

Supporting Information

Importance of Favourable Non-Covalent Contacts in the Stereoselective Synthesis of Tetrasubstituted Chromanones

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Table S1. TS energies (E), enthalpies (H), quasi-RRHO free energies (G), and single point electronic energies (E') for ligand **1c** in Hartrees.

Structure	E	H	G(quasi-RRO)	E'
TS(R)(2)	-2230.916377	-2230.214822	-2230.344131	-2231.630802
TS(R)(1)	-2230.935233	-2230.233462	-2230.362862	-2231.611808
TS(R)(3)	-2230.915029	-2230.213431	-2230.344367	-2231.610595
TS(R)(4)	-2230.916320	-2230.214816	-2230.344560	-2231.611684
TS(R)(5)	-2230.912486	-2230.210940	-2230.342210	-2231.608903
TS(R)(6)	-2230.923036	-2230.221156	-2230.351930	-2231.619431
TS(R)(7)	-2230.926896	-2230.225325	-2230.353977	-2231.620966
TS(R)(8)	-2230.931888	-2230.229887	-2230.359380	-2231.626568
TS(R)(9)	-2230.935583	-2230.233862	-2230.363119	-2231.632683
TS(R)(10)	-2230.934042	-2230.232370	-2230.361442	-2231.631293
TS(R)(11)	-2230.934042	-2230.232370	-2230.361440	-2231.631292
TS(R)(12)	-2230.935584	-2230.233861	-2230.363114	-2231.632685
TS(R)(13)*	-2230.936676	-2230.234735	-2230.363846	-2231.633801
TS(R)(14)	-2230.926513	-2230.225241	-2230.355771	-2231.624573
TS(R)(15)	-2230.931047	-2230.229095	-2230.359022	-2231.626326
TS(R)(16)	-2230.924828	-2230.223490	-2230.353681	-2231.622231
TS(R)(17)	-2230.924828	-2230.223489	-2230.353677	-2231.622231
TS(R)(18)	-2230.924083	-2230.222445	-2230.352770	-2231.618854
TS(R)(19)	-2230.921368	-2230.219811	-2230.350067	-2231.617134
TS(R)(20)	-2230.923937	-2230.222391	-2230.352879	-2231.621317
TS(S)(1)	-2230.925879	-2230.223923	-2230.354170	-2231.621037
TS(S)(2)	-2230.927224	-2230.225646	-2230.356033	-2231.623421
TS(S)(3)	-2230.927177	-2230.225644	-2230.356132	-2231.623231
TS(S)(4)	-2230.935793	-2230.233759	-2230.364211	-2231.631619
TS(S)(5)	-2230.923284	-2230.221312	-2230.351885	-2231.619074
TS(S)(6)	-2230.925341	-2230.223920	-2230.354345	-2231.622853
TS(S)(7)*	-2230.947480	-2230.245374	-2230.374472	-2231.641792
TS(S)(8)	-2230.925341	-2230.223920	-2230.354341	-2231.622853
TS(S)(9)	-2230.947480	-2230.245371	-2230.374455	-2231.641789
TS(S)(10)	-2230.932990	-2230.231021	-2230.361066	-2231.629974
TS(S)(11)	-2230.927177	-2230.225644	-2230.356150	-2231.623230
TS(S)(12)	-2230.936591	-2230.235011	-2230.364667	-2231.632007
TS(S)(13)	-2230.936592	-2230.235011	-2230.364663	-2231.632007
TS(S)(14)	-2230.926570	-2230.225202	-2230.355734	-2231.624553
TS(S)(15)	-2230.926544	-2230.225161	-2230.355806	-2231.624509
TS(S)(16)	-2230.927224	-2230.225646	-2230.356035	-2231.623421

* Lowest energy structures TS(R) and TS(S)

Table S2. Energy decomposition analysis model single point electronic energies (E') in Hartrees.

Model	E'
TS(R) ligand	-1336.723137
TS(S) ligand	-1336.725773
TS(R) imine model	-1083.022557
TS(S) imine model	-1083.024408
TS(R) Cl model	-2384.087757
TS(S) Cl model	-2384.091099
TS(R) without Ph	-1921.822956
TS(S) without Ph	-1921.828816
TS(R) without Bn	-1882.490651
TS(S) without Bn	-1882.494620

Table S3. TS energies (E), enthalpies (H), quasi-RRHO free energies (G), and single point electronic energies (E') for ligands **1a**, **1b**, **1d**, and **1e** in Hartrees.

Structure	E	H	G(quasi-RRHO)	E'
1a TS(R) TS1.1	-1702.149508	-1701.512904	-1701.625039	-1702.667883
1a TS(R) TS1.2	-1702.145283	-1701.508578	-1701.620761	-1702.662996
1a TS(R) TS2.1	-1702.149587	-1701.512785	-1701.624173	-1702.665818
1a TS(R) TS2.2	-1702.147195	-1701.510348	-1701.621914	-1702.663501
1a TS(R) TS2.6	-1702.148633	-1701.512335	-1701.624779	-1702.666508
1a TS(R) TS2.8	-1702.141554	-1701.504754	-1701.616404	-1702.659332
1a TS(S) TS1.1	-1702.150820	-1701.514571	-1701.627625	-1702.669351
1a TS(S) TS1.3	-1702.149168	-1701.512744	-1701.624515	-1702.667108
1a TS(S) TS1.4	-1702.147986	-1701.511498	-1701.624240	-1702.666582
1a TS(S) TS1.5	-1702.149284	-1701.512903	-1701.625913	-1702.667974
1a TS(S) TS2.1	-1702.153429	-1701.516819	-1701.628605	-1702.671282
1a TS(S) TS2.2	-1702.149413	-1701.512866	-1701.625295	-1702.667329
1a TS(S) TS2.5	-1702.150311	-1701.513897	-1701.625304	-1702.668511
1a TS(S) TS2.9	-1702.150453	-1701.513978	-1701.625902	-1702.668935
1b TS(R) TS1.1	-2039.183649	-2038.538163	-2038.659894	-2039.818593
1b TS(R) TS1.2	-2039.181501	-2038.535976	-2038.656881	-2039.814306
1b TS(R) TS1.4	-2039.181123	-2038.536003	-2038.657510	-2039.814853
1b TS(R) TS1.5	-2039.180080	-2038.534964	-2038.656123	-2039.813179
1b TS(R) TS2.1	-2039.184719	-2038.539275	-2038.660121	-2039.816713
1b TS(R) TS2.2	-2039.182635	-2038.537045	-2038.657866	-2039.814788
1b TS(R) TS2.4	-2039.184952	-2038.539506	-2038.660149	-2039.818307
1b TS(R) TS2.5	-2039.180404	-2038.535266	-2038.655923	-2039.812702
1b TS(R) TS2.6	-2039.184271	-2038.539168	-2038.660376	-2039.817566
1b TS(R) TS2.8	-2039.177282	-2038.531735	-2038.652529	-2039.810691
1b TS(S) TS1.1	-2039.185457	-2038.540311	-2038.662432	-2039.820125
1b TS(S) TS1.3	-2039.184165	-2038.538878	-2038.659718	-2039.817940

1b TS(S) TS1.4	-2039.182701	-2038.537439	-2038.659616	-2039.817617
1b TS(S) TS1.5	-2039.184002	-2038.538798	-2038.661079	-2039.819124
1b TS(S) TS1.7	-2039.188608	-2038.543185	-2038.664906	-2039.822468
1b TS(S) TS2.1	-2039.187367	-2038.541878	-2038.663043	-2039.821939
1b TS(S) TS2.2	-2039.183268	-2038.537858	-2038.659670	-2039.817670
1b TS(S) TS2.5	-2039.184378	-2038.539061	-2038.659692	-2039.819391
1b TS(S) TS2.6	-2039.188137	-2038.542968	-2038.664416	-2039.823262
1d TS(R) TS1.1	-2309.568906	-2308.805814	-2308.941106	-2310.292924
1d TS(R) TS1.2	-2309.568073	-2308.805068	-2308.940116	-2310.292073
1d TS(R) TS1.4	-2309.565157	-2308.802135	-2308.937257	-2310.289027
1d TS(R) TS1.6	-2309.564211	-2308.801056	-2308.935492	-2310.288014
1d TS(S) TS1.1	-2309.578962	-2308.815876	-2308.951385	-2310.300788
1d TS(S) TS1.2	-2309.578468	-2308.815289	-2308.950176	-2310.300191
1e TS(R) TS1.10	-2506.151573	-2505.237850	-2505.388548	-2506.941548
1e TS(R) TS1.16	-2506.138482	-2505.225103	-2505.376111	-2506.928379
1e TS(R) TS1.17	-2506.137217	-2505.223599	-2505.374619	-2506.926855
1e TS(R) TS1.1	-2506.155196	-2505.241759	-2505.392837	-2506.945622
1e TS(R) TS1.7	-2506.145620	-2505.232131	-2505.383150	-2506.935572
1e TS(S) TS1.1	-2506.169370	-2505.255732	-2505.406613	-2506.957425
1e TS(S) TS1.2	-2506.168406	-2505.254575	-2505.405297	-2506.956380
1e TS(S) TS1.7	-2506.159649	-2505.245949	-2505.396789	-2506.947307
1e TS(S) TS1.8	-2506.158690	-2505.245071	-2505.396298	-2506.946504
1e TS(S) TS1.9	-2506.157299	-2505.243512	-2505.394443	-2506.945049

Table S4. Energies (E), enthalpies (H), quasi-RRHO free energies (G), and single point electronic energies (E') for intermediate **5** using ligand **1c** in Hartrees.

Structure	E	H	G (quasi RRHO)	E'
5(R) open	-2230.957016	-2230.253433	-2230.3859450	-2231.656155
5(R) closed	-2230.962193	-2230.258942	-2230.392075	-2231.660959
5(S) open	-2230.954397	-2230.250908	-2230.383865	-2231.653175
5(S) closed	-2230.963013	-2230.259541	-2230.391923	-2231.660260

Table S5. Energies (E), enthalpies (H), quasi-RRHO free energies (G), and single point electronic energies (E') for ligand **1c** bound to PdCl₂ and unbound in open and closed conformations in Hartrees.

Structure	E	H	G (quasi RRHO)	E'
1c -PdCl ₂ open gas phase	-2383.538908	-2383.096526	-2383.199138	-2384.058886
1c -PdCl ₂ open solution	-2383.573462	-2383.131168	-2383.233991	-2384.094381
1c -PdCl ₂ closed	-2383.537215	-2383.095296	-2383.198867	-2384.058112

gas phase				
1c -PdCl ₂ closed solution	-2383.574875	-2383.132741	-2383.235925	-2384.096132
1c -free open gas phase	-1336.295738	-1335.865312	-1335.963372	-1336.717526
1c -free open solvent	-1336.307061	-1335.876880	-1335.974533	-1336.731117
1c -free closed gas phase	-1336.295582	-1335.865292	-1335.962976	-1336.716557
1c -free closed solvent	-1336.307583	-1335.877490	-1335.975330	-1336.730856

Table S6. NBO charge transfer energies for interactions in **Figure S2** in kcal mol⁻¹.

Donor NBO	Acceptor NBO	E TS(R)	E TS(S)
BD (1) C63 – H82	LP* (5) Pd37	3.33	3.16
BD (1) C63 – H82	LP* (6) Pd37	4.45	3.12
BD (1) C16 – H18	LP* (5) Pd37	0.91	0.39
BD (1) C16 – H18	LP* (6) Pd37	0.46	0.74
BD (1) C16 – H18	LP* (7) Pd37	0.06	0.00
BD (1) C16 – H18	LP* (8) Pd37	1.52	0.73
Total contribution to Pd:		10.73	8.14

Table S7. Energies (E), enthalpies (H), quasi-RRHO free energies (G), and single point electronic energies (E') for intermediate **4** for all ligands.

Structure	E	H	G (quasi RRHO)	E'
4-1a	-1702.184846	-1701.546856	-1701.663542	-1702.702502
4-1b	-2039.218079	-2038.571237	-2038.697650	-2039.852365
4-1c	-2230.975884	-2230.272304	-2230.405548	-2231.671767
4-1d	-2309.608573	-2308.843892	-2308.982794	-2310.330963
4-1e	-2506.197346	-2505.282156	-2505.436458	-2506.985707

The difference in the activation energy between the lowest energy transition state structures leading to the R and S products is attributed to the combination of stabilizing interaction energy and destabilizing distortion energy differences.

$$\Delta\Delta E^\ddagger = \Delta\Delta E_{int.} + \Delta\Delta E_{dist.} \quad (1)$$

The interaction and distortion components are further divided based on the molecular fragments in the system. “Ph” refers to the anionic phenyl being added to the chromane, while “C” refers to the chromane, and “S” refers to the forming complex of Ph and C as a single substrate fragment. “L” and “Pd” refer to the ligand and the palladium respectively.

$$\begin{aligned} \Delta\Delta E^\ddagger = & \Delta\Delta E_{L-Pd\ int.} + \Delta\Delta E_{L-Ph\ int.} + \Delta\Delta E_{L-C\ int.} + \Delta\Delta E_{Pd-Ph\ int.} + \\ & \Delta\Delta E_{Pd-C\ int.} + \Delta\Delta E_{Ph-C\ int.} + \Delta\Delta E_{L\ dist.} + \Delta\Delta E_{C\ dist.} + \Delta\Delta E_{Ph\ dist.} + \\ & \Delta\Delta E_{Pd\ dist.} \end{aligned} \quad (2)$$

The term we are interested in solving for is the relative interaction energy between the ligand and the forming complex S. To find this we must reduce the terms to expressions that can be computed. Many terms can be grouped together to give energy expressions that can be easily computed using model systems. The first of these is a model used to compute the relative distortion of the Pd-S complex (Figure S1a) by performing an EDA on the system where the ligand in the TS has been replaced with a di-imine.

$$\begin{aligned} \Delta\Delta E_{im.-Pd-S} = & \Delta\Delta E_{Pd\ dist.} + \Delta\Delta E_{C\ dist.} + \Delta\Delta E_{Ph\ dist.} + \Delta\Delta E_{Pd-Ph\ int.} \\ & + \Delta\Delta E_{Pd-C\ int.} + \Delta\Delta E_{Ph-C\ int.} + \Delta\Delta E_{im.-Pd\ int.} \\ & + \Delta\Delta E_{im.S\ int.} + \Delta\Delta E_{im.dist.} \end{aligned} \quad (3)$$

This expression is simplified by eliminating the terms involving the imine groups, as they are negligibly small.

$$\begin{aligned} \Delta\Delta E_{im.-Pd-S} = & \Delta\Delta E_{Pd\ dist.} + \Delta\Delta E_{C\ dist.} + \Delta\Delta E_{Ph\ dist.} + \Delta\Delta E_{Pd-Ph\ int.} \\ & + \Delta\Delta E_{Pd-C\ int.} + \Delta\Delta E_{Ph-C\ int.} \end{aligned} \quad (4)$$

This leaves an expression that includes six of the terms in equation (2) and can be easily computed. This term therefore constitutes the relative Pd-S distortion. Substituting into equation (2) gives:

$$\begin{aligned} \Delta\Delta E^\ddagger = & \Delta\Delta E_{L-Pd\ int.} + \Delta\Delta E_{L-Ph\ int.} + \Delta\Delta E_{L-C\ int.} + \Delta\Delta E_{L\ dist.} \\ & + \Delta\Delta E_{im.-Pd-S} \end{aligned} \quad (5)$$

The first term will be computed using the model in Figure S1b in which the substrates have been replaced by chlorines which are then optimized, conserving the transition state geometry of the L-Pd complex. Another energy decomposition is performed on this smaller system to isolate the relative L-Pd interaction energy.

$$\begin{aligned} \Delta\Delta E_{L-Pd-2Cl} = & \Delta\Delta E_{L-Pd\ int.} + \Delta\Delta E_{L\ dist.} + \Delta\Delta E_{L-2Cl\ int.} + \Delta\Delta E_{Pd-2Cl\ int.} \\ & + \Delta\Delta E_{Cl(1)-Cl(2)\ int.} + \Delta\Delta E_{Cl(1)\ dist.} + \Delta\Delta E_{Cl(2)\ dist.} \\ & + \Delta\Delta E_{Pd\ dist.} \end{aligned} \quad (6)$$

All terms but the first two are considered negligible, and the expression can be solved for $\Delta\Delta E_{L-Pd\ int.}$ to give an expression composed of two computable terms.

$$\Delta\Delta E_{L-Pd\ int.} = \Delta\Delta E_{L-Pd-2Cl} - \Delta\Delta E_{L\ dist.} \quad (7)$$

Substituting into equation (1) gives:

$$\Delta\Delta E^\ddagger = \Delta\Delta E_{L-Pd-2Cl} + \Delta\Delta E_{L-Ph\ int.} + \Delta\Delta E_{L-C\ int.} + \Delta\Delta E_{im.-Pd-S} \quad (8)$$

We can now combine the final unknown terms into the interaction of the ligand with the substrate. This does not include the interaction of the substrates with each other (effectively the relative bond energy) as we have already accounted for that in equation (4).

$$\Delta\Delta E^\ddagger = \Delta\Delta E_{L-Pd-2Cl} + \Delta\Delta E_{L-S\ int.} + \Delta\Delta E_{im.-Pd-S} \quad (9)$$

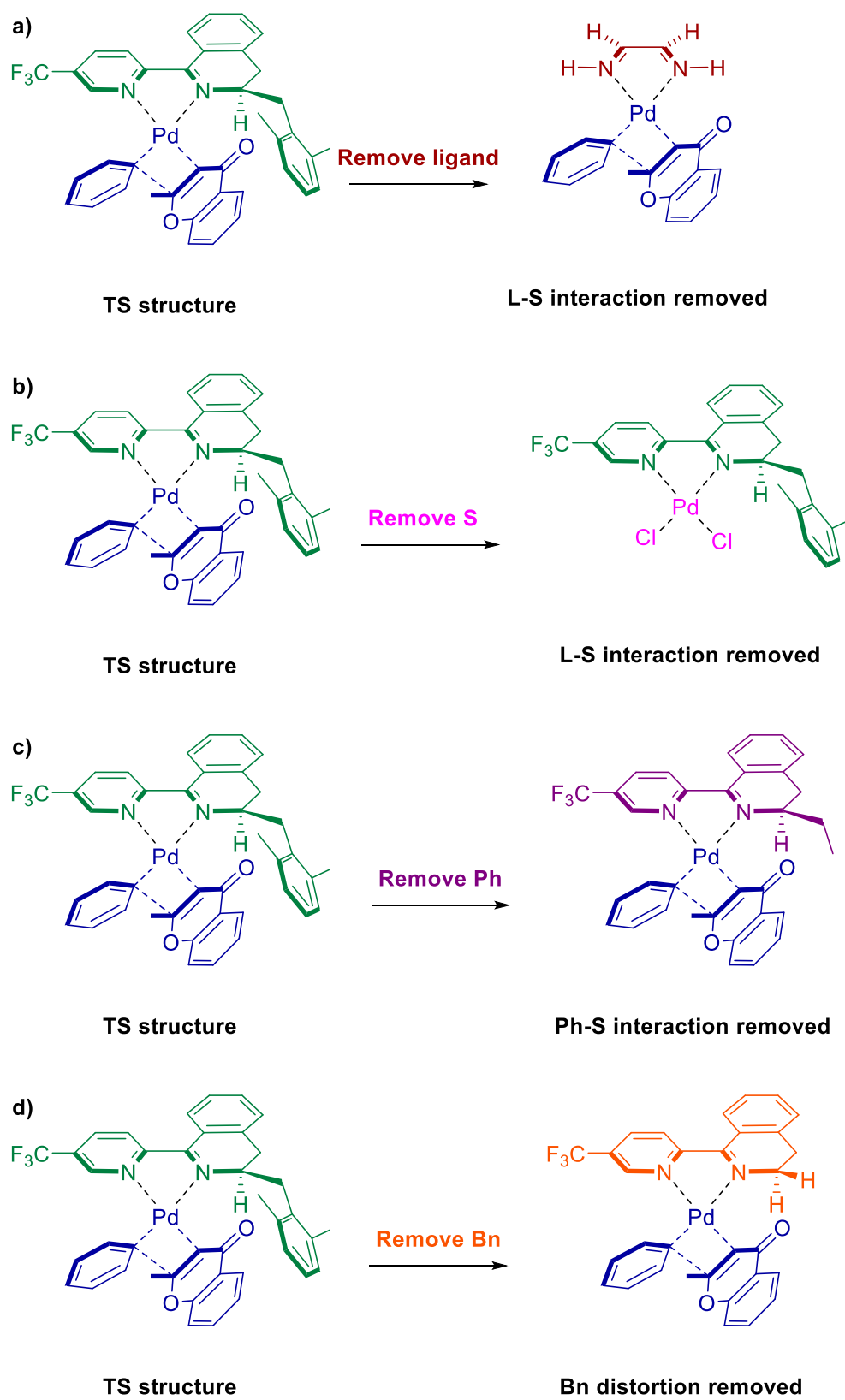
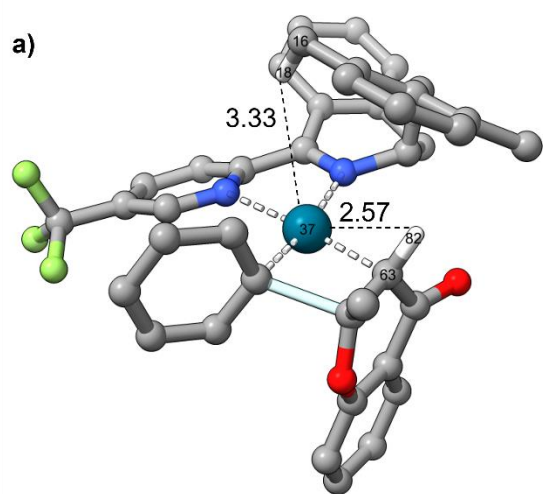
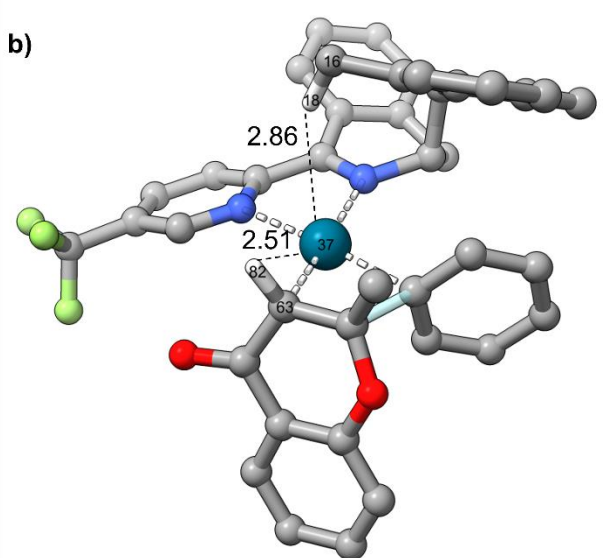


Figure S1: Models for energy decomposition analysis



TS-1c(S) (major)
 $\Delta\Delta G^\ddagger = 0.0$



TS-1c(R) (minor)
 $\Delta\Delta G^\ddagger = 5.1$

Figure S2: TS-1c(S) and TS-1c(R) with NBO charge transfer interactions shown. Select hydrogens shown for clarity.