chains that make up petrochemicals.