

THE COMPTON SCATTERING
EXPERIMENTS



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A NEW PERSPECTIVE BY K. STRANG

The Compton Scattering Experiments

The Compton scattering experiments in around 1923-25 used molybdenum K (alpha) as the primary radiation (high energy X-rays) and graphite as the scatterer and he used a Braggs spectrometer as the recording device to analyse the wavelengths of the scattered radiation (see Figure 1 below) – the experiment confirmed previous results showing that the scattered radiation had a longer wavelength than the incident wavelength. Compton then examined what would be expected if ‘each quantum of X-ray energy were concentrated in a single particle and would act as a unit on a single electron’. He arrived at the formula for the change of wavelength as a function of the angle of scattering:

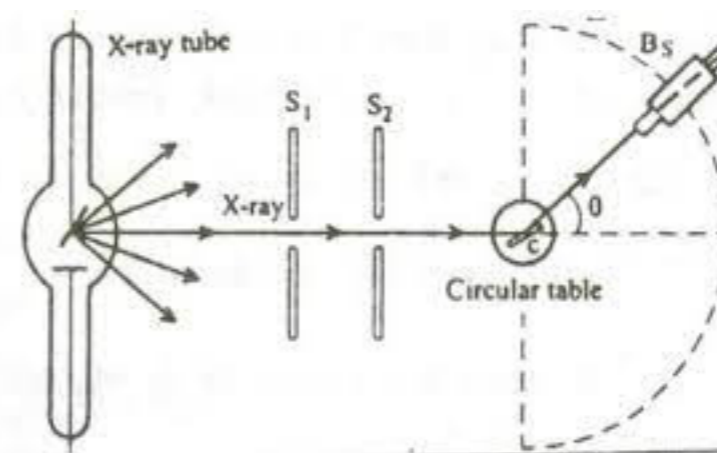
‘According to the classical theory, each X-ray affects every electron in the matter traversed, and the scattering observed is that due to the combined effects of all the electrons. From the point of view of the quantum theory, we may suppose that any particular quantum of X-rays is not scattered by all the electrons in the radiator, but spends all of its energy upon some particular electron. This electron will in turn scatter the ray in some definite direction, at an angle with the incident beam. This bending of the path of the quantum of radiation results in a change in its momentum. As a consequence, the scattering electron will recoil with a momentum equal to the change in momentum of the X-ray. The energy in the scattered ray will be equal to that in the incident ray minus the kinetic energy of the recoil of the scattering electron; and since the scattered ray must be a complete quantum, the frequency will be reduced in the same ratio as is the energy. Thus on the quantum theory we should expect the wave-length of the scattered X-rays to be greater than that of the incident rays.’

[A Quantum Theory of the Scattering of X-Rays by Light Elements, Physical Review, 1923 Vol 21, No. 5 p483]

Three points:

- (i) not all similar experiments produced the same result; (ii) while the mathematics and analysis in terms of quanta of light affecting single electrons proved fruitful, it did not necessarily prove that quanta (photons) actually exist; (iii) It was a mistake to compare his experiment with that of J.J. Thomson in 1906 – Thomson’s paper *On the Number of Corpuscles in an Atom*, Philosophical Magazine, Vol. 11, June 1906 p769-781 was primarily concerned with calculating the number of electrons or corpuscles in an atom and how that related to atomic weight. It has to be borne in mind how little was known about the structure of atoms at that time.

Figure 1



To be fair to Compton, he does express some reservations at the end of his paper especially the inability of quantum theory to explain the classic wave phenomena of interference:

‘The present theory depends essentially upon the assumption that each electron which is effective in the scattering scatters a complete quantum. It involves also the hypothesis that the quanta of radiation are received from definite directions and

are scattered in definite directions. The experimental support of the theory indicates very convincingly that a radiation quantum carries with it directed momentum as well as energy.

Emphasis has been laid upon the fact that in its present form the quantum theory of scattering applies only to light elements. The reason for this restriction is that we have tacitly assumed that there are no forces of constraint acting upon the scattering electrons. This assumption is probably legitimate in the case of the very light elements, but cannot be true for the heavy elements. For if the kinetic energy of recoil of an electron is less than the energy required to remove the electron from the atom, there is no chance for the electron to recoil in the manner we have supposed. The conditions of scattering in such a case remain to be investigated.

The manner in which interference occurs, as for example in the cases of excess scattering and X-ray reflection, is not yet clear. Perhaps if an electron is bound in the atom too firmly to recoil, the incident quantum of radiation may spread itself over a large number of electrons, distributing its energy and momentum among them, thus making interference possible. In any case, the problem of scattering is so closely allied with those of reflection and interference that a study of the problem may very possibly shed some light upon the difficult question of the relation between interference and the quantum theory .'[ibid.]

The attempt to shoehorn wave phenomena into a particle theory resulted in the hybrid quality 'particle-wave duality', a modern day griffin.