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Multiplicative Connectivity *KV* Indices of Dendrimers

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Abstract. The connectivity indices are applied to measure the chemical characteristics of chemical compounds in chemistry. In this paper, we introduce the multiplicative sum connectivity *KV* index, multiplicative product connectivity *KV* index, multiplicative *ABC KV* index and multiplicative *GA KV* index of a molecular graph. We determine these multiplicative connectivity *KV* indices of POPAM dendrimers and tetrathiafulvalene dendrimers.

Keywords: multiplicative sum connectivity *KV* index, multiplicative product connectivity *KV* index, multiplicative *ABC KV* index, multiplicative *GA KV* index, dendrimers.

AMS Mathematics Subject Classification (2010): 05*C*05, 05*C*07, 05*C*35.

1. Introduction

Let G be a finite, simple connected graph with vertex $V(G)$ and edge set $E(G)$. The degree $d(v)$ of a vertex v in G is the number of vertices adjacent to v. Let $M_G(v)$ denote the product of the degrees of all vertices adjacent to a vertex v. We refer to [1] for undefined term and notation.

Chemical Graph Theory is a branch of Mathematical Chemistry which has an important effect on the development of chemical sciences. Several topological indices have been considered in Theoretical Chemistry, especially in QSPR/QSAR research, see [1, 2].

Recently, Kulli introduced the first and second *KV* indices, defined as [4]

$$KV_1(G) = \sum_{uv\in(G)} \left[M_G(u) + M_G(v)\right],$$

$$KV_2(G) = \sum_{uv\in(G)} \left[M_G(u)M_G(v)\right].$$

Very recently, some novel variants of *KV* indices were studied such as hyper *KV* and square *KV* indices [5], connectivity *KV* indices [6], multiplicative *KV* indices and multiplicative hyper *KV* indices [7].

We introduce some multiplicative connectivity *KV* indices of a graph as follows:

The multiplicative sum connectivity *KV* index of a graph G is defined as

$$SKVII(G) = \prod_{uv\in E(G)} \frac{1}{\sqrt{M_G(u) + M_G(v)}} \tag{1}$$

The multiplicative product connectivity *KV* index of a graph *G* is defined as

$$PKVII(G)=\prod_{uv\in E(G)}\frac{1}{\sqrt{M_G(u)M_G(v)}} \tag{2}$$

The multiplicative atom bond connectivity *KV* index of a graph *G* is defined as

$$ABCKVII(G)=\prod_{uv\in E(G)}\sqrt{\frac{M_G(u)+M_G(v)-2}{M_G(u)M_G(v)}} \tag{3}$$

The multiplicative geometric-arithmetic *KV* index of a graph *G* is defined as

$$GAKVII(G)=\prod_{uv\in E(G)}\frac{2\sqrt{M_G(u)M_G(v)}}{M_G(u)+M_G(v)} \tag{4}$$

In recent years, some topological indices were studied, for example, in [8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19]. In this paper, some multiplicative connectivity *KV* indices for POPAM dendrimers and tetrathiafulvalene dendrimers are computed. For dendrimers, see [20].

2. Results for POPAM Dendrimers

The family of POPAM dendrimers is denoted by $POD_2[n]$. The graph of $POD_2[2]$ is shown in Figure 1.

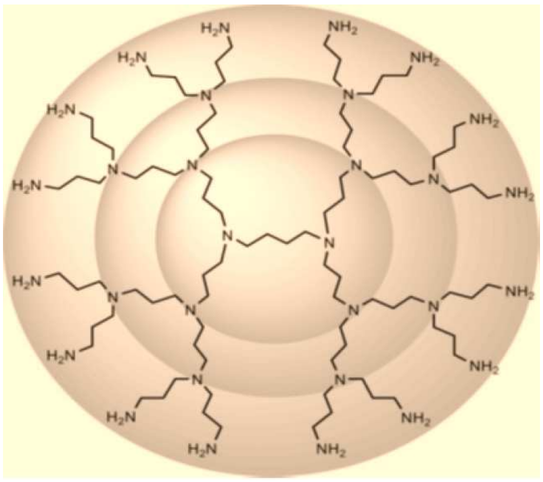

Figure 1: The graph of $POD_2[2]$

Let $G = POD_2[n]$. By algebraic method, we obtain that G has $2^{n+5} - 10$ vertices and $2^{n+5} - 11$ edges. The edge partition of $POD_2[n]$ based on the degree product of neighbors of end vertices of each edge is given in Table 1.

$M_G(u), M_G(v)\backslash uv \in E(G)$	(2, 2)	(2,4)	(4,4)	(4,6)	(6,8)
Number of edges	2^{n+2}	2^{n+2}	1	$3\times2^{n+2} - 6$	$3\times2^{n+2}-6$

Table 1: Edge partition of POD_2 $[n]$

Theorem 1. The multiplicative sum connectivity *KV* index of a POPAM dendrimer $POD_2[n]$ is

$$SKVII(POD_2[n]) = \left(\frac{1}{2}\right)^{2^{n+2}} \times \left(\frac{1}{\sqrt{6}}\right)^{2^{n+2}} \times \left(\frac{1}{2\sqrt{2}}\right)^{1} \times \left(\frac{1}{\sqrt{10}}\right)^{3\times 2^{n+2}-6} \times \left(\frac{1}{\sqrt{14}}\right)^{3\times 2^{n+2}-6}$$

Proof: Let $G = POD_2[n]$. By using equation (1) and Table 1, we have

$$SKVII(POD_2[n]) = \prod_{uv\in E(G)} \frac{1}{\sqrt{M_G(u)+M_G(v)}}$$

$$= \left(\frac{1}{\sqrt{2+2}}\right)^{2^{n+2}} \times \left(\frac{1}{\sqrt{2+6}}\right)^{2^{n+2}} \times \left(\frac{1}{\sqrt{4+4}}\right)^{1} \times \left(\frac{1}{\sqrt{4+6}}\right)^{3\times 2^{n+2}-6} \times \left(\frac{1}{\sqrt{6+8}}\right)^{3\times 2^{n+2}-6}$$

$$= \left(\frac{1}{2}\right)^{2^{n+2}} \times \left(\frac{1}{\sqrt{6}}\right)^{2^{n+2}} \times \left(\frac{1}{2\sqrt{2}}\right)^{1} \times \left(\frac{1}{\sqrt{10}}\right)^{3\times 2^{n+2}-6} \times \left(\frac{1}{\sqrt{14}}\right)^{3\times 2^{n+2}-6}$$

Theorem 2. The multiplicative product connectivity *KV* index of a POPAM dendrimer $POD_2\,[n]$ is

$$PKVII(POD_2[n]) = \left(\frac{1}{2}\right)^{2^{n+2}} \times \left(\frac{1}{2\sqrt{2}}\right)^{2^{n+2}} \times \frac{1}{4} \times \left(\frac{1}{2\sqrt{6}}\right)^{3\times 2^{n+2}-6} \times \left(\frac{1}{4\sqrt{3}}\right)^{3\times 2^{n+2}-6}$$

Proof: Let $G = POD_2[n]$. From equation (2), we have

$$PKVII(POD_2[n]) = \prod_{uv\in E(G)} \frac{1}{\sqrt{M_G(u)M_G(v)}}$$

By using Table 1, we deduce

$$PKVII(POD_2[n]) = \left(\frac{1}{\sqrt{2\times 2}}\right)^{2^{n+2}} \times \left(\frac{1}{\sqrt{2\times 4}}\right)^{2^{n+2}} \times \left(\frac{1}{\sqrt{4\times 4}}\right)^{1} \times \left(\frac{1}{\sqrt{4\times 6}}\right)^{3\times 2^{n+2}-6} \times \left(\frac{1}{\sqrt{6\times 8}}\right)^{3\times 2^{n+2}-6}$$

$$= \left(\frac{1}{2}\right)^{2^{n+2}} \times \left(\frac{1}{2\sqrt{2}}\right)^{2^{n+2}} \times \frac{1}{4} \times \left(\frac{1}{2\sqrt{6}}\right)^{3\times 2^{n+2}-6} \times \left(\frac{1}{4\sqrt{3}}\right)^{3\times 2^{n+2}-6}.$$

Theorem 3. The multiplicative atom bond connectivity *KV* index of a POPAM dendrimer $POD_2[n]$ is

$$ABCKVII(POD_2[n]) = \left(\sqrt{\frac{3}{8}}\right) \times \left(\frac{1}{2}\right)^{4\times 2^{n+2}-6} \times \left(\frac{1}{\sqrt{3}}\right)^{3\times 2^{n+2}-6}.$$

Proof: Let $G = POD_2[n]$. By using equation (3) and Table 1, we derive

$$ABCKVII(POD_2[n]) = \prod_{uv\in E(G)} \sqrt{\frac{M_G(u)+M_G(v)-2}{M_G(u)M_G(v)}}$$

$$= \left(\sqrt{\frac{2+2-2}{2\times 2}}\right)^{2^{n+2}} \times \left(\sqrt{\frac{2+4-2}{2\times 4}}\right)^{2^{n+2}} \times \left(\sqrt{\frac{4+4-2}{4\times 4}}\right)^{1} \times \left(\sqrt{\frac{4+6-2}{4\times 6}}\right)^{3\times 2^{n+2}-6} \times \left(\sqrt{\frac{6+8-2}{6\times 8}}\right)^{3\times 2^{n+2}-6}$$

$$= \left(\sqrt{\frac{3}{8}}\right) \times \left(\frac{1}{2}\right)^{4\times 2^{n+2}-6} \times \left(\frac{1}{\sqrt{3}}\right)^{3\times 2^{n+2}-6}.$$

Theorem 4. The multiplicative geometric-arithmetic *KV* index of a *POPAM* dendrimer $POD_2\,[n]$

$$GAKVII\left(POD_2[n]\right)=\left(\frac{2\sqrt{2}}{3}\right)^{2^{n+2}}\times\left(\frac{2\sqrt{6}}{5}\right)^{3\times 2^{n+2}-6}\times\left(\frac{4\sqrt{3}}{7}\right)^{3\times 2^{n+2}-6}.$$

Proof: Let $G = POD_2[n]$. By using equation (4), we obtain

$$GAKVII\left(POD_2[n]\right)=\prod_{uv\in E(G)}\frac{2\sqrt{M_G(u)M_G(v)}}{M_G(u)+M_G(v)}$$

Then by using Table 1, we deduce

$$GAKVII\left(POD_2[n]\right)=\left(\frac{2\sqrt{2\times 2}}{2+2}\right)^{2^{n+2}}\times\left(\frac{2\sqrt{2\times 4}}{2+4}\right)^{2^{n+2}}\times\left(\frac{2\sqrt{4\times 4}}{4+4}\right)^{1}\times\left(\frac{2\sqrt{4\times 6}}{4+6}\right)^{3\times 2^{n+2}-6}\times\left(\frac{2\sqrt{6\times 8}}{6+8}\right)^{3\times 2^{n+2}-6}$$

$$=\left(\frac{2\sqrt{2}}{3}\right)^{2^{n+2}}\times\left(\frac{2\sqrt{6}}{5}\right)^{3\times 2^{n+2}-6}\times\left(\frac{4\sqrt{3}}{7}\right)^{3\times 2^{n+2}-6}.$$

3. Results for tetrathiafulvalene dendrimers

The family of tetrathiafulvalene dendrimers is denoted by TD_2 [n], where n is the steps of growth in this type of dendrimers, see Figure 2.

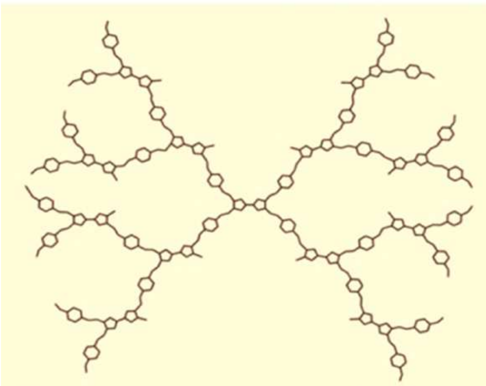

Figure 2: The graph of TD_2 [2]

Let $G = TD_2[n]$. By algebraic method, we obtain that G has $31 \times 2^{n+2} - 24$ vertices and $32 \times 2^{n+2} - 85$ edges. The edge partition of G based on the degree product of neighbors of end vertices of each edge is given in Table 2.

$M_G(u), M_G(v) \setminus uv \in E(G)$	Number of edges
(2, 3)	2^{n+2}
(3, 6)	$2^{n+2} - 4$
(3, 8)	2^{n+2}
(6, 6)	$7 \times 2^{n+2} - 16$
(6,8)	$11 \times 2^{n+2} - 24$
(6, 9)	$2^{n+2} - 4$
(6, 12)	$3 \times 2^{n+2} - 8$
(9, 12)	$8 \times 2^{n+2} - 24$
(12, 12)	$2 \times 2^{n+2} - 5$

Table 2: Edge partition of $TD_2[n]$

Theorem 5. The multiplicative sum connectivity *KV* index of a tetrathiafulvalene dendrimer $TD_2[n]$ is

$$SKVII\left(TD_2[n]\right)=\left(\frac{1}{\sqrt{5}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{3}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{11}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{12}}\right)^{7\times2^{n+2}-6}\times\left(\frac{1}{\sqrt{14}}\right)^{11\times2^{n+2}-24}$$
$$\times\left(\frac{1}{\sqrt{15}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{18}}\right)^{3\times2^{n+2}-8}\times\left(\frac{1}{\sqrt{21}}\right)^{8\times2^{n+2}-24}\times\left(\frac{1}{\sqrt{24}}\right)^{2\times2^{n+2}-5}$$

Proof: Let $G = TD_2[n]$. From equation (1) and using Table 2, we derive

$$SKVII\left(TD_2[n]\right)=\prod_{uv\in E(G)}\frac{1}{\sqrt{M_G(u)+M_G(v)}}$$
$$=\left(\frac{1}{\sqrt{2+3}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{3+6}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{3+8}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{6+6}}\right)^{7\times2^{n+2}-6}\times\left(\frac{1}{\sqrt{6+8}}\right)^{11\times2^{n+2}-24}$$
$$\times\left(\frac{1}{\sqrt{6+9}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{6+12}}\right)^{3\times2^{n+2}-8}\times\left(\frac{1}{\sqrt{9+12}}\right)^{8\times2^{n+2}-24}\times\left(\frac{1}{\sqrt{12+12}}\right)^{2\times2^{n+2}-5}$$
$$=\left(\frac{1}{\sqrt{5}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{3}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{11}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{12}}\right)^{7\times2^{n+2}-6}\times\left(\frac{1}{\sqrt{14}}\right)^{11\times2^{n+2}-24}$$
$$\times\left(\frac{1}{\sqrt{15}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{18}}\right)^{3\times2^{n+2}-8}\times\left(\frac{1}{\sqrt{21}}\right)^{8\times2^{n+2}-24}\times\left(\frac{1}{\sqrt{24}}\right)^{2\times2^{n+2}-5}$$

Theorem 6. The multiplicative product connectivity *KV* index of $TD_2[n]$ is

$$PKVII\left(TD_2[n]\right)=\left(\frac{1}{\sqrt{6}}\right)^{2^{n+2}}\times\left(\frac{1}{3\sqrt{2}}\right)^{2^{n+2}-4}\times\left(\frac{1}{2\sqrt{6}}\right)^{2^{n+2}}\times\left(\frac{1}{6}\right)^{7\times2^{n+2}-16}\times\left(\frac{1}{4\sqrt{3}}\right)^{11\times2^{n+2}-24}$$
$$\times\left(\frac{1}{3\sqrt{6}}\right)^{2^{n+2}-4}\times\left(\frac{1}{6\sqrt{2}}\right)^{3\times2^{n+2}-8}\times\left(\frac{1}{6\sqrt{3}}\right)^{8\times2^{n+2}-24}\times\left(\frac{1}{12}\right)^{2\times2^{n+2}-5}$$

Proof: Let G $TD_2[n]$. From equation (2) and by using Table 2, we obtain

$$PKVII\left(TD_2[n]\right)=\prod_{uv\in E(G)}\frac{1}{\sqrt{M_G(u)M_G(v)}}$$
$$=\left(\frac{1}{\sqrt{2\times3}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{3\times6}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{3\times8}}\right)^{2^{n+2}}\times\left(\frac{1}{\sqrt{6\times6}}\right)^{7\times2^{n+2}-6}\times\left(\frac{1}{\sqrt{6\times8}}\right)^{11\times2^{n+2}-24}$$
$$\times\left(\frac{1}{\sqrt{6\times9}}\right)^{2^{n+2}-4}\times\left(\frac{1}{\sqrt{6\times12}}\right)^{3\times2^{n+2}-8}\times\left(\frac{1}{\sqrt{9\times12}}\right)^{8\times2^{n+2}-24}\times\left(\frac{1}{\sqrt{12\times12}}\right)^{2\times2^{n+2}-5}$$
$$=\left(\frac{1}{\sqrt{6}}\right)^{2^{n+2}}\times\left(\frac{1}{3\sqrt{2}}\right)^{2^{n+2}-4}\times\left(\frac{1}{2\sqrt{6}}\right)^{2^{n+2}}\times\left(\frac{1}{6}\right)^{7\times2^{n+2}-6}\times\left(\frac{1}{4\sqrt{3}}\right)^{11\times2^{n+2}-24}$$
$$\times\left(\frac{1}{3\sqrt{6}}\right)^{2^{n+2}-4}\times\left(\frac{1}{6\sqrt{2}}\right)^{3\times2^{n+2}-8}\times\left(\frac{1}{6\sqrt{3}}\right)^{8\times2^{n+2}-24}\times\left(\frac{1}{12}\right)^{2\times2^{n+2}-5}.$$

Theorem 7. The multiplicative atom bond connectivity *KV* index of $TD_2[n]$ is

$$ABCKVII\left(TD_2[n]\right)=\left(\frac{1}{\sqrt{2}}\right)^{2^{n+2}}\times\left(\sqrt{\frac{7}{18}}\right)^{2^{n+2}-4}\times\left(\sqrt{\frac{3}{8}}\right)^{2^{n+2}}\times\left(\sqrt{\frac{5}{18}}\right)^{7\times 2^{n+2}-16}$$
$$\times\left(\frac{1}{2}\right)^{11\times 2^{n+2}-24}\times\left(\sqrt{\frac{13}{54}}\right)^{2^{n+2}-4}\times\left(\sqrt{\frac{2}{9}}\right)^{3\times 2^{n+2}-8}\times\left(\sqrt{\frac{19}{108}}\right)^{8\times 2^{n+2}-24}\times\left(\sqrt{\frac{11}{72}}\right)^{2\times 2^{n+2}-5}.$$

Proof: Let $G = TD_2[n]$. By using equation (3) and Table 2, we deduce

$$ABCKVII\left(TD_2[n]\right)=\prod_{uv\in E(G)}\sqrt{\frac{M_G(u)+M_G(v)-2}{M_G(u)M_G(v)}}$$
$$=\left(\sqrt{\frac{2+3-2}{2\times 3}}\right)^{2^{n+2}}\times\left(\sqrt{\frac{3+6-2}{3\times 6}}\right)^{2^{n+2}-4}\times\left(\sqrt{\frac{3+8-2}{3\times 8}}\right)^{2^{n+2}}\times\left(\sqrt{\frac{6+6-2}{6\times 6}}\right)^{7\times 2^{n+2}-16}$$
$$\times\left(\sqrt{\frac{6+8-2}{6\times 8}}\right)^{11\times 2^{n+2}-24}\times\left(\sqrt{\frac{6+9-2}{6\times 9}}\right)^{2^{n+2}-4}\times\left(\sqrt{\frac{6+12-2}{6\times 12}}\right)^{3\times 2^{n+2}-8}$$
$$\times\left(\sqrt{\frac{9+12-2}{9\times 12}}\right)^{8\times 2^{n+2}-24}\times\left(\sqrt{\frac{12+12-2}{12\times 12}}\right)^{2\times 2^{n+2}-5}$$
$$=\left(\frac{1}{\sqrt{2}}\right)^{2^{n+2}}\times\left(\sqrt{\frac{7}{18}}\right)^{2^{n+2}-4}\times\left(\sqrt{\frac{3}{8}}\right)^{2^{n+2}}\times\left(\sqrt{\frac{5}{18}}\right)^{7\times 2^{n+2}-16}\times\left(\frac{1}{2}\right)^{11\times 2^{n+2}-24}$$
$$\times\left(\sqrt{\frac{13}{54}}\right)^{2^{n+2}-4}\times\left(\sqrt{\frac{2}{9}}\right)^{3\times 2^{n+2}-8}\times\left(\sqrt{\frac{19}{108}}\right)^{8\times 2^{n+2}-24}\times\left(\sqrt{\frac{11}{72}}\right)^{2\times 2^{n+2}-5}.$$

Theorem 8. The multiplicative geometric-arithmetic *KV* index of $TD_2[n]$ is

$$GAKVII\left(TD_2[n]\right)=\left(\frac{2\sqrt{6}}{5}\right)^{2\times 2^{n+2}-4}\times\left(\frac{2\sqrt{2}}{3}\right)^{4\times 2^{n+2}-12}\times\left(\frac{4\sqrt{6}}{11}\right)^{2^{n+2}}\times\left(\frac{4\sqrt{3}}{7}\right)^{19\times 2^{n+2}-48}.$$

Proof: Let $G = TD_2[n]$. By using equation (4) and Table 2, we obtain

$$GAKVII\left(TD_2[n]\right)=\prod_{uv\in E(G)}\frac{2\sqrt{M_G(u)M_G(v)}}{M_G(u)+M_G(v)}$$
$$=\left(\frac{2\sqrt{2\times 3}}{2+3}\right)^{2^{n+2}}\times\left(\frac{2\sqrt{3\times 6}}{3+6}\right)^{2^{n+2}-4}\times\left(\frac{2\sqrt{3\times 8}}{3+8}\right)^{2^{n+2}}\times\left(\frac{2\sqrt{6\times 6}}{6+6}\right)^{7\times 2^{n+2}-16}\times\left(\frac{2\sqrt{6\times 8}}{6+8}\right)^{11\times 2^{n+2}-24}$$
$$\times\left(\frac{2\sqrt{6\times 9}}{6+9}\right)^{2^{n+2}-4}\times\left(\frac{2\sqrt{6\times 12}}{6+12}\right)^{3\times 2^{n+2}-8}\times\left(\frac{2\sqrt{9\times 12}}{9+12}\right)^{8\times 2^{n+2}-24}\times\left(\frac{2\sqrt{12\times 12}}{12+12}\right)^{2\times 2^{n+2}-5}$$
$$=\left(\frac{2\sqrt{2}}{5}\right)^{2\times 2^{n+2}-4}\times\left(\frac{2\sqrt{6}}{3}\right)^{4\times 2^{n+2}-12}\times\left(\frac{4\sqrt{6}}{11}\right)^{2^{n+2}}\times\left(\frac{4\sqrt{3}}{7}\right)^{19\times 2^{n+2}-48}.$$

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