scattered particles move at speeds well below the velocity of light. Had the forces active in Rutherford's experiment been other than those of electromagnetism, then indeed the quantitative result of Rutherford's calculations would have been incorrect.

3. The scattering of X-rays

Now let me turn to another class of scattering experiment, the scattering of light and X-rays from the atom. The scattering of light or X-rays from the atom is dominated by the extra-nuclear electrons, and not by the nucleus. The reason is that the interaction of light or X-rays, which are electromagnetic radiations, is with an electric *current*; in the scattering process such a current is produced by the recoiling particle from which the scattering takes place. If the mass of the recoiling particle is small, then a larger recoil current is produced. Thus the very light electrons surrounding the heavy nucleus are the principal contributors to the scattering of electromagnetic radiation by the atom.

This type of scattering was observed first by A. H. Compton in experiments beginning in 1922. In these experiments it was shown clearly that the dynamic properties of the incident X-ray beam were described by its photon characteristics, that is, by the particle-like energy and momentum variables of electromagnetic radiation predicted by a quantum mechanism.

It is characteristic of the process of scattering of X-rays by a free particle that the frequency and energy of the scattered quantum is shifted relative to those of the incident radiation. Particularly interesting is the fact that the shift in wavelength of the X-rays in the scattering process depends only on the mass of the particle struck and on the angle

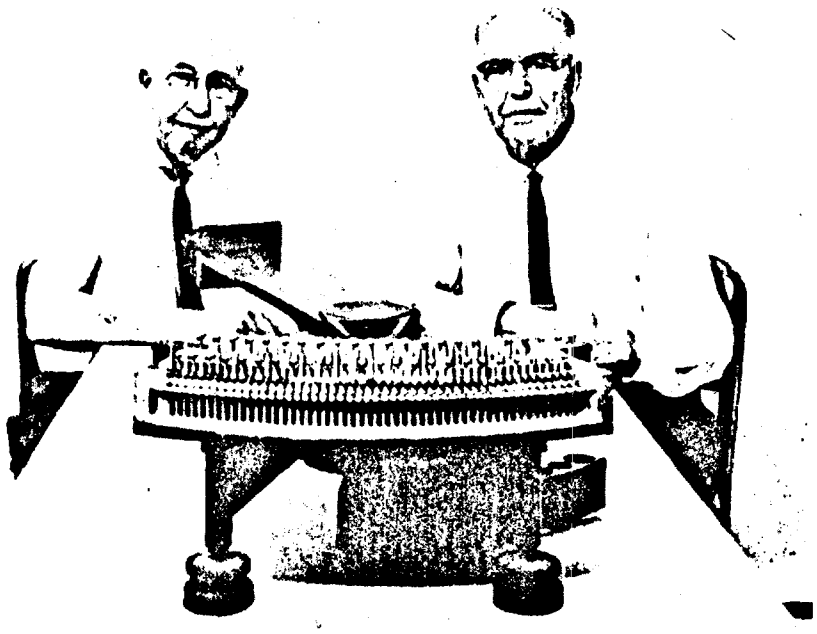

Fig. 3. Photograph of J. W. M. DuMond and his collaborator, Professor H. A. Kirkpatrick, with their multi-crystal spectrometer. This instrument was used to analyse the shape of X-ray spectra which resulted from the scattering of X-ray photons from various materials.