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Logarithm Multiplicative Wiener Index and Reciprocal Complementary Wiener Index of Certain Special Molecular Graphs

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Abstract

Chemical compounds and drugs are often modeled as graphs where each vertex represents an atom of molecule, and covalent bounds between atoms are represented by edges between the corresponding vertices. This graph derived from a chemical compounds is often called its molecular graph, and can be different structures. In this paper, we determine the logarithm multiplicative Wiener index and reciprocal complementary Wiener index of fan molecular graph, wheel molecular graph, gear fan molecular graph, gear wheel molecular graph, and their r-corona molecular graphs.

Keywords

Chemical Graph Theory, Logarithm Multiplicative Wiener Index, Reciprocal Complementary Wiener Index, *r*-Corona Molecular Graph

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1. Introduction

Wiener index, Gutman index, Shultz index, Geometric-arithmetic index and Zagreb indices are introduced to reflect certain structural features of organic molecules. Several papers contributed to determine the distance-based index or degree-based index of special molecular graphs (See Yan et al., [1-2], Gao et al., [3-4], Gao and Shi [5], Gao and Wang [6], Xi and Gao [7-8], Xi et al., [9], Gao et al., [10] for more detail). The notation and terminology used but undefined in this paper can be found in [11].

Gutman et al., [12] introduced the logarithm of multiplicative Wiener index of molecular graph G as:

$$\prod(G) = Ln(\sqrt{2\prod_{\{u,v\}\subseteq V(G)} d(u,v)})$$

Let $D = D(G)$ be the diameter of molecular graph G. Parallel to the Wiener index, the reciprocal complementary Wiener (RCW) index is defined by [13] as

$$RCW(G) = \sum_{\{u,v\}\subseteq V(G)} \frac{1}{1+D-d(u,v)}$$

Let P_n and C_n be path and cycle with n vertices. The molecular graph $F_n=\{v\} \vee P_n$ is called a fan molecular graph and the molecular graph $W_n=\{v\} \vee C_n$ is called a wheel molecular graph. Molecular graph $I_r(G)$ is called r- crown molecular graph of G which splicing r hangs edges for every vertex in G. By adding one vertex in every two adjacent vertices of the fan path P_n of fan molecular graph F_n, the resulting molecular graph is a subdivision molecular graph called gear fan molecular graph, denote as $\tilde{F}_n$. By adding one vertex in every two adjacent vertices of the wheel cycle C_n of wheel molecular graph W_n, The resulting molecular graph is a subdivision molecular graph, called gear wheel molecular graph, denoted as $\tilde{W}_n$.

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In this paper, we present the logarithm multiplicative Wiener index and reciprocal complementary Wiener index of $I_r(F_n)$, $I_r(W_n)$, $I_r(\tilde{F}_n)$ and $I_r(\tilde{W}_n)$.

2. Logarithm Multiplicative Wiener Index

Theorem 1. $\prod(I_r(F_n)) = Ln(\sqrt{2^{2nr+\frac{(n-1)(n-2)}{2}+(2n-1)+\frac{nr(r-1)}{2}} 3^{(2n-1)r^2+(n-1)(n-2)} 4^{\frac{(n-1)(n-2)}{2}r^2}})$.

Proof. Let $P_n=v_1v_2\ldots v_n$ and the r hanging vertices of vi be v_i^1, v_i^2,…, v_i^r $(1\le i\le n)$. Let v be a vertex in F_n beside P_n, and the r hanging vertices of v be v^1, v^2, …, v^r. By the definition of logarithm multiplicative Wiener index, we have

$$\begin{aligned}\prod(I_r(F_n)) = Ln((2\prod_{i=1}^{r} d(v,v^i) \times \prod_{i=1}^{n} d(v,v_i) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v,v_i^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{r} d(v_i^j,v^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n} d(v_i,v_j) \times \\ \prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v_i^j) \times \prod_{i=1}^{n}\prod_{j\in\{1,2,\cdots,n\}-i}\prod_{k=1}^{r} d(v_i,v_j^k) \times \prod_{i=1}^{n}\prod_{j=1}^{r-1}\prod_{k=j+1}^{r} d(v_i^j,v_i^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n}\prod_{k=1}^{r}\prod_{t=1}^{r} d(v_i^k,v_j^t))^{\frac{1}{2}}) \\ = Ln(\sqrt{2^{2nr+\frac{(n-1)(n-2)}{2}+(2n-1)+\frac{nr(r-1)}{2}} 3^{(2n-1)r^2+(n-1)(n-2)} 4^{\frac{(n-1)(n-2)}{2}r^2}}).\end{aligned}$$

Corollary 1. $\prod(F_n) = Ln(\sqrt{2^{\frac{(n-1)(n-2)}{2}+(2n-1)} 3^{(n-1)(n-2)}})$.

Theorem 2. $\prod(I_r(W_n)) = Ln(\sqrt{2^{2nr+\frac{n(n-1)}{2}+2n+1+\frac{nr(r-1)}{2}} 3^{2nr^2+n(n-3)} 4^{\frac{n(n-3)}{2}r^2}})$.

Proof. Let $C_n=v_1v_2\ldots v_n$ and v_i^1, v_i^2,…, v_i^r be the r hanging vertices of v_i $(1\le i\le n)$. Let v be a vertex in W_n beside C_n, and v^1, v^2, …, v^r be the r hanging vertices of v.

By the definition of logarithm multiplicative Wiener index, we have

$$\begin{aligned}\prod(I_r(W_n)) = Ln((2\prod_{i=1}^{r} d(v,v^i) \times \prod_{i=1}^{n} d(v,v_i) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v,v_i^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{r} d(v_i^j,v^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n} d(v_i,v_j) \times \\ \prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v_i^j) \times \prod_{i=1}^{n}\prod_{j\in\{1,2,\cdots,n\}-i}\prod_{k=1}^{r} d(v_i,v_j^k) \times \prod_{i=1}^{n}\prod_{j=1}^{r-1}\prod_{k=j+1}^{r} d(v_i^j,v_i^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n}\prod_{k=1}^{r}\prod_{t=1}^{r} d(v_i^k,v_j^t))^{\frac{1}{2}}) \\ = Ln(\sqrt{2^{2nr+\frac{n(n-1)}{2}+2n+1+\frac{nr(r-1)}{2}} 3^{2nr^2+n(n-3)} 4^{\frac{n(n-3)}{2}r^2}}).\end{aligned}$$

Corollary 2. $\prod(W_n) = Ln(\sqrt{2^{\frac{n(n-1)}{2}+2n+1} 3^{n(n-3)}})$.

Theorem 3.

$$\begin{aligned}\prod(I_r(\tilde{F}_n)) = Ln(2^{(n-\frac{1}{2})r^2+(5n-\frac{7}{2})r+(\frac{n^2}{2}+\frac{3n}{2}-2)} 3^{(3n-2)r^2+(n^2+3n-6)r+(n-1)(n-2)} 4^{r^2(\frac{n^2}{2}+\frac{3n}{2}-3)+2(n-1)(n-2)r+\frac{(n-2)(n-3)}{2}} \\ 5^{(n-1)(n-2)r^2+(n-3)(n-2)r} 6^{\frac{(n-2)(n-3)r^2}{2}})^{\frac{1}{2}}.\end{aligned}$$

Proof. Let Pn=v1v2…vn and $v_{i,i+1}$ be the adding vertex between vi and vi+1. Let v_i^1, v_i^2,…, v_i^r be the r hanging vertices of vi (1≤i≤n). Let $v_{i,i+1}^1$, $v_{i,i+1}^2$,…, $v_{i,i+1}^r$ be the r hanging vertices of $v_{i,i+1}$ $(1\le i\le n$-1). Let v be a vertex in F_n beside P_n, and the r hanging vertices of v be v^1, v^2, …, v^r.

By virtue of the definition of logarithm multiplicative Wiener index, we get

$$\prod(I_r(\tilde{F}_n)) = Ln((2\prod_{i=1}^{r} d(v,v^i) \times \prod_{i=1}^{n} d(v,v_i) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v,v_i^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{r} d(v_i^j,v^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n} d(v_i,v_j) \times$$

$$\prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v_i^j) \times \prod_{i=1}^{n}\prod_{j\in\{1,2,\cdots,n\}-i}\prod_{k=1}^{r} d(v_i,v_j^k) \times \prod_{i=1}^{n}\prod_{j=1}^{r-1}\prod_{k=j+1}^{r} d(v_i^j,v_i^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n}\prod_{k=1}^{r}\prod_{t=1}^{r} d(v_i^k,v_j^t) \times \prod_{i=1}^{n-1} d(v,v_{i,i+1}) \times$$

$$\prod_{i=1}^{n-1}\prod_{j=1}^{r} d(v,v^j_{i,i+1})$$

$$\times \prod_{i=1}^{r}\prod_{j=1}^{n-1} d(v^i,v_{j,j+1}) \times \prod_{i=1}^{r}\prod_{j=1}^{n-1}\prod_{k=1}^{r} d(v^i,v^k_{j,j+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{n-1} d(v_i,v_{j,j+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{n-1}\prod_{k=1}^{r} d(v_i,v^k_{j,j+1})$$

$$\times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{n-1} d(v_i^j,v_{k,k+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{n-1}\prod_{t=1}^{r} d(v_i^j,v^r_{k,k+1}) \times \prod_{i=1}^{n-2}\prod_{j=i+1}^{n-1} d(v_{i,i+1},v_{j,j+1}) \times \prod_{i=1}^{n-1}\prod_{j=1}^{r} d(v_{i,i+1},v^j_{i,i+1}) \times$$

$$\prod_{i=1}^{n-1}\prod_{j\in\{1,2,\cdots,n-1\}-i}\prod_{k=1}^{r} d(v_{i,i+1},v^k_{j,j+1}) \times \prod_{i=1}^{n-1}\prod_{j=1}^{r-1}\prod_{k=j+1}^{r} d(v^j_{i,i+1},v^k_{i,i+1}) \times \prod_{i=1}^{n-2}\prod_{j=i+1}^{n-1}\prod_{k=1}^{r}\prod_{t=1}^{r} d(v^k_{i,i+1},v^t_{j,j+1}))^{\frac{1}{2}})$$

$$= Ln(2^{(n-\frac{1}{2})r^2+(5n-\frac{7}{2})r+(\frac{n^2}{2}+\frac{3n}{2}-2)}3^{(3n-2)r^2+(n^2+3n-6)r+(n-1)(n-2)}4^{r^2(\frac{n^2}{2}+\frac{3n}{2}-3)+2(n-1)(n-2)r+\frac{(n-2)(n-3)}{2}}$$

$$5^{(n-1)(n-2)r^2+(n-3)(n-2)r}6^{\frac{(n-2)(n-3)r^2}{2}})^{\frac{1}{2}}.$$

Corollary 3. $\prod(\tilde{F}_n) = Ln\sqrt{2^{\frac{n^2}{2}+\frac{3n}{2}-2}3^{(n-1)(n-2)}4^{\frac{(n-2)(n-3)}{2}}}$.

Theorem 4. $\prod(I_r(\tilde{W}_n)) = Ln\sqrt{2^{nr^2+3nr+\frac{n^2}{2}+\frac{3n}{2}+1}3^{3nr^2+n(n+3)r+n(n-2)}4^{(\frac{n^2}{2}+\frac{3n}{2})r^2+2(n-2)nr+\frac{n(n-3)}{2}}5^{(n-2)nr^2+(n-3)nr}6^{\frac{n(n-3)}{2}r^2}}$.

Proof. Let $C_n=v_1v_2\ldots v_n$ and v be a vertex in W_n beside C_n. $v_{i,i+1}$ be the adding vertex between v_i and v_{i+1}. Let v^1 , v^2 , …, v^r . be the r hanging vertices of v and v_i^1 , v_i^2 ,…, v_i^r be the r hanging vertices of v_i ($1\le i\le n$). Let $v_{n,n+1}=v_{1,n}$ and $v^1_{i,i+1}$, $v^2_{i,i+1}$,…, $v^r_{i,i+1}$ be the r hanging vertices of $v_{i,i+1}$ ($1\le i\le n$). In view of the definition of logarithm multiplicative Wiener index, we deduce

$$\prod(I_r(\tilde{W}_n)) = Ln((2\prod_{i=1}^{r} d(v,v^i) \times \prod_{i=1}^{n} d(v,v_i) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v,v_i^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v^j) \times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{r} d(v_i^j,v^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n} d(v_i,v_j) \times$$

$$\prod_{i=1}^{n}\prod_{j=1}^{r} d(v_i,v_i^j) \times \prod_{i=1}^{n}\prod_{j\in\{1,2,\cdots,n\}-i}\prod_{k=1}^{r} d(v_i,v_j^k) \times \prod_{i=1}^{n}\prod_{j=1}^{r-1}\prod_{k=j+1}^{r} d(v_i^j,v_i^k) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n}\prod_{k=1}^{r}\prod_{t=1}^{r} d(v_i^k,v_j^t) \times \prod_{i=1}^{n} d(v,v_{i,i+1})$$

$$\times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v,v^j_{i,i+1})$$

$$\times \prod_{i=1}^{r}\prod_{j=1}^{n} d(v^i,v_{j,j+1}) \times \prod_{i=1}^{r}\prod_{j=1}^{n}\prod_{k=1}^{r} d(v^i,v^k_{j,j+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{n} d(v_i,v_{j,j+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{n}\prod_{k=1}^{r} d(v_i,v^k_{j,j+1})$$

$$\times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{n} d(v_i^j,v_{k,k+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{r}\prod_{k=1}^{n}\prod_{t=1}^{r} d(v_i^j,v^r_{k,k+1}) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n} d(v_{i,i+1},v_{j,j+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{r} d(v_{i,i+1},v^j_{i,i+1}) \times$$

$$\prod_{i=1}^{n}\prod_{j\in\{1,2,\cdots,n\}-i}\prod_{k=1}^{r} d(v_{i,i+1},v^k_{j,j+1}) \times \prod_{i=1}^{n}\prod_{j=1}^{r-1}\prod_{k=j+1}^{r} d(v^j_{i,i+1},v^k_{i,i+1}) \times \prod_{i=1}^{n-1}\prod_{j=i+1}^{n}\prod_{k=1}^{r}\prod_{t=1}^{r} d(v^k_{i,i+1},v^t_{j,j+1}))^{\frac{1}{2}})$$

$$= Ln\sqrt{2^{nr^2+3nr+\frac{n^2}{2}+\frac{3n}{2}+1}3^{3nr^2+n(n+3)r+n(n-2)}4^{(\frac{n^2}{2}+\frac{3n}{2})r^2+2(n-2)nr+\frac{n(n-3)}{2}}5^{(n-2)nr^2+(n-3)nr}6^{\frac{n(n-3)}{2}r^2}}\ .$$

Corollary 4. $\prod(\tilde{W}_n) = Ln\sqrt{2^{\frac{n^2}{2}+\frac{3n}{2}+1}3^{n(n-2)}4^{\frac{n(n-3)}{2}}}$.

3. Reciprocal Complementary Wiener Index

The notations for special molecular graphs can refer to Theorem 1- Theorem 4.

Theorem 5. $RCW(I_r(F_n))=(\frac{n^2}{2}-\frac{n}{3}+\frac{1}{2})r^2+(\frac{3}{4}n+\frac{1}{4})r+(\frac{2n^2}{3}+\frac{5}{12})$.

Proof. By the definition of reciprocal complementary Wiener index, we have

$$RCW(I_r(F_n))=\sum_{i=1}^{r}\frac{1}{1+D-d(v,v^i)}+\sum_{i=1}^{n}\frac{1}{1+D-d(v,v_i)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v,v_i^j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v^j)}+$$
$$\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i^j,v^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{1}{1+D-d(v_i,v_j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v_i^j)}+$$
$$\sum_{i=1}^{n}\sum_{j\in\{1,2,\cdots,n\}-i}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i,v_j^k)}+\sum_{i=1}^{n}\sum_{j=1}^{r-1}\sum_{k=j+1}^{r}\frac{1}{1+D-d(v_i^j,v_i^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\sum_{k=1}^{r}\sum_{t=1}^{r}\frac{1}{1+D-d(v_i^k,v_j^t)}$$
$$=\frac{1}{4}(r(n+1)+(2n-1))+\frac{1}{3}(2nr+\frac{(n-1)(n-2)}{2}+(2n-2)+\frac{nr(r-1)}{2})+\frac{1}{2}((2n-1)r^2+(n-1)(n-2))$$
$$+\frac{(n-1)(n-2)}{2}r^2$$
$$=(\frac{n^2}{2}-\frac{n}{3}+\frac{1}{2})r^2+(\frac{3}{4}n+\frac{1}{4})r+(\frac{2n^2}{3}+\frac{5}{12}).$$

Corollary 5. $RCW(F_n)=\frac{n^2-3n-3}{2}$.

Theorem 6. $RCW(I_r(W_n))=r^2(\frac{n^2}{2}-\frac{n}{2})+r(\frac{11}{12}n+\frac{1}{12})+(\frac{3}{2}n^2-\frac{1}{2}n)$.

Proof. By the definition of reciprocal complementary Wiener index, we have

$$RCW(I_r(W_n))=\sum_{i=1}^{r}\frac{1}{1+D-d(v,v^i)}+\sum_{i=1}^{n}\frac{1}{1+D-d(v,v_i)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v,v_i^j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v^j)}+$$
$$\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i^j,v^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{1}{1+D-d(v_i,v_j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v_i^j)}+$$
$$\sum_{i=1}^{n}\sum_{j\in\{1,2,\cdots,n\}-i}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i,v_j^k)}+\sum_{i=1}^{n}\sum_{j=1}^{r-1}\sum_{k=j+1}^{r}\frac{1}{1+D-d(v_i^j,v_i^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\sum_{k=1}^{r}\sum_{t=1}^{r}\frac{1}{1+D-d(v_i^k,v_j^t)}$$
$$=\frac{1}{4}(r(n+1)+2n)+\frac{1}{3}(2nr+\frac{n(n-1)}{2}+2n+\frac{nr(r-1)}{2})+\frac{1}{2}(2nr^2+n(n-3))+\frac{n(n-3)}{2}r^2$$
$$=r^2(\frac{n^2}{2}-\frac{n}{2})+r(\frac{11}{12}n+\frac{1}{12})+(\frac{3}{2}n^2-\frac{1}{2}n).$$

Corollary 6. $RCW(W_n)=\frac{n^2+5n}{2}$.

Theorem 7. $RCW(I_r(\tilde{F}_n))=\frac{55n^2-98n+54}{60}r^2+\frac{85n^2-145n+128}{60}r+\frac{31n^2-57n+44}{60}$.

Proof. By virtue of the definition of reciprocal complementary Wiener index, we get

$$RCW(I_r(\tilde{F}_n))=\sum_{i=1}^{r}\frac{1}{1+D-d(v,v^i)}+\sum_{i=1}^{n}\frac{1}{1+D-d(v,v_i)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v,v_i^j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v^j)}+$$

$$\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i^j,v^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{1}{1+D-d(v_i,v_j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v_i^j)}+\sum_{i=1}^{n}\sum_{j\in\{1,2,\cdots,n\}-i}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i,v_j^k)}+$$

$$\sum_{i=1}^{n}\sum_{j=1}^{r-1}\sum_{k=j+1}^{r}\frac{1}{1+D-d(v_i^j,v_i^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\sum_{k=1}^{r}\sum_{t=1}^{r}\frac{1}{1+D-d(v_i^k,v_j^t)}+\sum_{i=1}^{n-1}\frac{1}{1+D-d(v,v_{i,i+1})}+\sum_{i=1}^{n-1}\sum_{j=1}^{r}\frac{1}{1+D-d(v,v_{i,i+1}^j)}+$$

$$\sum_{i=1}^{r}\sum_{j=1}^{n-1}\frac{1}{1+D-d(v^i,v_{j,j+1})}+\sum_{i=1}^{r}\sum_{j=1}^{n-1}\sum_{k=1}^{r}\frac{1}{1+D-d(v^i,v_{j,j+1}^k)}+\sum_{i=1}^{n}\sum_{j=1}^{n-1}\frac{1}{1+D-d(v_i,v_{j,j+1})}+\sum_{i=1}^{n}\sum_{j=1}^{n-1}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i,v_{j,j+1}^k)}$$

$$+\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{n-1}\frac{1}{1+D-d(v_i^j,v_{k,k+1})}+\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{n-1}\sum_{t=1}^{r}\frac{1}{1+D-d(v_i^j,v_{k,k+1}^r)}+\sum_{i=1}^{n-2}\sum_{j=i+1}^{n-1}\frac{1}{1+D-d(v_{i,i+1},v_{j,j+1})}$$

$$+\sum_{i=1}^{n-1}\sum_{j=1}^{r}\frac{1}{1+D-d(v_{i,i+1},v_{i,i+1}^j)}+\sum_{i=1}^{n-1}\sum_{j\in\{1,2,\cdots,n-1\}-i}\sum_{k=1}^{r}\frac{1}{1+D-d(v_{i,i+1},v_{j,j+1}^k)}+\sum_{i=1}^{n-1}\sum_{j=1}^{r-1}\sum_{k=j+1}^{r}\frac{1}{1+D-d(v_{i,i+1}^j,v_{i,i+1}^k)}$$

$$+\sum_{i=1}^{n-2}\sum_{j=i+1}^{n-1}\sum_{k=1}^{r}\sum_{t=1}^{r}\frac{1}{1+D-d(v_{i,i+1}^k,v_{j,j+1}^t)}=$$

$$\frac{1}{6}(2nr+2n-1)+\frac{1}{5}((n-\frac{1}{2})r^2+(5n-\frac{7}{2})r+(\frac{n^2}{2}+\frac{3n}{2}-3))+\frac{1}{4}((3n-2)r^2+(n^2+3n-6)r+(n-1)(n-2))$$

$$+\frac{1}{3}(r^2(\frac{n^2}{2}+\frac{3n}{2}-3)+2(n-1)(n-2)r+\frac{(n-2)(n-3)}{2})+\frac{1}{2}((n-1)(n-2)r^2+(n-3)(n-2)r)+\frac{(n-2)(n-3)r^2}{2}=$$

$$\frac{55n^2-98n+54}{60}r^2+\frac{85n^2-145n+128}{60}r+\frac{31n^2-57n+44}{60}.$$

Corollary 7. $RCW(\tilde{F}_n)=\dfrac{14n^2-36n+33}{12}$.

Theorem 8. $RCW(I_r(\tilde{W}_n))=\dfrac{70n^2-63n}{60}r^2+\dfrac{85n^2-69n+10}{60}r+\dfrac{31n^2-12n+12}{60}$.

Proof. In view of the definition of reciprocal complementary Wiener index, we deduce

$$RCW(I_r(\tilde{W}_n))=\sum_{i=1}^{r}\frac{1}{1+D-d(v,v^i)}+\sum_{i=1}^{n}\frac{1}{1+D-d(v,v_i)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v,v_i^j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v^j)}+$$

$$\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i^j,v^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{1}{1+D-d(v_i,v_j)}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_i,v_i^j)}+$$

$$\sum_{i=1}^{n}\sum_{j\in\{1,2,\cdots,n\}-i}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i,v_j^k)}+\sum_{i=1}^{n}\sum_{j=1}^{r-1}\sum_{k=j+1}^{r}\frac{1}{1+D-d(v_i^j,v_i^k)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\sum_{k=1}^{r}\sum_{t=1}^{r}\frac{1}{1+D-d(v_i^k,v_j^t)}+$$

$$\sum_{i=1}^{n}\frac{1}{1+D-d(v,v_{i,i+1})}+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v,v_{i,i+1}^j)}+\sum_{i=1}^{r}\sum_{j=1}^{n}\frac{1}{1+D-d(v^i,v_{j,j+1})}+$$

$$\sum_{i=1}^{r}\sum_{j=1}^{n}\sum_{k=1}^{r}\frac{1}{1+D-d(v^i,v_{j,j+1}^k)}+\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{1}{1+D-d(v_i,v_{j,j+1})}+\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{r}\frac{1}{1+D-d(v_i,v_{j,j+1}^k)}$$

$$+\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{n}\frac{1}{1+D-d(v_i^j,v_{k,k+1})}+\sum_{i=1}^{n}\sum_{j=1}^{r}\sum_{k=1}^{n}\sum_{t=1}^{r}\frac{1}{1+D-d(v_i^j,v_{k,k+1}^r)}+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\frac{1}{1+D-d(v_{i,i+1},v_{j,j+1})}$$

$$+\sum_{i=1}^{n}\sum_{j=1}^{r}\frac{1}{1+D-d(v_{i,i+1},v_{i,i+1}^j)}+\sum_{i=1}^{n}\sum_{j\in\{1,2,\cdots,n\}-i}\sum_{k=1}^{r}\frac{1}{1+D-d(v_{i,i+1},v_{j,j+1}^k)}+\sum_{i=1}^{n}\sum_{j=1}^{r-1}\sum_{k=j+1}^{r}\frac{1}{1+D-d(v_{i,i+1}^j,v_{i,i+1}^k)}$$

$$+\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\sum_{k=1}^{r}\sum_{t=1}^{r}\frac{1}{1+D-d(v_{i,i+1}^{k},v_{j,j+1}^{t})}$$

$$=\frac{1}{6}(r(2n+1)+3n)+\frac{1}{5}(nr^2+3nr+\frac{n^2}{2}+\frac{3n}{2}+1)+\frac{1}{4}(3nr^2+n(n+3)r+n(n-2))$$

$$+\frac{1}{3}((\frac{n^2}{2}+\frac{3n}{2})r^2+2(n-2)nr+\frac{n(n-3)}{2})+\frac{1}{2}((n-2)nr^2+(n-3)nr)+\frac{n(n-3)}{2}r^2$$

$$=\frac{70n^2-63n}{60}r^2+\frac{85n^2-69n+10}{60}r+\frac{31n^2-12n+12}{60}.$$

Corollary 8. $RCW(\tilde{W}_n)=\dfrac{14n^2-24n+13}{12}$

4. Conclusion

In this paper, we present the logarithm multiplicative Wiener index and reciprocal complementary Wiener index of fan molecular graph, wheel molecular graph, gear fan molecular graph, gear wheel molecular graph, and their r-corona molecular graphs. The results obtained in our paper illustrate the promising application prospects for chemistry and pharmacy science.

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