Chemistry as a Derived Constraint System in Modal Theory

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Abstract

In Modal Theory (MT), chemistry is not a fundamental sector but an emergent consequence of a geometrically constrained scalar vacuum. All chemical behaviour is controlled indirectly through Standard Model parameters derived from a single phase lock at $\Delta\theta = 255^\circ$. This note traces the MT causal chain from the scalar Lagrangian to the conditions required for stable atoms and molecules, showing how the geometry forbids unstable or pathological chemistry and biases toward low-entropy, complex structures.

1 Framework

Modal Theory is a flat-space, two-real-scalar framework governed by

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

with

$$g_{\text{mode}} = 4\pi G, \qquad \Delta\theta_{\text{vac}} = 255^\circ.$$

No additional couplings or tunable parameters are introduced.

2 Role of Chemistry in MT

Chemistry consists of:

- Electromagnetic binding (atomic and molecular structure),
- Nuclear stability (existence of stable nuclei),
- Quantum mechanical orbital structure.

In MT, none of these are independent sectors. They are downstream consequences of derived Standard Model parameters.

3 Fine-Structure Constant and Atomic Binding

The fine-structure constant α governs electromagnetic interaction strength and therefore atomic size and chemical bonding.

In MT:

- The bare inverse coupling arises geometrically from Z_3 mode sums,
- One-loop renormalization is chirally suppressed by $\cos(255^\circ) \approx -0.2588$,
- The low-energy value stabilizes at $\alpha^{-1} \approx 137$.

If α were significantly larger or smaller, atomic orbitals would either collapse or fail to bind. MT fixes α in the narrow window compatible with chemistry.

4 Fermion Mass Hierarchy and Nuclear Stability

Stable chemistry requires:

- Light electrons for extended orbitals,
- Heavier nucleons for compact nuclei,
- Hierarchical quark masses to stabilize hadrons.

MT derives fermion masses from relic Gaussian overlaps produced by pre-decoherence Z_3 symmetry. No Yukawa tuning is required.

The resulting mass hierarchy naturally separates:

$$m_e \ll m_p \ll m_{\text{nuclei}},$$

a prerequisite for chemistry.

5 Gauge Structure and Chemical Forces

The electromagnetic U(1) symmetry emerges as a phase-invariance mode of the scalar system near the 255° lock. Strong and weak interactions arise from relic sideband structure.

Chemistry relies primarily on:

- QED for atomic and molecular bonding,
- QCD for nuclear cohesion.

MT constrains both through the same geometric mechanism, ensuring compatibility between nuclear and electronic scales.

6 Constraint-Driven Stability

The gradient stiffness term $\lambda(\nabla\Delta\theta)^2$ penalizes sharp phase variations, suppressing:

- Rapid decoherence of bound states,
- Runaway coupling instabilities,
- Symmetric but chemically unstable configurations.

Relic phase pockets act as buffers, filtering allowed excitations and stabilizing low-energy structures.

7 Forbidden Chemistry

Within MT, certain forms of chemistry are effectively forbidden:

- No stable atoms without hierarchical masses,
- No chemistry with unsuppressed electromagnetic running,
- No long-lived molecules in symmetric (non-chiral) vacua,
- No random chemical parameter variation.

Chemical structure is therefore tightly constrained by geometry.

8 Implications for Materials

Because chemistry is constrained geometrically:

- Materials may exhibit anisotropic response under driven coherence,
- Certain microstructures may retain phase memory,
- Directional fatigue or persistence effects may appear.

These effects are secondary manifestations of the same MT constraints explored in thrust and coherence experiments.

9 Summary

In Modal Theory:

- Chemistry is not fundamental,
- It is fixed by scalar phase geometry,
- Stability arises from chiral bias and relic filtering,
- Chemical complexity is a constrained outcome, not a coincidence.

The vacuum does not “design” chemistry. It permits only the chemistry consistent with its geometry.

Vault Status: Internal reference note. Consistent with MT v9/v10. Intended to support materials, chemistry-adjacent, and industrial discussions.