

The Chemistry Of Light Bulbs

Everyday light bulbs rely not only on simple materials but on esoteric ions and compounds. And while we take their product, visible light, for granted, the inner workings of these deceptively simple gadgets depend on the complex behaviour of electrons.

Let's consider three types of light bulbs. The light bulb of the short-lived variety, is the standard tungsten incandescent bulb. Inside the glass, electricity flows through a thin filament of the element tungsten (chemical symbol, W, for its old name *wolfram*). Because the wire is so thin, resistance is high, and it raises the temperature of the tungsten wire, so chosen because of its high melting point of 3410 °C. At the bulb's temperature, which is about 1000° cooler, excited electrons that return to lower energy states release photons of a frequency that is visible to the human eye. The radiation is intense in the red to yellow regions but compared to daylight, the spectrum of an incandescent light bulb is very weak in the 400 to 500 nm region (blue). This would be nice to verify with a prism, and is the reason that plants don't do as well if grown under such light. Although the heat is not sufficient to melt the tungsten it would certainly fry the heck out of it in an oxidizing atmosphere. Thus manufacturers replace oxygen with a mixture of the less reactive nitrogen and the noble gas argon. Note that a vacuum would not be a good solution because the tungsten would vaporize even more easily and dramatically shorten the bulb's lifespan. Even within an argon-nitrogen atmosphere, however, the heat causes some of the tungsten to sublime. Some of it returns to the wire as it bounces off the argon gas, but a good deal ends up on the glass. This is one of the reasons bulbs tend to get darker with increased use. The glass suffers more abuse from plain old electrons which fly off the filament as if it were a cathode ray tube from a conventional television set. Such electrons cause tiny black spots to appear. These first caught Edison's attention, but he had never time for further investigations; otherwise, as David Bodanis suggests, Edison may have discovered electrons before J.J. Thomson. To create a more diffuse light but perhaps in an attempt to camouflage all the future damage, manufacturers treat light bulb glass with **hydrofluoric acid** (HF), which creates that familiar frosty look.

Eventually the tungsten wire becomes so thin, that it snaps, breaking the circuit and sending you off to the hardware store. At one point people got tired of the bulb's limited duration, and they invented the halogen light bulb. This still uses tungsten but along with argon it includes a small amount of a halogen gas, namely chlorine. The reactive gas combines with the tungsten vapour and deposits it again on the filament. In other words it recycles the tungsten, rather than letting it wastefully deposit on the glass. Of course it is very unlikely that the metal will be perfectly and evenly replaced all along the coiled filament. Weak spots eventually develop, and the coil still breaks, but it takes a lot longer, and halogens outlive their regular counterparts. The glass has to be able to withstand higher temperatures, so they use a purer form of silicon dioxide, one that unfortunately gets ruined by oils on our skin. If these bulbs are mishandled as such, the grease has to be washed away with alcohol.

To avoid wasting energy in the form of heat, fluorescent lights, ubiquitous in our schools, operate by a totally different principle. They contain a small amount of

mercury(Hg), which emits ultraviolet light when excited by electrical energy. The story cannot end there because ultraviolet(uv) is invisible to the human eye. The walls of the bulbs are coated with a phosphor, usually a halophosphate such as $\text{Ca}_5(\text{PO}_4)_3(\text{F,Cl})$ with ions of Sb^{3+} and Mn^{2+} that absorb the uv radiation. The excited electrons then release visible light, compliments of fluorescence. In this form of luminescence, an excited electron returns from a specific molecular orbital to a lower one without inverting its spin. The resulting light has the bulk of its intense wavelengths in the yellow and blue regions. But relative to natural light, fluorescence is weak in the red regions. Plants will again remain unhappy, unless you buy ore expensive fluorescent lights which try to compensate for this weakness by substituting antimony and manganese ions in the phosphor with europium and terbium ions.

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