



REACTION INTELLIGENCE FOR PROCESS CHEMISTRY

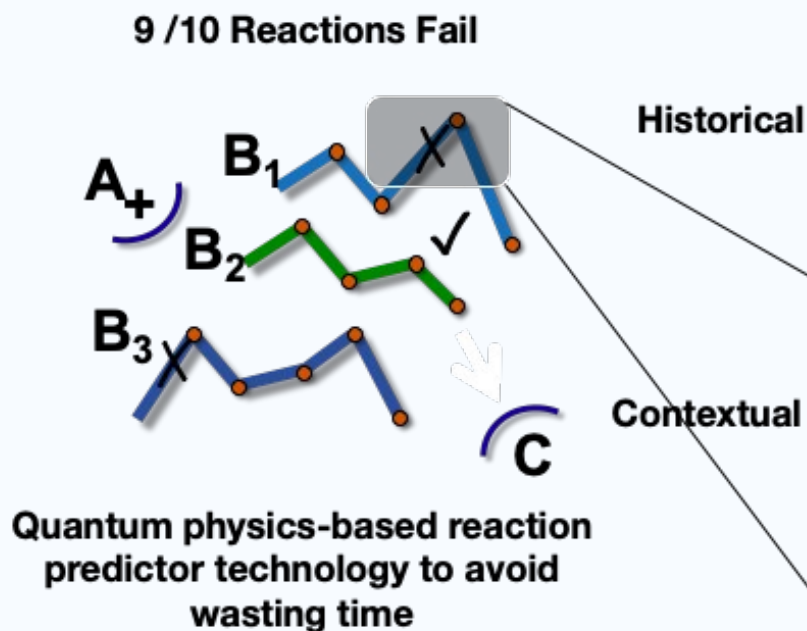
Physics-based simulation and machine learning reveal
why reactions fail — and what to test next.

CLIENT TECHNOLOGY OVERVIEW

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Published conditions often fail when the chemistry changes

A workable recipe for one molecule may fail after a small structural, equipment or process change.



WHY TRANSFER FAILS

Literature conditions describe one substrate, one apparatus and one operating window.

A single atom can change protonation, selectivity or the rate-determining step.

Without a mechanism, chemists repeat broad screens to find the workable region again.

Representative campaign: 9 of 10 tested reactions failed

Ai.Qimia turns a synthesis question into decisions

A client does not receive another black-box score.
The output is an interpretable package a chemist can challenge, test and use

01

ROUTE

Which pathways and intermediates are viable?

Route feasibility • pathway risk • realistic intermediates

02

MECHANISM

What controls rate, failure and selectivity?

Transition states • rate-determining step • competing paths

03

CONDITIONS

What should the laboratory test next?

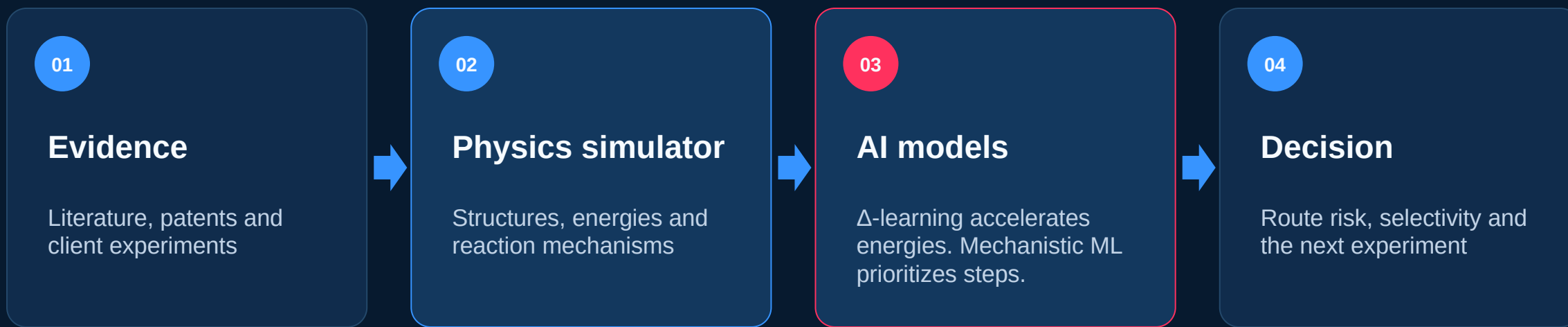
Selectivity drivers • key variables • prioritized experiments

DELIVERABLE • Mechanism, predictions and a laboratory validation plan

Physics and AI form a closed prediction loop

04

AI accelerates the expensive parts of simulation and directs where physics should look next



FEEDBACK

New experimental results improve the next prediction

The closed loop combines simulated ground truth with customer data while preserving a physics-based starting model.

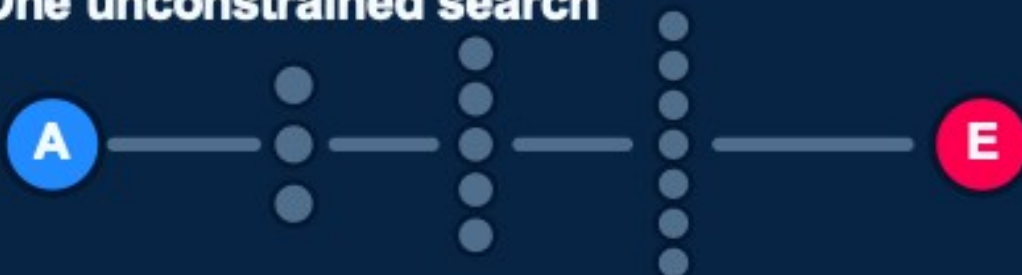
Model development with HES-SO and the University of Geneva

A learned midpoint divides the mechanism search

C constrains the route, but the platform must still discover B, D and the connecting transition states.

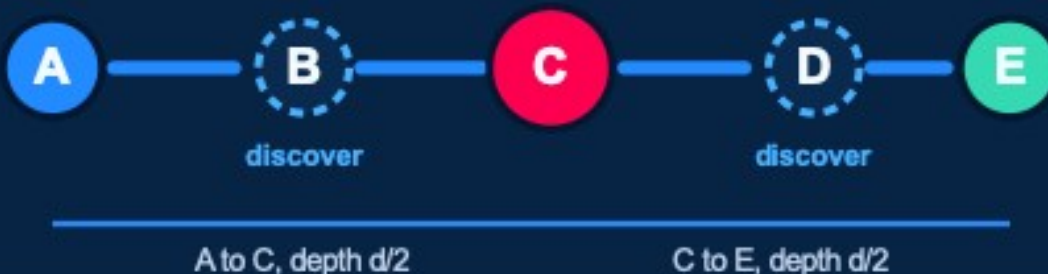
MECHANISM SEARCH

One unconstrained search



Search frontier grows by approximately b at each step

C divides the search



SEARCH-SPACE MATH

Example: $b = 20$, $d = 4$, 1 ms per state

Direct four-step breadth-first search

$$1 + 20 + 400 + 8,000 + 160,000$$

$$168,421 \text{ states} = 168.4 \text{ seconds}$$

Two searches of depth two

$$2 \times (1 + 20 + 400) = 842 \text{ states}$$

$$0.842 \text{ seconds}$$

approximately 200× faster

Energy predictions prune implausible branches before the expensive calculations.

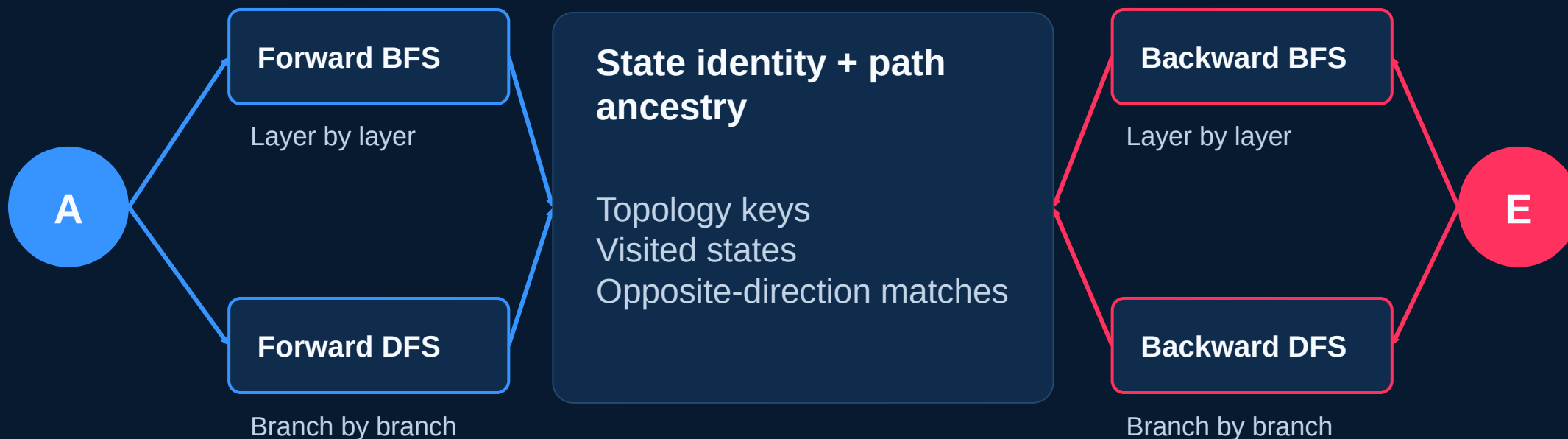
Four concurrent searches explore one reaction graph

Two directions × two traversal strategies share intermediate states.

REACTANTS

SHARED INTERMEDIATE REGISTRY

PRODUCTS

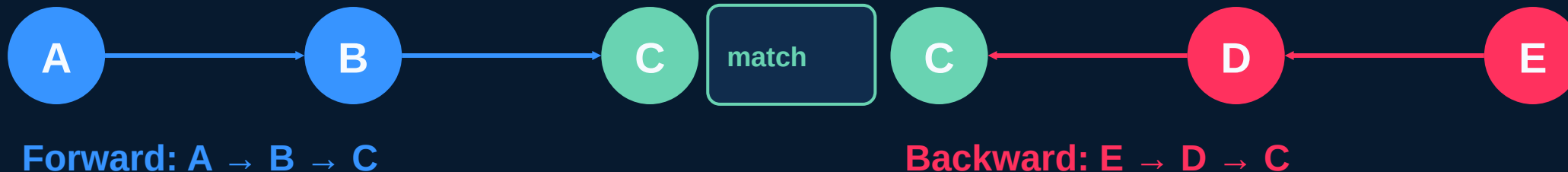


Breadth explores alternatives; depth pursues a route. Opposite directions can meet early.

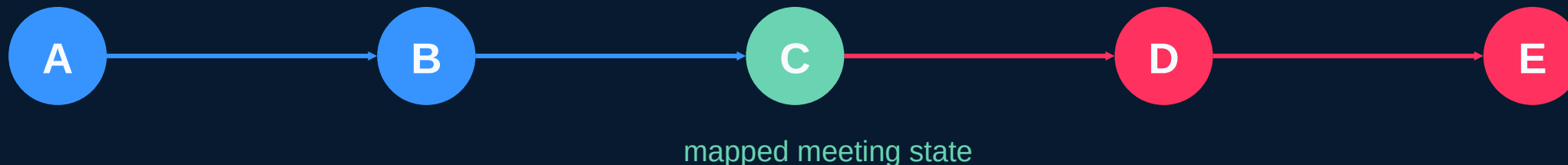
A shared intermediate joins the two search frontiers

A topology match locates a candidate meeting point; atom alignment makes it usable.

SEARCH TRACES



ONE FORWARD-READING ROUTE



Reverse the backward segment, remove the duplicate meeting state, then join the path.

One atom frame. One consistent bond ledger.

A stitched route must preserve chemical meaning across opposite search directions.

1 ALIGN ATOMS

Backward indices

7 — 12

map 7 → 2; 12 → 9

Forward frame: **2 — 9**

2 INVERT TRANSITIONS

Backward ledger

BREAK (7,12)

↓ reverse + remap

MAKE (2,9)

3 REBUILD THE TRACE

A → B → C → D → E

Chronological steps
Mapped atom pairs
MAKE / BREAK actions
Bond-order changes

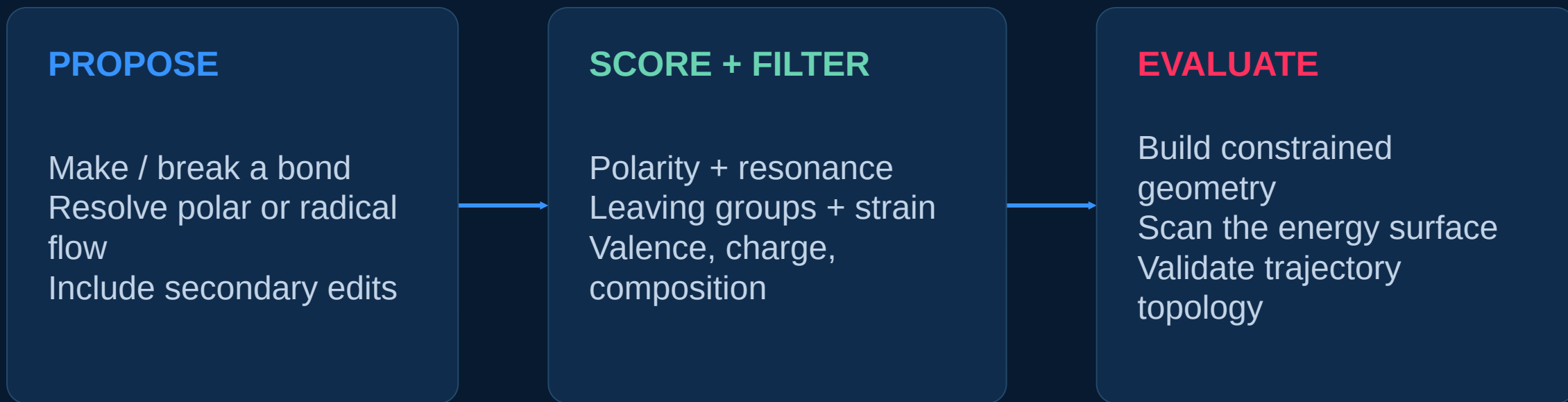
Bond-order increase ↔ decrease is inverted too; geometry constraints are recorded separately.

Atom indices are local identifiers; remapping prevents the right action hitting the wrong atom.

Physics guides edits; quantum calculations test the path

Chemical scoring proposes plausible steps before expensive geometry and energy evaluation.

Microstates and resonance forms supply alternative electronic starting points.



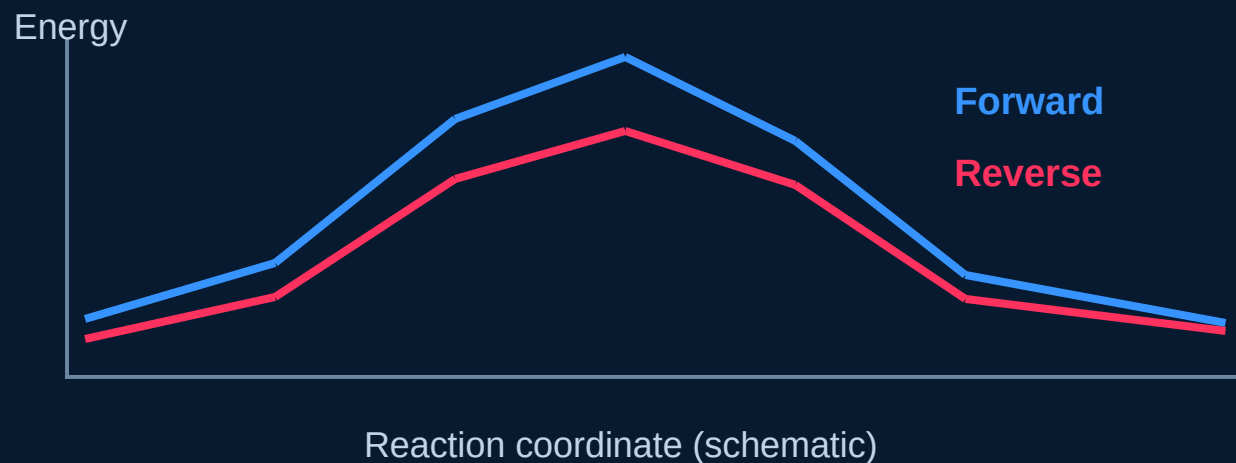
Search scores prioritize candidates. They are not activation barriers or rate constants.

Reverse return tests the path before kinetics

Product → reactant → product scans reveal geometry-dependent path hysteresis.

Product → reverse scan → recovered reactant geometry

Recovered geometry → forward return → product



FROM PATH TO RATE

Validate both topologies
Measure max / RMS ΔE
Retain scan quality

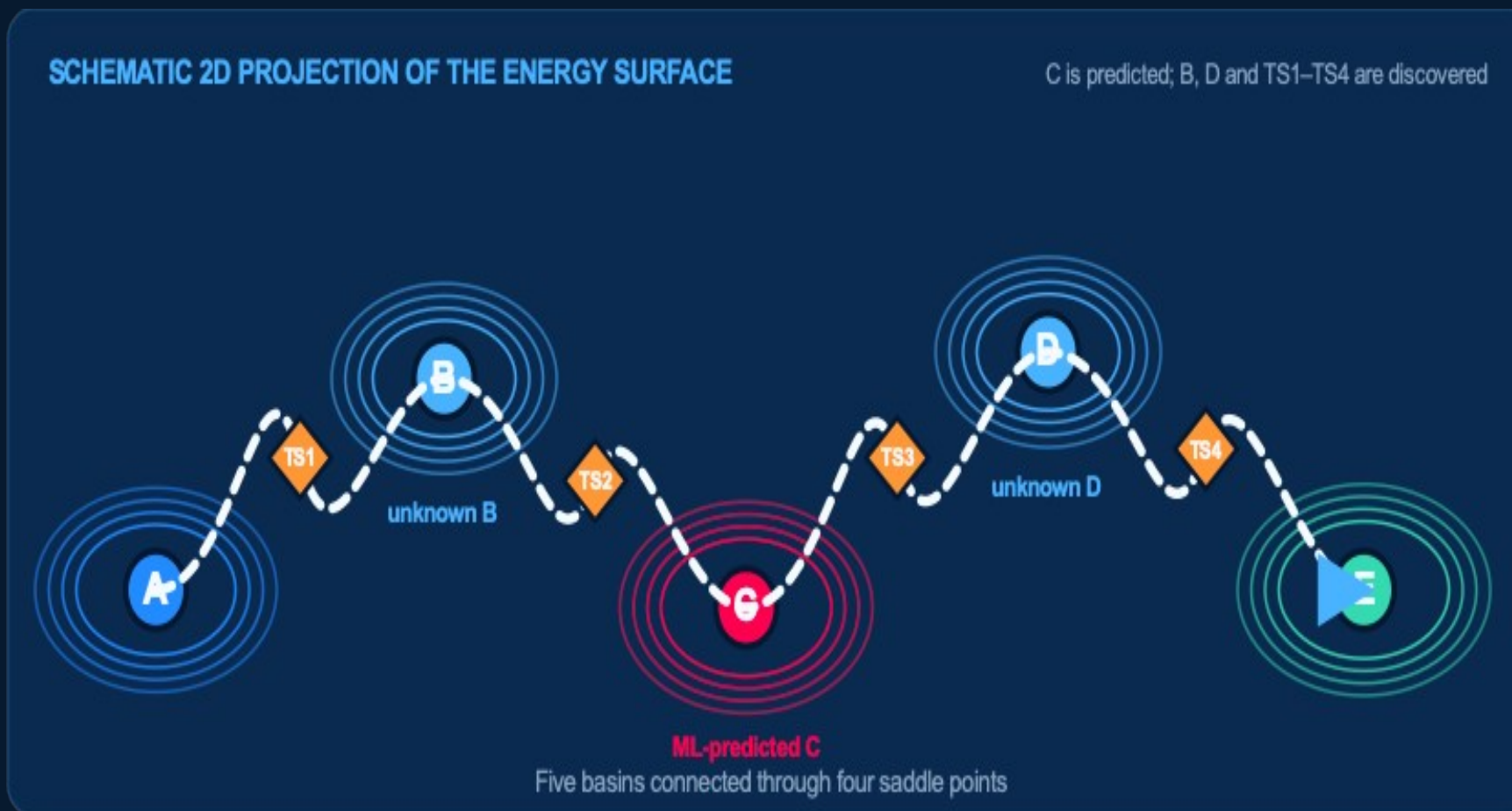
$$\Delta G^\ddagger \rightarrow k_i(T)$$

Microstate weights p_i
 $k_{\text{obs}} = \sum_i p_i k_i$

Keep both valid trajectories; diagnose hysteresis before interpreting barriers and rates.

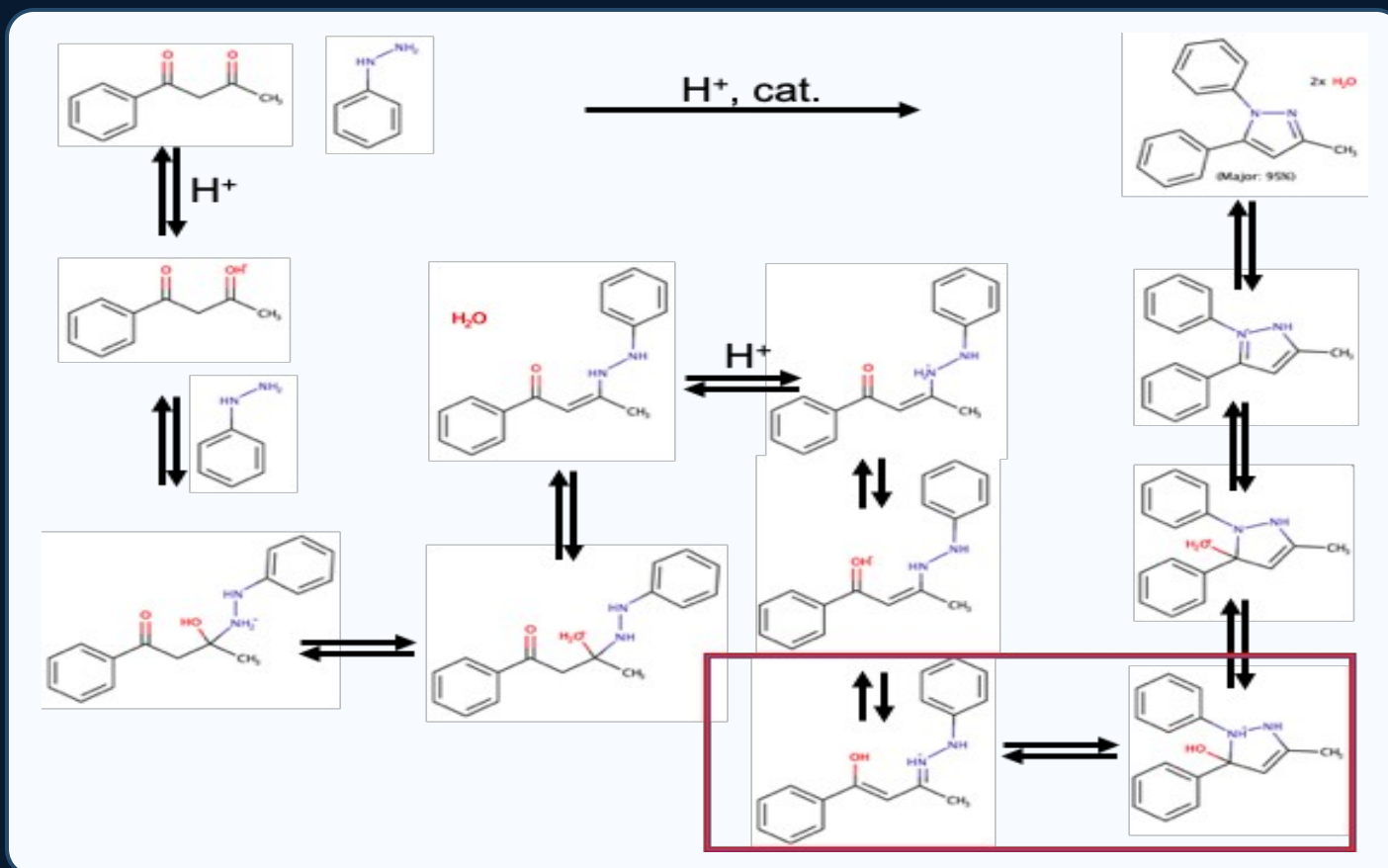
The simulator navigates the energy surface around the learned anchor

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The search discovers B, D and four transition states while connecting A to E through C.

Case study: mechanism and regiochemistry were both uncertain



THE DECISION

Which path is chemically viable?

Which transition state controls the rate?

Why does one regioisomer win?

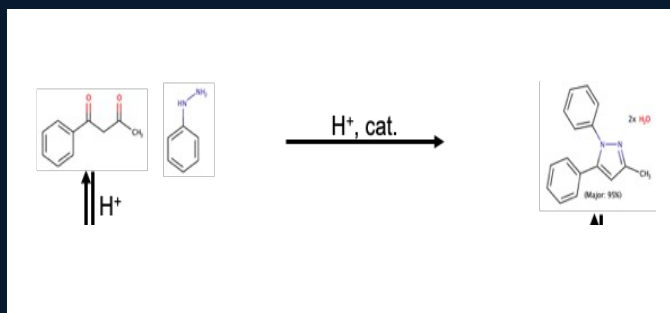
A connected mechanism resolves viability, rate and regioselectivity.

From a 2D hypothesis to a quantitative mechanism

07a

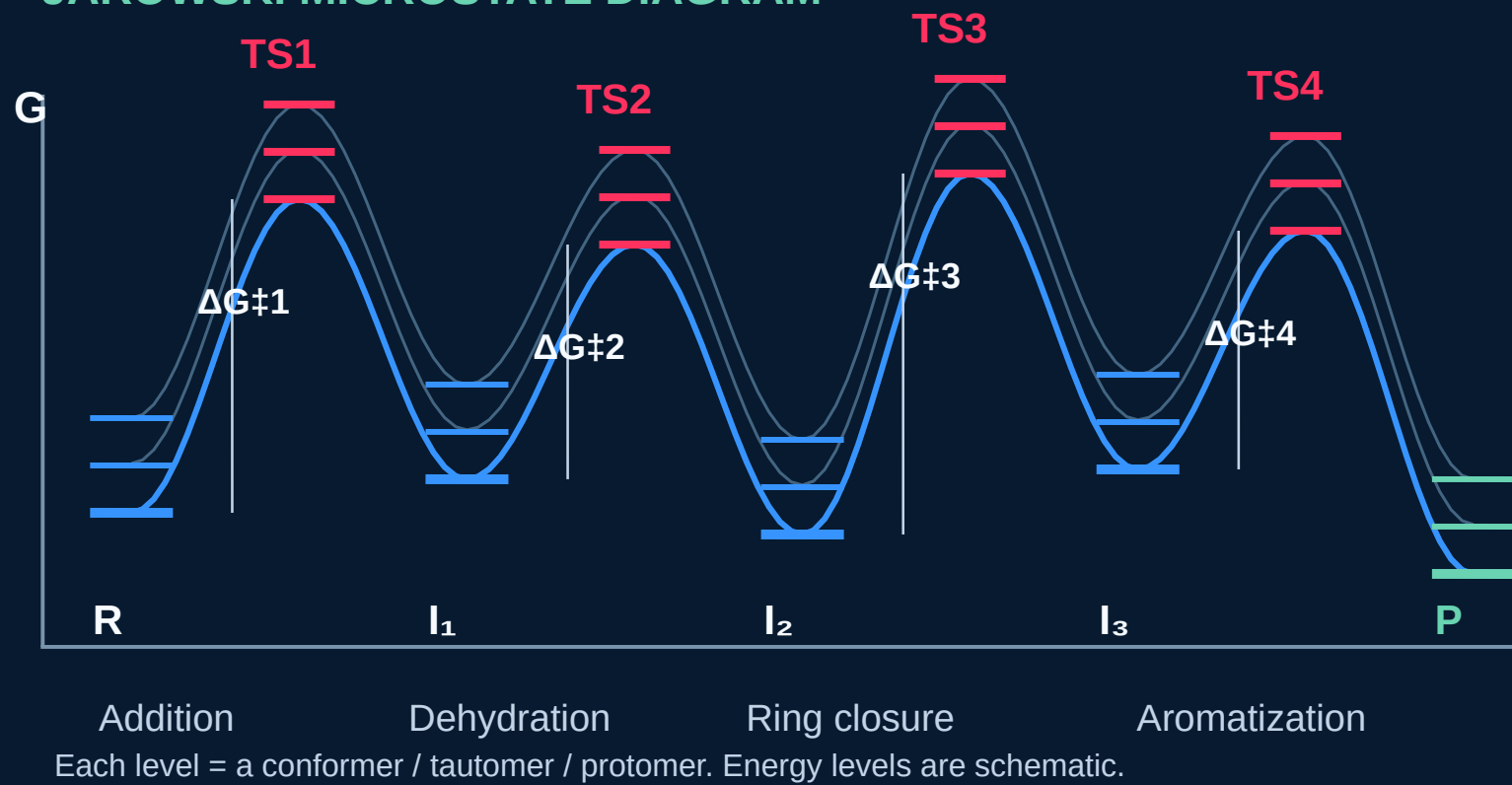
Resolve every intermediate and transition-state ensemble—not only a single lowest-energy path.

CHEMICAL HYPOTHESIS



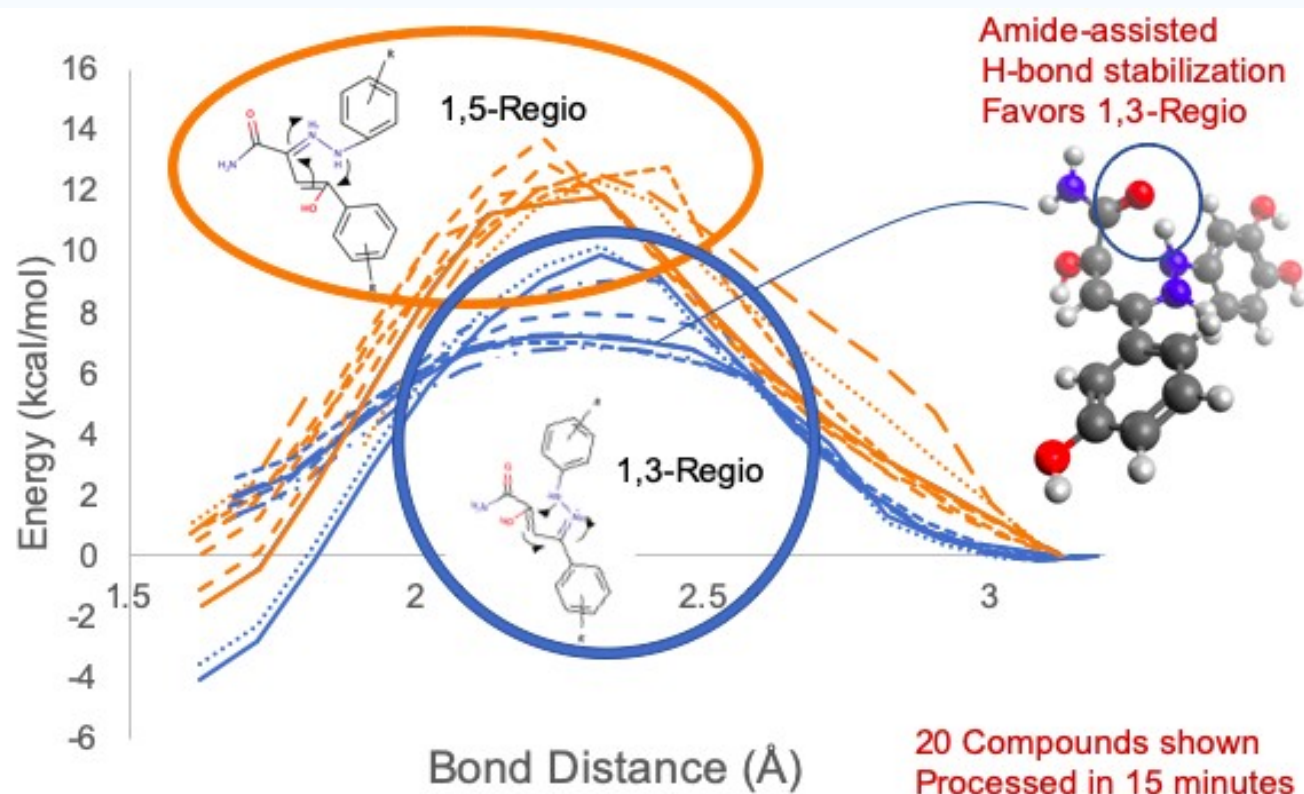
Which route operates?
Which step controls rate?
Why this regioisomer?

JAROWSKI MICROSTATE DIAGRAM



Microstate populations + activation free energies → competing rates, selectivity and conditions.

The model explained the regioselectivity



MECHANISTIC INSIGHT

Amide-assisted H-bond stabilization favors the 1,3-regioisomer.

20 related compounds

processed in 15 minutes

Mechanistic insight explains the observed selectivity across related compounds.

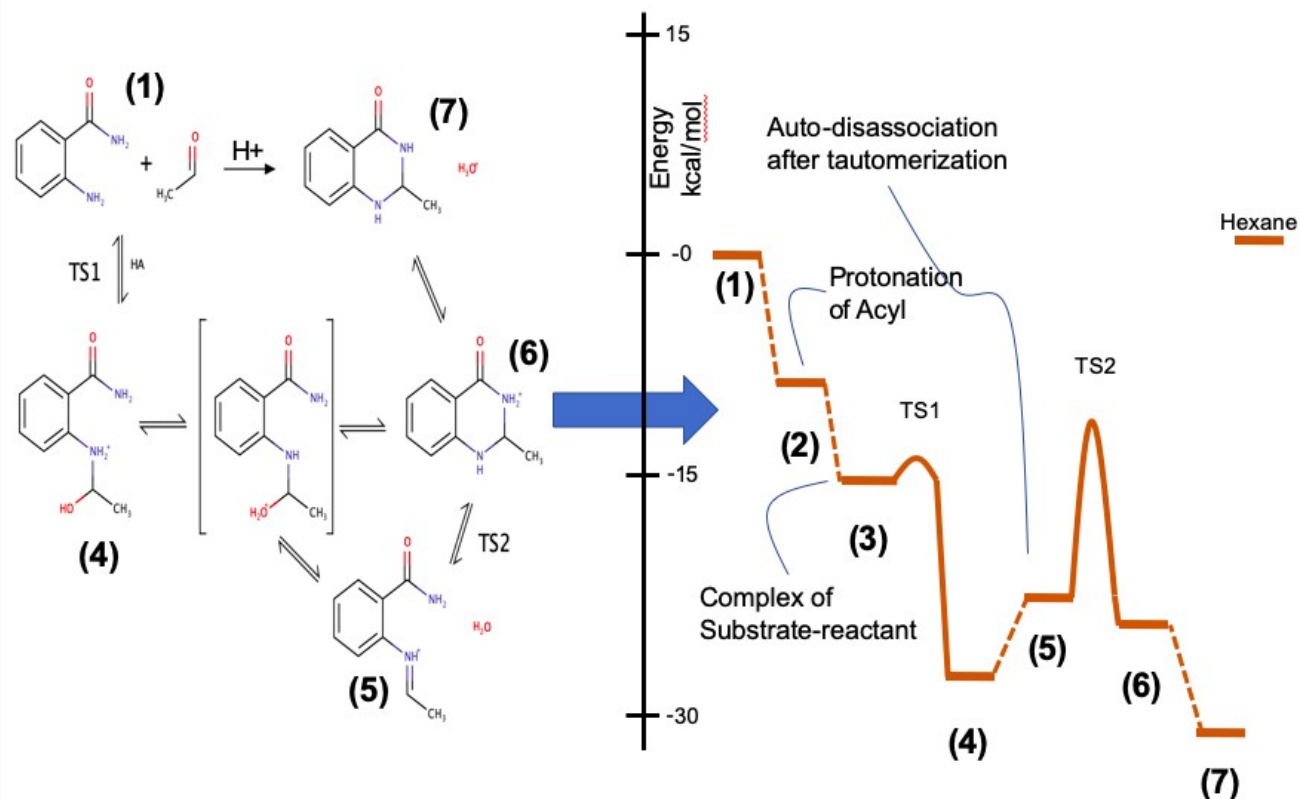
From a 2D hypothesis to a quantitative mechanism

MECHANISTIC MODEL

We transform your 2D hypothesis into quantitative thermodynamic and kinetic data.

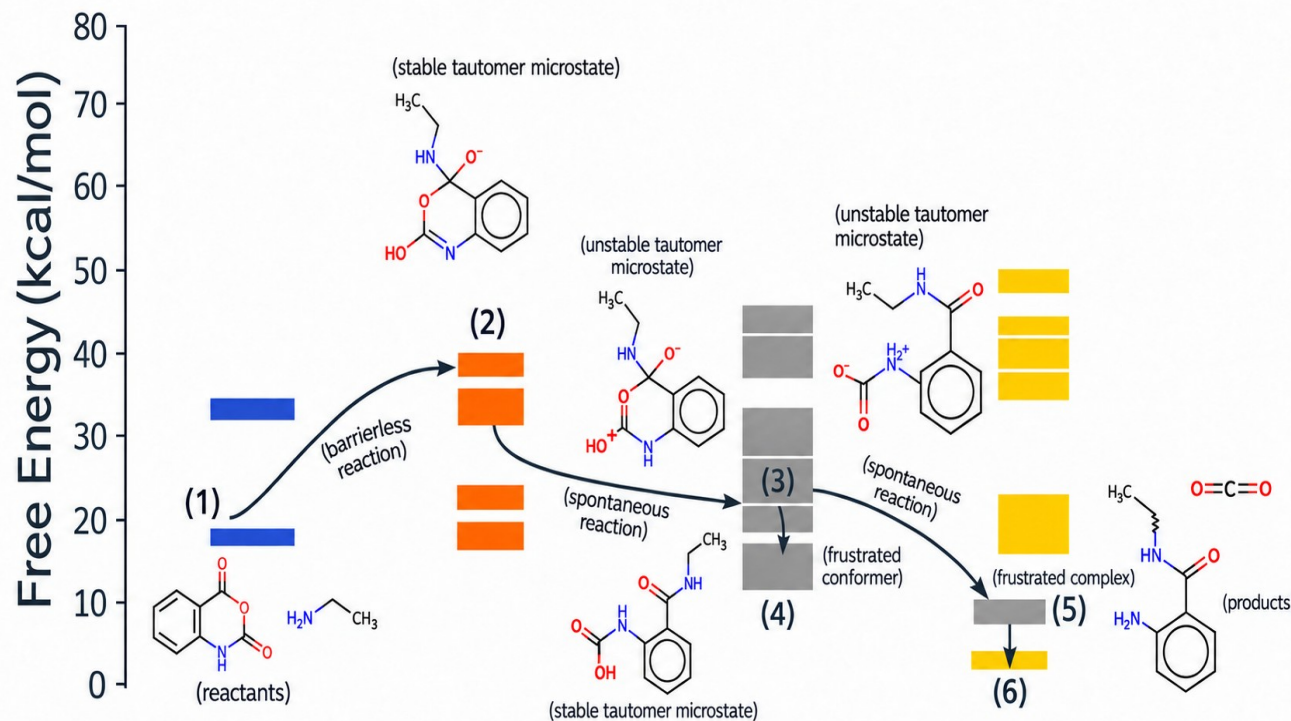
Thermodynamics ranks intermediates and pathways.

Kinetics identifies the controlling barriers and competing steps.



A quantitative definition of how the reaction works

Elementary steps across the microstate ensemble



FULLY ATOMISTIC

Each elementary step is resolved down to the microstate.

Tautomers, stereoisomers and conformers contribute according to their populations.

Single-state rate

$$k_i = \kappa(kBT/h) \exp[-(G_i^\ddagger - G_i)/RT]$$

Boltzmann population

$$p_i = \exp[-\Delta G_i/RT] / \sum_j \exp[-\Delta G_j/RT]$$

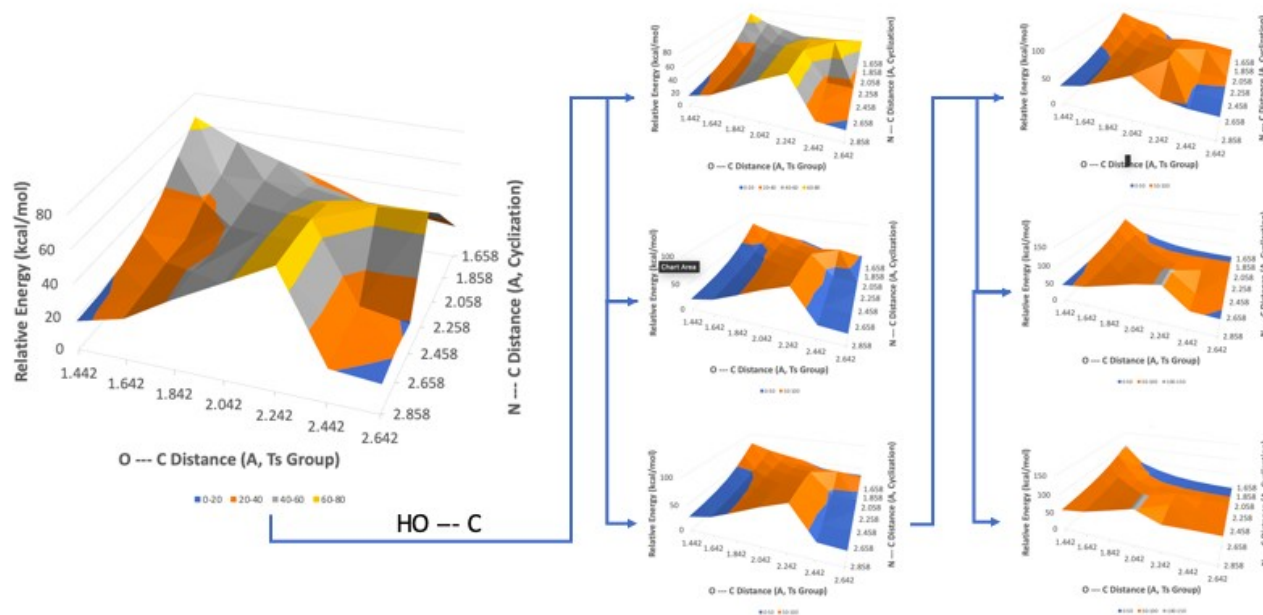
Observed ensemble rate

$$k_{obs} = \sum_i p_i k_i$$

The reactive ensemble can differ from the lowest-energy structure alone.

Mechanistic insight changed the experimental decision

Neutral Mechanism Results – Hypersurface is represented as layered surfaces at fixed HO --- C Lengths



NEUTRAL PATH

>40 kcal/mol

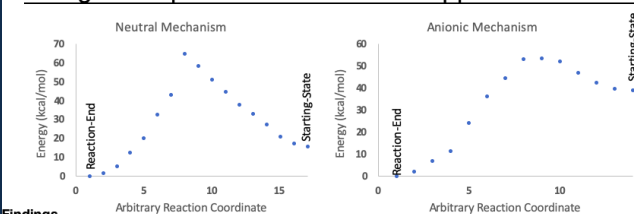
Forward barrier prohibits the proposed neutral mechanism.

ANIONIC PATH

≈15 kcal/mol

Viable at r.t.; prioritize conditions consistent with this pathway.

Reaction Barriers – Hypersurface is Traversed Using a Steepest Descent / Ascent Approach



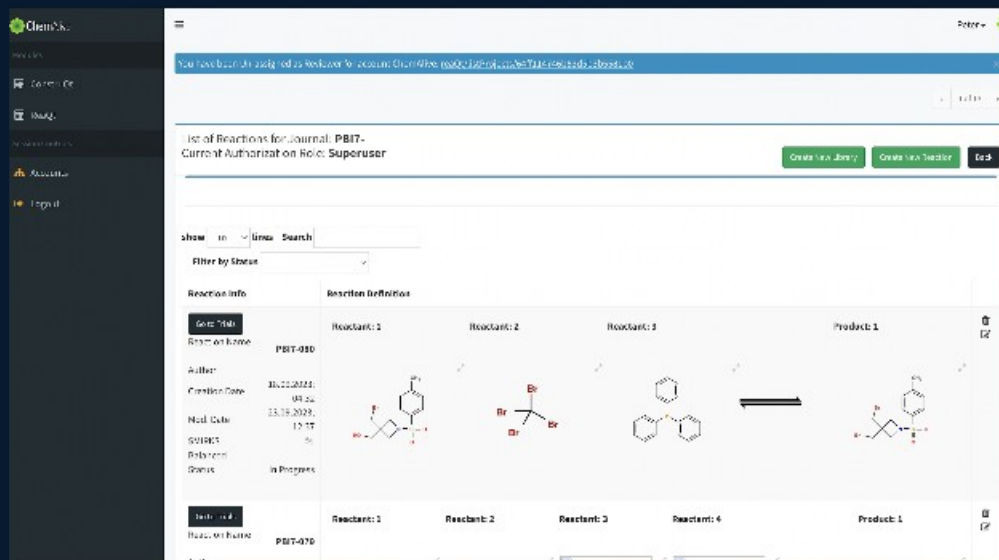
Findings

- Neutral mechanism is prohibited by unstable oxonium formed on cyclization with a forward barrier over 40 kcal/mol.
- Anionic mechanism should be available at room temperature with a forward barrier of ca. 15 kcal/mol.
- Both mechanism are thermally exothermic and essentially non-equilibrium reactions

Outcome: deprioritize the neutral route and focus validation on the anionic mechanism.

Ten years solving difficult industrial chemistry problems

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OPERATING EXPERIENCE

Our team has supported industrial chemistry decisions for more than a decade

Chemistry-aware reaction workflows

Infrastructure designed to scale and preserve results

SELECTED INDUSTRIAL PARTNERS

SpiroChem

Danone / evian

Puraffinity

Aurorium

SSE

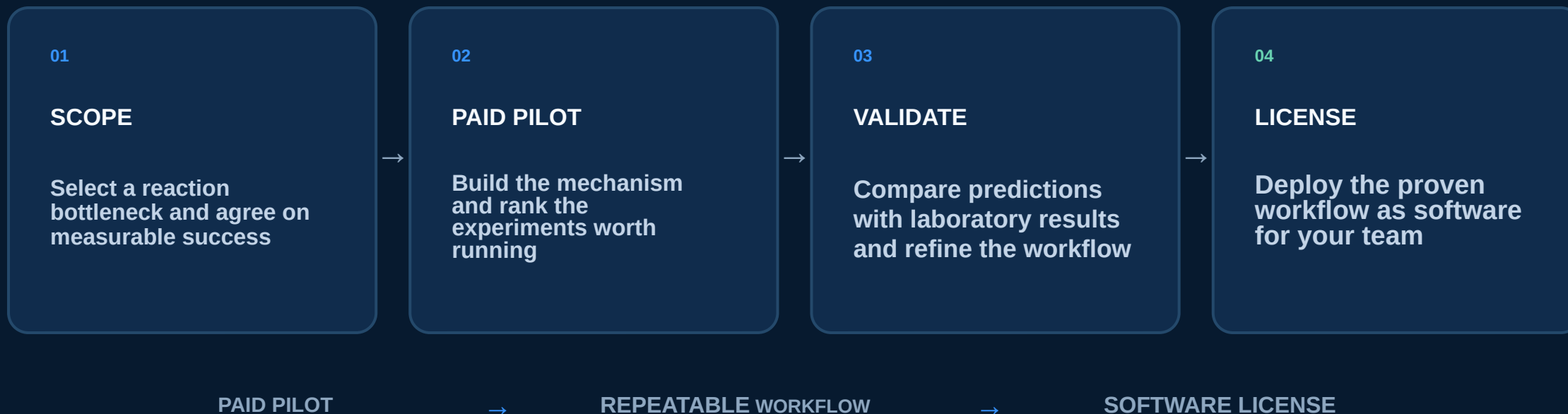
PIPELINE



Ai.Qimia converts this experience into a focused product and commercial platform

Paid pilots establish fit before software licensing

We solve one real reaction problem with your team. Once the workflow performs on your chemistry, we license the platform for repeat use.



Have a reaction challenge? Please get in touch.