Neon
An overview
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<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Text</td>
<td>19</td>
</tr>
<tr>
<td>4.2 Images</td>
<td>20</td>
</tr>
<tr>
<td>4.3 Content license</td>
<td>22</td>
</tr>
</tbody>
</table>
Chapter 1

Overview

1.1 Neon

This article is about the noble gas. For other uses, see Neon (disambiguation).

Neon is a chemical element with symbol Ne and atomic number 10. It is in group 18 (noble gases) of the periodic table. Neon is a colorless, odorless, inert monatomic gas under standard conditions, with about two-thirds the density of air. It was discovered (along with krypton and xenon) in 1898 as one of the three residual rare inert elements remaining in dry air, after nitrogen, oxygen, argon and carbon dioxide are removed. Neon was the second of these three rare gases to be discovered, and was immediately recognized as a new element from its bright red emission spectrum. The name neon is derived from the Greek word, νέον (néon), neuter singular form of νέος [neos], meaning new. Neon is chemically inert and forms no uncharged chemical compounds.

During cosmic nucleogenesis of the elements, large amounts of neon are built up from the alpha-capture fusion process in stars. Although neon is a very common element in the universe and solar system (it is fifth in cosmic abundance after hydrogen, helium, oxygen and carbon), it is very rare on Earth. It composes about 18.2 ppm of air by volume (this is about the same as the molecular or mole fraction), and a smaller fraction in Earth’s crust. The reason for neon’s relative scarcity on Earth and the inner (terrestrial) planets, is that neon forms no compounds to fix it to solids, and is highly volatile, therefore escaping from the planetesimals under the warmth of the newly ignited Sun in the early Solar System. Even the atmosphere of Jupiter is somewhat depleted of neon, presumably for this reason.

Neon gives a distinct reddish-orange glow when used in either low-voltage neon glow lamps or in high-voltage discharge tubes or neon advertising signs. The red emission line from neon is also responsible for the well known red light of helium–neon lasers. Neon is used in a few plasma tube and refrigerant applications but has few other commercial uses. It is commercially extracted by the fractional distillation of liquid air. It is considerably more expensive than helium, since air is its only source.

1.1.1 History

Neon gas-discharge lamps forming the symbol for neon “Ne”

Neon (Greek νέον (néon), neuter singular form of νέος meaning “new”), was discovered in 1898 by the British chemists Sir William Ramsay (1852–1916) and Morris W. Travers (1872–1961) in London, England. Neon was discovered when Ramsay chilled a sample of air until it became a liquid, then warmed the liquid and captured the gases as they boiled off. The gases nitrogen, oxygen, and argon had been identified, but the remaining gases were isolated in roughly their order of abundance, in a six-week period beginning at the end of May 1898. First to be identified was krypton. The next, after krypton had been removed, was a gas which gave a brilliant red light under spectroscopic discharge. This gas, identified in June, was named neon, the Greek analogue of “novum”, (new), the name Ramsay’s son suggested. The characteristic brilliant red-orange color that is emitted by gaseous neon when excited electrically was noted immediately; Travers later wrote, “the blaze of crimson light from the tube told its own story and was a sight to dwell upon and never forget.” Finally, the same team discovered xenon by the same process, in June.

Neon’s scarcity precluded its prompt application for light-
Neon played a role in the basic understanding of the nature of atoms in 1913, when J. J. Thomson, as part of his exploration into the composition of canal rays, channeled streams of neon ions through a magnetic and an electric field and measured their deflection by placing a photographic plate in their path. Thomson observed two separate patches of light on the photographic plate (see image), which suggested two different parabolas of deflection. Thomson eventually concluded that some of the atoms in the neon gas were of higher mass than the rest. Though not understood at the time by Thomson, this was the first discovery of isotopes of stable atoms. It was made by using a crude version of an instrument we now term as a mass spectrometer.

1.1.2 Isotopes

Main article: Isotopes of neon

Neon is the second lightest inert gas. Neon has three stable isotopes: $^{20}$Ne (90.48%), $^{21}$Ne (0.27%) and $^{22}$Ne (9.25%). $^{21}$Ne and $^{22}$Ne are partly primordial and partly nucleogenic (i.e., made by nuclear reactions of other nuclides with neutrons or other particles in the environment) and their variations in natural abundance are well understood. In contrast, $^{20}$Ne (the chief primordial isotope made in stellar nucleosynthesis) is not known to be nucleogenic or radiogenic (save for cluster decay production, which is thought to produce only a small amount). The causes of the variation of $^{20}$Ne in the Earth have thus been hotly debated.\footnote{14}

The principal nuclear reactions which generate nucleogenic neon isotopes start from $^{24}$Mg and $^{25}$Mg, which produce $^{21}$Ne and $^{22}$Ne, respectively, after neutron capture and immediate emission of an alpha particle. The neutrons that produce the reactions are mostly produced by secondary spallation reactions from alpha particles, in turn derived from uranium-series decay chains. The net result yields a trend towards lower $^{20}$Ne/$^{22}$Ne and higher $^{21}$Ne/$^{22}$Ne ratios observed in uranium-rich rocks such as granites.\footnote{15} Neon-21 may also be produced in a nucleogenic reaction, when $^{20}$Ne absorbs a neutron from various natural terrestrial neutron sources.

In addition, isotopic analysis of exposed terrestrial rocks has demonstrated the cosmogenic (cosmic ray) production of $^{21}$Ne. This isotope is generated by spallation reactions on magnesium, sodium, silicon, and aluminium. By analyzing all three isotopes, the cosmogenic component can be resolved from magmatic neon and nucleogenic neon. This suggests that neon will be a useful tool in determining cosmic exposure ages of surface rocks and meteorites.\footnote{16}

Similar to xenon, neon content observed in samples of volcanic gases is enriched in $^{20}$Ne, as well as nucleogenic $^{21}$Ne, relative to $^{22}$Ne content. The neon isotopic content of these mantle-derived samples represents a non-atmospheric source of neon. The $^{20}$Ne-enriched components are attributed to exotic primordial rare gas components in the Earth, possibly representing solar neon. Elevated $^{20}$Ne abundances are found in diamonds, further suggesting a solar neon reservoir in the Earth.\footnote{17}

1.1.3 Characteristics

Neon is the second-lightest noble gas, after helium. It glows reddish-orange in a vacuum discharge tube. Also, neon has the narrowest liquid range of any element: from...
1.1. NEON

Neon discharge tube

24.55 K to 27.05 K (−248.45 °C to −245.95 °C, or −415.21 °F to −410.71 °F). It has over 40 times the refrigerating capacity of liquid helium and three times that of liquid hydrogen (on a per unit volume basis). In most applications it is a less expensive refrigerant than helium.\[1\][18][19]

Spectrum of neon with ultraviolet (at left) and infrared (at right) lines shown in white

Neon plasma has the most intense light discharge at normal voltages and currents of all the noble gases. The average color of this light to the human eye is red-orange due to many lines in this range; it also contains a strong green line which is hidden, unless the visual components are dispersed by a spectroscope.\[20\]

Two quite different kinds of neon lighting are in common use. Neon glow lamps are generally tiny, with most operating at about 100–250 volts.\[21\] They have been widely used as power-on indicators and in circuit-testing equipment, but light-emitting diodes (LEDs) now dominate in such applications. These simple neon devices were the forerunners of plasma displays and plasma television screens.\[22][23\] Neon signs typically operate at much higher voltages (2–15 kilovolts), and the luminous tubes are commonly meters long.\[24\] The glass tubing is often formed into shapes and letters for signage as well as architectural and artistic applications.

1.1.4 Occurrence

Stable isotopes of neon are produced in stars. $^{20}$Ne is created in fusing helium and oxygen in the alpha process, which requires temperatures above 100 megakelvins and masses greater than 3 solar masses.

Neon is abundant on a universal scale; it is the fifth most abundant chemical element in the universe by mass, after hydrogen, helium, oxygen, and carbon (see chemical element). Its relative rarity on Earth, like that of helium, is due to its relative lightness, high vapor pressure at very low temperatures, and chemical inertness, all properties which tend to keep it from being trapped in the condensing gas and dust clouds which resulted in the formation of smaller and warmer solid planets like Earth.

Neon is monatomic, making it lighter than the molecules of diatomic nitrogen and oxygen which form the bulk of Earth’s atmosphere; a balloon filled with neon will rise in air, albeit more slowly than a helium balloon.\[25\]

Neon’s abundance in the universe is about 1 part in 750 and in the Sun and presumably in the proto-solar system nebula, about 1 part in 600. The Galileo spacecraft atmospheric entry probe found that even in the upper atmosphere of Jupiter, the abundance of neon is reduced (depleted) by about a factor of 10, to a level of 1 part in 6,000 by mass. This may indicate that even the ice-planetesimals which brought neon into Jupiter from the outer solar system, formed in a region which was too warm for them to have kept their neon (abundances of heavier inert gases on Jupiter are several times that found in the Sun).\[26\]

Neon is rare on Earth, found in the Earth’s atmosphere at 1 part in 55,000, or 18.2 ppm by volume (this is about the same as the molecule or mole fraction), or 1 part in 79,000 of air by mass. It comprises a smaller fraction in the crust. It is industrially produced by cryogenic fractional distillation of liquefied air.\[1\]

1.1.5 Applications

Neon signs may use neon along with other noble gases

Neon is often used in signs and produces an unmistakable bright reddish-orange light. Although still referred to as “neon”, other colors are generated with different noble gases or by varied colors of fluorescent lighting.

Neon is used in vacuum tubes, high-voltage indicators, lightning arrestors, wave meter tubes, television tubes, and helium–neon lasers. Liquefied neon is commercially
used as a cryogenic refrigerant in applications not requiring the lower temperature range attainable with more extreme liquid helium refrigeration.

Both neon gas and liquid neon are relatively expensive – for small quantities, the price of liquid neon can be more than 55 times that of liquid helium. The driver for neon’s expense is the rarity of neon, which unlike helium, can only be obtained from air. The triple point temperature of neon (24.5561 K) is a defining fixed point in the International Temperature Scale of 1990.[2]

### 1.1.6 Compounds

Neon is the first p-block noble gas. Neon is generally considered to be inert. No true neutral compounds of neon are known. However, the ions Ne⁺, (NeAr)⁺, (NeH)⁺, and (HeNe⁺) have been observed from optical and mass spectrometric studies, and there are some unverified reports of an unstable hydrate.[1]

### 1.1.7 See also

- Expansion ratio
- Neon sign
- Neon lamp

### 1.1.8 References


[7] Group 18 refers to the modern numbering of the periodic table. Older numberings described the rare gases as Group 0 or Group VIIA (sometimes shortened to 8). See also Group (periodic table).


1.1.9 External links

- Neon at *The Periodic Table of Videos* (University of Nottingham)
- WebElements.com – Neon.
- It’s Elemental – Neon
- USGS Periodic Table – Neon
- Atomic Spectrum of Neon
- Neon Museum, Las Vegas
Chapter 2

Isotopes

2.1 Isotopes of neon

Neon (Ne) possesses three stable isotopes, $^{20}$Ne, $^{21}$Ne, and $^{22}$Ne. In addition, 16 radioactive isotopes have been discovered ranging from $^{16}$Ne to $^{34}$Ne, all short-lived. The longest-lived is $^{24}$Ne with a half-life of 3.38 minutes. All others are under a minute, most under a second. The least stable is $^{16}$Ne with a half-life of $9\times10^{-21}$ s. See isotopes of carbon for notes about the measurement.

Standard atomic mass: 20.1797(6) u

A chart showing the abundances of the naturally-occurring isotopes of neon.

2.1.1 Table

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<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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Notes

- The isotopic composition refers to that in air.
- The precision of the isotope abundances and atomic mass is limited through variations. The given ranges should be applicable to any normal terrestrial material.
- Geologically exceptional samples are known in which the isotopic composition lies outside the reported range. The uncertainty in the atomic mass may exceed the stated value for such specimens.
- Commercially available materials may have been subjected to an undisclosed or inadvertent isotopic fractionation. Substantial deviations from the given mass and composition can occur.
- Values marked # are not purely derived from experimental data, but at least partly from systematic trends. Spins with weak assignment arguments are enclosed in parentheses.
- Uncertainties are given in concise form in parentheses after the corresponding last digits. Uncertainty values denote one standard deviation, except isotopic composition and standard atomic mass from IUPAC which use expanded uncertainties.

2.1.2 References

- Isotope masses from:

- Isotopic compositions and standard atomic masses from:

- Half-life, spin, and isomer data selected from the following sources. See editing notes on this article’s talk page.
2.1. ISOTOPES OF NEON


Chapter 3

Miscellany

3.1 Neon sign

See also: Neon lighting
In the signage industry, neon signs are electric signs lighted by long luminous gas-discharge tubes that contain rarefied neon or other gases. They are the most common use for neon lighting, which was first demonstrated in a modern form in December 1910 by Georges Claude at the Paris Motor Show. While they are used worldwide, neon signs were extremely popular in the United States from about 1920–1960. The installations in Times Square were famed, and there were nearly 2000 small shops producing neon signs by 1940. In addition to signage, neon lighting is now used frequently by artists and architects, and (in a modified form) in plasma display panels and televisions. The signage industry has declined in the past several decades, and cities are now concerned with preserving and restoring their antique neon signs.

3.1.1 History

The neon sign is an evolution of the earlier Geissler tube, which is an electrified glass tube containing a "rarefied" gas (the gas pressure in the tube is well below atmospheric pressure). When a voltage is applied to electrodes inserted through the glass, an electrical glow discharge results. Geissler tubes were quite popular in the late 1800s, and the different colors they emitted were characteristics of the gases within. They were, however, unsuitable...
3.1. NEON SIGN

for general lighting; the pressure of the gas inside typically declined in use. The direct predecessor of neon tube lighting was the Moore tube, which used nitrogen or carbon dioxide as the luminous gas and a patented mechanism for maintaining pressure; Moore tubes were sold for commercial lighting for a number of years in the early 1900s.[8][9]

The discovery of neon in 1898 included the observation of a brilliant red glow in Geissler tubes.[10] Immediately following neon’s discovery, neon tubes were used as scientific instruments and novelties.[11] A sign created by Perley G. Nutting and displaying the word “neon” may have been shown at the Louisiana Purchase Exposition of 1904, although this claim has been disputed.[12] In any event, the scarcity of neon would have precluded the development of a lighting product. However, after 1902, Georges Claude’s company in France, Air Liquide, began producing industrial quantities of neon, essentially as a byproduct of their air liquefaction business.[9] From December 3–18, 1910, Claude demonstrated two 12-metre (39 ft) long bright red neon tubes at the Paris Motor Show.[1][13] This demonstration lit a peristyle of the Grand Palais (a large exhibition hall).[14] Claude’s associate, Jacques Fonseque, realized the possibilities for a business based on signage and advertising. By 1913 a large sign for the vermouth Cinzano illuminated the night sky in Paris, and by 1919 the entrance to the Paris Opera was adorned with neon tube lighting.[2] Over the next several years, patents were granted to Claude for two innovations still used today: a “bombardment” technique to remove impurities from the working gas of a sealed sign, and a design for the internal electrodes of the sign that prevented their degradation by sputtering.[9]

In 1923, Georges Claude and his French company Claude Neon introduced neon gas signs to the United States by selling two to a Packard car dealership in Los Angeles. Earle C. Anthony purchased the two signs reading “Packard” for $1,250 apiece.[1] Neon lighting quickly became a popular fixture in outdoor advertising. Visible even in daylight, people would stop and stare at the first neon signs for hours, dubbed “liquid fire.”[15]

The next major technological innovation in neon lighting and signs was the development of fluorescent tube coatings. Jacques Risler received a French patent in 1926 for these.[3] Neon signs that use an argon/mercury gas mixture emit a good deal of ultraviolet light. When this light is absorbed by a fluorescent coating, preferably inside the tube, the coating (called a “phosphor”) glows with its own color. While only a few colors were initially available to sign designers, after the Second World War (1939–1945) phosphor materials were researched intensively for use in color televisions. About two dozen colors were available to neon sign designers in the 1960s, and today there are nearly 100 available colors.[5]

3.1.2 Fabrication

An enormous number of colors can be created by combinations of different gases and fluorescent coatings in the tube.

Neon tube signs[16][17][18][19] are produced by the craft of bending glass tubing into shapes. A worker skilled in this craft is known as a glass bender, neon bender or tube bender. The neon tube is made out of 4-5’ straight sticks of colored glass tubing. Tubing in external diameters ranging from about 8–15 mm with a 1 mm wall thickness is most commonly used, although 6 mm tubing is now commercially available in colored glass tubes. The tube is heated in sections using several types of burners that are selected according to the amount of glass to be heated for each bend. These burners include ribbon, cannon, or crossfires, as well as a variety of gas torches. Ribbon burners are strips of fire that make the gradual bends while crossfires, when used, make the sharp bends.

The interior of the tubes may be coated with a thin phosphorescent powder coating, affixed to the interior wall of the tube by a binding material. The tube is filled with a purified gas mixture, and the gas ionized by a high voltage applied between the ends of the sealed tube through cold cathodes welded onto the ends. The color of the light emitted by the tube may be just that coming from the gas, or the light from the phosphor layer. Different phosphor-coated tubing sections may be butt welded together using
glass working torches to form a single tube of varying colors, for effects such as a sign where each letter displays a different color letter within a single word, such as shown in the sign in the photo above right.

“Neon” is used to denote the general type of lamp, but neon gas is only one of the types of tube gases principally used in commercial application. Pure neon gas is used to produce only about a third of the colors. The greatest number of colors is produced by filling with another inert gas, argon, and a drop of mercury (Hg) which is added to the tube immediately after purification. When the tube is ionized by electrification, the mercury evaporates into mercury vapor, which fills the tube and produces strong ultraviolet light. The ultraviolet light thus produced excites the various phosphor coatings designed to produce different colors. Even though this class of neon tubes use no neon at all, they are still denoted as “neon.” Mercury-bearing lamps are a type of cold-cathode fluorescent lamps.

Each type of neon tubing produces two completely different possible colors, one with neon gas and the other with argon/mercury. Some “neon” tubes are made without phosphor coatings for some of the colors. Clear tubing filled with neon gas produces the ubiquitous yellowish orange color with the interior plasma column clearly visible, and is the cheapest and simplest tube to make. Traditional neon glasses in America over 20 years old are lead glass that are easy to soften in gas fires, but recent environmental and health concerns of the workers has prompted manufacturers to seek more environmentally safe special soft glass formulas. One of the vexing problems avoided this way is lead glass’ tendency to burn into a black spot emitting lead fumes in a bending flame too rich in the fuel/oxygen mixture. Another traditional line of glasses was colored soda lime glasses coming in a myriad of glass color choices, which produce the highest quality, most hypnotically vibrant and saturated hues. Still more color choices are afforded in either coating, or not coating, these colored glasses with the various available exotic phosphors.

**Long lifetime**

It is the wide range of colors and the ability to make a tube that can last for years if not decades without replacement, that makes this an art. Since these tubes require so much custom labor, they would have very little economic viability if they did not have such a long lifetime when well processed. The intensity of neon light produced increases slowly as the tube diameter grows smaller, that is, the intensity varies inversely with the square root of the interior diameter of the tubing, and the resistance of the tube increases as the tubing diameter decreases accordingly, because tube ionization is greatest at the center of the tube, and the ions migrate to and are recaptured and neutralized at the tube walls. The greatest cause of neon tube failure is the gradual absorption of neon gas by high voltage ion implantation into the interior glass walls of the tubes which depletes the gas, and eventually causes the tube resistance to rise to a level that it can no longer light at the rated voltage, but this may take well over 50 years if the tube is properly processed during bombardment and gas back-filling.

The actual cause of 80% of neon sign failures is the burnout of the high voltage electrical wires connecting the tubes inside of metal conduits. A very common type of neon sign is made from a formed metal box having a colored translucent face, called “channel lettering”. Newer channel letter signs are being replaced by high brightness LEDs.

This long lifetime has created a practical market for neon use for interior architectural cove lighting in a wide variety of uses including homes, where the tube can be bent to any shape, fitted in a small space, and can do so without requiring tube replacement for a decade or more.

**Tube bending**

A section of the glass is heated until it is malleable; then it is bent into shape and aligned to a neon sign pattern paper containing the graphics or lettering that the final product will ultimately conform to. This is where the art of neon comes in, that takes some artisans from a year up to several years of practice to master. A tube bender corks off the hollow tube before heating and holds a latex rubber blow hose at the other end, through which he gently presses a small amount of air to keep the tube diameter constant as it is bending. The trick of bending is to bend one small section or bend at a time, heating one part of the tubing so that it is soft, without heating some other part of the tube as well, which would make the bend uncontrollable. A bend, once the glass is heated, must be brought to the pattern and fitted rapidly before the glass hardens again because it is difficult to reheat once completely cooled without risking breakage. It is frequently necessary to skip one or more bends and come back to it later, by measuring carefully along the length of the tube. One tube letter may contain 7-10 small bends, and mistakes are not easily corrected without going back and starting all over again. If more tubing is required, another piece is welded onto it, or the parts can be all welded onto each other at the final step. The finished tube must be absolutely vacuum tight to operate, and it must be vacuum clean inside. Once the tube is filled with mercury, if any mistake is made after that, the entire tube has to, or should be, started over anew, because breathing heated mercury impregnated glass and phosphor causes long term heavy metal poisoning in neon workers. Sticks of tubing are joined until the tube reaches an impractical size, and several tubes are joined in series with the high voltage neon transformer. Extreme ends of the electrical circuit must be isolated from each other to prevent tube puncture and buzzing from corona effect.
3.1. NEON SIGN

Bombardment

A cold cathode electrode is melted (or welded) to each end of the tube as it is finished. The electrodes are also traditionally lead glass and contain a small metal shell with two wires protruding through the glass to which the sign wiring will later be attached. All welds and seals must be perfectly leak-proof to high vacuum before proceeding further.

The tube is attached to a manifold which is itself attached to a high-quality vacuum pump. The tube is then evacuated of air until it reaches near-vacuum. During evacuation, a high current is forced through the tube via the wires protruding from each electrode (in a process known as “bombarding”). This current and voltage is far above the level that occurs in final operation of the tube. The current depends on the specific electrodes used and the diameter of the tube, but is typically in the 45 mA to 80 mA range, at an applied voltage usually between 5,000-36,000 V DC. The bombarding transformer acts as an adjustable constant current source, and the voltage produced depends on the length and pressure of the tube. Typically the operator will maintain the pressure as high as the bombarder will allow to ensure maximum power dissipation and heating.

This very high power dissipation in the tube heats the glass walls to a temperature of several hundred degrees Celsius, and any dirt and impurities within are drawn off in the gasified form by the vacuum pump. The greatest impurities that are driven off this way are the gases that coat the inside wall of the tubing by adsorption, mainly oxygen, carbon dioxide, and especially water vapor. The current also heats the electrode metal to over 600°C, producing a bright orange incandescent color. The cathodes are prefabricated hollow metal shells with a small opening (sometimes a ceramic donut aperture) which contains in the interior surface of the shell a light dusting of a cold cathode low work function powder (usually a powder ceramic molar eutectic point mixture including BaCO$_2$), combined with other alkaline earth oxides, which reduces to BaO$_2$ when heated to about 500 degrees F, and reduces the work function of the electrode for cathodic emission. Barium Oxide has a work function of roughly 2 whereas tungsten at room temperature has a work function exponentially 100 times more, or 4.0. This represents the cathode drop or electron energy required to remove electrons from the surface of the cathode. This avoids the necessity of using a hot wire thermoelectric cathode such as is used in conventional fluorescent lamps. And for that reason, neon tubes are extremely long lived when properly processed, in contrast to fluorescent tubing, because there is no wire filament as there is in a fluorescent tube to burn out like a common light bulb. The principal purpose of doing this is to purify the interior of the tube before the tube is sealed off so that when it is operated, these gases and impurities are not driven off and released by the plasma and the heat generated into the sealed tube, which would quickly burn the metal cathodes and mercury droplets (if pumped with argon/mercury) and oxidize the interior gases and cause immediate tube failure. The more thorough the purification of the tube is, the longer lasting and stable the tube will be in actual operation. Once these gases and impurities are liberated under pre-filling bombardment into the tube interior they are quickly evacuated by the pump.

While still attached to the manifold, the tube is allowed to cool while pumping down to the lowest pressure the system can achieve. It is then filled to a low pressure of a few torr of neon (millimeters of mercury) with one of the noble gases, or a mixture of them, and sometimes a small amount of mercury. This gas fill pressure represents roughly 1/100th of the pressure of the atmosphere. The required pressure depends on the gas used and the diameter of the tube, with optimal values ranging from 6 Torr (0.8 kPa) (for a long 20 mm tube filled with argon/mercury) to 27 Torr (3.6 kPa) (for a short 8 mm diameter tube filled with pure neon). Neon or argon are the most common gases used; krypton, xenon, and helium are used by artists for special purposes but are not used alone in normal signs. A premixed combination of argon and helium is often used in lieu of pure argon when a tube is to be installed in a cold climate, since the helium increases voltage drop (and thus power dissipation), warming the tube to operating temperature faster. Neon glows bright red or reddish orange when lit. When argon or argon/helium is used, a tiny droplet of mercury is added. Argon by itself is very dim pale lavender when lit, but the droplet of mercury fills the tube with mercury vapor when sealed, which then emits ultraviolet light upon electrification. This ultraviolet emission allows finished argon/mercury tubes to glow with a variety of bright colors when the tube has been coated on the interior with ultraviolet-sensitive phosphors after being bent into shape.

Heat processed neon tubes

An alternative way of processing finished neon tubes has also been used. Because the only purpose of bombardment by electrical means is to purify the interior of tubes, it is also possible to produce a tube by heating the tube externally either with a torch or with an oven, while heating the electrode with a radio frequency induction heating (RFIH) coil. While this is less productive, it creates a cleaner custom tube with significantly less cathode damage, longer life and brilliance, and can produce tubes of very small sizes and diameters, down to 6mm OD. The tube is heated thoroughly under high vacuum without external electrical application, until the outgassed gases can be seen to have been totally depleted and the pressure drops to a high vacuum again. Then the tube is filled, sealed and the mercury dropped and shaken.
**Electrical wiring**

The finished glass pieces are illuminated by either a neon sign transformer or a switched-mode power supply running at voltages ranging between 3-15 kV and currents between 20 and 120 mA. These power supplies operate as constant-current sources (a high voltage supply with a very high internal impedance), since the tube has a negative characteristic electrical impedance. Standard tube tables established in the early days of neon are still used that specify the gas fill pressures, in either Ne or Hg/Ar, as a function of tube length in feet, tube diameter and transformer voltage.

The standard traditional neon transformer, a magnetic shunt transformer, is a special non-linear type designed to keep the voltage across the tube raised to whatever level is necessary to produce the fixed current needed. The voltage drop of a tube is proportional to length and so the maximum voltage and length of tubing fed from a given transformer is limited.

Compact high frequency inverter-converter transformers developed in the early 1990s are used, especially when low Radio Frequency Interference (RFI) is needed, such as in locations near high-fidelity sound equipment. At the typical frequency of these solid state transformers, the plasma electron-ion recombination time is too long to extinguish and reignite the plasma at each cycle, unlike the case at power line frequency. The plasma does not broadcast high frequency switching noise and remains ionized continually, becoming radio noise free.

The most common current rating is 30 mA for general use, with 60 mA used for high-brightness applications like channel letters or architectural lighting. 120 mA sources are occasionally seen in illuminating applications, but are uncommon since special electrodes are required to withstand the current, and an accidental shock from a 120 mA transformer is much more likely to be fatal than from the lower current supplies.

The efficiency of neon lighting ranges between that of ordinary incandescent lights and that of fluorescent lamps, depending on color. On a per-watt basis, incandescents produce 10 to 20 lumens, while fluorescents produce 50 to 100 lumens. Neon light efficiency ranges from 10 lumens per watt for red, up to 60 lumens for green and blue when these colors result from internal phosphor coatings.\[^{20}\]

**Blocking out and coating**

A trick of the eye is used to produce visually distinct neon display segments by blocking out parts of the tube with an opaque coating. One complete assembly may be composed of contiguous tube elements joined by glass welding to one another so that the same current passes through, for example, several letters joined end to end from cathode to cathode. To the untrained eye, this looks like separate tubes, but the electrical splice is the plasma inside the crossover glass itself. The entire tube lights up, but the segments that the viewer is not supposed to see are covered with highly opaque special black or gray glass paint. This heat-resistant coating is either painted on or dipped. Without blockout paint, the unintended visual connections would make the display appear confusing.

In most mass-produced low-priced signs today, clear glass tubing is coated with translucent paint to produce colored light. In this way, several different colors can be produced inexpensively from a single glowing tube. Over time, elevated temperatures, thermal cycling, or exposure to weather may cause the colored coating to flake off the glass or change its hue. A more expensive alternative is to use high-quality colored glass tubing, which retains a more stable appearance as it ages.

**3.1.3 Applications**

Light-emitting tubes form colored lines with which a text can be written or a picture drawn, including various decorations, especially in advertising and commercial signage. By programming sequences of switching parts on and off, there are many possibilities for dynamic light patterns that form animated images.

In some applications, neon tubes are increasingly being replaced with LEDs, given the steady advance in LED luminosity and decreasing cost of high-intensity LEDs.\[^{21}\] However, proponents of neon technology maintain that they still have significant advantages over LEDs.\[^{22}\]

Neon illumination is valuable to invoke 1940s or 1950s nostalgia in marketing and in historic restoration of architectural landmarks from the neon era. Architecture in the streamline moderne era often deployed neon to accent structural pigmented glass built into the façade of a 1930s or 1940s structure; many of these buildings now qualify for inclusion on historic registers such as the US National Register of Historic Places if their historic integrity is faithfully maintained.\[^{23}\]
3.1. NEON SIGN

3.1.4 Images of neon signs

- Helium
- Neon
- Argon
- Krypton
- Xenon
- A deteriorated, 1950s era sign typical of Googie architecture; “Ships” was a chain of coffee shops in Los Angeles.[1]
- Original Whitey’s Restaurant “EAT” sign in Arlington, VA


3.1.5 See also

- Neon lighting
- Gas discharge lamp
- Crackle tube
- Plasma globe
- Pundit Light
- Neon message board
- Westinghouse Sign
- Timeline of lighting technology

3.1.6 References


[14] Testelin, Xavier. “Reportage - Il était une fois le néon No. 402”. Retrieved 2010-12-06. Claude’s 1910 demonstration of neon lighting lit the peristyle of the Grand Palais in Paris; this webpage includes a contemporary photograph that gives an impression of it. It is part of an extensive selection of images of neon lighting; see “Reportage - Il était une fois le néon”.

[15] These anecdotes and the phrase “liquid fire” are often used in references discussing the first neon tube lights in Los Angeles, but the primary source is not provided. One example of a typical, tertiary reference is Bellis, Mary. “The History of Neon Signs: Georges Claude and Liquid Fire”. *about.com*.


3.1.7 Further reading

- Keen, Judy (October 6, 2008). “Save neon signs, fans urge”. USA Today.

3.1.8 External links

- “Neon Muzeum”. NeonMuzeum.com. Website of an organization devoted to preserving Polish neon signs; in English.

3.2 Neon lamp

See also: Neon lighting

A neon lamp (also neon glow lamp) is a miniature gas discharge lamp. The lamp typically consists of a small glass capsule that contains a mixture of neon and other gases at a low pressure and two electrodes (an anode and a cathode). When sufficient voltage is applied and sufficient current is supplied between the electrodes, the lamp produces an orange glow discharge. The glowing portion in the lamp is a thin region near the cathode; the larger and much longer neon signs are also glow discharges, but they use the positive column which is not present in the ordinary neon lamp. Neon glow lamps are widely used as indicator lamps in the displays of electronic instruments and appliances.

Neon was discovered in 1898 by William Ramsay and Morris W. Travers. The characteristic, brilliant red color that is emitted by gaseous neon when excited electrically was noted immediately; Travers later wrote, “the blaze of crimson light from the tube told its own story and was a sight to dwell upon and never forget.”[1]

Neon’s scarcity precluded its prompt application for electric lighting along the lines of Moore tubes, which used electric discharges in nitrogen. Moore tubes were commercialized by their inventor, Daniel McFarlan Moore, in the early 1900s. After 1902, Georges Claude’s company, Air Liquide, was producing industrial quantities of neon as a byproduct of his air liquefaction business, and in December 1910 Claude demonstrated modern neon lighting based on a sealed tube of neon. In 1915 a U.S. patent was issued to Claude covering the design of the electrodes for neon tube lights;[2] this patent became the basis for the monopoly held in the U.S. by his company, Claude Neon Lights, through the early 1930s.[3]

Around 1917, Daniel Moore developed the neon lamp while working at the General Electric Company. The lamp has a very different design from the much larger neon tubes used for neon lighting. The difference in design was sufficient that a U.S. patent was issued for the lamp in 1919.[4] A Smithsonian Institution website notes, “These small, low power devices use a physical principle called coronal discharge. Moore mounted two electrodes close together in a bulb and added neon or argon gas. The electrodes would glow brightly in red or blue, depending on the gas, and the lamps lasted for years. Since the electrodes could take almost any shape imaginable, a popular application has been fanciful decorative lamps. Glow lamps found practical use as indicators in instrument panels and in many home appliances until the widespread commercialisation of Light Emitting Diodes (LEDs) in the 1970s.”[5]
3.2. NEON LAMP

3.2.2 Description

A small electric current, (For a 5 mm bulb diameter NE-2 lamp, the quiescent current is about 400 uA) which may be AC or DC, is allowed through the tube, causing it to glow orange-red. The gas is typically a Penning mixture, 99.5% neon and 0.5% argon, which has lower striking voltage than pure neon, at a pressure of 1-20 torr. The lamp glow discharge lights at its striking voltage. The voltage required to sustain the discharge is significantly (~30%) lower than the striking voltage. This is due to the organization of positive ions near the cathode. When driven from a DC source, only the negatively charged electrode (cathode) will glow. When driven from an AC source, both electrodes will glow (each during alternate half cycles). These attributes make neon bulbs (with series resistors) a convenient low-cost voltage testers; they determine whether a given voltage source is AC or DC, and if DC, the polarity of the points being tested. Neon lamps operate using a low current glow discharge. Higher power devices, such as mercury-vapor lamps or metal halide lamps use a higher current arc discharge. Low pressure sodium-vapor lamps use a neon Penning mixture for warm up and can be operated as giant neon lamps if operated in a low power mode.

Once the neon lamp has reached breakdown, it can support a large current flow. Because of this characteristic, electrical circuitry external to the neon lamp must limit the current through the circuit or else the current will rapidly increase until the lamp is destroyed. For indicator-sized lamps, a resistor typically limits the current. Larger neon sign sized lamps often use a specially constructed high voltage transformer with high leakage inductance or other electrical ballast to limit the available current.

When the current through the lamp is lower than the current for the highest-current discharge path, the glow discharge may become unstable and not cover the entire surface of the electrodes.\(^6\) This may be a sign of aging of the indicator bulb, and is exploited in the decorative “flicker flame” neon lamps. However, while too low a current causes flickering, too high a current increases the wear of the electrodes by stimulating sputtering, which coats the internal surface of the lamp with metal and causes it to darken.

The potential needed to strike the discharge is higher than what is needed to sustain the discharge. When there is not enough current, the glow forms around only part of the electrode surface. Convective currents make the glowing areas flow upwards, not unlike the discharge in a Jacob's ladder. A photoionization effect can also be observed here, as the electrode area covered by the glow discharge can be increased by shining light at the lamp.

In comparison with incandescent light bulbs, neon lamps have much higher luminous efficacy. Incandescence is heat-driven light emission, so a large portion of the electric energy put into an incandescent bulb is converted into heat. Non-incandescent light sources such as neon light bulbs, fluorescent light bulbs, and light emitting diodes are therefore much more energy efficient than normal incandescent light bulbs. Green neon bulbs\(^7\) can produce up to 65 lumens per watt of power input, while white neon bulbs have an efficacy of around 50 lumens per watt. In contrast, a standard incandescent light bulb only produces around 13.5 lumens per watt.\(^8\)

3.2.3 Applications

Small neon lamps are most widely used as indicators in electronic equipment and appliances, due to their low power consumption, long life, and ability to operate off mains power. Larger lamps are used in neon signage. Most small neon (indicator-sized) lamps, such as the common NE-2, break down at between 90 and 110 volts. The breakdown feature of neon lamps allows them to be used as very simple voltage regulators or overvoltage protection devices. In the 1960s General Electric (GE), Signalite, and other firms made special extra-stable neon
CHAPTER 3. MISCELLANY

The digits of a Nixie tube.

Like other gas discharge lamps, the neon bulb has negative resistance; its voltage falls with increasing current after the bulb reaches its breakdown voltage. Therefore the bulb has hysteresis; its turn-off (extinction) voltage is lower than its turn-on (breakdown) voltage. This allows it to be used as an active switching element. Neon bulbs were used to make relaxation oscillator circuits for low frequency applications such as flashing warning lights, stroboscopes tone generators in electronic organs, and as time bases and deflection oscillators in early cathode ray oscilloscopes. Neon bulbs can also be bistable, and were even used to build digital logic circuits such as logic gates, flip-flop, binary memories, and digital counters. At least some of these lamps had a glow concentrated into a small spot on the cathode, which made them unsuited to use as indicators. These were sometimes called “circuit-component” lamps, the other variety being indicators. A variant of the NE-2 type lamp, the NE-77, had three parallel wires (in a plane) instead of the usual two. It was also intended primarily to be a circuit component.

Neon lamps have been historically used as microwave and millimeter-wave detectors (‘plasma diodes’ or GDDs-Glow Discharge Detectors) up to about 100 GHz or so and in such service were said to exhibit comparable sensitivity (of the order of a few 10s to perhaps 100 microvolts) to the familiar 1N23-type catwhisker-contacted silicon diodes once ubiquitous in microwave equipment. More recently it has been found that these lamps work well as detectors even at submillimeter (‘terahertz’) frequencies and they have been successfully used as pixels in several experimental imaging arrays at these wavelengths. In these applications the lamps are operated either in ‘starvation’ mode (to reduce lamp-current noise) or in normal glow discharge mode; some literature references their use as detectors of radiation up into the optical regime when operated in abnormal glow mode. Coupling of microwaves into the plasma may be in free space, in waveguide, by means of a parabolic concentrator (e.g., Winston cone), or via capacitive means via a loop or dipole antenna mounted directly to the lamp.

In 1930s radio sets, neon lamps were used as tuning indicators, called “tuneons” and would give a brighter glow as the station was tuned in correctly. Because of their comparatively fast response time, in the early development of television neon lamps were used as the light source in many mechanical-scan TV displays.

Although most of these applications use ordinary off-the-shelf dual-electrode lamps, in one case it was found that special 3 (or more) electrode lamps, with the extra electrode acting as the coupling antenna, provided even better results (lower noise and higher sensitivity). This discovery received an application patent (Kopeika et al.)

Neon lamps with several shaped electrodes were used as alphanumeric displays known as Nixie tubes. These have since been replaced by other display devices such as light emitting diodes, vacuum fluorescent displays, and liquid crystal displays. Novelty glow lamps with shaped electrodes (such as flowers and leaves), often coated with phosphors, have been made for artistic purposes. In some of these, the glow that surrounds an electrode is part of the design.

Unlit and lit neon lamps (NE-2 type) and their light spectrum.

Colour

Neon indicator lamps are normally orange, and are frequently used with a coloured filter over them to improve contrast and change their colour to red or a redder orange, or less often green.

They can also be filled with argon, krypton, or xenon rather than neon, or mixed with it. While the electrical operating characteristics remain similar, the lamps light with a bluish glow (including some ultraviolet) rather than...
3.2. NEON LAMP

Phosphor-coloured neon lamps

neon’s characteristic reddish-orange glow. Ultraviolet radiation then can be used to excite a phosphor coating inside of the bulb and provide a wide range of various colors, including white.[19] A mixture of neon and krypton can be used for green glow, but nevertheless “green neon” lamps are more commonly phosphor-based.

Latching

Since at least the 1940s, argon, neon, and phosphored glow thyratron latching indicators (which would light up upon an impulse on their starter electrode and extinguish only after their anode voltage was cut) were available for example as self-displaying shift registers in large-format, crawling-text dot-matrix displays,[20] or, combined in a 4x4, four-color phosphored-thyratron matrix, as a stackable 625-color RGBA pixel for large video graphics arrays.[21] Multiple-cathode and/or anode glow thyrratrons called Dekatrons could count forwards and backwards while their count state was visible as a glow on one of the numbered cathodes.[22] These were used as self-displaying divide-by-n counter/timer/prescalers in counting instruments, or as adder/subtracters in calculators.

3.2.4 See also

- Timeline of lighting technology
- List of light sources
- Pearson-Anson effect
- Magic eye tube
- Neon sign
- Light art

3.2.5 References

[6] C.R. Dougherty, T.D. Foulke, J.D. Harden, T.L. Hewitt, F.N. Peters, R.D. Smith, and J.W. Tuttle, *General Electric Glow Lamp Manual*, 2nd ed. (General Electric Company, 1966), Chapter 1: Physics and characteristics of glow lamps: Theory of gaseous conduction in the glow lamp, pages 1-3; see Fig. 1.1. Characteristic curve of the neon lamp. In the current vs. voltage curve in this article, the portion of the curve between points A and B correspond to the points E and F in Fig. 1.1. From p. 2: “After breakdown occurs the lamp passes through a transition region EF which is an unstable region of operation. The shaded portion indicates the region in which oscillation can occur. This region is often referred to as the negative resistance region, since voltage decreases as current increase[s], contrary to normal behavior in a resistive element. … As the current through the lamp is allowed to increase further, the lamp enters the normal glow discharge region represented by section FG where the point G corresponds to the point C in the current vs. voltage graph of this article] in Fig. 1.1 where voltage changes a minimum amount with a change in current. … In the normal glow region the glow is confined to a portion of the cathode surface and the amount of cathode surface covered by the glow is somewhat proportional to the tube current.”
[7] “Other emitted colors such as green, yellow and blue are available through secondary emission by coating the inside surface of the envelope with phosphor.” — International Light Technology


[18] See:


Chapter 4

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