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STUDIES OF ATOMIC NUCLEI[1]

It is well known that a study of the single scattering of α particles by the elements led to the nuclear theory of the atom, and has provided us with a direct method of measuring the nuclear charge of the elements. The pioneer experiments in this field were made by Geiger and Marsden in 1913, who showed that the number of particles scattered at different angles was in close accord with the nuclear theory, assuming an inverse square law for the forces between the α particle and the nucleus. The variation of scattering with velocity of the α particle was in close accord with this law. Their results were subsequently extended by the experiments of Chadwick, who made direct measurements of the nuclear charge. Most of the experiments of Geiger and Marsden were made with silver and gold. Using α particles of average range about 4 cms of air, they found that the law of inverse square held, at any rate approximately, for the closest distance of approach of the α particle, *viz.*, about 4×10^{-12} cms for gold. These results suggested that the nuclei of even the heavy elements must be of radius less than this small distance.

In a collision of an α particle with a light atom the distance of approach in a close collision is much smaller than the above, and direct evidence has been obtained that the law of the inverse square breaks down completely in the case of a close collision between an α particle and a hydrogen nucleus. More recently Bieer compared the scattering of α particles by aluminium and gold, and found the relative number of particles scattered by aluminium and gold to decrease as the angle of scattering was increased. Assuming that the scattering by gold was normal—*i.e.*, in agreement with an inverse square law—he suggested that the discrepancy in aluminium might be due to the combined action of an attractive force superimposed on a normal repulsive force. From calculation he concluded that an attractive force varying as r^{-4} fitted in best with his experimental results. In the light of these conclusions it became of importance to re-examine the question whether the law of inverse square holds accurately for the heavy elements for the closest possible distances of approach, and to determine as accurately as possible the variation of the scattering with velocity for the lighter elements.

[1] Abstract of a lecture given before the Royal Institution of Great Britain, March 27, 1925.

For this purpose, Dr. Chadwick and I have used a modified method, and examined for a number of elements the scattering at an angle of about 135°, for α particles of different velocities. The source of α rays (radium B and C deposited on a metal disc) was hermetically sealed in a brass tube covered at one end by a thin film of collodion of stopping power about 2 to 3 mm of air for α rays. This was necessary to avoid radioactive contamination. The α rays fell on the radiator of small area of stopping power 2 to 5 mms of air carried on a frame of Acheson graphite. Extra care was taken to avoid extraneous scattering. By introducing thin sheets of mica of known stopping power in the path of the α rays, the variation of the number of α particles with velocity was directly determined. In this way measurements were made for α particles between the ranges of 6.7 cms and 2 cms. The straggling of the α particles in their passage through the mica made this method unreliable for shorter ranges of the α particles.

In this way it was found that the number of particles scattered by silver and gold through an average angle of about 135° varied inversely as the square of the energy of the incident α particles over the whole range. In the case of gold measurements were also made for smaller angles by the direct method of measuring the nuclear charge, previously used by Chadwick, and no variation in the law of the inverse square could be observed. Similar results were observed with a thin film of uranium obtained on graphite by sputtering. In this case it was difficult to determine the actual thickness of the film, but the variation in number of scattered α particles with velocity followed the regular law.

In the case of aluminium an unexpected result was observed. The scattering for 6.7 cms α particle was less than the theoretical, and rapidly *decreased* as the velocity of the α particles was diminished, falling to a minimum for particles of range about 5 cms. It then increased again and tended towards the theoretical value for slow-speed α particles. It is of interest to note that the velocity of the α particles for this minimum of scattering is about the same as the minimum velocity required to liberate protons from aluminium. It should be mentioned that even for the swiftest α particle the number of protons of range greater than 3 cms which appeared at an angle of 135° was only a small fraction of the total number of scattered α particles, indicating that the expulsion of a proton does not occur in all close collisions of the α particle with the nucleus.

From the observations on the scattering by a film of uranium, it is clear that the law of inverse squares holds, at any rate approximately, up to the closest distances of approach—*viz.*, about 3×10^{-12} cms. This raises a difficulty, since from radio-active evidence it is believed that the nuclear structure of uranium extends to a distance of about 7×10^{-12} cms. If the α particle liberated in the disintegration of uranium gains most of its energy in escaping in the repulsive field of the nucleus, its position before disintegration can not be less than 7×10^{-12} cms from the center of the nucleus, and may be greater if it is liberated with initial energy. It is for this reason that it has been considered probable for some time that the radioactive elements consist of a central charged nucleus surrounded at a distance by a satellite distribution of positively and negatively charged particles. If these form a symmetrical doublet-like structure extending over a short linear distance, it may be difficult to detect the presence of such a satellite distribution by direct scattering experiments. A similar idea may be used to explain the peculiar behavior of the aluminium nucleus. In such a case the distance apart of the satellites or doublets may be comparable with their distance from the main nucleus. It is easy to see on such an assumption that α particles of appropriate speed may just enter the satellite region where the electrical field may be relatively weak, and thus show a marked defect in scattering. Swifter particles pass through the satellite distribution and come under the strong electric field of the central nucleus, where they are more effectively scattered.

It is obvious that an accurate determination of the scattering of α particles by the elements may supply important evidence, not only on the size of the nucleus, but on some of the details of its structure. A large amount of accurate data will be required to test the adequacy of any theory of nuclear structure.

Since the proof that protons can be expelled from the nuclei of many light elements, the fate of the bombarding α particle after the disintegration has been a matter of conjecture. To throw light on this question Blackett has recently photographed by the well-known expansion method the tracks of more than 400,000 α particles in nitrogen. In addition to a number of branching tracks which obey the laws of a perfectly elastic collision, eight branching tracks were observed in which the laws of an elastic collision were not obeyed. In these photographs the fine track of the proton was clearly visible, and also that of the recoiling nucleus, but in no case was there any sign of a third branch due to the escaping α particle. He concluded that the α particle was captured in a collision which led to the ejection of a proton. The branches were co-planar, indicating that momentum was conserved in such collisions. The length of the tracks of the proton and recoiling nucleus was in good accord with such an assumption. These experiments suggest, at any rate in the case of nitrogen, that the α particle is captured by the nucleus. If no electron is expelled, the resulting nucleus should have a mass $14+4-1=17$, and a nuclear charge $7+2-1=8$—*i.e.*, it should be an isotope of oxygen. It thus appears that the nucleus may increase rather than diminish in mass as the result of collisions in which a proton is expelled.

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MACKENZIE PARK AS A FIELD FOR SURVEY, EXPLORATION, LITERATURE AND ART

MACKENZIE PARK and the surrounding district affords a splendid opportunity for university summer parties, students, professors and others desiring a field in which to carry on surveys and explorations, writing and art work, for practice, experiment or other purposes. Mackenzie Park is the name locally applied in the Norway of Canada to a strip of country approximately twenty miles north and south by seventy miles east and west lying near the southern edge of the bottom lands of Bella Coola River and the eastern shore of South Bentinck Arm. Mackenzie Park is at the head of one of the longest fiords midway of the coast of British Columbia. It was so named in honor of Sir Alexander Mackenzie, the first white man to cross America north of Mexico and, who, surfeited with scenery in his long trip from Montreal through the Canadian Rockies, wrote superlatively of the scenery of the area now known as Mackenzie Park.

A petition has been made that this area might be turned over for administration by the Dominion Parks as a great out-of-doors museum and sanctuary for the conservation of animal and plant life, beautiful scenery and pure water. Any surveys and explorations, literature and art treating of the park or vicinity would be conducive to this end.

As a field for physiography, topography and mapping the area is excellent, being unsurveyed British Columbia Crown lands extending from sea level to about 10,000 feet altitude. It consequently affords ample opportunity for either practice or practical work. An aeroplane photographic survey would be useful in developing the park.

From the geographic and geological standpoint, many parts of the park have never been seen by white men. The many glaciers and waterfalls should prove of interest. From one point on Mackenzie Highway eighteen glaciers may be seen. Southeast and partly within the park is a glacier which is said to be forty miles long. The great number of glaciers ensures that a variety of glacial problems may be presented. Two glaciers may be seen from the Bella Coola Post Office and another from a point one mile up the road. In the park are thousands of waterfalls, some of them large. One near the eastern edge of the park is said by reliable frontiersmen to make a clear leap of over 828 feet. If this be true, it is the fifth highest known fall in the world, second highest in the western hemisphere and the highest in Canada. Surely the opportunity to first measure this fall or to take good large photographs, motion pictures, sketches or paintings of it should appeal to many university students or men of leisure. Hot springs are found on South Bentinck Arm.

From a botanical standpoint the park and surrounding region are practically unknown. Great variety of plant life and plant problems may be expected in this area, which extends from the sea, salt marshes and lowlands to the mountain peaks on the one hand and which presents climatic conditions ranging from the rather moist sea coast climate to the semi-arid conditions of the region embracing the eastern end of the Bella Coola valley where irrigation is practiced. Throughout the region there are four species of giant trees, thousands of them being over six feet in diameter—red cedar, cottonwood, Douglas fir and aeroplane spruce. On the western edge of the park the vegetation is luxuriant and semi-tropical. On the east are Jack-pine barrens.

Zoologically the area is interesting. Grizzly bear tracks may certainly be found within twenty-four hours after arrival at Bella Coola, at least in August or September. A hunter living near Mackenzie Highway in 1924 left home in the morning, went on foot to a glacier in the park not far distant and was able before supper time to bring back a mountain goat. Fourteen eagles have been counted on a single stub at the edge of the park area. The sea is very deep off Bella Coola and in it is such life as sea fans and sand sharks. The several varieties of salmon taken in North Bentinck Arm for the two canneries within five miles of Bella Coola offer many zoological problems.

From the anthropological standpoint the Bella Coola Indians are of interest. They are of the Salish linguistic stock and North Pacific Coast culture. They live within two miles of Bella Coola and may be seen working for the canneries. About one fifth of the known petroglyphs of Canada lie within a day's motorboat run of Bella Coola. The material culture, social organization and folk-lore of the Bella Coola has been studied for the National Museum of Canada, but much remains to be done. In archeology, linguistics and physical anthropology, the field is almost untouched. The rituals and dramas may still be seen