

Topic 6D: Modern Physics – Energy of a Photon and Energy/Mass Equivalence ($E=mc^2$)

Skill 57: Energy of a photon Both Photons & Electrons exhibit Wave/Particle Duality

Meaning they show wave behavior (diffraction, interference) & particle behavior (momentum collisions)
When a photon hits an atom, the energy can be absorbed to change the energy level (n) of electrons in an atom. Each type of atom has a specific set of energy levels at which electrons exist. Each energy level indicates the # of e's required for the electrons to SEE PRT For Hydrogen & Mercury Atom Energy level

Hydrogen Ionization

$n=5$	0.085 eV
$n=4$	-0.85 eV
$n=3$	-1.51 eV
$n=2$	-3.40 eV
$n=1$ - Ground State	-13.6 eV

When a photon is absorbed electrons move up to a higher level or escape (ionization)

The energy must be absorbed in specific quantities → quantization
that match gaps between energy levels or be greater than or equal to amount of energy needed for ionization
is quantum physics

Escape → ionize

Energy given on diagrams is given in electronvolts eV
to convert eV's to Joules use $1\text{eV} = 1.6 \times 10^{-19}\text{J}$

- If electrons are bounced up from the ground state without ionizing they will fall back down: Emitting a photon that matches energy of the gap

Ex: At $n=5$ an electron can fall: For any level add the energy level of all # below (but not including)

From 5 to 4 $4+3$ 3 to 2 2 to 1
or 5 to 3 and 4 to 2 then 3 to 1 then 4 to 1
or 5 to 2 then 4 to 1
or 5 to 1

For 5 Add $4+3+2+1 = 10$

For 4 Add $3+2+1 = 6$

For 3 Add $2+1 = 3$

This determines the # of possible photons

To find the Energy of a photon for an electron changing energy levels.

- Find the difference in eV's between levels
ie ΔE for $n=1$ & $n=2$ in Hydrogen is 10.2 eV

- Convert to Joules

$$10.2\text{eV} \times \frac{1.6 \times 10^{-19}\text{J}}{1\text{eV}} = 1.63 \times 10^{-18}\text{J}$$

To find frequency corresponding to Energy (in Joules)

use $E = hf$ h is Planck's constant,
or $E = hc/\lambda$ $= 6.63 \times 10^{-34}\text{Js}$

From frequency of photon to change in energy level

• use $E = hf$ or $E = hc/\lambda$ to find energy in Joules

• Convert to eV's using $1\text{eV} = 1.6 \times 10^{-19}\text{J}$

• Find corresponding gap in hydrogen or mercury

Skill 58: $E=mc^2$

Mass can be converted into energy by events such as matter/anti-matter annihilations, and nuclear reactions (fission, fusion), pair production.

The Energy equivalent of mass in Kg is found by using $E=mc^2$ (This in Energy in Joules)
or $m = \frac{E}{c^2}$

The difference between the amount of mass present before and after an event is known as the MASS DEFECT

If mass defect is in universal mass units (u) Energy equivalent can be found in MeV's by using conversion $1\text{u} = 9.31 \times 10^2\text{MeV} = 1\text{u} = 9.31 \times 10^8\text{eV}$

To convert from Energy in eV's to Joules use $1\text{eV} = 1.6 \times 10^{-19}\text{J}$