

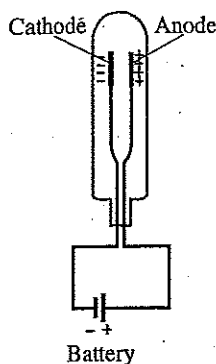
17-10 Thermionic Emission and the Cathode-Ray Tube

FIGURE 17-10 If the cathode inside the evacuated glass tube is heated to glowing, negatively charged “cathode rays” (electrons) are “boiled off” and flow across to the anode (+) to which they are attracted.

An important device that makes use of voltage, and that allows us to “visualize” voltages in the sense of displaying graphically how a voltage changes in time, is the *cathode ray tube* (CRT). A CRT used in this way is an *oscilloscope*—but an even more common use of a CRT is as the picture tube of television sets and computer monitors.

The operation of a CRT depends on the phenomenon of **thermionic emission**, discovered by Thomas Edison (1847–1931) in the course of experiments on developing the electric light bulb. To understand how thermionic emission occurs, consider two small plates (electrodes) inside an evacuated “bulb” or “tube” as shown in Fig. 17-10, to which is applied a potential difference (by a battery, say). The negative electrode is called the **cathode**[†], the positive one the **anode**. If the negative cathode is heated (usually by an electric current, as in a light bulb) so that it becomes hot and glowing, it is found that negative charge leaves the cathode and flows to the positive anode. These negative charges are now called electrons, but originally they were called **cathode rays** since they seemed to come from the cathode (see Section 27-1 on the discovery of the electron).

We can understand how electrons might be “boiled off” a hot metal plate if we treat electrons like molecules in a gas. This makes sense if electrons are relatively free to move about inside a metal, which is consistent with metals being good conductors. However, electrons don’t readily escape from the metal. There are forces that keep them in. For example, if an electron were to escape outside the metal surface, a net positive charge would remain behind, and this would attract the electron back. To escape, an electron would have to have a certain minimum kinetic energy, just as molecules in a liquid must have a minimum \overline{KE} to “evaporate” into the gaseous state. We saw in Chapter 13 that the average kinetic energy (\overline{KE}) of molecules in a gas is proportional to the absolute temperature T . We can apply this idea, but only very roughly, to free electrons in a metal as if they made up an “electron gas.” Of course, some electrons have more \overline{KE} than average and others less. At room temperature, very few electrons would have sufficient energy to escape. At high temperature, \overline{KE} is larger and many electrons escape—just as molecules evaporate from liquids, which occurs more readily at high temperatures. Thus, significant thermionic emission occurs only at elevated temperatures.

CRT The **cathode-ray tube** (CRT) derives its name from the fact that inside an evacuated glass tube, a beam of cathode rays (electrons) is directed to various parts of a screen to produce a “picture.” A simple CRT is diagrammed in Fig. 17-11. Electrons emitted by the heated cathode are accelerated by a high voltage (5000–50,000 V) applied to the anode. The electrons pass out of this “electron gun” through a small hole in the anode. The inside

[†]These terms were coined by Michael Faraday and come from the Greek words meaning, respectively, “descent” and “a way up.”