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Information-Theoretic Mechanics of Survival in Maximum-Entropy Environments

Static Minimax Disturbance Attenuation, Coordination-Deficit Costs, and the Placed Source as Categorical Right Adjoint

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Abstract

We formulate a finite coordination between endogenous supply and exogenous registry preparation in the substituted-chrysene framework. A binomial slack count identifies the uniform l-site registry with 2^{l-1} states, while a dimensionless coordination-deficit comparison distinguishes unequal-inventory lattice costs from a physical free-energy minimization. For two explicit 18-carbon graphs, perfect-matching counts and one-orbital spectra give a zero-field chrysene–tetracene gap comparison; a perturbation-norm condition supplies a sufficient bounded-field extension. Independent Gibbs contacts define the coefficients of an explicit static disturbance surrogate. Its induced L^2 gain is minimized by equal allocation of a fixed total energy-splitting budget. Finite bias leaves positive entropy and full registry support. A reverse-inclusion category of supports containing a chosen target admits a natural adjunction with the discrete category of pointed species words, with identity monad; thermodynamic work bounds require a separate cyclic isothermal implementation. A three-component indicator functional characterizes feasible sequence, boundary and scaffold configurations without asserting a unique morphology. Finally, under a specified radius law, fixed scaffold and quaternary boundary alphabet, we prove a surface-capacity inequality for every integer $L \geq 233$ and derive its asymptotic utilization. At $L = 233$, the model compares 682 interior bits with 4,754 boundary bits. The resulting capacity budget is distinct from a gravitational entropy bound. The mathematical results are accompanied by reproducible verification and explicitly scoped Lean certificates, with molecular realization expressed through experimentally testable conditions.

Keywords: Chrysene Formalism; survival in maximum entropy; $\mathcal{H}_\infty$ minimax control; coordination-deficit model; graph spectra; categorical adjunction; surface-code capacity.

1 Introduction

The Source and the Placed Source distinguish the supply of substituted-chrysene species from the preparation of a particular registry [Sch26f, Sch26d, Sch26e, Sch26b]. This paper coordinates that distinction with the geometric-slack, control and categorical program of Articles 4 and 9 [Sch26c, Sch26a]. Its central construction combines a finite registry, a static disturbance-attenuation surrogate and a support-poset adjunction. The molecular interpretation is expressed through additional realization conditions rather than identified with these mathematical objects.

Four questions organize the analysis. How does a count of registry alternatives relate to combinatorial entropy? What precise minimax problem can an energy-biased registration model solve? Which categorical structure relates a distinguished configuration to ensembles containing it? Finally, when does a stipulated boundary alphabet have enough states to encode a stipulated interior alphabet? These questions admit explicit answers without identifying state-count entropy with a complete thermodynamic potential, or a model surface capacity with a gravitational entropy law.

The geometric part compares two specified lattice costs and two specified 18-carbon graphs. The control part supplies an actual induced L^2 gain for a diagonal surrogate, separating this result from the Gibbs equilibrium law used to choose its coefficients. The category part proves a natural hom-set bijection and records the distinct physical assumptions required for a work inequality. The final part gives a feasibility result for a three-component architecture and a surface/interior capacity

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inequality with a complete all-length argument. The updated Article 94 containment convention and Article 96 thermodynamic distinctions govern the numerical examples [Sch26g, Sch26b].

Convention 1.1 (Scope and notation)**.** Set $m = l - 1$, $E_l = \{0,1\}^m$ and $d = 2^m$, with $l \geq 2$. Entropies H are in bits and S in natural units unless stated otherwise. A uniform alphabet has entropy equal to the logarithm of its cardinality; cardinality alone is only a maximum-entropy bound for a nonuniform law. The positive hopping magnitude is $\beta > 0$ and temperature is $T > 0$. Integer site span is denoted n; genome length is denoted L to keep their distinct roles explicit. Every molecular interpretation requires a calibrated common realization of the states, energies, operations and measurements.

2 Slack counts, lattice costs and additive projection

Definition 2.1 (Combinatorial and registry slack)**.** For integers $N_f \geq 1$ and $g \geq 0$, define

$$W_{N_f}(g) = \binom{N_f + g}{N_f}. \tag{1}$$

For a pointed registry (E_l, η^0) define $g_{\mathrm{reg}} = d-1$. The choice $N_f = 1$ identifies $W_1(g_{\mathrm{reg}}) = d$; it is a count-preserving encoding of alternatives, not an identification of registry states with physical voids.

Lemma 2.2 (Monotonicity and the uniform registry)**.** $W_{N_f}(0) = 1$ *and* $W_{N_f}(g+1) > W_{N_f}(g)$*. Under the uniform registry law,*

$$g_{\mathrm{reg}} = 2^{l-1} - 1, \qquad H(E_l) = l - 1. \tag{2}$$

For $l = 6$ *these values are* 31 *alternatives,* 32 *states and* 5 *bits.*

Proof. The ratio of successive binomial coefficients is $(N_f + g + 1)/(g+1) > 1$. For $N_f = 1$, $W_1(g) = g + 1$, and substitution gives d. A uniform law on d points has entropy $\log_2 d = m$. □

This is a monotonic combinatorial law. A physical second law additionally specifies the system, ensemble, dynamics and entropy exchange; it is not inferred merely from increasing a state-count parameter.

Definition 2.3 (Coordination-deficit cost)**.** Let $\phi \in (0, 1]$. In a stipulated n^3-site bulk model set $C_3(n) = 6\phi n^3$, and in a separate n^2-site sheet model set $C_2(n) = 4\phi n^2$. These are dimensionless deficit counts. A physical free energy would require a common conserved inventory, energy coefficients, entropy and environmental terms.

Proposition 2.4 (Comparison of specified costs)**.** *For integer* $n \geq 1$*,*

$$C_3(n) - C_2(n) = 2\phi n^2(3n - 2) > 0. \tag{3}$$

At $n = 3$ *and* $\phi = 1$ *the two costs are* 162 *and* 36*, with difference* 126*. This compares unequal site counts* n^3 *and* n^2*. At fixed site count* N*, the corresponding stipulated costs would instead be* $6\phi N$ *and* $4\phi N$*.*

Proof. Subtract and factor. Since $3n - 2 \geq 1$, the difference is positive. The last statement follows by summing the stipulated per-site deficits over the same N sites. □

Thus the algebraic comparison does not prove that a fixed amount of matter spontaneously collapses into a sheet. It isolates the bookkeeping premise that a chemical or mechanical model would need to justify.

Proposition 2.5 (Additive projection and complete sites)**.** *The coordinate projection*

$$\pi : (\mathbb{F}_2)^3 \longrightarrow (\mathbb{F}_2)^2, \quad (a, b, c) \longmapsto (a, b) \tag{4}$$

is a surjective additive homomorphism with kernel $\{(0,0,0),(0,0,1)\}$*. It is not a homomorphism of the fields* $\mathbb{F}_8$ *and* $\mathbb{F}_4$*. In a nearest-neighbor box* $B(n_x, n_y, n_z)$ *with all six prescribed contacts present, every interior site has deficit* $6 - 6 = 0$*.*

Proof. Coordinate addition commutes with projection; every pair has two preimages. A nonzero unital homomorphism from a field is injective, so no such homomorphism maps an eight-element field into a four-element field. The box statement counts its four lateral and two vertical incidences. Retaining the discarded bit together with the projection is lossless; the projection alone loses one bit under the uniform law. □

The labels $\mathbb{F}_8$ and $\mathbb{F}_4$ therefore describe additive alphabets here, not an established chemical dimensional-reduction mechanism. Similarly, a complete incidence pattern does not certify a mechanically stable or chemically bonded assembly.

3 The two graph spectra and a bounded perturbation result

The verification source specifies the chrysene graph by named carbon vertices and tetracene by two nine-vertex chains with rungs at positions $0, 2, 4, 6, 8$. Both are connected bipartite graphs with 18 vertices and 21 edges. Let A_c, A_t be their real symmetric adjacency matrices and use the one-orbital model $H_j = -\beta A_j$. The half-filled frontier gap is the separation of the ninth and tenth ordered energies.

Theorem 3.1 (Zero-field comparison)**.** *For these two explicit graphs the perfect-matching counts and determinants are*

$$\begin{aligned} K_c &= 8, \quad \det A_c = -64, \\ K_t &= 5, \quad \det A_t = -25. \end{aligned} \tag{5}$$

The tetracene gap is

$$g_t = \beta(\sqrt{7 - 2\sqrt{5}} - 1), \tag{6}$$

and the numerical gaps are $g_c \approx 1.0403\,\beta$ *and* $g_t \approx 0.5899\,\beta$*, with ratio* 1.7634*.*

Proof. In the listed bipartition, write $A_j = \left(\begin{smallmatrix} 0 & B_j \\ B_j^{\mathsf{T}} & 0 \end{smallmatrix}\right)$. Enumeration of the nine-by-nine matching permutations gives 8 and 5; separate exact determinant elimination gives the displayed determinants. The identity $\det A_j = (-1)^9(\det B_j)^2$ is also checked, rather than assuming that a matching count always equals $|\det B_j|$. For tetracene the exact squared-spectrum polynomial factors as $(x-1)(x^4-12x^3+46x^2-65x+25)(x^4-8x^3+18x^2-13x+1)$. Direct substitution of $x = [(\sqrt{7-2\sqrt{5}}-1)/2]^2$ gives zero. Its positive square root lies in the frontier interval certified below, which contains the smallest positive singular value. This identifies the stated radical, independently of decimal agreement. The companion also constructs the characteristic polynomial of $B_j B_j^{\mathsf{T}}$ in exact integer arithmetic and uses rational Sturm root counts to certify $1.0402 < g_c/\beta < 1.0403$ and $0.5899 < g_t/\beta < 0.5900$. These disjoint intervals establish strict ordering independently of the rounded eigensolver outputs. The companion distinguishes these exact enclosures from decimal numerical evaluations. □

Proposition 3.2 (A sufficient small-perturbation condition)**.** *Let* V_c, V_t *be Hermitian perturbations with* $\|V_j\| \le \varepsilon_j$*. The perturbed frontier gaps obey*

$$g_j - 2\varepsilon_j \le g_j' \le g_j + 2\varepsilon_j. \tag{7}$$

Consequently $g_c' > g_t'$ *whenever*

$$2(\varepsilon_c + \varepsilon_t) < g_c - g_t. \tag{8}$$

Proof. The min–max principle bounds each ordered eigenvalue displacement by the operator norm of the perturbation. Subtract the ninth from the tenth eigenvalue and apply both inequalities. □

For a specified Stark model $V_j = EX_j$ the sufficient condition uses $|E|\|X_j\|$. This local bound replaces a claim of gap ordering over an unspecified entire field range. No exact channel orthogonality follows from a gap comparison alone: that requires specified channel vectors and an invariant decomposition of the full perturbed operator. Graph gaps are not optical, transport or quasiparticle gaps without an additional electronic model [BB97].

4 Static minimax attenuation and equilibrium registration

Hypothesis 4.1 (Independent Gibbs contacts)**.** Each of m binary contacts has two logical states of equal degeneracy, with adverse-minus-target energy splitting $u_r \ge 0$, is equilibrated at temperature T after adequate relaxation, and has error probability

$$q_r(u_r) = \frac{1}{1 + e^{u_r/(k_B T)}}. \tag{9}$$

The contacts are independent when product fidelity is used. These are equilibrium energy splittings, not activation barriers or arbitrary adversarial disturbance laws.

Definition 4.2 (Diagonal disturbance surrogate)**.** For fixed control vector u, set $a_r(u) = 2q_r(u_r)$, $D(u) = \mathrm{diag}(a_1, \dots, a_m)$ and define on $L^2([0,\infty); \mathbb{R}^m)$

$$z(t) = D(u)w(t), \qquad \gamma(u) = \sup_{w \ne 0} \frac{\|z\|_{L^2}}{\|w\|_{L^2}}. \tag{10}$$

This is a memoryless linear surrogate with constant transfer matrix. Its induced gain is a genuine $\mathcal{H}_\infty$ norm under that static convention. It is not a derived dynamic plant model of a chemical synthesis cascade.

Theorem 4.3 (Budgeted minimax allocation)**.** *For $B \geq 0$ and admissible controls $u_r \geq 0$, $\sum_r u_r \leq B$,*

$$\gamma(u) = \max_r \frac{2}{1 + e^{u_r/(k_B T)}}, \qquad \min_u \gamma(u) = \frac{2}{1 + e^{B/(mk_B T)}}. \tag{11}$$

The minimizer is the equal allocation $u_r = B/m$.

Proof. Pointwise $\|D(u)w\| \leq (\max_r a_r)\|w\|$, and equality is attained by any nonzero square-integrable disturbance supported on a maximizing coordinate. The function $a(u)$ is strictly decreasing. Since $\min_r u_r \leq B/m$, $\max_r a(u_r) \geq a(B/m)$. Equal allocation attains this bound. Equality forces every coordinate to be at least B/m; the budget then forces equality in every coordinate. □

At $u = 0$ the gain is 1. Chemical purity or retained mass is a different observable, not an $\mathcal{H}_2$ norm. A dynamic $\mathcal{H}_2$ comparison would require a stable transfer model, input covariance and performance output. The static surrogate has direct feedthrough and should not be assigned a finite continuous-time $\mathcal{H}_2$ norm.

Proposition 4.4 (Finite-fidelity gate and residual entropy)**.** *For equal splitting u, put $p = 1 - q(u)$. The target word has probability $F = p^m$. To obtain $F \geq f \in (2^{-m}, 1)$ it is necessary and sufficient that*

$$u \geq k_B T \ln \frac{f^{1/m}}{1 - f^{1/m}}. \tag{12}$$

At equality $\gamma = 2(1 - f^{1/m})$. For $m = 5$, the 95% and 99% gates have gains approximately 0.0204 and 0.0040, respectively. At every finite u, all 2^m words have positive probability and

$$H_{\mathrm{reg}} = m h_2(q) > 0, \tag{13}$$

where $h_2(q) = -q \log_2 q - (1 - q) \log_2 (1 - q)$. Zero entropy occurs only in the ideal infinite-bias limit.

Proof. Solve $p^m \geq f$ using the monotonic logistic law. Independence gives the product entropy. For finite u, $0 < q \leq 1/2$, so every word probability and $h_2(q)$ are positive. □

Proposition 4.5 (Conditional information and plaquette identities)**.** *If a random registry X is uniform on E_l and a controller record U satisfies $H(X \mid U) \leq \epsilon$, then $I(X; U) \geq m - \epsilon$. For a vertex assignment $x_v \in \mathbb{F}_4$ and directed edge differences $d_{uv} = x_v - x_u$, every plaquette has $\sum_{e \in \partial p} d_e = 0$.*

Proof. The first statement is $I(X; U) = H(X) - H(X \mid U)$. The second telescopes on a cycle. In characteristic two the sign reversal is harmless, but edge orientation still specifies the coboundary construction. □

The information inequality is a necessary condition for reducing uncertainty by observation; it is not a universal lower bound on mutual information for open-loop physical reset. A fixed reset can erase X without learning it. The plaquette identity concerns exact vertex differences; it does not by itself construct an error-correcting Goppa code or establish a minimum distance.

5 A support-poset adjunction and its thermodynamic realization

Definition 5.1 (Pointed species and support ensembles)**.** Let $\mathcal{S}_l = \{D, I, T\}^l$ and fix $\eta^0 : \mathcal{S}_l \to E_l$. The discrete category $\mathbf{C}_0$ has objects $(S, \eta^0(S))$ and only identity morphisms. The category $\mathbf{C}_{\mathrm{exp}}$ has objects (S, Ω) with $\eta^0(S) \in \Omega \subseteq E_l$. A unique arrow $(S, \Omega_1) \to (S', \Omega_2)$ exists exactly when $S = S'$ and $\Omega_2 \subseteq \Omega_1$. Thus each species fibre is a reverse-inclusion poset. Define

$$F(S, \eta^0(S)) = (S, E_l), \qquad G(S, \Omega) = (S, \eta^0(S)). \tag{14}$$

There are 3^l objects in $\mathbf{C}_0$, not 2^{l-1}. At $l = 6$ this is 729 pointed species words; each registry fibre contains 32 possible registry words and 2^{31} supports containing its distinguished word.

Theorem 5.2 (Adjunction and identity monad)**.** *The maps above define functors with $F \dashv G$ and $GF = \mathrm{id}_{\mathbf{C}_0}$. Their hom-set bijection is*

$$\mathrm{Hom}_{\mathbf{C}_{\mathrm{exp}}}(FX, Y) \cong \mathrm{Hom}_{\mathbf{C}_0}(X, GY). \tag{15}$$

Both sets are singletons when species words agree and empty otherwise. The unit is identity and the counit is the support arrow $(S, E_l) \to (S, \Omega)$; both triangle identities hold.

Proof. All arrows preserve species. F takes identities to identities, while G takes every support arrow to the identity on its species. Since every allowed support is a subset of E_l, an arrow $FX \to Y$ exists exactly when the species agree, which is the condition for $X \to GY$. The unique possible map of these zero- or one-element hom-sets is bijective and natural. The unit and its image under F are identities; the counit at

$FX = (S, E_I)$ is also identity. Applying G to any counit yields identity, proving both triangles. □

The left adjoint F is fully faithful because its hom-sets agree with those of $\mathbf{C}_0$. The functor G is generally not full: distinct incomparable supports map to the same species object.

If $|\Omega| < d$, the counit is not invertible in the reverse-inclusion poset. Hence this adjunction is not generally an equivalence. The counit contracts the full support to Ω, not necessarily to the target singleton. The functor G selects a distinguished representative as a mathematical map; a device implementing reset needs a separate dynamical and thermodynamic description.

Hypothesis 5.3 (Cyclic isothermal support reset)**.** A physical implementation begins uniformly on d logically degenerate states, ends on a support of size r, has the same degenerate Hamiltonian at the endpoints, returns its controls to their initial settings, exchanges heat with a bath at T, and accounts for all work and auxiliary resources. Initial side information is absent.

Proposition 5.4 (Conditional work bound)**.** *Under this hypothesis,*

$$W_{\mathrm{on}} \geq k_B T(\ln d - S_f) \geq k_B T \ln(d/r). \tag{16}$$

For a uniform final support, the second bound is the endpoint free-energy difference. It is an ideal reversible lower bound, not a categorical cost assigned to every abstract arrow.

Proof. The isothermal work inequality bounds work below by the change in nonequilibrium free energy. Endpoint internal energy is unchanged by degeneracy, so this change is $k_B T(\ln d - S_f)$. Entropy on a support of size r is at most $\ln r$. Finite-time dissipation and control costs may raise the required work [RW14, Sch26b]. With heat Q_{bath} positive into the bath, $W_{\mathrm{on}} = \Delta U + Q_{\mathrm{bath}}$. Here $\Delta U = 0$ at degenerate endpoints; a noncyclic biased endpoint requires the internal-energy term. □

6 Tripartite feasibility and surface capacity

Definition 6.1 (Three-component constraint functional)**.** Let $\mathcal{A}_1, \mathcal{A}_2, \mathcal{A}_3$ be explicitly nonempty admissible classes of nonempty sequence, boundary and scaffold objects. Their physical properties, such as selective permeability and mechanical bracing, are imposed assumptions. Put $I_i(M) = 0$ for $M \in \mathcal{A}_i$ and $+\infty$ otherwise, including $M = \emptyset$, and define $\mathcal{S}(M_1, M_2, M_3) = \sum_i I_i(M_i)$.

Theorem 6.2 (Feasibility, not uniqueness)**.** *The minimum value is zero and the minimizer set is exactly $\mathcal{A}_1 \times \mathcal{A}_2 \times \mathcal{A}_3$. Every configuration missing a required component is inadmissible. A unique minimizer occurs only if every class is a singleton.*

Proof. Each summand is either zero or infinity. The sum is zero exactly when every component is admissible. Nonempty classes give a product witness. If any class has two members, fixing witnesses in the others gives two distinct minimizers; the converse is immediate. □

This is a constraint theorem for the chosen architecture. It has no differential variation and is not an Euler–Lagrange uniqueness theorem or a derivation of spontaneous biological unfolding. A useful refinement would specify finite energies, admissible deformations, transport, conservation laws and a measured mechanical model, then ask whether an actual minimizer exists and is stable [Hel73].

Hypothesis 6.3 (Interior and boundary alphabets)**.** Fix a 54-node scaffold with at most 16 local states per node, an L-base-pair sequence with at most four letters per position, a lumen radius

$$R(L) = c\sqrt{L} - d_b, \quad c = 0.89923, \quad d_b = 4, \tag{17}$$

in nanometres, and tile area $a = 0.50\,\mathrm{nm}^2$. Only lengths with $R(L) > 0$ are considered. Each independently addressable boundary tile is stipulated to support four states. Correlations can reduce actual entropy below these alphabet capacities.

Definition 6.4 (Capacity budget)**.** The maximum interior description length and the stipulated boundary capacity are

$$\begin{aligned} C_{\mathrm{int}}(L) &= 2L + 216, \\ N_\partial(L) &= \left\lfloor \frac{4\pi R(L)^2}{a} \right\rfloor, \\ C_\partial(L) &= 2N_\partial(L). \end{aligned} \tag{18}$$

Actual interior Shannon entropy satisfies $H_{\mathrm{int}} \leq C_{\mathrm{int}}$. An injection of the full formal interior alphabet into the formal boundary alphabet exists exactly when $C_{\mathrm{int}} \leq C_\partial$.

Proof. The product alphabet has at most $4^L 16^{54}$ states. The boundary alphabet has 4^{N_∂} states. Finite sets admit an injection

precisely when their cardinalities are ordered. No physically local encoding or reconstruction operation is furnished by this cardinality argument. □

Theorem 6.5 (A sufficient capacity inequality for all $L \geq 233$)**.** *With the stated constants and fixed scaffold,* $C_{\mathrm{int}}(L) < C_{\partial}(L)$ *for every integer* $L \geq 233$*.*

Proof. Since $\lfloor x \rfloor > x - 1$, it suffices to show

$$Q(L) := \frac{8\pi}{a}(c\sqrt{L} - d_b)^2 - 2L - 218 > 0. \tag{19}$$

For $L \geq 233$, $\sqrt{L} > 15$, $c > 0.89$, $d_b = 4$, $a = 1/2$, and $\pi > 3$. Differentiation gives

$$Q'(L) = \frac{8\pi}{a}\left(c^2 - \frac{cd_b}{\sqrt{L}}\right) - 2. \tag{20}$$

The bracket is $c(c - 4/\sqrt{L}) > 0.89(0.89 - 4/15) > 0.55$, so $Q'(L) > 48(0.55) - 2 > 0$. At $L = 233$, $R > 0.89(15) - 4 = 9.35$, hence

$$Q(233) > 48(9.35)^2 - 466 - 218 > 0. \tag{21}$$

Monotonicity proves the claim over the entire half-line, not merely over a finite sweep. □

At $L = 233$, the unrounded radius law gives $R \approx 9.72615023\,\mathrm{nm}$, $N_{\partial} = 2377$, $C_{\mathrm{int}} = 682$ and $C_{\partial} = 4754$, a utilization of approximately 14.3458%. The floor is applied before rounding the radius.

The lower endpoint 233 is the corrected illustrative containment threshold for the $3 \times 3 \times 6$ box under the geometric convention used in the Article 94 revision [Sch26g]; it is not a universal minimum genome length. The capacity inequality itself already holds at smaller admissible lengths. Both the radius and the threshold must be recalibrated if a different membrane or packing model is used.

Corollary 6.6 (Asymptotic capacity ratio)**.** *For fixed* 54*-node scaffold,*

$$\lim_{L\to\infty} \frac{C_{\mathrm{int}}(L)}{C_{\partial}(L)} = \frac{a}{4\pi c^2} \approx 4.92\%. \tag{22}$$

Proof. $C_{\partial}(L) = (8\pi c^2/a)L + O(\sqrt{L})$, while $C_{\mathrm{int}}(L) = 2L + 216$. Divide by L. The all-length inequality was established separately; it does not follow merely from this limit. If scaffold size grows with L, its growth changes the numerator and may change the result. □

This is a molecular-alphabet capacity model. It is not the Bekenstein–Hawking entropy law $S_{\mathrm{BH}}/k_B = A/(4\ell_P^2)$: no gravitational horizon, Planck-area coefficient or holographic reconstruction theorem appears here [Bek73, Haw76]. The useful question is whether experimentally identifiable membrane degrees of freedom can carry and read the proposed information.

7 Interpretation and experimental tests

The mathematical components have different evidential roles. The slack and category constructions are exact finite descriptions; the minimax theorem is exact for its stipulated static map; the graph spectra are properties of two explicit unperturbed Hamiltonians; and the surface calculation is a capacity comparison for chosen alphabets. None alone establishes a chemically unique survivor, an origin-of-life pathway, or a cosmological selection law.

A molecular test program should identify specific substituted species and their populations, measure packing and orientation distributions, characterize both equilibrium energy differences and switching rates, and determine whether a control budget can be mapped to the surrogate coefficients. Stark spectroscopy must distinguish permanent-dipole and polarizability differences between competing states, respect solvent screening and field-induced reactions, and use chemically tolerable fields [BB97]. Hückel matching counts and Clar structures are structural descriptors, not measured kinetic stability or free energies. Substitution, electron correlation, environment and geometry relaxation must be included before comparing real spectral or chemical robustness.

For the proposed boundary encoding, composition, area per molecule, independent addressability, readout error, retention time and energetic costs must be established. Structural characterization, temperature-dependent relaxation and leakage, conditional registry correlations, degradation under specified illumination/oxygen/solvent, and full-cycle work and heat bookkeeping provide separate tests of the proposed implementation. A closed geometric surface is not necessarily an impermeable or viable membrane; a connected scaffold is not necessarily a mechanical shock absorber. A tripartite feasibility model is valuable as a design constraint only after those independent functions are specified and tested.

8 Conclusion

The Source–Placed Source comparison admits a rigorous combination of slack counting, static minimax attenuation and a support-poset adjunction. Equal energy allocation minimizes the largest surrogate gain, while finite Gibbs preparation retains positive registry entropy. The adjunction has an identity

monad but does not itself implement physical erasure; a work inequality follows under a separate cyclic thermodynamic hypothesis. Exact graph data support a zero-field comparison and a norm-bounded perturbation criterion. A three-component indicator functional characterizes admissibility rather than a unique physical minimum, and the stipulated surface alphabet has sufficient cardinality for the fixed-scaffold interior model over the proved length range. These results make the mathematical structure explicit and separate it from the measurements needed for molecular realization.

A Hypothesis and dependency register

Uniform registry.
Equality $H = m$ requires uniformity. Without it, $H \leq m$ and the cardinality formulas remain.

Coordination-deficit model.
The costs $6\phi n^3$ and $4\phi n^2$ compare different inventories. Their arithmetic survives without a physical energy interpretation.

One-orbital graph Hamiltonians.
Spectral claims use the explicit A_c, A_t and positive hopping magnitude. Matching counts remain graph facts if this electronic model fails.

Gibbs independence and surrogate.
Product fidelity uses independent binary Gibbs contacts. The minimax proof uses the stated static diagonal operator and budget, not an unspecified chemical transfer function.

Support categories.
Both categories use fixed species words and a chosen target section. Morphisms are reverse inclusions and the proof is internal to these definitions.

Cyclic reset.
The work bound requires degenerate endpoints, a bath, full control accounting and no free side information. The abstract adjunction survives without these physical premises.

Tripartite constraints.
Feasibility depends on nonempty admissible classes. It does not establish their chemical existence or uniqueness.

Capacity and geometry.
The inequality uses fixed $N_{\mathrm{lat}} = 54$, stated $R(L)$, a, and quaternary tile capacity. Changing these parameters requires a new comparison.

B Verification and formal-proof scope

The verification companion regenerates the manuscript's numerical values from executed code and distinguishes exact checks from numerical evaluations. It covers binomial counts, additive projection, explicit graph matching/determinant calculations, gate coefficients, finite category instances, and capacity arithmetic. Negative controls test rejected inherited claims. The Lean companion supplies the scoped theorems and dependency audits listed in its coverage map; it does not certify molecular synthesis, arbitrary-time control, general thermodynamics or the complete analytic argument merely by checking numerical instances.

The imported Articles 4 and 9 motivate the language of slack and control. This revision establishes only the statements proved above, not a blanket validation of every theorem-number attribution in those earlier papers. Articles 90, 94 and 96 provide the updated source, geometry and reset distinctions used here. The expanded referee report documents the corrections to inherited verification claims and to the categorical, field, control, uniqueness and surface-bound interpretations.

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