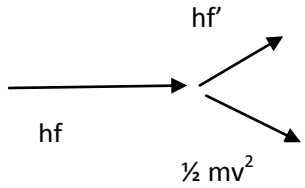
Compton Effect 12.4

Compton Effect – discovered by Compton, St. Louis Missouri 1923. Light has momentum!
- more experiments with photons reacting with matter (like photoelectric effect)

Experiment – xray photons were aimed at a thin carbon foil.
Result – electrons were emitted and lower energy xray photons were scattered.
Analysis – this result cannot be explained by wave theory
(if electrons oscillate with xray, would re-emit/scatter SAME freq.)
- this result cannot be explained by particle theory
(photons don't have mass & shouldn't experience collisions)

Compton said – analyze like a collision.
He said: $E_{\text{xray photon}} = E'_{\text{xray photon}} + E_{\text{electron}}$ where E' means after collision



Conservation of Energy held true!

Law of conservation of energy states: Energy before collision = energy after. Therefore:

$E_{xray} = hf_f + \frac{1}{2} mv^2$ …or…

Energy before = energy of lower x-ray + Ek of ejected electron

He checked to see **if momentum** held (if photon had 'mass')
Compton uses $E = mc^2$.
Since photons have no mass, he uses the mass equivalency (E/c^2).

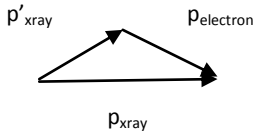
$m = E/c^2$
$p = mv$ now sub in mass equivalency for 'm'
$p = E/c^2 \cdot v$ now $E = hc/\lambda$ - planck's formula. Sub in for 'E'.
$p = hc/\lambda c^2 \cdot v$ now simplify

$p = h/\lambda$ Compton's formula!

Result: **momentum of a photon can be calculated**

$$p = h/\lambda$$

And the conservation of momentum held! It worked.



One can analyze the interaction above. Use $p = h/\lambda$ for the momentum of x-rays and $p = mv$ for momentum of electron. If one uses 2D momentum calculations learned earlier, the math works out! Momentum is conserved. X-rays (EMR with no mass) have momentum!!

Compton won the Nobel Prize for his research in 1927

Problems to Try

1. Calculate the momentum of a photon whose wavelength is 500 nm [**1.33×10^{-27} kg·m/s**]
2. What is the momentum of a photon with a frequency of 4.5×10^{15} Hz?
   [9.9×10^{-27} kg·m/s]
3. What is the momentum of a 150 eV photon? **[8.0×10^{-26} kg·m/s]**

- From Fundamentals of Physics p. 707