Re: Photons−atoms interactions

Source: http://sci.tech−archive.net/Archive/sci.physics.research/2004−11/0266.html

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From: Igor Khavkine (*k_igor_k_at_lycos.com*)
Date: 11/12/04

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Date: Fri, 12 Nov 2004 19:10:55 +0000 (UTC)
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On Thu, 11 Nov 2004 09:33:49 +0000, Kumar wrote:

> Igor Khavkine <k_igor_k@lycos.com> wrote in message
> news:<pan.2004.11.07.19.47.05.101066@lycos.com>...
>> On Sun, 07 Nov 2004 13:44:56 +0000, Kumar wrote:
>>
>> > I want to know about Photons−atoms interactions as under:−
>> >
>> > 1. Whether emitted photons from any atom will be exactly similar &
>> > with same energy as of absorbed photons?
>>
>> Any photon that can be absorbed can also be emitted. This is required
>> for the interaction Hamiltonian to be hermitian.

> Thanks for reply. You said, any photon can be absorbed & emitted. Do you
> mean to say any photon with any energy lavel can be absorbed by any atom
> or if there are some limitations to it?

Note that I was careful to say that any photon that _can be absorbed_, can also be emitted. The answer you your last question is hinges on what you mean by absorb. Any atom will interact with any photon, whether the end result will be absoption/emission depends on the details.

Suppose you have an atom in which the first excited state has energy E compared to the ground state. You bombard the atom with a bunch of photons of energy E, that is your initial state is

|atom in ground state>|bunch of photons of energy E>.

To see what happens you do some perturbation theory and try to calculate the final state. Here the Fermi Golden Rule comes in and tells you that, after a sufficiently long time, the biggest contribution to the final states comes from states that conserve energy (i.e. those whose energy is the same as the energy of the initial state). Since the first excited state is energy E above the ground state the final state will be dominated by

|atom in first excited state>|one less photon of energy E>,

In this scenario we say that the atom absorbed one photon. Conversely, if we start with

|atom in ground state>|bunch of photons of energy E' (different from E)>,

then since there is no excited state at energy E', the only choice of final state that will satisfy conservation of energy will be

|atom in ground state>|bunch of photons of energy E' (different from E)>.

Same as the initial state, here we say that the atom didn't absorb any photons.

Notice the important qualification "after a sufficiently long time" in the above description. If we relax this qualification and consider what happens at shorter time scales, things are not so clear cut and it's harder to talk about absorption. Namely, on intermediate time scales where Fermi's Golden Rule does not apply the atom will be in a more complicated superposition of states. To figure out what this superposition is we need to calculate more terms in perturbation theory. This calculation will tell us that the intermediate state will indeed have overlap with states of energies different from the initial state. However, the larger the violation of conservation of energy, the smaller the contribution from the state. For example if the atom is bombarded with photons of energy E/2, which falls right between the ground and first excited states, then the intermediate states will be dominated by superpositions of the ground and first excited states.

In a sense, one can talk about absorption here as well, but only very loosely. For example, we can say that an atom can absorb an photon of energy E/2, but will have to re−emit it very quickly since there is no actual state at that energy. But this description using absorption and emission is just a heuristic explanation of the process that I described in the previous paragraph.

It is very important to realize that all the talk about "violation of conservation of energy" is also quite heuristic. This image is only invoked when comparing specific states that may enter into the superposition that makes up the physical state. The expectation value of the energy of the whole system (atom + photons) is conserved at all times.

Hope this helps.

Igor