

Gasoline

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Gasoline /ˈɡæsəliːn/, known as **petrol** /ˈpɛtrəl/ outside North America, is a transparent, petroleum-derived liquid that is used primarily as a fuel in internal combustion engines. It consists mostly of organic compounds obtained by the fractional distillation of petroleum, enhanced with a variety of additives.

On average, a 42-gallon barrel of crude oil (159 L) yields about 19 US gallons (72 L) of gasoline when processed in an oil refinery, though this varies based on the crude oil source's assay.

The characteristic of a particular gasoline blend to resist igniting too early (which causes knocking and reduces efficiency in reciprocating engines) is measured by its octane rating. Gasoline is produced in several grades of octane rating. Tetraethyllead and other lead compounds are no longer used in most areas to regulate and increase octane-rating, but many other additives are put into gasoline to improve its chemical stability, control corrosiveness and provide fuel system 'cleaning,' and determine performance characteristics under intended use. Sometimes, gasoline also contains ethanol as an alternative fuel, for economic or environmental reasons.

Gasoline, as used worldwide in the vast number of internal combustion engines used in transport and industry, has a significant impact on the environment, both in local effects (e.g., smog) and in global effects (e.g., effect on the climate). Gasoline may also enter the environment uncombusted, as liquid and as vapors, from leakage and handling during production, transport and delivery, from storage tanks, from spills, etc. As an example of efforts to control such leakage, many (underground) storage tanks are required to have extensive measures in place to detect and prevent such leaks. Gasoline contains benzene and other known carcinogens.^[1] Gasoline inhalation can produce an intense high, however the practice is thought to cause severe organ damage, including mental retardation.^{[2][3][4]}



A Shell gasoline station in Hiroshima, Japan

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History

The first automotive combustion engines, so-called Otto engines, were developed in the last quarter of the 19th century in Germany. The fuel was a relatively volatile hydrocarbon obtained from coal gas. With a boiling point near 85 °C (octanes boil about 40 °C higher), it was well suited for early carburetors (evaporators). The development of a "spray nozzle" carburetor enabled the use of less volatile fuels. Further improvements in engine efficiency were attempted at higher compression ratios, but early attempts were blocked by knocking (premature explosion of fuel). In the 1920s, antiknock compounds were introduced by Thomas Midgley, Jr. and Boyd, specifically tetraethyllead (TEL). This innovation started a cycle of improvements in fuel efficiency that coincided with the large-scale development of oil refining to provide more products in the boiling range of gasoline. In the 1950s oil refineries started to focus on high octane fuels, and then detergents were added to gasoline to clean the jets in carburetors. The 1970s witnessed greater attention to the environmental consequences of burning gasoline. These considerations led to the phasing out of TEL and its replacement by other antiknock compounds. Subsequently, low-sulfur gasoline was introduced, in part to preserve the catalysts in modern exhaust systems.^[5]

Etymology and terminology

"Gasoline" is cited (under the spelling "gasolene") from 1863 in the *Oxford English Dictionary*. It was never a trademark, although it may have been derived from older trademarks such as "Cazeline" and "Gazeline".^[6]

Variant spellings of "gasoline" have been used to refer to raw petroleum since the 16th century.^[6] "Petrol" was first used as the name of a refined petroleum product around 1870 by British wholesaler Carless, Capel & Leonard, who marketed it as a solvent.^[7] When the product later found a new use as a motor fuel, Frederick Simms, an associate of Gottlieb Daimler, suggested to Carless that they register the trade mark "petrol",^[8] but by this time the word was already in general use, possibly inspired by the French *pétrole*,^[6] and the registration was not allowed. Carless registered a number of alternative names for the product, while their competitors used the term "motor spirit" until the 1930s.^{[9][10]}

The use of the word *Gasoline* instead of *Petrol* outside North America can often be confusing. Shortening *Gasoline* to *Gas*, which happens often, causes confusion with various forms of gas used as car fuel (compressed natural gas (CNG), liquefied natural gas (LNG) and liquefied petroleum gas (LPG)). In many countries, gasoline has a colloquial name derived from that of the chemical benzene (*e.g.*, German *Benzin*, Czech *benzín*, Dutch *benzine*, Italian *benzina*, Polish *benzyna*, Chilean Spanish *bencina*, Thai เบนซิน *bensin*, Greek βενζίνη *venzini*, Romanian *benzină*, Swedish *bensin*, Arabic بنزين *binzīn*). Argentina, Uruguay, Paraguay and Italy use the colloquial name *nafta* derived from that of the chemical naphtha.^[11]

Octane rating

Spark ignition engines are designed to burn gasoline in a controlled process called deflagration. However, the unburned mixture may autoignite by detonating from pressure and heat alone, rather than ignite from the spark plug at exactly the right time. This causes a rapid pressure rise which can damage the engine. This is often referred to as engine knocking or end-gas knock. Knocking can be reduced by increasing the gasoline's resistance to autoignition, which is expressed by its octane rating.

Octane rating is measured relative to a mixture of 2,2,4-trimethylpentane (an isomer of octane) and n-heptane. There are different conventions for expressing octane ratings, so the same physical fuel may have several different octane ratings based on the measure used. One of the best known is the research octane number (RON).

The octane rating of typical commercially available gasoline varies by country. In Finland, Sweden, and Norway, 95 RON is the standard for regular unleaded gasoline and 98 RON is also available as a more expensive option. In the UK, ordinary regular unleaded gasoline is 95 RON (commonly available), premium unleaded gasoline is always 97 RON, and super unleaded is usually 97–98 RON. However, both Shell and BP produce fuel at 102 RON for cars with high-performance engines and in 2006 the supermarket chain Tesco began to sell super unleaded gasoline rated at 99 RON. In the US, octane ratings in unleaded fuels can vary between 85^[12] and 87 AKI (91–92 RON) for regular, through 89–90 AKI (94–95 RON) for mid-grade (equivalent to European regular), up to 90–94 AKI (95–99 RON) for premium (European premium).

South Africa's largest city, Johannesburg, is located on the Highveld at 1,753 metres (5,751 ft) above sea level. So the South African AA recommends 95 octane gasoline (petrol) at low altitude and 93 octane for use in Johannesburg because "The higher the altitude the lower the air pressure, and the lower the need for a high octane fuel as there is no real performance gain".^[13]

The octane rating became important as the military sought higher output for aircraft engines in the late 1930s and the 1940s. A higher octane rating allows a higher compression ratio or supercharger boost, and thus higher temperatures and pressures, which translate to higher power output. Some scientists even predicted that a nation with a good supply of high octane gasoline would have the advantage in air power. In

1943, the Rolls-Royce Merlin aero engine produced 1,320 horsepower (984 kW) using 100 RON fuel from a modest 27 liter displacement. By the time of Operation Overlord during World War II both the RAF and USAAF were conducting some operations in Europe using 150 RON fuel (100/150 avgas), obtained by adding 2.5% aniline to 100 octane avgas.^[14] By this time the Rolls-Royce Merlin 66 was developing 2,000 hp using this fuel.

Stability

Quality gasoline should be stable for six months if stored properly but gasoline will break down slowly over time due to the separation of the components. Gasoline stored for a year will most likely be able to be burned in an internal combustion engine without too much trouble but the effects of long term storage will become more noticeable with each passing month until a time comes when the gasoline should be diluted with ever-increasing amounts of freshly made fuel so that the older gasoline may be used up. If left undiluted, improper operation will occur and this may include engine damage from misfiring and/or the lack of proper action of the fuel within a fuel injection system and from an onboard computer attempting to compensate (if applicable to the vehicle). Storage should be in an airtight container (to prevent oxidation or water vapors mixing in with the gas) that can withstand the vapor pressure of the gasoline without venting (to prevent the loss of the more volatile fractions) at a stable cool temperature (to reduce the excess pressure from liquid expansion, and to reduce the rate of any decomposition reactions). When gasoline is not stored correctly, gums and solids may be created, which can corrode system components and accumulate on wetted surfaces, resulting in a condition called "stale fuel". Gasoline containing ethanol is especially subject to absorbing atmospheric moisture, then forming gums, solids, or two phases (a hydrocarbon phase floating on top of a water-alcohol phase).

The presence of these degradation products in the fuel tank, fuel lines plus a carburetor or fuel injection components makes it harder to start the engine or causes reduced engine performance. On resumption of regular engine use, the buildup may or may not be eventually cleaned out by the flow of fresh gasoline. The addition of a fuel stabilizer to gasoline can extend the life of fuel that is not or cannot be stored properly though removal of all fuel from a fuel system is the only real solution to the problem of long term storage of an engine or a machine or vehicle. Some typical fuel stabilizers are proprietary mixtures containing mineral spirits, isopropyl alcohol, 1,2,4-trimethylbenzene, or other additives. Fuel stabilizer is commonly used for small engines, such as lawnmower and tractor engines, especially when their use is seasonal (low to no use for one or more seasons of the year). Users have been advised to keep gasoline containers more than half full and properly capped to reduce air exposure, to avoid storage at high temperatures, to run an engine for ten minutes to circulate the stabilizer through all components prior to storage, and to run the engine at intervals to purge stale fuel from the carburetor.^[5]

Gasoline stability requirements are set in standard ASTM D4814-14b. The standard describes the various characteristics and requirements of automotive fuels for use over a wide range of operating conditions in ground vehicles equipped with spark-ignition engines.

Energy content

Energy is obtained from the combustion of gasoline by the conversion of a hydrocarbon to carbon dioxide and water. The combustion of octane follows this reaction:



Gasoline contains about 46.7 MJ/kg (127 MJ/US gal, 35.3 kWh/US gal, 13.0 kWh/kg, 120,405 BTU/US gal) quoting the lower heating value.^[15] Gasoline blends differ, and therefore actual energy content varies according to the season and producer by up to 1.75% more or less than the average.^[16] On average, about 74 L of gasoline (19.5 US gal, 16.3 imp gal) are available from a barrel of crude oil (about 46% by volume), varying due to quality of crude and grade of gasoline. The remainder are products ranging from tar to naphtha.^[17]

A high-octane-rated fuel, such as liquefied petroleum gas (LPG) has an overall lower power output at the typical 10:1 compression ratio of a gasoline engine. However, with an engine tuned to the use of LPG (i.e. via higher compression ratios, such as 12:1 instead of 10:1), the power output can be improved. This is because higher-octane fuels allow for a higher compression ratio without knocking, resulting in a higher cylinder temperature, which improves efficiency. Also, increased mechanical efficiency is created by a higher compression ratio through the concomitant higher expansion ratio on the power stroke, which is by far the greater effect. The higher expansion ratio extracts more work from the high-pressure gas created by the combustion process. An Atkinson cycle engine uses the timing of the valve events to produce the benefits of a high expansion ratio without the disadvantages, chiefly detonation, of a high compression ratio. A high expansion ratio is also one of the two key reasons for the efficiency of diesel engines, along with the elimination of pumping losses due to throttling of the intake air flow.

The lower energy content (per liter) of LPG in comparison to gasoline is due mainly to its lower density. Energy content per kilogram is higher than for gasoline (higher hydrogen to carbon ratio, for an example see Standard enthalpy of formation).

Molecular weights of the above reagents are C₈H₁₈ 114, O₂ 32, CO₂ 44, H₂O 18; therefore 1 kg of fuel reacts with 3.51 kg of oxygen to produce 3.09 kg of carbon dioxide and 1.42 kg of water.

Density

The density of gasoline ranges from 0.71–0.77 kg/L (719.7 kg/m³; 0.026 lb/in³; 6.073 lb/US gal; 7.29 lb/imp gal), higher densities having a greater volume of aromatics.^[18] Since gasoline floats on water, water cannot generally be used to extinguish a gasoline fire unless used in a fine mist. Finished marketable gasoline is traded with a standard reference of 0.755 kg/L, and its price is escalated/de-escalated according to its actual density.

Chemical analysis and production

Gasoline is produced in oil refineries. Roughly 19 US gallons (72 L) of gasoline is derived from a 42-gallon (159 L) barrel of crude oil. Material separated from crude oil via distillation, called virgin or straight-run gasoline, does not meet specifications for modern engines (particularly the octane rating, see below), but can be pooled to the gasoline blend.

The bulk of a typical gasoline consists of hydrocarbons with between 4 and 12 carbon atoms per molecule (commonly referred to as C4-C12).^[5] It is a mixture of paraffins (alkanes), cycloalkanes (naphthenes), and olefins (alkenes), where the usage of the terms paraffin and olefin is particular to the oil industry. The actual ratio depends on:

- the oil refinery that makes the gasoline, as not all refineries have the same set of processing units;
- the crude oil feed used by the refinery;
- the grade of gasoline, in particular, the octane rating.

The various refinery streams blended to make gasoline have different characteristics. Some important streams are:

- straight-run gasoline**, usually also called naphtha is distilled directly from crude oil. Once the leading source of fuel, its low octane rating required lead additives. It is low in aromatics (depending on the grade of crude oil), containing some cycloalkanes (naphthenes) and no olefins (alkenes). Between 0 and 20% of this stream is pooled into the finished gasoline, because the supply of this fraction is insufficient and its RON is too low. The chemical properties (namely octane and RVP) of the straight-run gasoline can be improved through reforming and isomerisation. However, before feeding those units, the naphtha needs to be split in light and heavy naphtha. Straight-run gasoline can be also used as a feedstock into steam-crackers to produce olefins.
- reformate**, produced in a catalytic reformer has a high octane rating with high aromatic content, and relatively low olefins (alkenes). Most of the benzene, toluene, and xylene (the so-called BTX) are more valuable as chemical feedstocks and are thus removed to some extent.
- catalytic cracked gasoline** or catalytic cracked naphtha, produced from a catalytic cracker, with a moderate octane rating, high olefins (alkene) content, and moderate aromatics level.
- hydrocrackate** (heavy, mid, and light) produced from a hydrocracker, with medium to low octane rating and moderate aromatic levels.
- alkylate** is produced in an alkylation unit, using as feedstocks isobutane and alkenes. Alkylate contains no aromatics and alkenes and has high MON.
- isomerate** is obtained by isomerizing low octane straight run gasoline to iso-paraffins (non-chain alkanes, like isooctane). Isomerate has medium RON and MON, but nil aromatics and olefins.
- butane** is usually blended in the gasoline pool, although the quantity of this stream is limited by the RVP specification.

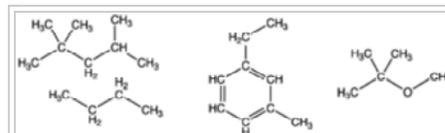
The terms above are the jargon used in the oil industry and terminology varies.

Currently, many countries set limits on gasoline aromatics in general, benzene in particular, and olefin (alkene) content. Such regulations led to increasing preference for high octane pure paraffin (alkane) components, such as alkylate, and is forcing refineries to add processing units to reduce benzene content. In the EU the benzene limit is set at 1% volume for all grade of automotive gasoline.

Gasoline can also contain other organic compounds, such as organic ethers (deliberately added), plus small levels of contaminants, in particular organosulfur compounds, but these are usually removed at the refinery.

Additives

Antiknock additives



Some of the main components of gasoline: isooctane, butane, 3-ethyltoluene, and the octane enhancer MTBE.



A pumpjack in the United States



An oil rig in the Gulf of Mexico



A plastic container for storing gasoline used in Germany

Almost all countries in the world have phased out automotive leaded fuel. In 2011 six countries^[19] were still using leaded gasoline: Afghanistan, Myanmar, North Korea, Algeria, Iraq and Yemen. It was expected that by the end of 2013 those countries would ban leaded gasoline,^[20] but it has not occurred. Algeria will replace leaded with unleaded automotive fuel only in 2015. Different additives have replaced the lead compounds. The most popular additives include aromatic hydrocarbons, ethers and alcohol (usually ethanol or methanol). For technical reasons the use of leaded additives is still permitted worldwide for the formulation of some grades of aviation gasoline such as 100LL, because the required octane rating would be technically infeasible to reach without the use of leaded additives.

Tetraethyllead

Gasoline, when used in high-compression internal combustion engines, tends to autoignite (*detonate*) causing damaging "engine knocking" (also called "pinging" or "pinking") noise. To address this problem, tetraethyllead (TEL) was widely adopted as an additive for gasoline in the 1920s. With the discovery of the extent of environmental and health damage caused by the lead, however, and the incompatibility of lead with catalytic converters, leaded gasoline was phased out in the USA beginning in 1973. By 1995, leaded fuel accounted for only 0.6% of total gasoline sales and under 2000 short tons (1814 t) of lead per year in the USA. From 1 January 1996, the U.S. Clean Air Act banned the sale of leaded fuel for use in on-road vehicles in the USA. The use of TEL also necessitated other additives, such as dibromoethane. First European countries started replacing lead by the end of the 1980s and by the end of the 1990s leaded gasoline was banned within the entire European Union. Reduction in the average blood lead level is believed to have been a major cause for falling violent crime rates in the United States^[21] and South Africa.^[22] A statistically significant correlation has been found between the usage rate of leaded gasoline and violent crime: taking into account a 22-year time lag, the violent crime curve virtually tracks the lead exposure curve.^{[23][24]}

Lead Replacement Petrol

Lead Replacement Petrol (LRP) was developed for vehicles designed to run on leaded fuel and incompatible with unleaded. Rather than tetraethyl lead it contains other metal such as potassium compounds or methylcyclopentadienyl manganese tricarbonyl (MMT); these are purported to buffer soft exhaust valves and seats so that they do not suffer recession due to the use of unleaded fuel.

LRP was marketed during and after the phaseout of leaded motor fuels in the United Kingdom, Australia, South Africa and some other countries. Consumer confusion led to widespread mistaken preference for LRP rather than unleaded,^[25] and LRP was phased out 8 to 10 years after the introduction of unleaded.^[26]

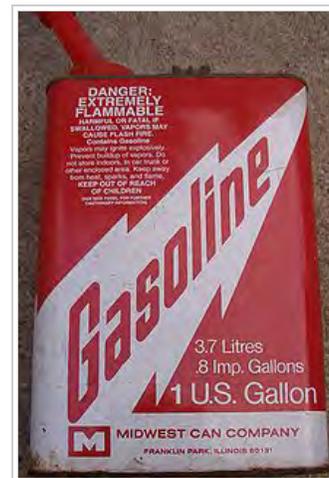
MMT

Methylcyclopentadienyl manganese tricarbonyl (MMT) is used in Canada and in Australia to boost octane.^[27] It also helps old cars designed for leaded fuel run on unleaded fuel without need for additives to prevent valve problems. Its use in the US has been restricted by regulations.^[28] Its use in the EU is restricted by Article 8a of the Fuel Quality Directive^[29] following its testing under the Protocol for the evaluation of effects of metallic fuel-additives on the emissions performance of vehicles.^[30]

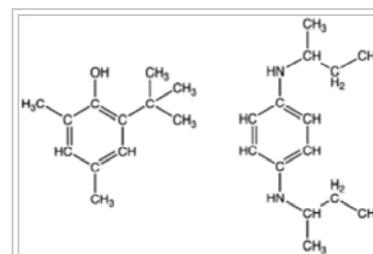
Fuel stabilizers (antioxidants and metal deactivators)

Gummy, sticky resin deposits result from oxidative degradation of gasoline upon long term storage. These harmful deposits arise from the oxidation of alkenes and other minor components in gasoline (see drying oils). Improvements in refinery techniques have generally reduced the susceptibility of gasolines to these problems. Previously, catalytically or thermally cracked gasolines are most susceptible to oxidation. The formation of these gums is accelerated by copper salts, which can be neutralized by additives called metal deactivators.

This degradation can be prevented through the addition of 5–100 ppm of antioxidants, such as phenylenediamines and other amines.^[5] Hydrocarbons with a bromine number of 10 or above can be protected with the combination of unhindered or partially hindered phenols and oil-soluble strong amine bases, such as hindered phenols. "Stale" gasoline can be detected by a colorimetric enzymatic test for organic peroxides produced by oxidation of the gasoline.^[31]



A gas can



Substituted phenols and derivatives of phenylenediamine are common antioxidants used to inhibit gum formation in gasoline (gasoline).

Gasolines are also treated with metal deactivators, which are compounds that sequester (deactivate) metal salts that otherwise accelerate the formation of gummy residues. The metal impurities might arise from the engine itself or as contaminants in the fuel.

Detergents

Gasoline, as delivered at the pump, also contains additives to reduce internal engine carbon buildups, improve combustion, and to allow easier starting in cold climates. High levels of detergent can be found in Top Tier Detergent Gasolines. The specification for Top Tier Detergent gasolines was developed by four automakers: GM, Honda, Toyota and BMW. According to the bulletin, the minimal EPA requirement is not sufficient to keep engines clean.^[32] Typical detergents include alkylamines and alkyl phosphates at the level of 50–100 ppm.^[5]

Ethanol

European Union

In the EU, 5% ethanol can be added within the common gasoline spec (EN 228). Discussions are ongoing to allow 10% blending of ethanol (available in Finnish, French and German gas stations). In Finland most gasoline stations sell 95E10, which is 10% of ethanol; and 98E5, which is 5% ethanol. Most gasoline sold in Sweden has 5–15% ethanol added.

Brazil

In Brazil, the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP) requires gasoline for automobile use to have 27.5% of ethanol added to its composition.^[33] Pure hydrated ethanol is also available as a fuel.

Australia

Legislation requires retailers to label fuels containing ethanol on the dispenser, and limits ethanol use to 10% of gasoline in Australia. Such gasoline is commonly called E10 by major brands, and it is cheaper than regular unleaded gasoline.

United States

The federal Renewable Fuel Standard (RFS) effectively requires refiners and blenders to blend renewable biofuels (mostly ethanol) with gasoline, sufficient to meet a growing annual target of total gallons blended. Although the mandate does not require a specific percentage of ethanol, annual increases in the target combined with declining gasoline consumption has caused the typical ethanol content in gasoline to approach 10%. Most fuel pumps display a sticker that states that the fuel may contain up to 10% ethanol, an intentional disparity that reflects the varying actual percentage. Until late 2010, fuels retailers were only authorized to sell fuel containing up to 10 percent ethanol (E10), and most vehicle warranties (except for flexible fuel vehicles) authorize fuels that contain no more than 10 percent ethanol. In parts of the United States, ethanol is sometimes added to gasoline without an indication that it is a component.

India

The Government of India in October 2007 decided to make 5% ethanol blending (with gasoline) mandatory. Currently, 10% Ethanol blended product (E10) is being sold in various parts of the country.^{[34][35]}

Ethanol has been found in at least one study to damage catalytic converters.^[36]

Dye

In Australia, the lowest grade of gasoline (RON 91) is dyed a light shade of red/orange and the medium grade (RON 95) is dyed yellow.^[37]

In the United States, aviation gasoline (avgas) is dyed to identify its octane rating and to distinguish it from kerosene-based jet fuel, which is clear.^[38]

In Canada the gasoline for marine and farm use is dyed red and is not subject to road tax.

Oxygenate blending

Oxygenate blending adds oxygen-bearing compounds such as MTBE, ETBE, ethanol, and biobutanol. The presence of these oxygenates reduces the amount of carbon monoxide and unburned fuel in the exhaust gas. In many areas throughout the US, oxygenate blending is mandated by EPA regulations to reduce smog and other airborne pollutants. For example, in Southern California, fuel must contain 2% oxygen by weight, resulting in a mixture of 5.6% ethanol in gasoline. The resulting fuel is often known as reformulated gasoline (RFG) or oxygenated gasoline, or in the case of California, California reformulated gasoline. The federal requirement that RFG contain oxygen was dropped on 6 May 2006 because the industry had developed VOC-controlled RFG that did not need additional oxygen.^[39]

MTBE was phased out in the US due to ground water contamination and the resulting regulations and lawsuits. Ethanol and, to a lesser extent, the ethanol-derived ETBE are common replacements. A common ethanol-gasoline mix of 10% ethanol mixed with gasoline is called gasohol or E10, and an ethanol-gasoline mix of 85% ethanol mixed with gasoline is called E85. The most extensive use of ethanol takes place in Brazil, where the ethanol is derived from sugarcane. In 2004, over 3.4 billion US gallons (2.8 billion imp gal/13 million m³) of ethanol was produced in the United States for fuel use, mostly from corn, and E85 is slowly becoming available in much of the United States, though many of the relatively few stations vending E85 are not open to the general public.^[40] The use of bioethanol, either directly or indirectly by conversion of such ethanol to bio-ETBE, is encouraged by the European Union Directive on the Promotion of the use of biofuels and other renewable fuels for transport. Since producing bioethanol from fermented sugars and starches involves distillation, though, ordinary people in much of Europe cannot legally ferment and distill their own bioethanol at present (unlike in the US, where getting a BATF distillation permit has been easy since the 1973 oil crisis).

Safety

Environmental considerations

Combustion of 1 U.S. gallon (3.8 L) of gasoline produces 8.74 kilograms (19.3 lb) of carbon dioxide (2.3 kg/l), a greenhouse gas.^[41]

The main concern with gasoline on the environment, aside from the complications of its extraction and refining, is the potential effect on the climate. Unburnt gasoline and evaporation from the tank, when in the atmosphere, reacts in sunlight to produce photochemical smog. Vapor pressure initially rises with some addition of ethanol to gasoline, but the increase is greatest at 10% by volume. At higher concentrations of ethanol above 10%, the vapor pressure of the blend starts to decrease. At a 10% ethanol by volume, the rise in vapor pressure may potentially increase the problem of photochemical smog. This rise in vapor pressure could be mitigated by increasing or decreasing the percentage of ethanol in the gasoline mixture.

The chief risks of such leaks come not from vehicles, but from gasoline delivery truck accidents and leaks from storage tanks. Because of this risk, most (underground) storage tanks now have extensive measures in place to detect and prevent any such leaks, such as monitoring systems (Veeder-Root, Franklin Fueling).

Production of gasoline consumes 0.63 gallon of water per mile driven.^[42]

Toxicity

The safety data sheet for unleaded gasoline shows at least 15 hazardous chemicals occurring in various amounts, including benzene (up to 5% by volume), toluene (up to 35% by volume), naphthalene (up to 1% by volume), trimethylbenzene (up to 7% by volume), methyl *tert*-butyl ether (MTBE) (up to 18% by volume, in some states) and about ten others.^[43] Hydrocarbons in gasoline generally exhibit low acute toxicities, with LD50 of 700 – 2700 mg/kg for simple aromatic compounds.^[44] Benzene and many antiknocking additives are carcinogenic.

People can be exposed to gasoline in the workplace by swallowing it, breathing in vapors, skin contact, and eye contact. The National Institute for Occupational Safety and Health (NIOSH) has designated gasoline as a carcinogen.^[45]

Inhalation

Inhaled (huffed) gasoline vapor is a common intoxicant that has become epidemic in some poorer communities and indigenous groups in Australia, Canada, New Zealand, and some Pacific Islands.^[46] In response, Opal fuel has been developed by the BP Kwinana Oil Refinery in Australia, and contains only 5% aromatics, which weakens the effects of inhalation.^[47]

Flammability

Like other hydrocarbons, gasoline burns in a limited range of its vapor phase and, coupled with its volatility, this makes leaks highly dangerous when sources of ignition are present. Gasoline has a lower explosive limit of 1.4% by volume and an upper explosive limit of 7.6%. If the concentration is below 1.4%, the air-gasoline mixture is too lean and does not ignite. If the concentration is above 7.6%, the mixture is too rich and also does not ignite. However, gasoline vapor rapidly mixes and spreads with air, making unconstrained gasoline quickly flammable.

Use and pricing



The United States accounts for about 44% of the world's gasoline consumption.^[48] In 2003 The US consumed 476 gigaliters (126 billion U.S. gallons; 105 billion imperial gallons),^[49] which equates to 1.3 gigaliters (340 million U.S. gallons; 290 million imperial gallons) of gasoline each day. The US used about 510 gigaliters (130 billion U.S. gallons; 110 billion imperial gallons) of gasoline in 2006, of which 5.6% was mid-grade and 9.5% was premium grade.^[50]

Europe

Unlike the US, countries in Europe impose substantial taxes on fuels such as gasoline. The price of gasoline in Europe is typically about three times that in the US.

United States

From 1998 to 2004, the price of gasoline fluctuated between \$1 and \$2 USD per U.S. gallon.^[51] After 2004, the price increased until the average gas price reached a high of \$4.11 per U.S. gallon in mid-2008, but receded to approximately \$2.60 per U.S. gallon by September 2009.^[51] More recently, the U.S. experienced an upswing in gasoline prices through 2011,^[52] and by 1 March 2012, the national average was \$3.74 per gallon.

In the United States, most consumer goods bear pre-tax prices, but gasoline prices are posted with taxes included. Taxes are added by federal, state, and local governments. As of 2009, the federal tax is 18.4¢ per gallon for gasoline and 24.4¢ per gallon for diesel (excluding red diesel).^[53] Among states, the highest gasoline tax rates, including the federal taxes as of 2005, are New York (62.9¢/gal), Hawaii (60.1¢/gal), and California (60¢/gal).^[52]

About 9% of all gasoline sold in the US in May 2009 was premium grade, according to the Energy Information Administration. *Consumer Reports* magazine says, "If [your owner's manual] says to use regular fuel, do so—there's no advantage to a higher grade."^[54] The Associated Press said premium gas—which is a higher octane and costs more per gallon than regular unleaded—should be used only if the manufacturer says it is "required".^[55] Cars with turbocharged engines and high compression ratios often specify premium gas because higher octane fuels reduce the incidence of "knock", or fuel pre-detonation.^[56] The price of gas varies during the summer and winter months.^[57]

Comparison with other fuels

Volumetric and mass energy density of some fuels compared with gasoline (in the rows with gross and net, they are from^[58]):

Fuel type	Gross MJ/L	MJ/kg	Gross BTU/gal (imp)	Gross BTU/gal (U.S.)	Net BTU/gal (U.S.)	RON
Conventional gasoline	34.8	44.4 ^[59]	150,100	125,000	115,400	91–92
Autogas (LPG) (Consisting mostly of C3 and C4 hydrocarbons)	26.8	46		95,640		108
Ethanol	21.2 ^[59]	26.8 ^[59]	101,600	84,600	75,700	108.7 ^[60]
Methanol	17.9	19.9 ^[59]	77,600	64,600	56,600	123
Butanol ^[2]	29.2	36.6	6,087	7,311		91–99
Gasohol	31.2		145,200	120,900	112,400	93/94
Diesel(*)	38.6	45.4	166,600	138,700	128,700	25
Biodiesel	33.3–35.7 ^[61]			126,200	117,100	
Avgas (high octane gasoline)	33.5	46.8	144,400	120,200	112,000	
Jet fuel (kerosene based)	35.1	43.8	151,242	125,935		
Jet fuel (naphtha)				127,500	118,700	
Liquefied natural gas	25.3	~55	109,000	90,800		
Liquefied petroleum gas		46.1		91,300	83,500	
Hydrogen	10.1 (at 20 kelvin)	142			130 ^[62]	

(*) Diesel fuel is not used in a gasoline engine, so its low octane rating is not an issue; the relevant metric for diesel engines is the cetane number



Uncontrolled burning of gasoline produces large quantities of soot and carbon monoxide.

See also

- Aviation fuel
- Butanol fuel – replacement fuel for use in unmodified gasoline engines
- Diesel fuel
- Filling station
- Fuel dispenser
- Fuel saving device
- Gasoline and diesel usage and pricing
- Gasoline gallon equivalent
- Internal combustion engine (ICE)
- Jerrycan
- List of automotive fuel brands
- List of gasoline additives
- Natural-gas condensate#Drip gas
- Octane rating
- World oil market chronology from 2003

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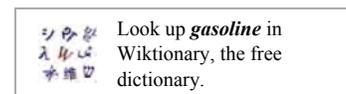
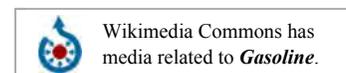
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