

Shuttling Rules

iQuHack 2025 - Himshikha

Conditions for Allowed Transitions

Storage Zone to Gate Zone ($S[i] \rightarrow G[j, k]$)

1. Index Alignment:

If $S[i_1], S[i_2], \dots, S[i_n]$ are moved to $G[j_1, k_1], G[j_2, k_2], \dots, G[j_n, k_n]$, then:

$$i_1 < i_2 < \dots < i_n \implies j_1 < j_2 < \dots < j_n$$

2. No Path Crossings:

For every pair of atoms $S[i_a]$ and $S[i_b]$, their destinations $G[j_a, k_a]$ and $G[j_b, k_b]$ must satisfy:

$$i_a < i_b \implies j_a \leq j_b \text{ and } k_a \leq k_b$$

3. Distinct Destination Indices:

$$G[j_a, k_a] \neq G[j_b, k_b] \quad \forall a \neq b$$

Gate Zone to Storage Zone ($G[j, k] \rightarrow S[i]$)

1. Index Alignment:

If $G[j_1, k_1], G[j_2, k_2], \dots, G[j_n, k_n]$ are moved to $S[i_1], S[i_2], \dots, S[i_n]$, then:

$$j_1 < j_2 < \dots < j_n \implies i_1 < i_2 < \dots < i_n$$

2. No Path Crossings:

For every pair of atoms $G[j_a, k_a]$ and $G[j_b, k_b]$, their destinations $S[i_a]$ and $S[i_b]$ must satisfy:

$$j_a < j_b \implies i_a < i_b$$

3. Distinct Destination Indices:

$$S[i_a] \neq S[i_b] \quad \forall a \neq b$$

Within-Zone Moves ($S[i] \rightarrow S[i']$ or $G[j, k] \rightarrow G[j', k']$)

1. **No Path Crossings:** - For storage zone moves:

For every pair of atoms $S[i_a]$ and $S[i_b]$ being moved to $S[i'_a]$ and $S[i'_b]$, their destinations must satisfy:

$$i_a < i_b \implies i'_a < i'_b$$

- For gate zone moves:

For every pair of atoms $G[j_a, k_a]$ and $G[j_b, k_b]$ being moved to $G[j'_a, k'_a]$ and $G[j'_b, k'_b]$, their destinations must satisfy:

$$j_a < j_b \implies j'_a < j'_b$$

2. **Distinct Destination Indices:** - For storage zone moves:

$$S[i'_a] \neq S[i'_b] \quad \forall a \neq b$$

- For gate zone moves:

$$G[j'_a, k'_a] \neq G[j'_b, k'_b] \quad \forall a \neq b$$

Gate Specific Rules

1. CZ gate (a 2-qubit entangling gate) requires indices in the gate set to be neighbors.
2. Global 1-qubit gates affect the storage and gate qubits, while global 2-qubit gates only affect/can happen in the gate set.
3. Local 1-qubit and 2-qubit gates can only happen in the gate set.
4. We can only apply 10 local gates or 60 global gates at a time.
5. We can apply, at maximum, 5 CZ gates at once.

Notes

- **Atomic Collision Avoidance:**

No two atoms can occupy the same site at any time.

- **Preservation of Order:**

The relative order of indices must always be maintained, ensuring no reordering during transitions.