Energy Absorption Buildup Factor for Some Cellulose Derivatives

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Abstract

Five parametric geometric progression method has been applied to compute the gamma rays energy absorption buildup factors for some cellulose derivatives such as cellulose acetate, cellulose triacetate and cellulose nitrate in the intermediate energy region 15 keV - 15 MeV at the penetration depths of 1 - 40 mean free path (mfp). The values of equivalent atomic number (Z_{eq}) at different photon energies has been provided in tabulated form and the variation of energy absorption buildup factor with penetration depth and chemical composition has been shown graphically for some selected photon energies and penetration depths. It has been observed that cellulose nitrate has higher Z_{eq} than cellulose acetate as well as cellulose triacetate. However, energy absorption buildup factor values for the selected cellulose derivatives shows different behaviors with respect to penetration depth and photon energy.

1. Introduction

Cellulose derivatives namely cellulose acetate ($C_6H_{10}O_5$), cellulose triacetate ($C_{12}H_{16}O_8$) and cellulose nitrate ($C_6H_7N_3O_{11}$) have been selected for present investigations. Cellulose acetate is used as a film base in photography, as a component in some adhesives, and as a frame material for eyeglasses, it is also used as a synthetic fiber in the manufacture of cigarette filters and playing cards. Cellulose triacetate is used in polarizer films for LCD projectors, specialized overhead projector transparencies, motion picture film, and for packaging. The nitrocellulose was initially used as an explosive and was an early film forming material. Cellulose nitrate is a highly flammable compound formed by nitrating cellulose. It is used as a propellant or low-order explosive, it was originally known as guncotton. Nitrocellulose plasticized by camphor was used by Kodak, and other suppliers, from the late 1880s as a film base in photography, X-ray films and motion picture films; and is known as nitrate film.

2. Computational Work

WinXCom [1] the mass attenuation coefficient database has been used to generate the mass attenuation coefficient values for the selected cellulose derivatives, which were further utilized to compute equivalent atomic number (Z_{eq}), energy absorption GP fitting parameters and finally, energy absorption buildup factors. The details of computational work have been provided in our previous article [2].

3. Results and Discussion

The equivalent atomic numbers for the selected cellulose derivatives is provided in Table 1. It has been observed that equivalent atomic number is maximum for cellulose nitrate and minimum for cellulose acetate in the entire energy range. These higher equivalent atomic number values of cellulose nitrate can be explained on the basis of higher concentration (weight fraction) of carbon, nitrogen and oxygen in cellulose nitrate as compared to other cellulose derivatives.

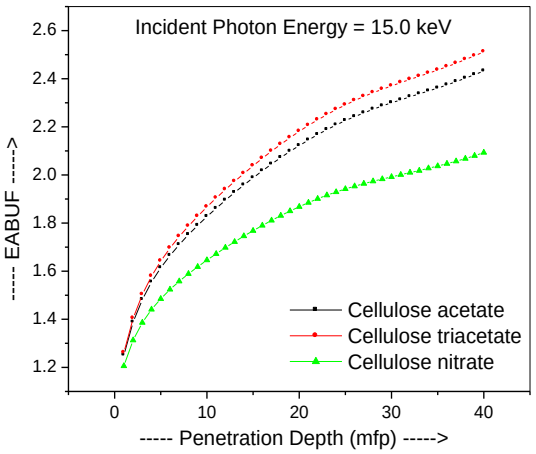

Fig. 1. Variation of EABUF with penetration depth for the selected cellulose derivatives at 15 keV

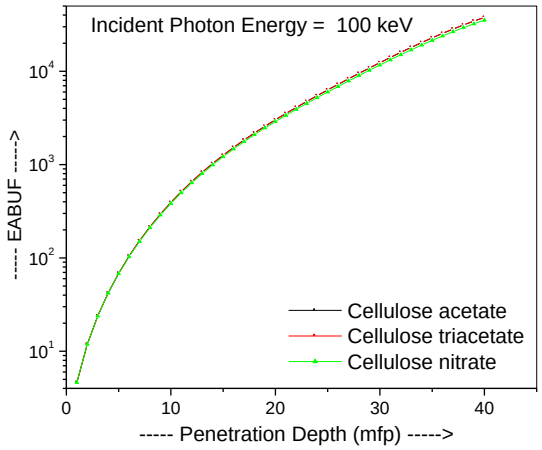

Fig. 2. Variation of EABUF with penetration depth for the selected cellulose derivatives at 100 keV

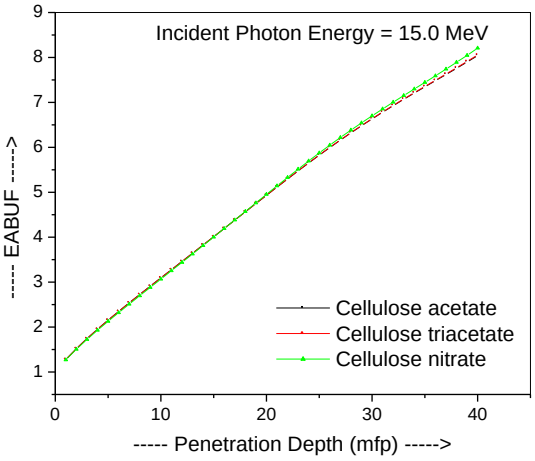

Fig. 3. Variation of EABUF with penetration depth for the selected cellulose derivatives at 15 MeV

The simultaneous variation of energy absorption buildup factor with penetration depth and chemical composition for the selected cellulose derivatives at some photon energies of 15 keV, 100 keV and 15 MeV has been shown in Figs 1-3 respectively. From all the figures, it has been observed that EABUF increases with the increase in penetration depth of cellulose derivatives. However, the rate of increase in EABUF is different at different photon energies. Moreover, the rate of increase in EABUF also depends on the chemical composition/equivalent atomic numbers. At lower photon energy (15 keV), the rate of increase in EABUF for the selected cellulose derivatives is very slow. It can be explained on the basis of dominance of photoelectric absorption process at lower photon energy.

Further, at lower photon energy, an inverse relationship between EABUF and Z_{eq} can be clearly visualized in Fig. 1. It is due to the strong dependence of cross-section for photoelectric effect on atomic number of interacting material. At intermediate photon energy (100 keV), the rate of increase in EABUF for the selected cellulose derivatives is very rapid. It can be explained on the basis of dominance

Table 1. Equivalent Atomic Numbers for Cellulose Derivatives

Energy (MeV)	Cellulose acetate	Cellulose triacetate	Cellulose nitrate
0.015	6.902	6.836	7.354
0.02	6.953	6.878	7.359
0.03	6.952	6.885	7.363
0.04	6.968	6.874	7.318
0.05	6.87	6.779	7.289
0.06	7.05	7.059	7.382
0.08	7.239	6.901	7.299
0.1	6.885	6.885	6.947
0.15	6.885	6.885	6.947
0.2	6.885	6.885	6.947
0.3	6.885	6.885	6.947
0.4	6.885	6.885	6.947
0.5	6.872	6.885	6.905
0.6	6.872	6.885	6.905
0.8	6.872	6.885	6.905
1.0	6.872	6.885	6.905
1.5	6.872	6.885	6.905
2.0	6.872	6.885	6.905
3.0	6.814	6.885	6.845
4.0	6.769	6.594	6.903
5.0	6.775	6.791	6.910
6.0	6.687	6.715	6.876
8.0	6.003	6.115	7.539
10.0	6.549	6.261	7.104
15.0	6.320	6.379	7.079

of Compton scattering process at intermediate photon energy.

Moreover, at higher photon energy (15 MeV), the rate of increase in EABUF is slower than the increasing rate at intermediate energy and faster than the increasing rate at lower energy. It is due to the dominance of pair production at higher energy. It has been also observed that at intermediate and higher photon energies, EABUF becomes almost independent of Z_{eq} values. It can be explained on the basis of weak dependence of cross-section for Compton scattering and pair production effect on atomic number of interacting material.

4. Conclusion

EABUF strongly depends on chemical composition/Z_{eq} value in the lower photon energy and becomes independent of this factor at intermediate and higher photon energies.
Among the selected cellulose derivative, cellulose nitrate shows least value for EABUF at lower energy. Hence, it offers least absorption rate to X-ray absorption.

References

[1] L. Gerward, N. Guilbert, K. Bjorn Jensen and H. Levring (2001) X-ray absorption in matter. Reengineering XCom. Radiat. Phys. Chem.60, 23.

[2] P.S. Singh, T. Singh and P. Kaur (2008) Variation in energy absorption buildup factors with incident photon energy and penetration depth of some commonly used solvents. Ann. Nucl. Energy, 35: 1093.