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Induced absorption definition physics

Using the example of electron transitions associated with visible and ultraviolet interactions with matter, the absorption of a photon occurs only if the quantum energy of the photon exactly matches the energy gap between the initial and the end states. If there are no energy states that can elevate the system from the lower to the upper state, if there are no energy states that can elevate the system from the lower to the upper state, then the matter will be transparent for this radiation. Energy levels associated with molecules, atoms and nuclei are generally discrete, quantized energy levels and transitions between these levels usually involve the absorption or emission of photons. Electron energy levels were used as an example, but there are also quantized energy levels for molecular vibrations and rotations. Transitions between vibration quantum states typically occur in infrared, and transitions between rotational quantum states are typically in the microwave range of the electromagnetic spectrum. It is possible that excited electrons in atoms and molecules have a different type of interaction that lowers their energy before they can make a downward transition. In this case, they would emit a photon with lower energy and longer wavelength. This process is called fluorescence when it happens essentially instantaneously. It is also possible that material can hold the energy of arousal for a long time, gradually downward transitions with emissions. This delayed emission is called phosphorescence. Since we know from the Einstein A and B coefficients that the absorption and emission probabilities are equal, the existence of phosphorescence would mean that some interaction occurred quickly after the initial absorption, which put the electrons in a much more stable and long-lasting state, so that they could not immediately fall back down. Interactions of radiation with matter absorption, spontaneous emission and stimulated emission are three interconnected energy conversion processes. Chapter 6 discussed absorption-based devices, including solar cells and photodetectors. Devices based on spontaneous emission include LEDs and lamps. Optical amplifiers and lasers work on the basis of stimulated emissions. Absorption is the process by which optical energy is converted into internal energy from electrons, atoms or molecules. When a photon is absorbed, the energy can cause an electron in an atom to pass from a lower to a higher energy level, altering the electron's internal impulse and the electron's internal quantum numbers. This process was presented in Chapter 6 on the basis of Demonstrates. Energy in a solar cell or photodetector is then converted into electricity, as the excited charge carriers can travel more freely through the material. The electrons that absorb the energy can be part of atoms that make up solids, liquids, gases, or plasmas. They can be used to recreate isolated neutral atoms, ionic compounds or complicated Molecules. In addition, the electrons that absorb the energy can be part of conductive, insulating or semi-conductive materials. The absorbed photons can be optical photons with single energies in the range of 1.9 to 3.1 eV, which can be detected by human eyes. Alternatively, they can have energies that are several orders of magnitude greater or smaller than the energy of a visible photon. In isolated neutral neonatoms in the ground state, for example, electrons take the energy level of 2p, but not the energy level of 3s. These energy levels are separated by an energy gap of (E_g = 1.96) eV, which corresponds to the energy of red photons with wavelength 632.8 nm [31]. If a photon of this energy enters neon gas, the photon can be absorbed, and an electron of a neon atom would be stimulated to the higher energy level. Photons with smaller energy would not be absorbed. Photons with higher energy can be absorbed depending on the permissible energy level. Another example is the energy gap of the semiconductor gallium phosphide GaP 2.2 eV, which corresponds to the energy of a green photon of the wavelength 549 nm. If a photon of this energy acts on a piece of gallium phosphide, it can be absorbed. Spontaneous emission is an energy conversion process in which an excited electron or molecule decays to an available lower energy level, emitting a photon. This process is natural and does not involve interaction of other photons. The average decay time due to spontaneous emission is called spontaneous emission life. At some excited energy levels, this spontaneous decay occurs on average within nanoseconds, while in other materials it occurs within a few seconds [10, p. 480]. As with absorption, this process can occur in isolated atoms, ionic compounds, molecules and other types of materials, and it can occur in solids, liquids and gases. Energy is preserved when the electron disintegrates to the lower level, and that energy must go somewhere. The energy can be converted into heat, mechanical vibrations or electromagnetic photons. When converted into photons, the process is called spontaneous emission, and the energy of the generated photon is equal to the amount of energy between the electron energy levels involved. The emitted photon can have any direction, phase and electromagnetic polarization. There are many ways in which an electron can be stimulated to a higher energy level [10, p. 455]. Spontaneous emission processes can be classified on the basis of the energy source that stimulates the electrons, and these classes are listed in table ('PageIndex{1}'. If the original energy source for spontaneous emission is the process is called photoluminescence. Light up in the dark materials while radiating light. When the original form of energy is supplied by a chemical reaction, the process is called chemiluminescence. Light rods produce a spontaneous emission by chemiluminescence. If the original energy form is energy Voltage is called the process electroluminescence. LEDs emit light through electroluminescence. If the original energy form is caused by sound waves, the process is called sonoluminescence. If the original form of energy is due to accelerated electrons hitting a target, this process is called cathodoluminescence. When spontaneous emission occurs in a living organism, like a fireflies, the process is called bioluminescence. Spontaneous Emission Energy Source Photoluminescence Optical Electromagnetic Waves Chemiluminescence Chemical Reactions Electroluminescence Applied Stresses Sonoluminescence Sound Waves Bioluminescence Biological Processes Table ('PageIndex{1}'): Spontaneous emission is classified based on the energy source [10, p. 455]. At temperatures above absolute zero, some electrons in atoms are thermally excited at energy levels above the ground state. These electrons disintegrate and emit a photon by spontaneous emission. Each object at a temperature above absolute zero naturally emits photons by spontaneous emission, and this process is called blackbody radiation. In 1900, Max Planck derived a formula for the energy density per unit bandwidth of a blackbody radiator, assuming that only discrete energies are allowed [10, p. 453]. His work matched well-known experimental data, and it is one of the fundamental ideas of quantum mechanics. More specifically, the spectral energy density per bandwidth, (u) is given in the units (fracJ-J-Cdot-S-M-3, by [u= frac8 pi f2-k_BT. The equation Ref7.1.1 contains a number of constants, including the speed of light in free space, the Planck constant, and the Boltzmann constant of (k_B. In addition, the frequency is in Hz and the temperature in Kelvin. A nice derivative can be found under [84, p. 186]. The first term represents the number of modes per unit of frequency per volume unit, while the second term represents the average energy per mode. The expression can be written as a function of the wavelength instead of the frequency with the substitution. Photons emitted by a blackbody cooler have a relatively large wavelength range, and this bandwidth depends on temperature. The PageIndex{1} figure records the energy density per unitbandwidth for blackbody radiators as a function of wavelength at temperatures 3000, 4000 and 5000 K. The room temperature corresponds to about 300 K. Visible photons have wavelengths between 400 nm (< .lambda <) 650 nm. From the figure we can see that black body radiators emit more photons at higher temperatures as well as have a larger fraction of the photon emitted values in the visible range. Figure :('PageIndex{1}'): Spectral energy density of a This figure is publicly available [85]. Stimulated emission is the process in which an excited electron or molecule interacts with a photon, decomposing to an available lower energy level and thereby As with other processes, this process can occur in isolated atoms, ionic compounds, organic molecules and other types of materials, and it can occur in solids, liquids and gases. When an incoming photon whose energy corresponds to the difference between the permissible energy levels interacts with an electron in an excited state, a stimulated emission may occur. The energy of the excited electron is converted into the energy of a photon. The stimulated photon has the same frequency, direction, phase and electromagnetic polarization as the incoming photon that initiated the process [10, p. 436]. Figure{2} : Energy level diagrams illustrating absorption, spontaneous emissions and stimulated emissions. The processes of absorption, spontaneous emission and stimulated emission are illustrated by energy level diagrams in Fig. (PageIndex{2}. Energy is on the vertical axis, and nothing is displayed on the horizontal axis. Only two energy levels are displayed, so this diagram illustrates only a small fraction of the possible energy level of a material. The lower energy level is labeled with 1. It can, for example.B represent the highest energy level consumed by an electron in an isolated atom, or it can represent the valence band of a semiconductor. The higher energy level is marked with 2 and can represent the lowest unoccupied energy level of an electron in an isolated atom or the conduction band of a semiconductor. The point represents an electron that takes the energy level at the beginning of the process. The squiggly arrows represent a photon absorbed or emitted by the process. The vertical arrow shows how the inner energy of the electron changes in the process. During absorption, an electron gains energy from an incoming photon, and the inner energy of the electron increases. During spontaneous emission, the internal energy of an electron decreases and a photon is emitted. Stimulated emission occurs when a photon interacts with the electron, with energy equal to the energy gap of the planes. The electron decompiles to the lower energy level, and a photon is generated at the same frequency, direction, phase and electromagnetic polarization as the original photon. The figures do not illustrate any change in the position of the electrons. Instead, they illustrate a change in energy and inner dynamics. The descriptions of the above processes include changes in the energy level of an electron. However, absorption, spontaneous emission and stimulated emission can include vibrational energy states of molecules. For example, a photon can be absorbed by a molecule, and the energy can cause the molecule to be removed from a permissible to another with higher internal energy. Similarly, this molecule can spontaneously disintegrate from the higher energy state into a lower energy state, which emits a photon through spontaneous emission or stimulated emission. An example of molecular vibration states is a carbon dioxide laser. This laser laser Infrared light by stimulated emission at 10.6%, and the stimulated emission occurs between the permissible vibration energy levels of the molecule (Text_2[31, p. 217]. However, in order to simplify the discussion in this text, we assume that electron energy levels are involved. This assumption applies to most, but not all, energy conversion devices. What factors determine the speed of these processes? Suppose it is only two energy levels. The number of electrons per unit volume in the lower state is called (n_1 n_1), and the number of electrons per unit volume in the upper state is called (n_2. The absorption rate is referred to as (| dn_2 left) the rate of spontaneous emission is called (dn_2 left, the rate of spontaneous emission is called (left), and the rate of stimulated issuance is referred to as (links.fracdn_2,_| d-, and the rate of stimulated issuance is referred to as (left-dn_2, and the rate of stimulated issuance is called (left.fracdn_2), and the rate of the stimulated issuance is referred to as (left.fracdn_2, and the rate of the stimulated issuance is called (left.fracdn_2|. Since only two energy levels are involved in this system, we can describe the rates of the processes in terms of either the upper or lower energy level. For example, we can write the absorption rate either as the change in population density in relation to the time of the upper state or the change in population density in relation to the time of the lower state. | dn_1| dn_2 Absorption can only occur if an electron is present in the lower energy level. In addition, the absorption rate is proportional to the number of electrons in the lower state. In addition, the absorption rate depends on the number of incoming photons. As in equation Ref7.1.1, the spectral energy density per bandwidth in units ('frac'J'cdot s'm'3') represents. We can model the absorption rate based on these factors [84, ch. 6] [86, ch. 7]. B_{12}n_1u| dn_1| dn_2 The constant of proportionality (B_{12}) is called the Einstein B coefficient, and it has units '(frac'm' 3' The spontaneous emission depends on the number of electrons in the upper energy level. We can model the speed of spontaneous emission as [-links.fracdn_2/right|_spont = - left A_21 A_{21}n_2| dn_1. and it has the units (frac{1}s) [84, ch. 6] [86, ch. 7]. No photons are needed to initiate spontaneous emissions. We can model the rate of stimulated emission as [-dn_1| dn_2 left B_{21}n_2u|. The proportionality constant (B_21) is called another Einstein B coefficient, and it also contains the units (fracm3J cdot s2) [84, ch. 6] [86, ch. 7]. The rate of stimulated emission depends on the number of electrons in the upper energy level. The stimulated emission an incoming photon, so that the rate is also dependent on the spectral energy density per Bandwidth (u)). If we take into account the factors that affect the absorption rate, spontaneous emission and stimulated emission, we can see some similarities and differences in the processes. With absorption, the population of electrons in the upper energy level increases, and the population of the lower energy level decreases. As both spontaneous and stimulated emissions occur, the population of the upper energy level decreases and the population of the lower energy level increases. Both the absorption rate and the rate of stimulated emission depend on both the electron population in an energy level and the energy of incoming photons, while the rate of spontaneous emission does not depend on the energy of the incoming photons. This similarity between absorption and stimulated emission is reflected in the velocity equations, equations 7.1.3 and ref.7.1.5. Einstein showed that if one of the coefficients describing absorption, spontaneous emission or stimulated emission is known, the other coefficients can be calculated from it. We can combine the above terms to determine the overall population rate of the state. dn_2 = -A_{21}n_2 + B_{12}n_1u - B_{21}n_2u. In the equilibrium at which photons are absorbed and emitted at the same rate, this population rate is zero. ['left.'frac'dn_2"dt"right|_'equilibrium' = 0 = -A_{21}n_2 + B_{12}n_1u - B_{21}n_2u'] We can solve the energy density per bandwidth, . (u'). [B_{12}n_1u - B_{21}n_2u = A_{21}n_2 n_2 n_1 B_{21} B_{12} n_2 n_1 A_{21} represents the electron density in the lower energy state, divided by the electron density in the upper equilibrium. This amount is a function of temperature. Assuming many permissible energy states, the number of occupied states decreases exponentially with temperature, an idea known as Boltzmann statistics. The amount (frac k_BT g_1 g_2 n_1 n_2 g_2, g_1) represents the degeneration stage, which is the number of approved electrons in the upper state over the number of permitted electrons in the lower state [84, p. 186]. In this expression, the characters (g_1 g_1) and (g_2 g_2) are a uniform measurement of the number of ways in which electrons can occupy an energy state. The equations 'ref'7.1.10' and 'ref'7.1.11' can be combined. [u = frac A_{21} (fracg_1 g_2 frac-k_BT-k_BT-right) B_{12}-B_{21}-Label7.1.11 B_{21} A_{21} k_BT g_2B_{21} g_1B_{12} Consider a blackbody radiator, a conductive wire that is constantly supplied with heat so that it remains in equilibrium at temperature (T). | dn_2 An expression for the energy density per unit bandwidth of this system is given by the equation Ref7.1.1. The equation Ref7.1.12 gives a second expression for the energy density per bandwidth and has been relative relative absorption, spontaneous emission and stimulated emission. These equations can be combined to link the rates of the different processes. ['frac'8'B_{21} A_{21} k_{1} {3} {3}'k_ g_{2} B_{21} g_{1} B_{12}'The above equation applies to the conditions [fracA_{21}B_{21} = frac8 pi h f {3}, {3} label (label, 7,1,15) and g_1B_{12}g_2B_{21}we can quickly calculate the other two Einstein coefficients from the equations Ref7.1.15 and ref (Ref). These equations provide further insight into the operation of lasers and other devices based on stimulated emission. The total upper-body population rate is given by the total population rate of the state, which is indicated by n_{2} the U-B_{21} n_{2} u-A_{21} n_{2}-A_{21} n_{2}+g_{1} g_{2} B_{21} n_{1} u-B_{21} n_{2} u', which can be simplified with a certain algebra. n_{1} g_{1} g_{2} n_{2} B_{21} A_{21} n_{2} n_{2} The term in brackets is the net upper body population. Optical gain and lasing can only occur if the term in parentheses is positive. The condition [n_2 - frac g_2 g_1 n_1 >0 is called the population inversion [86, p. 189]. It only occurs when the system is supplied with sufficient energy by optical, electrical or thermal means, so that there are more electrons in the upper energy level than the lower energy level. The inversion of the population has nothing to do with the inversion symmetry discussed in p. 2.3.2. See Appendix C for an explanation of inversion and other overloaded terms. Conditions.

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