

# Resonance Alignment Without Empirical Filling Exceptions

The SRT–UQI Periodic Table and Technology

Sam Blouin

## Abstract

This paper introduces a self-contained, technology-forward framework in which a single universal wave and a fixed *quantum increment* (UQI) turn physics and chemistry into one exponential ledger. Within any one scale, sources add linearly; across nested environments, responses compose multiplicatively, forcing exact exponentials for clocks and optics. The UQI contributes a fixed *click* in the exponent, so complex evolutions are just sums of discrete steps. On this foundation, the entire periodic table ( $Z=1\text{--}118$ ) is generated as a *resonance ledger* driven by three integers: (i) the number of angular nodes (column:  $s, p, d, f$ ), (ii) the number of radial rings (row), and (iii) the frontier occupancy (position within the cell). With only these counts, families line up automatically—alkali, alkaline earth, halogen, noble, transition, and lanthanide/actinide—while textbook “exceptions” reduce to ordinary occupancy choices inside a fixed node cell rather than violations of structure. A parameter-free *exposure* score (how open the frontier is, moderated by angular complexity) recovers core trends at a glance: alkali  $>$  alkaline, halogen  $>$  noble, monotone  $p$ -row descent, and clean  $d/f$  progressions. The same ledger powers immediate technology. (i) **AI-free predictors:** integer features enable transparent screening of size, reactivity, and stability without fitted parameters. (ii) **Increment-native quantum control:** the UQI click becomes a universal  $Z$ -rotation step; basis changes wrap any axis, yielding step-accurate gates and calm calibration. (iii) **Resonance-indexed metamaterials:** engineered index fields realize lensing, delay, and wave steering under the same exponential law. On the physics side, an isotropic optical metric preserves classic first-order tests and yields **crisp, parameter-free second-order discriminators** (few- $\mu\text{s}$  near-limb bending; tens-of-ps Shapiro offsets) for modern astrometry and time transfer. The payoff is practical unification: one wave, one exponent, integer geometry, and a single click. The periodic table becomes an executable map; advanced devices become step-accurate implementations of the same resonance law; and measurements at both the quantum and cosmic ends close the loop.

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## 1 Ledger Axioms (Forwarding UQI)

### Equation 1: Forced exponential response

Let  $\Phi$  denote a dimensionless potential-like accumulator and  $\kappa$  a unit-matching constant. Source additivity and response multiplicativity imply

$$\mathcal{R}(\Phi) = \exp(\kappa \Phi).$$

### Equation 2: Discrete–continuous synthesis

For a sequence of  $N$  steps and a smooth background  $\Phi$ ,

$$\mathcal{R}(\Phi; N) = \exp(\kappa \Phi + N \delta_\star).$$

### Equation 3: No free Knobs Exposure

The frontier exposure (openness moderated by angular complexity) is

$$E(\ell, F) = \frac{C_\ell - F}{C_\ell(\ell + 1)}, \quad C_\ell = 2(2\ell + 1).$$

It decreases monotonically with  $F$  in each block and with  $\ell$  across blocks

NIST Atomic Spectroscopy (Basic Concepts): section 3 “Atomic States, Shells, and Configurations” defines subshells and the maximum occupancy  $2(2\ell + 1)$  ( $C_\ell$ ); our exposure  $E(\ell, F) = (C_\ell - F)/[C_\ell(\ell + 1)]$  extends this to quantify how open a subshell is

We are going to bridge the exposure E with UQI

### Equation Channel Form

$$\text{(SRT)} \quad \mathcal{R} = e^{\kappa U} \Rightarrow X = \ln \mathcal{R} = \kappa U, \quad \text{(UQI)} \quad X \approx k \delta_*, \quad k \in \mathbb{Z}$$

### Definition Operational step $s$ (what you fit/test)

On real data you use a working step  $s$  (log units) to lock  $X$  to integers:

$$k = \text{round}\left(\frac{X}{s}\right), \quad r = X - k s, \quad \mathbf{E} = e^X$$

If universality holds you may set  $s = \delta_*$ ; otherwise  $s$  can be a local best-fit for the dataset.

### Definition Chemical channel (subscript “chem”)

We tag chemical quantities with “chem” so they do not get mixed with other channels:

$$X_{\text{chem}}, \quad \mathbf{E}_{\text{chem}} = e^{X_{\text{chem}}}, \quad s_{\text{chem}}, \quad Q_{\text{chem}}, \quad Q_{\text{ref,chem}}.$$

A monotone *data map* sends a measured observable  $Q_{\text{chem}}$  to  $X_{\text{chem}}$ :

$$X_{\text{chem}} = \varsigma \ln\left(\frac{Q_{\text{chem}}}{Q_{\text{ref,chem}}}\right), \quad \varsigma \in \{+1, -1\}.$$

## 2 Bridge Chemical Exposure E

### Definition Glossary — overview (expanded, reader-friendly)

Symbols you will see everywhere (with units and purpose).

- $\Phi$  [ $\text{m}^2 \text{s}^{-2}$ ] — **resonance potential**. Think “energy per unit mass.”  $\Phi_{\text{bg}}$  is the *background* part; local contributions add on top. (same units as  $c^2$ )  $U \equiv \Phi/c^2$  is *dimensionless*
- $U \equiv \Phi/c^2$  (dimensionless) — **dimensionless potential**.  $U_{\text{eff}} = \Phi_{\text{eff}}/c^2$  with  $\Phi_{\text{eff}} = \Phi_{\text{bg}} + \sum_j \Phi^{(j)}$ . Subscripts:  $(\cdot)_{\text{eff}}$  = effective (bg + local);  $(\cdot)_{\text{bg}}$  = background only.
- $X$  (dimensionless) — **log-response**. It *adds* across nested environments.
- $E \equiv e^X$  (dimensionless) — **exposure factor**. It *multiplies* across nested environments.
- $\kappa$  (dimensionless) — **channel weight** linking physics to the log-response:  $X_{\text{uqi}} = \kappa U_{\text{eff}}$ . Typical values: +1 time/clock; -1 inverse-time (chem/rates); -2 optical/-gravimetric; +2 intensity (amplitude)
- $\delta_\star > 0$  (dimensionless) — **universal step** (UQI “click”) postulated to be common across channels.
- $s > 0$  (dimensionless) — **operational step** used for integer locking on a given dataset (often  $s = \delta_\star$  when testing universality).
- $k \in \mathbb{Z}$ ,  $r \in \mathbb{R}$  — **rung and residual** in log-space:  $k = \text{round}(X/s)$ ,  $r = X - k s$ .
- $Q_{\text{obs}}$  — **measured observable** (e.g.,  $I_1$  in eV,  $A$  in eV,  $K$  dimensionless,  $k$  in  $\text{s}^{-1}$  or matched units/order).  $Q_{\text{obs}} > 0$  to define a log safely.
- $Q_{\text{ref}}$  — **reference baseline** for  $Q_{\text{obs}}$  to form a *dimensionless* ratio  $Q_{\text{obs}}/Q_{\text{ref}}$ . Choose a *cohort* baseline (e.g., period median, series median, or phase standard) and keep it fixed within that cohort.
- $\varsigma \in \{+1, -1\}$  — **sign map for the data channel** chosen so that  $X_{\text{chan}}$  *increases when intuitive “exposure” increases*. Examples:  $\varsigma = -1$  for  $I_1$  (bigger  $I_1 \Rightarrow$  less exposure),  $\varsigma = +1$  for  $A, K, k$ .
- Subscripts:  $(\cdot)_{\text{chem}}$  marks **chemistry/data-channel** quantities;  $(\cdot)_{\text{eff}}$  the **effective field**;  $(\cdot)_{\text{bg}}$  the **background**.

## Claim Sign Map to the $-1$ chemical channel $\varsigma$

**Aim.** Turn any monotone lab observable into a common exponential scale, then read coarse rungs and fine residuals. Chemistry lands in the inverse-time ( $\kappa = -1$ ) channel.

**Step 1 — Normalize and take logs (build the ladder).**

$$\underbrace{X}_{\text{log ladder}} = \underbrace{\varsigma}_{\text{sign map}} \ln\left(\frac{Q_{\text{obs}}}{Q_{\text{ref}}}\right) \quad \underbrace{E}_{\text{exposure factor}} = e^X$$

$$\underbrace{Q_{\text{obs}}}_{\text{your data}}, \quad \underbrace{Q_{\text{ref}}}_{\text{baseline (same set)}}, \quad \underbrace{\varsigma \in \{+1, -1\}}_{\text{choose so that } X \uparrow \text{ means "more exposed"}}$$

**Step 2 — Tie the ladder to one field (pick the channel).**

$$\underbrace{X}_{\text{same } X} = \underbrace{\kappa}_{\text{channel weight}} \underbrace{\frac{U_{\text{eff}}}{\Phi/c^2}}_{\text{field}} \implies \kappa \in \{+1, -1, -2, +2\}$$

- $\kappa = +1$  : clock/mass (durations dilate)
- $\kappa = -1$  : inverse-time/rate (chemistry; rates contract)
- $\kappa = -2$  : optical/gravimetric (light/geometry double weight)
- $\kappa = +2$  : intensity (amplitude squared)

**Step 3 — Why chemistry is  $\kappa = -1$  (rates oppose clocks).**

$$\underbrace{T}_{\text{clock duration}} \propto e^{+U_{\text{eff}}} \implies \underbrace{f = \frac{1}{T}}_{\text{rate/frequency}} \propto e^{-U_{\text{eff}}} \implies \boxed{X_{\text{chem}} = -U_{\text{eff}}}$$

*Interpretation:* when the local field makes clocks run slower ( $+U_{\text{eff}}$ ), chemical rates slow too, hence the opposite sign.

**Step 4 — Pick the sign map  $\varsigma$  from data behavior.**

- $\varsigma = +1$  :  $Q$  grows with exposure (e.g.  $k$ ,  $K$ , many affinities)
- $\varsigma = -1$  :  $Q$  falls with exposure (e.g.  $I_1$  used as stability proxy)

This guarantees  $E = e^X$  increases when the process is “more exposed.”

**Step 5 — Integer geometry (rungs and residual).**

$$k = \text{round}\left(\frac{X}{s}\right), \quad r = X - k s, \quad \underbrace{X}_{\text{total}} = \underbrace{k s}_{\text{coarse rung}} + \underbrace{r}_{\text{fine chemistry}}$$

Choose the operational step  $s$  (set  $s = \delta_*$  when testing a universal increment).

**One-line example (Na, first ionization energy).**

$$I_1 = 5.139 \text{ eV}, \quad Q_{\text{ref}} = 9.256 \text{ eV}, \quad \varsigma = -1 \Rightarrow X = -\ln(5.139/9.256) = 0.588$$

With  $s = 0.10$ :  $k = 6$ ,  $r = -0.012$  and  $E = e^{0.588} \approx 1.80$ . Clocks would use  $\kappa = +1$  (same field, opposite sign); chemistry uses  $\kappa = -1$ .

- **Fine chemistry (what  $r$  collects):** small intrinsic structure effects (configuration, pairing, correlation, spin-orbit, crystal/ligand fields) *and* small extrinsic perturbations (solvent, T/P, strain, measurement bias, *impurities/defects*); in SRT, all appear as tiny shifts in  $U_{\text{eff}}$  and thus in the log-residual  $r$ .

- Ionization energy 41 449.44±0.03 cm<sup>-1</sup> (5.139117±0.000013 eV)

- NIST Atomic Spectra Database — <sup>5</sup>verified first-ionization energies for Period 3 elements; each row lists Na → Ar, and taking the median of those eight values gives  $Q_{\text{ref,chem}} \approx 9.256 \text{ eV}$ .

## 2.1 Bridge From UQI To Chemical Exposure E

### Definition Chemical exposure function E

E is the *dimensionless* factor that compiles how a chemical system’s electronic structure is “exposed” (available) under nested sub-environments (nuclear charge, shells, bonding partners, lattice/solvent, field). By definition,

$$E \equiv \exp(X), \quad X \equiv \kappa_{\text{chem}} U_{\text{eff}} = \sum_j s_j \delta_\star$$

where  $U_{\text{eff}}$  is the effective (dimensionless) potential for the chemical channel. In practice we *estimate*  $X$  from a monotone observable via a log map.

## Mid-Step Estimator and Integer Geometry: Ionisation and Affinity (Periods 2–3)

**Estimator principle.** In the SRT ledger, the *mid-step* is not a state but the line that separates random noise from a real transition. The acceptance logic follows three zones:

- A:** accepted rung (locked)  $|r| \leq s/6$ ,
- N:** noise zone (between rung and mid-step)  $s/6 < |r| \leq s/2$ ,
- O:** outlier (beyond mid-step, true reject)  $|r| > s/2$ .

With  $s = 0.3015$ , the half-step limit is  $s/2 = 0.1508$ . Every measured value remains within this bound; thus no true outliers (O) occur.

### A1. Period 2 (Li–Ne): Second Ionisation $I_2$ [eV], $Q_{\text{ref}} = 32.286$

Element	$Q$	$\mathcal{E}$	$k$	$r$	$ r $	State
Li	75.65	-0.857	-3	0.047	0.047	A
Be	18.21	0.578	2	-0.025	0.025	A
B	25.15	0.250	1	-0.052	0.052	N
C	24.38	0.283	1	-0.019	0.019	A
N	29.61	0.080	0	0.080	0.080	N
O	35.13	-0.086	0	-0.086	0.086	N
F	34.98	-0.081	0	-0.081	0.081	N
Ne	40.97	-0.233	-1	0.069	0.069	N

*Phase summary:* 3 A, 5 N, 0 O.

*Comment.* All points lie within the half-step envelope; no outliers appear. The few N cases (B, N, O, F, Ne) correspond to elements near half-filled subshells, where exposure fluctuates across the estimator line but does not break the pattern.

### A2. Period 3 (Na–Ar): Second Ionisation $I_2$ [eV], $Q_{\text{ref}} = 21.554$

Element	$Q$	$\mathcal{E}$	$k$	$r$	$ r $	State
Na	47.31	-0.787	-3	0.117	0.117	N
Mg	15.04	0.353	1	0.051	0.051	N
Al	18.83	0.141	0	0.141	0.141	N
Si	16.35	0.273	1	-0.028	0.028	A
P	19.78	0.084	0	0.084	0.084	N
S	23.34	-0.079	0	-0.079	0.079	N
Cl	23.82	-0.100	0	-0.100	0.100	N
Ar	27.63	-0.250	-1	0.052	0.052	N

*Phase summary:* 1 A, 7 N, 0 O.

*Comment.* All Period 3 data remain inside the estimator window. The wider noise zone reflects shell-opening effects (Na) and subshell starts (Al), which push values toward the mid-step boundary but never beyond it.

### B1. Period 2 (positive EA): $Q_{\text{ref}} = 1.262$ eV

Element	$Q$	$\mathcal{E}$	$k$	$r$	$ r $	State
Li	0.618	0.756	3	-0.149	0.149	N
B	0.280	1.538	5	0.031	0.031	A
C	1.262	0.000	0	0.000	0.000	A
O	1.461	-0.146	0	-0.146	0.146	N
F	3.401	-0.993	-3	-0.088	0.088	N

*Phase summary:* 2 A, 3 N, 0 O.

*Comment.* The noise-region cases (Li, O, F) coincide with weakly bound or half-filled configurations. The law holds: no data pass the mid-step line.

### B2. Period 3 (positive EA): $Q_{\text{ref}} = 1.068 \text{ eV}$

Element	$Q$	$\mathcal{E}$	$k$	$r$	$ r $	State
Na	0.548	0.635	2	0.032	0.032	A
Al	0.433	0.910	3	0.006	0.006	A
Si	1.390	-0.245	-1	0.057	0.057	N
P	0.747	0.328	1	0.027	0.027	A
S	2.077	-0.653	-2	-0.050	0.050	A
Cl	3.613	-1.230	-4	-0.024	0.024	A

*Phase summary:* 5 A, 1 N, 0 O.

*Comment.* Only Si approaches the mid-step threshold; all others lock cleanly. No true rejects appear.

**Synthesis.** Across 27 values, 11 are fully accepted (A), 16 lie in the noise region (N), and none exceed the mid-step threshold (O = 0). The estimator therefore verifies that all chemical energies fall inside the expected ladder geometry: noise occasionally reaches the mid-step but never crosses it. The integer spacing  $s = 0.3015$  remains valid across both ionisation and affinity channels.



### 3 Bridge From UQI To Chemistry Geometry

#### Claim Why geometry appears: rungs and steps from the UQI law

**1. The origin.** The Universal Quantum Increment (UQI) asserts that all measurable responses follow a logarithmic step rule

$$X = k \delta_{\star} + r, \quad |r| \leq \epsilon_X.$$

Here  $\delta_{\star}$  is the fixed step of the logarithmic coordinate  $X$ ,  $k \in \mathbb{Z}$  labels discrete rungs, and  $r$  is the small residual. This structure does not describe an external grid; it *is* the grid on which all physical quantities are expressed once the exponential law  $\mathcal{R} = \exp(\kappa U)$  is accepted. The geometry of the world therefore becomes a *geometry of increments*.

**2. From arithmetic to geometry.** Additive arithmetic in  $X$  generates a spatial picture: each allowed value of  $X$  corresponds to a plane in the abstract  $\Phi/c^2$ -space, separated from its neighbours by one  $\delta_{\star}$ . Stack these planes and the result is a ladder of rungs. Because  $X$  is logarithmic, equal increments of  $X$  mean multiplicative ratios of the underlying quantity  $Q$ :

$$\frac{Q_{k+1}}{Q_k} = e^{\delta_{\star}}.$$

The ladder is therefore geometric in the mathematical sense: equal ratios, not equal differences.

**3. The geometry of rungs.** Each rung represents a stable resonance basin in the universal wave; moving from  $k$  to  $k+1$  multiplies the underlying energy, frequency, or probability density by  $e^{\delta_{\star}}$ . The world built on these rungs has no continuous height; it advances in quantised steps of logarithmic amplitude. The “distance” between rungs is thus not measured in metres but in units of  $\delta_{\star}$  on the  $\ln Q$  axis.

**4. Why this is called geometry.** Ordinary geometry measures length and area with rulers. UQI geometry measures *resonance separation* with the ruler  $\delta_{\star}$ . Surfaces of constant  $k$  act like iso-potential sheets, and moving across one step is equivalent to rotating the universal phase by  $2\pi \delta_{\star}$ . Hence the word *geometry*: the ladder of rungs is the metric structure of the logarithmic universe.

**5. Transition to atomic structure.** When applied to atoms, these rungs appear as the integer levels extracted from measured exposures. Each  $k$  marks a coarse resonance plateau; each residual  $r$  marks the local curvature inside that plateau. Later, the integers  $(\ell, n, F)$  will supply the geometric coordinates that locate these rungs within the orbital architecture. But the principle itself—the appearance of rungs and steps—comes entirely from the UQI law and its exponential form.

**Summary.** Geometry arises because the UQI transforms every continuous quantity  $Q$  into its logarithmic exposure  $X = \ln(Q/Q_{\text{ref}})$ , which can only change by integer multiples of  $\delta_{\star}$  plus a small residual. Those integers are the rungs, and their spacing  $\delta_{\star}$  is the single ruler of resonant geometry across all scales.

## Claim Which geometry the UQI acts on

### 1. Two kinds of geometry coexist.

- **Static geometry:** the integer lattice  $(\ell, n, F)$  fixes the *shape* of available states. It is a geometry of form and count: angular nodes, radial rings, and occupancy seats. This part is purely combinatorial and defines the theatre of possible wave patterns.
- **Dynamic geometry:** the Universal Quantum Increment (UQI) introduces a geometry of *resonant spacing* on top of that lattice. It governs the separation between successive stable configurations, telling how the system moves from one discrete shape to another.

**2. What the UQI modifies.** The UQI does not change the static lattice itself (orbitals remain defined by  $\ell$ ,  $n$ , and  $F$ ); it *resizes the metric* of the logarithmic space in which these states are expressed. In effect it sets the scale of change between adjacent configurations:

$$\Delta X = \delta_\star \iff \frac{Q_{k+1}}{Q_k} = e^{\delta_\star}.$$

Within a fixed  $(\ell, n)$  block, each increase of  $F$  therefore shifts the logarithmic exposure  $E$  by one UQI fraction, and a change of block  $(\ell \rightarrow \ell+1)$  corresponds to a full  $\delta_\star$  step.

**3. The geometry actually affected.** The UQI acts on the *metric geometry* of the exposure coordinate  $E$ , not on the orbital shapes themselves. Concretely:

- It rescales how far apart successive orbitals appear when plotted in logarithmic energy or potential space.
- It imposes equal ratio spacing between the mean exposures of successive rungs inside the same shell.
- It aligns block boundaries ( $s \rightarrow p$ ,  $p \rightarrow d$ ) with full  $\delta_\star$  jumps, fixing the global alignment of the table.

**4. Visual picture.** Think of  $(\ell, n, F)$  as coordinates on a discrete grid and  $E$  as an axis rising out of that grid. UQI supplies the ruler for the vertical direction: each  $\delta_\star$  marks a layer of constant resonance potential. The table of elements thus becomes a three-dimensional staircase: horizontal directions  $(\ell, n, F)$  define seats, vertical increments  $(k \delta_\star)$  define resonance height.

**5. Summary.** The geometry affected by the UQI is not spatial shape but *metric geometry in logarithmic space*. It sets the distance between energy rungs while leaving the orbital lattice unchanged. Static geometry (shape, count) comes from quantum structure; dynamic geometry (step spacing, resonance scaling) comes from the UQI. Together they define the complete integer geometry of matter.

### Definition 3: Integer geometry of orbitals

**One picture to keep in mind.** Think of each element as choosing a seat in a theater:

- The **column** is the *section* of the theater:  $s, p, d, f$ . We index this by the integer  $\ell \in \{0, 1, 2, 3\}$ .
- The **row** is the *row number* (the period):  $n = 1, 2, 3, \dots$
- Within a section, there are a fixed number of **seats** (capacity). We call the seat count *capacity*  $C_\ell = 2(2\ell + 1)$  and the number currently occupied *frontier occupancy*  $F \in \{1, \dots, C_\ell\}$ .

These three integers  $(\ell, n, F)$  locate the element's *frontier orbital cell*.

### Example

**Plain-language view of the three integers.**

1. **Angular nodes**  $\ell$  (which section?):  $s$  has  $\ell = 0$ ,  $p$  has  $\ell = 1$ ,  $d$  has  $\ell = 2$ ,  $f$  has  $\ell = 3$ .
2. **Radial rings**  $n$  (which row?): period number on the periodic table.
3. **Frontier occupancy**  $F$  (how many seats filled in the active section?): for  $s$ , capacity  $C_0 = 2$  so  $F = 1, 2$ ; for  $p$ ,  $C_1 = 6$  so  $F = 1, \dots, 6$ ; for  $d$ ,  $C_2 = 10$ ; for  $f$ ,  $C_3 = 14$ .

### Example

**How to find  $(\ell, n, F)$  for any element (quick recipe).**

1. Look at the **block**:  $s$ -block ( $\ell = 0$ ),  $p$ -block ( $\ell = 1$ ),  $d$ -block ( $\ell = 2$ ),  $f$ -block ( $\ell = 3$ ).
2. Read the **period** number on the left of the periodic table: that is  $n$ .
3. Count electrons in the **frontier subshell** for that block: that count is  $F$ . Example in Period 3: Na is  $3s^1$  so  $(\ell, n, F) = (0, 3, 1)$ ; Mg is  $3s^2$  so  $(0, 3, 2)$ ; Al is  $3p^1$  so  $(1, 3, 1)$ ; ...; Ar is  $3p^6$  so  $(1, 3, 6)$ .

## Definition Visual – orbitals, subshells, blocks, angular nodes, radial rings

**Orbital (one "room").** A single 3D standing wave where an electron may be found (a probability cloud). *Capacity:* 2 electrons (with opposite spin) per orbital. *Picture:* a shaped cloud in space; electrons do not orbit like planets, they occupy this cloud.

**Subshell (a group of same-shaped rooms).** All orbitals that share the same shape label  $\ell$  (read by letters  $s, p, d, f$ ) and the same radial ring  $n$ . We write this as  $ns, np, nd, nf$  (e.g.,  $3p$ ). *How many orbitals in a subshell?*  $2\ell + 1$ . *Capacity of a subshell:*  $C_\ell = 2(2\ell + 1)$  electrons.

**Block (where you are on the table).** The periodic table is split into  $s$ -,  $p$ -,  $d$ -, and  $f$ -blocks according to *which subshell gets the last added electron*. *Rule of thumb:*  $s$ -block = left 2 columns;  $p$ -block = right 6 columns;  $d$ -block = middle 10 columns;  $f$ -block = bottom 14 cells.

**Radial ring (shell, the row number).** Indexed by  $n = 1, 2, 3, \dots$  and roughly tracks distance from the nucleus and baseline energy. For main-group elements, the period number is the shell  $n$  used by the frontier subshell ( $n$  for  $s$  and  $p$ ; for transition and inner-transition series the frontier can be  $(n-1)d$  or  $(n-2)f$ ). *Picture:* concentric layers (rings) around the nucleus:  $n = 1$  inner, then  $n = 2$ , etc.

**Angular nodes (shape-setting "cuts" through the cloud).** An *angular node* is a surface (plane or cone) where the wavefunction passes through zero, slicing the cloud into lobes with alternating sign. The number of angular nodes equals  $\ell$ . *This integer is what distinguishes  $s, p, d, f$  shapes.*

- $s$  ( $\ell = 0$ ): 0 angular nodes. *Picture:* a single, roughly spherical cloud.
- $p$  ( $\ell = 1$ ): 1 angular node (a nodal plane). *Picture:* two lobes (a dumbbell) on opposite sides of that plane. There are 3 orientations ( $p_x, p_y, p_z$ ).
- $d$  ( $\ell = 2$ ): 2 angular nodes. *Picture:* four-leaf clover types; 5 orientations in total.
- $f$  ( $\ell = 3$ ): 3 angular nodes. *Picture:* more intricate multi-lobed shapes; 7 orientations.

**At-a-glance table.**

Label	$\ell$	# orbitals = $2\ell + 1$	Capacity = $2(2\ell + 1)$	Angular nodes
$s$	0	1	2	0
$p$	1	3	6	1
$d$	2	5	10	2
$f$	3	7	14	3

**One concrete snapshot (how to read an electron label).** Take silicon: configuration ends in  $3p^2$ . Translation: radial ring  $n = 3$ ; subshell letter  $p$  so  $\ell = 1$  (one angular node); in that  $3p$  subshell there are  $2\ell + 1 = 3$  orbitals and up to 6 electrons; silicon has 2 of those 6 seats filled. It therefore lies in the  $p$ -block (right side of the table).

**Mental model to keep.** First choose the *ring* ( $n$ ), then the *shape* (set by angular nodes  $\ell$ ), then *which seat* within that shape (an orbital, 2 electrons each). Blocks on the periodic table simply tell you which shape is being filled at the frontier.

## Deeper View of the Operands $N$ and $C$

**Operands as resonance counters.** In every ledger row,  $N$  and  $C$  are not arbitrary integers but discrete *resonance counters* drawn from the same universal standing-wave rule that quantizes the field itself. They arise from the closure condition of the universal wave:

$$\oint_{\text{shell}} \mathbf{k} \cdot d\boldsymbol{\ell} = 2\pi n, \quad n \in \mathbb{Z}.$$

The integer  $n$  counts the number of field nodes (half-wavelengths) that fit exactly within the boundary of that shell. In an atom, these nodes correspond to electron *seats*. Thus:

$$\boxed{N = \text{number of occupied nodes}}, \quad \boxed{C = \text{total number of available nodes}}.$$

**Hierarchy of capacities.** Each subshell capacity  $C$  follows the familiar  $2(2\ell + 1)$  rule, which in this framework reflects the number of unique phase-orientation channels available to the spacitron resonance at that angular momentum:

$$C_s = 2(2 \times 0 + 1) = 2, \quad C_p = 2(2 \times 1 + 1) = 6, \quad C_d = 2(2 \times 2 + 1) = 10.$$

The pattern 2, 6, 10, ... corresponds to successive *azimuthal corridors* in the same standing-wave geometry.

**What the operands measure numerically.** When we compute  $f = N/C$ , we are forming the *fraction of resonance modes actually engaged* in that shell. This fraction determines how far the oscillation has progressed between its birth and closure:

$$f = \frac{N}{C} \iff \text{phase advance} = 2\pi f \pmod{2\pi}.$$

Hence  $f = 0.5$  corresponds to a phase advance of  $\pi$  — the universal *mid-step*, where the field reverses sign; that reversal is not destructive — it's the moment when the field's increment changes polarity and begins feeding the next resonance

**Connection to the universal increment  $\delta_\star$ .** Each full subshell ( $f = 1.0$ ) advances the logarithmic ledger by one *click*:

$$\Delta = \delta_\star, \quad \Delta\phi = 2\pi \delta_\star,$$

so that each discrete addition of an electron corresponds to a step  $\Delta f = 1/C$  within that click. The integer operand  $N$  therefore represents not merely “how many electrons,” but how many sub-increments of  $\delta_\star/C$  have been realized inside that rung.

**Numerical evidence.** Using the Period 4 series as example:

$$\begin{array}{lll} \text{Sc: } N/C & = & 1/10 \quad (f = 0.1) \\ \text{V: } N/C & = & 3/10 \quad (f = 0.3) \\ \text{Cr: } N/C & = & 5/10 \quad (f = 0.5) \\ \text{Fe: } N/C & = & 6/10 \quad (f = 0.6) \\ \text{Cu: } N/C & = & 10/10 \quad (f = 1.0) \end{array}$$

The operands remain discrete because each shell's structure supports only integer node counts, while their ratio  $f$  translates these counts into a continuous resonance coordinate.

### Summary

- $N$ : number of occupied resonance nodes (actualized standing-wave sectors).
- $C$ : number of available sectors defined by the shell's symmetry.

- $N/C = f$ : normalized phase position in the universal oscillation, running from  $0 \rightarrow 1$ .
- Each increment  $1/C$  corresponds to a micro-step of  $\delta_*/C$  in the logarithmic ledger.

In this way, the discrete operands  $N$  and  $C$  form the *integer skeleton* of the resonance wave's otherwise continuous geometry.

### Deeper Structure of the Operands and the Mid-Step Acceptance (Period 3 Narrative)

**Operands as resonance integers.** In the Period 3 ledger, each subshell is a bounded resonance cavity characterized by a total number of available seats  $C$  and an actual number of occupied seats  $N$ . These are not empirical counts only; they are the integer solutions to the resonance-closure condition of the universal wave:

$$\oint_{\text{shell}} \mathbf{k} \cdot d\boldsymbol{\ell} = 2\pi n, \quad n \in \mathbb{Z}.$$

Each completed loop corresponds to a node, and every node to a seat. Hence  $C$  measures how many distinct node sectors can fit within the shell, while  $N$  tells how many of them are actively filled.

**Normalized fraction and field phase.** The ratio

$$f = \frac{N}{C}, \quad 0 \leq f \leq 1,$$

locates the system's position within one complete resonance. In the Period 3 atoms:

$N/C$	$f$	$\phi = 2\pi f$	Interpretation
0	0.0	0	Field just beginning (Na start)
0.5	0.5	$\pi$	Mid-step: amp crosses zero, inc flips (P, half-filled $p^3$ )
1.0	1.0	$2\pi$	Full closure: upper-step acceptance (Ar, $p^6$ closure)

Between these points the field travels continuously through its oscillation: the rising half ( $0 < f < 0.5$ ) expands the potential outward (donor phase), the returning half ( $0.5 < f < 1.0$ ) contracts it inward (acceptor phase).

**Mid-step estimator boundaries.** The mid-step estimator defines the tolerance band around the equilibrium point:

$$|f - 0.5| \leq \epsilon_f, \quad \epsilon_f \simeq \frac{1}{6} \approx 0.167.$$

For the  $3p$  sequence ( $C = 6$ ):

$f < 0.333$	below band: rising field (Al, Si)
$0.333 < f < 0.667$	inside band: mid-step resonance (P, S)
$f > 0.667$	above band: returning field, accepted phase (Cl, Ar)

The band edges therefore occur roughly between  $N = 2$  and  $N = 4$ : the halfway corridor where donor and acceptor behaviors coexist.

**Acceptance to the upper step.** Crossing  $f = 0.5$  corresponds to a phase advance of  $\pi$ ; the field's amplitude passes through zero and its incremental sign changes. Physically this is the moment when the lower resonance has exhausted its expansion and the same

oscillation begins to feed the formation of the next rung. The system is thus said to be *accepted into the upper step*. At that moment, energy flow reverses direction: what was emission becomes absorption, what was giving becomes holding. In Period 3 this inversion happens between silicon and phosphorus, matching the observed switch from metallic to nonmetallic character. [NIST Atomic Spectra Database](#).

#### Claim How the integers help a reader

- $(\ell, n)$  tells you *where* you are: which block and which row.
- $F$  tells you *how far* you are across that block.
- $E$  and its integer companion  $k$  turn real data (eV) into an easy ladder of levels so that block changes (like  $s \rightarrow p$ ) become visible as clean steps, while chemistry-specific tweaks live in the small residual  $r$ .

#### Claim Takeaway in one line

Three integers  $(\ell, n, F)$  say where the frontier electrons sit; one log-exposure  $E$  plus its integer level  $k$  shows how the data step with that seating; the small residual  $r$  tells the chemistry story.

## 4 From integers to the periodic ledger

### Claim 1: Family alignment without exceptions — rigorous formulation

**Operands and capacity.** Each frontier cell is labeled by  $(\ell, n, F)$  with angular type  $\ell \in \{0, 1, 2, 3\}$ , principal index  $n$ , and integer seat count  $F \in \{0, \dots, C_\ell\}$ . The intrinsic capacity is

$$C_\ell = 2(2\ell + 1) \quad (\text{from } (2\ell+1) \text{ orbital orientations} \times 2 \text{ spin}).$$

Define the occupancy fraction and mid-step:

$$f_\ell \equiv \frac{F}{C_\ell}, \quad f_\ell = \frac{1}{2} \text{ marks the half-filled condition.}$$

**Ledger invariants.** (i) *Fixed capacity:*  $C_\ell$  never changes. (ii) *Frontier identification:* the chemical block is the highest  $\ell$  with  $0 < F < C_\ell$  at that  $n$ ; if none, the frontier is *closed*. (iii) *Discrete progression:*  $F$  advances in integers only; half-filled and closed states are the only symmetry points ( $f_\ell = \frac{1}{2}$  and 1). (iv) *Acceptance rule (upper step):* when  $f_\ell \geq \frac{1}{2}$  the frontier behaves as “accepted” (returning half); when  $f_\ell < \frac{1}{2}$  it is in the rising half.

**Family map from integers.**

- ***s*-block** ( $\ell=0$ ,  $C_0=2$ ).  $F=1 \Rightarrow$  alkali;  $F=2 \Rightarrow$  alkaline earth / inert closure. Helium is inert because  $F=C_0$ .
- ***p*-block** ( $\ell=1$ ,  $C_1=6$ ).  $F=1, \dots, 6$  enumerate the main-group ladder;  $F=5 \Rightarrow$  halogen;  $F=6 \Rightarrow$  noble (frontier-closed).
- ***d*-block** ( $\ell=2$ ,  $C_2=10$ ). Two integers control behavior: the *closure index*  $F_d$  (toward 0, 5, 10) and the *valence index*  $F^* \equiv F_d + F_s$  (with the coupled  $s$  seats at the same  $n$ ). The family (Group 3...12) follows  $F^*$ , while stability features (half/closed) follow  $F_d$ .
- ***f*-block** ( $\ell=3$ ,  $C_3=14$ ). Analogously,  $F_f$  controls half/closed (7, 14), with mild  $s/d$  coupling not altering the  $F_f$  ladder.

**Why “no exceptions.”** Reconfigurations (e.g. Cr :  $3d^5 4s^1$  vs.  $3d^4 4s^2$ ; Cu :  $3d^{10} 4s^1$ ) change the *distribution* between coupled seats but preserve the *integers that label families*:

$$F^* = F_d + F_s \quad (\text{hence Group identity}) \quad \text{and} \quad C_\ell, f_\ell.$$

Thus “exceptions” are internal allocations within the fixed  $(\ell, n)$  ledger, not violations of it.

**Mid-step acceptance and trends.** Half-filled states ( $f_\ell = \frac{1}{2}$ ) are locally stable plateaus. Across a period, quantities tied to frontier hardness/softness (e.g.  $I_1$ ) change slope at  $f_\ell = \frac{1}{2}$  (“mid-step”), and tighten further as  $f_\ell \rightarrow 1$  (closure). Main-group examples:  $p^3$  (mid-step) and  $p^6$  (closure).  $d/f$  examples:  $d^5$ ,  $f^7$  (mid-step) and  $d^{10}$ ,  $f^{14}$  (closure).



## Example

### Minimal algorithm (any element).

1. Find the highest open  $(\ell, n)$ : this is the frontier cell (block).
2. Read  $F$  in that cell; compute  $f_\ell = F/C_\ell$ .
3. *Main group* ( $\ell = 0, 1$ ): the family is the  $F$ -label (alkali/alkaline;  $p^k$  with halogen  $k=5$ , noble  $k=6$ ).
4. *Transitions* ( $\ell = 2$ ): compute  $F^* = F_d + F_s$  for the group label; use  $F_d$  for half/closed diagnostics.
5. *Inner transitions* ( $\ell = 3$ ): track  $F_f$  (half at 7, closure at 14); small  $s/d$  borrowings do not alter  $F_f$  milestones.

**Net effect.** All families arise from the integers  $(\ell, n, F)$  and the universal capacity  $C_\ell$ . Half-filled and closed cases appear exactly at the rational boundaries  $F = C_\ell/2$  and  $F = C_\ell$ . Apparent anomalies are redistributions among coupled frontier seats that conserve the family-defining integers.

For  $d$ -block ( $\ell=2$ ,  $C_2=10$ ), exposure values are  $(10 - F)/30$ , descending uniformly from 0.300 (early transition) to 0 (full  $d^{10}$ ).

## 5 Technology alignment (executability (experimental))

### Definition 4: Increment-native rotations

**Primitive.** Let  $Z(\theta) = \exp(-\frac{i}{2}\theta\sigma_z)$ . The hardware exposes a *universal quantization increment* (UQI)  $\delta_\star \in (0, 1]$  and a stable “click” angle

$$\theta_\star = 2\pi\delta_\star,$$

so the only tunable amplitude is an *integer*  $k$ , giving  $Z(k\theta_\star)$  exactly.

**Axis re-targeting (basis conjugation).** Any single-qubit rotation is  $R_{\hat{n}}(\theta) = \exp(-\frac{i}{2}\theta\hat{n}\cdot\vec{\sigma})$  with  $\hat{n} \in \mathbb{S}^2$ . For any unitary frame  $U$ ,

$$U Z(\theta_\star) U^\dagger = R_{\hat{n}}(\theta_\star), \quad \hat{n} = U\hat{z}U^\dagger.$$

Concrete choices (useful in control libraries):

$$R_x(\theta) = H Z(\theta) H, \quad R_y(\theta) = S^\dagger H Z(\theta) H S,$$

where  $H$  and  $S$  are fixed, pre-calibrated frame changes. (*Note:* if only  $Z$ -clicks exist,  $H, S$  themselves can be compiled via a short integer-click library plus any native  $\pi/2$  pulse you already have; otherwise treat  $H, S$  as provided primitives.)

**Mid-step acceptance (binary, hardware-native).** Define the phase fraction  $f \equiv \theta/(2\pi)$ . At  $f = \frac{1}{2}$  we cross  $\pi$  radians (a *sign flip* in the  $X/Y$  quadratures under Ramsey readout). With only integer clicks available, the acceptance test is: choose the smallest integer  $k$  such that  $k\theta_\star \geq \pi$ ; the mid-step is accepted as soon as  $k\theta_\star \in [\pi, \pi + \frac{1}{2}\theta_\star)$  (nearest-click rule). This is robust to slow drift because it depends on a *binary* observable (sign).

#### Equation 4: Step-accurate gate composition

**Composition model (exact and approximate).** Let  $A_j \equiv -\frac{i}{2} k_j \theta_\star \hat{n}_j \cdot \vec{\sigma}$  where each  $k_j \in \mathbb{Z}$  and each axis  $\hat{n}_j$  is set by a frame  $U_j$ . Then

$$\prod_{j=1}^m \exp(A_j) = \exp\left(A_{\text{sum}} + E_2 + E_3 + \dots\right),$$

with

$$A_{\text{sum}} = \sum_{j=1}^m A_j, \quad E_2 = \frac{1}{2} \sum_{i < j} [A_i, A_j], \quad E_3 = \frac{1}{12} \sum_{i, j} ([A_i, [A_i, A_j]] + [A_j, [A_j, A_i]]), \dots$$

By Pauli algebra  $(\hat{a} \cdot \vec{\sigma})(\hat{b} \cdot \vec{\sigma}) = (\hat{a} \cdot \hat{b}) \mathbb{I} + i(\hat{a} \times \hat{b}) \cdot \vec{\sigma}$ ,

$$[A_i, A_j] = -2i \alpha_i \alpha_j (\hat{n}_i \times \hat{n}_j) \cdot \vec{\sigma}, \quad \alpha_j \equiv \frac{1}{2} k_j \theta_\star.$$

Hence, to second order,

$$\prod_{j=1}^m \exp(A_j) = \exp\left(-\frac{i}{2} \underbrace{\left[\sum_j k_j \theta_\star \hat{n}_j\right]}_{\text{vector sum}} + \frac{1}{2} \underbrace{\sum_{i < j} k_i k_j \theta_\star^2 (\hat{n}_i \times \hat{n}_j)}_{\text{non-commuting correction}} + \mathcal{O}(\theta_\star^3) \cdot \vec{\sigma}\right).$$

**When the simple “sum” is exact.** If all  $\hat{n}_j$  are parallel (or anti-parallel), then  $[A_i, A_j] = 0$  and the product is *exactly*

$$\prod_j U_j Z(k_j \theta_\star) U_j^\dagger = R_{\hat{n}}\left(\sum_j k_j \theta_\star\right).$$

**Suppressing non-commutation without analog tunables.** With only integer clicks, we can still cancel low-order errors using palindromic/Suzuki patterns:

$$(\text{Strang}) \quad e^{A/2} e^B e^{A/2} = \exp(A + B + \mathcal{O}(\|A\|^3 + \|B\|^3)).$$

If half-clicks are unavailable, use *cycle dithering*: alternate  $\lfloor k/2 \rfloor$  and  $\lceil k/2 \rceil$  across two cycles to realize the same mean as  $k/2$  while keeping integer clicks per cycle; palindromes then cancel all  $\mathcal{O}(\theta_\star^2)$  cross-terms over the two-cycle macrostep.

### Definition 5: Resonance-indexed media

**Index shaping at integer resolution.** Let the scalar *design field*  $\Phi(x)$  be laid down on a fabrication grid, and define

$$n(x) = \exp(\kappa \Phi(x)), \quad \kappa \in \mathbb{R}.$$

In the small-contrast regime,  $n(x) \approx 1 + \kappa \Phi(x)$ , so integer “clicks” on  $\Phi$  translate linearly to  $\Delta n$  resolutions. In the eikonal limit ( $u(x) = A(x)e^{ik_0 S(x)}$ ), the ray trajectories are geodesics of the optical metric  $n^2(x) dx^2$ , and  $S$  satisfies  $|\nabla S| = n(x)$ . *Therefore* precomputing  $\Phi$  imposes lensing, group delay, and steering *without any continuous tuning*—just integer voxel clicks.

**Design primitives (click-native).**

- *Lensing:* choose  $\Phi(r) = \frac{r^2}{2f}$ ; then  $n(r) \approx 1 + \kappa \frac{r^2}{2f}$  reproduces a GRIN parabolic lens for small  $\kappa r^2$ .
- *Beam steering:* choose a linear ramp  $\Phi(x) = \beta x$  giving  $n(x) \approx 1 + \kappa \beta x$  (prism).
- *Delay lines:* choose  $\Phi$  localized along a path; group delay is  $\Delta t \approx \frac{1}{c} \int (n - 1) ds \approx \frac{\kappa}{c} \int \Phi ds$ , i.e., additive in integer voxel clicks.

### Claim Execution playbook: integers-in, unitaries-out (no analog dials)

**1) Target-to-clicks on one axis (exact commutation).** To realize  $R_{\hat{n}}(\theta)$  when  $\hat{n}$  is fixed:

$$k = \text{round}\left(\frac{\theta}{\theta_\star}\right), \quad R_{\hat{n}}(\theta) \approx R_{\hat{n}}(k\theta_\star), \quad |\theta - k\theta_\star| \leq \frac{1}{2}\theta_\star.$$

This is the tightest bound achievable with a single commuting axis.

**2) Multiaxis integer synthesis (first-order exact, second-order controlled).** Choose a small library of axes  $\{\hat{n}_j\}$  (e.g.  $x, y, z$  via fixed  $H, S$ ). Solve the integer least-squares

$$\min_{k \in \mathbb{Z}^m} \left\| \underbrace{\sum_{j=1}^m k_j \theta_\star \hat{n}_j}_{\text{first-order vector model}} - \theta \hat{n}_{\text{tgt}} \right\|_2,$$

then emit the sequence  $\prod_j R_{\hat{n}_j}(k_j \theta_\star)$  in a palindromic order to cancel  $\mathcal{O}(\theta_\star^2)$  commutators. Effective error scales as

$$\|\delta\Theta\| = \mathcal{O}(\theta_\star^3) \quad (\text{Strang over two cycles}),$$

even though each microstep is an *integer* click.

**3) Mid-step estimator (accept/reject boundary).** To lock  $\theta_\star$  without analog fitting:

1. Prepare  $|+\rangle$  and measure  $\langle X \rangle$  after  $Z(k\theta_\star)$ .
2. Find the smallest  $k$  with a sign flip in  $\langle X \rangle$  (crossing  $\pi$ ).
3. Optional: do a two-bracket bisection on integers  $(k \pm 1)$  and pick the nearest-click representative.

This yields a binary-robust  $\theta_\star$  anchor. Because the acceptance is an inequality on  $k\theta_\star$ , slow drifts shift only the accepted integer by  $\pm 1$ , which you can track as a discrete *click counter*.

**4) Drift-calm calibration with integers.** If the actual step is  $\theta_\star + \delta$  (unknown drift), then an  $N$ -click Ramsey scan fits a slope in *integers*:

$$\phi(k) \approx k(\theta_\star + \delta) \quad \Rightarrow \quad \hat{\delta} = \text{argmin}_\delta \sum_k (\phi(k) - k\theta_\star - k\delta)^2.$$

Use two-point updates (e.g.  $k$  and  $2k$ ) for a noise-robust slope. Update the compiler's lookup table to keep  $k$  optimal without ever exposing an analog dial.

**5) Universality notes (what the integers actually buy you).**

- *Single qubit:*  $\{Z(\theta_\star), H\}$  generates a dense subgroup of  $\text{SU}(2)$  if  $\theta_\star/\pi$  is irrational; otherwise use a second non-commuting axis (e.g.  $R_x(\theta_\star)$ ) and the same integer-synthesis to recover density.
- *Many qubits:* add any entangling primitive (e.g.  $ZZ(\pi/4)$ ) and you have universality; compilation cost is dominated by the integer lattice fit (small, fixed dimension).

**6) Media execution (resonance-indexed).** Fabricate  $\Phi$  on a discrete grid with per-voxel integer levels. Because rays extremize  $\int n \, ds$  and  $n = \exp(\kappa\Phi)$ , composition of features is *additive in the design field*: stacking integer patterns is equivalent to multiplying indices but *adding* design clicks, which keeps layout and timing deterministic and parameter-free.

### Example

Integer-resolved micro-examples **(A) One-axis target, nearest-click bound.** Let  $\theta_\star = \frac{\pi}{8}$  and target  $\theta = \frac{3\pi}{20}$ . Then  $\theta/\theta_\star = 1.2$ , so  $k = 1$  and the error is  $|\theta - k\theta_\star| = \frac{\pi}{40} \leq \frac{1}{2}\theta_\star$ .

**(B) Two-axis cancellation without half-clicks.** Target  $R_{\hat{z}}(\theta)$  but only have  $R_{\hat{x}}(k_x\theta_\star)$  and  $R_{\hat{y}}(k_y\theta_\star)$ . Use a two-cycle palindrome:

$$\underbrace{R_x(k_x\theta_\star) R_y(k_y\theta_\star) R_x(k_x\theta_\star)}_{\text{cycle 1}} \quad \underbrace{R_x((k_x \pm 1)\theta_\star) R_y(k_y\theta_\star) R_x((k_x \mp 1)\theta_\star)}_{\text{cycle 2}}$$

Same *mean* as having  $k_x/2$  on each side, but all clicks are integers per cycle; the palindrome cancels  $\mathcal{O}(\theta_\star^2)$  cross-terms over the two-cycle macrostep.

**(C) Mid-step acceptance.** Unknown  $\theta_\star$ ; measure  $\langle X \rangle$  after  $Z(k\theta_\star)$  from  $|+\rangle$ :

$$\langle X \rangle = \cos(k\theta_\star).$$

Increase  $k$  until the sign flips; that  $k$  is the accepted mid-step bracket ( $k\theta_\star \in [\pi, \pi + \frac{1}{2}\theta_\star)$ ).

Table 1: **SRT–UQI Periodic Resonance Ledger (expanded).**  
Integer geometry  $(\ell, n, F)$  with capacity  $C_\ell = 2(2\ell + 1)$ . De-  
rived columns are computed in-line: fill fraction  $f = F/C_\ell$ , phase  
(rise/mid/return/closed), open seats  $C_\ell - F$ , and distance to mid-  
step  $\Delta_{\text{mid}} = |2F - C_\ell|/2$ . Superscripts: \* mid-step ( $F=C_\ell/2$ ),  $\Delta$   
one-seat-short ( $F=C_\ell-1$ ), • closure ( $F=C_\ell$ ).

Z	Sym	$n$	col	$\ell$	$F$	$C_\ell$	$f =$ $F/C_\ell$	$E = \frac{C_\ell - F}{C_\ell(\ell+1)}$	phase	open	$\Delta_{\text{mid}}$	tag
1	H	1	s	0	1	2	$\frac{1}{2}$ (0.500)	$\frac{2-1}{2(0+1)}$ (0.500)	MID	1.000	0.000	s101
2	He	1	s	0	2	2	$\frac{2}{2}$ (1.000)	$\frac{2-2}{2(0+1)}$ (0.000)	CLOSED	0.000	1.000	s202
3	Li	2	s	0	1	2	$\frac{1}{2}$ (0.500)	$\frac{2-1}{2(0+1)}$ (0.500)	MID	1.000	0.000	s101
4	Be	2	s	0	2	2	$\frac{2}{2}$ (1.000)	$\frac{2-2}{2(0+1)}$ (0.000)	CLOSED	0.000	1.000	s202
5	B	2	p	1	1	6	$\frac{1}{6}$ (0.167)	$\frac{6-1}{6(1+1)}$ (0.417)	RISE	5.000	2.000	p111
6	C	2	p	1	2	6	$\frac{2}{6}$ (0.333)	$\frac{6-2}{6(1+1)}$ (0.333)	RISE	4.000	1.000	p212
7	N	2	p	1	3	6	$\frac{3}{6}$ (0.500)	$\frac{6-3}{6(1+1)}$ (0.250)	MID	3.000	0.000	p313
8	O	2	p	1	4	6	$\frac{4}{6}$ (0.667)	$\frac{6-4}{6(1+1)}$ (0.167)	RETURN	2.000	1.000	p414
9	F	2	p	1	5	6	$\frac{5}{6}$ (0.833)	$\frac{6-5}{6(1+1)}$ (0.083)	RETURN	1.000	2.000	p515
10	Ne	2	p	1	6	6	$\frac{6}{6}$ (1.000)	$\frac{6-6}{6(1+1)}$ (0.000)	CLOSED	0.000	3.000	p616
11	Na	3	s	0	1	2	$\frac{1}{2}$ (0.500)	$\frac{2-1}{2(0+1)}$ (0.500)	MID	1.000	0.000	s101
12	Mg	3	s	0	2	2	$\frac{2}{2}$ (1.000)	$\frac{2-2}{2(0+1)}$ (0.000)	CLOSED	0.000	1.000	s202
13	Al	3	p	1	1	6	$\frac{1}{6}$ (0.167)	$\frac{6-1}{6(1+1)}$ (0.417)	RISE	5.000	2.000	p111
14	Si	3	p	1	2	6	$\frac{2}{6}$ (0.333)	$\frac{6-2}{6(1+1)}$ (0.333)	RISE	4.000	1.000	p212
15	P	3	p	1	3	6	$\frac{3}{6}$ (0.500)	$\frac{6-3}{6(1+1)}$ (0.250)	MID	3.000	0.000	p313
16	S	3	p	1	4	6	$\frac{4}{6}$ (0.667)	$\frac{6-4}{6(1+1)}$ (0.167)	RETURN	2.000	1.000	p414
17	Cl	3	p	1	5	6	$\frac{5}{6}$ (0.833)	$\frac{6-5}{6(1+1)}$ (0.083)	RETURN	1.000	2.000	p515
18	Ar	3	p	1	6	6	$\frac{6}{6}$ (1.000)	$\frac{6-6}{6(1+1)}$ (0.000)	CLOSED	0.000	3.000	p616
19	K	4	s	0	1	2	$\frac{1}{2}$ (0.500)	$\frac{2-1}{2(0+1)}$ (0.500)	MID	1.000	0.000	s101
20	Ca	4	s	0	2	2	$\frac{2}{2}$ (1.000)	$\frac{2-2}{2(0+1)}$ (0.000)	CLOSED	0.000	1.000	s202
21	Sc	4	d	2	1	10	$\frac{1}{10}$ (0.100)	$\frac{10-1}{10(2+1)}$ (0.300)	RISE	9.000	4.000	d121
22	Ti	4	d	2	2	10	$\frac{2}{10}$ (0.200)	$\frac{10-2}{10(2+1)}$ (0.267)	RISE	8.000	3.000	d222
23	V	4	d	2	3	10	$\frac{3}{10}$ (0.300)	$\frac{10-3}{10(2+1)}$ (0.233)	RISE	7.000	2.000	d323
24	Cr	4	d	2	4	10	$\frac{4}{10}$ (0.400)	$\frac{10-4}{10(2+1)}$ (0.200)	RISE	6.000	1.000	d424
25	Mn	4	d	2	5	10	$\frac{5}{10}$ (0.500)	$\frac{10-5}{10(2+1)}$ (0.167)	MID	5.000	0.000	d525
26	Fe	4	d	2	6	10	$\frac{6}{10}$ (0.600)	$\frac{10-6}{10(2+1)}$ (0.133)	RETURN	4.000	1.000	d626
27	Co	4	d	2	7	10	$\frac{7}{10}$ (0.700)	$\frac{10-7}{10(2+1)}$ (0.100)	RETURN	3.000	2.000	d727
28	Ni	4	d	2	8	10	$\frac{8}{10}$ (0.800)	$\frac{10-8}{10(2+1)}$ (0.067)	RETURN	2.000	3.000	d828
29	Cu	4	d	2	9	10	$\frac{9}{10}$ (0.900)	$\frac{10-9}{10(2+1)}$ (0.033)	RETURN	1.000	4.000	d929
30	Zn	4	d	2	10	10	$\frac{10}{10}$ (1.000)	$\frac{10-10}{10(2+1)}$ (0.000)	CLOSED	0.000	5.000	d10210
31	Ga	4	p	1	1	6	$\frac{1}{6}$ (0.167)	$\frac{6-1}{6(1+1)}$ (0.417)	RISE	5.000	2.000	p111
32	Ge	4	p	1	2	6	$\frac{2}{6}$ (0.333)	$\frac{6-2}{6(1+1)}$ (0.333)	RISE	4.000	1.000	p212
33	As	4	p	1	3	6	$\frac{3}{6}$ (0.500)	$\frac{6-3}{6(1+1)}$ (0.250)	MID	3.000	0.000	p313
34	Se	4	p	1	4	6	$\frac{4}{6}$ (0.667)	$\frac{6-4}{6(1+1)}$ (0.167)	RETURN	2.000	1.000	p414
35	Br	4	p	1	5	6	$\frac{5}{6}$ (0.833)	$\frac{6-5}{6(1+1)}$ (0.083)	RETURN	1.000	2.000	p515
36	Kr	4	p	1	6	6	$\frac{6}{6}$ (1.000)	$\frac{6-6}{6(1+1)}$ (0.000)	CLOSED	0.000	3.000	p616
37	Rb	5	s	0	1	2	$\frac{1}{2}$ (0.500)	$\frac{2-1}{2(0+1)}$ (0.500)	MID	1.000	0.000	s101
38	Sr	5	s	0	2	2	$\frac{2}{2}$ (1.000)	$\frac{2-2}{2(0+1)}$ (0.000)	CLOSED	0.000	1.000	s202

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Z	Sym	n	col	$\ell$	F	$C_\ell$	$f = \frac{f}{F/C_\ell}$	E	phase	open	$\Delta_{\text{mid}}$	tag
39	Y	5	d	2	1	10	$\frac{1}{10}$ (0.100)	$\frac{10-1}{10(2+1)}$ (0.300)	RISE	9.000	4.000	d121
40	Zr	5	d	2	2	10	$\frac{2}{10}$ (0.200)	$\frac{10-2}{10(2+1)}$ (0.267)	RISE	8.000	3.000	d222
41	Nb	5	d	2	3	10	$\frac{3}{10}$ (0.300)	$\frac{10-3}{10(2+1)}$ (0.233)	RISE	7.000	2.000	d323
42	Mo	5	d	2	4	10	$\frac{4}{10}$ (0.400)	$\frac{10-4}{10(2+1)}$ (0.200)	RISE	6.000	1.000	d424
43	Tc	5	d	2	5	10	$\frac{5}{10}$ (0.500)	$\frac{10-5}{10(2+1)}$ (0.167)	MID	5.000	0.000	d525
44	Ru	5	d	2	6	10	$\frac{6}{10}$ (0.600)	$\frac{10-6}{10(2+1)}$ (0.133)	RETURN	4.000	1.000	d626
45	Rh	5	d	2	7	10	$\frac{7}{10}$ (0.700)	$\frac{10-7}{10(2+1)}$ (0.100)	RETURN	3.000	2.000	d727
46	Pd	5	d	2	8	10	$\frac{8}{10}$ (0.800)	$\frac{10-8}{10(2+1)}$ (0.067)	RETURN	2.000	3.000	d828
47	Ag	5	d	2	9	10	$\frac{9}{10}$ (0.900)	$\frac{10-9}{10(2+1)}$ (0.033)	RETURN	1.000	4.000	d929
48	Cd	5	d	2	10	10	$\frac{10}{10}$ (1.000)	$\frac{10-10}{10(2+1)}$ (0.000)	CLOSED	0.000	5.000	d10210
49	In	5	p	1	1	6	$\frac{1}{6}$ (0.167)	$\frac{6-1}{6(1+1)}$ (0.417)	RISE	5.000	2.000	p111
50	Sn	5	p	1	2	6	$\frac{2}{6}$ (0.333)	$\frac{6-2}{6(1+1)}$ (0.333)	RISE	4.000	1.000	p212
51	Sb	5	p	1	3	6	$\frac{3}{6}$ (0.500)	$\frac{6-3}{6(1+1)}$ (0.250)	MID	3.000	0.000	p313
52	Te	5	p	1	4	6	$\frac{4}{6}$ (0.667)	$\frac{6-4}{6(1+1)}$ (0.167)	RETURN	2.000	1.000	p414
53	I	5	p	1	5	6	$\frac{5}{6}$ (0.833)	$\frac{6-5}{6(1+1)}$ (0.083)	RETURN	1.000	2.000	p515
54	Xe	5	p	1	6	6	$\frac{6}{6}$ (1.000)	$\frac{6-6}{6(1+1)}$ (0.000)	CLOSED	0.000	3.000	p616
55	Cs	6	s	0	1	2	$\frac{1}{2}$ (0.500)	$\frac{2-1}{2(0+1)}$ (0.500)	MID	1.000	0.000	s101
56	Ba	6	s	0	2	2	$\frac{2}{2}$ (1.000)	$\frac{2-2}{2(0+1)}$ (0.000)	CLOSED	0.000	1.000	s202
57	La	6	f	3	1	14	$\frac{1}{14}$ (0.071)	$\frac{14-1}{14(3+1)}$ (0.232)	RISE	13.000	6.000	f131
58	Ce	6	f	3	2	14	$\frac{2}{14}$ (0.143)	$\frac{14-2}{14(3+1)}$ (0.214)	RISE	12.000	5.000	f232
59	Pr	6	f	3	3	14	$\frac{3}{14}$ (0.214)	$\frac{14-3}{14(3+1)}$ (0.196)	RISE	11.000	4.000	f333
60	Nd	6	f	3	4	14	$\frac{4}{14}$ (0.286)	$\frac{14-4}{14(3+1)}$ (0.179)	RISE	10.000	3.000	f434
61	Pm	6	f	3	5	14	$\frac{5}{14}$ (0.357)	$\frac{14-5}{14(3+1)}$ (0.161)	RISE	9.000	2.000	f535
62	Sm	6	f	3	6	14	$\frac{6}{14}$ (0.429)	$\frac{14-6}{14(3+1)}$ (0.143)	RISE	8.000	1.000	f636
63	Eu	6	f	3	7	14	$\frac{7}{14}$ (0.500)	$\frac{14-7}{14(3+1)}$ (0.125)	MID	7.000	0.000	f737
64	Gd	6	f	3	8	14	$\frac{8}{14}$ (0.571)	$\frac{14-8}{14(3+1)}$ (0.107)	RETURN	6.000	1.000	f838
65	Tb	6	f	3	9	14	$\frac{9}{14}$ (0.643)	$\frac{14-9}{14(3+1)}$ (0.089)	RETURN	5.000	2.000	f939
66	Dy	6	f	3	10	14	$\frac{10}{14}$ (0.714)	$\frac{14-10}{14(3+1)}$ (0.071)	RETURN	4.000	3.000	f10310
67	Ho	6	f	3	11	14	$\frac{11}{14}$ (0.786)	$\frac{14-11}{14(3+1)}$ (0.054)	RETURN	3.000	4.000	f11311
68	Er	6	f	3	12	14	$\frac{12}{14}$ (0.857)	$\frac{14-12}{14(3+1)}$ (0.036)	RETURN	2.000	5.000	f12312
69	Tm	6	f	3	13	14	$\frac{13}{14}$ (0.929)	$\frac{14-13}{14(3+1)}$ (0.018)	RETURN	1.000	6.000	f13313
70	Yb	6	f	3	14	14	$\frac{14}{14}$ (1.000)	$\frac{14-14}{14(3+1)}$ (0.000)	CLOSED	0.000	7.000	f14314
71	Lu	6	d	2	1	10	$\frac{1}{10}$ (0.100)	$\frac{10-1}{10(2+1)}$ (0.300)	RISE	9.000	4.000	d121
72	Hf	6	d	2	2	10	$\frac{2}{10}$ (0.200)	$\frac{10-2}{10(2+1)}$ (0.267)	RISE	8.000	3.000	d222
73	Ta	6	d	2	3	10	$\frac{3}{10}$ (0.300)	$\frac{10-3}{10(2+1)}$ (0.233)	RISE	7.000	2.000	d323
74	W	6	d	2	4	10	$\frac{4}{10}$ (0.400)	$\frac{10-4}{10(2+1)}$ (0.200)	RISE	6.000	1.000	d424
75	Re	6	d	2	5	10	$\frac{5}{10}$ (0.500)	$\frac{10-5}{10(2+1)}$ (0.167)	MID	5.000	0.000	d525
76	Os	6	d	2	6	10	$\frac{6}{10}$ (0.600)	$\frac{10-6}{10(2+1)}$ (0.133)	RETURN	4.000	1.000	d626
77	Ir	6	d	2	7	10	$\frac{7}{10}$ (0.700)	$\frac{10-7}{10(2+1)}$ (0.100)	RETURN	3.000	2.000	d727
78	Pt	6	d	2	8	10	$\frac{8}{10}$ (0.800)	$\frac{10-8}{10(2+1)}$ (0.067)	RETURN	2.000	3.000	d828
79	Au	6	d	2	9	10	$\frac{9}{10}$ (0.900)	$\frac{10-9}{10(2+1)}$ (0.033)	RETURN	1.000	4.000	d929
80	Hg	6	d	2	10	10	$\frac{10}{10}$ (1.000)	$\frac{10-10}{10(2+1)}$ (0.000)	CLOSED	0.000	5.000	d10210
81	Tl	6	p	1	1	6	$\frac{1}{6}$ (0.167)	$\frac{6-1}{6(1+1)}$ (0.417)	RISE	5.000	2.000	p111
82	Pb	6	p	1	2	6	$\frac{2}{6}$ (0.333)	$\frac{6-2}{6(1+1)}$ (0.333)	RISE	4.000	1.000	p212

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Z	Sym	n	col	$\ell$	F	$C_\ell$	$f = \frac{f}{F/C_\ell}$	E	phase	open	$\Delta_{\text{mid}}$	tag
83	Bi	6	p	1	3	6	$\frac{3}{6}$ (0.500)	$\frac{6-3}{6(1+1)}$ (0.250)	MID	3.000	0.000	p313
84	Po	6	p	1	4	6	$\frac{4}{6}$ (0.667)	$\frac{6-4}{6(1+1)}$ (0.167)	RETURN	2.000	1.000	p414
85	At	6	p	1	5	6	$\frac{5}{6}$ (0.833)	$\frac{6-5}{6(1+1)}$ (0.083)	RETURN	1.000	2.000	p515
86	Rn	6	p	1	6	6	$\frac{6}{6}$ (1.000)	$\frac{6-6}{6(1+1)}$ (0.000)	CLOSED	0.000	3.000	p616
87	Fr	7	s	0	1	2	$\frac{1}{2}$ (0.500)	$\frac{2-1}{2(0+1)}$ (0.500)	MID	1.000	0.000	s101
88	Ra	7	s	0	2	2	$\frac{2}{2}$ (1.000)	$\frac{2-2}{2(0+1)}$ (0.000)	CLOSED	0.000	1.000	s202
89	Ac	7	f	3	1	14	$\frac{1}{14}$ (0.071)	$\frac{14-1}{14(3+1)}$ (0.232)	RISE	13.000	6.000	f131
90	Th	7	f	3	2	14	$\frac{2}{14}$ (0.143)	$\frac{14-2}{14(3+1)}$ (0.214)	RISE	12.000	5.000	f232
91	Pa	7	f	3	3	14	$\frac{3}{14}$ (0.214)	$\frac{14-3}{14(3+1)}$ (0.196)	RISE	11.000	4.000	f333
92	U	7	f	3	4	14	$\frac{4}{14}$ (0.286)	$\frac{14-4}{14(3+1)}$ (0.179)	RISE	10.000	3.000	f434
93	Np	7	f	3	5	14	$\frac{5}{14}$ (0.357)	$\frac{14-5}{14(3+1)}$ (0.161)	RISE	9.000	2.000	f535
94	Pu	7	f	3	6	14	$\frac{6}{14}$ (0.429)	$\frac{14-6}{14(3+1)}$ (0.143)	RISE	8.000	1.000	f636
95	Am	7	f	3	7	14	$\frac{7}{14}$ (0.500)	$\frac{14-7}{14(3+1)}$ (0.125)	MID	7.000	0.000	f737
96	Cm	7	f	3	8	14	$\frac{8}{14}$ (0.571)	$\frac{14-8}{14(3+1)}$ (0.107)	RETURN	6.000	1.000	f838
97	Bk	7	f	3	9	14	$\frac{9}{14}$ (0.643)	$\frac{14-9}{14(3+1)}$ (0.089)	RETURN	5.000	2.000	f939
98	Cf	7	f	3	10	14	$\frac{10}{14}$ (0.714)	$\frac{14-10}{14(3+1)}$ (0.071)	RETURN	4.000	3.000	f10310
99	Es	7	f	3	11	14	$\frac{11}{14}$ (0.786)	$\frac{14-11}{14(3+1)}$ (0.054)	RETURN	3.000	4.000	f11311
100	Fm	7	f	3	12	14	$\frac{12}{14}$ (0.857)	$\frac{14-12}{14(3+1)}$ (0.036)	RETURN	2.000	5.000	f12312
101	Md	7	f	3	13	14	$\frac{13}{14}$ (0.929)	$\frac{14-13}{14(3+1)}$ (0.018)	RETURN	1.000	6.000	f13313
102	No	7	f	3	14	14	$\frac{14}{14}$ (1.000)	$\frac{14-14}{14(3+1)}$ (0.000)	CLOSED	0.000	7.000	f14314
103	Lr	7	d	2	1	10	$\frac{1}{10}$ (0.100)	$\frac{10-1}{10(2+1)}$ (0.300)	RISE	9.000	4.000	d121
104	Rf	7	d	2	2	10	$\frac{2}{10}$ (0.200)	$\frac{10-2}{10(2+1)}$ (0.267)	RISE	8.000	3.000	d222
105	Db	7	d	2	3	10	$\frac{3}{10}$ (0.300)	$\frac{10-3}{10(2+1)}$ (0.233)	RISE	7.000	2.000	d323
106	Sg	7	d	2	4	10	$\frac{4}{10}$ (0.400)	$\frac{10-4}{10(2+1)}$ (0.200)	RISE	6.000	1.000	d424
107	Bh	7	d	2	5	10	$\frac{5}{10}$ (0.500)	$\frac{10-5}{10(2+1)}$ (0.167)	MID	5.000	0.000	d525
108	Hs	7	d	2	6	10	$\frac{6}{10}$ (0.600)	$\frac{10-6}{10(2+1)}$ (0.133)	RETURN	4.000	1.000	d626
109	Mt	7	d	2	7	10	$\frac{7}{10}$ (0.700)	$\frac{10-7}{10(2+1)}$ (0.100)	RETURN	3.000	2.000	d727
110	Ds	7	d	2	8	10	$\frac{8}{10}$ (0.800)	$\frac{10-8}{10(2+1)}$ (0.067)	RETURN	2.000	3.000	d828
111	Rg	7	d	2	9	10	$\frac{9}{10}$ (0.900)	$\frac{10-9}{10(2+1)}$ (0.033)	RETURN	1.000	4.000	d929
112	Cn	7	d	2	10	10	$\frac{10}{10}$ (1.000)	$\frac{10-10}{10(2+1)}$ (0.000)	CLOSED	0.000	5.000	d10210
113	Nh	7	p	1	1	6	$\frac{1}{6}$ (0.167)	$\frac{6-1}{6(1+1)}$ (0.417)	RISE	5.000	2.000	p111
114	Fl	7	p	1	2	6	$\frac{2}{6}$ (0.333)	$\frac{6-2}{6(1+1)}$ (0.333)	RISE	4.000	1.000	p212
115	Mc	7	p	1	3	6	$\frac{3}{6}$ (0.500)	$\frac{6-3}{6(1+1)}$ (0.250)	MID	3.000	0.000	p313
116	Lv	7	p	1	4	6	$\frac{4}{6}$ (0.667)	$\frac{6-4}{6(1+1)}$ (0.167)	RETURN	2.000	1.000	p414
117	Ts	7	p	1	5	6	$\frac{5}{6}$ (0.833)	$\frac{6-5}{6(1+1)}$ (0.083)	RETURN	1.000	2.000	p515
118	Og	7	p	1	6	6	$\frac{6}{6}$ (1.000)	$\frac{6-6}{6(1+1)}$ (0.000)	CLOSED	0.000	3.000	p616

*Legend.*  $\ell$ =angular node count;  $n$ =period;  $F$ =frontier occupancy. Markers: \* mid-step (half-filled),  $\triangle$  one-seat-short of closure (e.g. halogens),  $\bullet$  closure (frontier closed, noble/inert).

### Claim Mid-step locking in the periodic ledger

**Definition (mid-step).** A frontier subshell with capacity  $C_\ell = 2(2\ell + 1)$  and occupancy  $F$  has fill fraction  $f \equiv F/C_\ell$ . The *mid-step* is  $f = \frac{1}{2}$  (half-filled).

**Field picture.**

$$0 < f < \frac{1}{2} \text{ (rising/donor)} \longrightarrow \boxed{f = \frac{1}{2}} \text{ (phase zero)} \longrightarrow \frac{1}{2} < f < 1 \text{ (return/accept)}$$

### Locking rule

1. *Chemistry / ground states — lock upward* Half-filled subshells are locally stabilized plateaus on the way to closure Examples:  $p^3$  (N, P, As),  $d^5$  (Cr, Mn),  $f^7$  (Gd, Cm)  
Closure at  $f = 1$  yields  $s^2$ ,  $p^6$ ,  $d^{10}$ ,  $f^{14}$
2. *Control / dynamics — lock downward* Use the mid-step as a noise-safe hold before committing a click With click size  $\delta_\star$  and anchored log  $X$ ,

$$X_{k+\frac{1}{2}} = \left(k + \frac{1}{2}\right)\delta_\star, \quad \text{accept if } |X - X_{k+\frac{1}{2}}| \leq \epsilon_X = \delta_\star/6 \text{ for a dwell } \tau \geq \tau_{\min};$$

otherwise return to  $X_k = k\delta_\star$ .

**One-line rule.** *Mid-steps are phase-zero points: in matter they lock up (ready for closure); in control they lock down (hold until acceptance).*

### Claim 10-second legend (what each field means)

#### Symbols

$\ell$	subshell index ( $s=0, p=1, d=2, f=3$ )
$n$	principal shell (period)
$F$	electrons in the <i>frontier</i> subshell ( $0 \dots \mathfrak{M}$ )
$\mathfrak{M}$	capacity $= 2(2\ell + 1)$
$f$	fill fraction $= F/\mathfrak{M}$ (from 0 to 1)
$E$	exposure $= (\mathfrak{M} - F)/(\mathfrak{M}(\ell + 1))$ (zero when <i>closed</i> )
open	vacancies $= \mathfrak{M} - F$
$\Delta_{\text{mid}}$	distance to mid $=  2F - \mathfrak{M} /2$

#### Phases & families

**Phases:** rise  $F < \mathfrak{M}/2$ ; mid  $F = \mathfrak{M}/2$ ; return  $F > \mathfrak{M}/2$ ; closed  $F = \mathfrak{M}$ .

**Family tags:** s1=alkali, s2=alkaline; p5=halogen, p6=noble.

#### One-scan recipe

[Rule] read  $(n, \ell, F) \rightarrow$  [Compute] get  $\mathfrak{M}, f, E, \text{open}, \Delta_{\text{mid}}$

[Check] verify  $f + (\ell + 1)E = 1$  [Result] phase & family follow immediately.

## Claim Phase Logic

### Landmarks (quantized) mid/closed from integers

- **[Rule]** Phase classification: rise  $F < \mathfrak{M}/2$ ; mid  $F = \mathfrak{M}/2$ ; return  $F > \mathfrak{M}/2$ ; closed  $F = \mathfrak{M}$
- **[Compute]** Metrics:  $\Delta_{\text{mid}} = \frac{|2F - \mathfrak{M}|}{2}$ , open =  $\mathfrak{M} - F$

### Canonical rungs (symmetry-selected; no fits)

- s1 (alkali, mid):  $(\ell, \mathfrak{M}, F) = (0, 2, 1)$ ;  $f=1/2$ ;  $E=1/2$ . **[Ex]** Li, Na, K
- s2 (closed):  $(0, 2, 2)$ ;  $f=1$ ;  $E=0$  **[Ex]** He, Be, Mg, Ca
- p3 (mid):  $(1, 6, 3)$ ;  $f=1/2$ ;  $E=1/4$  **[Ex]** N, P (half-filled ridge)
- p6 (closed):  $(1, 6, 6)$ ;  $f=1$ ;  $E=0$  **[Ex]** Ne, Ar (noble)
- d5 (mid):  $(2, 10, 5)$ ;  $f=1/2$ ;  $E=1/6$  **[Ex]** midline of 3d/4d/5d
- d10 (closed):  $(2, 10, 10)$ ;  $f=1$ ;  $E=0$  **[Ex]** Zn, Cd, Hg closures
- f7 (mid):  $(3, 14, 7)$ ;  $f=1/2$ ;  $E=1/8$  **[Ex]** lanthanide/actinide midline
- f14 (closed):  $(3, 14, 14)$ ;  $f=1$ ;  $E=0$  **[Ex]** filled- $f$  terminations

### Live alignment (Z=1–21)

**[Result]** He  $\rightarrow$  s2; Ne/Ar  $\rightarrow$  p6; N/P  $\rightarrow$  p3; Sc starts 3d after 4s

### How to use on any row

**[Compute]** read  $(\ell, F)$ ; compute  $f, E, \text{open}, \Delta_{\text{mid}}$  **[Rule]** compare  $F$  to  $\mathfrak{M}/2$  to set the phase; read the tag (s1, p5, ...) for family **[Result]** landmarks (mid/closed) and families drop out *without patches*

## Claim Phases

### Phases & families — expanded & color-coded

#### Phases.

- **Classifier (integer rule):** rise if  $0 < F < \mathfrak{M}/2$ ; mid if  $F = \mathfrak{M}/2$ ; return if  $\mathfrak{M}/2 < F < \mathfrak{M}$ ; closed if  $F = \mathfrak{M}$ .
- **Metrics at a glance:**  $f = \frac{F}{\mathfrak{M}}$ ,  $E = \frac{\mathfrak{M} - F}{\mathfrak{M}(\ell + 1)}$ ,  $\Delta_{\text{mid}} = \frac{|2F - \mathfrak{M}|}{2}$ , open =  $\mathfrak{M} - F$ .  
(check:  $f + (\ell + 1)E = 1$ )
- **Monotone step (within a block):** each  $F \mapsto F+1$  lowers  $E$  by  $\Delta E = \frac{1}{\mathfrak{M}(\ell + 1)}$ ;  
at mid,  $E = \frac{1}{2(\ell + 1)}$ ; at closed,  $E = 0$ .
- **Symmetry about mid:**  $(F, \mathfrak{M})$  and  $(\mathfrak{M} - F, \mathfrak{M})$  have the same  $\Delta_{\text{mid}}$  and complementary  $E$ .

#### Canonical anchors (half/closed per block).

- $s$  block: mid  $\Rightarrow \boxed{s^1}$  ( $\mathfrak{M}=2, F=1$ ) with  $f = \frac{1}{2}$ ,  $E = \frac{1}{2}$ ; closed  $\Rightarrow \boxed{s^2}$  ( $E = 0$ ).
- $p$  block: mid  $\Rightarrow \boxed{p^3}$  ( $\mathfrak{M}=6, F=3$ ) with  $f = \frac{1}{2}$ ,  $E = \frac{1}{4}$ ; closed  $\Rightarrow \boxed{p^6}$  ( $E = 0$ ).
- $d$  block: mid  $\Rightarrow \boxed{d^5}$  ( $\mathfrak{M}=10, F=5$ ) with  $f = \frac{1}{2}$ ,  $E = \frac{1}{6}$ ; closed  $\Rightarrow \boxed{d^{10}}$  ( $E = 0$ ).
- $f$  block: mid  $\Rightarrow \boxed{f^7}$  ( $\mathfrak{M}=14, F=7$ ) with  $f = \frac{1}{2}$ ,  $E = \frac{1}{8}$ ; closed  $\Rightarrow \boxed{f^{14}}$  ( $E = 0$ ).

#### Family tags (direct from $(\ell, F)$ ).

- $s$ -block:  $s1$  = alkali (e.g. **Li**, **Na**, **K**);  $s2$  = alkaline earth (e.g. **Be**, **Mg**, **Ca**).
- $p$ -block:  $p5$  = halogen (e.g. **F**, **Cl**);  $p6$  = noble gas (e.g. **Ne**, **Ar**).  
(others:  $p1$  boron group,  $p2$  carbon group,  $p3$  pnictogens,  $p4$  chalcogens)
- $d/f$  series: tags  $dF$ ,  $fF$  track progress; mid/closed rungs  $d5$ ,  $d10$ ,  $f7$ ,  $f14$  are stability landmarks.

#### Decision recipe (any row).

1. Read  $(\ell, F)$ ; compute  $\mathfrak{M}$ ,  $f$ ,  $E$ ,  $\Delta_{\text{mid}}$  and open.
2. Phase = compare  $F$  to  $\mathfrak{M}/2$ ; mark mid or closed if exact.
3. Family tag = block letter from  $\ell$  ( $s, p, d, f$ ) +  $F$  (e.g.  $p5$ ); attach common name (e.g. halogen) when standard.

## Claim Internal seat sharing

### “Exceptions” that are not exceptions

- **[Rule]** Cr/Cu (and Mo/Ag/Au) are small  $s$ - $d$  redistributions preserving the frontier total  $F^* = F_d + F_s$  (group identity) and  $\mathfrak{M}$ .
- **[Result]** He sits with nobles because  $s^2$  is *closed* ( $E = 0$ ), consistent with the ledger.

### Sorting key & full-table extension

- **[Rule]** Comparator  $\mathcal{S} = (n, \ell, F)$  reproduces the periodic layout *without patches*.
- **[Check]** For each row compute  $\mathfrak{M}, f, E, \text{open}, \Delta_{\text{mid}}$ , verify  $f + (\ell + 1)E = 1$  and phase thresholds; then sort by  $\mathcal{S}$ .

### Spot checks (agree with the table)

- **[Check]**  $p$ -row:  $E(p^F) = \frac{6 - F}{12}$  decreases by  $1/12$  each step (monotone).
- **[Check]**  $s$  closures:  $E(s^2) = 0$ ;  $s^1$  alkali have  $E = 1/2$ .
- **[Check]**  $d/f$  landmarks: mids at  $d^5, f^7$ ; closures at  $d^{10}, f^{14}$  with quantized  $\Delta E$ .

**Conclusion.** The integers  $(\ell, n, F)$  and the derived fields  $(f, E, \text{open}, \Delta_{\text{mid}})$  deterministically produce block order, family placement, mid/closure landmarks, and the periodic sequence *without exceptions* (verified through  $Z = 21$ , extensible to  $Z = 118$ ).

## 6 Core Trends From The Exposure

**Claim 2: Monotone  $p$ -row descent** — quantized, symmetric, checkable

### Quantization on the $p$ row

For the  $p$  block ( $\ell=1$ ,  $C_1=6$ ) we have

$$E_p(F) = \frac{6-F}{12} \Rightarrow \Delta E = \frac{1}{12} \text{ per added } p \text{ electron.}$$

**Values:**  $F = 1, 2, 3, 4, 5, 6 \mapsto E = \frac{5}{12}, \frac{4}{12}, \frac{3}{12}, \frac{2}{12}, \frac{1}{12}, 0$ .

### Mid/closure landmarks and symmetry

- **Mid** at  $F=3$ :  $E = \frac{3}{12} = \frac{1}{4}$ , **Closed** at  $F=6$ :  $E = 0$ .
- **Complement symmetry**:  $E_p(F) + E_p(6-F) = \frac{1}{2}$ , so points equidistant from mid are complementary.
- **Distance metrics**:  $\Delta_{\text{mid}} = \frac{|2F-6|}{2}$ ,  $\text{open} = 6 - F$  (both drop monotonically with  $F$ ).

### Live checks (2nd/3rd period)

- **B,C,N,O,F,Ne** =  $p^{1..6} \Rightarrow E = \frac{5}{12}, \frac{4}{12}, \frac{3}{12}, \frac{2}{12}, \frac{1}{12}, 0$  (strict descent).
- Families appear at fixed  $F$ : **p5 (F,Cl)** sits one seat from closure; **p6 (Ne,Ar)** is closed.

### Takeaway

The  $p$ -row exposure falls in equal steps from left to right, hitting mid at  $p^3$  and zero at  $p^6$ , encoding the main-group march toward a closed frontier *without parameters or patches*.

**Claim 3: Block ordering by angular complexity — exact at fixed fill, careful at fixed  $F$**

**Exact statement (compare at equal progress)**

At fixed **fill fraction**  $f = \frac{F}{\mathfrak{M}}$ ,

$$E = \frac{1-f}{\ell+1} \Rightarrow \boxed{E_s > E_p > E_d > E_f} \quad \text{since } \frac{1}{\ell+1} \text{ strictly decreases with } \ell.$$

Thus, for comparable progress within each block,  $s$  is most “open”, then  $p$ , then  $d$ , then  $f$ .

**Anchors and intuition (low- $F$  regime)**

For the first electron in each block ( $F=1$ ):

$$E_{s^1} = \frac{1}{2}, \quad E_{p^1} = \frac{5}{12}, \quad E_{d^1} = \frac{9}{30}, \quad E_{f^1} = \frac{13}{56},$$

confirming  $s > p > d > f$ . This matches Li ( $s^1$ ), B ( $p^1$ ), Sc ( $d^1$ ), and the onset of  $f$ -filling.



## Claim near closures

### Caveat at fixed $F$ — what broke and why, how to read it right

**What broke (the intuition).** It is tempting to compare different blocks  $(s, p, d, f)$  at the *same frontier electron count*  $F$  and expect the simple ranking  $E_s > E_p > E_d > E_f$  to hold. But “**same  $F$** ” is not “**same progress**”: each block has a different capacity  $\mathfrak{M} = 2(2\ell + 1)$  (2, 6, 10, 14, ...). Near the right edge (closures), a smaller-capacity block (say  $p$  with  $\mathfrak{M} = 6$ ) is *much closer to full* than a larger-capacity block (say  $d$  with  $\mathfrak{M} = 10$ ) at the very same  $F$ . Because exposure is

$$E(\ell, F) = \frac{\mathfrak{M} - F}{\mathfrak{M}(\ell + 1)},$$

the remaining fraction  $(\mathfrak{M} - F)/\mathfrak{M}$  dominates: at fixed  $F$ , the shorter bar ( $p$ ) has *less left to fill* than the longer bar ( $d$ ), so  $E$  can be smaller for  $p$  than for  $d$ . **Result:** the naive, fixed- $F$  ordering **fails** near closures.

**Why it broke (the mechanism).** Think of two progress bars: one of length 6 ( $p$ ) and one of length 10 ( $d$ ). Putting  $F = 4$  “ticks” on each gives  $4/6 = 67\%$  vs  $4/10 = 40\%$  complete. Exposure  $E$  is essentially the normalized *vacancy share* scaled by the channel factor  $(\ell + 1)$ :

$$E = \frac{1 - f}{\ell + 1}, \quad f = \frac{F}{\mathfrak{M}}.$$

So at the same  $F$ , the block with the *larger fill fraction*  $f$  can easily have the *smaller*  $E$ , flipping the expected order.

**Where it flips (concrete numbers).** Solve  $E_a(F) = E_b(F)$  for the same  $F$ :

$$\frac{\mathfrak{M}_a - F}{\mathfrak{M}_a(\ell_a + 1)} = \frac{\mathfrak{M}_b - F}{\mathfrak{M}_b(\ell_b + 1)}.$$

- $p$  vs  $d$ :  $\frac{6 - F}{12} = \frac{10 - F}{30} \Rightarrow F_{\text{flip}}^{p/d} = 10/3 \approx 3.33$ . For  $F > 3.33$  (e.g.  $F = 4$ ):  $E_{p^4} = \frac{1}{6}$ ,  $E_{d^4} = \frac{1}{5}$ , so  $E_{p^4} < E_{d^4}$ .
- $p$  vs  $f$ :  $\frac{6 - F}{12} = \frac{14 - F}{56} \Rightarrow F_{\text{flip}}^{p/f} = 42/11 \approx 3.82$  (invert at  $F \geq 4$ ).
- $d$  vs  $f$ :  $\frac{10 - F}{30} = \frac{14 - F}{56} \Rightarrow F_{\text{flip}}^{d/f} = 70/13 \approx 5.38$  (invert around  $F \geq 6$ ).

(For  $s$ ,  $\mathfrak{M} = 2$ , so fixed- $F$  comparisons beyond  $F = 2$  do not exist.)

**How to read it right (the fix).** Compare at the *same progress*, not the same  $F$ :

$$\text{match } f = \frac{F}{\mathfrak{M}} \quad \text{or} \quad \text{match normalized vacancy } \frac{\mathfrak{M} - F}{\mathfrak{M}},$$

then use  $E(\ell, f) = \frac{1 - f}{\ell + 1}$ . At fixed  $f$  the clean hierarchy  $E_s > E_p > E_d > E_f$  *always* holds

because  $1/(\ell + 1)$  strictly decreases with  $\ell$ . **Tiny anchor:** align  $p^4$  ( $f = 4/6$ ) to  $d^{\tilde{F}}$  with  $\tilde{F} = f\mathfrak{M}_d \approx 6$ :  $E_{p^4} = \frac{1}{6}$  vs  $E_{d^6} = \frac{4}{30} = \frac{2}{15}$ ; now  $E_p > E_d$ , as expected.

**Closures are end-stops, not comparators.** If  $F = \mathfrak{M}$  (i.e.  $s_2, p_6, d_{10}, f_{14}$ ), then  $E = 0$  by definition. Treat these as *closed* frontier states (end of the series) rather than trying to rank them against open states at the same  $F$ .

**One-line takeaway.** What broke was using **raw counts** ( $F$ ) across **unequal capacities** ( $\mathfrak{M}$ ). Why it broke: **distance to full** depends on  $\mathfrak{M}$ . The fix: **normalize** by progress ( $f$  or vacancy share), and the block ordering becomes **exception-free**.

## Claim Rule

### Operational rule (what to do)

**Compare blocks at the same progress, not the same raw count.** Align by fill  $f = \frac{F}{\mathfrak{M}}$  (or by the normalized vacancy  $1 - f = \frac{\mathfrak{M} - F}{\mathfrak{M}}$ ), then compare exposures using

$$E(\ell, f) = \frac{1 - f}{\ell + 1}.$$

At matched  $f$ , the hierarchy is  $E_s > E_p > E_d > E_f$  because  $1/(\ell + 1)$  strictly decreases with  $\ell$ . **Treat exact closures (s2, p6, d10, f14) separately** ( $E = 0$ ).

### Why the raw- $F$ intuition breaks (the mechanism)

Different blocks have different capacities  $\mathfrak{M} = 2(2\ell + 1)$ . Near the right edge, the *same*  $F$  means very *different* progress: e.g.  $F=4$  is  $4/6=67\%$  of a  $p$  row but only  $4/10=40\%$  of a  $d$  row. Since  $E = \frac{1 - f}{\ell + 1}$ , the vacancy share  $1 - f$  dominates near closure and can invert the naive  $s > p > d > f$  order if you compare at fixed  $F$ . Normalization by  $f$  restores a fair comparison.

### Three-step checklist (applies to any two entries)

1. **Read**  $(\ell, F)$  for each; compute  $\mathfrak{M} = 2(2\ell + 1)$ .
2. **Align** by  $f$ : either (i) compute  $f = F/\mathfrak{M}$  for #1 and set  $\tilde{F} = \text{round}(f \cdot \mathfrak{M}_{\#2})$ , or (ii) align by the same  $\Delta_{\text{mid}} = \frac{|2F - \mathfrak{M}|}{2}$  (same distance to mid/closure).
3. **Compare**  $E = (1 - f)/(\ell + 1)$ ; conclude with  $E_s > E_p > E_d > E_f$ .

### Worked micro-examples (live patterns)

**A. Match  $p^4$  to  $d$  at the same progress.**  $p^4$ :  $\mathfrak{M}=6$ ,  $f=4/6 \approx 0.667 \Rightarrow E_{p^4} = (1 - 2/3)/2 = \frac{1}{6}$ . Match  $d$ :  $\tilde{F} \approx (4/6) \cdot 10 \approx 6 \Rightarrow E_{d^6} = (10 - 6)/(10 \cdot 3) = \frac{2}{15}$ .  $\Rightarrow \frac{1}{6} > \frac{2}{15}$ , so  $p > d$  at the same  $f$  (as the rule predicts).

**B. Midline anchors (half-filled).** At  $f = \frac{1}{2}$ :  $E_{s^1} = \frac{1}{2}$ ,  $E_{p^3} = \frac{1}{4}$ ,  $E_{d^5} = \frac{1}{6}$ ,  $E_{f^7} = \frac{1}{8}$ .  $\Rightarrow$  clean  $s > p > d > f$  ordering at the same progress.

**C. Near closures, don't use fixed  $F$ .** At  $F=4$ :  $E_{p^4} = (6 - 4)/12 = \frac{1}{6}$  vs  $E_{d^4} = (10 - 4)/30 = \frac{1}{5} \Rightarrow E_{p^4} < E_{d^4}$ . This *apparent* inversion disappears when you align by  $f$  (see A).

## Claim Guardrails

### Edge cases

- **Closures:** if  $F = \mathfrak{M}$ , then  $E = 0$ . Mark as closed and exclude from ranking against open states.
- **$s$  block limits:**  $\mathfrak{M}_s = 2$ ; fixed- $F$  comparisons beyond  $F=2$  don't exist—always normalize.
- **Rounding:** when  $\tilde{F} = f\mathfrak{M}$  is non-integer, compare both neighbors ( $\lfloor \tilde{F} \rfloor, \lceil \tilde{F} \rceil$ ); the ordering remains the same because  $E$  varies linearly in  $F$  within a block.
- **Mid distance:** matching by  $\Delta_{\text{mid}} = \frac{|2F - \mathfrak{M}|}{2}$  (same steps from half-filled) is equivalent to matching  $f$  symmetrically about  $1/2$ .

### Ready-reference formulas (one glance)

$$\mathfrak{M} = 2(2\ell + 1), \quad f = \frac{F}{\mathfrak{M}}, \quad E = \frac{1 - f}{\ell + 1}, \quad \Delta_{\text{mid}} = \frac{|2F - \mathfrak{M}|}{2}, \quad \text{open} = \mathfrak{M} - F.$$

$$\Rightarrow \boxed{f + (\ell + 1)E = 1} \quad (\text{row sanity check}).$$

### One-line takeaway

**What broke:** raw  $F$  compares *unequal* capacities.    **Fix:** normalize by  $f$  (or vacancy share);    **Result:**  $s > p > d > f$  holds *without exceptions*, and closures remain  $E = 0$  end-stops.

## Claim 4: Frontier closure at $F = \mathfrak{M}$ — zero exposure, end stops

### Definition and consequences

If  $F = \mathfrak{M}$  then

$$E = \frac{\mathfrak{M} - \mathfrak{M}}{\mathfrak{M}(\ell + 1)} = 0,$$

i.e. the frontier shell is **closed**. No open seats,  $\text{open} = \mathfrak{M} - F = 0$ ; the entry sits at the end stop of its block.

### Canonical closures (by block)

- $s$ : s2 (He, Be/Mg/Ca row ends)  $\Rightarrow E=0$ .
- $p$ : p6 (Ne, Ar, ...)  $\Rightarrow$  noble closure.
- $d$ : d10 (Zn, Cd, Hg) marks closed transition segments.
- $f$ : f14 closes the lanthanide/actinide filling arc.

### Quick test on any row

Read  $(\ell, F)$ , compute  $\mathfrak{M} = 2(2\ell + 1)$ ; if  $F = \mathfrak{M}$  then declare closure ( $E = 0$ , mid distance  $\Delta_{\text{mid}} = \mathfrak{M}/2$ ). This rule **uniformly** identifies inert end points across  $s/p/d/f$  without ad hoc exceptions.

## 7 Discussion and outlook

### Claim Discussion & Outlook — One Exponential, One Click

**One wave, one rule.** The ledger shows that *atomic families*, *optical scaling*, and *quantum control* are all instances of the same mapping

$$\mathcal{R} = \exp(\kappa U), \quad U \equiv \Phi/c^2, \quad X \equiv \ln \mathcal{R} = \kappa U,$$

with a single discrete increment  $\delta_\star$  such that  $X = k\delta_\star + r$ . Add sources within a scale, multiply responses across scales, and count progress in clicks. This removes fitted parameters and “filling exceptions,” compresses disparate domains into one syntax, and compiles directly to device primitives (increment-native gates; resonance-indexed media).

**What unifies.**

- *Periodic ledger.* Capacities  $C_\ell = 2(2\ell + 1)$  and integers  $F$  generate rows and families; exposure  $E = (C_\ell - F)/[C_\ell(\ell + 1)]$  sets half/closed states. d-series “promotions” conserve s+d bundle counts, so the ledger never breaks.
- *Optics and time.* The same generator  $U$  governs  $\Gamma_t = e^{+U}$  and  $n = e^{-2U}$ , yielding exact exponentials (not series fits) and the invariant  $\Gamma_t n^{1/2} = 1$ .
- *Control.* A fixed phase step  $\theta_\star = 2\pi\delta_\star$  realizes  $Z(\theta_\star)$  clicks; Clifford wrappers retarget any axis; mid-step dwell at  $\theta_\star/2$  gives robust accept/reject under noise.

**From principle to protocol (purely operational next steps).**

- *Open spec.* Publish the four laws, click acceptance  $|r| \leq \delta_\star/6$ , and the ledger schema  $(\ell, n, F, E, \text{phase})$ .
- *Cross-domain tests with the same  $\delta_\star$  and  $\mathcal{R}$ .*
  1. *Chemistry:* table-wide  $I_1, I_2, \text{EA} \rightarrow X = \varsigma \ln(Q/Q_{\text{ref}})$ ; test integer locking at half/closed rungs.
  2. *Optics:* clock networks across gravitational steps; verify exponentials and  $\Gamma_t n^{1/2} = 1$  without free coefficients.
  3. *Astrometry/timing:* near-limb deflection & Shapiro 2PN terms; check the parameter-free exponential metric discriminator (few- $\mu\text{as}$ ; tens-of-ps).
  4. *Control:* calibrate  $\theta_\star$  by mid-step; compile  $R_{\hat{n}}(2\pi\delta_\star)$  via  $Z$ -clicks; predict  $F_{\text{avg}} \approx 1 - (2\pi r)^2/6$ .

**Edges behave, not break.** d-block “exceptions” (Cr, Cu, Pd, Pt, Au) preserve s+d bundle counts  $F_{sd}^\star$ , so family, exposure, and phase remain intact. For f-rows, anchoring Ce and Th yields clean 14-seat arcs; early actinide density can live partly in  $d$  while the ledger reserves the first f-seat—an index choice, not a failure.

**Bottom line.** One exponential with one click is a working grammar: the same  $\delta_\star$  and the same  $\mathcal{R}$  eliminate patches, align chemistry/optics/control, and translate directly into hardware. What remains is logistics—publish the spec, run cross-domain tests, and let the integers speak.

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