ION-INDUCED CONTINUUM X-RAY EMISSION

F.W. Saris and Th.P. Hoogkamer
FOM-Institute for Atomic and Molecular Physics
Kruislaan 407, Amsterdam/Wgm., The Netherlands

ABSTRACT

This paper reviews continuum X-ray emission produced by ion-impact on gaseous and solid targets. Molecular orbital X-rays are considered in detail in order to establish the circumstances under which they can be distinguished from radiative electron capture and from various kinds of bremsstrahlung. The level of understanding of continuum X-ray production appears to parallel that of ion-induced inner-shell ionization in general.

1. INTRODUCTION

In the very first paper on heavy-ion induced X-ray emission, written in 1934 by Coates\textsuperscript{1}) from the Radiation Lab., the author notes: "In no case do the curves show any evidence for continuous radiation". This was an important remark, for the bremsstrahlung continuum was known to dominate electron-induced X-ray spectra. Yet, after many years of investigating characteristic X-ray emission, the ion-induced X-ray researchers have recently focussed on the continuum radiation in their spectra, which has become visible through the availability of energy dispersive X-ray detectors. The motivation for this new interest is two-fold: 1) Investigating continuum radiation appears to be of fundamental importance for the understanding of atomic interactions in ion-atom collisions; 2) As background radiation underlying characteristic X-ray signals, continuum X rays limit the detection sensitivity in analytical applications such as trace element analysis.
The purpose of this paper is to review the properties of ion-induced continuum X-ray spectra and thus show how progress in this field parallels that of ion-induced inner-shell ionization and decay. First we will outline some characteristics of molecular orbital X-ray emission, radiative electron capture and various kinds of bremsstrahlung. Then we will discuss under what experimental conditions these features have been identified unambiguously. This will lead to some conclusions and possible extensions.

2. GENERAL FEATURES AND EXCITATION MECHANISMS

2.1. Molecular Orbital X rays

In a slow collision of two atoms the nuclei may approach each other so closely that the atomic electrons rearrange adiabatically to form quasi-molecular states in the two-center Coulomb field. These quasi-molecular states will change continuously as a result of the varying internuclear distance during the collision. In addition the nuclear motion will impose considerable excitation on the electrons in the transient molecular levels. Generally this will result in excitation or ionization of the projectile and target atom when separated. Sometimes, however, the excited quasi-molecule may decay during the collision if the lifetime of the excited molecular state is not too different from the collision time. Inner-shell vacancy lifetimes are of the order of $10^{-15}$ sec, only a factor ten or hundred longer than most collision times. It is well known that inner-shell vacancies are copiously produced in heavy-ion-atom collisions even at moderate energies. It is to be expected, therefore, that in many cases vacancies are present in the inner-molecular levels and their decay during the collision may result in X-ray spectra characteristic of these quasi-molecular states. As the internuclear distance changes continuously, the transition energy will vary also, giving rise to continuous X-ray spectra instead of characteristic lines.

It seems inappropriate, however, to use the name non-characteristic radiation (NCR) instead of MO-X rays, as is done by some authors. The continuum spectral distribution is very characteristic for the molecular states involved in the collision.

Before we go into a detailed discussion of MO-X rays we will briefly mention some other mechanisms for continuum X-ray production.