38.55. Model: Photons are emitted when an atom undergoes a quantum jump from a higher energy level to a lower energy level. On the other hand, photons are absorbed in a quantum jump from a lower energy level to a higher energy level. Because most of the atoms are in the $n = 1$ ground state, the only quantum jumps in the absorption spectrum start from the $n = 1$ state.

Visualize: Please refer to Figure P38.55.

Solve: **(a)** The ionization energy is $|E_1| = 6.5$ eV.

(b) The absorption spectrum consists of the transitions $1 \rightarrow 2$ and $1 \rightarrow 3$ from the ground state to excited states. According to the Bohr model, the required photon frequency and wavelength are

$$f = \frac{\Delta E}{h} \Rightarrow \lambda = \frac{c}{f} = \frac{hc}{\Delta E}$$

where $\Delta E = E_f - E_i$ is the energy change of the atom. Using the energies given in the figure, we calculated the values in the table below.

Transition	E_f (eV)	E_i (eV)	ΔE (eV)	λ (nm)
$1 \rightarrow 2$	−3.0	−6.5	3.5	355
$1 \rightarrow 3$	−2.0	−6.5	4.5	276

(c) Both wavelengths are ultraviolet ($\lambda < 400$ nm).

(d) A photon with wavelength $\lambda = 1240$ nm has an energy $E_{photon} = hf = hc/\lambda = 1.0$ eV. Because E_{photon} must exactly match ΔE of the atom, a 1240 nm photon can be emitted only in a $3 \rightarrow 2$ transition. So, after the collision the atom was in the $n = 3$ state. Before the collision, the atom was in its ground state ($n = 1$). Thus, an electron with $v_i = 1.4 \times 10^6$ m/s collided with the atom in the $n = 1$ state. The atom gained 4.5 eV in the collision as it is was excited from the $n = 1$ to $n = 3$, so the electron lost 4.5 eV = 7.20×10^{-19} J of kinetic energy. Initially, the kinetic energy of the electron was

$$K_i = \tfrac{1}{2} m_{elec} v_i^2 = \tfrac{1}{2}(9.11 \times 10^{-31}\text{ kg})(1.4 \times 10^6\text{ m/s})^2 = 8.93 \times 10^{-19}\text{ J}$$

After losing 7.20×10^{-19} J in the collision, the kinetic energy is

$$K_f = K_i - 7.20 \times 10^{-19}\text{ J} = 1.73 \times 10^{-19}\text{ J} = \tfrac{1}{2} m_{elec} v_f^2 \Rightarrow v_f = \sqrt{\frac{2K_f}{m_{elec}}} = \sqrt{\frac{2(1.73 \times 10^{-19}\text{ J})}{9.11 \times 10^{-31}\text{ kg}}} = 6.16 \times 10^5\text{ m/s}$$