

CHEMISTRY

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Supporting Information

The Mechanism of Copper-Catalyzed Trifunctionalization of Terminal Allenes

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Table of contents

Figure S1. Conformational isomers 13a and 13b possessing the steric hindrance by cyclohexyl group toward <i>re</i> - and <i>si</i> -face, respectively.	S1
Figure S2. Newman projections of transition state structures 14a-TS and 14b-TS . Relative free energy differences (kcal/mol) are in parenthesis. Hydrogen atoms bound to carbon atoms are omitted for the sake of clarity.	S2
Figure S3. Transition state structures derived from major 13a (a) and minor conformer 13b (b) in the second borocupration step. Hydrogen atoms bound to carbon atoms are omitted for clarity. All bond lengths are in Å. Relative free energy differences in kcal/mol are in parenthesis.	S2
Figure S4. Energy profiles of <i>syn</i> -elimination derived from the minor conformer 15b .	S2
Table S1. Computed energy components for DFT-optimized structures.	S3
Table S2. Cartesian coordinates of the optimized geometries.	S5
Table S3. Vibrational frequencies (in cm^{-1}) of the optimized structures.	S32

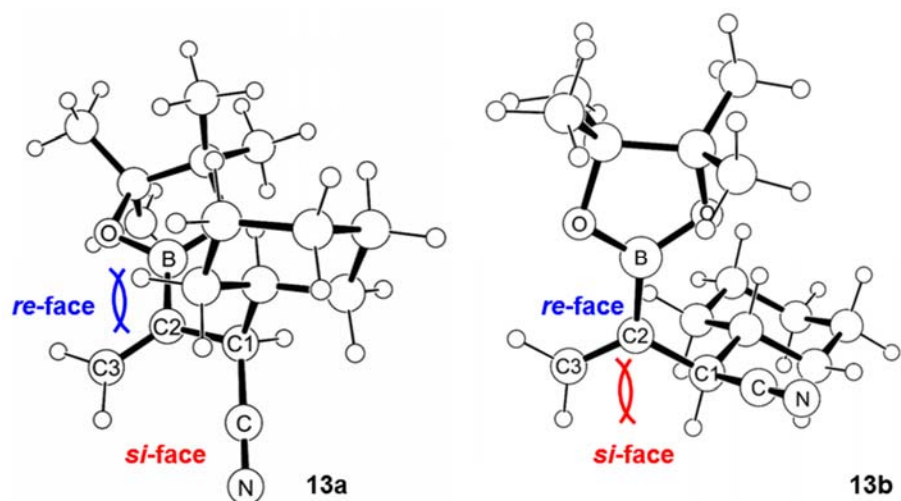


Figure S1. Conformational isomers **13a** and **13b** possessing the steric hindrance by cyclohexyl group toward *re*- and *si*-face, respectively.

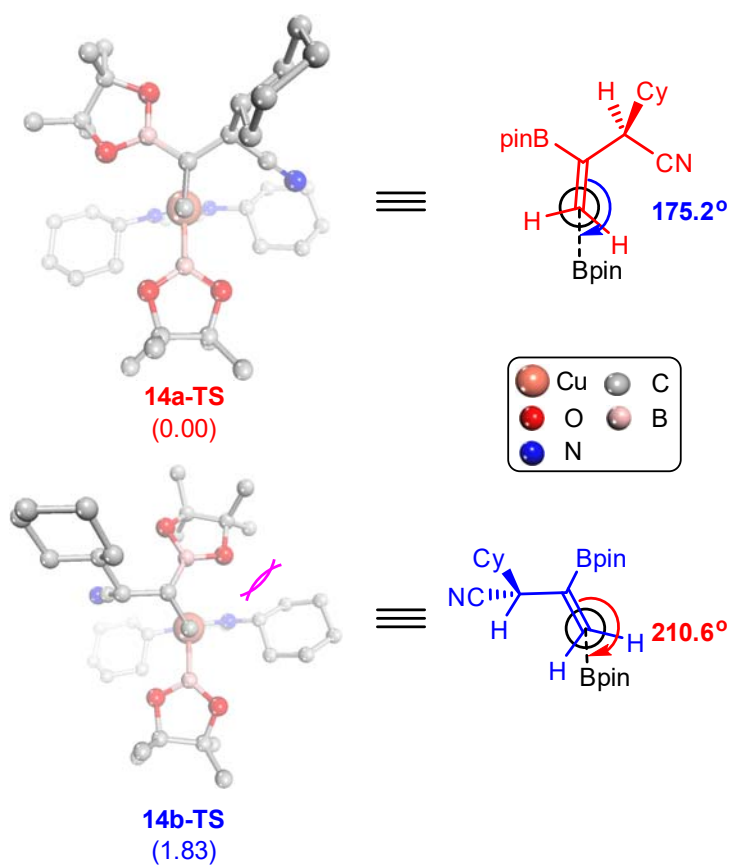


Figure S2. Newman projections of transition state structures **14a-TS** and **14b-TS**. Relative free energy differences (kcal/mol) are in parenthesis. Hydrogen atoms bound to carbon atoms are omitted for the sake of clarity.

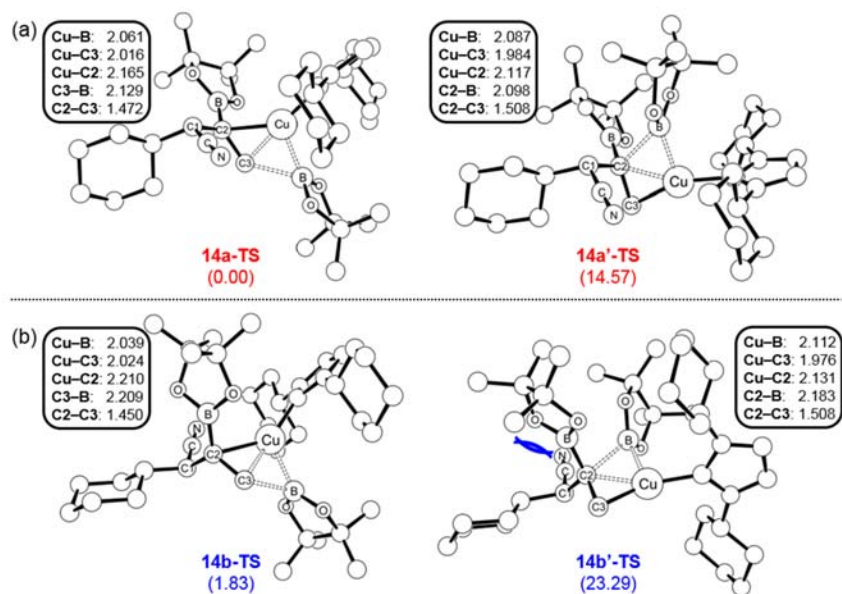


Figure S3. Transition state structures derived from major **13a** (a) and minor conformer **13b** (b) in the second borocupration step. Hydrogen atoms bound to carbon atoms are omitted for clarity. All bond lengths are in Å. Relative free energy differences in kcal/mol are in parenthesis.

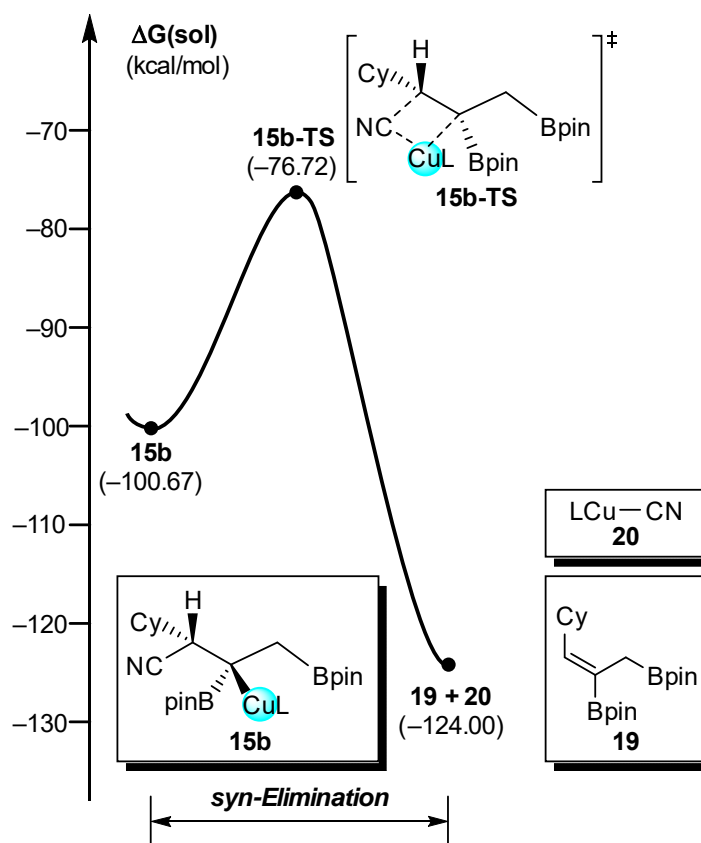


Figure S4. Energy profiles of *syn*-elimination derived from the minor conformer **15b**.

Table S1. Computed energy components for DFT-optimized structures

	E(SCF)/(eV)	ZPE/(kcal/mol)	S(gas)/(cal/mol · K)	G(solv)/(kcal/mol)
	cc-pVTZ(-f)/LACV3P**	6-31G**/LACVP**	6-31G**/LACVP**	6-31G**/LACVP**
1	-6799.055	236.96	147.573	-15.24
2	-10761.671	78.03	88.697	-33.09
3	-22391.536	228.87	139.441	-8.05
3-TS	-53010.862	544.13	254.308	-11.51
4	-16941.987	0.51	54.866	-40.79
5	-30618.966	314.63	164.103	-12.22
6	-17542.292	194.59	122.285	-5.1
7	-35468.914	349.94	190.533	-12.31
8	-9564.127	130.56	92.071	-1.71
9a	-45033.487	481.42	236.364	-7.41
9b	-45033.433	481.56	232.811	-8.57
9c	-45033.5	481.52	225.821	-7.33
9d	-45033.506	481.68	232.649	-8.00
9a-TS	-45033.213	481.47	228.241	-8.50
9b-TS	-45033.048	481.84	225.938	-8.83
9c-TS	-45033.176	481.38	224.8	-8.06
9d-TS	-45031.805	480.53	225.38	-9.35
10a	-45035.373	483.73	226.365	-10.01
10b	-45034.985	483.57	227.652	-10.47
10c	-45035.012	483.45	223.561	-7.77
10d	-45035.003	483.32	226.954	-8.95
10a-TS	-77665.067	631.85	310.039	-13.55
10a-TS'	-77664.712	632.2	306.309	-13.86
11	-32629.19	146.96	137.357	-11.87
12	-54377.374	377.9	213.607	-14.5
13a	-23288.864	253.82	148.674	-8.35
13b	-23288.836	253.75	149.051	-8.08
14a	-58758.666	605	283.339	-11.72
14a'	-58758.928	605.14	275.083	-8.93
14b	-58758.659	604.97	282.829	-10.05

14b'	-58758.608	604.97	281.46	-10.64
14a-TS	-58758.517	604.8	278.142	-11.46
14a'-TS	-58757.94	604.83	271.61	-12.17
14b-TS	-58758.452	604.71	279.711	-9.83
14b'-TS	-58757.485	604.96	271.658	-11.49
15a	-58759.591	605.69	279.438	-14.31
15a'	-58759.269	605.56	278.725	-14.72
15b	-58759.874	606.15	276.059	-10.72
15b'	-58759.342	605.44	281.865	-13.83
15a-TS	-61909.355	636.11	298.210	-13.17
15b-TS	-58758.754	604.42	277.809	-10.34
16	-3150.282	32.21	56.832	-5.01
17	-27407.77	261.77	153.035	-13.84
18	-34502.168	377.22	192.991	-10.3
19	-31957.955	363.03	183.807	-5.58
20	-26801.518	241.088	152.282	-17.78

Table S2. Cartesian coordinates of the optimized geometries

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	N	0.364362635	6.958447043	-8.114740394	O	-0.271386063	1.172520273	-3.485614357	
	C	-0.051706435	6.089618283	-7.118131420	O	1.144324722	2.407911749	-2.178496072	
	H	1.174775353	5.094759211	-5.562738151	C	0.546716287	1.420854281	-1.289223634	
	H	-1.081095064	5.795325706	-6.994490011	C	-0.018915386	0.361747211	-2.302007940	
	Cu	2.780923133	8.265680704	-9.207421775	C	-0.610771205	5.275528584	-7.349055710	
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	C	-2.076016808	7.192924798	-11.064071593	H	-1.570909625	5.693190514	-7.033075907	
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H	-2.093706608	-5.630643845	8.782540321	H	1.293169856	2.379412413	-6.308088303
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C	-0.198416278	0.307104409	5.940884113	C	-0.179588556	5.788527489	-8.413548470
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H	-2.325565577	0.081706427	6.129133224	H	-0.155602247	8.704628944	-9.922672272
H	-1.373275995	0.060276955	7.713460922	H	0.331375599	6.554721832	-11.567629814
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C	1.084016919	4.652821541	4.116658211	C	0.951837003	3.876134634	-11.442371368
H	-0.021936078	2.847117662	3.596492052	C	0.179282039	4.053122997	-10.131257057
H	1.728290439	2.665078402	3.545619249	H	-1.743270636	3.570930243	-9.265891075
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H	1.1111237168	5.033667088	3.088114023	H	1.948291063	4.325311184	-11.357616425
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C	-1.781159997	-4.394591331	4.307250500	H	0.723901629	3.547351599	-9.322811127
C	-3.193543434	-4.483529568	3.712481260	C	-1.237859607	9.272064209	-7.494634151
C	-0.873154581	-5.518057346	3.785887480	C	-0.642064214	7.892449379	-7.197807312
H	-1.322185159	-3.442959070	4.023769855	C	0.571006596	7.991793633	-6.261135101
C	-3.131685734	-4.460105419	2.175784111	C	0.163868338	8.673462868	-4.945741653
H	-3.803507090	-3.655976534	4.093482018	C	-0.473405749	10.049853325	-5.199539661
H	-3.672092915	-5.415896893	4.046759605	C	-1.654859900	9.951584816	-6.179065704
C	-0.812524974	-5.479849339	2.251852512	H	-2.095313787	9.176042557	-8.171757698
H	0.123037547	-5.387223244	4.217958450	H	-0.490555704	9.901967049	-7.998178005
H	-1.258874774	-6.492580891	4.118858337	H	-1.395884275	7.282527447	-6.688337803
C	-2.216825962	-5.570933819	1.633877635	H	0.951747775	6.982108593	-6.071736813
H	-2.744403362	-3.484706402	1.849918127	H	1.367709756	8.558403015	-6.764794827
H	-4.141429901	-4.554350376	1.759115577	H	1.037241220	8.772986412	-4.290891171
H	-0.175706506	-6.292448044	1.880787849	H	-0.551113009	8.019236565	-4.432054996
H	-0.338020951	-4.536338329	1.957497001	H	-0.805961549	10.496003151	-4.254613876
H	-2.156883717	-5.511697292	0.540442526	H	0.282201111	10.729823112	-5.619877815
H	-2.657833338	-6.550202370	1.872451544	H	-2.065565586	10.946074486	-6.389303684

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9a-TS
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C	-3.101771832	5.817548752	-3.881492853	H	-0.480183750	-0.035063084	-6.537545681
C	-3.312351942	7.217017651	-3.314427137	H	-2.174226046	-0.304047585	-6.136760712
C	-2.905136108	4.802947044	-2.748652935	H	-0.067998841	0.953180611	-4.310761452
H	-3.770645142	4.768866539	-2.079458475	H	-1.929191709	1.327690005	-2.707913399
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C	-4.163426399	5.357525826	-4.936657906	H	-0.651127875	-0.790047944	-2.424864054
C	-5.321612358	4.538170815	-4.375411034	H	-1.453916669	-2.912824392	-3.448911905
C	-4.693542004	6.513418198	-5.796360493	H	-2.765769720	-2.052440166	-4.251484871

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H 0.228231296 -1.623068333 -4.755568504

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9b-TS
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C 3.181851864 3.003318787 -8.586590767
C 3.663292885 2.943668604 -10.032126427
C 3.581898928 1.726677060 -7.836899757
H 4.665733337 1.573771834 -7.842553139
H 3.106782913 0.868724346 -8.320948601
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C 4.835466862 4.226145744 -6.977445126
C 3.596775532 5.556383610 -8.707814217
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H 5.007887840 5.179109097 -6.468602657
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9c-TS
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C -0.171379030 -5.227073193 2.993521690
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C	-1.110131621	-4.233089447	0.814494014	H	-5.622575784	7.741985346	-6.172773297
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H	0.449262351	-4.371405602	3.278845549	H	-5.878335920	9.070200087	-7.324015154
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H	0.787433386	-5.308091164	1.075829625	H	-3.279122378	8.228260430	-8.994212063
H	-2.010681391	-4.680222988	0.373179406	H	-2.166949970	9.355957123	-8.192402546
C	0.162380323	-3.476933718	7.970539093	H	-2.565526917	11.256572200	-6.930835542
C	1.635735393	-3.902270555	7.840482712	H	-3.212821378	11.755121630	-5.367075344
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C	0.547967136	-2.791408300	10.360430717	C	-0.679717552	7.150340066	-5.445482999
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H	-1.390171289	-3.287749052	9.474519730	H	-1.677899520	5.272573550	-5.446745493
H	2.553173065	-2.078602314	8.511634827	H	0.148002945	5.168589926	-5.266686240
H	0.182675734	-2.892378330	11.388906479	C	-2.286101945	3.179677113	-10.613199472
H	2.638915300	-2.618729353	10.930029869	N	-1.372537864	4.090859304	-10.108441660
C	-0.788021564	-3.841603756	5.705030441	C	-1.438033115	4.144870459	-8.747951634
H	-0.308452219	-4.664254665	9.722678185	N	-2.387591463	3.232405778	-8.410302005
H	0.468832076	-1.726572514	10.101426125	C	-2.927489592	2.637605010	-9.541892488
H	2.108500719	-4.268937588	10.613783836	H	-2.391010366	2.976233860	-11.666526418
H	3.561038733	-3.495689392	8.744288445	H	-3.688131330	1.875979461	-9.496349365
H	1.701309085	-4.983161449	8.035026550	Cu	-0.484239312	5.530498503	-7.793274566
H	0.069895364	-2.430245399	7.660403252	C	-3.928703547	4.312437474	-6.820903508
H	-0.626916289	-6.336876392	1.192597985	C	-4.469309637	4.310933339	-5.384117892
H	0.297930747	-6.114982128	3.434117317	C	-5.077177506	2.948915816	-5.015108507
H	-2.150944233	-5.927311420	3.480151176	C	-4.074523685	1.807114910	-5.255675799
H	-3.294851542	-4.142959118	2.656593084	C	-3.562176489	1.800188655	-6.708737830
H	-2.174608946	-2.416593552	1.356035352	C	-2.933828067	3.157942788	-7.040260076
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H	-1.122980714	-6.024924278	8.142211914	H	-4.756807493	4.190202295	-7.534550189
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C	0.687973619	-0.582817256	4.205532074	H	-5.973526509	2.774503806	-5.628389559
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C	0.740494490	1.073969722	6.751054287	H	-4.412948409	1.608942607	-7.377691758
C	1.880100608	0.115804903	6.369780540	H	-2.067603929	3.305061063	-6.386637335
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10a-TS
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C	-5.247380739	8.206989396	-7.086582317	C	1.704131289	11.800882847	-13.553918167
C	-3.216717037	9.069271666	-8.297250674	H	2.695305145	12.178936684	-13.818894469
				H	0.964900519	12.540714550	-13.883675087
				H	1.524737454	10.886585621	-14.130710834
				S	1.247591185	10.619190295	-7.592573490

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10a-TS'
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11
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12
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13b

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14b
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14a-TS
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14a'-TS

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C	-3.019978477	1.240075111	1.600651124	H	2.320671674	5.698159991	0.747458148
C	-3.374209683	-0.018589924	0.792615726	H	2.826139374	5.705417282	-0.945005454
C	-2.129088687	-0.882475887	0.535581049	H	3.638301650	3.657568619	1.174284477
C	-1.023727017	-0.074016710	-0.164913496	H	4.727231631	2.422461850	-0.667355559
C	-0.674339322	1.172643688	0.659998279	H	4.313940622	3.704114571	-1.809747785
H	-1.614474319	2.911554456	1.526569276	H	6.659526878	3.991910201	-1.052434031
H	-2.270481376	2.443825523	-0.046297861	H	6.144975934	4.009027233	0.630354965
H	-3.905526301	1.869251040	1.742970039	H	6.507925126	6.340249826	-0.159054453
H	-2.680558047	0.945189016	2.603181768	H	5.389818356	6.088536822	-1.496234892
H	-4.138625572	-0.603279075	1.316703293	H	4.233187551	7.294702116	0.351208741
H	-3.811514340	0.280255986	-0.171164241	H	4.671318175	6.024469174	1.486886857
H	-2.385796154	-1.758638513	-0.070256312				

Table S3. Vibrational frequencies (in cm^{-1}) of the optimized structures

=====							350.80	355.09	357.36	365.48	368.57	376.25
1	=====						378.17	382.98	387.34	391.09	399.32	404.99
=====							416.11	423.11	436.08	438.60	454.19	456.51
24.23	31.99	34.91	37.38	58.24	78.36	471.89	473.14	490.07	497.08	511.59	520.33	
103.41	111.42	153.99	167.92	190.04	206.16	522.65	523.70	531.64	540.84	566.54	584.01	
239.03	239.59	270.19	304.32	354.09	360.96	585.33	616.17	646.70	647.14	664.00	675.06	
368.33	393.24	400.64	402.47	452.46	453.62	693.38	722.39	739.95	765.90	768.72	774.05	
474.67	517.28	523.08	567.27	655.38	690.77	806.85	810.81	815.10	820.37	824.54	828.20	
731.42	764.09	773.49	808.07	808.67	822.48	847.00	866.64	870.10	870.42	872.85	886.59	
822.68	829.55	869.16	872.39	912.49	912.55	910.47	911.42	914.50	916.03	920.84	921.65	
913.02	915.60	943.83	943.95	1003.60	1020.65	931.32	932.76	937.26	940.97	944.30	945.44	
1044.34	1044.65	1057.02	1067.94	1075.75	1075.80	952.00	966.25	968.08	980.81	983.31	988.23	
1098.15	1098.20	1109.12	1109.60	1136.72	1169.37	1005.75	1021.04	1023.23	1023.34	1029.72	1032.92	
1171.64	1221.66	1222.20	1222.97	1272.09	1275.13	1041.40	1043.53	1058.88	1059.64	1064.19	1069.48	
1297.58	1297.72	1303.43	1303.74	1320.58	1339.98	1069.58	1076.92	1078.83	1081.35	1098.48	1099.04	
1340.97	1341.26	1367.20	1374.39	1374.72	1388.42	1107.41	1111.21	1112.10	1136.48	1170.94	1172.97	
1388.49	1388.57	1393.19	1393.67	1393.87	1396.14	1178.02	1179.95	1187.75	1188.43	1210.73	1214.90	
1401.75	1440.36	1462.46	1469.71	1495.92	1496.10	1222.53	1226.56	1227.41	1234.02	1239.58	1245.65	
1501.44	1501.53	1504.41	1504.48	1509.18	1509.34	1255.96	1257.91	1263.10	1269.89	1274.50	1276.93	
1523.04	1523.08	1613.43	3019.87	3020.06	3023.74	1280.90	1283.28	1295.94	1296.58	1300.05	1301.59	
3023.83	3027.24	3027.39	3032.98	3033.00	3034.89	1309.95	1324.17	1341.29	1342.69	1347.78	1369.77	
3035.00	3068.37	3068.83	3081.92	3082.05	3083.50	1375.08	1377.01	1386.74	1388.36	1393.69	1394.70	
3083.61	3086.78	3086.88	3087.73	3087.84	3094.54	1394.81	1398.18	1401.93	1402.65	1405.27	1407.17	
3094.76	3291.44	3311.22										
=====							1410.41	1411.21	1414.85	1415.78	1424.54	1425.17
2	=====						1429.51	1435.18	1436.70	1447.24	1468.43	1482.47
=====							1484.30	1484.66	1486.36	1493.50	1494.94	1495.33
46.23	46.54	236.14	289.15	289.52	330.38	1496.41	1497.37	1497.89	1499.02	1500.20	1501.28	
347.29	347.36	479.45	479.66	519.08	762.07	1501.81	1504.03	1504.97	1505.58	1509.22	1509.36	
883.49	883.64	948.10	1040.01	1040.20	1061.92	1510.68	1514.19	1516.02	1518.66	1519.63	1520.42	
1238.15	1238.36	1270.30	1388.14	1388.23	1413.51	1522.15	1523.49	1524.77	1525.88	1529.17	1541.24	
1482.33	1492.47	1492.54	1505.52	1505.58	1526.77	1541.66	1545.37	1598.49	2996.94	2998.75	3003.99	
3013.07	3013.22	3023.93	3084.54	3084.76	3093.64	3008.06	3011.72	3016.30	3016.47	3019.22	3021.15	
3096.81	3101.32	3101.51										
=====							3022.59	3024.96	3025.67	3027.42	3028.67	3029.50
3	=====						3032.66	3038.21	3043.95	3047.14	3051.02	3055.06
=====							3059.02	3059.64	3063.98	3069.25	3070.10	3073.97
18.37	39.86	48.29	101.52	104.52	126.17	3077.03	3079.12	3079.53	3080.73	3082.30	3084.90	
172.94	190.12	228.80	234.33	244.12	244.76	3086.22	3088.79	3090.75	3091.13	3091.73	3098.01	
291.06	293.28	296.41	302.03	325.58	326.89	3098.70	3102.72	3111.10	3114.45	3122.01	3125.27	
336.78	338.12	356.59	363.72	372.25	383.11	3134.77	3136.24	3139.20	3139.77	3143.64	3148.73	
397.08	415.44	420.17	445.56	472.32	506.00	3152.15	3157.41	3164.15	3198.96	3288.73	3308.47	
524.05	526.30	583.82	585.36	608.31	667.37	=====						
675.03	678.54	754.98	839.93	845.69	850.82	4	=====					
868.17	880.25	939.17	939.85	947.73	948.01	357.06						
970.42	971.27	979.81	987.18	1023.05	1023.39	=====						
1032.25	1033.98	1137.68	1139.24	1161.07	1188.46	5	=====					
1190.10	1191.02	1203.03	1244.38	1244.55	1270.99	14.21	24.89	29.61	34.79	48.87	53.93	
1271.85	1305.06	1307.48	1311.25	1327.17	1414.54	56.21	66.35	104.03	109.36	125.11	164.03	
1414.86	1417.52	1417.69	1426.45	1427.38	1427.69	176.93	202.97	206.65	239.86	240.99	256.70	
1437.44	1438.94	1485.49	1485.82	1493.85	1494.05	276.40	302.52	313.92	326.44	340.17	353.66	
1497.89	1498.48	1501.59	1501.67	1518.55	1518.96	359.78	366.43	375.97	392.72	399.79	405.99	
1520.20	1520.62	1523.40	1523.77	1541.80	1541.98	452.92	453.82	470.08	474.14	475.91	517.46	
3047.85	3049.63	3050.32	3052.12	3052.30	3054.14	523.32	570.23	612.20	652.14	691.47	725.07	
3056.64	3058.54	3120.47	3121.00	3122.18	3122.78	759.64	765.98	772.90	808.82	810.12	816.30	
3128.47	3130.12	3130.56	3132.29	3133.62	3134.84	824.11	830.57	869.74	873.20	890.45	894.08	
3134.90	3136.15	3151.32	3151.67	3153.10	3153.40	912.09	913.00	914.26	917.01	944.41	944.54	
=====							962.34	1004.37	1019.50	1024.88	1044.95	1045.06
3-TS	=====						1047.29	1053.04	1057.57	1067.87	1076.63	1077.71
=====							1099.60	1100.10	1108.70	1109.26	1134.25	1170.97
-154.87	11.18	19.97	28.25	31.77	38.71	1172.39	1220.72	1222.88	1224.01	1236.37	1238.68	
40.48	49.88	53.87	66.30	67.36	73.89	1247.87	1271.95	1275.90	1297.44	1297.86	1302.56	
78.31	82.57	87.53	103.61	116.37	121.37	1303.38	1319.24	1341.68	1341.79	1342.84	1365.96	
123.83	133.14	135.03	147.76	156.57	171.63	1375.07	1375.35	1388.53	1389.54	1389.61	1393.16	
179.29	192.86	199.18	212.54	233.12	238.58	1393.66	1394.72	1394.97	1395.41	1396.00	1402.03	
244.30	245.84	256.20	263.64	268.54	280.60	1420.17	1441.98	1464.33	1469.82	1483.88	1493.59	
289.19	295.98	297.92	302.65	306.73	313.60	1495.95	1496.15	1496.31	1501.35	1501.58	1504.61	
319.12	324.13	329.08	332.62	340.06	345.30	1504.72	1506.06	1508.90	1509.31	1509.36	1523.14	
=====							1523.30	1527.29	1608.92	2979.67	2996.31	3006.00

3017.45 3017.93 3020.53 3021.19 3023.87 3024.69
3028.97 3029.82 3031.15 3031.90 3046.60 3060.27
3063.81 3065.21 3068.11 3077.65 3079.04 3079.26
3080.82 3080.90 3083.94 3084.13 3085.38 3085.58
3090.59 3091.15 3091.97 3097.95 3289.13 3308.99

1493.54 1495.93 1500.15 1502.95 1507.75 1521.85
2071.15 2978.57 3017.00 3018.00 3022.18 3023.58
3031.97 3066.40 3071.20 3071.51 3077.09 3084.14
3117.63 3130.69 3204.52

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42.32 58.01 109.40 115.96 137.34 223.10
230.99 233.39 252.10 269.23 289.22 294.90
300.56 309.22 327.15 337.34 360.64 365.33
378.06 395.93 411.46 442.28 471.54 481.90
520.78 533.77 585.48 627.85 677.03 680.29
759.88 854.36 869.79 891.09 928.57 937.26
940.85 946.17 972.00 979.22 980.09 1022.09
1026.55 1050.66 1069.11 1070.19 1144.91 1189.00
1192.22 1238.89 1250.36 1270.34 1274.88 1286.06
1301.05 1341.96 1414.72 1415.34 1416.80 1417.57
1427.44 1437.17 1443.10 1486.03 1486.88 1490.48
1493.46 1498.73 1501.98 1503.76 1504.60 1517.26
1518.20 1520.08 1523.23 1524.16 1541.66 1543.40
3047.36 3048.02 3049.75 3051.73 3054.59 3055.19
3058.67 3119.04 3120.40 3121.99 3123.58 3129.23
3130.46 3131.29 3131.64 3133.67 3136.00 3144.70
3148.85 3152.11 3152.57

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14.37 14.64 22.65 29.28 32.39 44.82
53.36 68.70 94.78 105.36 110.80 117.85
132.50 175.87 179.40 200.92 220.11 232.38
240.14 240.45 243.94 291.15 292.27 302.72
305.30 325.97 337.45 353.41 357.16 364.21
366.62 379.71 394.36 400.81 404.86 405.32
452.23 453.83 474.04 478.04 517.58 523.73
523.92 560.70 565.14 584.25 654.71 671.60
688.37 728.46 763.90 773.58 786.53 809.14
810.04 817.76 823.87 830.38 843.72 866.55
869.83 873.16 913.32 913.47 913.58 915.94
934.05 943.02 945.07 945.16 965.80 979.61
1004.12 1019.90 1020.13 1030.70 1045.11 1045.20
1055.05 1062.07 1076.63 1076.76 1097.61 1099.90
1100.06 1109.30 1109.77 1128.58 1149.55 1170.17
1171.22 1185.77 1199.75 1220.68 1222.49 1223.14
1235.26 1242.74 1265.41 1270.48 1273.95 1298.14
1298.23 1302.66 1303.51 1309.85 1317.86 1337.43
1342.07 1342.33 1365.49 1375.35 1375.64 1388.35
1390.32 1390.38 1393.01 1395.35 1395.52 1396.39
1399.97 1409.14 1411.42 1422.05 1431.62 1439.42
1461.08 1467.04 1485.35 1493.38 1496.06 1496.31
1498.25 1499.99 1501.58 1501.70 1504.81 1504.88
1509.38 1509.55 1518.53 1518.58 1522.24 1523.45
1523.52 1540.46 1611.35 3016.41 3016.46 3019.56
3019.70 3023.03 3023.18 3029.56 3029.75 3031.37
3031.52 3040.90 3043.07 3045.64 3049.90 3063.10
3063.82 3077.34 3077.53 3079.34 3079.43 3082.77
3082.90 3084.40 3084.59 3090.78 3090.97 3109.58
3110.06 3120.82 3122.88 3130.61 3132.47 3145.88
3146.02 3285.30 3305.45

8

49.68 112.15 168.41 243.32 295.71 334.55
348.71 375.42 424.68 450.67 523.49 588.23
691.81 790.11 806.42 852.80 868.22 891.70
906.14 915.85 936.72 962.18 1026.26 1038.06
1047.52 1072.69 1098.73 1105.20 1148.51 1172.74
1216.30 1265.74 1296.19 1304.30 1330.39 1335.27
1359.50 1378.62 1383.28 1392.21 1394.89 1413.22

9a

13.05 16.02 23.52 25.19 31.92 34.62
35.07 50.98 56.04 61.17 69.67 76.64
80.85 84.27 106.81 110.51 115.37 123.58
144.42 155.73 168.73 181.76 197.91 206.94
215.38 236.20 240.62 242.72 251.97 252.57
269.59 294.04 299.50 299.86 307.02 314.36
330.53 340.15 342.14 353.19 360.43 364.40
368.81 380.16 392.90 402.27 403.17 406.53
410.55 415.75 445.84 451.80 453.98 455.54
474.69 477.24 518.49 523.94 525.71 536.76
559.32 562.93 585.27 594.31 649.33 669.54
674.44 687.33 716.61 763.80 774.73 781.29
796.50 805.39 805.44 807.77 809.90 813.88
821.91 829.93 845.14 854.42 867.56 869.20
872.18 887.76 905.05 910.39 914.76 914.87
916.85 927.60 935.51 943.18 944.19 944.32
946.99 966.01 968.42 979.37 1004.09 1018.35
1021.72 1029.08 1031.42 1044.35 1044.50 1046.93
1050.55 1053.35 1059.91 1062.83 1076.55 1076.85
1090.44 1095.44 1098.79 1099.59 1102.35 1107.55
1109.74 1124.30 1127.36 1138.48 1166.08 1170.20
1172.71 1186.98 1193.20 1207.54 1219.18 1222.12
1224.18 1234.02 1242.28 1254.53 1267.03 1268.07
1272.83 1296.27 1297.34 1297.53 1298.17 1302.49
1306.92 1310.02 1314.44 1318.53 1335.34 1338.20
1341.55 1343.86 1362.65 1370.30 1373.46 1374.43
1384.24 1385.85 1387.92 1388.55 1389.30 1391.43
1392.00 1392.65 1393.49 1395.23 1396.12 1399.75
1407.93 1410.97 1413.68 1423.80 1433.51 1439.42
1460.33 1470.31 1471.28 1485.81 1491.76 1494.04
1495.25 1495.87 1497.87 1499.84 1500.27 1500.96
1501.47 1502.86 1504.04 1504.18 1507.02 1508.64
1510.67 1518.17 1519.45 1521.80 1522.68 1522.72
1524.84 1540.63 1613.28 1892.04 3011.06 3013.37
3013.94 3015.03 3015.59 3016.75 3016.86 3018.00
3019.83 3020.49 3023.69 3025.71 3026.37 3028.81
3031.93 3038.69 3042.39 3044.89 3047.03 3051.55
3063.35 3064.72 3068.81 3070.27 3070.30 3074.93
3075.19 3076.79 3077.43 3077.54 3077.90 3081.40
3084.72 3085.25 3097.11 3099.60 3113.06 3114.89
3120.91 3121.05 3124.20 3125.91 3129.87 3131.82
3144.69 3146.12 3176.14 3196.62 3286.64 3306.96

9b

18.78 20.63 25.41 30.99 34.45 41.14
45.66 54.99 62.77 67.15 67.69 76.08
80.33 88.64 102.49 106.36 119.65 127.76
141.63 153.56 170.13 179.01 193.32 214.83
218.39 233.22 242.52 244.23 248.82 249.01
257.19 291.57 295.15 302.49 305.16 323.73
330.40 341.33 342.12 354.50 363.23 366.41
374.35 378.94 391.23 393.96 403.09 410.59
417.27 419.46 441.95 454.47 455.68 459.19
474.51 479.64 519.45 521.41 524.23 527.64
558.91 564.89 580.25 585.07 648.35 672.67
683.45 691.76 718.13 762.24 773.59 778.37
804.63 808.02 808.14 812.68 812.86 825.07
831.97 842.06 845.48 854.99 864.51 870.47
872.71 882.08 903.97 910.59 914.17 915.74
920.62 921.88 933.70 942.98 943.41 944.33
948.81 965.15 966.79 978.78 1004.30 1018.10
1020.51 1023.88 1031.01 1045.29 1046.50 1046.92

1052.16 1052.98 1060.24 1062.42 1074.88 1079.71
 1081.15 1096.38 1096.86 1103.02 1103.66 1110.08
 1111.39 1120.92 1130.19 1138.13 1163.92 1172.18
 1172.65 1185.83 1191.84 1208.25 1215.29 1222.43
 1226.07 1226.89 1241.68 1250.69 1265.42 1269.78
 1273.03 1296.62 1296.89 1298.63 1301.34 1304.33
 1306.30 1311.54 1313.52 1317.04 1334.77 1337.35
 1342.43 1353.07 1356.37 1369.82 1373.21 1376.11
 1383.34 1386.08 1387.31 1388.28 1391.04 1391.30
 1391.75 1394.12 1395.06 1396.23 1399.41 1400.45
 1405.19 1410.51 1412.68 1423.52 1433.01 1437.99
 1464.83 1466.65 1472.94 1486.47 1489.98 1493.88
 1494.42 1497.07 1498.43 1499.55 1499.96 1501.77
 1502.23 1503.07 1503.80 1505.52 1506.87 1510.51
 1512.35 1517.31 1518.57 1521.37 1522.58 1524.56
 1527.61 1539.31 1611.22 1929.87 3005.53 3009.26
 3012.63 3013.94 3014.87 3015.21 3015.41 3018.92
 3020.47 3020.98 3022.02 3026.17 3027.10 3029.39
 3037.87 3039.55 3040.96 3044.01 3045.58 3050.30
 3065.38 3067.47 3068.23 3070.95 3071.30 3072.55
 3074.45 3074.83 3076.91 3076.94 3077.63 3080.88
 3084.08 3089.26 3091.42 3099.91 3110.67 3112.14
 3120.00 3122.80 3126.04 3128.01 3132.98 3133.46
 3133.83 3146.34 3148.41 3210.00 3287.28 3309.01

9c

5.89 17.35 26.03 29.55 35.39 38.28
 45.87 50.96 60.82 64.37 68.87 74.28
 82.66 98.64 109.40 112.78 120.38 135.69
 141.04 163.82 165.16 177.64 213.38 218.14
 223.91 234.75 241.82 248.17 252.12 253.18
 257.56 275.39 289.16 293.21 299.58 328.35
 329.52 340.24 347.45 357.12 361.42 365.04
 369.71 378.34 386.27 397.41 403.13 409.73
 420.25 428.27 449.15 453.09 454.30 469.80
 472.17 476.86 519.45 519.83 524.12 527.25
 558.88 566.37 572.62 585.25 640.36 648.29
 673.49 692.98 710.85 762.72 774.32 779.03
 799.14 804.20 807.59 811.62 818.29 823.51
 830.13 839.82 848.75 859.45 863.71 871.01
 872.67 905.22 906.19 908.56 910.74 912.84
 916.76 920.14 935.46 941.94 945.50 946.97
 951.17 964.82 966.64 977.99 1005.30 1017.10
 1021.34 1031.28 1042.30 1045.09 1045.26 1045.67
 1051.24 1054.97 1062.56 1067.20 1076.76 1082.87
 1084.59 1096.53 1098.89 1101.31 1106.68 1108.81
 1111.37 1128.20 1131.10 1140.13 1160.51 1172.01
 1177.37 1187.98 1191.80 1209.55 1217.06 1221.50
 1230.74 1234.96 1242.74 1246.07 1268.11 1271.42
 1280.11 1293.38 1294.75 1297.03 1297.53 1302.61
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 3108.76 3110.84 3113.40 3121.26 3123.40 3129.64
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9d

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9a-TS

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9b-TS

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9d-TS

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14b

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14b'

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15b

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15b-TS

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