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Strong Processes and Transient States

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Certain difficulties raised by Einstein and Schrödinger in connection with the quantum theory of radiation are discussed and resolved in terms of the author's theory of the double solution.

1. ON THE NATURE OF QUANTUM TRANSITIONS

In an important contribution in a book published in 1953, Einstein[1] introduced a very interesting idea according to which, whenever a quantum transition takes place with exchange of energy and momentum between two particles, something must then intervene "which should possess an atomic structure as well as the electron itself." His idea was that something important would then happen that could not be described by means of the usual quantum formalism (which disregards the localization of the particles and focuses attention solely upon the wave function), for this formalism can neither describe the structure of the particles nor account for the possibility of collisions arising among them.

Let us clear up the meaning of Einstein's somewhat inaccurate text. Let us consider an atom of hydrogen which is initially in a stationary state denoted by one of its eigenfunctions ψ_i. A charged particle traveling in the neighborhood of the atom will then disturb its state and this perturbation will be represented by the Coulomb potential e/r of the incident particle.

If the perturbation is weak, the initial ψ_i changes into $\psi = \sum_j c_j \psi_j$ with $c_i \simeq 1$ and c_j very small for $j \neq i$. We may say that by means of the perturbation the ψ_i component is slightly weakened and some small components ψ_j then show up. Now, according to the current theory, at the end of the weak interaction the atom will have a probability $| c_i |^2$ almost equal to unity of having remained in its initial state and a very small probability $| c_j |^2$ of having gone over into one of the ψ_j states. Yet the energy variations $W_j - W_i$ of the atom, corresponding to unlikely transitions, can have great values. The paradox set off by Einstein then consists in the following: How can it be that a very weak interaction may in certain cases bring about an important transfer of energy?

Besides, what we have just said about the interaction between a particle and an atom can be generalized to all the cases of interactions between particles or sets of particles which end by an important transfer of energy and momentum. In all the cases of this type, there must be first an overlapping of the waves of the particles in one region of the space. Since the particles are then found in the same volume, a "contact" between the very small regions which constitute the particles may then occur at a given moment. Einstein's idea surely was that it is this "contact," or "collision," which would then make possible a sudden transfer of energy and momentum between the particles. But the very meaning of collision implies that particles are localized throughout the space. The usual quantum mechanics, by just making use of wave formalisms without including any element allowing the definition of the position of a particle, can by no means account for any process of collision. The weak perturbing potential appearing in the usual wave equations can only modify the "weak process" of the evolution of the wave by bringing about some new components. It cannot produce, as was most accurately noticed by Einstein, the "strong process" arising with the sudden transfer of a finite energy.

Up to now we have employed the concepts of the usual quantum theory. We shall now consider the same question from the point of view of the theory of the double solution, whose basis we now briefly review. The true physical wave, which I call the wave v, would be a wave with very weak energy whose existence could not become directly manifest by means of observable phenomena. But this wave could carry one or several particles which would constitute in the midst of the wave some small region(s) with a great concentration of energy. Each particle would possess an internal frequency so that it could be thought of as a small clock, and along its trajectory within the wave v the wave and the clock would always remain in phase. It follows that the particles have a regular motion, the guidance motion, imposed by the evolution of the wave. Overlapping this regular motion there is a random Brownian motion probably arising from the unceasing aleatory energy

exchanges between the particle and a hidden medium, the subquantum medium. The physically meaningless wave ψ with its statistical character, which is usually considered in quantum mechanics, is defined by means of the wave v as $\psi = Cv$, where C is a normalization factor such that $\int |\psi|^2 d\tau = N$, N being the number of particles carried by the wave. I shall not lengthen these considerations of the theory of the double solution, whose developments can be found in Ref. 2, but rather discuss an important notion. When the wave v, which according to our view is a physical reality, is formed by a superposition of monochromatic components, such components do not have a separate, independent existence, for what is a physical reality is solely the superposition itself. We shall later recognize the importance of this remark.

With the ideas of the theory of the double solution, we are led to saying that if a localized particle during its motion through space comes across another localized particle, a very swift process takes place, which the evolution wave equations are unable to account for, such that each particle will leave its original wave v and become attached to one of the components of this wave, with a breaking of the phase relations and total conservation of energy and momentum.

Of course, the emission and absorption of a photon by an atom must fit into this scheme. To ensure this, one must conceive that in the process of emission an atomic electron which is initially in contact with an annihilated photon of zero energy (perhaps hidden in the subquantum medium) supplies a certain amount of energy so that the photon will be transformed into an observable photon of nonzero energy. The process of absorption will be exactly the inverse.

We are thus led again to make a distinction between the "weak processes" described by the propagation of the wave v which have a continuous character, and the "strong processes" involving the particles where almost the whole energy is concentrated. Of course, Bohr quantum jumps are but particular strong processes. We do not say, as Bohr did, that such quantum jumps "transcend any description in the frame of space–time." We rather confine ourselves to saying that they defy any description within the framework of a theory which disregards the localization of the particles.

We shall now get back to the same ideas and consider them from another point of view.

2. THE TWO STAGES OF A QUANTUM TRANSITION

The assemblage of the wave and the particle as it is put forward by the theory of the double solution may be considered as bearing a "superstructure" and a "substructure" in the following way.

(a) *The substructure* is framed by the wave v whose evolution is causal and, at least in a first approximation, linear. This evolution is deduced from the classical equations of the wave ψ (or of the electromagnetic waves in the case of the photon), since we assume the relation $\psi = Cv$, where C is a normalization factor. Both waves v and ψ obey the same equation of propagation and are restricted to the same boundary conditions. But there is a great difference in the nature of the two types of waves, for v is a real physical wave with very weak amplitude, whereas ψ, whose amplitude is arbitrarily normalized and which lacks the additivity property peculiar to the solutions of a linear equation, is not a true wave. The function ψ is but a probability representation.

(b) *The superstructure* is constituted by the particles (i.e., regions with great concentration of the field) embodied in the wave v and moving in such a way that they remain in phase with it. It is this superstructure that is revealed through observable phenomena, yet such phenomena cannot receive a satisfactory explanation as long as the hidden substructure is not taken into account.

As an application of the ideas developed in the preceding paragraph, we shall now consider the simple case of two particles at the observable microphysical level, other than photons. Let us assume that in their initial state these particles are carried by two wave trains which are nearly monochromatic and far enough apart for them to occupy two entirely separated regions in space. If the wave trains are brought near so that they are juxtaposed, an interaction then begins which, according to the current theory, is given by a causal and linear evolution of the wave ψ of the system in configuration space. The initial state, which was represented in configuration space by a wave ψ_i composed of two entirely separate parts, then becomes a wave $\psi = \sum c_l \psi_l$ given by the superposition of the Fourier components corresponding to propagations of waves in physical space. In the course of that evolution, a process suddenly takes place which cannot be represented by means of the usual wave formalism, such that at the end, the two particles are attached again to two wave trains completely separated in physical space. The wave ψ in configuration space then has the form ψ_f, which is the sum of two parts entirely separated in that configuration space.

In full, there was a transition from the initial state represented by $\psi = \psi_i$ to a final state denoted by $\psi = \psi_f$ but, and this is very important, this transition has been accomplished in two steps. The first one, a linear, causal, slow transition, is precisely represented by means of the ordinary equations of wave mechanics; the second one, which is impossible to describe at the present, is very quick and involves an important conservative interchange of energy and momentum between the two particles with a breaking of the phase

relations. We may say that the first step is a process which is well described by the evolution of the substructure, whereas the second step is mainly a process that takes place at the level of the superstructure and thus lies beyond the scope of the current theory.

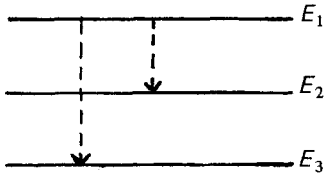
It is important to remark that when the system reaches the state defined in configuration space by the function $\psi = \sum c_l \psi_l$, several quantum transitions are then possible from the state ψ to any state ψ_l. In agreement with the idea of Einstein, who regarded the sudden exchange of noticeable amounts of energy and momentum between the particles during the quantum transition as an effect of "granular" nature, one may think that the possibility for several different quantum transitions is due to the different ways the particles may come into collision, the collision being defined as the contact of the boundary structures of the particles. These contacts correspond to those points of the configuration space where we have $x_1 = x_2$, $y_1 = y_2$, $z_1 = z_2$. The success of the current wave mechanics shows that the probability of the transition $\psi = \sum_l c_l \psi_l \to \psi_k$ is equal to $| c_k |^2$, which is a result that can also be found by means of the theory of the double solution. In addition, we note that, as will now be shown, the existence of the first slow causal linear step of the process of collision is necessary for us to account for the width of the emitted spectral lines.

3. SPECTRAL WIDTH AND PRECURSORY STATES

It is assumed in the classical wave theory of light that atoms can emit wave trains of spectral width $\delta\nu$ during a time τ and it can be shown that $\tau \cdot \delta\nu \cong 1$. In the emission of ordinary light, the length of such wave trains is generally of the order of a meter. Only in the case of Hertzian waves and light waves emitted by lasers does one obtain wave trains of greater length, corresponding to a much longer time of coherence. In the classical theory of radiation the interpretation of the spectral width of the lines does not seem to raise any difficulties, but such is not the case in the current quantum theory. When an atom emits light by means of a quantum jump (such as was conceived by Bohr), it should emit a strictly monochromatic radiation, which is impossible. For that reason, the orthodox quantum mechanics was led to the development of a theory of the natural width of spectral lines as can be found in the book of Heitler.[3] But this theory seems to meet with a serious difficulty, as we shall now show.

Let us consider this theory of the width of spectral lines and confine ourselves to a particular case that can be easily generalized. We shall envisage an atomic system with three stationary states which will be labeled 1, 2, 3,

with decreasing energy. We then have the following scheme of possible transitions starting from the initial state 1:



The atom being initially in the state of energy E_1, we assume that by means of a quantum transition it will go either into the state of energy E_2 or into the state of energy E_3. In the initial state, the wave function ψ of the atom is $\psi_i = \psi_1$. We suppose that during the lapse of time preceding the quantum emission, the wave ψ evolves from its initial form ψ_1 and that at the instant t we may write

$$\psi(t) = c_1(t)\,\psi_1 + c_2(t)\,\psi_2 + c_3(t)\,\psi_3 \tag{1}$$

Let us still assume, somewhat arbitrarily, that we must have $c_1(t) = e^{-t/2\tau}$, so that the probability of the state 1 at the instant t is $|\,c_1\,|^2 = e^{-t/\tau}$, τ being the mean lifetime of the state of energy E_1. One may then calculate $c_2(t)$ and $c_3(t)$ and, of course, one gets $|\,c_1(t)|^2 + |\,c_2(t)|^2 + |\,c_3(t)|^2 = 1$. Now since the term $c_1\psi_1$ appearing in (1) is $e^{-t/2\tau}\psi_1$, it can be developed as a Fourier integral and therefore we see that the state 1 is no longer monochromatic with frequency E_1/h, but rather exhibits a small spectral width. With regard to that spectral broadening of level 1, the possible quantum transitions $1 \rightarrow 2$ and $1 \rightarrow 3$ correspond to the emission of electromagnetic wave trains with spectral width $\delta\nu$. We obtain the relation $\tau\delta\nu \cong 1$ for the emitted wave train and thus prove the assumption according to which the traveling time τ of this wave train at a point of space may be equated to the mean life τ of the state 1 in the emitting atom.

Everything thus seems satisfactory. Yet, as a matter of fact, besides some mathematical difficulties that appear in the calculation, one is led to a paradoxical conclusion. In fact, the natural width of the line emitted in a quantum transition, for instance $E_1 \rightarrow E_2$, would then depend not only upon the transition that actually took place but also upon all the transitions which were possible but *did not take place* (here $E_1 \rightarrow E_3$). Such an interpretation seems to me impossible to admit, for a phenomenon cannot depend upon other phenomena which were possible but which have not been brought about. And yet the theoretical prediction is confirmed by experiment.

The paradox one thus meets can be removed if one makes use of the notions of weak processes and strong processes introduced here. Let us

consider again the problem of the width of spectral lines in the framework of our ideas. In the initial state, the wave function v of the atom is $v_i = (1/C)\,\psi_i$. Then begins a linear causal evolution of the wave v in interaction with a precursory electromagnetic field also of the v type which carries no photons as yet. The above calculation for the wave ψ is still true for the wave v so that, if we divide Eq. (1) by C, we get

$$v(t) = c_1(t)\,v_1 + c_2(t)\,v_2 + c_3(t)\,v_3 \tag{2}$$

where it is assumed that $c_1(t) = e^{-t/2\tau}$. But it must be remarked that, since the wave v is for us a real wave, the three terms on the right-hand side of (2) do not have an independent existence: Only the wave $v(t)$ which is formed by their superposition has a physical existence. The wave function (2) defines the "precursory state" which precedes a quantum emission and is the only one having real existence. In a corresponding way, a precursory electromagnetic field then appears, i.e., a weak process of the v type which carries no photons. This field is formed by the superposition of two components of frequencies $\nu_{12} = (E_1 - E_2)/h$ and $\nu_{13} = (E_1 - E_3)/h$. Each one of these components has a spectral width $\delta\nu \cong 1/\tau$ depending simultaneously upon the three quantized states of the atom we have been considering. But here the spectral width is not due to the probabilities of the transitions $1 \to 2$ and $1 \to 3$ *which did not take place as yet*, but rather to the causal evolution caused by the interaction of the precursory field v of the atom with the precursory electromagnetic field v.

A quantum transition suddenly arises (a swift, strong process) whose description completely surpasses the usual wave theory since it clearly shows the localized character of the particles. Let us assume that it is the transition $1 \to 2$ which is brought about. Then, according to our conception, the atomic electron leaves the wave $v(t)$ given by (2) and goes over into the wave $v_2 = (1/C)\,\psi_2$. In a corresponding way, as is necessary for the conservation of energy, a photon (perhaps arising from the subquantum medium) then appears in the electromagnetic wave train of frequency ν_{12} and spectral width $\delta\nu$. At length, there is an emission by the atom of a photon carried by an electromagnetic wave v corresponding to a spectral line of frequency ν_{12} and spectral width $\delta\nu$. Similar considerations can be given for the case of the transition $1 \to 3$.

The paradox issuing from the current theory and which has been pointed out in the foregoing thus seems to disappear. The spectral width of a line emitted by a quantum transition is not due to the probability of a transition that did not take place: It is due instead to the causal evolution of the weak process of the v type preceding the quantum transition.

The hidden thermodynamics of the particles, which is the natural

complement of the theory of the double solution in its present form, allows us to see[4] that the monochromatic quantized states have a greater thermodynamical probability than the precursory states which are defined by means of a superposition of monochromatic waves. It follows that the passage back from a precursory state to a monochromatic stationary state is associated with an increase of the thermodynamical probability. The quantized states are then more stable than those whose wave function is of the form $\psi = \sum_l c_l \psi_l$, and this is a point to the which we shall return in the sequel.

In the preceding we have studied the case of the spontaneous emission (as defined by Einstein) of a photon by an atom. Similar considerations might be set up in the case where a wave carrying a photon strikes an atom (or a molecule). A precursory transient state may then occur which ends by a sudden quantum transition, with an increase of the thermodynamical probability, which, according to the different cases, may engender a stimulated emission or absorption in the sense of Einstein, a Compton effect, or a Raman effect.

What seems illusory and incorrect in the currently adopted conception is that it considers as independent states the Fourier components appearing in the expression of the wave during the precursory process, when the real quantum transition has not yet taken place. One thus takes for independent quantum states what in fact are but the terms appearing in the calculation (by means of the method of the variation of the constants) of the evolution of the *coherent* wave (v or ψ) during the precursory process. Therefore one is led to consider the particle or the system as being spread over several quantum states, when in fact it is in a sole transient state with fluctuating energy. The confusion is rendered easy by the fact that the development of the expression of the wave in the precursory state involves the whole ensemble of quantum transitions which could take place but actually were not brought about.

This can perhaps be seen more clearly in the case where, continuing the parallel, in the calculation of the wave components use is made of intermediate states ψ_j such that, the direct transition $\psi_i \to \psi_k$ being impossible, it may nevertheless take place by means of the double transition $\psi_i \to \psi_j \to \psi_k$. It is then seen that the transitions $\psi_i \to \psi_j$ and $\psi_j \to \psi_k$ do not conserve energy, whereas the whole transition $\psi_i \to \psi_j \to \psi_k$ does conserve it, which is often interpreted by saying that, due to uncertainty relation $\delta W \delta t \simeq h$, the time duration δt of the whole process is too brief for us to apply the conservation of the energy to the steps of this process. This is what has led to the introduction of the strange notion of virtual particles (for instance, virtual photons) violating the conservation law for the energy. Here again we take for a physical reality what is but a step in a calculation, for the intermediate states E_j are not physically accomplished but rather the terms

arising in the calculation of the *indecomposable* precursory state existing before the real quantum transition.

4. INTRODUCTION OF SOME IDEAS OF SCHRÖDINGER IN THE PRECEDING THEORY

In a paper entitled "Are there quantum jumps?" Schrödinger[5] noticed that the "privilege" attached to the stationary states seemed not to be justified. Why, he said, is it assumed that a quantized system is always found in a stationary state $\psi = \psi_k$, when the general form of the wave function, the solution of a linear equation, evidently is but $\psi = \sum_j c_j \psi_j$? He inferred from this that the stationary states had usurped their privileged situation.

Starting from this idea, Schrödinger sought a picture of the phenomenon of radiation emission by an atom in a classical way without Bohr quantum jumps. He thought one must start from the formula $\psi = \sum_j c_j \psi_j$ denoting a superposition of stationary states and he defined the corresponding electric moment σ of the atom by putting $\psi_j = a_j e^{(i/\hbar)E_j t}$, where the a_j may be complex, and writing

$$\sigma_q = -e \int \psi^* \psi q \, d\tau = \sum_{ik} c_k^* c_i (\sigma_q)_{ki}$$

where $q = x, y, z$ and

$$(\sigma_q)_{ki} = -e \int q \psi_k^* \psi_i \, d\tau = -e \int a_k^* a_i q \, d\tau \, e^{(i/\tau)(E_i - E_k)t}$$

The atom should then radiate as an ensemble of oscillators with electric moment $(\sigma_q)_{ki}$ and thus emit all the Bohr frequencies $\nu_{ik} = (E_i - E_k)/h$. He regarded this result as a sort of classical interpretation of radiation by means of quantum transitions. But it is easily seen that such an interpretation meets with serious objections: The frequencies would then be emitted all at once and nothing would then resemble the quantum jumps of Bohr, the initial state would not play any particular role, all the quantized states would arise in the same way, etc.

Nevertheless, if one adopts the conceptions of the theory of the double solution and if one assumes the existence of the precursory states as we have defined them in the foregoing, it seems possible to give to Schrödinger's idea an acceptable and very interesting form.

Let us take the case of a spontaneous emission of N_i atoms in the initial quantum state of energy E_i. The precursory state as formerly defined is denoted in the usual formalism by a function ψ of the form $\psi = c_i \psi_i + \sum_k c_k \psi_k$, the sum $\sum_k$ being extended over the states of energy $E_k < E_i$. In this

precursory state, the electric moment considered by Schrödinger has a component σ_q of frequency ν_{ik} which is

$$(\sigma_q)_{ik} = -ec_k^* c_i \int \psi_k^* \psi_i q \, d\tau \qquad (q = x, y, z)$$

With regard to the ensemble of N_i atoms, the energy radiated in the form of a wave of frequency ν_{ik} with electric field parallel to the q axis will be given, according to the classical theory of radiation, by the formula

$$N_i \frac{64\pi^4 \nu_{ik}^4}{3c^3} |(\sigma_q)_{ik}|^2 = N_i \mid c_k \mid^2 \mid c_i \mid^2 e^2 \left| \int \psi_k^* \psi_i q \, d\tau \right|^2 \frac{64\pi^4 \nu_{ik}^4}{3c^3}$$

$$= N_{i \to k} e^2 \left| \int \psi_k^* \psi_i q \, d\tau \right|^2 \frac{64\pi^4 \nu_{ik}^4}{3c^3}$$

where $N_{i \to k} = N_i \mid c_k \mid^2 \mid c_i \mid^2$ is the number of atoms which pass from the initial state of energy E_i to the final state of energy E_k.

We must now take a closer look at the picture thus obtained. According to our view, during the precursory state there is in the atom an electronic wave v of the form

$$v = a_i e^{-t/2\tau} e^{(i/\hbar) E_i t} + \sum_k c_k a_k e^{(i/\hbar) E_k t}$$

This wave v will carry, under a form which will be made precise later, a variable electric field whose Fourier components can be written in the form

$$(\sigma_q)_{ik} = -e \int a_k^* a_i q \, d\tau \, e^{-t/2\tau} e^{(i/\hbar)(E_i - E_k)t}$$

In other words, there would exist in the wave v of the atom during the precursory state a variable distribution of electricity whose spectral composition would comprise all the frequencies corresponding to the Bohr quantum transitions capable of being emitted. According to classical laws, this weak, variable distribution of electricity would radiate around the atom a very weak electromagnetic wave of the v type carrying no photons and which would also comprise all the frequencies capable of being emitted by the atom. At the very weak level of the wave v all the quantum emissions would be in a certain way *prefigured* and at that level everything would then be accomplished in a classical way in agreement with the guiding idea of Schrödinger.

But what is not classical is the way the precursory state ends by a strong process with exchange of energy. Such a process could not be depicted by means of a theory such as Schrödinger's, which disregarded the localization of the particles. The atomic electron will then go into one of the components

with frequency ν_k of the electronic wave v of the precursory state, the probability of such a transition being $|c_k|^2$. According to the hidden thermodynamics of the particle, this sudden return of the electron to a stationary state of lesser energy than that of the initial state corresponds to an increasing entropy or, more precisely and due to the emission of the photon, to a decreasing free energy and this is what justifies the prerogative of the stationary states that was contested by Schrödinger.

We thus see that Schrödinger's conceptions can be adopted in order to describe the substructure during the precursory state without prejudice to the prerogative of stationary states (which is of thermodynamical origin, according to our view) and this must remain true in the absorption processes as well as in the spontaneous or stimulated emission processes. We may say that at the level of the substructure, i.e., of the wave v, everything looks as if the classical electromagnetic theory were correct. This conclusion, which could probably be related to the correspondence principle, is one of the reasons for the validity of employing the classical electromagnetic theory in many calculations in spite of the unquestionable existence of photons. But there is still an important point to be discussed.

5. THE ROLE PLAYED BY THE CHARGE OF THE ELECTRON DURING THE PRECURSORY STATE

Let us first remark that it seems assured that the wave v of an electron comprises a very small electric charge of density $-ea^2$ spread over all its extent. In fact, if we consider an electronic wave v which does not carry an electron and if we assume that such a wave is subjected to the action of an external electromagnetic field, the presence in the equation of evolution of a term $-eV$, where V is the potential of the external field, shows that this propagation is affected at every point by the action of the electric field, which seems to entail the idea that a very small fraction of the electron charge is spread over all the wave v.

Nevertheless, with our conception of an electron localized in the wave, almost the whole charge $-e$ must be localized in the electron itself. In the stationary states of the atom where, according to our ideas, the electron follows its motion although there must be no radiation of energy to the exterior, the difficulty is similar to that encountered in the early Bohr theory of the atom where the electron was assumed to describe circular or elliptic orbits and yet, against the predictions of the classical electromagnetic theory, the atom in its stationary state does not emit electromagnetic energy.

Pondering over the problem, we are led to some conclusions which seem to be very interesting. Let us take an atom of hydrogen where the electron

follows its guidance motion over a circular trajectory around an axis OZ. By making use of the polar coordinates r, α, θ this case is realized when the wave v has the form

$$v_k = a_k(r, \alpha, \theta)\, e^{(i/\hbar)(E_k t - mvr\alpha)}$$

with a_k real and $\psi_k = Cv_k$. The angular momentum of the electron over a guidance circular trajectory is then a nonzero integer multiple of h. Then, according to our conception, the guidance trajectories of the electron are small circles of radius r described with the velocity v, r and v being related by $vr = n\hbar/m$, where n is an integer. In the early form of the theory of the double solution where the random perturbations of subquantum origin were not taken into account, the electron followed only one of these circular trajectories so that one could not see why it did not radiate. But in the present form of the theory the electron is compelled, by means of the unceasing subquantum perturbations, to constantly go from one of its circular trajectories defined above to another of these trajectories, with v and r varying in such a way that their product remains constant. This is the reason why the probability that the electron is present in an element of volume $d\tau$ of the atom is equal to $|\psi|^2 d\tau$ where $|\psi| = Ca_k(r, \alpha, \theta)$ does not depend upon time. This circumstance, by establishing a sort of incoherence among the emissions which would correspond to the elements of trajectories of the electron, assures that the total stationary state of the atom does not radiate, which perhaps could be more precisely proved by means of a more fully developed calculation. It then seems that we may draw the following conclusion: *For a state of an atom to radiate it is required that the quantity* $|\psi|^2$ *depend on time.*

However, in the precursory states previously defined, the wave v of the electron is formed by a superposition of components with frequencies of the form $\nu_i - \nu_k$ equal to the frequencies that can be emitted by means of Bohr transitions. The quantity $|\psi|^2$ in these precursory states is thus a function of time and, in agreement with the classical conceptions and the ideas of Schrödinger, there is then an emission of an electromagnetic wave v which does not yet carry any photon and which is the superposition of the components corresponding to all the frequencies $\nu_i - \nu_k$. It is only afterward that this precursory state suddenly ceases by means of the strong process or "Einstein collision" accompanied by an emission of one of the frequencies $\nu_i - \nu_k$, whereas the atom goes over into the stationary state of energy $h\nu_k$ with conservation of the total energy.

It seems that one must draw the conclusion that the emission during a precursory state of a very weak electromagnetic wave around the atom involves not only the very weak electric charge of the electronic wave v,

but also the totality of the electric charge concentrated in the particle "electron," which charge is in a way statistically spread during the precursory state by means of the subquantum perturbations over the whole extent of the electronic wave v.

6. LAST REMARK AND CONCLUSION

An important remark must still be made about the general scheme proposed here which concerns stimulated emission and absorption. In fact, such a scheme is only valid when the precursory state of the atom can be represented by a superposition of eigenfunctions corresponding to the unperturbed states of the atom. Now, this condition may cease when the action of the electromagnetic wave incident upon the atom is strong enough to modify sensibly the undulatory state of the atom. This could be related to the very interesting work of Georges Lochak and his collaborators.

In addition, the problem of the stimulated transitions requires a more thorough study. In particular, one should explain why the stimulated emissions or absorptions are proportional to the number of photons carried by the incident wave. This is perhaps due to the fact that the incident electromagnetic wave v, in spite of being very weak, acts as if it were much more intense because the photons which it carries bring to the atom some "patterns" of a much more intense electromagnetic wave which are spread statistically over all the wave by means of the subquantum random perturbations.[2,6]

Of course, the ideas developed here are but general indications which need to be more fully developed, but which probably constitute the basis upon which one must build the real theory of interaction between matter and radiation.

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