



Lecture 3

Petrochemicals Engineering

Chemical and Physical Properties

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Liquefied natural gas (LNG)

- When natural gas is cooled to a temperature of approximately $-260\text{ }^{\circ}\text{F}$ ($-160\text{ }^{\circ}\text{C}$) at atmospheric pressure it condenses to a liquid called liquefied natural gas (LNG).
- One volume of this liquid takes up about 1/600th the volume of natural gas at a stove burner tip.
- LNG is only about 45% the density of water.
- LNG is odorless, colorless, non-corrosive, and non-toxic.
- When vaporized it burns only in concentrations of 5% to 15% when mixed with air.
- Neither LNG, nor its vapor, can explode in an unconfined environment.

Compressed natural gas (CNG)

- Is natural gas pressurized and stored in welding bottle-like tanks at pressures up to 3,600 psig (25 MPa).
- Typically, it is same composition of the local "pipeline" gas, with some of the water removed.



Liquid petroleum gas (LPG)

- ▶ Sometimes called propane is often confused with LNG and vice versa. They are not the same and the differences are significant.
- ▶ Varieties of LPG bought and sold include mixes that are primarily propane, mixes that are primarily butane, and mixes including propane, propylene, n-butane, butylene and iso-butane.
- ▶ Depending on the season in winter more propane, in summer more butane. Vapor pressures, at 30°C, are for commercial propane in the range 10-12 bar (1 to 1.2 MPa), for commercial butane, 2-4 bar (0.2 to 0.4 MPa).
- ▶ In some countries, LPG is composed primarily of propane (upwards to 95%) and smaller quantities of butane.
- ▶ LPG (sometimes called autogas) has also been used as fuel in light duty vehicles for many years. An increasing number of petrol stations around the world offer LPG pumps as well. A final example that should not be forgotten is that the "bottled gas" can often be found under barbecue grills.



LPG compared to natural gas

- ▶ Has a significantly higher heating value
- ▶ Requires a different air-to-gas mixture (propane: 24:1, butane: 30:1) for good combustion.
- ▶ LPG can be stored as a liquid in tanks by applying pressure alone. While the distribution of LNG requires heavy infrastructure investments (pipelines, etc.), LPG is portable. This fact makes LPG very interesting for developing countries and rural areas.

Gas Specifications and Standard Conditions

- ▶ Market sales of natural gas require some specifications set by the consumers regarding the maximum contents allowable for the following: acidic gases and sulfur, oxygen and carbon dioxide, water vapor, and liquefiable hydrocarbons. The thermal heating content of the gas sets another value to be met as a minimum.

Table 1: Typical Composition of Natural Gas

Name	Formula	Volume (%)
Methane	CH ₄	>85
Ethane	C ₂ H ₆	3–8
Propane	C ₃ H ₈	1–2
Butane	C ₄ H ₁₀	<1
Pentane	C ₅ H ₁₂	<1
Carbon dioxide	CO ₂	1–2
Hydrogen sulfide	H ₂ S	<0.5
Nitrogen	N ₂	<0.5
Helium	He	<0.5

Natural Gas Fundamentals

- ▶ Natural gas exists in nature under pressure in rock reservoirs in the Earth's crust, either in conjunction with and dissolved in heavier hydrocarbons and water or by itself. It is produced from the reservoir similarly to or in conjunction with crude oil. Natural gas has been formed by the degradation of organic matter accumulated in the past millions of years. Two main mechanisms (*biogenic and thermogenic*) are responsible for this degradation \
- ▶ *Biogenic gas* is formed at shallow depths and low temperatures by the anaerobic bacterial decomposition of sedimentary organic matter. Biogenic gas consists almost entirely of methane.
- ▶ *Methanogens* are microscopic organisms which live in environments devoid of oxygen and chemically decompose organic matter, creating methane as a byproduct.
- ▶ *Thermogenic gas* is formed at deeper depths by:
 - (1) Thermal cracking of sedimentary organic matter into hydrocarbon liquids and gas
 - (2) Thermal cracking of oil at high temperatures into gas.Thermogenic gas can also contain significant concentrations of ethane, propane, butanes, and heavier hydrocarbons.



Chemical and Physical Properties

- Natural gas is colorless, odorless, tasteless, shapeless, and lighter than air. The natural gas after appropriate treatment for acid gas reduction, odorization, and hydrocarbon and moisture dew point adjustment would then be sold within prescribed limits of pressure, calorific value, and possibly *Wobbe index* (often referred to as the *Wobbe number*). The Wobbe index (calorific value divided by the specific gravity) gives a measure of the heat input to an appliance through a given aperture at a given gas pressure.

Table 4: Properties of Natural Gas

Properties	Value
Relative molar mass	17–20
Carbon content, weight %	73.3
Hydrogen content, weight %	23.9
Oxygen content, weight %	0.4
Hydrogen/carbon atomic ratio	3.0–4.0
Relative density, 15°C	0.72–0.81
Boiling point, °C	–162
Autoignition temperature, °C	540–560
Octane number	120–130
Methane number	69–99
Stoichiometric air/fuel ratio, weight	17.2
Vapour flammability limits, volume %	5–15
Flammability limits	0.7–2.1
Lower heating/calorific value, MJ/kg	38–50
Stoichiometric lower heating value, MJ/kg	2.75
Methane concentration, volume %	80–99
Ethane concentration, volume %	2.7–4.6
Nitrogen concentration, volume %	0.1–15
Carbon dioxide concentration, volume %	1–5
Sulfur concentration, weight % ppm	<5
Specific CO ₂ formation, g/MJ	38–50

► Quality

The amount of energy that is obtained from the burning of a volume of natural gas is measured in British thermal units (Btu). The value of natural gas is calculated by its Btu content.

► Transportation

Gas, as a result of the storage difficulties, needs to be transported immediately to its destination after production from a reservoir. There are a number of options for transporting natural gas energy from oil and gas fields to market. These include :

- ❖ pipelines,
- ❖ liquefied natural gas (LNG),
- ❖ compressed natural gas (CNG),
- ❖ gas to solids (GTS), i.e., hydrates,
- ❖ gas to power (GTP), i.e., electricity,
- ❖ gas to liquids (GTL), with a wide range of possible products, including clean fuels, plastic precursors, or methanol





Thank you