The following reaction sequence is responsible for the atmospheric production of ozone.

\[ \text{O}_2 + h\nu \rightarrow 2\text{O} \]

\[ \text{O} + \text{O}_2 \rightarrow \text{O}_3 \]

The \( \text{O}_2 \) bond energy is 498 kJ/mol. What is the maximum wavelength of light that can initiate this reaction?

\[ h = 6.62 \times 10^{-34} \text{ J sec} \]
\[ c = 3.00 \times 10^8 \text{ m/sec} \]
\[ N = 6.02 \times 10^{23} \text{ mol}^{-1} \]

The energy of the incoming photon

\[ E_{\text{K.E.}} = h\nu_{\text{photon}} - h\nu_0 \]

The threshold is called the “work function” of a metal. It represents the chemical binding energy of the electron, \( E_{\text{binding}} \).
Potassium has a threshold energy or work function of $3.7 \times 10^{-19}$ J

Will a 700 nm red photon eject an electron?
Will a 400 nm violet photon eject an electron?

$$E_{K.E.} = h \nu_{\text{photon}} - h \nu_0$$

E = $2.28 \times 10^{-19}$ J  **No** red photon (700 nm)
E = $4.96 \times 10^{-19}$ J  **Yes** violet photon (400 nm)

$3.7 \times 10^{-19}$ J x $6.02 \times 10^{23}$ = 223,000 J / mol

Potassium has a threshold energy or work function of $3.7 \times 10^{-19}$ J

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Electron diffraction
The photoelectron effect shows us than photons are particles, but they can be diffracted like waves!

Schematic representation of an apparatus that measures the absorption spectrum of a gaseous element. The gas in the tube absorbs light at specific wavelengths, called “lines,” so the intensity of transmitted light is low at these particular wavelengths.

Schematic representation of an apparatus that measures the emission spectrum of a gaseous element. Emission lines appear bright against a dark background. The spectrum shown is the emission spectrum for hydrogen atoms.
The emission spectra from gaseous samples of Na, Hg, and Ne. These unique emission patterns provide valuable clues about atom structure.

Bohr Theory of Hydrogen atoms

The electron in a hydrogen atom moves around the nucleus only in certain allowed circular orbits.

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The Bohr Model

The Bohr Model

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The electron in a hydrogen atom moves around the nucleus only in certain allowed circular orbits.

What is the Energy (also frequency and wave length) of light that is necessary to ionize a H atom (that is remove a e- and form H+ (i.e. what is the energy needed to excite the electron from n=1 to n = ∞)?

Bohr model completely explains the H line spectra but only works for other 1electron systems He⁺, Li²⁺
Light has both wave and particle properties. Matter (electrons) has both wave and particle properties.

Light has particle properties. Its energy is quantized.

Light can exert a pressure. This means it has momentum.

For a normal object:

\[ \text{momentum} = p = \mu u \quad \text{where } u \text{ stands for velocity} \]

For light: \( (p = mc) \)

\[ \text{Energy} = mc^2 = pc = h\nu = hc/\lambda \]

\[ \nu = c/\lambda \quad \text{thus } p = h/\lambda \quad \text{or } \lambda = h/p \quad \text{for light} \]

For normal object: \( p = \mu u \) thus we have: \( \lambda = h/\mu u \)

This is called the: de Broglie equation

All matter has wavelike properties

The de Broglie Wavelengths of several objects

<table>
<thead>
<tr>
<th>Substance</th>
<th>Mass (g)</th>
<th>Speed (m/s)</th>
<th>( \lambda ) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow e-</td>
<td>( 9 \times 10^{-28} )</td>
<td>1.0</td>
<td>( 7 \times 10^{-4} )</td>
</tr>
<tr>
<td>Fast e-</td>
<td>( 9 \times 10^{-28} )</td>
<td>( 5.9 \times 10^6 )</td>
<td>( 1 \times 10^{-10} )</td>
</tr>
<tr>
<td>Alpha particle</td>
<td>( 6.6 \times 10^{-24} )</td>
<td>( 1.5 \times 10^7 )</td>
<td>( 7 \times 10^{-15} )</td>
</tr>
<tr>
<td>One gram mass</td>
<td>1.0</td>
<td>0.01</td>
<td>( 7 \times 10^{-29} )</td>
</tr>
<tr>
<td>baseball</td>
<td>142</td>
<td>25.0</td>
<td>( 2 \times 10^{-34} )</td>
</tr>
<tr>
<td>Earth</td>
<td>( 6.0 \times 10^{27} )</td>
<td>( 3 \times 10^4 )</td>
<td>( 4 \times 10^{-63} )</td>
</tr>
</tbody>
</table>

Quantum Mechanical Description of the Atom

Physicists: Erwin Schrödinger, Werner Heisenberg, Louis DeBroglie

\[ \hat{H}\psi = E\psi \]

\( \hat{H} \) is Hamiltonian: Mathematical expression which includes terms for Kinetic and Potential Energy

Schrödinger's Equation

\( E \) is Energy (eigenvalue)

\( \psi \) Wavefunction, (eigenfunction)

\[ \psi(x,y,z) \rightarrow \text{orbitals} \]

\[ \psi^2 \text{ probability of finding an electron} \]

Infinite high walls

What happens when you put the particle in the box?

If the particle just acted like a ball in a regular box it would just sit on the bottom or if it had some excess energy it might bounce around a bit.

But we want to model an electron in a very small box and under such circumstances the particle acts like a wave.
A particle in a box

E\text{nergie}_n = \frac{n^2 h^2}{8mL^2}

Principal quantum number \( n \)

Excited State

Ground State

\( E_{\text{photon}} = E_2 - E_1 = \hbar \nu_1 \)