

# Diagrams and algebraic expressions at order 4 in MBPT

RDL, JR, PA, MD, AT, TD, JPE

August 1, 2018

Valid diagrams: 39  
 Singles: 4  
 Doubles: 12  
 Triples: 16  
 Quadruples: 7  
 Quintuples and higher excitation levels: 0

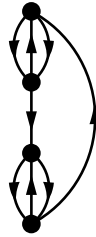
## Contents

<b>1</b>	<b>Singles</b>	<b>1</b>
<b>2</b>	<b>Doubles</b>	<b>2</b>
<b>3</b>	<b>Triples</b>	<b>5</b>
<b>4</b>	<b>Quadruples</b>	<b>9</b>

## 1 Singles

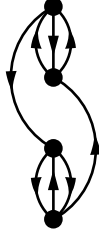
**Diagram 1:**

$$\frac{1}{4} \sum \frac{v_{abij} v_{ijak} v_{kclm} v_{lm bc}}{\epsilon_{ab}^{ij} \epsilon_b^k \epsilon_{bc}^{lm}} \quad (1)$$



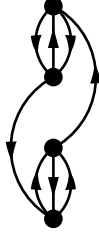
**Diagram 2:** Complex conjugate diagram: 3

$$-\frac{1}{4} \sum \frac{v_{abij} v_{ijak} v_{cd bl} v_{kl cd}}{\epsilon_{ab}^{ij} \epsilon_b^k \epsilon_{cd}^{kl}} \quad (2)$$



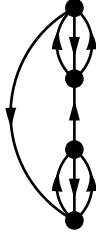
**Diagram 3:** Complex conjugate diagram: 2

$$-\frac{1}{4} \sum \frac{v_{abij} v_{icab} v_{jdkl} v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_c^j \epsilon_{cd}^{kl}} \quad (3)$$



**Diagram 4:**

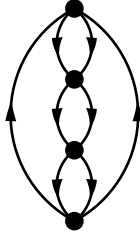
$$\frac{1}{4} \sum \frac{v_{abij} v_{icab} v_{deck} v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_c^j \epsilon_{de}^{jk}} \quad (4)$$



## 2 Doubles

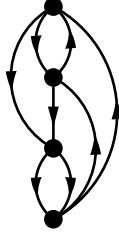
**Diagram 5:**

$$\frac{1}{16} \sum \frac{v_{abij} v_{ijkl} v_{klmn} v_{mnab}}{\epsilon_{ab}^{ij} \epsilon_{ab}^{kl} \epsilon_{ab}^{mn}} \quad (5)$$



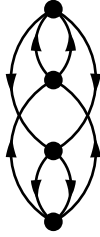
**Diagram 6:** Complex conjugate diagram: 8

$$\frac{1}{2} \sum \frac{v_{abij} v_{ijkl} v_{kcam} v_{lm bc}}{\epsilon_{ab}^{ij} \epsilon_{ab}^{kl} \epsilon_{bc}^{lm}} \quad (6)$$



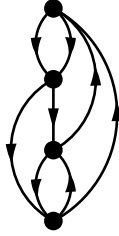
**Diagram 7:** Complex conjugate diagram: 14

$$\frac{1}{16} \sum \frac{v_{abij} v_{ijkl} v_{cdab} v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{ab}^{kl} \epsilon_{cd}^{kl}} \quad (7)$$



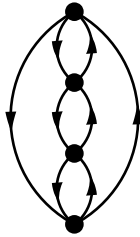
**Diagram 8:** Complex conjugate diagram: 6

$$\frac{1}{2} \sum \frac{v_{abij} v_{icak} v_{jklm} v_{lm bc}}{\epsilon_{ab}^{ij} \epsilon_{bc}^{jk} \epsilon_{bc}^{lm}} \quad (8)$$



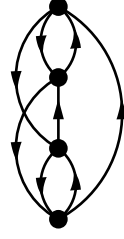
**Diagram 9:**

$$\sum \frac{v_{abik} v_{icaj} v_{jdcl} v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{cb}^{jk} \epsilon_{bd}^{kl}} \quad (9)$$



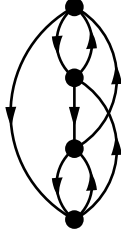
**Diagram 10:**

$$- \sum \frac{v_{abij} v_{icak} v_{jdcl} v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{cb}^{jk} \epsilon_{bd}^{kl}} \quad (10)$$



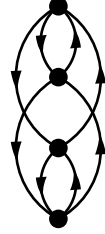
**Diagram 11:**

$$-\sum \frac{v_{abik}v_{icaj}v_{jdbl}v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{bc}^{jk} \epsilon_{cd}^{kl}} \quad (11)$$



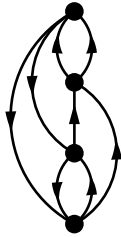
**Diagram 12:**

$$\sum \frac{v_{abij}v_{icak}v_{jdbl}v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{bc}^{jk} \epsilon_{cd}^{kl}} \quad (12)$$



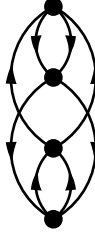
**Diagram 13:** Complex conjugate diagram: 15

$$\frac{1}{2} \sum \frac{v_{abij}v_{icak}v_{debc}v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_{bc}^{jk} \epsilon_{de}^{jk}} \quad (13)$$



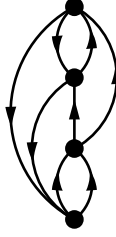
**Diagram 14:** Complex conjugate diagram: 7

$$\frac{1}{16} \sum \frac{v_{abij}v_{cdab}v_{ijkl}v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{cd}^{ij} \epsilon_{cd}^{kl}} \quad (14)$$



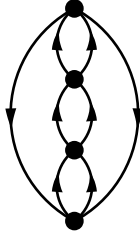
**Diagram 15:** Complex conjugate diagram: 13

$$\frac{1}{2} \sum \frac{v_{abij} v_{cdab} v_{ieck} v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_{cd}^{ij} \epsilon_{de}^{jk}} \quad (15)$$



**Diagram 16:**

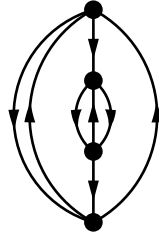
$$\frac{1}{16} \sum \frac{v_{abij} v_{cdab} v_{efcd} v_{ijef}}{\epsilon_{ab}^{ij} \epsilon_{cd}^{ij} \epsilon_{ef}^{ij}} \quad (16)$$



### 3 Triples

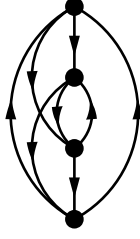
**Diagram 17:**

$$\frac{1}{4} \sum \frac{v_{abil} v_{icjk} v_{jkcm} v_{lmab}}{\epsilon_{ab}^{il} \epsilon_{cab}^{jk} \epsilon_{ab}^{lm}} \quad (17)$$



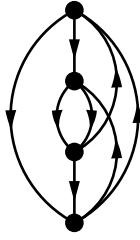
**Diagram 18:**

$$\frac{1}{2} \sum \frac{v_{abij} v_{ickl} v_{jkcm} v_{lmab}}{\epsilon_{ab}^{ij} \epsilon_{cab}^{kl} \epsilon_{ab}^{lm}} \quad (18)$$



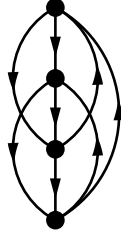
**Diagram 19:**

$$\frac{1}{2} \sum \frac{v_{abil} v_{icjk} v_{jkam} v_{lm bc}}{\epsilon_{ab}^{il} \epsilon_{abc}^{jkl} \epsilon_{bc}^{lm}} \quad (19)$$



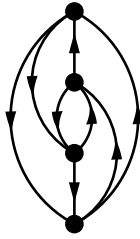
**Diagram 20:**

$$\sum \frac{v_{abij} v_{ickl} v_{jkam} v_{lm bc}}{\epsilon_{ab}^{ij} \epsilon_{abc}^{jkl} \epsilon_{bc}^{lm}} \quad (20)$$



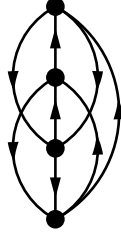
**Diagram 21:** Complex conjugate diagram: 25

$$- \sum \frac{v_{abik} v_{icjl} v_{jdac} v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{acb}^{jkl} \epsilon_{bd}^{kl}} \quad (21)$$



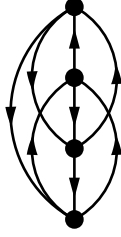
**Diagram 22:** Complex conjugate diagram: 26

$$\frac{1}{2} \sum \frac{v_{abij} v_{ickl} v_{jdac} v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{acb}^{jkl} \epsilon_{bd}^{kl}} \quad (22)$$



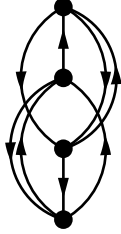
**Diagram 23:** Complex conjugate diagram: 29

$$\frac{1}{2} \sum \frac{v_{abik} v_{icjl} v_{jdab} v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{abc}^{jkl} \epsilon_{cd}^{kl}} \quad (23)$$



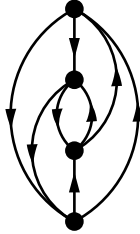
**Diagram 24:** Complex conjugate diagram: 30

$$-\frac{1}{4} \sum \frac{v_{abij} v_{ickl} v_{jdab} v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{abc}^{jkl} \epsilon_{cd}^{kl}} \quad (24)$$



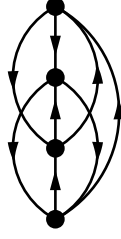
**Diagram 25:** Complex conjugate diagram: 21

$$-\sum \frac{v_{abik} v_{cdaj} v_{ijcl} v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{cbd}^{ijk} \epsilon_{bd}^{kl}} \quad (25)$$



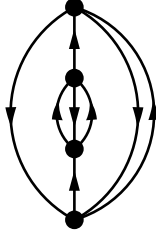
**Diagram 26:** Complex conjugate diagram: 22

$$\frac{1}{2} \sum \frac{v_{abij} v_{cdak} v_{ijcl} v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{cbd}^{ijk} \epsilon_{bd}^{kl}} \quad (26)$$



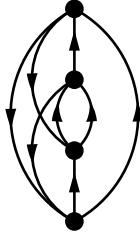
**Diagram 27:**

$$\frac{1}{4} \sum \frac{v_{abjk} v_{cdai} v_{iecd} v_{jkbe}}{\epsilon_{ab}^{jk} \epsilon_{cdb}^{ijk} \epsilon_{be}^{jk}} \quad (27)$$



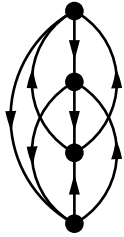
**Diagram 28:**

$$\frac{1}{2} \sum \frac{v_{abij} v_{cdak} v_{iecd} v_{jkbe}}{\epsilon_{ab}^{ij} \epsilon_{cdb}^{ijk} \epsilon_{be}^{jk}} \quad (28)$$



**Diagram 29:** Complex conjugate diagram: 23

$$\frac{1}{2} \sum \frac{v_{abik} v_{cdaj} v_{ijbl} v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{bcd}^{ijk} \epsilon_{cd}^{kl}} \quad (29)$$



**Diagram 30:** Complex conjugate diagram: 24

$$-\frac{1}{4} \sum \frac{v_{abij} v_{cdak} v_{ijbl} v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{bcd}^{ijk} \epsilon_{cd}^{kl}} \quad (30)$$



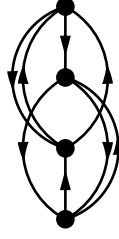


Diagram 31:

$$\frac{1}{2} \sum \frac{v_{abjk} v_{cdai} v_{iebc} v_{jkde}}{\epsilon_{ab}^{jk} \epsilon_{bcd}^{ijk} \epsilon_{de}^{jk}} \quad (31)$$

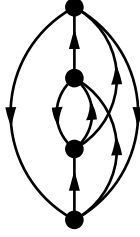
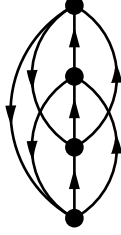


Diagram 32:

$$\sum \frac{v_{abij} v_{cdak} v_{iebc} v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_{bcd}^{ijk} \epsilon_{de}^{jk}} \quad (32)$$



## 4 Quadruples

Diagram 33:

$$-\frac{1}{4} \sum \frac{v_{abik} v_{cdjl} v_{ijcd} v_{klab}}{\epsilon_{ab}^{ik} \epsilon_{cdab}^{ijkl} \epsilon_{ab}^{kl}} \quad (33)$$

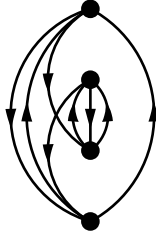


Diagram 34:

$$\frac{1}{16} \sum \frac{v_{abij} v_{cdkl} v_{ijcd} v_{klab}}{\epsilon_{ab}^{ij} \epsilon_{cdab}^{ijkl} \epsilon_{ab}^{kl}} \quad (34)$$

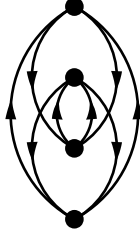


Diagram 35:

$$-\frac{1}{4} \sum \frac{v_{abkl} v_{cdij} v_{ijac} v_{klbd}}{\epsilon_{ab}^{kl} \epsilon_{acbd}^{ijkl} \epsilon_{bd}^{kl}} \quad (35)$$

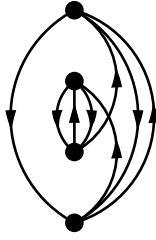


Diagram 36:

$$\sum \frac{v_{abik} v_{cdjl} v_{ijac} v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{acbd}^{ijkl} \epsilon_{bd}^{kl}} \quad (36)$$

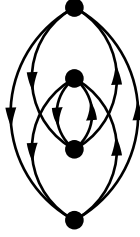


Diagram 37:

$$-\frac{1}{4} \sum \frac{v_{abij} v_{cdkl} v_{ijac} v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{acbd}^{ijkl} \epsilon_{bd}^{kl}} \quad (37)$$



Diagram 38:

$$\frac{1}{16} \sum \frac{v_{abkl} v_{cdij} v_{ijab} v_{klcd}}{\epsilon_{ab}^{kl} \epsilon_{abcd}^{ijkl} \epsilon_{cd}^{kl}} \quad (38)$$

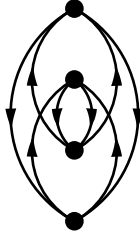


Diagram 39:

$$-\frac{1}{4} \sum \frac{v_{abik} v_{cdjl} v_{ijab} v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{abcd}^{ijkl} \epsilon_{cd}^{kl}} \quad (39)$$

