

Chemistry as Phase-Filtered Overlap Geometry in Modal Theory

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Purpose

This note derives chemical bonding as a downstream geometric consequence of the phase-locked scalar vacuum in Modal Theory (MT). No new forces, particles, or semantic assumptions are introduced. Chemistry emerges as a constraint system governed by phase coherence and gradient stiffness.

1 Modal Theory Core

The MT vacuum consists of two real scalar fields Φ_1, Φ_2 with Lagrangian

$$\mathcal{L} = \frac{1}{2}(\partial\Phi_1)^2 + \frac{1}{2}(\partial\Phi_2)^2 - g_{\text{mode}}\Phi_1\Phi_2\cos(\Delta\theta) + \lambda(\nabla\Delta\theta)^2, \quad (1)$$

where

$$\Delta\theta = \theta_1 - \theta_2, \quad \Delta\theta_{\text{vac}} = 255^\circ.$$

The final term penalizes sharp spatial variation of the phase difference. All chemistry is assumed to occur deep in the low-energy, phase-locked regime.

2 Amplitude–Phase Variables

Write the scalar fields as

$$\Phi_1 = \rho \cos \theta_1, \quad \Phi_2 = \rho \cos \theta_2, \quad \Delta\theta = \theta_1 - \theta_2,$$

where $\rho \simeq \rho_0$ is the vacuum amplitude determined by MT. The scalar potential fixes the preferred phase lock but allows smooth spatial variation at energetic cost set by λ .

3 Minimal Matter Coupling

Fermions couple minimally to the scalar background through a real, phase-sensitive Yukawa interaction

$$\mathcal{L}_{\text{int}} = -y\bar{\psi}\psi\rho\cos(\Delta\theta - \theta_\star), \quad (2)$$

with $\theta_\star = 255^\circ$. This introduces no additional complex phase; the phase dependence arises solely from the vacuum configuration.

At energies well below the scalar mass scale, fermions propagate in an effective phase background.

4 Emergent Phase Connection

The fermion Hamiltonian acquires an effective coupling to the phase gradient,

$$\mathcal{H}_{\text{eff}} \supset \frac{1}{2m} (\mathbf{p} - \hbar\alpha \nabla \Delta\theta(\mathbf{x}))^2, \quad (3)$$

corresponding to an emergent vector potential

$$\mathbf{A}_\theta = \hbar\alpha \nabla \Delta\theta.$$

The coefficient α is an EFT parameter induced by the underlying Yukawa coupling.

5 Bonding as Phase-Filtered Overlap

Consider two atomic wavefunctions ψ_A, ψ_B . The bonding overlap integral becomes

$$S_{AB} \propto \int d^3x \psi_A^*(\mathbf{x}) \psi_B(\mathbf{x}) \exp \left[i\alpha \int_{\gamma(\mathbf{x})} \nabla \Delta\theta \cdot d\mathbf{l} \right]. \quad (4)$$

For slowly varying $\Delta\theta$ across the overlap region,

$$S_{AB} \approx \int d^3x \psi_A^* \psi_B e^{i\alpha(\Delta\theta_B - \Delta\theta_A)}.$$

Bonding energy is lowered proportionally to $|S_{AB}|^2$.

6 Gradient Energy Penalty

Phase variation across the overlap region incurs a gradient cost

$$E_{\text{grad}} = \lambda \int |\nabla \Delta\theta|^2 d^3x \sim \lambda(\Delta\theta)^2 \frac{A}{L}, \quad (5)$$

where A is the overlap area and L the bond length.

A stable bond requires

$$E_b \gtrsim \lambda(\Delta\theta)^2 \frac{A}{L}. \quad (6)$$

Thus overlaps that force sharp phase variation are energetically suppressed.

7 Back-Reaction and Closure

Matter sources the phase equation of motion through

$$\mathcal{L}_{\text{int}} = -J(x)f(\Delta\theta), \quad J(x) \sim y\bar{\psi}\psi,$$

leading to

$$2\lambda\nabla^2\Delta\theta - V'(\Delta\theta) = J(x)f'(\Delta\theta). \quad (7)$$

Chemical density and bonding therefore source phase curvature, closing the dynamical loop.

8 Interpretation

Chemical bonding in MT is a geometric filtering process:

- Overlap lowers electronic energy.
- Phase gradients raise vacuum energy.
- Only overlaps compatible with smooth phase alignment persist.

Relic phase basins and chiral bias further restrict allowed geometries, providing a natural origin for molecular stability, handedness, and complexity.

Conclusion

Chemistry is not fundamental in Modal Theory. It emerges as the set of overlap configurations that survive the phase-gradient penalty imposed by the locked scalar vacuum. Atomic and molecular structure follow from geometric constraints on phase coherence, with no additional assumptions required.