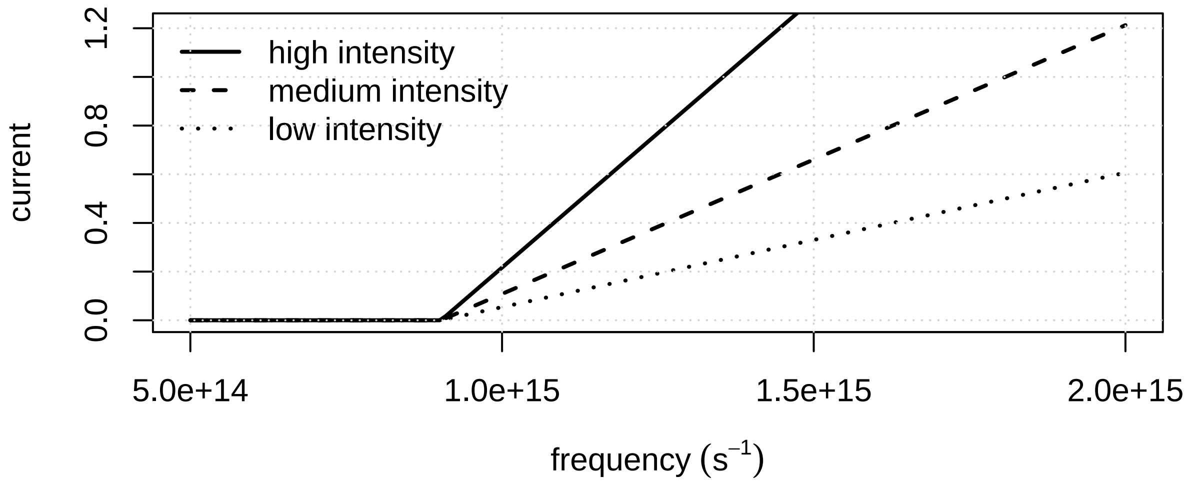
Key for Photoelectric Effect Worksheet

Effect of Intensity of Light Source (Fixed Metal: Zn)

To collect the data shown below, a clean surface of Zn was exposed to a light source, which was operated at three levels of intensity: high, medium, and low. The number of photoelectrons emitted was measured as a function of the frequency of the light source.



In all three experiments, no photoelectrons are emitted when the frequency is smaller than 9.0×10^{14} s^{-1}. We call this the threshold frequency, ν_o. What is the minimum energy of light—we call this the binding energy—needed to produce a photoelectron from Zn?

- We know that the relationship between frequency and energy is $E = h\nu$; thus, the energy in this case is

$$(6.626 \times 10^{-34} \text{ Js})(9.0 \times 10^{14} \text{ s}^{-1}) = 6.0 \times 10^{-19} \text{ J}$$

which is the binding energy of the electron in zinc.

Why does increasing the intensity of the light source have an effect on the measured current when $\nu > \nu_o$, but not when $\nu < \nu_o$?

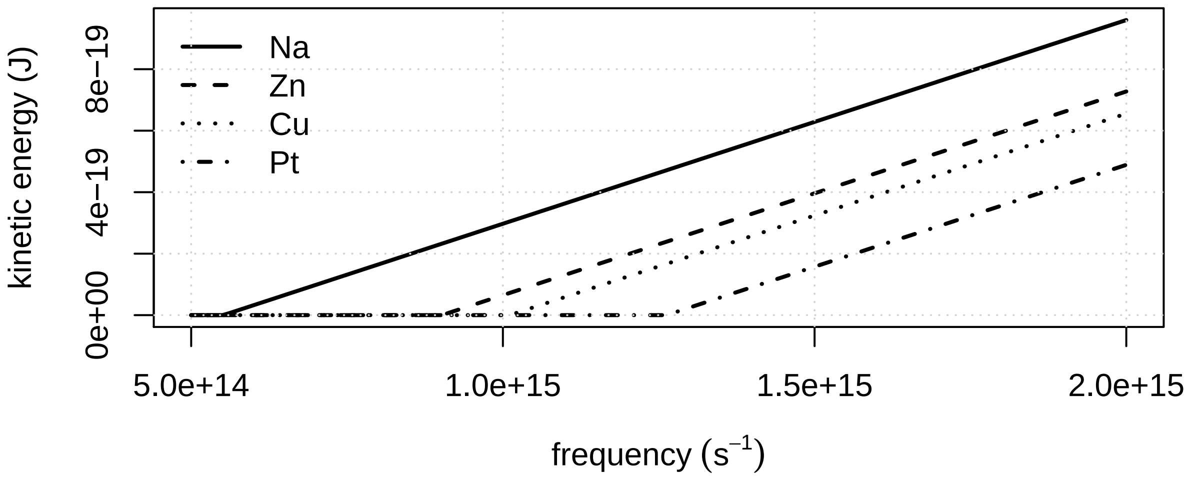
- We know from $E = h\nu$ that increasing ν results in an increase in energy. If $\nu < \nu_o$, then the energy of a photon of light is not sufficient to overcome the electron's binding energy and no photoelectron is omitted.

What is the significance of the different slopes in the data when $\nu > \nu_o$?

- The higher the intensity, the greater the number of photons striking the metal and the greater the number of photoelectrons emitted (provided that $\nu > \nu_o$).

Effect of Metal (Fixed Intensity of Light)

To collect the data shown below, clean surfaces of Na, Zn, Cu, and Pt were exposed to a light source. The kinetic energy of emitted photoelectrons were measured as a function of the frequency of the light source.



Estimate the threshold frequency, ν_o, for each metal to the nearest decimal point and calculate its binding energy, BE, for an electron, placing your results in the following table (note: the values for Zn are taken from the first part of this worksheet).

element	ν_o (s^{-1})	BE (J)
Na	5.5×10^{14}	3.6×10^{-19}
Zn	9.0×10^{14}	6.0×10^{-19}
Cu	1.0×10^{15}	6.6×10^{-19}
Pt	1.3×10^{15}	8.6×10^{-19}

For these four metals, which one gives up its electrons most easily? Which of these metals holds on most tightly to its electrons? How do you know this? Does the difference in their respective binding energies make sense given what you may know about the reactivity of these elements?

- The smaller the binding energy, the easier it is to release a photoelectron; thus, Na gives up its electrons most easily and Pt holds on most tightly to its electrons.
- We will study reactivity more as the semester unfolds, but you may know the following general details about these metals. Pt will not dissolve in the strong acids HCl or HNO_3, although it will dissolve in a mixture of the two. Copper will dissolve in HNO_3 but not HCl. Zinc will dissolve in both acids. Sodium will react with in water.

For $\nu > \nu_o$, there is a linear relationship between kinetic energy, KE, the frequency, ν of the light. A straight line has the general form $y = mx + b$. If y is KE and x is ν, then what are the slope, m, and the y-intercept, b? Is this consistent with the observation that all four metals have the same slope when $\nu > \nu_o$?

- The slope, m, must be Plank's constant, h, as $h\nu$ is an energy; this is consistent with the observation that the slope is the same for all four metals. The y-intercept, b, must be the negative of the binding energy, $-BE$, as this will give a KE of 0 when $h\nu = BE$.

Binding energies usually are reported, not for a single atom, but for 6.022×10^{23}, which we call a mole, and in kJ instead of J. The number 6.022×10^{23} is called Avogadro's number, N_A, To convert a BE in J/atom to kJ/mol, we multiply by N_A and covert from J to kJ; thus, for Zn we have

$$BE = 6.0 \times 10^{-19} \text{ J} \times 6.022 \times 10^{23} \text{ mol}^{-1} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = 360 \text{ kJ}$$