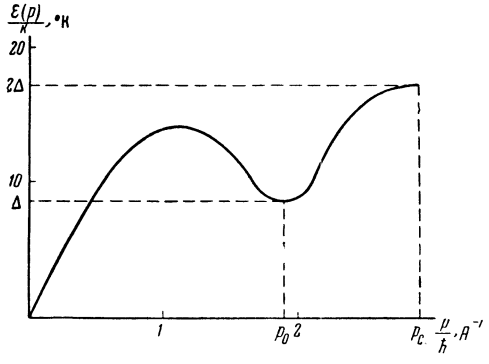
= 17.3° K, obtained by investigation of the inelastic scattering of neutrons. In this case it was shown that the function $\epsilon(p)$ in this region has a negative second derivative, i.e., that the spectrum begins to "bend." In the opinion of the authors of the communication, this suggests the presence of a second maximum in the function $\epsilon(p)$.

The purpose of the present note is to turn attention to the fact that this phenomenon actually has another explanation. That is, we have shown[2] that the curve of the energy spectrum of liquid helium II generally cannot rise above the energy $\epsilon = 2\Delta$. This is connected with the fact that an elementary excitation with energy $\epsilon \geq 2\Delta$ can divide into two excitations with energy $\epsilon = \Delta$. At the energy $\epsilon = 2\Delta$ the curve $\epsilon(p)$ reaches a maximum and breaks off, so that this point is the end point of the spectrum. Close to it the spectrum has the form

$$\varepsilon(p) = 2\Delta - \alpha \exp[-a/(p_c - p)], \qquad (1)$$

where p_c is the momentum for which the energy is equal to 2Δ while α and a are certain constants. Thus the complete curve of the spectrum of elementary excitations of liquid helium II has, qualitatively, the form shown in the drawing. However, it should be noted that, until experimental data become available, theoretical prediction of the behavior of the curve $\epsilon(p)$ was not completely unique, inasmuch as the possibility was not excluded that the velocity of the excitation at some point with $\epsilon < 2\Delta$ would not equal the velocity of sound.* In this case the curve $\epsilon(p)$ would be gradually washed out because of radiation of phonons, not achieving the value 2Δ. The data obtained in reference 1 precisely show that this is not the case, i.e., that the spectrum without damping achieves the energy 2Δ where it must terminate.



We also note that the probability of the creation of a single excitation with energy ϵ by a neutron vanishes as $\epsilon \to 2\Delta$ according to the law

$$w = A \frac{(2\Delta - \varepsilon)}{a} \ln^2 \frac{\alpha}{2\Delta - \varepsilon}. \qquad (2)$$

This is in qualitative agreement with the fact that, for the maximum energy obtained in reference 1, $\epsilon = 17.1°$ K, the probability of the creation of an excitation amounts to 6 per cent of the probability of the creation of an excitation with $\epsilon = \Delta$.

*We do not mention another method of termination of the spectrum described in reference 2, inasmuch as it is extremely improbable in helium.

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NEGATIVE ABSORPTION IN METAL VAPORS

S. G. RAUTIAN and I. I. SOBEL'MAN

P. N. Lebedev Physics Institute, Academy of Sciences of the U.S.S.R.

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SCHAWLOW and Townes[1] have considered the use of negative absorption for the amplification and generation of radiation in the optical region of the spectrum. As an example they have considered potassium vapor, excited by ultraviolet light from a potassium lamp. However, the intensity of the exciting light proved to be insufficient, and this behavior is typical for metals. The use of a different source cannot be a universal method, since there exist at most 2 or 3 coinciding pairs of lines from different elements suitable for the purpose in view. There is therefore a limited outlook for the direct optical excitation of metal vapors. It seems possible to circumvent this difficulty by working with a mixture of two gases, in which a resonance level of one gas is close to an excited level of the other. Under these conditions we can expect an intense optical excitation of the first gas and an effective population of the neighboring level in the other, thanks to resonance transfer of the excitation energy. It is this effect,

in fact, which leads to an intense sensitization of fluorescence.[2,3]

As an example, let us consider a mixture of sodium and mercury vapors, irradiated by Hg resonance radiation, $\lambda = 2537$ A. The displacements ΔE of a number of Na levels from the Hg 6^3P_1 resonance level, and their radiation widths A, are given in the table. Using the data of reference 4 on the intensity of sensitized fluorescence, and knowing the transition probabilities, it is easy to ascertain that the levels 9^2S and 8^2P are populated approximately in the ratio 1 : 5, while their populations exceed those of the other s and p levels by at least one order of magnitude.

Levels	E, cm^{-1}	ΔE, cm^{-1}	$A \times 10^{-6}$, sec^{-1}
10^2S	39983.0	573	—
9^2S	39574.5	162	1.5
8^2S	38968.3	—444	2.4
7^2S	38011.7	—1400	3.8
9^2P	39794.3	382	—
8^2P	39298.8	—113	0.25
7^2P	38540.8	—871	0.45
8^2D	39728.1	316	—
7^2D	39200.4	—212	3.1
6^2D	38387.1	—1025	5.2

Let us calculate N_{8p}, the absolute concentration of sodium on the 8^2P level. An estimate of the effective cross section σ for the transfer of excitation in the case of exact resonance ($\Delta E = 0$) gives $\sigma \approx 3 \times 10^{-14}$ cm^2. If $E \neq 0$, but $\sqrt{\sigma}\,\Delta E/vh \sim 1$, as in our case, then the cross section diminishes, but not by more than an order of magnitude. Hence we can take as the lower limit $\sigma = 3 \times 10^{-15}$ cm^2. An estimate of the probability of quenching collisions and of the transfer of excitation energy from Na to Hg shows that, for a partial concentration of 10^{14} to 10^{15} cm^{-3}, which is convenient for a number of reasons of an experimental nature, these processes can be neglected. Under these circumstances

$$N_{8p} = \frac{\sigma v N_{Na}}{p} \frac{b N_{Hg}}{A} = \frac{\sigma v N_{Na}}{A_{8p}} \frac{3\lambda^3}{8\pi c} \frac{\mathscr{E}}{h\delta\nu} N_{Hg},$$

where N_{Na} and N_{Hg} are the total concentrations of Na and Hg, A_{8p} and A are the radiation widths of the Na 8^2P and the Hg 6^3P_1 levels, b is the excitation probability of Hg, v is the relative velocity, $\mathscr{E}$ is the intensity of illumination, and $\delta\nu$ is the line width of the excitation. Bactericidal and other similar low-pressure mercury lamps permit one to obtain[9] $\mathscr{E} \sim 10^{-12}$ w/cm^2 when $\delta\nu \lesssim 1$ cm^{-1}. When $N_{Na} = 5 \times 10^{14}$, $N_{Hg} = 2 \times 10^{14}$, and $T = 600°K$ we have $N_{8p} = 3 \times 10^9$ cm^{-3}.

As has already been mentioned, the n^2S and n^2D levels lie below 8^2P, and are considerably less populated. Therefore the absorption coefficients k for the transitions n^2S-8^2P and n^2D-8^2P are negative. This means that the stimulated emission exceeds the absorption. Under the given conditions, the line widths are determined by the Doppler effect $\delta\nu = \delta\nu_D$, and in that case, as is well known,

$$|k| = 2\sqrt{\pi \ln 2}\,(e^2/mc) f N_{8p}/\delta\nu_D,$$

where f is the oscillator strength for a transition from the 8^2P level. The most convenient transitions are 8^2S-8^2P ($\lambda = 30.2\mu$; f = 1.1) and 7^2S-8^2P ($\lambda = 7.77\mu$; f = 0.037). In the first case $|k| = 2$, and in the second $|k| = 0.02$. Both these values of $|k|$ are large enough to be used in the proposed system for the purpose of amplifying and generating infrared radiation.* The transitions n^2P-9^2S can also be used.

The high values of N_{8p} and $|k|$ have arisen as a result of the high density of the resonance radiation (see reference 1, where the excitation of non-resonant radiation is considered). Note also that we have not considered the effect of "imprisonment" of radiation in the above treatment. Since $\sigma v N_{Na}/A \sim 10^{-2}$, the quenching of the mercury resonance fluorescence is not important, and this effect leads to an increase in N_{8p}.

The authors express their thanks to P. A. Bazhulin for discussions of the work.

*The Na level scheme which we have considered above shows that the corresponding frequencies will not be absorbed because of transitions from the 8^2P level to higher levels.

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BEHAVIOR OF THE TOTAL CROSS SECTION FOR THE PHOTOPRODUCTION OF π MESONS AT HIGH ENERGIES

E. D. ZHIZHIN

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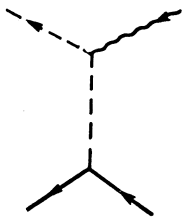
We shall consider the process of collision of a photon with a nucleon for very high incident photon energies $\omega \gg m$, where ω is the photon energy in the c.m. system and m is the mass of the nucleon. At such energies, processes involving the production of two or more π mesons, as well as processes involving the production of heavier mesons, etc., are already possible.

In order to obtain some information on the behavior of the total cross section for the photoproduction of π mesons at high energies, we shall estimate the contribution to this cross section from peripheral interactions. The condition for a collision to be peripheral is $l \gg \omega/\mu$,[1] where μ is the mass of the π meson, and l is the orbital angular momentum. For such large l the basic contribution to the amplitude is made by terms corresponding to a diagram with one virtual meson (see figure). Making use of the results of reference 2 [see formula (6)], we obtain the following expression for the amplitude of the photoproduction of π mesons with an orbital angular momentum l and parity $(-1)^{l+1}$:



$$|a^{(1)}_{l\pm\frac{1}{2},l,M}| = (eg\pi\mu^2/2\omega^3)\sqrt{\omega/2\mu}\exp(-\mu l/\omega). \quad (1)$$

Here $g^2 = 0.08(2m/\mu)^2$; $e^2 = 1/137$; $M = \pm 3/2$ and $\pm 1/2$ are the projections of the total angular momentum on the z axis (the z axis is chosen in the direction of the incident photon momentum).

The total cross section of the process can be written in the form $\sigma = \sigma_0 + \sigma_1$. Here σ_0 contains the contribution from the nonperipheral part of the π-meson photoproduction process, σ_1 is the peripheral part of the cross section. Only one-meson amplitudes with orbital angular momenta $l > \omega/\mu$ contribute to it.

The cross section σ_1 is written in the following way:

$$\sigma_1 = \sum_j \sum_{l=\omega/\mu}^{\infty} \sum_{M=-3/2}^{3/2} |a^{(1)}_{jlM}|^2. \quad (2)$$

Performing the summation, we obtain

$$\sigma_1 = e^2g^2\pi^2\mu^2/15\omega^4.$$

This expression corresponds to small scattering angles $\theta \lesssim \mu/\omega$. Since $\sigma_0 > 0$, then

$$\sigma > e^2g^2\pi^2\mu^2/15\omega^4. \quad (3)$$

Hence the total cross section for the π meson photoproduction process at high energies cannot drop more rapidly than ω_{lab}^{-2}, where ω_{lab} is the photon energy in the laboratory system. This conclusion is evidently not in agreement with the results obtained from the statistical-hydrodynamical theory of multiple production of particles,[3,4] which predicts that the total cross section of the process at high energies should drop exponentially with an increase in energy: $\sigma \sim \exp(-kE^{1/4})$.

In conclusion, I wish to express my graitude to I. Ya. Pomeranchuk for suggesting the problem and for helpful comments.

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