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Editorial

Helium: Sources, Applications, Supply, and Demand

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1. Properties, Sources, and Supply

Helium is an inert gas with no color or odor. Its critical point is −268 °C and 2.27 bar, its boiling point is −269 °C (4 K), and it remains in a liquid state at pressures below 2.5 bar. Under standard conditions, helium behaves as an ideal gas, with a density of 179 g/m^3, a specific heat capacity of 5.238 kJ/(kg K), and a thermal conductivity of 0.143 W/(m K). The specific heat of vaporization of helium is 0.084 kJ/mol. The two significant isotopes are He-4, naturally abundant at 99.99%, and He-3 (0.000137%). Both isotopes are stable, with a density of 0.1785 kg/m^3 at 298 K [1].

Helium was first produced in 1895 through the addition of acid to uranium, which led to the isolation of the resulting gas. Later, in 1905, helium was identified within natural gas.

For many years, helium has been disregarded and considered an undesired byproduct of natural gas production facilities. In methane production, helium is often vented into the atmosphere, which is counterproductive, as the cost of purifying helium from the air is higher than that of methane [2,3].

The modern approach to helium extraction from natural gas involves the fractional distillation of natural gas by cooling the gas to separate helium from hydrocarbons and nitrogenous compounds. The initial stage of the industrial supply chain involves natural gas extraction and processing, where helium is treated as a valuable byproduct and separated through cryogenic processes from other components, e.g., carbon dioxide, hydrogen, nitrogen, and hydrocarbons. At this point, so-called "crude helium" is obtained, with a purity of 60–80%. To achieve a higher purity, different gases like hydrogen, oxygen, and water are separated from crude helium to produce "Grade-A" helium, i.e., helium with a purity of 99.99% [2,4].

Following purification, helium can be liquefied for specific applications or stored as a gas under high pressure. The distribution of liquid helium is challenging due to technical complications and significant losses caused by the boiling-of-gas process. Alternatively, helium can be stored and transported as a compressed gas. In the third level of the supply chain, refiners sell helium to end-users, non-refiners, or smaller gas distributors who commercialize and transport the gas using trucks and storage tanks. The helium market is characterized by complexity due to inelastic demand, the production of helium solely as a byproduct, and the limited number of helium-producing companies [5].

Possible disturbances in the helium supply chain have already been observed, leading to helium shortages and price fluctuations. The U.S. government recognized the strategic importance of helium for national defense and, therefore, developed the Federal Helium Reserve, which was used for airships until the 1950s [6]. However, in 1995, the first helium shortage caused market difficulties [7]. Subsequent shortages were Helium Shortage 2.0 (which occurred in 2010 [8]) and Helium Shortage 3.0 (2018–2019). Helium shortages impact prices due to various factors, such as limited helium sources and international trade restrictions. The COVID-19 pandemic also had significant negative effects on the helium market. Unplanned maintenance and fire incidents at some helium production facilities affected the production capacity and supply chain stability. Recent helium supply developments raise concerns about a potential Helium Shortage 4.0 [9].

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2. Applications and Demand

Helium is an irreplaceable cryogenic coolant, particularly for temperatures below −256 °C. Its numerous applications span various industries. Helium acts as an inert gas in welding technology to shield the welding point from oxygen infiltration. Helium also finds applications in the leakage testing of critical products across different technologies. Additionally, food producers utilize helium for packaging and sealing products to maintain hermetic conditions.

The significance of helium extends to the realm of superconductivity [10]. Despite advancements in high-temperature superconductors, helium remains the preferred coolant to keep superconductors below their transition temperature, notably in magnetic resonance imaging. Moreover, helium plays a crucial role in nuclear magnetic spectroscopy, as superconductors in magnets must be cooled to cryogenic temperatures to achieve superconductivity [11].

Additionally, NASA and similar organizations worldwide are significant consumers of helium for cooling hydrogen and oxygen propulsion rockets. Helium is also employed as a pressurized inert gas in rocket fuel supply systems.

In laser technologies, helium serves as a buffer gas in helium–neon excimer lasers [12].

In high-temperature nuclear reactors that use graphite as a moderator, helium acts as a coolant.

Helium is also critical in manufacturing optical fibers, providing sufficient cooling to prevent fiber breakage and increase drawing speed. Furthermore, there is potential market growth for helium usage in electronics, particularly in semiconductor production, where helium creates an inert environment around silicon to prevent undesired reactions. According to projections, the semiconductor industry's revenue is expected to continue growing, which could significantly increase the helium market for semiconductor and optic fiber production in future.

With the growing hydrogen economy, i.e., the liquid hydrogen supply chain, there is a potential rise in the demand for helium [13].

In the field of intensive care medicine, a helium–oxygen mixture is used as a breathing gas for patients, reducing resistance in constrictions.

Various efforts have been made to enhance helium conservation and optimize its usage to address the challenges posed by helium supply and demand. Researchers and policymakers have been exploring alternative sources of helium, including recycling. Additionally, strategic planning and international cooperation are essential to avoid potential helium shortages and mitigate the impact on critical industries [14].

In recent years, the helium market has witnessed a shift in dynamics, with new players and emerging technologies influencing demand and production patterns. As new applications and uses for helium continue to emerge, understanding the market dynamics and predicting future demand trends will be crucial for sustainable helium management [15].

Furthermore, improvements in cryogenic technologies and helium recovery processes have the potential to increase helium supply efficiency and reduce its environmental impact. Public awareness and education about the significance of helium conservation are also essential aspects of sustainable helium management [16].

3. Environmental Concerns

Helium is not one of the greenhouse gases. It is primarily extracted from natural gas. The extraction process typically involves drilling for natural gas, and helium is separated from the gas stream at processing facilities. The extraction of helium is energy-intensive and can involve the release of greenhouse gases during drilling, transportation, and processing. Carbon dioxide and methane emissions are common byproducts of the natural gas extraction process and are often associated with helium extraction. Natural gas containing helium is sometimes vented or flared during extraction when it cannot be effectively captured or transported. This results in the direct release of greenhouse gases into the atmosphere. Strategies to reduce greenhouse gas emissions associated with helium extraction include the improved capture and utilization of vented or flared gases. There are ample opportunities for further research into the environmental impact of helium extraction and the development of cleaner extraction methods. Recycling helium can reduce the need for continuously growing extraction and associated greenhouse gas emissions. Governments and environmental agencies are increasingly aware of the environmental impact of helium extraction [17]. They may introduce regulations and incentives to reduce emissions associated with helium production.

4. Conclusions

As the demand for helium continues to rise, particularly in the semiconductor industry, and with uncertainties in helium production due to facility issues, export restrictions, and geopolitical tensions, the global helium market faces challenges and uncertainties. Strategic planning and cooperation among helium-producing countries are essential to ensure a stable and sustainable helium supply for critical applications in various industries. Monitoring market dynamics, technological advancements, and geopolitical developments will be crucial in addressing potential helium supply disruptions and ensuring a steady helium supply for the future. As the demand for helium continues to grow, it is crucial to find more sustainable and environmentally friendly ways to extract and use this gas.

Conflicts of Interest: The authors declare no conflict of interest.

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