

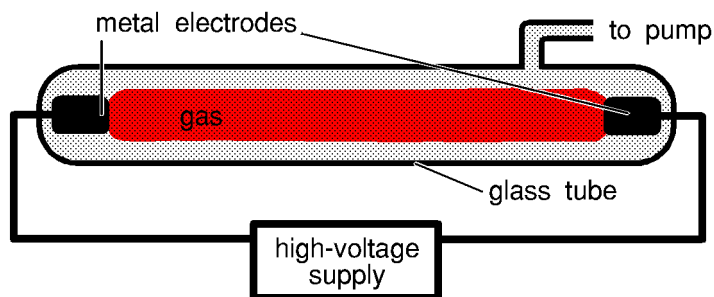
# Chemical of the Week

## GASES THAT EMIT LIGHT

When an electric current is passed through a gas, the gas emits light. This emission is exploited in many electric lamps. Fluorescent lamps, “neon” signs, and mercury-vapor and sodium-vapor lamps are common examples of this kind of electric lighting, called gas-discharge lamps. The colors of gas-discharge lamps vary widely depending on the identity of the gas and the construction of the lamp.

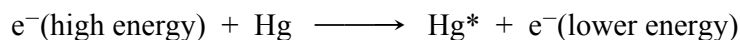
Gases at atmospheric pressure are not very good conductors of electricity. Therefore, to pass a current through a gas requires a special apparatus, called a gas-discharge tube. A gas-discharge tube is usually a glass tube with two electrodes sealed through its walls. When a voltage is applied to the two electrodes and the pressure of the gas in the tube is reduced, eventually a pressure is reached at which a current flows, and the gas begins to glow.

The glow usually appears when the pressure is between 5 and 15 torr. Neon signs operate in this way; a tube having an electrode at each end is filled with a gas at low pressure and a high voltage (generally in the range of 1000 to 5000 volts) is applied to the electrodes. The identity of the gas in the tube determines the color of the glow. Neon emits a red glow, helium produces pale yellow, and argon yields blue. Mercury vapor also emits blue light, and sodium vapor emits yellow. The majority of neon signs contain either neon gas or a mixture of neon and mercury vapor. A range of colors spanning the visible spectrum can be produced by using colored tubing or fluorescent coatings inside the tubes.

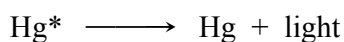


Fluorescent lamps are constructed in a similar fashion to neon lamps: a glass tube filled with mercury vapor and having an electrode at each end. However, the interior of the tube is coated with a fluorescent material, one that emits visible light when it is exposed to ultraviolet radiation. Ultraviolet radiation with a wavelength of 254 nm is produced along with the blue light that is emitted when an electric current is passed through mercury vapor. This ultraviolet radiation is invisible but contains more energy than the visible light emitted. The energy from the ultraviolet light is absorbed by the fluorescent coating inside the fluorescent lamp and re-emitted as visible light.

The light emitted by a gas, when an electric current flows through it, results from collisions between atoms in the gas and electrons of the current. When a voltage is applied to the two electrodes of a gas discharge tube, an electric field is created between the electrodes. In an electric field, a free electron will accelerate away from the negative electrode and toward the positive electrode. When such an electron collides with a gas molecule in its path, it may transfer some of its energy to the gas molecule, producing a gas molecule in an excited (high-energy) state.

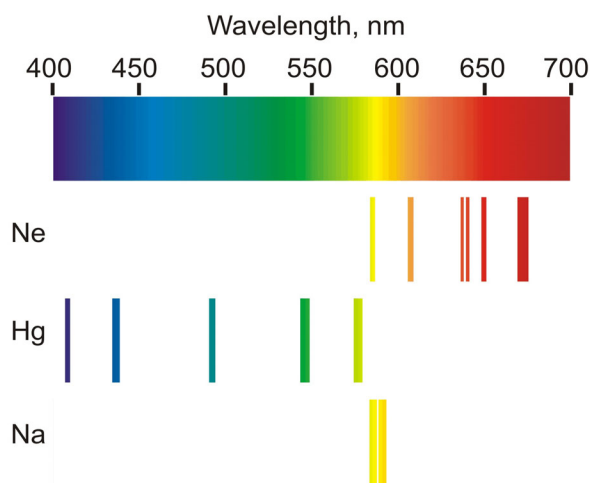


In this equation,  $\text{Hg}^*$  represents an atom of mercury in an excited state. The excited gas molecule does not remain in a high-energy state for long. It can return to its lowest-energy state, the ground state, by emitting its excess energy as light.

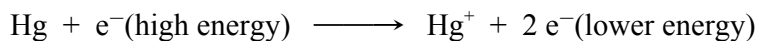


This is the source of the glow of a discharge tube.

Because atoms and molecules can exist only in certain specific energy states, the energy emitted by the excited molecule is limited to differences between these states. Only certain energies of light are emitted. The color of the glow is determined by the energy of the emitted light. The energy of the light is related to its wavelength by the equation  $E = hc/\lambda$ , where  $\lambda$  is the wavelength,  $h$  is Planck's constant ( $6.63 \times 10^{-34}$  J sec), and  $c$  is the speed of light ( $3.00 \times 10^8$  m/sec). Therefore, only certain wavelengths of light are emitted by gases in a discharge tube. The figure shows how wavelength is related to color and the wavelengths of light emitted by several gases.



Not all gas discharge lamps use gas at low pressure. In some discharge lamps, the pressure of the gas during operation is 1 to 2 atmospheres. These are “high-pressure” discharge lamps. Examples include mercury-vapor and sodium-vapor street lamps. These lamps operate in a similar fashion to low-pressure lamps. However, to start current flowing through a gas at high pressure requires a very high voltage. Once the current begins to flow, the voltage is reduced. In these lamps, the gas is actually ionized; the electrons traveling between the electrodes have enough energy to knock electrons out from the gas molecules.



The ions and electrons produced are accelerated in the electric field, contributing to the current and colliding with and exciting other molecules. In a high-pressure discharge, the concentration of excited molecules is much higher than in a low-pressure discharge. For this reason, these lamps are much brighter and more suitable for outdoor lighting.

Gas-discharge lamps are more efficient than incandescent lamps. Incandescent lamps operate by heating a tungsten filament so hot that it glows. A great deal of the energy consumed in this process is used to heat the filament. Only 18% of the energy consumed by a typical 100-watt incandescent light bulb is converted into visible light. In contrast, discharge lamps convert over 50% of the energy they consume into visible light. The efficiency of fluorescent lamps approaches 80%.

A gas-discharge tube is the heart of many lasers, such as the He-Ne laser. This laser contains a discharge tube filled with 85% helium and 15% neon at a pressure of 2–3 torr. At each end of the tube is a mirror. Some of the light emitted by the excited gas molecules becomes trapped between the mirrors, being reflected back and forth repeatedly. When this light passes excited gas molecules, it stimulates them to emit their energy parallel to the passing light. The effect of this is to amplify the intensity of the light beam trapped between the mirrors. (The word “laser” is an acronym from *light amplification by stimulated emission of radiation*.) One of the mirrors allows about 1% of the light to pass through it, and a parallel beam of monochromatic light leaves the tube. The He-Ne laser emits light with a wavelength of 632.8165 nm. This light is produced by excited neon atoms. The presence of helium in the discharge tube increases the intensity of neon's emission by a factor of 200. The helium absorbs energy from the electrons and transfers it to neon, which is a more efficient emitter.