

# Diagrams and algebraic expressions at order 4 in MBPT

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

May 16, 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>
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<b>4</b>	<b>Quadruples</b>	<b>12</b>

## 1 Singles

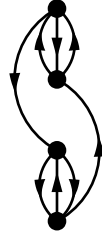
**Diagram 1:**

$$\frac{1}{4}(-1)^{5-3} \sum \frac{v_{abij} v_{ijak} v_{kclm} v_{lm bc}}{\epsilon_{ab}^{ij} \epsilon_b^k \epsilon_{bc}^{lm}} \quad (1)$$



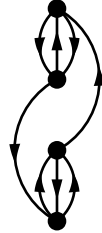
**Diagram 2:** Complex conjugate diagram: 3

$$\frac{1}{4}(-1)^{4-3} \sum \frac{v_{abij} v_{ijak} v_{cdbl} v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_b^k \epsilon_{cd}^{kl}} \quad (2)$$



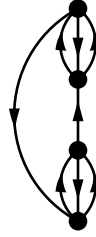
**Diagram 3:** Complex conjugate diagram: 2

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



**Diagram 4:**

$$\frac{1}{4}(-1)^{3-3} \sum \frac{v_{abij} v_{icab} v_{deck} v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_c^j \epsilon_{de}^{jk}} \quad (4)$$



## 2 Doubles

Diagram 5:

$$\frac{1}{16}(-1)^{6-2} \sum \frac{v_{abij}v_{ijkl}v_{klmn}v_{mnab}}{\epsilon_{ab}^{ij} \epsilon_{ab}^{kl} \epsilon_{ab}^{mn}} \quad (5)$$

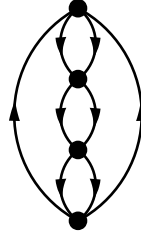
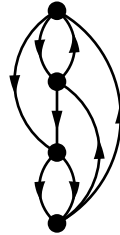


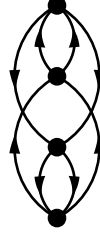
Diagram 6: Complex conjugate diagram: 8

$$\frac{1}{2}(-1)^{5-3} \sum \frac{v_{abij}v_{ijkl}v_{kcam}v_{lmbc}}{\epsilon_{ab}^{ij} \epsilon_{ab}^{kl} \epsilon_{bc}^{lm}} \quad (6)$$



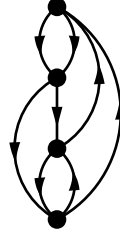
**Diagram 7:** Complex conjugate diagram: 14

$$\frac{1}{16}(-1)^{4-2} \sum \frac{v_{abij}v_{ijkl}v_{cdab}v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{ab}^{kl} \epsilon_{cd}^{kl}} \quad (7)$$



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

$$\frac{1}{2}(-1)^{5-3} \sum \frac{v_{abij}v_{icak}v_{jklm}v_{lmbc}}{\epsilon_{ab}^{ij} \epsilon_{bc}^{jk} \epsilon_{bc}^{lm}} \quad (8)$$



**Diagram 9:**

$$\frac{1}{1}(-1)^{4-4} \sum \frac{v_{abik}v_{icaj}v_{jdcl}v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{cb}^{jk} \epsilon_{bd}^{kl}} \quad (9)$$

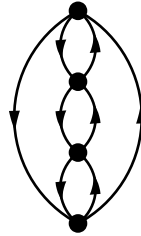


Diagram 10:

$$\frac{1}{1}(-1)^{4-3} \sum \frac{v_{abij}v_{icak}v_{jdcl}v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{cb}^{jk} \epsilon_{bd}^{kl}} \quad (10)$$

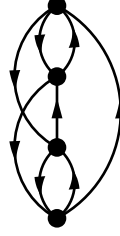


Diagram 11:

$$\frac{1}{1}(-1)^{4-3} \sum \frac{v_{abik}v_{icaj}v_{jdbl}v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{bc}^{jk} \epsilon_{cd}^{kl}} \quad (11)$$

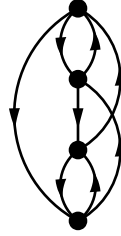
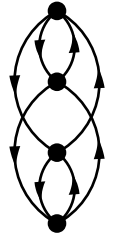


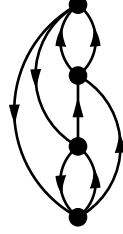
Diagram 12:

$$\frac{1}{1}(-1)^{4-4} \sum \frac{v_{abij}v_{icak}v_{jdbl}v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{bc}^{jk} \epsilon_{cd}^{kl}} \quad (12)$$



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

$$\frac{1}{2}(-1)^{3-3} \sum \frac{v_{abij}v_{icak}v_{debc}v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_{bc}^{jk} \epsilon_{de}^{jk}} \quad (13)$$



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

$$\frac{1}{16}(-1)^{4-2} \sum \frac{v_{abij}v_{cdab}v_{ijkl}v_{klcd}}{\epsilon_{ab}^{ij} \epsilon_{cd}^{ij} \epsilon_{cd}^{kl}} \quad (14)$$



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

$$\frac{1}{2}(-1)^{3-3} \sum \frac{v_{abij}v_{cdab}v_{ieck}v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_{cd}^{ij} \epsilon_{de}^{jk}} \quad (15)$$

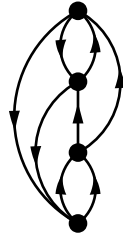
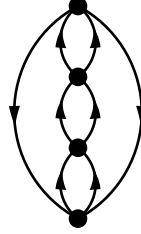


Diagram 16:

$$\frac{1}{16}(-1)^{2-2} \sum \frac{v_{abij}v_{cdab}v_{efcd}v_{ijef}}{\epsilon_{ab}^{ij} \epsilon_{cd}^{ij} \epsilon_{ef}^{ij}} \quad (16)$$



### 3 Triples

Diagram 17:

$$\frac{1}{4}(-1)^{5-1} \sum \frac{v_{abil}v_{icjk}v_{jkcm}v_{lmab}}{\epsilon_{ab}^{il} \epsilon_{cab}^{jkl} \epsilon_{ab}^{lm}} \quad (17)$$

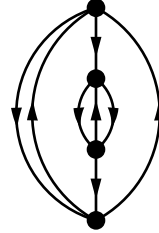
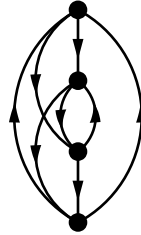


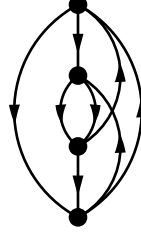
Diagram 18:

$$\frac{1}{2}(-1)^{5-1} \sum \frac{v_{abij}v_{ickl}v_{jkcm}v_{lmab}}{\epsilon_{ab}^{ij} \epsilon_{cab}^{jkl} \epsilon_{ab}^{lm}} \quad (18)$$



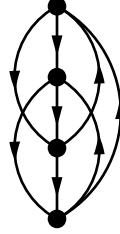
**Diagram 19:**

$$\frac{1}{2}(-1)^{5-3} \sum \frac{v_{abil}v_{icjk}v_{jkam}v_{lm bc}}{\epsilon_{ab}^{il} \epsilon_{abc}^{jkl} \epsilon_{bc}^{lm}} \quad (19)$$



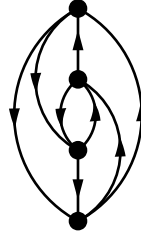
**Diagram 20:**

$$\frac{1}{1}(-1)^{5-1} \sum \frac{v_{abij}v_{ickl}v_{jkam}v_{lm bc}}{\epsilon_{ab}^{ij} \epsilon_{abc}^{jkl} \epsilon_{bc}^{lm}} \quad (20)$$



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

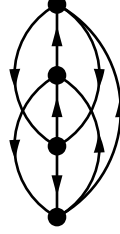
$$\frac{1}{1}(-1)^{4-3} \sum \frac{v_{abik}v_{icjl}v_{jdac}v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{acb}^{jkl} \epsilon_{bd}^{kl}} \quad (21)$$





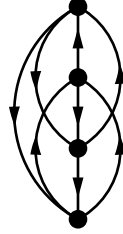
**Diagram 22:** Complex conjugate diagram: 26

$$\frac{1}{2}(-1)^{4-2} \sum \frac{v_{abij}v_{ickl}v_{jdac}v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{acb}^{kl} \epsilon_{bd}^{kl}} \quad (22)$$



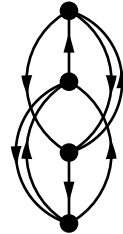
**Diagram 23:** Complex conjugate diagram: 29

$$\frac{1}{2}(-1)^{4-2} \sum \frac{v_{abik}v_{icjl}v_{jdab}v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{abc}^{jkl} \epsilon_{cd}^{kl}} \quad (23)$$



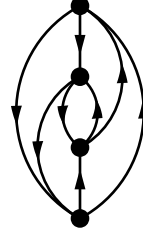
**Diagram 24:** Complex conjugate diagram: 30

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



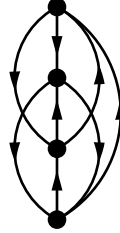
**Diagram 25:** Complex conjugate diagram: 21

$$\frac{1}{1}(-1)^{4-3} \sum \frac{v_{abik} v_{cdaj} v_{ijcl} v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{cbd}^{ijk} \epsilon_{bd}^{kl}} \quad (25)$$



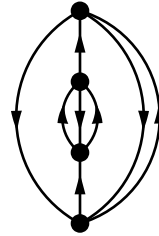
**Diagram 26:** Complex conjugate diagram: 22

$$\frac{1}{2}(-1)^{4-2} \sum \frac{v_{abij} v_{cdak} v_{ijcl} v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{cbd}^{ijk} \epsilon_{bd}^{kl}} \quad (26)$$



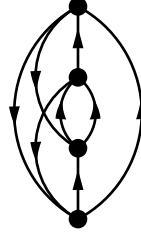
**Diagram 27:**

$$\frac{1}{4}(-1)^{3-1} \sum \frac{v_{abjk} v_{cdai} v_{iecd} v_{jkbe}}{\epsilon_{ab}^{jk} \epsilon_{cdb}^{ijk} \epsilon_{be}^{jk}} \quad (27)$$



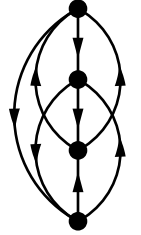
**Diagram 28:**

$$\frac{1}{2}(-1)^{3-3} \sum \frac{v_{abij}v_{cdak}v_{iecd}v_{jkbe}}{\epsilon_{ab}^{ij} \epsilon_{cdb}^{jk} \epsilon_{be}^{jk}} \quad (28)$$



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

$$\frac{1}{2}(-1)^{4-2} \sum \frac{v_{abik}v_{cdaj}v_{ijbl}v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{bcd}^{jk} \epsilon_{cd}^{kl}} \quad (29)$$



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

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

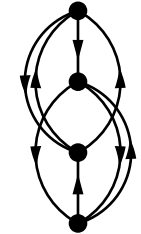


Diagram 31:

$$\frac{1}{2}(-1)^{3-1} \sum \frac{v_{abjk}v_{cdai}v_{iebc}v_{jkde}}{\epsilon_{ab}^{jk} \epsilon_{bcd}^{jk} \epsilon_{de}^{jk}} \quad (31)$$

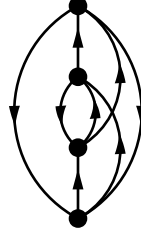
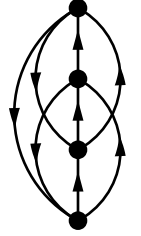


Diagram 32:

$$\frac{1}{1}(-1)^{3-1} \sum \frac{v_{abij}v_{cdak}v_{iebc}v_{jkde}}{\epsilon_{ab}^{ij} \epsilon_{bcd}^{jk} \epsilon_{de}^{jk}} \quad (32)$$



## 4 Quadruples

Diagram 33:

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

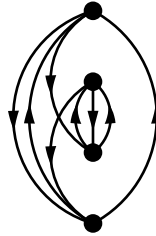


Diagram 34:

$$\frac{1}{16}(-1)^{4-2} \sum \frac{v_{abij}v_{cdkl}v_{ijcd}v_{klab}}{\epsilon_{ab}^{ij} \epsilon_{cdab}^{ijkl} \epsilon_{ab}^{kl}} \quad (34)$$

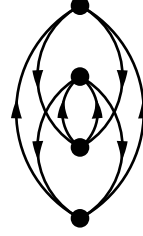


Diagram 35:

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

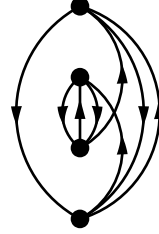


Diagram 36:

$$\frac{1}{1}(-1)^{4-4} \sum \frac{v_{abik}v_{cdjl}v_{ijac}v_{klbd}}{\epsilon_{ab}^{ik} \epsilon_{acbd}^{ijkl} \epsilon_{bd}^{kl}} \quad (36)$$

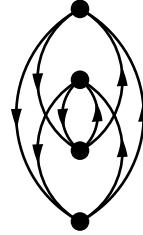


Diagram 37:

$$\frac{1}{4}(-1)^{4-3} \sum \frac{v_{abij}v_{cdkl}v_{ijac}v_{klbd}}{\epsilon_{ab}^{ij} \epsilon_{acbd}^{ijkl} \epsilon_{bd}^{kl}} \quad (37)$$



Diagram 38:

$$\frac{1}{16}(-1)^{4-2} \sum \frac{v_{abkl}v_{cdij}v_{ijab}v_{klcd}}{\epsilon_{ab}^{kl} \epsilon_{abcd}^{ijkl} \epsilon_{cd}^{kl}} \quad (38)$$

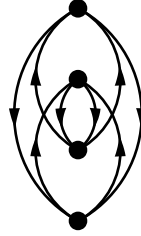


Diagram 39:

$$\frac{1}{4}(-1)^{4-3} \sum \frac{v_{abik}v_{cdjl}v_{ijab}v_{klcd}}{\epsilon_{ab}^{ik} \epsilon_{abcd}^{ijkl} \epsilon_{cd}^{kl}} \quad (39)$$

