confirmation of this theory gives a basis for using the H^{-2} law at small distances.

9.) The observed deviation from the H^{-2} law, toward lower values, for large distances (10^{-5} cm) indicates (as is easily seen) a small effect of molecular forces on the rate of coagulation of aerosols with particle diameters greater than 3×10^{-5} cm.

10.) The data obtained demonstrate the existence of molecular forces of long range surface interaction, which is one of the corner stones of the contemporary theory of the stability and coagulation of colloids.

11.) The data show that deviations from the 6th power law of the charge, which occurs in the Hardy – Schulze rule, are to be expected for very low concentrations of electrolyte and highly charged ions of opposite sign.

12.) It is pointed out that the measured values of molecular attractive forces in the experiments of Overbeek and Sparnaay exceed both the theoretical values as well as our results by 3 – 4 orders of magnitude, apparently because effects not related to molecular forces played a part in their measurements.

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Elastic Scattering of 310 Mev π^+ Mesons from Protons

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The angular distribution of 310 mev π^+ mesons elastically scattered by protons in photoemulsions has been measured. The differential scattering cross section based on 427 observed cases has been obtained in the center-of-mass system.

The phase analysis, taking into account only the *S* and *P* states, and assuming the Fermi solution, gave the following values for the phase shifts: $\alpha_3 = -23^\circ$, $\alpha_{33} = 132^\circ$, $\alpha_{31} = -9^\circ$. The *D* state, apparently, contributes little to scattering in comparison with the *S* and *P* states.

EXPERIMENTS conducted in recent years for studying the scattering of π mesons have made possible the development of a series of essential laws of interaction of π mesons with nucleons. These experiments have shown that the scattering cross section attains a maximum value for energies of π mesons near 200 mev.[1,2] Attempts have been made to associate this maximum with the existence of an excited state of the nucleon.[3] Theoretical estimates for such an assumption lead to a satisfactory agreement with experiment over a significant range of meson energies.

The combined available evidence for total and differential cross sections for meson nucleon scattering gives reason to think that the experimental results for meson scattering down to an energy of 230 mev could be satisfactorily explained on the supposition that only *S* and *P* states participate in the scattering. It might be expected that even at meson energies of 200-250 mev the *D* states likewise should take part in the scattering; however, the poor accuracy of the measurements does not permit evaluation of the role in the scattering played by the states with the higher values of the orbital momentum. For π mesons with energies greater than 230 mev there are no reliable measurements at all of the differential cross section for meson-nucleon scattering.*

In the present work the differential cross section for elastic scattering of 310 mev π^+ mesons from hydrogen has been measured with the help of photoemulsions. Electron-sensitive photographic plates with an emulsion layer thickness of 400 μ were exposed to a beam of π^+ mesons emerging from the meson magnetic spectrometer.[5] The mesons originated from the paraffin target on bombarding it with a beam of 660 mev protons emerging from the synchrocyclotron chamber; the π^+ mesons, proceeding from the target at an angle of 7.3°, were deflected by the magnetic field after an initial collimation, and in the form of a narrow converging beam fell on the second collimator, to the rear of which were installed the photographic plates. The meson energy at the collimator was equal to 338 mev. A copper absorber having a thickness of 2 cm was placed to the rear of the collimator to protect the plates from protons falling on them. The energy possessed by the mesons after passage through the absorber was estimated to be 310 ± 10 mev.

The search for cases of scattering was carried out by examining the surface of the photographic plates using immersion objectives, the microscope having a total magnifying power of 450 x. A second survey was made of the entire surfaces of the photographic plates for the most complete recording of the scattering events. In order to determine the recording efficiency, which is somewhat different for various scattering angles, a portion of the surface of the photographic plates was carefully examined under a higher magnification (~ 630 x). The corrections which were introduced on the basis of the results obtained from such a survey decreased for angles greater than 110° in the center-of-mass system, and did not exceed 4–5%.

The elastically scattered events were identified with the aid of the following criteria, derived from the laws of conservation of energy and momentum:

1. The angular correlation between the scattered meson and the proton recoil. Cases in which the angular correlation differed from the calculated value by more than 1° were discarded.

2. Coplanarity. The condition for coplanarity is fulfilled for the case when

$$\sin\Phi = \frac{\cos\delta_0\cos\delta_1\cos\delta_2}{\sin\vartheta}$$

$$\times[\sin\vartheta_2\,\mathrm{tg}\,\delta_1 - \sin\vartheta_1\,\mathrm{tg}\,\delta_2 + \mathrm{tg}\,\delta_0\sin(\vartheta_1 - \vartheta_2)] = 0,$$

where δ_0, δ_1, δ_2 are the angles of inclination of the tracks of the incoming meson, the scattered meson, and the proton recoil with respect to the plane of the emulsion, respectively; θ_1 and θ_2 are the scattering angles of the meson and of the proton recoil, respectively, in the plane of the emulsion; θ is the angle between the scattered meson and the proton recoil in the plane of the emulsion; and Φ is the angle between the track of the incident meson and the plane passing through the tracks of the scattered meson and the proton recoil.

Cases for which $\Phi > 1°$ were discarded, being regarded as not satisfying the condition for coplanarity.

3. For cases of scattering through small angles for which the proton recoil stopped in the emulsion, corresponding to a low energy, it was required that the energy be equal to the calculated value.

Scattering events caused by mesons whose tracks in the photoemulsion were deflected from the primary direction of the meson beam through angles greater than 3°, corresponding to the average angle of multiple scattering in the copper absorber, were not counted.

Altogether 427 scattering events were found in the angle interval 10° – 170° in the center-of-mass system. The differential scattering cross section, calculated on the basis of the observed results, is presented in the diagram. It was assumed that the total scattering cross section of mesons from hydrogen for an energy of 310 mev was equal to 70×10^{-27} cm^2.[6] The interval of summation is 20°

The representation of the experimental results in the form of an analysis into a series of Legendre polynomials showed that the most important terms are those of the zeroth, first, and second orders.

Noting this circumstance, and taking into account the fact that the curve, evaluated without the presence of the higher terms, agrees entirely satisfactorily with the experimental results, it then becomes possible to express the differential

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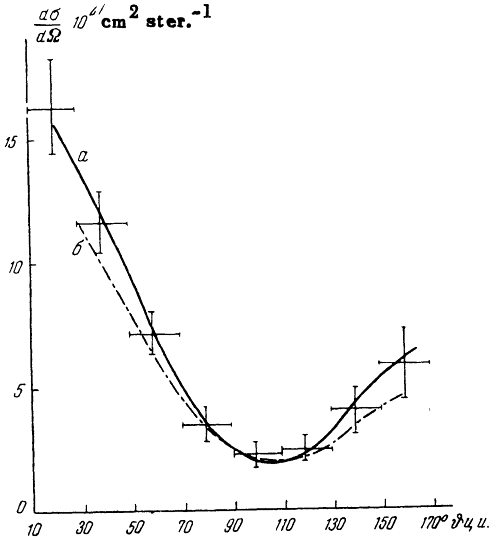
*There exists a short communication[4] regarding the scattering of mesons at energies of 260, 300, and 400 mev. In this work, utilizing a diffusion chamber, 100, 151, and 47 $\pi^+ - p$ scattering events, respectively, are analyzed for mesons with the indicated higher energies.

cross section in the form of a decomposition involving only the first three polynomials. The final expression for the differential cross section then becomes

$$d\sigma/d\Omega = [(2.4 \pm 0.2) + (4.9 \pm 0.4)\cos\vartheta + (9.3 \pm 0.7)\cos^2\vartheta] \cdot 10^{-27}\ \mathrm{cm}^2/\mathrm{ster.}$$

The solid curve *a* on the drawing is obtained using this formula.



Differential cross section for 310 mev π mesons elastically scattered from protons. *a* — experimental curve, *b* — curve calculated on the supposition of an excited nucleon state.

Thus, the results of our experiments indicate that the scattering of 310 mev π^+ mesons can be satisfactorily explained in the first approximation if it is assumed that only *S* and *P* states participate in the scattering. An insufficiently high accuracy in the observed results does not afford an opportunity of making definite conclusions concerning the magnitude of the *D* state contribution to the scattering. However, one can expect that the *D* state plays a comparatively smaller role in scattering than the *S* and the *P* states.

The phase analysis for scattering was carried out for the Fermi solution[7] using graphical methods. The phase shifts for the S, $P_{3/2}$, and $P_{1/2}$ states with an isotopic spin of $T = 3/2$ were found to be $\alpha_3 = -23°$, $\alpha_{33} = 132°$, and $\alpha_{31} = -9°$.

Experimental data show that the phase α_{33} passes through 90° in the region of meson energies about 200 mev. This fact indicates the presence of resonance interactions of π mesons with nucleons in states with total and isotopic spins equal to 3/2. The value $\alpha_{33} = 132°$ for a meson energy of 310 mev does not contradict the supposition concerning the existence of such a resonance interaction.

It is interesting to compare the observed results with the calculations based on the assumption of the existence of an excited nucleon state.[3] Such calculations (curve *b* in the drawing) were carried out on the supposition that only *S* and *P* states take part in the scattering. The validity of neglecting the contributions of the higher states is confirmed by our measurements. As is seen from the drawing, the calculated curve reproduces well the general character of the angular distribution of elastically scattered π^+ mesons.

In conclusion we would like to express our gratitude to Prof. M. G. Meshcheriakov for his guidance of the work, as well as to B. C. Neganov and V. P. Zrelov for assistance in conducting the experiment.

Note added in proof: With the help of the high-speed electron calculating machine (BECM) a more rigorous analysis of the results was undertaken. Taking into account only the *S* and *P* waves, the following values for the phase shifts were obtained: $\alpha_3 = -22.7°$, $\alpha_{33} = 130.9°$, $\alpha_{31} = -7.0°$. Taking into account the *D* wave also, the phase shifts have the values $\alpha_3 = -16.8°$, $\alpha_{33} = 129.6°$, $\alpha_{31} = -2.0°$, $\delta_{33} = 2.6°$, $\delta_{35} = -6.5°$, . . . , where δ_{33} and δ_{35} are the phase shifts corresponding, respectively, to the $D_{3/2}$ and the $D_{5/2}$ states for an isotopic spin of $T - 3/2$.

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