Phys 202

Recitation 8

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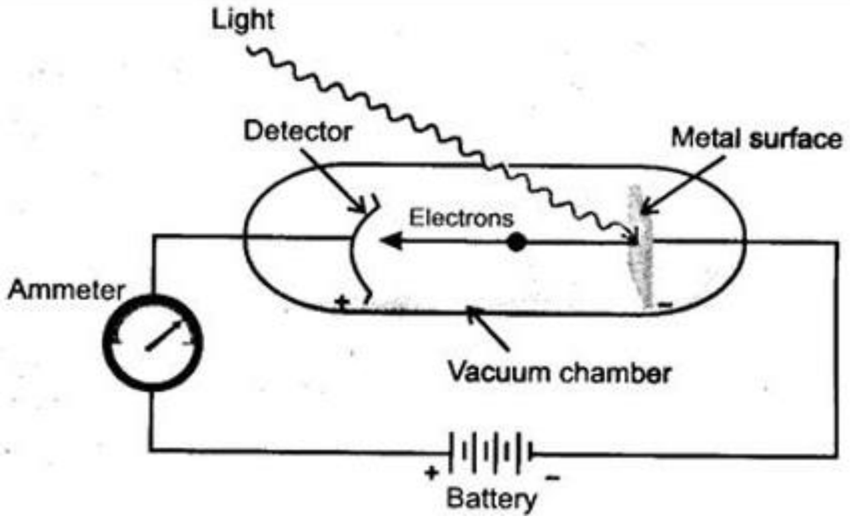
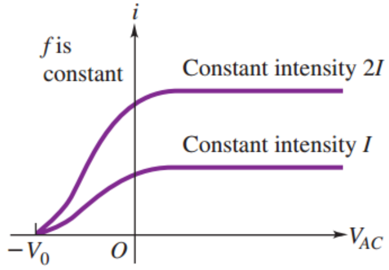
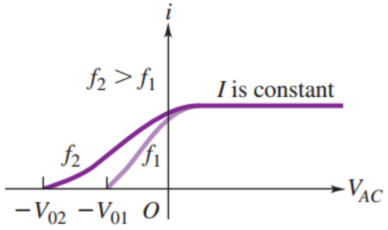
Photoelectric Effect





▲ **FIGURE 28.2** Photocurrent I as a function of V_{AC}.



▲ **FIGURE 28.3** Variation of stopping potential with frequency. The potential of the anode with respect to the cathode is V_{AC}.

Energy of a photon

The energy E of an individual photon is equal to a constant times the frequency f of the photon; that is,

$$E = hf, \tag{28.2}$$

Stopping potential

The reversed potential difference required to stop the electron flow completely is called the stopping potential, denoted by V_0. From the preceding discussion,

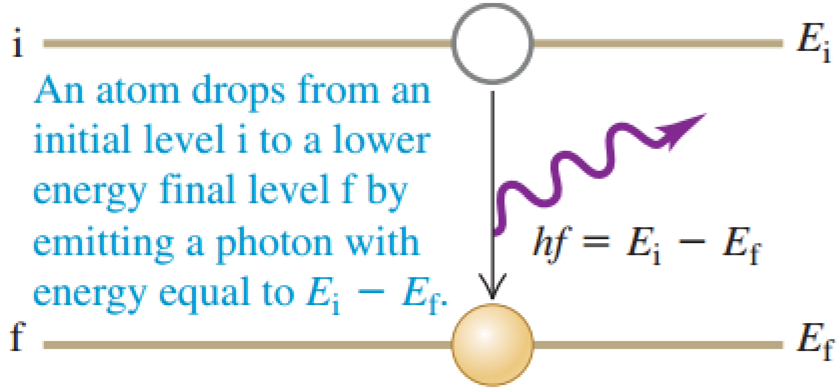
$$\frac{1}{2}mv_{max}^2 = eV_0. \tag{28.1}$$

Stopping Potential: $$eV_0 = hf - \phi,$$

Atomic Spectra

Bohr's hypothesis
If E_i is the initial energy of an atom before a transition from one energy level to another, E_f is the atom's (smaller) final energy after the transition, and the energy of the emitted photon is hf, then

$$hf = E_i - E_f. \quad (28.7)$$



$$E_n = \frac{-13.6\ \text{eV}}{n^2}.$$

11. ●● When ultraviolet light with a wavelength of 400.0 nm falls on a certain metal surface, the maximum kinetic energy of the emitted photoelectrons is measured to be 1.10 eV. What is the maximum kinetic energy of the photoelectrons when light of wavelength 300.0 nm falls on the same surface?

***28.11. Set Up:** $\frac{1}{2}mv_{\text{max}}{}^2 = hf - \phi$

Solve: Use the data for 400.0 nm to calculate ϕ:

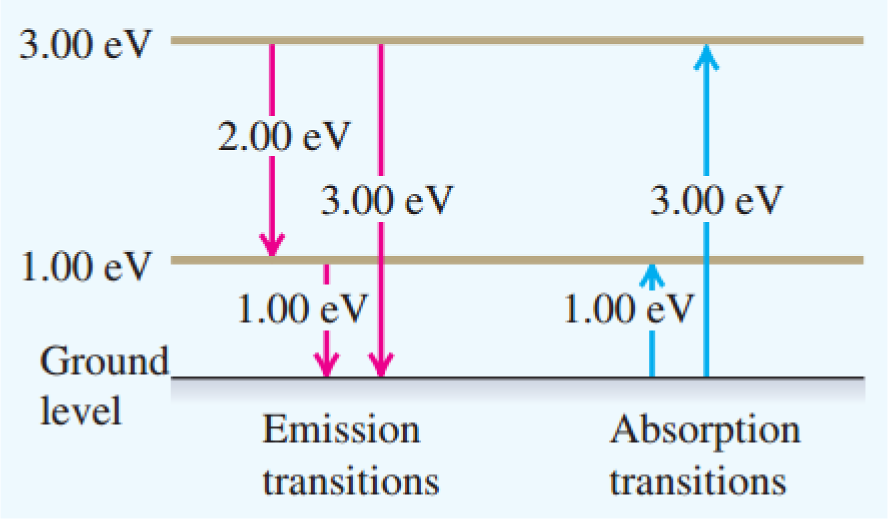
$$\phi = \frac{hc}{\lambda} - \frac{1}{2}mv_{\text{max}}{}^2 = \frac{(4.136\times10^{-15}\ \text{eV}\cdot\text{s})(3.00\times10^{8}\ \text{m/s})}{400.0\times10^{-9}\ \text{m}} - 1.10\ \text{eV} = 3.10\ \text{eV} - 1.10\ \text{eV} = 2.00\ \text{eV}.$$

Then for 300.0 nm,

$$\frac{1}{2}mv_{\text{max}}{}^2 = hf - \phi = \frac{hc}{\lambda} - \phi = \frac{(4.136\times10^{-15}\ \text{eV}\cdot\text{s})(3.00\times10^{8}\ \text{m/s})}{300.0\times10^{-9}\ \text{m}} - 2.00\ \text{eV}.$$

$$\frac{1}{2}mv_{\text{max}}{}^2 = 4.14\ \text{eV} - 2.00\ \text{eV} = 2.14\ \text{eV}.$$

A hypothetical atom has three energy levels: the ground-state level and levels 1.00 eV and 3.00 eV above the ground state. **(a)** Find the frequencies and wavelengths of the spectrum lines for this atom. **(b)** What wavelengths can be *absorbed* by the atom if it is initially in the ground state?



SOLVE Part (a): The possible photon energies E, corresponding to the transitions shown, are 1.00 eV, 2.00 eV, and 3.00 eV. Each photon frequency f is given by $f = E/h$. For 1.00 eV, we get

$$f = \frac{E}{h} = \frac{1.00\ \text{eV}}{4.136 \times 10^{-15}\ \text{eV} \cdot \text{s}} = 2.42 \times 10^{14}\ \text{Hz}.$$

For 2.00 eV and 3.00 eV, $f = 4.84 \times 10^{14}$ Hz and 7.25×10^{14} Hz, respectively. We find the wavelengths from $\lambda = c/f$. For 1.00 eV,

$$\lambda = \frac{c}{f} = \frac{3.00 \times 10^{8}\ \text{m/s}}{2.42 \times 10^{14}\ \text{Hz}} = 1.24 \times 10^{-6}\ \text{m} = 1240\ \text{nm}.$$

For 2.00 eV and 3.00 eV, the wavelengths are 620 nm and 414 nm, respectively.

24. ●● An electron in an excited state of hydrogen makes a transition from the $n = 5$ level to the $n = 2$ level. (a) Does the atom emit or absorb a photon during this process? How do you know? (b) Calculate the wavelength of the photon involved in the transition.

28.24. Set Up: If an atom gains energy in a transition, conservation of energy requires that a photon is absorbed. If the atom loses energy in a transition, a photon is emitted. The transition energy of the atom equals the energy of the photon that is absorbed or emitted.

Solve: (a) $E_n = -\frac{13.6 \text{ eV}}{n^2}$ so $E_5 = -0.544 \text{ eV}$ and $E_2 = -3.40 \text{ eV}$. In the $n = 5$ to $n = 2$ transition the atom loses energy and a photon is emitted.

(b) $E_i - E_f = E_5 - E_2 = 2.86 \text{ eV}$

$$E_i - E_f = \frac{hc}{\lambda} \text{ so } \lambda = \frac{hc}{E_5 - E_2} = \frac{1.240 \times 10^{-6} \text{ eV} \cdot \text{m}}{2.86 \text{ eV}} = 434 \text{ nm}$$

Quiz

10. • What would the minimum work function for a metal have to be for visible light (having wavelengths between 400 nm and 700 nm) to eject photoelectrons?