Advanced Topic:
Microscopic View of Incandescence

What is really happening at the microscopic level to cause the filament to glow when a voltage is applied across it? When a voltage is applied, the resultant electric field accelerates the free electrons in the tungsten metal. These electrons gain energy as they are accelerated. They then collide with the ions in the solid lattice and inelastically transfer some of their energy to the ions. Thus, the system of free electrons and ions cores, i.e. the tungsten wire, heats up. From energy conservation, this heat must be removed by some mechanism once the wire reaches an equilibrium temperature. This heat is removed by thermal conduction down the filament to the connecting wires and by the gas to the glass bulb and metal base, by thermal convection by the surrounding gas and by radiation. For a 100 W bulb, 82% of the heat energy is dissipated as radiation, 12% is dissipated by thermal convection of the gas and 6% is dissipated by thermal conduction. Most of the 82% of heat energy dissipated as radiation is in the infrared region (72%), while the rest is dissipated as predominantly visible light (10%), as shown in Fig. 2.

For a hot gas of say, hydrogen atoms, the radiation arises from colliding atoms of hydrogen that inelastically collide and knock their electrons into higher energy orbital shells. These electrons then fall back into an allowed lower energy orbital shell and emit light corresponding to the energy difference between the two orbital shells. In a solid, the situation is somewhat different. The discrete energy level of the electron orbital shell of an isolated atom is spread out into a continuum of very closely spaced energy levels when the free electron moves in the presence of a large numbers of atoms in a periodic array as there are in a solid, as shown in Fig. 3. Now, an energetic free electron (made energetic by its acceleration due to the applied voltage or by a collision with another energetic electron or by a collision with an energetically vibrating ion in the lattice) will lose its some of its energy by giving off radiation corresponding to the difference in energy between the electron's energy levels. In a solid, these energy levels are closely spaced, so that the radiation that is emitted is continuous, not discrete as it would be for an isolated atom. This is the origin of the blackbody radiation discussed earlier.