From the point of view considered here, it is interesting to estimate the cross section of backward scattering of $\pi^-$ mesons by protons in the process

$$\pi^- + p \rightarrow \pi^- + p, \tag{4}$$

inasmuch as diagrams similar to those responsible for the cancellation of the backward scattering in reactions (1) and (2) may occur in this scattering. Such an estimate was made for a $\pi^-$-meson momentum 2.8 Mev/c by a method completely similar to that described in our previous paper.[3] We merely selected the quasi-elastic $\pi^-$-p scattering cases, by using additional criteria based on the kinematics of the quasi-elastic process, namely the approximate complanarity (accurate to 15°) and the correspondence between the angles of emission of the charged particles. The cross section of the reaction (4) for l.s. angles greater than 90° (for an interval approximately 1 sr in the c.m.s.) was found to be less than 0.03 mb. This estimate is obtained without subtracting the possible contribution from the background due to creation of $\pi^0$ mesons. The cross section for elastic backward scattering, $\sigma < 0.03$ mb, compared with the cross sections for elastic $\pi^-$-p scattering given by Wood et al,[6] confirms that the character of the scattering varies with increasing energy.

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# *MOLECULAR PHOTODISSOCIATION AS A MEANS OF OBTAINING A MEDIUM WITH A NEGATIVE ABSORPTION COEFFICIENT*

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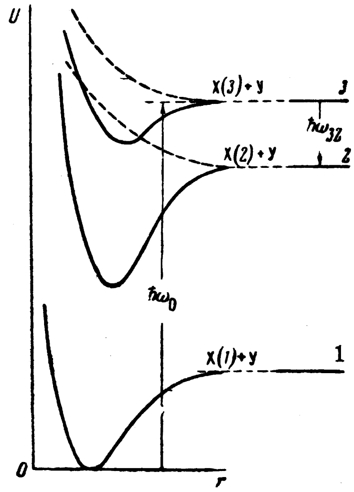
POPULATION inversion in various systems (atoms, molecules, crystals etc.) can be used, as is well known, to obtain a negative absorption coefficient and can be produced by means of optical excitation.[1-7] A new method of obtaining population inversion is discussed below.

We are concerned here with the production of excited atoms as a result of photodissociation of molecules. For simplicity we consider a diatomic molecule XY. In the figure we show a number of typical potential energy curves corresponding to the electron ground and excited states in a molecule (the atomic levels of the X atom are shown in the right side of the figure). Two kinds of curves are possible (these are shown by solid lines and dashed lines in the figure); the following discussion applies to both kinds. The absorption of a photon characterized by a frequency $\omega \gtrsim \omega_0$ causes dissociation of the molecule; as a result one of the atoms (for example, X) can be left in an excited state. Under certain conditions (cf. [1]) an inverted distribution between levels 3 and 2 is obtained in the X atoms, that is to say, the inequality $N_3/g_3 > N_2/g_2$ is satisfied, where N and g are the populations and statistical weights of the corresponding levels shown in the right side of the figure.* This population inversion can be used for



amplification and generation of electromagnetic radiation at the frequency of the atomic transition $\omega_{32}$.

An important feature of the scheme under discussion is the fact that the molecule can, in principle, absorb energy over a relatively wide spectral range ($\sim 10^3$ cm$^{-1}$) whereas the width of the atomic radiation line is small ($\sim 0.01 - 0.1$ cm$^{-1}$). This situation favors high gain factors $k_\omega$. The expression for $k_\omega$ can be written in the form

$$k_\omega = \frac{\lambda^2}{4}\frac{A_{32}}{\gamma A_3}\frac{Q}{\hbar\omega_0}, \quad Q = \int\limits_{\omega>\omega_0} E_\omega \varkappa_\omega \, d\omega. \tag{1}$$

Here, $\lambda$, $\gamma$ and $A_{32}$ are respectively the wavelength, the line width and the Einstein coefficient for the $3 \rightarrow 2$ transition; $A_3$ is the total decay probability for level 3, $E_\omega$ is the spectral power density (w/cm$^2$-cycle) of the exciting radiation; $\kappa_\omega$ is the absorption coefficient associated with the dissociation process $XY \rightarrow X(3) + Y$. The quantity Q is obviously the power absorbed per unit volume as a result of this process. If $E_\omega$ varies slowly in the region of effective absorption, then

$$Q = E_\omega \bar{\varkappa}_\omega \Gamma, \quad k_\omega = \frac{\lambda^2}{4}\frac{E_\omega \bar{\varkappa}_\omega}{\hbar\omega_0}\frac{A_{32}}{A_3}\frac{\Gamma}{\gamma}, \tag{2}$$

where $\bar{\kappa}_\omega$ is the mean value of $\kappa_\omega$, while $\Gamma$ is the width of the absorption peak. It is easily shown that (1) and (2) are valid for all other versions of optical excitation. It is evident from (2) that, all other conditions being equal, $k_\omega$ is determined by the parameter $M = (A_{32}/A_3)\Gamma/\gamma$.† When the atom is excited directly[1,2] $A_{32}/A_3 \lesssim 1$ while the widths $\Gamma$ and $\gamma$ are usually determined by the Doppler effect, i.e., $\Gamma/\gamma = \omega_0/\omega_{32} \lesssim 10$. Consequently $M \lesssim 10$ in this case. In crystals $\Gamma \sim 10^3$ cm$^{-1}$, $\gamma \sim 1 - 10$ cm$^{-1}$ and $A_{32}/A_3 \lesssim 1$[3-6] so that $M \sim 10^2 - 10^3$. In the method proposed here, however, the absorption spectrum is as wide as it is in crystals ($\Gamma \sim 10^3$ cm$^{-1}$) but $\gamma$ is appreciably smaller; to be specific, in the visible and near-infrared, $\gamma \sim 0.01 - 0.1$ cm$^{-1}$. Hence, when $A_{32}/A_3 \sim 1$ we have $M \sim 10^4 - 10^5$. Thus, the advantages of the first two cases—a wide excitation spectrum and a narrow atomic radiation spectrum, can be combined.

An estimate of the absolute magnitude of the absorption coefficient in a typical case ($\gamma = 0.03$ cm$^{-1}$, $\lambda = 1\,\mu$, $\lambda_0 = 2\pi c/\omega_0 = 2000$ A) gives $k_\omega = 0.3Q\, A_{32}/A_3$ where Q is expressed in units of w/cm$^3$. Consequently even with relatively low values $Q \sim 1$ w/cm$^3$ we can obtain $k_\omega = 0.3$ cm$^{-1}$, which is somewhat greater than the value required to achieve the oscillation.

All the considerations given above for diatomic molecules apply equally to molecules composed of more than two atoms. Hence, in principle there are wide possibilities for the choice of suitable systems. It is obvious that a number of practical considerations must be taken into account. For instance, the term system must be such that the frequency $\omega_0$ lies in the required spectral region and the vapor pressure must be high at reasonable temperatures. The most suitable materials are those which can be produced in the working vessel because the decay products must be easily removed from the vessel and so on. However, the basic problem in choosing a suitable system is the fact that the only well-studied photodissociation processes are those for which one of the atoms is at a resonance level.[8]

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*We note that the inequality $N_3/g_3 > N_1/g_1$ cannot be satisfied in practice because the lifetime of the atom in the ground state, which is determined by recombination, attachment at the walls, etc., is much greater than the lifetime of the excited states.

†The quantity $\bar{\kappa}_\omega$ is determined by the need for illuminating the sample and is of order unity in various versions of optical excitation. In practice this is achieved by an appropriate choice of concentration of the absorbing centers.

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