Fluorescent lamps

A.C. Norman
anorman@bishopheber.cheshire.sch.uk

Lightbulbs have come a long way since the first discharge tubes were invented by William Crookes in 1870. He passed an electric discharge through gases at low pressure and found that the colour of the discharge seen depended on the gas in the tube. Such discharges gave rise to line spectra when the light was passed through a diffraction grating or a prism.

The first fluorescent lamps used either mercury vapour which gave a bluish light or sodium lamps which gave a yellow light. The latter had the advantage that they produced improved illumination in fog, but had the disadvantage that all colours except yellow looked different shades of grey. People walking home at night looked terrible. It really wasn't acceptable and modern fluorescent lights have coatings inside which absorb some of the initial radiation from the gas in the lamp and reradiate it at different frequencies to give a light closer to the continuous spectrum from the Sun.

Now compact fluorescent lamps are being used instead of ordinary lightbiulbs in the home with energy saving advantages.

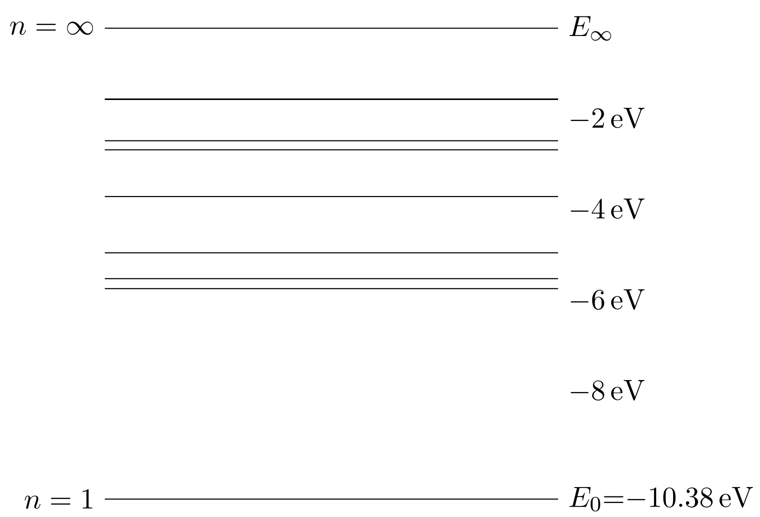
Fact File
$E_2 - E_1 = hf$, where E_2 and E_1 are electron energy levels in an atom and hf is the energy of the emitted photon.
$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
$c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$
$1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$

Warm-up problems

1. Describe how the characteristic colours arise in the excited gases in the discharge tubes in terms of electrons within the atom and line spectra.
2. What is meant by *ionization*, *excitation* and *de-excitation*?
3. Describe how the coatings worked in terms of energy levels and excitation.

Regular problems

4. Why did the early sodium lamps give such peculiar lighting, and *why were these these lamps good fog lamps rather than ordinary lighting?
5. The wavelengths of visible light emitted from a hydrogen lamp are 656 nm, 486 nm, 434 nm and 410 nm.
   (a) What photons energies do these correspond to?
   (b) If they are all due to electron jumps down to the second energy level in the hydrogen atom at $-3.4\,\mathrm{eV}$, calculate the next four energy levels in eV.
6. The diagram below shows the energy levels of mercury.



(a) Estimate the energy needed to excite the atom from the ground state to the highest energy level shown in the diagram.

(b) Mercury atoms in an excited state at -4.95 eV can de-excite directly or indirectly to the ground state. Show that the photons released could have six different energies.

(c) The highest energy photons from the previous part have wavelengths of 254 nm. Use this to calculate the energy of the level above the ground state for mercury.

WOTAN DELUX BULBS
Brightness 11W
Power consumption 20%
Lamp life 8000 h
Not dimmable
11W 240–250 V 50/60 Hz

7. (a) How much energy would be saved in a week if the modern lightbulb shown was on for 4 hr every night instead of an ordinary bulb giving the same illumination?

   (b) Why does this bulb have such a low power consumption compared to an ordinary bulb?

Extension problems

8. (a) Calculate the energy in eV of photons of sodium light of wavelength 590 nm.

   (b) *If the distance travelled by electrons in the sodium lamp between collisions is 1.0×10^{-4} m, calculate the electric field strength needed to cause the emission of sodium light.

   HINT: Electric field strength is measured in $\text{V}\,\text{m}^{-1}$. Consider the definition of the electron volt, and what 'voltage' (i.e. field potential) the electron must move through between collisions to gain enough energy to cause another atom to emit a photon of light.

   (c) **What would happen to the electric field if the gas was at a higher pressure?

9. (a) If you encounter a puddle on a rainy day with a thin layer of oil on its surface, you might see some rainbow patterns. How do these arise?

   (b) What pattern would you expect to see if you observe the same puddle at night time, lit only be a (sodium) street lamp?