THE MEASUREMENT OF "ENHANCED" L AND M X-RAY YIELDS FROM CHARGE-INDUCED STUDIES WITH PROTONS AND \(^1\text{H}_2\) ION BEAMS

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Earlier work on Charge Induced X-rays (CHIX) was extended to include the X-ray energy region between 0.70 to 4.0 keV. Protons of 700 keV, and \(^1\text{H}_2\) ion beams of equivalent proton energies in the range 350–450 keV were used to produce "enhanced" yields of L and M X-rays from a suitable selection of highly compacted non-conducting samples. "Enhancement" factors are given and possible applications are mentioned.

Previous studies\(^1\text{–}^9\) on Charge Induced X-ray investigations (CHIX) involved the measurement of "enhanced" K X-ray yields. This work is an extension and examines the magnitude of L and M X-ray yields in non-conducting targets.

Generally speaking, the production cross-sections for these lower energy X-rays are a few orders of magnitude higher\(^1\text{–}^9\) than those for the corresponding K X-rays. Earlier reports\(^2,4,6,9\) showed that the CHIX effect in insulating targets is accentuated when the PIXE yield becomes negligibly small. With protons this was previously achieved\(^2\) by reducing the incident beam energy to 400 keV at which energy the K X-ray yield is much reduced. However, direct excitation of L and M X-rays even at such reduced incident energies would produce comparatively higher PIXE yields than in the corresponding K X-ray case. This study describes such measurements and produced "enhancement" factors corrected for range effects. One possible application of ultra-soft X-rays is in photoelectron spectroscopy.\(^1\text{1}\) The generation therefore, of such "enhanced" yields for the production of monoenergetic beams of ultra-low X-rays could be useful for this purpose.

Experimental

Sample preparation: A wide selection of binary metal fluorides were used for investigation. These included FeF\(_3\), CoF\(_2\), CuF\(_2\), ZnF\(_2\), ZrF\(_4\), PdF\(_2\), InF\(_3\) and PbF\(_2\). The powdered fluorides were compressed into pellets of 13 mm diameter and between 0.5 and 2 mm thick, in a Beckmann evacuable press. Before the powder was weighed into

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the press volume, a disc of filter paper and a ring of paper board were inserted to help retain the integrity of the pellet and to avoid undue contact between the powder and the compression steel cylinders. Thereafter, a second ring and a filter paper disc were placed on top of the pellet material, before pressure of up to 10 tonnes were applied to compress the powder. Pellets were stored in a desiccator over silica gel until required.

Previous reports\(^6,7\) indicated that the condition of the targets was critical. Looseness of the compressed powder, or cracks in the pellets resulted in low charge build-up and hence erratic results in the X-ray yields. For this reason, special care has to be used in the preparation of pellets for irradiation.

High purity targets of the corresponding metals were cut to the same dimensions for comparative measurements.

**Irradiation and measurement:** The protecting paper layers were removed from the pellets, and the samples were mounted in a vertical steel ladder\(^12\) remotely controlled by a stepping motor, which enabled each target in turn to be positioned accurately in the path of the bombarding beam. The front of the ladder was covered with a strip of plastic material to prevent excitation of X-rays from the ladder components. Holes of 10 mm diameter in the plastic cover retained the targets, which was held in position at the back by copper springs. The ladder fitted into a multi-purpose scattering chamber\(^13\) at the 6 MV Faure Van de Graaff accelerator. The chamber was electrically insulated from the beam tube and from its vertical support by inserts of Teflon rods, so that it acted as its own Faraday cup.

The targets were viewed with a horizontally mounted dipstick Si(Li) detector, the position of which could be adjusted from 2 to 22 cm from the point of incidence of the beam on the target surface. The detector had an active area of 25 mm\(^2\) and a resolution of 200 eV for the Mn K\(_\alpha\) X-ray. The front of the detector was shielded from stray radiation by a lead collimator with a 6 mm diameter aperture, which fitted over the dipstick for a length of 4 cm. The detector was further screened from gamma radiation by standard lead bricks. The position of the detector and the intensity of the bombarding current were optimised so that, in most cases, the dead time did not exceed about 15%. The softness of the X-rays measured prevented the use of absorbers. Samples were irradiated with protons of 700 keV and \(^1\)H\(_2\) molecule-ion beams between 700-900 keV. The molecule-ion is expected to dissociate into a proton and a neutral hydrogen atom, but the latter becomes ionised almost immediately along its path within the target material, producing equivalent proton energies between 350–450 keV. Beam energies were restricted by the conditions at the accelerator. Currents ranged from about 1 to about 3 nA, depending on the intensity of the X-ray flux generated by the beam. In order to ensure that valid comparisons could be made, the experimental measuring conditions were kept constant for the fluoride-metal pairs, and the same conditions of beam current and measurements were used for both the proton and molecule-ion beams.