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Energy of the photons (1.3 book reference)

→ the photons have not rest mass and the frequency v of the electromagnetic wave

The amount of energy carrier by the photon can be obtened according:

Unit: 299495 ms^{-1}

Unit: Ev ← $\boxed{E = h\nu}$ or $\boxed{E = \frac{hc}{\lambda}}$ → Unit: m

Unit: Hz

Unit: $4,135667 \times 10^{-15}$ eV eV s

$\boxed{\nu = \frac{c}{\lambda}}$ The numerical value cab be obtained from $\boxed{E(ev) = \frac{1240}{\lambda(nm)}}$

CONSIDERATIONS

- Photons energies increases when wave length decreases

- Photon have not rest mass, The have a momentum equal $h\nu/c$ and virtual dinamic mass $m = h/\lambda c$

Energy of Particles with mass

Followed the relativity principles from classical physics principles is not constant when the particle velocity v are:

The mass

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

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Where m_0 is the rest mass $(v=0)$ and c is the velocity of the light in vacuo.

The particle momentum is given by $m\vec{v} = \vec{m_0 v_0} / \sqrt{1 - v^2/c^2}$

rest mass $m_0 \rightarrow E = m_0 c^2$

→ Rest mass of the electron is 511 eV

When the particle is moving the ENERGY is the sum of the energy corresponding to its rest mass and the translation kinetic energy, so the total energy of the particle becomes of $E = mc^2$ according to Einstein

$$\underbrace{mc^2 = m_0 c^2 + T}_{\text{Energy due to the particle movement}} \} \text{ Translation Kinetic energy}$$

When the particle velocity becomes small the above equation becomes closer to the classical value of $T = \frac{1}{2} m v^2$

Binding energies in atoms.

The binding energies is the energy required to dissociate a given structure or substructure (usually is denote with "w")

Mass defect

The energy required to create a bond in a system is lost by the system and induces a mass decrease. So mass defect is the difference between the mass of an object and the sum of the masses of its constituent particles. Explained by Einstein with:

Energy create a bond $\leftarrow E = mc^2 \rightarrow$ Velocity of ligth.

↳ Decrease mass

eco

Electron binding energy and levels of the atomic shells

The electron of an inner shell of atom is attracted by the nucleus with an electrostatic force greater than the force applied by the nucleus to an electron of an outer shell.

The binding energy required to extract a given electron from an atom depends on the shell considered and the electric charge Z of the nucleus, according:

$$\boxed{W = 13.6\ \frac{(Z-b)^2}{n^2}}$$

W = Binding energy of the electron (eV)
Z = Atomic number of the atom (Proton)
n = Electron shell number
b = Constant used for correct the "screening effect"

Considerations: Outer shell (less dependent of Z number)
→ Ranking from 1 to 16 eV (whatever value of Z)

PERTURBATION OF THE BINDING ENERGIES

(1.4 Book reference)

Excitation

If a given atom absorbs external energy at a level smaller than any electron binding energy, and electron maybe moved from one shell to another, farther from the nucleus. This corresponds to a higher level of internal energy. The atom is then said to be excited

If the electron moves, for example, from the L shell to the M shell is because the absorbed energy ΔW is such that:

$$\boxed{\Delta W = W_M - W_L}$$

outer shell → W_M; W_L → Inner shell

W_m and W_L begin binding energies of M and L shell.

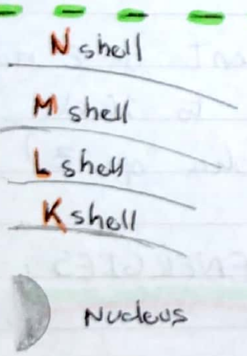
If the energy given to the atom, increasing its internal energy, is defined as positive, then the binding energies should be considered as negative.

Example: tungsten

$$W_L = -11280 \text{ eV} \qquad W_M = -2810 \text{ eV}$$

$$\Delta W = (-2810 \text{ eV}) - (-11280 \text{ eV})$$
$$= 8470 \text{ eV}$$

* Peripheral electrons have a weak binding energies and exitation can be produced with low energy photons (UV or visible)



Ionisation

If a given atom absorbs external energy at a level equal to or higher than an electron binding energy, an electron becomes free because its link with the atom has been broken. As a result, the electrical equilibrium in the atom is no longer maintained and the atom becomes a positive ion.

→ For a given electron to be removed from the atom, the energy transfer must be higher than the binding energy of this electron.

The excess of energy is, in principle, shared between the ionised atom and the electron kinetic energy.

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Emission of photon with energy excess

Equilibrium recovery : Fluorescence

When the a given atom receiving amount of energy, leading to excitation or ionisation, an atom has excess of internal energy, becomes unstable, and tends to return to its fundamental state. This recovery of the fundamental state is associated with re-emission of energy.

In the fluorescence process, the energy re-emission is made through prompt (Immediate) emission of one or several photons.

Fluorescence Process

After the excitation or ionization → vacancies or holes appear in the electron shells and are promptly filled by electrons cascading from energy levels corresponding to shells farther from the nucleus. As the vacancies are filled, energy is released (for instance through photon emission) and internal energy is reduced (of the atom)

The emitted photons are called characteristic x-rays

Emission of electrons

Equilibrium recovery : Auger effect

Occasionally, the equilibrium recovery may be used to eject a second electron instead of a photon. This ejected electron is called an Auger electron. Like fluorescence photons, Auger electrons have a well defined energies

→ Probability Auger electron is higher for low Z biological media than the probability of fluorescence close 1 for $Z < 10$ and 0.1 for $Z > 80$

GLOSSARY

Z → protons → Atomic Number

N → Neutrons

e → electron → 1.602×10^{-19} C → mass rest = 9.109×10^{-31} kg

Electronic shell (the z peripheral electrons) → K → L → M → N.

Mass number ← A

Atomic number ← Z

X → Element nuclide symbol

$${}^{A}_{Z}X$$

Isotones → atoms with the same number of neutrons.

$^{51}_{23}V$ $^{52}_{24}Cr$ $^{54}_{26}Fe$

Mass number: Total number of nucleus.

$\boxed{N + Z = A}$ $N = A - Z$

Isotopes → The same number of protons with different number of neutrons

$^{13}_{6}C$ $^{14}_{6}C$

Isobars → The same number of nucleons (A)

$^{40}_{19}A$ $^{40}_{19}K$