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Total Bremsstrahlung Cross-Section for Al, Ti, Sn and Pb at Incident Electron Energy of 10 keV, 50 keV and 100 keV

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The total bremsstrahlung cross-sections which include the contribution of Polarization bremsstrahlung (PB) into ordinary bremsstrahlung (OB) for Al, Ti, Sn and Pb for an incident electron of energy 10 keV, 50 keV and 100 keV were studied. In these calculations, theories of Elwert corrected (non-relativistic) Bethe-Heitler theory (1939), Avdonina and Pratt (1999) and Amusia (1985) were compared. The theory of Amusia (1985) was modified by introducing the factors of modified Elwert factor and higher order Born correction factor. Bethe-Heitler theory (1939) describes ordinary bremsstrahlung (OB) however Avdonina and Pratt (1999) and Amusia (1985) included the contribution of Polarization bremsstrahlung (PB) into ordinary bremsstrahlung (OB). From the comparison of these theories, it was found that for high Z element the total bremsstrahlung cross-sections calculated by the modified Amusia (1985) and Avdonina and Pratt (1999) theories were higher by 10-30% from the Elwert corrected (non-relativistic) Bethe-Heitler theory at 1 keV and 3 keV photon energies respectively. At higher photon energies the modified Amusia theory is more accurate. However, it was found that for low Z element the Avdonina and Pratt theory is more accurate particularly at lower photon energy. The deviation of bremsstrahlung cross-sections among the different theories indicates the importance of polarization bremsstrahlung in the bremsstrahlung process.

Key Words: Total Bremsstrahlung, Polarization Bremsstrahlung and Ordinary Bremsstrahlung

INTRODUCTION

Ordinary bremsstrahlung (OB) is the process by which the photon is emitted by the electron decelerating in the static field of the target. Polarization bremsstrahlung (PB) is the process by which the photon is emitted by the target as a result of its polarization by incident electron. Total bremsstrahlung (BS) cross-section is the sum of OB and PB. The different theoretical models[1-3] are available for the study of ordinary bremsstrahlung in thin and thick target materials. All these theoretical models describe the OB without the contribution of polarization bremsstrahlung which plays an important role particularly in bremsstrahlung process.

The calculation of polarization bremsstrahlung has been presented by several authors[4-6]. For high, but non-relativistic electron energies, in the born approximation Amusia[7] has shown that PB can be included with OB in a 'stripped' atom (SA) approximation. Two methods, given by Korol *et al.*[8] and Avdonina and Pratt[9] are available for the calculation of bremsstrahlung spectra in SA. Korol *et al.*[10] have further given that these methods for calculation of bremsstrahlung spectra in SA are equivalent. All these theoretical models include ordinary bremsstrahlung with polarization bremsstrahlung in SA.

THEORETICAL CALCULATIONS

The total bremsstrahlung cross-sections which include the contribution of Polarization bremsstrahlung (PB) into ordinary bremsstrahlung (OB) for Al, Ti, Sn and Pb for an incident electron of energy10 keV, 50 keV and 100 keV were studied. In these calculations, theories of Elwert corrected (non-relativistic) Bethe-Heitler theory[1], Avdonina and Pratt[9] and Amusia[7] were compared. Avdonina and Pratt[9] has proposed to use a composite expression for bremsstrahlung cross-section ($\sigma^2_{cor}(k)$), which include polarization bremsstrahlung with ordinary bremsstrahlung in SA,

$$\sigma^2_{cor}(k) = \sigma_B(k) - \frac{\sqrt{3}}{\pi}\ln(\frac{q_+}{q_-}) + \sigma^1_{cor}(k) \qquad (1)$$

Where $\sigma_B(k)$ is the bremsstrahlung cross-section[9] which include a screening parameter, $q_\pm$ is momentum transfer and ($\sigma^1_{cor}(k)$) is given by

$$\sigma^1_{cor}(k) = C(T_i, Z)F_{\mathrm{mod}}\,\sigma_{BH}(k) \qquad (2)$$

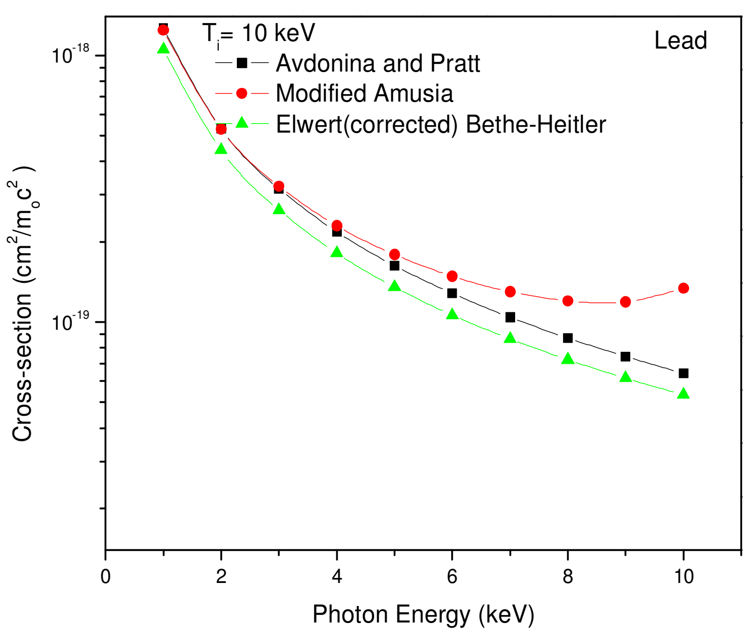
Where $\sigma_{BH}(k)$ is Bethe-Heitler cross-section[2], F_{mod} is modified Elwert factor and $C(T_i, Z)$ is higher order Born correction factor. The theory of Amusia[7] was modified by introducing the factors of modified Elwert factor and higher order Born correction factor and is given by

$$k\sigma_{\mathrm{mod}}(k) = C(T_i, Z)F_{\mathrm{mod}}\,\frac{16\times Z^2}{3\times c^3 \times 2T_i}\ln\frac{4T_i}{k} \qquad (3)$$

Typical plots of lead at incident electron energy 10 keV and 100 keV are shown in Fig. 1.

RESULTS AND DISSCUSSION

From the comparison of these theories it was found for T_i = 10 keV the modified Amusia theory is more accurate to describe the bremsstrahlung process[11]. But at the incident electron energy T_i = 50 keV, 100 keV the modified Amusia theory becomes inaccurate at lower photon energy for all elements. But, at higher photon energies the modified Amusia theory is more accurate as compared to the Avdonina and Pratt theory[9] and Elwert (Corrected) Bethe–Heitler theory[2] for the incident electron energy 10 keV, 50 keV and 100 keV. The Total bremsstrahlung cross-section calculated from Avdonina and Pratt[9] and modified Amusia theories which include PB into OB were higher by 10% and 30% at 1 keV and 3 keV photon energies from the Elwert (corrected) Bethe-Heitler theory[2] which describes OB at incident electron energy of 10 keV, 50 keV and 100 keV particularly for high Z elements. These deviations among the different theories clearly indicate the importance of PB in the bremsstrahlung process. Therefore, the contribution of PB into OB cannot be neglected while studying the bremsstrahlung process particularly at lower and medium photon energy. Further studies are required to improve the modified Amusia theory so that it becomes more accurate at lower photon energy with increase of incident electron energy. Extensive studies are needed both theoretically and as well as experimentally to check the contribution of PB into OB in the bremsstrahlung process.



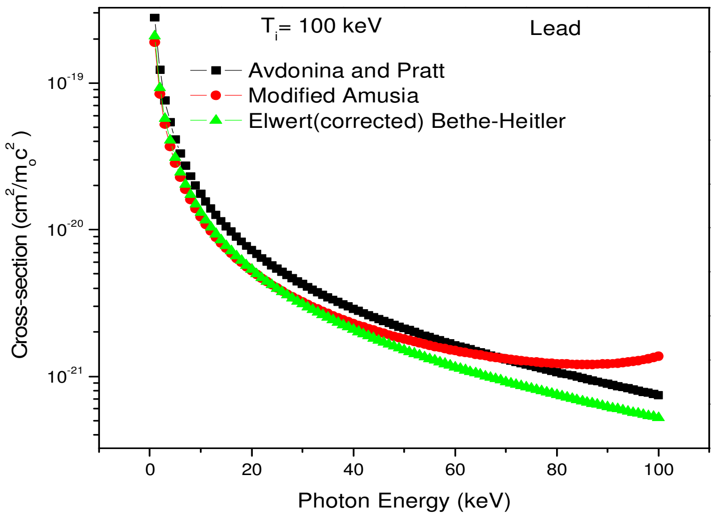


Fig. 1. Typical plots of total bremsstrahlung cross-section in units of (cm^2/m_oc^2) versus photon energy in keV at incident electron energy of 10 keV and 100 keV for Pb

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