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The terms contributing to the cluster diagrams arising from the form of  $V_N$  as shown in the figure below are,



Figure 1: Particle-hole, particle-hole form of  $V_N$

$$\begin{aligned} \langle \Phi_{ab}^{rs} | V_N T_2^{(0)} T_1^{(1)} + V_N T_2^{(0)} T_2^{(1)} + V_N T_1^{(0)} T_2^{(1)} + V_N T_2^{(0)} T_1^{(0)} T_1^{(1)} + \frac{1}{2} V_N T_1^{(0)} T_1^{(0)} T_2^{(1)} + \\ \frac{1}{2} V_N T_1^{(0)} T_1^{(0)} T_1^{(1)} + \frac{1}{6} V_N T_1^{(0)} T_1^{(0)} T_1^{(0)} T_1^{(1)} | \Phi_0 \rangle \end{aligned} \quad (1)$$

In the list of figures, figures from Page No. 4 to Page No. 22 refer to the cluster diagrams arising from the  $V_N$  given in Fig. 1. The notation used to denote the form of  $V_N$  is as follows:

- The Coulomb matrix element is written in order of the vertices, first vertex-1, then vertex-2. For each of the vertices, first the annihilated particle/hole index is mentioned, then the created particle/hole index is mentioned. For example the above diagram is denoted as (particle-hole, particle-hole) form of  $V_N$ .

1.

$$= \frac{\delta(k_2, k_3) \delta(k_1, k_3)}{[k_3] [k_3]} (-1)^{J_r + J_s + J_c + J_d}$$

2.

$$= \frac{\delta(k_2, k_3)}{[k_3]} (-1)^{J_b + J_r + J_q + J_c + 2J_b}$$

$$\left\{ \begin{matrix} k_1 & J_r & J_b \\ k_3 & J_q & J_c \end{matrix} \right\}$$

3.

$$= \frac{\delta(k_2, k_1)}{[k_1]} (-1)^{J_q + J_b + J_c + J_r + 2J_b}$$

$$\left\{ \begin{matrix} k_1 & J_p & J_a \\ k_3 & J_r & J_c \end{matrix} \right\}$$

4.

$$= \frac{\delta(J_a, J_c)}{[J_a]} (-1)^{J_q + J_b + J_a + J_r + 2J_r}$$

Figure 2: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(1)}$

5.

$$= \frac{\delta(J_p, J_r)}{[J_p]} (-1)^{J_b + J_q + J_p + J_c + 2J_q} \left\{ \begin{matrix} k_1 & J_q & J_b \\ k_3 & J_p & J_c \end{matrix} \right\}$$

6.

$$= (-1)^{J_b + J_q + J_c + J_r} \left\{ \begin{matrix} k_2 & J_p & J_a \\ k_3 & J_q & J_c \end{matrix} \right\} \left\{ \begin{matrix} k_2 & J_q & J_c \\ k_1 & J_r & J_b \end{matrix} \right\}$$

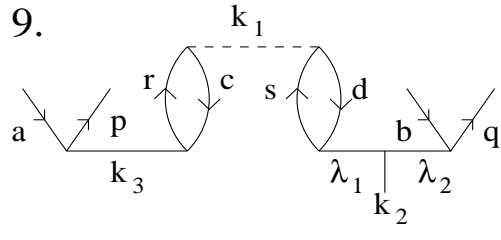
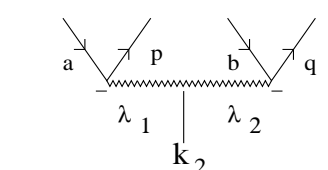
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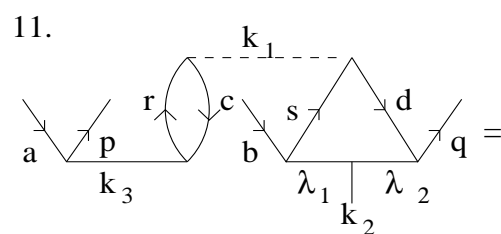
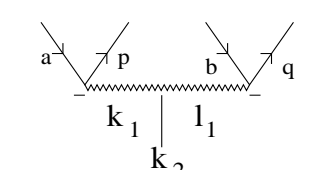
$$= \frac{\delta(k_1, k_3)}{[k_1]} \frac{\delta(J_b, J_a)}{[J_b]} (-1)^{J_a + J_q + J_r + J_c}$$

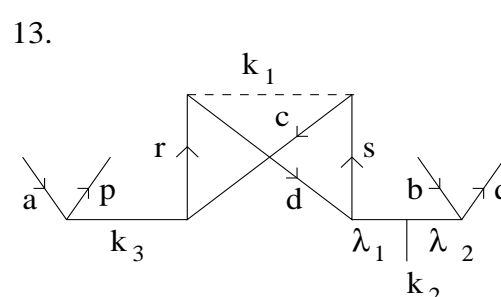
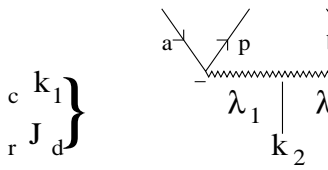
8.

$$= \frac{\delta(k_1, k_3)}{[k_1]} \frac{\delta(J_p, J_q)}{[J_q]} (-1)^{J_r + J_c + J_q + J_b}$$

Figure 3: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(1)}$

9.  =  $\frac{\delta(\lambda_1, k_3)}{[k_3]} (-1)^{J_r + J_c + J_s + J_d}$  

11.  =  $\frac{\sum [l_1] \delta(k_1, k_3)}{[k_1]} (-1)^{J_r + J_c + J_d + J_q}$   $\left\{ \begin{matrix} J_s & J_b & \lambda_1 \\ k_1 & l_1 & k_2 \\ J_d & J_q & \lambda_2 \end{matrix} \right\}$  

13.  =  $\frac{\delta(\lambda_1, k_3)}{[k_3]} (-1)^{3J_c + J_r + J_d + J_s}$   $\left\{ \begin{matrix} J_s & J_c & k_1 \\ \lambda_1 & J_r & J_d \end{matrix} \right\}$  

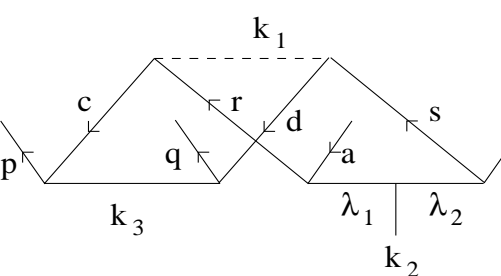
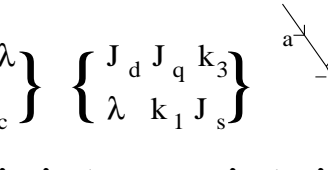
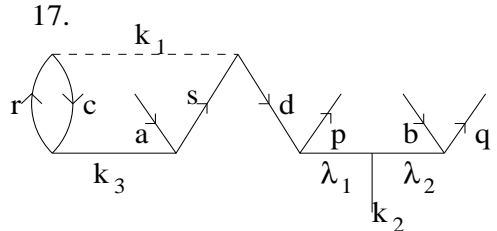
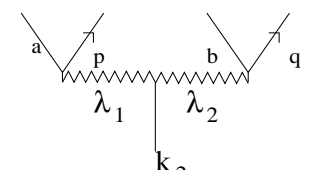
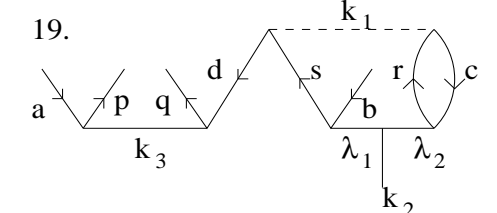
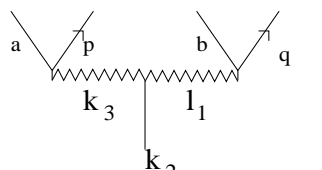
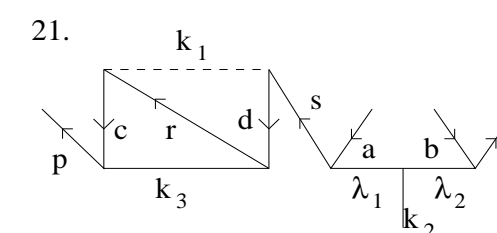
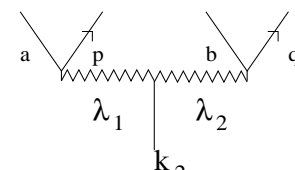
15.  =  $\frac{\sum [l_1 l_2 \lambda]}{\lambda} (-1)^{J_r + J_a + J_b + J_s + 2J_d}$   $\left\{ \begin{matrix} k_1 & k_3 & \lambda \\ J_p & J_r & J_c \end{matrix} \right\} \left\{ \begin{matrix} J_d & J_q & k_3 \\ \lambda & k_1 & J_s \end{matrix} \right\}$    
 $\left\{ \begin{matrix} l_1 & l_2 & k_2 \\ \lambda_2 & \lambda_1 & \lambda \end{matrix} \right\} \left\{ \begin{matrix} \lambda & \lambda_2 & l_2 \\ J_b & J_q & J_s \end{matrix} \right\} \left\{ \begin{matrix} \lambda & l_1 & \lambda_1 \\ J_a & J_r & J_p \end{matrix} \right\}$

Figure 4: Diagrams contributing to  $V_N T_2^{(0)} T_2^{(1)}$

17.  = 
$$\frac{\delta(J_d, J_a)}{[J_d]} \frac{\delta(k_3, k_1)}{[k_3]} (-1)^{J_r + J_c + J_s + J_a}$$
 

19.  = 
$$\sum_{l_1} [l_1] (-1)^{J_d + J_q + J_r + J_c + k_2 + \lambda_1 + k_3} \left\{ \begin{matrix} J_d & k_2 & J_b \\ \lambda_1 & J_s & k_1 \end{matrix} \right\}$$
 

21.  = 
$$\frac{\delta(J_p, J_s)}{[J_s]} (-1)^{J_c + J_p + J_r + J_d} \left\{ \begin{matrix} J_c & k_3 & J_p \\ J_d & J_r & k_1 \end{matrix} \right\}$$
 

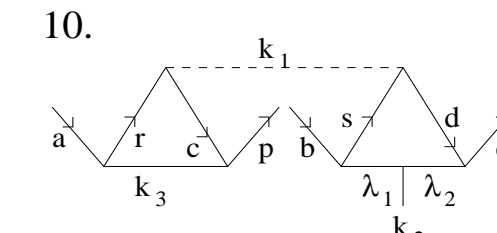
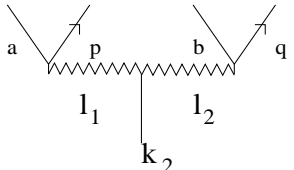
10.  = 
$$\sum_{l_1 l_2} [l_1 l_2] \frac{\delta(k_1, l_1)}{[k_1]} (-1)^{J_r + J_c + J_s + J_b + 2J_d + \lambda_2 + l_2}$$
 
$$\left\{ \begin{matrix} J_s & \lambda_1 & J_b \\ k_1 & k_2 & l_2 \\ J_d & \lambda_2 & J_q \end{matrix} \right\} \left\{ \begin{matrix} k_1 & J_p & J_a \\ k_3 & J_r & J_c \end{matrix} \right\}$$
 

Figure 5: Diagrams contributing to  $V_N T_2^{(0)} T_2^{(1)}$



12.

$$= \sum_{l_1} [l_1] (-1)^{J_r + J_c + J_s + J_d + k_1 + l_1 + 2J_p} \delta(k_1, l_1) \frac{\delta(l_1, \lambda_1)}{[l_1][k_1]} \begin{Bmatrix} k_1 & J_p & J_a \\ k_3 & J_r & J_c \end{Bmatrix}$$

14.

$$= \sum_{l_1, l_2, l'_1, l'_2} [l_1, l_2, l'_1, l'_2] (-1)^{J_r + J_q + J_d + J_a + l_1 + l_2 + l'_1 + l_1 + k_3} \begin{Bmatrix} k_1 & \lambda_1 & l'_1 \\ J_p & J_r & J_c \end{Bmatrix} \begin{Bmatrix} k_1 & l'_2 & \lambda_2 \\ J_q & J_d & J_s \end{Bmatrix} \begin{Bmatrix} l'_1 & l_1 & k_3 \\ J_a & J_r & J_p \end{Bmatrix}$$

$$\begin{Bmatrix} l'_2 & l_2 & k_3 \\ l_1 & l'_1 & k_2 \end{Bmatrix} \begin{Bmatrix} l'_2 & k_3 & l_2 \\ J_b & J_q & J_s \end{Bmatrix} \begin{Bmatrix} l'_1 & l'_2 & k_2 \\ \lambda_2 & \lambda_1 & k_1 \end{Bmatrix}$$

16.

$$= \sum_{l_1, l_2, \lambda} [l_1, l_2, \lambda] (-1)^{J_c + J_b + J_p + J_s + k_1 + l_1 + \lambda_2 + k_2 + \lambda + l_2 + k_3 + \lambda_1} \begin{Bmatrix} k_1 & k_3 & \lambda \\ J_a & J_c & J_r \end{Bmatrix} \begin{Bmatrix} k_1 & \lambda & k_3 \\ J_q & J_d & J_s \end{Bmatrix} \begin{Bmatrix} \lambda & l_1 & \lambda_1 \\ J_p & J_c & J_a \end{Bmatrix}$$

$$\begin{Bmatrix} l_2 & k_2 & l_1 \\ \lambda_1 & \lambda & \lambda_2 \end{Bmatrix} \begin{Bmatrix} \lambda & \lambda_2 & l_1 \\ J_b & J_q & J_s \end{Bmatrix}$$

Figure 6: Diagrams contributing to  $V_N T_2^{(0)} T_2^{(1)}$

18.

$$\begin{aligned}
 &= \frac{\delta(k_1, k_3)}{[k_1]} \frac{\delta(J_p, J_s)}{[J_s]} \\
 &(-1)^{J_r + J_c + J_d + J_p}
 \end{aligned}$$

20.

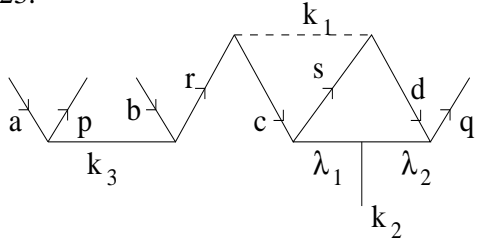
$$\begin{aligned}
 &= \frac{\delta(k_1, \lambda_2)}{[k_1]} \sum_{l_1} [l_1] (-1)^{J_s + J_d + J_r + J_b} \\
 &\quad + k_1 + k_2 + l_1 \\
 &\begin{Bmatrix} J_b & J_q & l_1 \\ k_2 & k_3 & J_r \end{Bmatrix} \begin{Bmatrix} J_c & \lambda_1 & J_q \\ k_2 & J_r & k_1 \end{Bmatrix}
 \end{aligned}$$

22.

$$\begin{aligned}
 &= (-1)^{J_r + J_c + J_a + J_s} \begin{Bmatrix} J_s & J_a & k_1 \\ J_r & J_c & k_3 \end{Bmatrix} \\
 &\begin{Bmatrix} J_s & J_a & k_1 \\ J_r & J_c & k_3 \end{Bmatrix}
 \end{aligned}$$

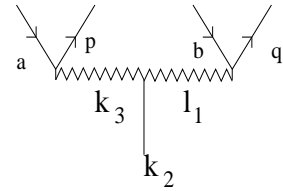
Figure 7: Diagrams contributing to  $V_N T_2^{(0)} T_2^{(1)}$

23.

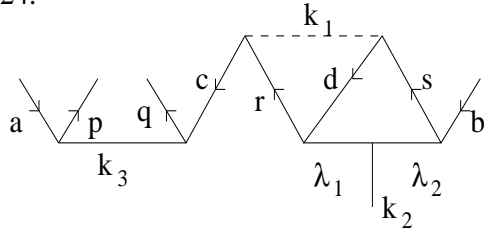


$$= \sum_{l_1} [l_1] (-1)^{J_c + J_r + J_s + J_r + \lambda_2 + l_1 + J_r + J_b}$$

$$\left\{ \begin{matrix} k_2 & l_1 & k_3 \\ J_b & J_r & J_q \end{matrix} \right\} \left\{ \begin{matrix} J_r & J_d & \lambda_1 \\ J_s & J_c & k_1 \end{matrix} \right\} \left\{ \begin{matrix} J_r & J_q & k_2 \\ \lambda_2 & \lambda_1 & J_d \end{matrix} \right\}$$



24.



$$= \sum_{l_1} [l_1] (-1)^{J_r + J_d + J_c + J_q + 2J_b + \lambda_1 + k_3}$$

$$\left\{ \begin{matrix} J_c & J_s & \lambda_1 \\ J_d & J_r & k_1 \end{matrix} \right\} \left\{ \begin{matrix} k_1 & l_1 & k_3 \\ J_q & J_c & J_b \end{matrix} \right\} \left\{ \begin{matrix} \lambda_1 & \lambda_2 & k_2 \\ J_b & J_c & J_s \end{matrix} \right\}$$

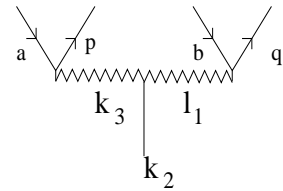


Figure 8: Diagrams contributing to  $V_N T_2^{(0)} T_2^{(1)}$

25.

$$\begin{aligned}
 &= \sum_{l_1} [l_1] \frac{\delta(\lambda_1, l_1)}{[l_1]} (-1)^{J_c + J_s + J_r + J_d} \\
 &\quad \left\{ \begin{matrix} J_d & J_r & \lambda_1 \\ J_c & J_s & k_1 \end{matrix} \right\} \left\{ \begin{matrix} J_r & J_d & \lambda_1 \\ J_p & J_a & k_3 \end{matrix} \right\}
 \end{aligned}$$

26.

$$\begin{aligned}
 &= \sum_{l_1} [l_1] (-1)^{J_r + J_d + J_b + J_q + \lambda_2 + k_2 + J_q + l_1} \\
 &\quad \left\{ \begin{matrix} J_c & J_q & \lambda_1 \\ k_3 & l_1 & k_2 \\ J_s & J_b & \lambda_2 \end{matrix} \right\}
 \end{aligned}$$

Figure 9: Diagrams contributing to  $V_N T_2^{(0)} T_2^{(1)}$

27.

$$= \delta(k_1, 0) \delta(k_1, \lambda_1) \delta(k_2, \lambda_2) [k_2]^{-1/2} (-1)^{J_r + J_c + J_q + J_b} \delta(J_r, J_c)$$

28.

$$= \delta(k_1, 0) \delta(J_q, J_b) (-1)^{J_r + J_c + J_a + J_p} [J_b]^{-1/2} \left\{ \begin{matrix} J_a & J_p & k_2 \\ \lambda_2 & \lambda_1 & J_q \end{matrix} \right\} \delta(J_r, J_c)$$

29.

$$= \delta(J_q, J_b) \frac{\delta(J_c, J_r)}{[J_c]} (-1)^{J_q + J_c + k_1} [J_c]^{1/2} \delta(\lambda_1, 0) \delta(k_2, \lambda_2) [\lambda_2]^{-1/2} [J_b]^{-1/2}$$

30.

$$= \delta(J_r, J_b) (-1)^{2J_p + J_q + J_b + J_a + J_p} \delta(J_q, J_c) (-1)^{k_1 + \lambda_1 + \lambda_2} \frac{[J_b]^{-1/2}}{[J_q]} \left\{ \begin{matrix} J_a & J_p & k_2 \\ \lambda_2 & \lambda_1 & J_q \end{matrix} \right\}$$

Figure 10: Diagrams contributing to  $V_N T_1^{(0)} T_2^{(1)}$

31.

$$\delta(J_p, J_c) [J_p]^{-1/2} (-1)^{J_p + J_b + J_r + J_a + \lambda_1 + k_2}$$

$$\left\{ \begin{matrix} J_p & J_q & \lambda_1 \\ J_b & J_r & k_1 \end{matrix} \right\} \left\{ \begin{matrix} J_p & J_a & k_2 \\ \lambda_2 & \lambda_1 & J_q \end{matrix} \right\}$$

32.

$$\delta(J_q, J_a) [J_q]^{-1/2} (-1)^{J_a + J_r + J_b + J_p + \lambda_2}$$

$$\left\{ \begin{matrix} J_a & J_c & \lambda_1 \\ J_r & J_b & k_1 \end{matrix} \right\} \left\{ \begin{matrix} J_a & J_p & k_2 \\ \lambda_2 & \lambda_1 & J_c \end{matrix} \right\}$$

33.

$$\delta(J_p, J_b) [J_b]^{-1/2} \frac{\delta(k_1, \lambda_2)}{[k_1]} (-1)^{J_a + J_p + J_r + J_c + 2J_c + \lambda_1}$$

$$\left\{ \begin{matrix} J_p & k_2 & J_a \\ \lambda_1 & J_q & k_1 \end{matrix} \right\}$$

34.

$$\delta(J_q, J_a) [J_q]^{-1/2} \frac{\delta(k_1, \lambda_2)}{[k_1]} (-1)^{J_a + J_p + J_r + J_c + 2J_b + k_1 + k_2}$$

$$\left\{ \begin{matrix} J_a & k_2 & J_p \\ \lambda_1 & J_b & k_1 \end{matrix} \right\}$$

Figure 11: Diagrams contributing to  $V_N T_1^{(0)} T_2^{(1)}$

35.

$$\begin{aligned}
 &= (-1)^{J_r + J_c + J_b + J_q + 2J_d + k_3 + l_1} \\
 &\sum_{l_1} [l_1] \frac{\delta(k_1, k_3)}{[k_1]} [J_b]^{-1/2} \delta(J_b, J_s) \\
 &\left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_q & J_b & J_d \end{matrix} \right\}
 \end{aligned}$$

36.

$$\begin{aligned}
 &= (-1)^{J_r + J_c + J_b + J_q + 2J_s + k_1 + k_2 + k_3} \\
 &\sum_{l_1} [l_1] \frac{\delta(k_1, k_3)}{[k_1]} [J_q]^{-1/2} \delta(J_q, J_d) \\
 &\left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_b & J_q & J_s \end{matrix} \right\}
 \end{aligned}$$

Figure 12: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

37.

$$\begin{aligned}
 &= \sum_{l_1} [1_1] (-1)^{J_{b^+} J_{q^+} J_{r^+} J_{c^+} k_2} \\
 &\delta(J_q, J_d) [J_q]^{-1/2} \left\{ \begin{matrix} J_q & J_s & k_3 \\ J_c & J_r & k_1 \end{matrix} \right\} \\
 &\left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_b & J_q & J_s \end{matrix} \right\} \quad \begin{array}{c} \text{Diagram with external lines } a, b, p, q \text{ and internal lines } k_3, l_1, k_2 \end{array}
 \end{aligned}$$

38.

$$\begin{aligned}
 &= \sum_{l_1} [1_1] (-1)^{J_{c^+} J_{b^+} J_{r^+} J_{q^+} l_1 + k_3} \\
 &\delta(J_s, J_b) [J_s]^{-1/2} \left\{ \begin{matrix} J_b & J_d & k_3 \\ J_r & J_c & k_1 \end{matrix} \right\} \\
 &\left\{ \begin{matrix} l_1 & k_3 & k_2 \\ J_d & J_q & J_b \end{matrix} \right\} \quad \begin{array}{c} \text{Diagram with external lines } a, b, p, q \text{ and internal lines } k_3, l_1, k_2 \end{array}
 \end{aligned}$$

Figure 13: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$



39.

$$= \sum_{l_1, l_2} [l_1 l_2] (-1)^{J_r + J_c + J_q + J_b + l_1 + l_2} \frac{\delta(k_1, l_1)}{[k_1]} \delta(J_b, J_s) [J_b]^{-1/2} \left\{ \begin{matrix} J_p & J_a & l_1 \\ J_r & J_c & k_3 \end{matrix} \right\}$$

$$\left\{ \begin{matrix} J_q & J_b & J_d \\ l_1 & k_2 & l_2 \end{matrix} \right\}$$

40.

$$= \sum_{l_1, l_2} [l_1 l_2] (-1)^{J_b + J_q + J_c + J_r + k_2} \delta(J_q, J_d) [J_q]^{-1/2} \frac{\delta(k_1, l_1)}{[k_1]} \left\{ \begin{matrix} J_p & J_a & k_1 \\ J_r & J_c & k_3 \end{matrix} \right\}$$

$$\left\{ \begin{matrix} k_1 & k_2 & l_2 \\ J_b & J_q & J_s \end{matrix} \right\}$$

Figure 14: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

41.

$$= \sum_{l_1} \left[ \begin{matrix} J_s + J_d + J_b + J_q + 2J_d + k_3 \\ l_1 \end{matrix} \right] (-1)^{J_s + J_d + J_b + J_q + 2J_d + k_3} \delta(J_r, J_b) [J_b]^{-1/2} \frac{\delta(k_1, k_2)}{[k_1]}$$

$$\left\{ \begin{matrix} k_2 & l_1 & k_3 \\ J_q & J_c & J_b \end{matrix} \right\}$$

42.

$$= \sum_{l_1} \left[ \begin{matrix} J_r + J_q + J_b + J_d + J_s + J_r \\ l_1 \end{matrix} \right] (-1)^{J_r + J_q + J_b + J_d + J_s + J_r + k_1 + l_1} \delta(J_c, J_q) [J_c]^{-1/2} \frac{\delta(k_1, k_2)}{[k_1]}$$

$$\left\{ \begin{matrix} k_1 & l_1 & k_3 \\ J_b & J_r & J_q \end{matrix} \right\}$$

Figure 15: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

43.

$$= \sum_{[l_1]} (-1)^{J_s + J_d + J_b + J_q + 2J_q + k_1 + k_2 + k_3} l_1$$

$$\frac{\delta(k_1, k_4)}{[k_1]} \delta(J_r, J_c) [J_r]^{-1/2}$$

$$\left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_b & J_q & J_r \end{matrix} \right\}$$

44.

$$= \sum_{[l_1]} (-1)^{J_s + J_d + J_r + J_b + J_r + J_q + k_1 + l_1} l_1$$

$$\frac{\delta(k_1, k_4)}{[k_1]} \delta(J_r, J_c) [J_r]^{-1/2}$$

$$\left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_q & J_b & J_r \end{matrix} \right\}$$

Figure 16: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

45.

$$\sum_{l_1} [l_1] \delta(J_s, J_b) [J_s]^{-1/2} (-1)^{J_r + J_d + J_b + J_q + k_3}$$

$$\begin{Bmatrix} J_c & J_b & k_2 \\ J_d & J_r & k_1 \end{Bmatrix} \begin{Bmatrix} k_3 & k_2 & l_1 \\ J_b & J_q & J_c \end{Bmatrix}$$

46.

$$\sum_{l_1} [l_1] \delta(J_q, J_d) [J_q]^{-1/2} (-1)^{J_c + J_s + J_q + J_b + k_2 + l_1}$$

$$\begin{Bmatrix} J_r & J_q & k_2 \\ J_s & J_c & k_1 \end{Bmatrix} \begin{Bmatrix} k_3 & k_2 & l_1 \\ J_b & J_r & J_q \end{Bmatrix}$$

Figure 17: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

47.

$$= \sum_{l_1} [1_{l_1}] [J_r]^{-1/2} (-1)^{J_r + J_c + J_b + J_q + 2J_c + k_1 + k_2 + k_3} \delta(J_r, J_d) \frac{\delta(J_s, J_c)}{[J_c]}$$

$$\left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_b & J_q & J_c \end{matrix} \right\}$$

48.

$$= \sum_{l_1} [1_{l_1}] [J_c]^{-1/2} (-1)^{J_r + J_c + J_b + J_q + 2J_r + k_1 + l_1} \delta(J_c, J_s) \frac{\delta(J_r, J_d)}{[J_r]} \left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_q & J_b & J_r \end{matrix} \right\}$$

Figure 18: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

49.

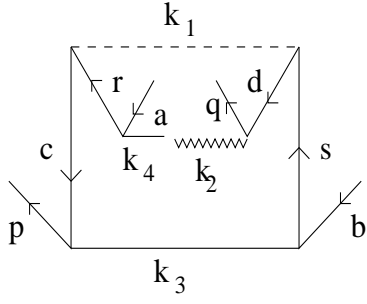
$$= \sum_{l_1, l_2} [l_1 l_2] \delta(J_c, J_p) (-1)^{J_p + J_a + J_b + J_d + J_b + J_q + l_2} [J_c]^{-1/2} \begin{Bmatrix} l_1 & l_2 & k_2 \\ J_q & J_d & J_b \end{Bmatrix} \begin{Bmatrix} k_1 & l_1 & k_3 \\ J_a & J_r & J_p \end{Bmatrix} \begin{Bmatrix} J_d & J_b & l_1 \\ k_3 & k_1 & J_s \end{Bmatrix}$$

50.

$$= \sum_{l_1, l_2} [l_1 l_2] \delta(J_c, J_p) (-1)^{J_b + J_s + 2J_a + J_p + J_a} [J_p]^{-1/2} \begin{Bmatrix} l_1 & l_2 & k_2 \\ J_b & J_s & J_q \end{Bmatrix} \begin{Bmatrix} k_1 & l_1 & k_3 \\ J_a & J_r & J_p \end{Bmatrix} \begin{Bmatrix} J_s & J_q & l_1 \\ k_3 & k_1 & J_d \end{Bmatrix} + k_1 + k_3 + k_2$$

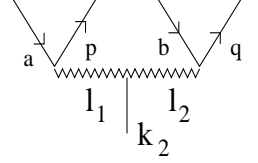
Figure 19: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

51.

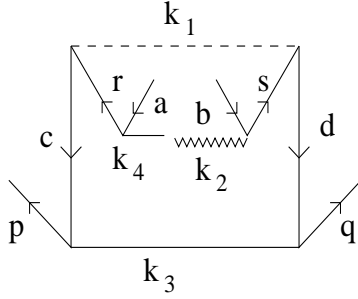


$$= \sum_{l_1, l_2} [l_1 l_2] \delta(J_r, J_a) (-1)^{J_d + J_a + J_p + J_q + k_1 + k_3 + l_1 + l_2 + 2J_d}$$

$$[J_a]^{-1/2} \left\{ \begin{matrix} k_1 & l_1 & k_3 \\ J_p & J_c & J_a \end{matrix} \right\} \left\{ \begin{matrix} J_d & J_b & l_1 \\ k_3 & k_1 & J_s \end{matrix} \right\} \left\{ \begin{matrix} l_1 & l_2 & k_2 \\ J_q & J_d & J_b \end{matrix} \right\}$$



52.



$$= \sum_{l_1, l_2} [l_1 l_2] \delta(J_r, J_a) (-1)^{J_s + J_b + J_a + J_p + 2J_b + k_2 + l_1}$$

$$[J_a]^{-1/2} \left\{ \begin{matrix} k_1 & l_1 & k_3 \\ J_p & J_c & J_a \end{matrix} \right\} \left\{ \begin{matrix} J_s & J_q & l_1 \\ k_3 & k_1 & J_d \end{matrix} \right\} \left\{ \begin{matrix} l_1 & l_2 & k_2 \\ J_b & J_s & J_q \end{matrix} \right\}$$

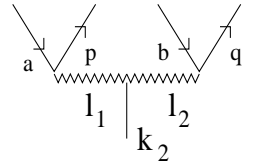
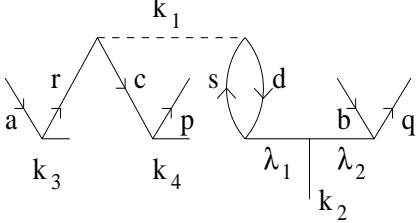
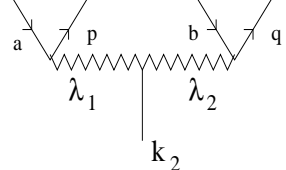
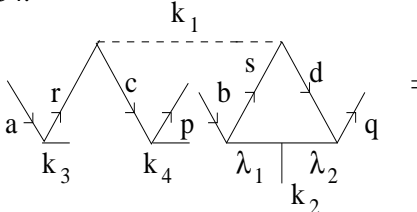
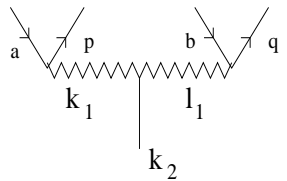
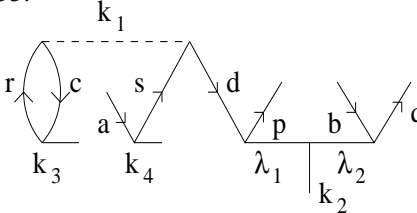
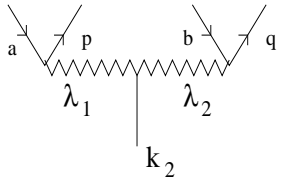


Figure 20: Diagrams contributing to  $V_N T_2^{(0)} T_1^{(0)} T_1^{(1)}$

53.  = 
$$\frac{\delta(J_r, J_a) \delta(J_p, J_c) [J_r J_p]^{-1/2} \delta(k_1, \lambda_1)}{(-1)^{J_s + J_d + 2J_d + k_1} [k_1]}$$
 

54.  = 
$$\frac{\delta(J_r, J_a) \delta(J_c, J_p) [J_r J_p]^{-1/2} J_b + J_s + 2J_q \sum [l_1]}{(-1)^{l_1 + k_1 + \lambda_2} \begin{Bmatrix} J_s & J_b & \lambda_1 \\ J_d & J_q & \lambda_2 \\ k_1 & l_1 & k_2 \end{Bmatrix}}$$
 

55.  = 
$$\frac{\delta(k_1, k_3) \delta(J_s, J_a) \delta(J_a, J_c) [J_s J_a]^{-1/2}}{(-1)^{J_r + J_d + J_a + J_c} [k_1]}$$
 

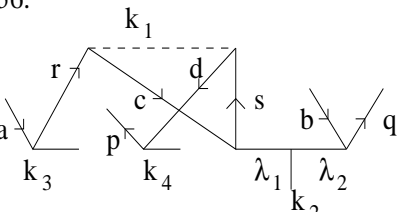
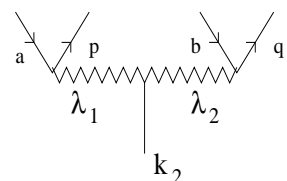
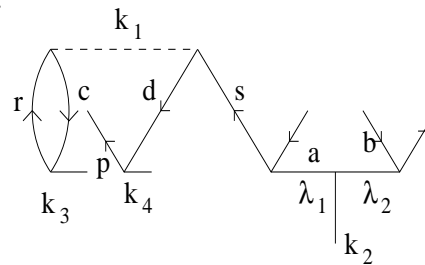
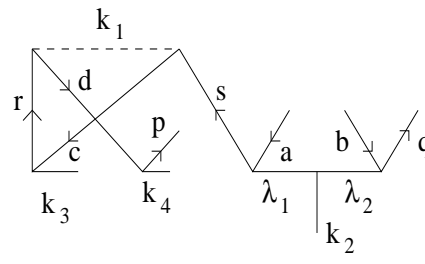
56.  = 
$$\frac{\delta(J_r, J_a) \delta(J_p, J_d) [J_r J_p]^{-1/2}}{(-1)^{J_c + J_s + \lambda_1} \begin{Bmatrix} J_a & J_p & \lambda_1 \\ J_s & J_c & k_1 \end{Bmatrix}}$$
 

Figure 21: Diagrams contributing to  $V_N T_1^{(0)} T_1^{(0)} T_2^{(1)}$

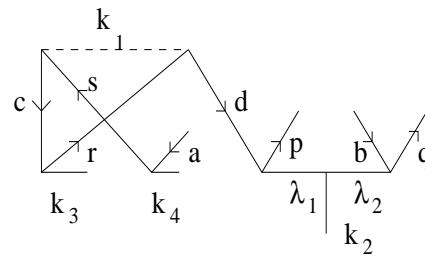


57. 

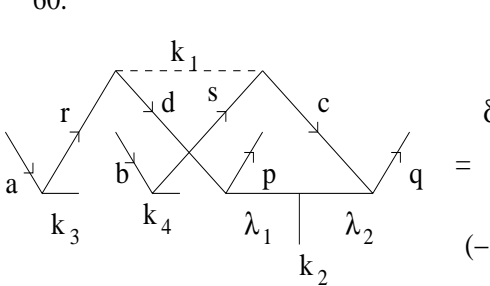
$$= \frac{\delta(k_1, 0)}{[k_1]} \delta(J_p, J_d) [J_p]^{-1/2} \delta(J_p, J_s) [J_p]^{-1/2}$$

58. 

$$= \delta(J_r, J_c) \delta(J_d, J_p) \frac{[J_r J_p]^{-1/2}}{[J_p]} \delta(J_p, J_s)$$

59. 

$$= \delta(J_s, J_a) \frac{\delta(J_a, J_d)}{[J_a]} [J_c J_s]^{-1/2} \delta(J_r, J_c)$$

60. 

$$= \delta(J_r, J_a) \delta(J_s, J_b) [J_r J_s]^{-1/2} \sum_{l_1, l_2} [l_1 l_2]$$

$$(-1)^{J_a + J_b + J_p + J_q + l_1 + k_1 + k_2 + \lambda_1}$$

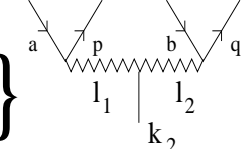
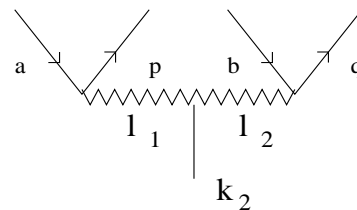
$$\left\{ \begin{matrix} k_1 & \lambda_1 & l_1 \\ J_p & J_a & J_d \end{matrix} \right\} \left\{ \begin{matrix} l_2 & k_2 & l_1 \\ \lambda_1 & k_1 & \lambda_2 \end{matrix} \right\} \left\{ \begin{matrix} k_1 & l_2 & \lambda_2 \\ J_q & J_c & J_b \end{matrix} \right\}$$


Figure 22: Diagrams contributing to  $V_N T_1^{(0)} T_1^{(0)} T_2^{(1)}$

61.

$$= \delta(J_c, J_p) \delta(J_b, J_s) [J_b J_c]^{-1/2} \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_a + J_p + J_b + J_q + k_2} \left\{ \begin{matrix} k_1 & \lambda_1 & l_1 \\ J_a & J_p & J_r \end{matrix} \right\} \left\{ \begin{matrix} l_2 & k_2 & l_1 \\ \lambda_1 & k_1 & \lambda_2 \end{matrix} \right\} \left\{ \begin{matrix} k_1 & l_2 & \lambda_2 \\ J_q & J_d & J_b \end{matrix} \right\}$$



62(a).

$$= \delta(J_d, J_p) \delta(J_c, J_q) [J_p J_q]^{-1/2} \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_q + J_b + k_1 + \lambda_1 + 2 J_p + k_2} \left\{ \begin{matrix} k_1 & \lambda_1 & l_1 \\ J_a & J_p & J_s \end{matrix} \right\} \left\{ \begin{matrix} l_2 & k_2 & l_1 \\ \lambda_1 & k_1 & \lambda_2 \end{matrix} \right\} \left\{ \begin{matrix} k_1 & l_2 & \lambda_2 \\ J_b & J_r & J_q \end{matrix} \right\}$$

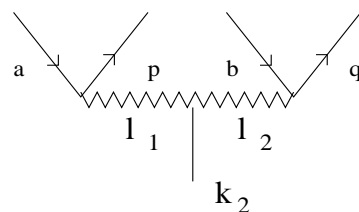


Figure 23: Diagrams contributing to  $V_N T_1^{(0)} T_1^{(0)} T_2^{(1)}$

62(b).

$$\begin{array}{c}
\begin{array}{c}
\text{Diagram 62(b): A diagram with a dashed line at the top labeled } k_1. \text{ On the left, a vertical line labeled } r \text{ has a loop labeled } c \text{ with momentum } k_3. \text{ A line labeled } a \text{ goes from the loop to a vertex labeled } q. \text{ From } q, \text{ a line labeled } b \text{ goes to another vertex labeled } p. \text{ From } p, \text{ a wavy line labeled } k_2 \text{ goes down. A line labeled } k_4 \text{ goes from } q \text{ to } p.
\end{array}
= \frac{\delta(J_a, J_b) \delta(k_1, k_3)}{[k_3]} (-1)^{J_r + J_c + k_1 + 2J_c} \delta(J_q, J_a) \delta(J_r, J_p) [J_a]^{-1/2} [J_a]^{-1/2} \begin{array}{c} \text{Diagram 62(b) result: A wavy line labeled } k_2 \text{ with a vertex labeled } a \text{ and } p.
\end{array}
\end{array}$$

63.

$$\begin{array}{c}
\begin{array}{c}
\text{Diagram 63: A diagram with a dashed line at the top labeled } k_1. \text{ On the left, a vertical line labeled } r \text{ has a loop labeled } c \text{ with momentum } k_3. \text{ A line labeled } p \text{ goes from the loop to a vertex labeled } b. \text{ From } b, \text{ a line labeled } q \text{ goes to another vertex labeled } a. \text{ From } a, \text{ a wavy line labeled } k_2 \text{ goes down. A line labeled } k_4 \text{ goes from } b \text{ to } a.
\end{array}
= \frac{\delta(k_1, k_3) \delta(J_p, J_b)}{\delta(J_q, J_p) [J_p]^{-1/2} [J_b]^{-1/2}} (-1)^{J_r + J_c + k_1 + 2J_c} \delta(J_r, J_p) \begin{array}{c} \text{Diagram 63 result: A wavy line labeled } k_2 \text{ with a vertex labeled } a \text{ and } p.
\end{array}
\end{array}$$

64.

$$\begin{array}{c}
\begin{array}{c}
\text{Diagram 64: A diagram with a dashed line at the top labeled } k_1. \text{ On the left, a vertical line labeled } q \text{ has a loop labeled } c \text{ with momentum } k_3. \text{ A line labeled } b \text{ goes from the loop to a vertex labeled } p. \text{ From } p, \text{ a line labeled } r \text{ goes to another vertex labeled } a. \text{ From } a, \text{ a wavy line labeled } k_2 \text{ goes down. A line labeled } k_4 \text{ goes from } p \text{ to } a.
\end{array}
= \frac{\delta(J_b, J_q) \delta(J_p, J_r)}{\delta(J_c, J_p) [J_c]^{-1/2} [J_q]^{-1/2}} (-1)^{J_p + J_q + k_1 + 2J_p} \begin{array}{c} \text{Diagram 64 result: A wavy line labeled } k_2 \text{ with a vertex labeled } a \text{ and } p.
\end{array}
\end{array}$$

65.

$$\begin{array}{c}
\begin{array}{c}
\text{Diagram 65: A diagram with a dashed line at the top labeled } k_1. \text{ On the left, a vertical line labeled } q \text{ has a loop labeled } b \text{ with momentum } k_3. \text{ A line labeled } r \text{ goes from the loop to a vertex labeled } c. \text{ From } c, \text{ a line labeled } p \text{ goes to another vertex labeled } a. \text{ From } a, \text{ a wavy line labeled } k_2 \text{ goes down. A line labeled } k_4 \text{ goes from } c \text{ to } a.
\end{array}
= \frac{\delta(J_q, J_a) \delta(J_b, J_r)}{\delta(J_a, J_c) [J_b J_q]^{-1/2} [J_a]} (-1)^{J_a + J_b + k_1 + 2J_c} \begin{array}{c} \text{Diagram 65 result: A wavy line labeled } k_2 \text{ with a vertex labeled } a \text{ and } p.
\end{array}
\end{array}$$

Figure 24: Diagrams contributing to  $V_N T_1^{(0)} T_1^{(0)} T_1^{(1)}$

66.

$$= \frac{\delta(J_q, J_a) \delta(J_b, J_p)}{[k_2]} \delta(k_1, k_2) (-1)^{J_s + J_c + k_2 + 2J_c}$$

$$[J_a J_b]^{-1/2}$$

67.

$$= \frac{\delta(J_q, J_a) \delta(J_p, J_d)}{[J_q J_d]^{-1/2}} (-1)^{J_b + J_r + k_2}$$

$$\left\{ \begin{matrix} J_a & J_p & k_2 \\ J_r & J_b & k_1 \end{matrix} \right\}$$

Figure 25: Diagrams contributing to  $V_N T_1^{(0)} T_1^{(0)} T_1^{(1)}$

68.

$$\begin{aligned}
 &= \sum_{l_1} [l_1] \delta(J_a, J_r) \delta(J_p, J_c) \\
 & [J_a J_b J_p]^{-1/2} \delta(J_b, J_s) \\
 & (-1)^{J_b + J_q + l_1} \left\{ \begin{matrix} k_1 & k_2 & l_1 \\ J_q & J_b & J_d \end{matrix} \right\}
 \end{aligned}$$

69.

$$\begin{aligned}
 &= \sum_{l_1} [l_1] \delta(J_r, J_a) \delta(J_c, J_p) \\
 & (-1)^{J_q + J_b + k_1 + k_2} \\
 & \delta(J_q, J_d) [J_a J_p J_q]^{-1/2} \left\{ \begin{matrix} J_b & k_2 & J_s \\ k_1 & J_q & l_1 \end{matrix} \right\}
 \end{aligned}$$

Figure 26: Diagrams contributing to  $V_N T_1^{(0)} T_1^{(0)} T_1^{(0)} T_1^{(1)}$

1.

$$= \sum_{l_1, l_2} [l_1 l_2] (-1)^{J_a + J_p + J_b + J_q + k_1 + k_2 + l_2 + \lambda_2}$$

$$\left\{ \begin{matrix} l_1 & k_1 & \lambda_1 \\ J_r & J_a & J_p \end{matrix} \right\} \left\{ \begin{matrix} l_1 & l_2 & k_2 \\ \lambda_2 & \lambda_1 & k_1 \end{matrix} \right\} \left\{ \begin{matrix} l_2 & \lambda_2 & k_1 \\ J_s & J_q & J_b \end{matrix} \right\}$$

2.

$$= \delta(J_s, J_b) [J_s]^{-1/2} \sum_{\lambda} [\lambda] (-1)^{J_a + J_p + \lambda}$$

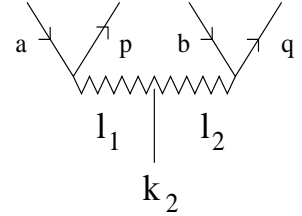
$$\left\{ \begin{matrix} \lambda & k_2 & k_1 \\ J_r & J_p & J_a \end{matrix} \right\}$$

Figure 27: Cluster amplitude diagrams arising from (particle-particle , particle-particle) form of  $V_N$

1.

$$= \sum_{l_1, l_2} [l_1 l_2] (-1)^{J_a + J_p + J_b + J_q + k_1 + k_2 + l_1 + \lambda_1}$$

$$\left\{ \begin{matrix} l_1 & k_1 & \lambda_1 \\ J_c & J_p & J_a \end{matrix} \right\} \left\{ \begin{matrix} l_1 & l_2 & k_2 \\ \lambda_2 & \lambda_1 & k_1 \end{matrix} \right\} \left\{ \begin{matrix} l_2 & \lambda_2 & k_1 \\ J_d & J_b & J_q \end{matrix} \right\}$$



2.

$$= \delta(J_c, J_p) [J_c]^{-1/2} \sum_{\lambda} [\lambda] (-1)^{J_b + J_q + \lambda}$$

$$\left\{ \begin{matrix} \lambda & k_2 & k_1 \\ J_d & J_b & J_q \end{matrix} \right\}$$

Figure 28: Cluster amplitude diagrams arising from (hole-hole , hole-hole ) form of  $V_N$

1.

$$= (-1)^{J_q + J_b + k_2} \left\{ \begin{matrix} J_p & J_a & k_2 \\ J_b & J_q & k_1 \end{matrix} \right\} \text{Diagram 1.1}$$

2.

$$= \sum_{l_1, l_2} [l_1 l_2] (-1)^{J_a + J_p + J_b + J_q + k_2} \left\{ \begin{matrix} l_1 & k_1 & \lambda_1 \\ J_r & J_a & J_p \end{matrix} \right\} \left\{ \begin{matrix} l_1 & l_2 & k_2 \\ \lambda_2 & \lambda_1 & k_1 \end{matrix} \right\} \left\{ \begin{matrix} l_2 & \lambda_2 & k_1 \\ J_c & J_b & J_q \end{matrix} \right\}$$

3.

$$= \delta(J_r, J_a) [J_r]^{-1/2} \sum_{\lambda} [\lambda] (-1)^{J_b + J_q + \lambda} \left\{ \begin{matrix} \lambda & k_2 & k_1 \\ J_c & J_b & J_q \end{matrix} \right\} \text{Diagram 3.1}$$

Figure 29: Cluster amplitude diagrams arising from (particle-particle, hole-hole) form of  $V_N$



4.

$$\begin{aligned}
 &= \delta(J_c, J_q) [J_q]^{-1/2} \sigma_{\lambda} [\lambda] (-1)^{J_a + J_p + \lambda} \\
 &\quad \left\{ \begin{matrix} \lambda & k_1 & k_2 \\ J_r & J_a & J_p \end{matrix} \right\}
 \end{aligned}$$

5.

$$\begin{aligned}
 &= \sigma_{l_1} [l_1] \frac{\delta(l_1, \lambda_1)}{[l_1]} (-1)^{J_r + J_c + l_1} \\
 &\quad \left\{ \begin{matrix} l_1 & J_c & J_r \\ k_1 & J_p & J_a \end{matrix} \right\}
 \end{aligned}$$

Figure 30: Cluster amplitude diagrams arising from (particle-particle, hole-hole) form of  $V_N$

10.

$$= \frac{\delta(k_1, k_2)}{[k_2]} (-1)^{J_q + J_b + k_1 + 2 J_b}$$

11.

$$= \frac{\delta(k_1, \lambda_1)}{[k_1]} (-1)^{J_r + J_c + k_1 + 2 J_c}$$

12.

$$= \sum_{l_1} [l_1] (-1)^{J_r + J_b + 2 J_q + \lambda_2 + k_1 + l_1} \begin{Bmatrix} J_b & \lambda_1 & J_r \\ J_q & \lambda_2 & J_c \\ l_1 & k_2 & k_1 \end{Bmatrix}$$

Figure 31: Cluster amplitude diagrams arising from the (hole-particle, particle-hole) form of  $V_N$

13.

$$= \delta(J_r, J_b) [J_b]^{-1/2} \sum_{\lambda} [\lambda] (-1)^{J_b + J_q + \lambda}$$

$$\left\{ \begin{matrix} \lambda & k_2 & k_1 \\ J_c & J_b & J_q \end{matrix} \right\}$$

14.

$$= \delta(J_c, J_q) [J_q]^{-1/2} \sum_{l_1} [l_1] (-1)^{J_q + J_b + k_1 + k_2}$$

$$\left\{ \begin{matrix} l_1 & k_2 & k_1 \\ J_r & J_q & J_b \end{matrix} \right\}$$

Figure 32: Cluster amplitude diagrams arising from the (hole-particle, particle-hole) form of  $V_N$

15.

$$\delta ( J_r, J_a ) [ J_a ]^{-1/2} \frac{ \delta ( k_1, k_2 ) }{ [ k_1 ] } (-1)^{ J_q + J_b + k_1 + 2 J_b }$$

16.

$$\frac{ \delta ( k_1, k_3 ) }{ [ k_1 ] } [ J_p ]^{-1/2} (-1)^{ J_q + J_b + k_1 + 2 J_b } \delta ( J_q, J_b )$$

17.

$$\delta ( J_q, J_b ) [ J_q ]^{-1/2} \frac{ \delta ( J_p, J_r ) }{ [ J_p ] } (-1)^{ 3 J_p + J_q + k_1 }$$

Figure 33: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

18.

$$\begin{aligned}
 & \delta ( J_r , J_a ) [ J_a ]^{-1/2} (-1)^{J_b + J_q + k_2} \\
 & \left\{ \begin{matrix} J_a & J_p & k_2 \\ J_q & J_b & k_1 \end{matrix} \right\}
 \end{aligned}$$

19.

$$\begin{aligned}
 & (-1)^{J_a + J_p + J_q + 3 J_b + \lambda_1} \\
 & \left\{ \begin{matrix} k_2 & J_a & J_p \\ J_r & \lambda_2 & \lambda_1 \end{matrix} \right\}
 \end{aligned}$$

20.

$$\begin{aligned}
 & (-1)^{J_a + J_p + J_q + J_b + \lambda_1} \\
 & \left\{ \begin{matrix} J_r & J_p & \lambda_2 \\ J_q & J_b & k_1 \end{matrix} \right\} \left\{ \begin{matrix} J_a & k_2 & J_p \\ \lambda_2 & J_r & \lambda_1 \end{matrix} \right\}
 \end{aligned}$$

Figure 34: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

21.

$$= \frac{\delta(k_1, k_2)}{[k_1]} \sum_{l_1} [l_1] (-1)^{3J_c + J_s + J_q + J_b + k_1 + l_1}$$

$$\left\{ \begin{matrix} l_1 & k_1 & k_3 \\ J_r & J_b & J_q \end{matrix} \right\}$$

22.

$$= \sum_{l_1} [l_1] (-1)^{J_b + J_q + J_s + J_c + k_2 + l_1}$$

$$\left\{ \begin{matrix} J_q & J_r & k_2 \\ J_c & J_s & k_1 \end{matrix} \right\} \left\{ \begin{matrix} k_2 & k_3 & l_1 \\ J_b & J_q & J_r \end{matrix} \right\}$$

23.

$$= \sum_{l_1} [l_1] (-1)^{J_r + J_c + J_q + J_b + k_2}$$

$$\left\{ \begin{matrix} J_q & J_s & k_3 \\ J_c & J_r & k_1 \end{matrix} \right\} \left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_b & J_q & J_s \end{matrix} \right\}$$

Figure 35: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

24.

$$\begin{aligned}
 &= \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_a + J_p + J_q + J_c + l_2 + 2J_s} \\
 &\quad \left\{ \begin{matrix} l_1 & k_1 & k_3 \\ J_r & J_a & J_p \end{matrix} \right\} \left\{ \begin{matrix} l_1 & k_2 & l_2 \\ J_q & J_b & J_c \end{matrix} \right\} \left\{ \begin{matrix} l_1 & J_c & J_b \\ J_s & k_3 & k_1 \end{matrix} \right\} \\
 &\quad \begin{array}{c} a \quad p \quad b \quad q \\ \diagdown \quad \diagup \quad \diagdown \quad \diagup \\ \text{---} \text{---} \text{---} \text{---} \\ \diagup \quad \diagdown \quad \diagup \quad \diagdown \\ l_1 \quad l_2 \\ | \\ k_2 \end{array}
 \end{aligned}$$

25.

$$\begin{aligned}
 &= \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_a + J_p + J_s + J_b + 2J_q + k_1 + k_2 + k_3} \\
 &\quad \left\{ \begin{matrix} l_1 & k_1 & k_3 \\ J_r & J_a & J_p \end{matrix} \right\} \left\{ \begin{matrix} J_s & J_q & l_1 \\ k_3 & k_1 & J_c \end{matrix} \right\} \left\{ \begin{matrix} k_2 & l_2 & l_1 \\ J_q & J_s & J_b \end{matrix} \right\} \\
 &\quad \begin{array}{c} a \quad p \quad b \quad q \\ \diagdown \quad \diagup \quad \diagdown \quad \diagup \\ \text{---} \text{---} \text{---} \text{---} \\ \diagup \quad \diagdown \quad \diagup \quad \diagdown \\ l_1 \quad l_2 \\ | \\ k_2 \end{array}
 \end{aligned}$$

Figure 36: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

26.

$$\begin{aligned}
 & \sum_{l_1} [l_1] \frac{\delta(k_3, k_1)}{[k_1]} (-1)^{J_a + J_p + J_c + J_s + 2 J_r} \\
 & \quad + l_1 + k_1 \\
 & \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_r & J_a & J_p \end{matrix} \right\} \\
 & \text{Diagram with wavy lines and angular momenta } l_1, k_3, k_2
 \end{aligned}$$

27.

$$\begin{aligned}
 & \delta(J_r, J_a) \delta(J_s, J_b) [J_r J_s]^{-1/2} \sum_{l_1} [l_1] \\
 & (-1)^{J_b + J_q + l_1} \left\{ \begin{matrix} l_1 & k_2 & k_1 \\ J_c & J_b & J_q \end{matrix} \right\} \\
 & \text{Diagram with wavy lines and angular momenta } k_1, l_1, k_2
 \end{aligned}$$

28.

$$\begin{aligned}
 & \delta(J_s, J_b) \delta(J_c, J_q) [J_q J_s]^{-1/2} \sum_{l_1} [l_1] \\
 & (-1)^{J_a + J_p + l_1} \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_r & J_a & J_p \end{matrix} \right\} \\
 & \text{Diagram with wavy lines and angular momenta } l_1, k_1, k_2
 \end{aligned}$$

Figure 37: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$



29.

$$\begin{aligned}
 & \text{Diagram 29} = \frac{\delta(k_1, \lambda_1)}{[k_1]} \delta(J_s, J_a) (-1)^{J_r + J_c + k_1 + 2J_c} [J_s]^{-1/2} \\
 & \text{Diagram 29} = \text{Diagram 29 (wavy)}
 \end{aligned}$$

30.

$$\begin{aligned}
 & \text{Diagram 30} = \delta(J_s, J_b) [J_s]^{-1/2} (-1)^{J_r + J_c + \lambda_2} \\
 & \text{Diagram 30} = \begin{Bmatrix} J_q & J_b & \lambda_2 \\ J_c & J_r & k_1 \end{Bmatrix} \text{Diagram 30 (wavy)}
 \end{aligned}$$

31.

$$\begin{aligned}
 & \text{Diagram 31} = \delta(J_c, J_q) \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_q + J_b + J_a + J_p + k_1 + l_2 + \lambda_2 + k_2} \\
 & \text{Diagram 31} = [J_q]^{-1/2} \begin{Bmatrix} k_1 & \lambda_1 & l_1 \\ J_a & J_p & J_r \end{Bmatrix} \begin{Bmatrix} l_1 & l_2 & k_2 \\ \lambda_2 & \lambda_1 & k_1 \end{Bmatrix} \\
 & \text{Diagram 31} = \begin{Bmatrix} k_1 & l_2 & \lambda_2 \\ J_b & J_s & J_q \end{Bmatrix} \text{Diagram 31 (wavy)}
 \end{aligned}$$

Figure 38: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

32.

$$= \delta(J_r, J_q) [J_r]^{-1/2} \delta(J_s, J_c) \delta(k_1, 0)$$

33.

$$= \delta(J_c, J_a) [J_a]^{-1/2} \sum_{l_1} [l_1] (-1)^{J_r + J_b + 2J_c + \lambda_2 + k_1 + l_1}$$

$$\left\{ \begin{matrix} J_b & J_r & \lambda_1 \\ J_q & J_c & \lambda_2 \\ l_1 & k_1 & k_2 \end{matrix} \right\}$$

34.

$$= \delta(J_r, J_c) [J_r]^{-1/2} \frac{\delta(J_s, J_p)}{[J_s]}$$

$$(-1)^{J_r + J_p + k_1 + 2J_s}$$

Figure 39: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

35.

$$\begin{aligned}
 &= \sum_{l_1} [l_1] \delta(J_s, J_a) [J_a]^{-1/2} \delta(J_c, J_q) [J_q]^{-1/2} \\
 &\quad (-1)^{J_b + J_q + k_1 + k_2} \left\{ \begin{matrix} k_1 & l_1 & k_2 \\ J_b & J_r & J_q \end{matrix} \right\}
 \end{aligned}$$

36.

$$\begin{aligned}
 &= \sum_{l_1} [l_1] (-1)^{J_c + J_s + k_1 + J_a + J_p + l_1} \\
 &\quad \left\{ \begin{matrix} k_1 & J_q & J_b \\ k_3 & J_s & J_c \end{matrix} \right\} \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_r & J_a & J_p \end{matrix} \right\}
 \end{aligned}$$

Figure 40: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

37.

$$= \delta ( J_b J_s ) [ J_b ]^{-1/2} \sum_{l_1 l_2} [ l_1 l_2 ] (-1)^{J_a + J_p + J_b + J_q + 2 J_q + \lambda_2 + k_2}$$

$$\left\{ \begin{matrix} k_1 & \lambda_1 & l_1 \\ J_a & J_p & J_r \end{matrix} \right\} \left\{ \begin{matrix} l_1 & l_2 & k_2 \\ \lambda_2 & \lambda_1 & k_1 \end{matrix} \right\} \left\{ \begin{matrix} k_1 & l_2 & \lambda_2 \\ J_q & J_c & J_b \end{matrix} \right\}$$

Figure 41: Cluster amplitude diagrams arising from the (particle-particle, particle-hole) form of  $V_N$

$$\begin{aligned}
 & \text{Diagram 1} = \sum_{l_1} [l_1] (-1)^{J_a + J_p + l_1} \\
 & \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_r & J_a & J_p \end{matrix} \right\} \text{Diagram 2}
 \end{aligned}$$

$$\begin{aligned}
 & \text{Diagram 3} = \sum_{l_1} [l_1] (-1)^{J_a + J_p + k_1 + k_2} \\
 & \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_c & J_p & J_a \end{matrix} \right\} \text{Diagram 4}
 \end{aligned}$$

Figure 42: Cluster amplitude diagrams arising from the (particle-particle, hole-particle) form of  $V_N$

1.

$$= \delta(J_p, J_c) [J_c]^{-1/2} \frac{\delta(k_1, k_2)}{[k_1]}$$

$$(-1)^{J_q + J_b + k_2 + 2J_q} \begin{array}{c} a \swarrow \nearrow p \\ \text{wavy line } k_2 \end{array}$$

2.

$$= \frac{\delta(k_1, k_3) \delta(J_a, J_c) [J_a]^{-1/2}}{[k_1]}$$

$$(-1)^{J_q + J_b + k_1 + 2J_b} \delta(J_q, J_b)$$

$$\begin{array}{c} a \swarrow \nearrow p \\ \text{wavy line } k_2 \end{array}$$

3.

$$= \delta(J_q, J_c) [J_q]^{-1/2} \frac{\delta(J_a, J_b)}{[J_b]}$$

$$(-1)^{3J_a + J_q + k_1} \begin{array}{c} a \swarrow \nearrow p \\ \text{wavy line } k_2 \end{array}$$

Figure 43: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

4.

$$\begin{aligned}
 &= \delta ( J_b , J_p ) [ J_p ]^{-1/2} (-1)^{J_c + J_q + k_2} \\
 &\left\{ \begin{array}{ccc} J_a & J_p & k_2 \\ J_q & J_c & k_1 \end{array} \right\}
 \end{aligned}$$

5.

$$\begin{aligned}
 &= \frac{\delta ( k_1 , \lambda_2 )}{[ k_1 ]} (-1)^{J_a + J_p + k_2 + J_q + J_b + k_1 + 2 J_b} \\
 &\left\{ \begin{array}{ccc} k_2 & J_a & J_p \\ J_c & \lambda_1 & \lambda_2 \end{array} \right\}
 \end{aligned}$$

6.

$$\begin{aligned}
 &= (-1)^{J_a + J_p + J_q + J_c + \lambda_2 + k_2} \\
 &\left\{ \begin{array}{ccc} J_b & \lambda_2 & J_a \\ J_c & k_1 & J_q \end{array} \right\} \left\{ \begin{array}{ccc} J_a & k_2 & J_p \\ \lambda_1 & J_b & \lambda_2 \end{array} \right\}
 \end{aligned}$$

Figure 44: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

7.

$$= \frac{\delta(k_1, k_2)}{[k_1]} \sum_{l_1} [l_1] (-1)^{J_r + J_c + J_q + J_b + k_1 + k_2 + k_3 + 2J_d} \left\{ \begin{matrix} l_1 & k_2 & k_3 \\ J_d & J_q & J_b \end{matrix} \right\} \left\{ \begin{matrix} k_2 & l_1 & k_3 \\ J_d & J_q & J_b \end{matrix} \right\}$$

8.

$$= \sum_{l_1} [l_1] (-1)^{J_b + J_q + J_r + J_c + k_3} \left\{ \begin{matrix} J_b & J_d & k_2 \\ J_r & J_c & k_1 \end{matrix} \right\} \left\{ \begin{matrix} k_2 & l_1 & k_3 \\ J_q & J_d & J_b \end{matrix} \right\}$$

9.

$$= \sum_{l_1} [l_1] (-1)^{J_r + J_c + J_p + J_a + k_2} \left\{ \begin{matrix} J_a & J_d & k_3 \\ J_r & J_c & k_1 \end{matrix} \right\} \left\{ \begin{matrix} k_3 & k_2 & l_1 \\ J_p & J_a & J_d \end{matrix} \right\}$$

Figure 45: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$



10.

$$\begin{aligned}
 & \sum_{l_1, l_2} [l_1, l_2] (-1)^{J_a + J_d + J_q + J_p + l_1 + k_1 + 2J_c + l_2 + k_3} \\
 & \begin{Bmatrix} l_1 & k_1 & k_3 \\ J_c & J_p & J_a \end{Bmatrix} \begin{Bmatrix} l_1 & k_2 & l_2 \\ J_q & J_b & J_d \end{Bmatrix} \\
 & \begin{Bmatrix} l_1 & J_d & J_b \\ J_r & k_3 & k_1 \end{Bmatrix} \begin{Bmatrix} k_2 & l_2 & l_1 \\ J_q & J_r & J_b \end{Bmatrix}
 \end{aligned}$$

11.

$$\begin{aligned}
 & \sum_{l_1, l_2} [l_1, l_2] (-1)^{J_a + J_p + J_r + J_b + 2J_r + k_2 + l_1} \\
 & \begin{Bmatrix} l_1 & k_1 & k_3 \\ J_c & J_p & J_a \end{Bmatrix} \begin{Bmatrix} J_r & J_q & l_1 \\ k_3 & k_1 & J_d \end{Bmatrix} \\
 & \begin{Bmatrix} k_2 & l_2 & l_1 \\ J_q & J_r & J_b \end{Bmatrix}
 \end{aligned}$$

Figure 46: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

12.

$$\sum_{l_1} [l_1] (-1)^{J_a + J_p + J_c + J_s + 2J_d + k_2} \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_d & J_p & J_a \end{matrix} \right\} \frac{\delta(k_3, k_1)}{[k_1]}$$

13.

$$\delta(J_p, J_d) \delta(J_b, J_s) \sum_{l_1} [l_1] [J_b J_d]^{-1/2} (-1)^{J_b + J_q + l_1} \left\{ \begin{matrix} l_1 & k_2 & k_1 \\ J_c & J_b & J_q \end{matrix} \right\}$$

14.

$$\delta(J_s, J_b) \delta(J_c, J_q) [J_q J_s]^{-1/2} \sum_{l_1} [l_1] (-1)^{J_a + J_p + k_1 + k_2} \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_d & J_p & J_a \end{matrix} \right\}$$

Figure 47: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

15.

$$\begin{aligned}
 & \text{Diagram 15} = \frac{\delta(k_1, \lambda_1)}{[k_1]} (-1)^{J_r + J_c + k_1 + 2J_c} \\
 & \delta(J_p, J_d) [J_d]^{-1/2} \text{Diagram 15'}
 \end{aligned}$$

16.

$$\begin{aligned}
 & \text{Diagram 16} = \delta(J_d, J_p) [J_p]^{-1/2} (-1)^{J_r + J_c + \lambda_1} \\
 & \delta(l_1, \lambda_1) \left\{ \begin{matrix} J_a & J_p & \lambda_1 \\ J_r & J_c & k_1 \end{matrix} \right\} \text{Diagram 16'}
 \end{aligned}$$

17.

$$\begin{aligned}
 & \text{Diagram 17} = \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_q + J_b + J_a + J_p + \lambda_1 + l_2 + \lambda_2 + l_1 + k_2} \\
 & \delta(J_c, J_q) [J_q]^{-1/2} \left\{ \begin{matrix} l_1 & l_2 & k_2 \\ \lambda_2 & \lambda_1 & k_1 \end{matrix} \right\} \\
 & \left\{ \begin{matrix} k_1 & l_2 & \lambda_2 \\ J_b & J_s & J_q \end{matrix} \right\} \left\{ \begin{matrix} k_1 & \lambda_1 & l_1 \\ J_p & J_a & J_d \end{matrix} \right\} \text{Diagram 17'}
 \end{aligned}$$

Figure 48: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

18.

$$= \delta(J_b, J_d) (-1)^{J_s + J_c + 2J_c} \delta(J_r, J_c) \delta(k_1, 0) [J_d]^{-1/2}$$

19.

$$= \delta(J_p, J_d) \sum_{l_1} [l_1] (-1)^{J_q + J_c + 2J_b + \lambda_1 + k_2} [J_d]^{-1/2} \left\{ \begin{matrix} k_1 & k_2 & l_1 \\ J_r & \lambda_1 & J_b \\ J_c & \lambda_2 & J_q \end{matrix} \right\}$$

20.

$$= \delta(J_r, J_c) [J_r]^{-1/2} \frac{\delta(J_b, J_d)}{[J_d]} (-1)^{J_b + J_c + k_1 + 2J_b}$$

Figure 49: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

21.

$$\begin{aligned}
 &= \sum_{l_1} [l_1] \delta(J_p, J_d) [J_p]^{-1/2} \delta(J_c, J_q) \\
 & \quad (-1)^{J_b + J_q + k_1 + k_2} \left\{ \begin{matrix} k_1 & l_1 & k_2 \\ J_b & J_r & J_q \end{matrix} \right\} [J_q]^{-1/2}
 \end{aligned}$$

22.

$$\begin{aligned}
 &= \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_c + J_s + k_2 + J_a + J_p} \\
 & \quad \frac{\delta(k_1, l_2)}{[k_1]} \left\{ \begin{matrix} l_1 & k_1 & k_2 \\ J_d & J_p & J_a \end{matrix} \right\} \left\{ \begin{matrix} k_1 & J_q & J_b \\ k_3 & J_s & J_c \end{matrix} \right\}
 \end{aligned}$$

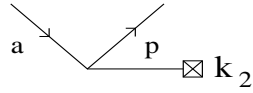
Figure 50: \*\*Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

23.

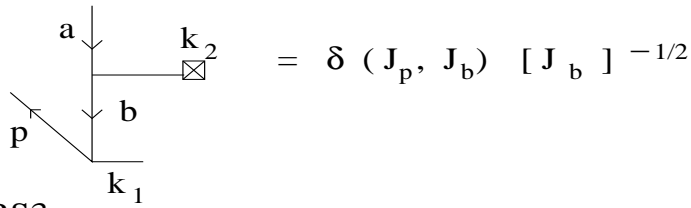
$$\begin{aligned}
 &= \sum_{l_1 l_2} [l_1 l_2] (-1)^{J_a + J_p + J_b + J_q + k_1 + \lambda_1 + k_2 + l_1} \\
 &\delta(J_b J_s) [J_b]^{-1/2} \left\{ \begin{matrix} k_1 & \lambda_1 & l_1 \\ J_p & J_a & J_d \end{matrix} \right\} \left\{ \begin{matrix} l_2 & l_1 & k_1 \\ \lambda_1 & \lambda_2 & k_2 \end{matrix} \right\} \\
 &\left\{ \begin{matrix} k_1 & l_2 & \lambda_2 \\ J_q & J_c & J_b \end{matrix} \right\}
 \end{aligned}$$

Figure 51: Cluster amplitude diagrams arising from the (hole-hole, particle-hole) form of  $V_N$

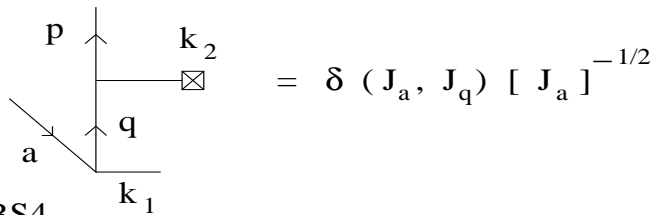
BS1.



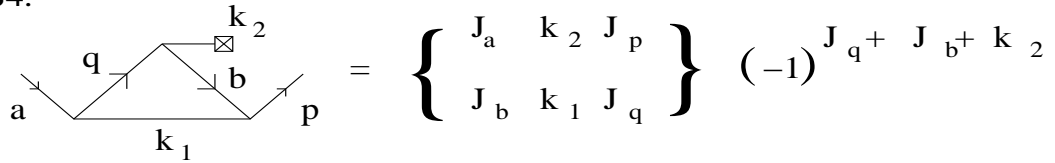
BS2.



BS3.



BS4.



BS5.

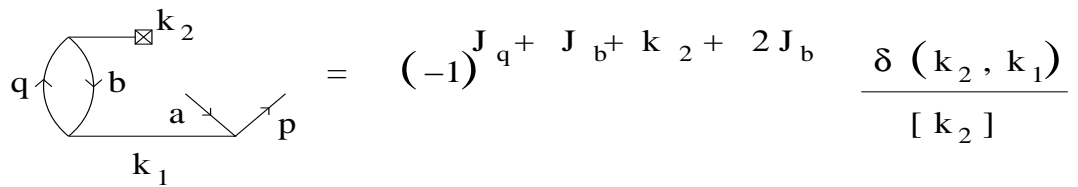


Figure 52: Diagrams contributing to the RHS of CCEDM equation - Singles

BD1.

$$= \sigma_{l_1} [1_1] (-1)^{J_a + J_p + k_1 + k_2} \left\{ \begin{matrix} l_1 & k_2 & k_1 \\ J_r & J_a & J_p \end{matrix} \right\}$$

BD2.

$$= \sigma_{l_1} [1_1] (-1)^{J_a + J_p + l_1} \left\{ \begin{matrix} l_1 & k_2 & k_1 \\ J_c & J_p & J_a \end{matrix} \right\}$$

BD3.

$$= \delta(J_a, J_p) [J_a]^{-1/2} \sigma_{l_1} [1_1] (-1)^{J_a + J_p + l_1} \left\{ \begin{matrix} l_1 & k_2 & k_1 \\ J_c & J_p & J_a \end{matrix} \right\}$$

BD4.

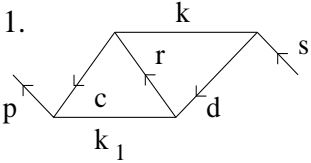
$$= \delta(J_c, J_p) [J_p]^{-1/2} \sigma_{l_1} [1_1] (-1)^{J_a + J_p + k_1 + k_2} \left\{ \begin{matrix} l_1 & k_2 & k_1 \\ J_r & J_a & J_p \end{matrix} \right\}$$

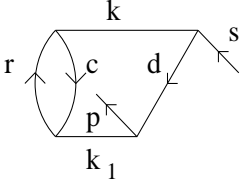
Figure 53: Diagrams contributing to RHS of CCEDM equation - Doubles

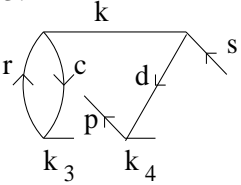


$$\begin{aligned}
& \text{Diagram 1: } \begin{array}{c} \text{p} \leftarrow \text{a} \\ \text{---} \boxtimes k_2 \\ \text{---} \oplus k_1 \end{array} = \frac{\delta(k_1, k_2)}{[k_1]} (-1)^{J_a + J_p + k_1 + 2J_a} \uparrow k_1 \\
& \text{Diagram 2: } \begin{array}{c} \text{p} \leftarrow \text{a} \quad \text{q} \leftarrow \text{b} \\ \text{---} \lambda_1 \boxtimes \lambda_2 \\ \text{---} \lambda_3 \oplus \lambda_4 \\ \text{---} k_1 \end{array} = \frac{\delta(k_2, k_1)}{[k_2]} \frac{\delta(\lambda_1, \lambda_3)}{[\lambda_1]} \frac{\delta(\lambda_2, \lambda_4)}{[\lambda_2]} (-1)^{J_a + J_p + J_b + J_q + \lambda_1 + \lambda_2} \uparrow k_2 \\
& \text{Diagram 3: } \begin{array}{c} \text{a} \leftarrow \text{q} \quad \text{b} \leftarrow \text{p} \\ \text{---} \lambda_1 \boxtimes \lambda_2 \\ \text{---} \lambda_3 \oplus \lambda_4 \\ \text{---} k_1 \end{array} = \frac{\delta(k_2, k_1)}{[k_2]} (-1)^{J_p + J_q + 2J_a + \lambda_1 + k_2 + \lambda_4} \left\{ \begin{array}{ccc} \lambda_1 & J_a & J_p \\ k_2 & \lambda_3 & \lambda_4 \\ \lambda & J_q & J_b \end{array} \right\} \uparrow k_2 \\
& \text{Diagram 4: } \begin{array}{c} \text{p} \leftarrow \text{a} \quad \text{q} \leftarrow \text{b} \\ \text{---} \lambda_1 \boxtimes \lambda_2 \\ \text{---} k_1 \oplus k_3 \end{array} = \frac{\delta(\lambda_1, k_2)}{[\lambda_1]} [\lambda_1]^{-1/2} (-1)^{\lambda_1 + \lambda_2 + k_2} \frac{\delta(k_1, \lambda_1)}{[\lambda_1]} (-1)^{J_p + J_a + k_1 + 2J_a} \uparrow k_1 \\
& \text{Diagram 5: } \begin{array}{c} \text{p} \leftarrow \text{b} \quad \text{q} \leftarrow \text{a} \\ \text{---} \lambda_1 \boxtimes \lambda_2 \\ \text{---} k_1 \oplus k_3 \end{array} = \frac{\delta(J_a, J_q)}{[J_q]} [J_q]^{-1/2} \frac{\delta(k_1, k_2)}{[k_1]} (-1)^{J_b + J_q + 2J_p + \lambda_1 + k_2} \left\{ \begin{array}{ccc} \lambda_1 & \lambda_2 & k_2 \\ J_b & J_p & J_q \end{array} \right\} \uparrow k_2
\end{aligned}$$

Figure 54: Diagrams contributing EDM at zeroth order

1.  = 
$$\frac{\delta(J_s, J_p)}{[J_s]} (-1)^{J_c + J_r + J_p + J_d} \begin{Bmatrix} k & J_r & J_c \\ k_1 & J_p & J_d \end{Bmatrix} \uparrow s$$

2.  = 
$$\frac{\delta(k, k_1)}{[k]} \frac{\delta(J_s, J_p)}{[J_s]} (-1)^{J_c + J_r + J_p + J_d + 2J_p} \uparrow s$$

3.  = 
$$\delta(k_1, 0) \delta(J_d, J_p) [J_p]^{-1/2} \delta(J_r, J_c) (-1)^{J_c + J_r} [J_p]^{-1/2} \delta(J_p, J_s) \uparrow s$$

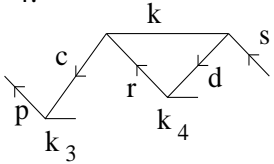
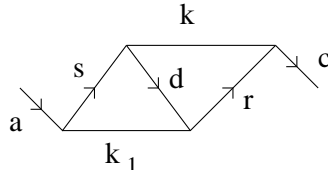
4.  = 
$$\delta(J_p, J_c) \delta(J_r, J_d) \delta(J_c, J_s) (-1)^{J_c + J_r + k_1 + 2J_r} \uparrow s [J_p]^{-1/2} [J_d]^{-1/2} [J_c]$$

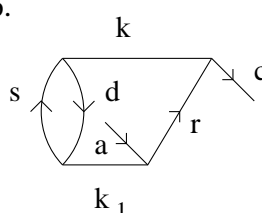
Figure 55: Angular factors for IMS diagrams arising from  $V_N T^{(0)}$  - particle-particle

5.



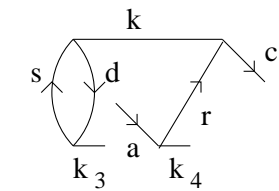
$$= \frac{\delta(J_c, J_a)}{[J_c]} (-1)^{J_c + J_r + J_s + J_d} \left\{ \begin{matrix} J_a & J_s & k_1 \\ J_d & J_r & k \end{matrix} \right\} \downarrow c$$

6.



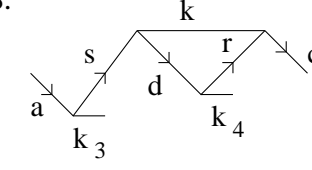
$$= \frac{\delta(k, k_1)}{[k]} \frac{\delta(J_c, J_a)}{[J_c]} (-1)^{J_s + J_d + J_r + J_c + 2J_c} \downarrow c$$

7.



$$= \delta(J_r, J_a) \delta(J_s, J_d) \delta(k, 0) [J_r]^{-1/2} (-1)^{J_s + J_d + 2J_d} [J_r]^{-1/2} \downarrow c$$

8.



$$= \frac{\delta(J_a, J_s)}{[J_c]} [J_a]^{-1/2} \delta(J_d, J_r) [J_d]^{-1/2} (-1)^{J_c + J_r + k + 2J_c} \downarrow c$$

Figure 56: Angular factors for IMS diagrams arising from  $V_N T^{(0)}$  - hole-hole

$$\begin{aligned}
& \text{Diagram 1} = (-1)^{J_d + J_r + J_s + J_p + \lambda_2} \begin{Bmatrix} J_d & \lambda_1 & J_s \\ J_c & k & J_r \end{Bmatrix} \begin{Bmatrix} \lambda_1 & \lambda_2 & k_2 \\ J_p & J_r & J_c \end{Bmatrix} \begin{array}{c} \uparrow p \\ \text{---} k_2 \\ \downarrow r \end{array} \\
& \text{Diagram 2} = \frac{\delta(k, \lambda_2)}{[k]} (-1)^{J_c + J_r + J_p + J_s + 2J_c + k + k_2} \begin{Bmatrix} k & \lambda_1 & k_2 \\ J_p & J_r & J_d \end{Bmatrix} \begin{array}{c} \uparrow p \\ \text{---} k_2 \\ \downarrow r \end{array} \\
& \text{Diagram 3} = \frac{\delta(k, k_2) \delta(J_d, J_p) [J_p]^{-1/2}}{[k_2]} (-1)^{J_s + J_c + k + 2J_c} \begin{array}{c} \uparrow p \\ \text{---} k_2 \\ \downarrow r \end{array} \\
& \text{Diagram 4} = \frac{\delta(J_r, J_c) \delta(J_s, J_d) \delta(J_c, J_s)}{(-1)^{J_d + J_r + k_1 + 2J_d} [J_r]^{-1/2} [J_d]^{-1}} \begin{array}{c} \uparrow p \\ \text{---} k_2 \\ \downarrow r \end{array} \\
& \text{Diagram 5} = \frac{\delta(J_s, J_c) \delta(k, 0) (-1)^{J_s + J_c + k + 2J_c}}{\delta(J_d, J_r) [J_r]^{-1/2}} \begin{array}{c} \uparrow p \\ \text{---} k_2 \\ \downarrow r \end{array} \\
& \text{Diagram 6} = \frac{\delta(J_p, J_c) (-1)^{J_s + J_d + k_2} [J_p]^{-1/2}}{\begin{Bmatrix} J_s & k_2 & J_d \\ J_r & k & J_p \end{Bmatrix}} \begin{array}{c} \uparrow p \\ \text{---} k_2 \\ \downarrow r \end{array}
\end{aligned}$$

Figure 57: Angular factors for EDM perturbed IMS diagrams - particle-particle

$$\begin{aligned}
& \begin{array}{c} \text{k} \\ \text{c} \nearrow \text{s} \text{---} \text{d} \text{---} \text{r} \searrow \text{a} \\ \lambda_1 \quad \lambda_2 \\ \text{k}_2 \end{array} = (-1)^{J_s + J_d + \lambda_1} \begin{array}{c} \text{a} \\ \text{---} \\ \text{c} \end{array} \text{k}_2 \\
& \quad \left\{ \begin{array}{ccc} J_s & \lambda_1 & J_d \\ J_r & k & J_c \end{array} \right\} \left\{ \begin{array}{ccc} \lambda_1 & \lambda_2 & k_2 \\ J_a & J_c & J_r \end{array} \right\} \\
& \begin{array}{c} \text{k} \\ \text{c} \nearrow \text{s} \text{---} \text{d} \text{---} \text{r} \text{---} \text{a} \\ \lambda_1 \quad \lambda_2 \\ \text{k}_2 \end{array} = \frac{\delta(k, \lambda_2)}{[k]} (-1)^{J_r + J_d + 2J_c + \lambda_1} \\
& \quad \left\{ \begin{array}{ccc} k_1 & \lambda_1 & k_2 \\ J_a & J_c & J_s \end{array} \right\} \begin{array}{c} \text{a} \\ \text{---} \\ \text{c} \end{array} \text{k}_2 \\
& \begin{array}{c} \text{k} \\ \text{r} \text{---} \text{d} \text{---} \text{s} \text{---} \text{c} \\ \text{k}_2 \quad \text{k}_3 \end{array} = \delta(J_s, J_a) \frac{\delta(k, k_2)}{[k]} [J_s]^{-1/2} \\
& \quad (-1)^{J_r + J_d + J_a + J_c + 2J_d} \begin{array}{c} \text{a} \\ \text{---} \\ \text{c} \end{array} \text{k}_2 \\
& \begin{array}{c} \text{k} \\ \text{a} \nearrow \text{r} \text{---} \text{d} \text{---} \text{s} \text{---} \text{c} \\ \text{k}_2 \quad \text{k}_3 \end{array} = \delta(J_d, J_s) [J_d]^{-1/2} \frac{\delta(J_c, J_r)}{[J_c]} \\
& \quad (-1)^{J_s + J_a + k + k_2} \begin{array}{c} \text{a} \\ \text{---} \\ \text{c} \end{array} \text{k}_2 \\
& \begin{array}{c} \text{k} \\ \text{r} \text{---} \text{d} \text{---} \text{s} \text{---} \text{c} \\ \text{k} \quad \text{k}_2 \end{array} = \delta(J_d, J_r) \delta(k, 0) (-1)^{J_r + J_d + k_2} \\
& \quad \delta(J_c, J_s) [J_c]^{-1/2} \begin{array}{c} \text{a} \\ \text{---} \\ \text{c} \end{array} \text{k}_2 \\
& \begin{array}{c} \text{k} \\ \text{a} \nearrow \text{r} \text{---} \text{d} \text{---} \text{s} \text{---} \text{c} \\ \text{k}_2 \end{array} = \delta(J_a, J_r) [J_r]^{-1/2} \left\{ \begin{array}{ccc} J_d & k_2 & J_s \\ J_c & k & J_r \end{array} \right\} \\
& \quad (-1)^{J_d + J_s + J_r + J_c} \begin{array}{c} \text{a} \\ \text{---} \\ \text{c} \end{array} \text{k}_2
\end{aligned}$$

Figure 58: Angular factors for EDM perturbed IMS diagrams - hole-hole

BD1.

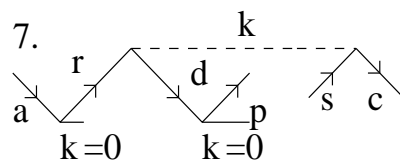
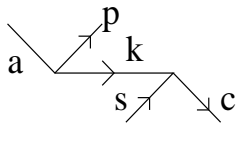
$$= \sigma_{l_1} [l_1] (-1)^{J_a + J_p + k_1 + k_2} \begin{Bmatrix} l_1 & k_2 & k_1 \\ J_r & J_a & J_p \end{Bmatrix}$$

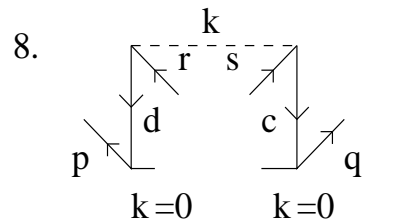
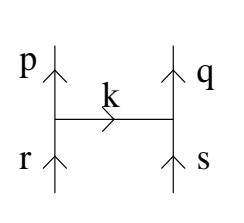
BD2.

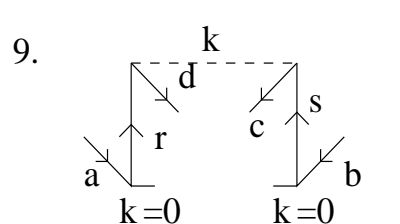
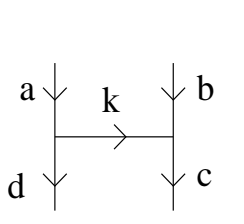
$$= \sigma_{l_1} [l_1] (-1)^{J_a + J_p + l_1} \begin{Bmatrix} l_1 & k_2 & k_1 \\ J_c & J_p & J_a \end{Bmatrix}$$

Figure 59: Angular factors for cluster diagrams arising from  $H_{EDM}$  perturbed IMS diagrams



7.  =  $\frac{\delta(J_a, J_r)}{[J_a]^{1/2}} \frac{\delta(J_d, J_p)}{[J_p]^{1/2}}$  

8.  =  $\frac{\delta(J_p, J_d)}{[J_p]^{1/2}} \frac{\delta(J_c, J_q)}{[J_c]^{1/2}}$  

9.  =  $\frac{\delta(J_a, J_r)}{[J_a]^{1/2}} \frac{\delta(J_s, J_b)}{[J_s]^{1/2}}$  

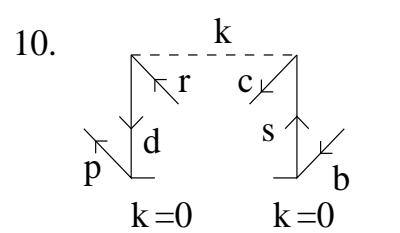
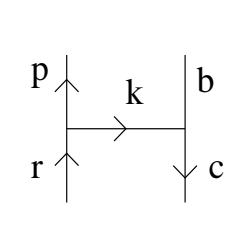
10.  =  $\frac{\delta(J_p, J_d)}{[J_p]^{1/2}} \frac{\delta(J_s, J_b)}{[J_s]^{1/2}}$  

Figure 61: Angular factors for Coulomb IMS diagrams



# 1 Transformation rule for diagrams

We obtain a general rule for transforming a given diagram into a diagram with all the arrows reversed and vertex phase altered accordingly.

The phase change in the transformation is given by,

$$phase = (-1)^{\left(\sum_{free} J_{free} + \sum_{in} 2J_{in}\right)} \quad (2)$$

where  $J_{free}$  = the free lines present in the diagram,  $J_{in}$  = incoming line. This is illustrated using an example shown in Fig.62, where  $J_1, J_5$  are the free lines and  $J_5$  is the incoming line.

For the case of a diagram representing  $T_2^{(1)}$  operator, this rule does not hold, as by convention there is no arrow on the rank  $K_2$ .

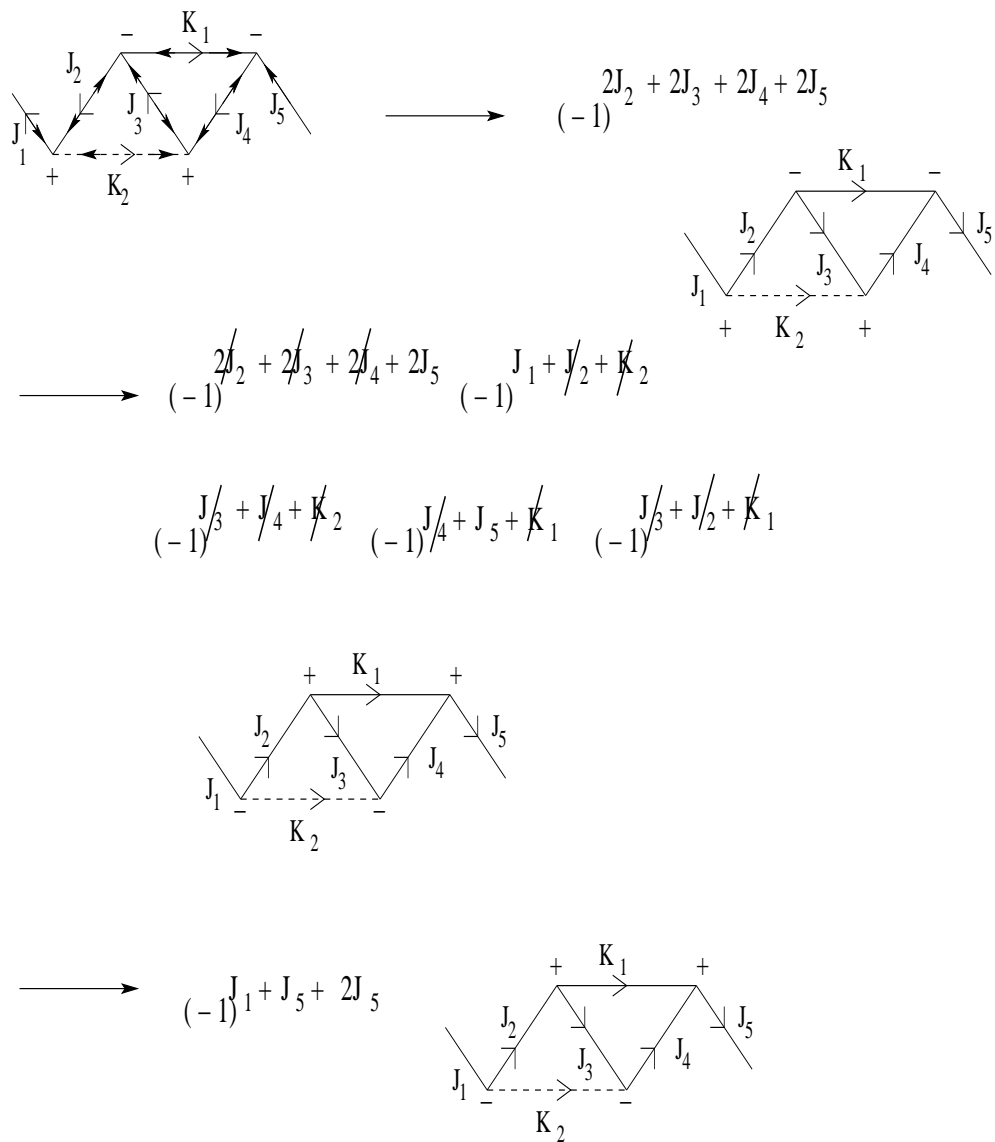


Figure 62: Figure illustrating the conversion of a given diagram to a diagram with direction of arrows reversed