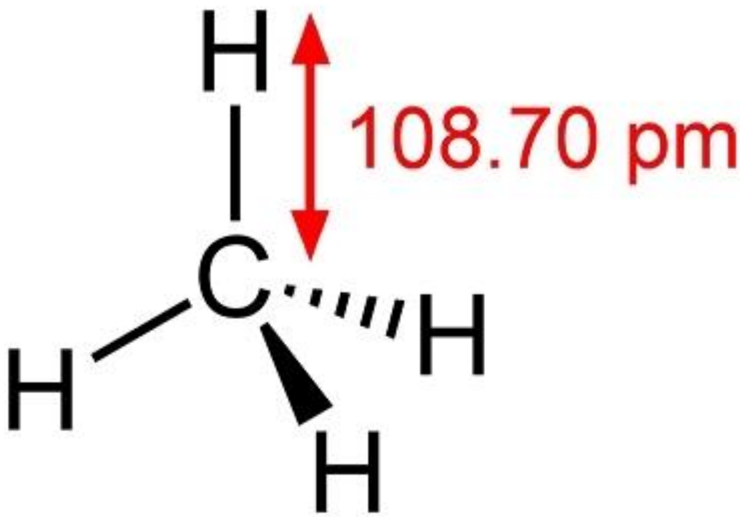
Methane



Introduction

Methane is a simple chemical molecule, having the formula **CH_4**. It is the the principal component of natural gas. Complete combustion of methane in the presence of oxygen produces carbon dioxide and water. The relative abundance of the alkane hydrocarbon methane makes it a widely used fuel, but, being a gas at typical ambient temperatures, methane is challenging to transport. Consequently, dedicated pipelines are often constructed for its long distance movement.

Methane is a powerful greenhouse gas produced both naturally and through human activities. It was first discovered by Alessandro Volta in 1776 who noticed bubbles rising from a pond and found that these bubbles could be ignited with a naked flame. Methane has a relatively short lifetime in the atmosphere, most molecules having been destroyed within 10 years of their release. However, the concentration of methane actually affects its own atmospheric lifetime. The primary mechanism for its destruction is by reaction with hydroxyl radicals (OH-), the greater the concentration of methane the more the reductive power of the atmosphere (the supply of hydroxyl radicals) is reduced. If this feedback is included, then the true atmospheric lifetime of methane extends to about 12 years.

Global warming

Methane has a global warming potential (GWP) of 30. This means that every kilogram of methane emitted to the atmosphere has the equivalent forcing effect on the Earth's climate of 30 times that of carbon dioxide over a 100 year period; however, recent research by Shindell et al. has demonstrated that the actual strength of methane is much higher than conventionally thought.

Combined with the fact that the percentage rate of concentration increase of methane is significantly greater than that of CO_2, one can argue that the role of methane in greenhouse gas accumulation appears to be comparable with carbon dioxide. For example, a conventional estimate of methane compared to carbon dioxide was offerred by Fahey in 2002; this estimate placed methane as roughly half of the radiative forcing contribution of CO_2, but it is not clear that Fahey's calculations included the role of methane as a carbon dioxide precursor, and they certainly did not account for the magnitude of the Siberian sub-sea shelf methane off-gassing only reported in 2010. This argument in favor of methane's importance is further strengthened by noting that the production of methane generally scales with the human population, in contrast to production of CO_2 is being mitigated by advances in emission control technology and increased stringency of governmental emission controls.

Concentrations of methane in the atmosphere have more than doubled since the pre-industrial period, rising from around 750 parts per billion (ppb) in the year 1750 to a 2010 level of around 1850 ppb. In the last decade the rate of increase has slowed, but recent analyses suggest that this may be to transient reductions in emissions from natural sources brought about by low rainfall. If rainfall in these major source areas returns to normal, methane concentrations can be expected to increase further.

Sources

Natural

Natural sources of methane have conventionally thought to be dominated by wetlands. Where soils are waterlogged and oxygen concentrations are low or zero, a group of microorganisms called *methanogens*may produce large amounts of methane as they respire carbon dioxide to derive energy. Wetland methane emissions are thought to comprise around 80 percent of the total natural methane source, with methane release from termites, methane hydrates (frozen deposits of methane), and the emission from the oceans also being important. Total annual methane emissions from natural sources are estimated to be around 250 million tonnes. A paper by Frank Keppler in 2006 suggested that vegetation may also be an important natural source of methane. His study indicated that up to a third of natural methane emissions may actually arise from this source. Then the current percentage estimate for wetland methane emissions is likely to be an overestimate.

In 2010, Siberian research has indicated that natural releases from sub-sea Arctic shelves is much larger than earlier realized and may be accelerating. These discoveries may underscore the fact that methane is likely at least as great a driver as carbon dioxide in climate alteration phenomena.

Industrial

Methane emissions resulting from human activities are now thought to exceed those from natural sources, annual emissions being around 320 million tonnes. The main human-made sources arise from losses occurring during oil, coal and gas extraction, from waste treatment, from landfill sites, rice cultivation and biomass burning.

Livestock

Domesticated animals are not natural in the sense that their populations are governed by human demand for meat, dairy and other products from these animals. Eructation and flatulence are the proximate causes of large quantities of methane emissions from cattle, sheep, goats and other livestock. The quantify of these emissions scale roughly with the human population explosion, and has risen dramatically since the early Holocene. Livestock grazing contributes an estimated 20 percent of all global methane emissions (not counting highly varible off-gassing of Arctic sub-sea formations); this value exceeds contributions by all fossil fuel combustion, according to some sources.

Sinks

The primary sink for methane is its destruction in the atmosphere by hydroxyl radicals. Significant amounts of methane are also oxidised by microorganisms (called methanotrophs) which use the methane as a source of carbon and energy. Methanotrophs are aerobic microbes and are usually found in well-drained soils or similar enevironments where they have a good supply of both oxygen and methane. The uptake of methane by these micobes constitutes only about five percent of the total methane sink of between 500 and 600 million tonnes per year. However, the methanotrophs are more important than this figure might indicate, as they also consume a great deal of methane before it is released to the atmosphere.

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