SUPPORTING INFORMATION

Catalytic Resonance Theory: The Catalytic Mechanics of Programmable Ratchets

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(1) *Elementary Ratchet Average Surface Coverage – Derivation*. The average surface coverage of an elementary reaction step ratchet (A* ↔ B*, blue and green states) was determined as follows. The rate of change of molecules on the surface was described with the forward and reverse rate constants of first order reactions for a single catalyst state.

$$\frac{d\theta_A}{dt} = -k_1\theta_A + k_{-1}\theta_B \qquad \text{(S1)}$$

The rate equation was rewritten as follows,

$$\frac{d\theta_A}{k_{-1} - \theta_A(k_1 + k_{-1})} = dt \qquad \text{(S2)}$$

Using the initial condition that $\theta_A(t) = \theta_A°$ for $t = 0$, the surface coverage of A* was determined for a single catalyst state (blue or green) at any time t, initial surface coverage of A*, and kinetic rate constants,

$$\theta_A = \frac{k_{-1} - [k_{-1} - \theta_A^{\circ}(k_1 + k_{-1})]e^{-(k_1 + k_{-1})t}}{(k_1 + k_{-1})} \qquad \text{(S3)}$$

The surface coverage of species A* at equilibrium for either catalyst state (blue or green) was calculated using the kinetic rate constants.

$$\theta_{A,state}^{EQ} = \frac{k_{-1}}{(k_1 + k_{-1})} \qquad \text{(S4)}$$

$$\theta_A = \frac{k_{-1}}{(k_1 + k_{-1})} - \frac{k_{-1}e^{-(k_1 + k_{-1})t}}{(k_1 + k_{-1})} + \frac{\theta_A^{\circ}(k_1 + k_{-1})e^{-(k_1 + k_{-1})t}}{(k_1 + k_{-1})} \qquad \text{(S5)}$$

$$\theta_A = \theta_{A,state}^{EQ} - \theta_{A,state}^{EQ}\, e^{-(k_1 + k_{-1})t} + \theta_A^{\circ} e^{-(k_1 + k_{-1})t} \qquad \text{(S6)}$$

$$\theta_A = \theta_{A,state}^{EQ} + \left[\theta_A^{\circ} - \theta_{A,state}^{EQ}\right]e^{-(k_1 + k_{-1})t} \qquad \text{(S7)}$$

Alternatively can also be written as:

$$\theta_A = \theta_{A,state}^{EQ} + \left[\theta_A^{\circ} - \theta_{A,state}^{EQ}\right]e^{-\frac{k_{-1}}{\theta_{A,state}^{EQ}}t} \qquad \text{(S8)}$$

The overall ratchet equilibrium was calculated for a catalyst oscillation period ($\tau_{blue} + \tau_{green}$) by determining the equilibrium concentration of surface species weighted by the time in each catalyst state (τ_{blue} or τ_{green} for blue or green),

$$\theta_A^{EQ} = \left(\frac{\tau_{green}}{\tau_{blue} + \tau_{green}}\right)\theta_{A,green}^{EQ} + \left(\frac{\tau_{blue}}{\tau_{blue} + \tau_{green}}\right)\theta_{A,blue}^{EQ} \quad \text{(S9)}$$

The average surface coverage of A* in each state was calculated by integrating the surface coverage over the timescale of that state period ($\tau_{blue} + \tau_{green}$) and then dividing by the time scale (τ_{blue} or τ_{green}).

$$\bar{\theta}_{A,state} = \left(\frac{1}{\tau_{state}}\right)\int_0^{\tau_{state}} \frac{k_{-1} - \left[k_{-1} - \theta_A^{\circ}(k_1 + k_{-1})\right]e^{-(k_1 + k_{-1})t}}{(k_1 + k_{-1})}\,dt \quad \text{(S10)}$$

with the analytical solution that is equation 4 in the main paper of:

$$\bar{\theta}_{A,state} = \frac{k_{-1}}{k_1 + k_{-1}} - \frac{1}{\tau_{state}}\left(\frac{k_{-1} - \theta_A^{o}(k_1 + k_{-1})}{(k_1 + k_{-1})^2}\left(1 - e^{-(k_1 + k_{-1})\tau_{state}}\right)\right) \quad \text{(S11)}$$

This can be further rewritten as follows

$$\bar{\theta}_{A,state} = \frac{k_{-1}}{(k_1 + k_{-1})} - \frac{1}{(k_1 + k_{-1})\tau_{state}}\left(\frac{k_{-1}}{(k_1 + k_{-1})}\left(1 - e^{-(k_1 + k_{-1})\tau_{state}}\right) - \theta_A^{o}\left(1 - e^{-(k_1 + k_{-1})\tau_{state}}\right)\right) \quad \text{(S12)}$$

$$\bar{\theta}_{A,state} = \theta_{A,state}^{EQ} - \frac{1}{(k_1 + k_{-1})\tau_{state}}\left(\theta_{A,state}^{EQ}\left(1 - e^{-(k_1 + k_{-1})\tau_{state}}\right) - \theta_A^{o}\left(1 - e^{-(k_1 + k_{-1})\tau_{state}}\right)\right) \quad \text{(S13)}$$

$$\bar{\theta}_{A,state} = \theta_{A,state}^{EQ} - \frac{1 - e^{-(k_1 + k_{-1})\tau_{state}}}{(k_1 + k_{-1})\tau_{state}}\left(\theta_{A,state}^{EQ} - \theta_A^{o}\right) \quad \text{(S14)}$$

$$\bar{\theta}_{A,state} - \theta_{A,state}^{EQ} = \frac{1 - e^{-(k_1 + k_{-1})\tau_{state}}}{(k_1 + k_{-1})\tau_{state}}\left(\theta_A^{o} - \theta_{A,state}^{EQ}\right) \quad \text{(S15)}$$

$$\frac{\bar{\theta}_{A,state} - \theta_{A,state}^{EQ}}{\theta_A^{o} - \theta_{A,state}^{EQ}} = \frac{1 - e^{-(k_1 + k_{-1})\tau_{state}}}{(k_1 + k_{-1})\tau_{state}} \quad \text{(S16)}$$

(2) *High Frequency Surface Coverage – Derivation*. Elementary catalytic ratchets operating at high frequency (*hf*) defined as applied frequencies far above the cutoff frequency ($f >> f_c$) were shown to approach a constant surface coverage value, $\bar{\theta}_{i,hf}$. This surface coverage for species, I, can be calculated from a derived quantity starting from the rate of conversion of C* to D*.

$$\frac{d\theta_C}{dt} = -k_1\theta_C + k_{-1}\theta_D = k_{-1} - \theta_C(k_1 + k_{-1}) \qquad \text{(S17)}$$

At high frequency at steady state, the rates of surface coverage change in each of the catalyst states (blue and green) weighted by the time of reaction in state *i*, τ_i, will be equal.

$$\tau_{blue} \left.\frac{d\theta_C}{dt}\right|_{blue} = -\tau_{green} \left.\frac{d\theta_C}{dt}\right|_{green} \qquad \text{(S18)}$$

The duty cycle was defined in the main text as,

$$D_B = \frac{\tau_{blue}}{\tau_{green} + \tau_{blue}};\ (1 - D_B) = D_G = \frac{\tau_{green}}{\tau_{green} + \tau_{blue}} \qquad \text{(S19)}$$

The time of reaction in state *i* is then represented as,

$$\tau_i = D_i\tau;\ \ \tau_B = D_B\tau \qquad \text{(S20)}$$

Where τ is the time of an entire oscillation period and is equal to $\tau_{blue} + \tau_{green}$. In the following derivation, the blue state is represented as 'B' and the green state is represented as 'G' for brevity. Equation S8 can then be written out yielding the following equation where the entire oscillation period, τ, cancels from both sides,

$$D_B\tau\left(k_{-1,B} - \theta_C\left(k_{1,B} + k_{-1,B}\right)\right) = -(1 - D_B)\tau\left(k_{-1,G} - \theta_C\left(k_{1,G} + k_{-1,G}\right)\right) \qquad \text{(S21)}$$

Solving for θ_C yields,

$$\bar{\theta}_{C,hf} = \frac{\left(D_B k_{-1,b} + (1-D_B)k_{-1,g}\right)}{\left(D_B k_{-1,b} + (1-D_B)k_{-1,g}\right) + \left(D_B k_{1,b} + (1-D_B)k_{1,g}\right)} = \frac{1}{1+\lambda} \qquad \text{(S22)}$$

Where λ is derived here in equation S12 and was defined in the main paper as,

$$\lambda = \frac{\left(k_{1,blue}D_B + k_{1,green}(1-D_B)\right)}{\left(k_{-1,blue}D_B + k_{-1,green}(1-D_B)\right)} \qquad \text{(S23)}$$

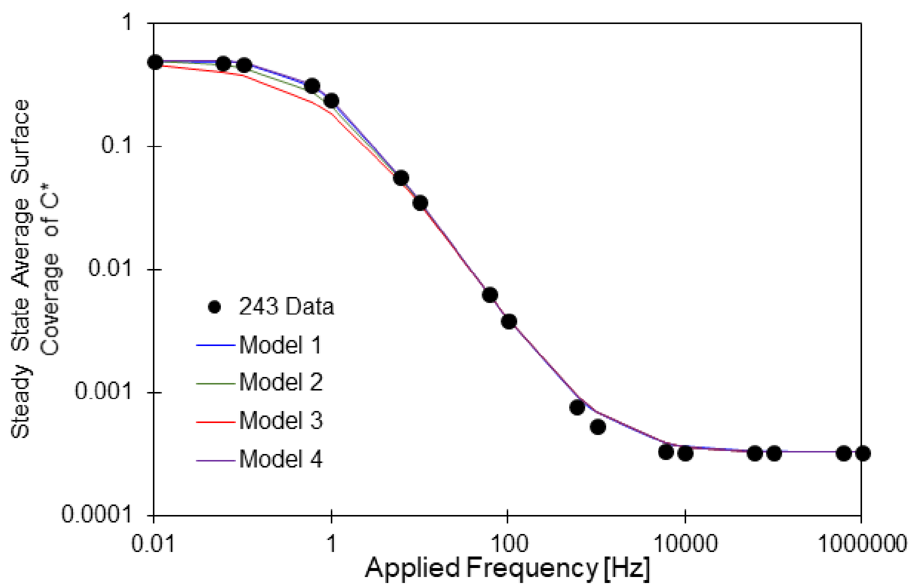
The ratchet directionality metric can also be written by substitution using equation S9 as,

$$\lambda = \frac{k_{1,blue}\tau_{blue} + k_{1,green}\tau_{green}}{k_{-1,blue}\tau_{blue} + k_{-1,green}\tau_{green}} = \sum_j \tau_j k_{1,j} \ / \sum_j \tau_j k_{-1,j} \qquad \text{(S24)}$$

(3) *Frequency Response Model Fitting*.

Table S0. Frequency Response Surface Coverage Model Equations.

Model Name	Model Form
Model 1 (Eq. 13)	$\bar{\theta}_{C,Avg} = \bar{\theta}_{C,eq} + \left(\frac{1}{(1+k_{II}\tau_{II}/4)^2}\right)\left(\frac{1}{1+\lambda} - \bar{\theta}_{C,eq}\right)$
Model 2	$\bar{\theta}_{C,Avg} = \bar{\theta}_{C,eq} + \left(\frac{1}{1+\frac{k_{II}\tau_{II}}{2}}\right)\left(\frac{1}{1+\lambda} - \bar{\theta}_{C,eq}\right)$
Model 3	$\bar{\theta}_{C,Avg} = \bar{\theta}_{C,eq} + \left(\frac{1}{(1+k_{II}\tau_{II})^{0.5}}\right)\left(\frac{1}{1+\lambda} - \bar{\theta}_{C,eq}\right)$
Model 4	$\bar{\theta}_{C,Avg} = \bar{\theta}_{C,eq} + \left(\frac{1}{(1+k_{II}\tau_{II}/6)^3}\right)\left(\frac{1}{1+\lambda} - \bar{\theta}_{C,eq}\right)$



Model Name	Sum of Squares
Model 1	0.00031
Model 2	0.00313
Model 3	0.02610
Model 4	0.00082

Figure S1. Four Models of Steady State Surface Coverage of C*described in Table S0 with the sum of squares error between the data at 243 K and the different models. Simulation data of the following catalytic ratchet system: α = 0.78, β = 0.67 eV, $\gamma_{D/C}$ = 2.0, $\delta_{C\text{-}D}$ = 0.3, ΔBE_C = 0.6 eV

Unique Programmable Elementary Catalytic Ratchets – Simulations of Figure 5.

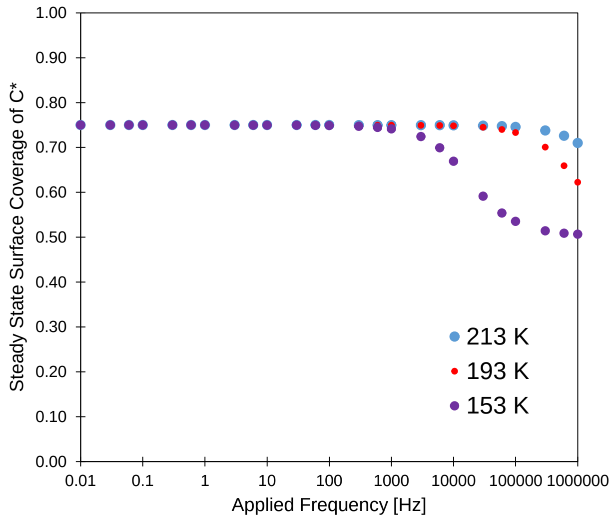


Figure S2. Simulation of the catalytic ratchet in **Figure 5a** with nonviable scaling in the main paper at 213 K (blue), 193 K (red), and 153 K (purple) at varying applied frequency indicates that the selected reaction system behaves as a forward (favors D*) ratchet, which is not consistent with its λ values less than unity (0.978, 0.953, and 0.938 at 153 K, 193 K, and 213 K, respectively).

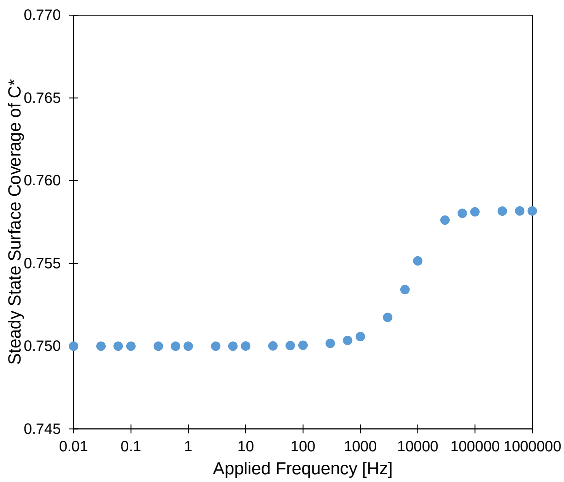


Figure S3. Simulation of the catalytic ratchet in **Figure 5b** with viable scaling in the main paper at 153 K (blue) at varying applied frequency indicates that the selected reaction system behaves as a reverse ratchet (favors C*) ratchet, which is consistent with its λ values less than unity (0.319).

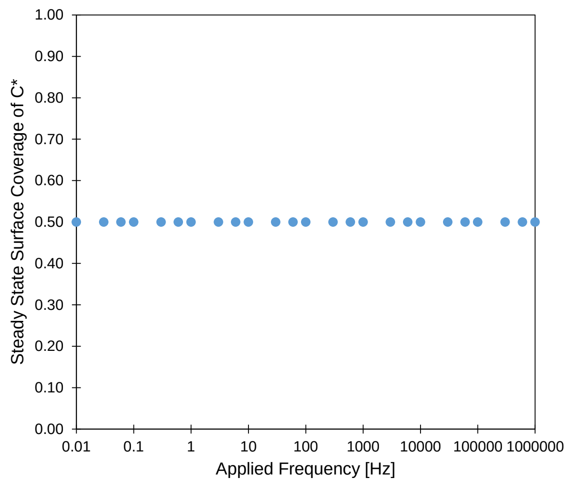


Figure S4. Simulation of the catalytic ratchet in **Figure 5c** in the main paper at 213 K at varying applied frequency indicates that the selected reaction system does not behave as a ratchet, consistent with its λ of unity.

(4) Figure Data Sets

Table S1. Simulation data for oscillation of the elementary step between C* and D* exhibits a steady state average surface coverage of C* (θ_C) that varies with temperature and applied oscillation frequency ($10^{-2} < f < 10^{6}$). ($\alpha = 0.78$, $\beta = 0.67$ eV, $\gamma_{D/C} = 2.0$, $\delta_{C\text{-}D} = 0.3$, $\Delta BE_C = 0.6$ eV) This data is presented as Figure 2d in the main paper.

Frequency (1/s)	193	203	213	223	233	243	253	263	273	283	293	303	313	323	333	343	353	363	373	383	393
0.01	0.020485	0.107231	0.319166	0.455158	0.4883655	0.496627	0.498922	0.499624	0.499858	0.499943	0.499975	0.499989	0.499995	0.499997	0.499999	0.499999	0.5	0.5	0.5	0.5	0.5
0.06	0.003511	0.020446	0.092666	0.27291	0.4302473	0.479762	0.49353	0.497744	0.49915	0.499657	0.499853	0.499933	0.499968	0.499984	0.499992	0.499996	0.499997	0.499999	0.499999	0.499999	0.5
0.1	0.002119	0.012418	0.058674	0.198644	0.3852392	0.46627	0.489216	0.49624	0.498584	0.499429	0.499755	0.499889	0.499947	0.499973	0.499986	0.499993	0.499996	0.499998	0.499999	0.499999	0.499999
0.6	0.000371	0.002127	0.010522	0.043776	0.1430472	0.314742	0.435325	0.47744	0.491503	0.496572	0.498528	0.499332	0.499681	0.499841	0.499917	0.499955	0.499975	0.499985	0.499991	0.499995	0.499997
1	0.000231	0.001291	0.00637	0.026939	0.0936451	0.239339	0.393208	0.4624	0.485839	0.494286	0.497547	0.498887	0.499469	0.499734	0.499862	0.499925	0.499958	0.499976	0.499986	0.499991	0.499994
6	5.79E-05	0.000244	0.001113	0.004696	0.0175949	0.057106	0.15183	0.299027	0.415272	0.465716	0.485283	0.49332	0.496811	0.498407	0.49917	0.499551	0.499748	0.499855	0.499913	0.499947	0.499967
10	4.77E-05	0.00016	0.000689	0.002856	0.0107032	0.035436	0.100039	0.223546	0.362549	0.442868	0.475471	0.488867	0.494686	0.497345	0.498617	0.499252	0.499581	0.499758	0.499856	0.499912	0.499945
60	4.12E-05	7.17E-05	0.000163	0.000544	0.0019020	0.006286	0.01904	0.051775	0.122273	0.237024	0.357773	0.433238	0.468113	0.484067	0.491701	0.49551	0.497485	0.498546	0.499134	0.49947	0.499668
100	4.11E-05	6.9E-05	0.00013	0.000359	0.0011888	0.00385	0.01163	0.032085	0.079018	0.166997	0.286741	0.389924	0.44686	0.473445	0.486168	0.492516	0.495808	0.497576	0.498557	0.499117	0.499446
600	4.1E-05	6.75E-05	0.000107	0.000168	0.0003125	0.000782	0.002151	0.005797	0.014803	0.035194	0.076543	0.148398	0.24781	0.347633	0.417212	0.4551	0.47485	0.485457	0.491341	0.494703	0.496679
1000	4.1E-05	6.75E-05	0.000106	0.000163	0.0002638	0.000543	0.001382	0.003609	0.009109	0.021722	0.048198	0.097716	0.17637	0.27504	0.365443	0.425261	0.458083	0.475761	0.485568	0.491172	0.494464
6000	4.1E-05	6.74E-05	0.000106	0.00016	0.0002333	0.000336	0.000503	0.000885	0.001866	0.004135	0.009027	0.019008	0.038085	0.071742	0.125227	0.199011	0.283224	0.359319	0.413686	0.447038	0.466785
10000	4.1E-05	6.74E-05	0.000106	0.00016	0.0002328	0.000331	0.00047	0.000717	0.001299	0.002691	0.005699	0.011838	0.023711	0.045259	0.081416	0.136193	0.208611	0.288726	0.360284	0.41204	0.444649
60000	4.1E-05	6.84E-05	0.000106	0.00016	0.0002324	0.000328	0.000451	0.000608	0.000811	0.001106	0.001628	0.002709	0.004887	0.008942	0.01614	0.028389	0.048244	0.07859	0.121719	0.177657	0.242381
100000	4.1E-05	6.84E-05	0.000106	0.00016	0.0002324	0.000328	0.000451	0.000606	0.0008	0.001053	0.001422	0.002075	0.003375	0.005875	0.010339	0.017964	0.030487	0.050148	0.079383	0.120073	0.172248
600000	4.1E-05	6.84E-05	0.000106	0.00016	0.0002324	0.000328	0.000451	0.000604	0.000794	0.001023	0.001297	0.001627	0.002033	0.00257	0.003372	0.00471	0.007013	0.010819	0.016779	0.025777	0.03895
1000000	4.1E-05	6.84E-05	0.000106	0.00016	0.0002324	0.000328	0.000451	0.000604	0.000794	0.001022	0.001295	0.001617	0.002	0.002466	0.003069	0.003933	0.005308	0.007588	0.011267	0.016913	0.025245
k1,blue	2.46E-11	3.59E-10	4.06E-09	3.69E-08	2.78286E-07	1.78E-06	9.78E-06	4.73E-05	0.000204	0.000793	0.002812	0.009168	0.027714	0.078234	0.207499	0.519921	1.236678	2.804412	6.086405	12.68548	25.46958
k-1,blue	0.001683	0.010075	0.05097	0.222966	0.859313416	2.963745	9.268831	26.57985	70.56049	174.8257	407.1477	896.7356	1877.87	3756.561	7208.249	13315.74	23757.45	41056.42	68900.66	112544.6	179300.3
k2,green	41.07875	149.4593	481.6829	1397.712	3701.357918	9046.787	20603.7	44077.14	89183.85	171683.4	316049.2	558840.1	952804.1	1571708	2515852	3918185	5950918	8832487	12834720	18290031	25598474
k-2,green	6.01E-07	5.32E-06	3.83E-05	0.000232	0.001198675	0.005419	0.021742	0.078491	0.257924	0.779205	2.182908	5.713327	14.06186	32.7323	72.42226	152.9879	309.771	603.3145	1133.767	2061.564	3636.26

Table S2-A. Kinetic Data of Elementary Ratchets for the Ratchet Directionality Metric, λ > 1 (Figure 4 in the main paper).

Dataset	k1,blue	k-1, blue	k2,green	k-2,green	(k1g + k1b)*0.5	(k-1g + k-1b)*0.5	λ
1	2.77E-02	1.88E+03	9.53E+05	1.41E+01	476402.0643	945.9660133	504
2	1.66E+04	5.10E+02	2.84E-01	1.73E+03	8319.021567	1118.373047	7
3	1.21E+07	1.47E+01	6.68E+02	1.02E+04	6069402.76	5099.281524	1190
4	6.22E+07	4.95E+00	3.42E+03	3.42E+03	31120582.06	1714.909293	18147
5	1.27E-02	2.04E+04	1.13E+05	3.73E+02	56710.79038	10391.07252	5
6	1.22E-24	3.03E+04	2.37E+06	8.11E-04	1183641.835	15140.80534	78
7	1.80E+10	7.88E-02	1.38E-02	8.42E+01	8995318768	42.16079428	213357431
8	2.75E+03	3.98E+00	3.52E+01	1.18E+01	1394.696993	7.916365723	176
9	2.99E+02	2.10E+04	5.10E+05	8.67E+02	254964.5455	10941.48812	23
10	1.12E+03	1.63E+05	1.97E+06	1.12E+03	984544.3444	82101.37564	12
11	4.16E-03	9.66E-01	3.77E+00	1.06E-03	1.888719802	0.483707409	4
12	1.21E-03	2.79E+06	1.02E+08	5.82E+01	50755312.99	1396450.032	36
13	0.016232303	4.58006E-06	1.78837E-05	0.004157147	0.008125093	0.002080863	4
14	2.45512E-12	387.3536188	582.8852371	9.791036568	291.4426185	198.5723277	1
15	19425.22858	0.011635111	10.50759777	1.752584586	9717.86809	0.882109848	11017
16	19425.22858	0.011635111	0.0006626	1106.234032	9712.614623	553.1228335	18
17	1151.795701	9.16976E-05	3.48782E-06	43.80986819	575.8978522	21.90497994	26
18	43.80986819	0.000810762	9.16976E-05	4.954915761	21.90497994	2.477863262	9
19	598.983352	0.006428394	0.017141291	0.087891178	299.5002466	0.047159786	6351
20	127129.7629	0.041170622	49.79386519	600.8773128	63589.77837	300.4592417	212
21	26015340438	4.41685E-05	28920520.19	28920520.19	13022130479	14460260.09	901
22	1209668831	0.000105898	7236.942879	17.70106806	604838034.1	8.850586977	68338748
23	59825819.2	0.002141243	3966.428021	32.2964687	29914892.81	16.14930497	1852395
24	24459317079	5.23733E-06	13204.15799	9.701612063	12229665142	4.85080865	2521160084
25	355858.3571	3.85001081	3672.409322	373.0680328	179765.3832	188.4590218	954
26	58406222.52	5503.746735	88797.07172	88797.07172	29247509.8	47150.40923	620
27	147583969.3	13907.16184	88797.07172	88797.07172	73836383.17	51352.11678	1438
28	28920520.19	1.191646845	5870.523539	5870.523539	14463195.36	2935.857593	4926
29	158384235.8	6.526095438	5870.523539	5870.523539	79195053.18	2938.524817	26951
30	1277038871	2.840039475	152.7215505	152.7215505	638519512.1	77.78079499	8209218
31	199158932	0.007128154	0.875430423	0.875430423	99579466.45	0.441279289	225660866
32	56984229.13	0.000126438	0.027080201	0.027080201	28492114.58	0.013603319	2094497236
33	833954827.5	0.001850393	0.027080201	0.027080201	416977413.8	0.014465297	28826052551
34	3893738.92	8.63949E-06	0.027080201	0.027080201	1946869.474	0.01354442	143739595
35	3893738.92	0.000247299	1.47763E-05	0.177183541	1946869.46	0.08871542	21945108
36	372093.8225	2.36325E-05	3.77965E-05	0.45322006	186046.9113	0.226621846	820958
37	9243471.288	0.048266741	0.070679215	145.2668655	4621735.68	72.65756612	63610

Table S2-B. Kinetic Data of Elementary Ratchets for the Ratchet Directionality Metric, $\lambda < 1$ (Figure 4 in the main paper).

Dataset	k1,blue	k-1, blue	k2,green	k-2,green	(k1g + k1b)*0.5	(k-1g + k-1b)*0.5	λ
38	1.04E-05	5.60E-01	1.88E-01	6.45E-11	0.094238132	0.280201599	0.336322608
39	1.04E-05	5.60E-01	1.40E-03	6.01E-06	0.000704218	0.280204606	0.002513229
40	1.29E-03	1.10E+07	1.12E+06	1.21E+01	558249.9543	5495310.258	0.101586613
41	5.05E-09	3.42E+03	1.47E+01	1.47E+01	7.36671919	1719.798555	0.004283478
42	5.19E-11	1.18E+01	2.07E+00	2.65E-02	1.036076949	5.937328198	0.17450222
43	1.76E+00	3.57E+10	1.29E+04	3.42E+01	6457.455145	17835413911	3.62058E-07
44	4.29E+00	4.47E+09	1.03E+04	5.75E+01	5170.86503	2236165001	2.31238E-06
45	7.16E+02	2.92E+04	6.62E+03	1.63E+02	3670.469939	14678.55128	0.250056689
46	1.64E+03	1.15E+05	3.98E+04	6.76E+01	20702.18037	57582.05653	0.359524852
47	0.002776585	4635.606641	425.605574	0.030241981	212.8041753	2317.818442	0.091812271
48	0.003294901	69068618.47	1315349.081	0.17301432	657674.542	34534309.32	0.019044091
49	0.002485126	5729798.935	157642.8319	0.090326173	78821.41719	2864899.513	0.027512803
50	6.12491E-15	12138137.57	3424.863671	2.17074E-11	1712.431835	6069068.787	0.000282157
51	113.6792769	0.032075434	3.773282457	877.1189507	58.7262797	438.575513	0.133902322
52	9.983432454	3452023.819	412041.9815	83.6396488	206025.9825	1726053.729	0.119362439
53	0.036756235	7039116.252	3424.863671	3424.863671	1712.450213	3521270.558	0.000486316
54	0.016977859	2029881724	83.6396488	412041.9815	41.82831333	1015146883	4.12042E-08
55	1.19066E-06	83709020.2	0.008973115	1824458.918	0.004487153	42766739.56	1.04922E-10
56	0.011635111	163.744831	1.752584586	5.784004503	0.882109848	84.76441776	0.010406605
57	0.00132472	32150.12658	866.6779529	7260.893479	433.3396388	19705.51003	0.021990785
58	2.49063E-06	1119.923347	16.23496489	195.9121277	8.117483691	657.9177376	0.012338144
59	1.08027E-29	441623.5461	0.019503136	413.5655088	0.009751568	221018.5558	4.4121E-08
60	3.12381E-26	1277038871	0.052813923	1119.923347	0.026406962	638519995.7	4.13565E-11
61	2.61209E-19	23748061.71	0.387290106	680.5598203	0.193645053	11874371.14	1.63078E-08
62	2.72684E-14	1321175.789	152.7215505	152.7215505	76.36077525	660664.2552	0.000115582
63	1.77005E-08	4455020.037	488418.4402	1943.784117	244209.2201	2228481.91	0.109585462
64	8.011E-08	5981392430	5377.774384	8.287368734	2688.887192	2990696219	8.99084E-07
65	7.07348E-19	64309059.14	1119.923347	0.052813923	559.9616737	32154529.6	1.74147E-05
66	1.36086E-23	24568.84036	374.351789	0.010727982	187.1758945	12284.42554	0.015236846
67	9.51366E-29	487601414.9	1740806.395	1.325758023	870403.1973	243800708.1	0.003570142
68	4.91009E-08	5870.523539	0.142237873	0.002026519	0.071118961	2935.262783	2.42292E-05
69	1.19499E-06	25049.62807	1.253723952	0.023876033	0.626862574	12524.82597	5.00496E-05
70	1.03936E-08	99102.87193	0.06775002	0.000465253	0.033875015	49551.4362	6.83633E-07
71	4.74413E-07	6016715241	88797.07172	88797.07172	44398.53586	3008402019	1.47582E-05

Table S3-A. Model results (Equation 13) of the time-averaged surface coverage of C* at temperatures of 213-393 K decreases in surface coverage of C* with increasing applied frequency. $\alpha = 0.78$, $\beta = 0.67$, $\gamma = 2$, $\delta = 0.3$, $\Delta BE_C = 0.6$ eV. Data are the lines in Figure 7a.

Frequency (1/s)	213	243	293	343	393
0.01	0.313484	0.499655	0.5	0.5	0.5
0.02	0.212473	0.498689	0.5	0.5	0.5
0.03	0.159901	0.497196	0.5	0.5	0.5
0.04	0.128036	0.495255	0.5	0.5	0.5
0.05	0.106719	0.492934	0.5	0.5	0.5
0.06	0.091473	0.490293	0.499999	0.5	0.5
0.07	0.080033	0.48738	0.499999	0.5	0.5
0.08	0.071136	0.484241	0.499999	0.5	0.5
0.09	0.064018	0.480912	0.499998	0.5	0.5
0.1	0.058196	0.477425	0.499998	0.5	0.5
0.2	0.030495	0.438584	0.499992	0.5	0.5
0.3	0.020681	0.399961	0.499983	0.5	0.5
0.4	0.015658	0.365322	0.49997	0.5	0.5
0.5	0.012606	0.335139	0.499953	0.5	0.5
0.6	0.010556	0.309004	0.499932	0.5	0.5
0.7	0.009083	0.286335	0.499908	0.5	0.5
0.8	0.007974	0.266576	0.499881	0.5	0.5
0.9	0.007109	0.249249	0.499849	0.5	0.5
1	0.006415	0.23396	0.499815	0.5	0.5
2	0.003276	0.144306	0.499287	0.499999	0.5
3	0.002222	0.104135	0.498455	0.499998	0.5
4	0.001695	0.081448	0.497352	0.499997	0.5
5	0.001377	0.066888	0.496009	0.499996	0.5
6	0.001166	0.056754	0.494454	0.499994	0.5
7	0.001015	0.049297	0.492709	0.499991	0.5
8	0.000901	0.043579	0.490798	0.499989	0.5
9	0.000813	0.039057	0.488739	0.499986	0.5
10	0.000742	0.03539	0.486551	0.499982	0.5
20	0.000424	0.018337	0.460309	0.49993	0.5
30	0.000318	0.012444	0.431411	0.499844	0.499999
40	0.000265	0.009457	0.403418	0.499727	0.499998
50	0.000233	0.007651	0.377523	0.499578	0.499998
60	0.000212	0.006442	0.354007	0.499399	0.499996
70	0.000197	0.005575	0.332801	0.499191	0.499995
80	0.000185	0.004924	0.313711	0.498956	0.499994
90	0.000177	0.004416	0.296509	0.498693	0.499992
100	0.00017	0.00401	0.280971	0.498405	0.49999
200	0.000138	0.002174	0.183098	0.494286	0.499961
300	0.000127	0.00156	0.135468	0.48842	0.499914
400	0.000122	0.001252	0.107521	0.481359	0.499848

Frequency (1/s)	213	243	293	343	393
500	0.000118624	0.001067722	0.089182177	0.473503048	0.499765342
600	0.0001165	0.000944564	0.076232867	0.465139828	0.499665022
700	0.000114984	0.000856567	0.066604813	0.456479924	0.499547994
800	0.000113846	0.000790554	0.059166797	0.447676713	0.4994147
900	0.000112962	0.000739201	0.053248488	0.438842073	0.499265571
1000	0.000112254	0.000698113	0.048427606	0.430057346	0.499101025
2000	0.000109069	0.000513154	0.0257376	0.352086774	0.496692624
3000	0.000108007	0.000451479	0.017793147	0.294595267	0.493132473
4000	0.000107477	0.000420637	0.013745854	0.252385526	0.488697936
5000	0.000107158	0.00040213	0.011292972	0.220498061	0.483605304
6000	0.000106946	0.000389792	0.009647391	0.195690605	0.478024041
7000	0.000106794	0.000380978	0.008466882	0.175891804	0.472087433
8000	0.00010668	0.000374368	0.007578701	0.159746597	0.465900623
9000	0.000106592	0.000369227	0.006886228	0.146340294	0.459546728
10000	0.000106521	0.000365114	0.006331197	0.135036415	0.453091524
20000	0.000106203	0.000346604	0.003821925	0.076800093	0.390410495
30000	0.000106096	0.000340434	0.002981249	0.054261068	0.338533641
40000	0.000106043	0.000337349	0.002560109	0.04231026	0.297560776
50000	0.000106012	0.000335498	0.002307168	0.034907622	0.265016726
60000	0.00010599	0.000334264	0.002138434	0.029872305	0.238756777
70000	0.000105975	0.000333382	0.002017856	0.026225417	0.217208063
80000	0.000105964	0.000332721	0.001927395	0.023462331	0.199247412
90000	0.000105955	0.000332207	0.001857019	0.021296518	0.184068034
100000	0.000105948	0.000331795	0.001800707	0.019553219	0.171081531
200000	0.000105916	0.000329944	0.001547187	0.011589302	0.101441871
300000	0.000105905	0.000329327	0.001462637	0.008890619	0.073250786
400000	0.0001059	0.000329019	0.001420354	0.007532882	0.058020145
500000	0.000105897	0.000328834	0.001394982	0.006715535	0.048487091
600000	0.000105895	0.00032871	0.001378066	0.006169506	0.041959341
700000	0.000105893	0.000328622	0.001365982	0.005778931	0.037209602
800000	0.000105892	0.000328556	0.00135692	0.005485695	0.033598645
900000	0.000105891	0.000328505	0.001349871	0.005257442	0.030760825
1000000	0.00010589	0.000328463	0.001344231	0.005074726	0.028471879

Table S3-B. Simulation results of the time-averaged surface coverage of C* at temperatures of 253-213 K decreases in surface coverage of C* with increasing applied frequency. ($\alpha = 0.7$, $\beta = 0.5$, $\gamma = 1.2$, $\delta = 0.5$, $\Delta BE_C = 0.2$ eV.) Data points in Figure 7b.

Frequency (1/s)	253	273	293	233	213
0.01	0.964983784	0.956786949	0.948168592	0.972618457	0.9795407
0.03	0.964983932	0.95678698	0.9481686	0.972619349	0.979548066
0.06	0.964984153	0.956787026	0.948168612	0.972620686	0.9795591
0.1	0.964984448	0.956787088	0.948168628	0.972622469	0.9795738
0.3	0.964985922	0.956787399	0.948168707	0.972631383	0.979647149
0.6	0.964988134	0.956787864	0.948168826	0.972644755	0.9797572
1	0.964991083	0.956788485	0.948168984	0.972662583	0.9799040
3	0.965005827	0.956791588	0.948169775	0.972751727	0.980636751
6	0.965027944	0.956796243	0.948170962	0.972885442	0.9816616
10	0.965057433	0.956802449	0.948172544	0.973063728	0.9826665
30	0.965204879	0.956833481	0.948180455	0.973953242	0.984084507
60	0.965426047	0.956880029	0.948192322	0.975183149	0.9843187
100	0.965720937	0.956942093	0.94821	0.976343455	0.9843728
300	0.967167524	0.957252413	0.948287258	0.977863937	0.984400415
600	0.968831961	0.957717882	0.948405928	0.978100754	0.9844030
1000	0.969942533	0.95833677	0.948564155	0.978154861	0.9844036
3000	0.970918468	0.960851992	0.949355179	0.978182425	0.984403863
6000	0.971036448	0.962333607	0.95051722	0.978185026	0.9844039
10000	0.971062384	0.962866947	0.951828942	0.978185582	0.9844039
30000	0.971075457	0.963186121	0.954162569	0.97818586	0.984403894
60000	0.971076687	0.963218216	0.954622273	0.978185886	0.9843598
100000	0.971076949	0.963225114	0.954732076	0.978185891	0.9844039
300000	0.97107708	0.963228571	0.954788733	0.978185883	0.984403897
600000	0.971077092	0.963228895	0.954794106	0.978094816	0.9844039
1000000	0.971077095	0.963228964	0.954795254	0.974870415	0.9844039
k1,blue	44.09383598	299.4274354	1565.429312	4.673544368	0.324987522
k-1,blue	4331.040939	21016.29828	82200.26263	680.5598203	75.54502413
k2,green	159.2934492	984.5679352	4745.703376	18.85158853	1.494313281
k-2,green	2497.621131	12618.40516	51102.76934	374.351789	39.28666494

Table S3-C. Model results of the time-averaged surface coverage of C* at temperatures of 253-213 K decreases in surface coverage of C* with increasing applied frequency. (α = 0.7, β = 0.5, γ = 1.2, δ = 0.5, ΔBE_C = 0.2 eV.) Lines in Figure 7b.

Frequency (1/s)	253	273	293	233	213
0.01	0.964984	0.956787	0.948169	0.972618	0.979537
0.02	0.964984	0.956787	0.948169	0.972618	0.979537
0.03	0.964984	0.956787	0.948169	0.972618	0.979537
0.04	0.964984	0.956787	0.948169	0.972618	0.979537
0.05	0.964984	0.956787	0.948169	0.972618	0.979538
0.06	0.964984	0.956787	0.948169	0.972618	0.979538
0.07	0.964984	0.956787	0.948169	0.972618	0.979538
0.08	0.964984	0.956787	0.948169	0.972618	0.979538
0.09	0.964984	0.956787	0.948169	0.972618	0.979539
0.1	0.964984	0.956787	0.948169	0.972618	0.979539
0.2	0.964984	0.956787	0.948169	0.972618	0.979544
0.3	0.964984	0.956787	0.948169	0.972618	0.979552
0.4	0.964984	0.956787	0.948169	0.972618	0.979563
0.5	0.964984	0.956787	0.948169	0.972619	0.979576
0.6	0.964984	0.956787	0.948169	0.972619	0.979591
0.7	0.964984	0.956787	0.948169	0.972619	0.979608
0.8	0.964984	0.956787	0.948169	0.972619	0.979627
0.9	0.964984	0.956787	0.948169	0.97262	0.979647
1	0.964984	0.956787	0.948169	0.97262	0.979668
2	0.964984	0.956787	0.948169	0.972627	0.979923
3	0.964984	0.956787	0.948169	0.972636	0.980205
4	0.964985	0.956787	0.948169	0.97265	0.980478
5	0.964985	0.956787	0.948169	0.972665	0.98073
6	0.964986	0.956787	0.948169	0.972684	0.98096
7	0.964986	0.956787	0.948169	0.972705	0.981167
8	0.964987	0.956787	0.948169	0.972727	0.981353
9	0.964988	0.956787	0.948169	0.972751	0.981521
10	0.964989	0.956787	0.948169	0.972777	0.981672
20	0.965003	0.956788	0.948169	0.973084	0.982628
30	0.965026	0.956789	0.948169	0.973418	0.983093
40	0.965054	0.95679	0.948169	0.973739	0.983366
50	0.965088	0.956792	0.948169	0.974034	0.983545
60	0.965126	0.956794	0.948169	0.9743	0.983672
70	0.965168	0.956797	0.948169	0.97454	0.983766
80	0.965213	0.9568	0.948169	0.974754	0.983838
90	0.965261	0.956803	0.94817	0.974947	0.983896
100	0.96531	0.956807	0.94817	0.975121	0.983943
200	0.965845	0.956858	0.948174	0.976206	0.984165
300	0.966356	0.956932	0.94818	0.976729	0.984243
400	0.966803	0.957021	0.948188	0.977034	0.984282
500	0.967184	0.95712	0.948198	0.977234	0.984306
600	0.967508	0.957225	0.94821	0.977375	0.984322
700	0.967787	0.957335	0.948224	0.977479	0.984334
800	0.968026	0.957446	0.948239	0.97756	0.984342
900	0.968235	0.957559	0.948255	0.977624	0.984349
1000	0.968418	0.95767	0.948273	0.977676	0.984355
2000	0.969465	0.958669	0.948497	0.977922	0.984379
3000	0.969923	0.959411	0.948767	0.978008	0.984387
4000	0.970179	0.959959	0.949048	0.978052	0.984392
5000	0.970342	0.960374	0.949323	0.978078	0.984394
6000	0.970455	0.960698	0.949584	0.978096	0.984396
7000	0.970538	0.960957	0.94983	0.978109	0.984397
8000	0.970601	0.961168	0.950058	0.978118	0.984398
9000	0.970651	0.961344	0.95027	0.978126	0.984398
10000	0.970692	0.961493	0.950467	0.978132	0.984399
20000	0.97088	0.962259	0.95181	0.978159	0.984401
30000	0.970944	0.962556	0.95253	0.978168	0.984402
40000	0.970977	0.962714	0.952973	0.978172	0.984403
50000	0.970997	0.962812	0.953271	0.978175	0.984403
60000	0.97101	0.962879	0.953486	0.978177	0.984403
70000	0.97102	0.962927	0.953648	0.978178	0.984403
80000	0.971027	0.962964	0.953775	0.978179	0.984403
90000	0.971032	0.962992	0.953876	0.97818	0.984403
100000	0.971037	0.963015	0.953959	0.97818	0.984403
200000	0.971057	0.963121	0.954356	0.978183	0.984404
300000	0.971064	0.963157	0.954498	0.978184	0.984404
400000	0.971067	0.963175	0.95457	0.978185	0.984404
500000	0.971069	0.963185	0.954615	0.978185	0.984404
600000	0.97107	0.963193	0.954644	0.978185	0.984404
700000	0.971071	0.963198	0.954666	0.978185	0.984404
800000	0.971072	0.963202	0.954682	0.978185	0.984404
900000	0.971073	0.963205	0.954694	0.978185	0.984404
1000000	0.971073	0.963207	0.954704	0.978185	0.984404

Table S3-D. Simulation results of the time-averaged surface coverage of C* at temperatures of 193-273 K decreases in surface coverage of C* with increasing applied frequency. ($\alpha = 0.5$, $\beta = 0.5$, $\gamma = 2$, $\delta = 0.3$, $\Delta BE_C = 0.5$ eV) Data points in Figure 7c.

Frequency (1/s)	193	213	233	253	273
0.01	0.500029542	0.500011941	0.50002383	0.50005138	0.5001000
0.03	0.500082657	0.500017398	0.50002465	0.50005154	0.500100092
0.06	0.50016233	0.500025582	0.50002589	0.50005179	0.5001002
0.1	0.50026856	0.500036495	0.50002754	0.50005213	0.5001002
0.3	0.500799713	0.50009106	0.50003579	0.5000538	0.500100668
0.6	0.501596442	0.500172906	0.50004816	0.50005631	0.5001013
1	0.502658748	0.500282034	0.50006465	0.50005966	0.5001022
3	0.507970275	0.500827677	0.50014712	0.50007639	0.500106436
6	0.515937566	0.50164614	0.50027083	0.50010149	0.5001128
10	0.526560619	0.502737425	0.50043577	0.50013496	0.5001214
30	0.579471419	0.508193848	0.50126047	0.5003023	0.500164117
60	0.651276393	0.516378482	0.50249753	0.50055331	0.5002282
100	0.721219822	0.527291327	0.50415	0.50088799	0.5003137
300	0.857954847	0.581583941	0.51239398	0.50256139	0.500740924
600	0.910690285	0.654272005	0.52476455	0.50507149	0.5013818
1000	0.933216026	0.723607755	0.54125803	0.5084183	0.5022363
3000	0.95023507	0.855964967	0.62069112	0.5251523	0.506508989
6000	0.952200358	0.905135687	0.70866295	0.55024683	0.5129180
10000	0.95263056	0.924098796	0.77675459	0.5833328	0.5214632
30000	0.952847158	0.936661588	0.88181093	0.70918433	0.564123004
60000	0.952867516	0.937996246	0.91027865	0.79699502	0.6241461
100000	0.95287186	0.938285085	0.91840898	0.84710522	0.6865209
300000	0.952874032	0.938430058	0.92289063	0.89827004	0.818029551
600000	0.952874236	0.938443668	0.92332698	0.90569329	0.8663286
1000000	0.952874279	0.938446572	0.92342044	0.90738072	0.8825021
k1,blue	0.000105898	0.004157147	0.08691013	1.1235861	9.983432454
k-1,blue	7236.942879	52217.11552	268367.69	1064754.73	3452023.819
k2,green	357.9128643	3424.863671	22239.2563	107434.155	412041.9815
k-2,green	0.002141243	0.063381853	1.04877032	11.1355984	83.6396488

Table S3-E. Model results of the time-averaged surface coverage of C* at temperatures of 193-273 K decreases in surface coverage of C* with increasing applied frequency. (α = 0.5, β = 0.5, γ = 2, δ = 0.3, ΔBE_C = 0.5 eV) Lines in Figure 7c.

Frequency (1/s)	Time (s)	193	213	233	253	273
0.01	100	0.50000001	0.5	0.5	0.5	0.5
0.02	50	0.50000009	0.5	0.5	0.5	0.5
0.03	33.33333333	0.5000002	0.5	0.5	0.5	0.5
0.04	25	0.50000036	0.5	0.5	0.5	0.5
0.05	20	0.50000056	0.50000001	0.5	0.5	0.5
0.06	16.66666667	0.50000081	0.50000001	0.5	0.5	0.5
0.07	14.28571429	0.50000111	0.50000001	0.5	0.5	0.5
0.08	12.5	0.50000144	0.50000002	0.5	0.5	0.5
0.09	11.11111111	0.50000183	0.50000002	0.5	0.5	0.5
0.1	10	0.50000225	0.50000002	0.500000001	0.5	0.5
0.2	5	0.50000897	0.5000001	0.500000002	0.5	0.5
0.3	3.333333333	0.50002009	0.50000021	0.500000005	0.5	0.5
0.4	2.5	0.50003556	0.50000038	0.500000009	0.5	0.5
0.5	2	0.50005532	0.5000006	0.500000014	0.500000001	0.5
0.6	1.666666667	0.50007931	0.50000086	0.50000002	0.500000001	0.5
0.7	1.428571429	0.50010748	0.50000117	0.500000027	0.500000001	0.5
0.8	1.25	0.50013976	0.50000153	0.500000035	0.500000001	0.5
0.9	1.111111111	0.50017611	0.50000193	0.500000044	0.500000002	0.5
1	1	0.50021647	0.50000238	0.500000055	0.500000002	0.5
2	0.5	0.50082922	0.50000948	0.500000219	0.500000009	0.5
3	0.333333333	0.50178841	0.50002123	0.500000492	0.50000002	0.5
4	0.25	0.50305027	0.50003757	0.500000874	0.500000036	0.5
5	0.2	0.50457633	0.50005843	0.500001365	0.500000057	0.5
6	0.166666667	0.50633271	0.50008375	0.500001964	0.500000081	0.50000001
7	0.142857143	0.50828956	0.50011348	0.500002671	0.500000111	0.50000001
8	0.125	0.51042048	0.50014753	0.500003487	0.500000145	0.50000001
9	0.111111111	0.51270216	0.50018587	0.50000441	0.500000183	0.50000001
10	0.1	0.51511395	0.50022842	0.50000544	0.500000226	0.50000001
20	0.05	0.54322158	0.50087337	0.500021605	0.500000903	0.50000006
30	0.033333333	0.57296612	0.50188023	0.500048266	0.500002028	0.50000013
40	0.025	0.60090836	0.50320134	0.500085199	0.500003601	0.50000024
50	0.02	0.62614111	0.50479504	0.500132185	0.500005618	0.50000037
60	0.016666667	0.64861417	0.50662483	0.500189008	0.500008077	0.50000053
70	0.014285714	0.66855778	0.50865872	0.500255459	0.500010978	0.50000072
80	0.0125	0.68627326	0.51086858	0.500331331	0.500014317	0.50000095
90	0.011111111	0.70205688	0.51322969	0.500416424	0.500018093	0.5000012

Frequency (1/s)	Time (s)	193	213	233	253	273
100	0.01	0.716174	0.51572	0.500511	0.500022	0.500001
200	0.005	0.802434	0.544453	0.501907	0.500088	0.500006
300	0.003333	0.842956	0.574432	0.504018	0.500195	0.500013
400	0.0025	0.866342	0.602295	0.5067	0.500342	0.500023
500	0.002	0.88154	0.627249	0.50984	0.500526	0.500036
600	0.001667	0.892204	0.649326	0.513344	0.500747	0.500052
700	0.001429	0.900097	0.668813	0.517134	0.501002	0.500071
800	0.00125	0.906174	0.686046	0.521146	0.501291	0.500092
900	0.001111	0.910997	0.701341	0.525328	0.501611	0.500116
1000	0.001	0.914918	0.714977	0.529637	0.501961	0.500143
2000	0.0005	0.933273	0.797467	0.574135	0.50686	0.500549
3000	0.000333	0.939663	0.835776	0.614079	0.513613	0.501191
4000	0.00025	0.942911	0.857767	0.647395	0.521504	0.502042
5000	0.0002	0.944877	0.872015	0.674905	0.530053	0.503079
6000	0.000167	0.946195	0.881991	0.697759	0.538937	0.504281
7000	0.000143	0.94714	0.889365	0.716941	0.547936	0.505629
8000	0.000125	0.947851	0.895037	0.73322	0.556903	0.507107
9000	0.000111	0.948405	0.899534	0.747182	0.56574	0.508701
10000	0.0001	0.948849	0.903187	0.759276	0.574381	0.510395
20000	0.00005	0.950855	0.920263	0.82642	0.64615	0.530765
30000	3.33E-05	0.951527	0.926197	0.85469	0.694841	0.553279
40000	0.000025	0.951863	0.929211	0.870223	0.728859	0.575149
50000	0.00002	0.952065	0.931035	0.880037	0.75373	0.595427
60000	1.67E-05	0.9522	0.932258	0.886799	0.772632	0.613875
70000	1.43E-05	0.952296	0.933134	0.891739	0.787458	0.630535
80000	1.25E-05	0.952368	0.933793	0.895507	0.799386	0.645553
90000	1.11E-05	0.952424	0.934307	0.898476	0.809183	0.659101
100000	0.00001	0.952469	0.934718	0.900874	0.817372	0.671349
200000	0.000005	0.952672	0.936577	0.911941	0.858572	0.748729
300000	3.33E-06	0.952739	0.9372	0.915732	0.874101	0.786516
400000	2.5E-06	0.952773	0.937511	0.917648	0.882247	0.808724
500000	0.000002	0.952793	0.937698	0.918803	0.887263	0.823311
600000	1.67E-06	0.952807	0.937823	0.919576	0.890662	0.833618
700000	1.43E-06	0.952816	0.937912	0.920129	0.893117	0.841284
800000	1.25E-06	0.952824	0.937979	0.920545	0.894974	0.847209
900000	1.11E-06	0.952829	0.938031	0.920869	0.896427	0.851925
1000000	0.000001	0.952834	0.938073	0.921128	0.897596	0.855766

Table S3-F. Model cutoff frequencies as a function of temperature for the three ratchets of Figure 7a-7c. Data are the lines of Figure 7d.

Inverse Temp (1/K)	Cutoff Frequency (Hz)
5.780346821	6.31806E-06
5.18134715	0.000420866
4.926108374	0.002518709
4.694835681	0.012742404
4.484304933	0.05574156
4.291845494	0.214828354
4.115226337	0.740936238
3.95256917	2.317207859
3.802281369	6.644962889
3.663003663	17.6401236
3.533568905	43.70643492
3.412969283	101.7869163
3.300330033	224.1839073
3.194888179	469.4675414
3.095975232	939.1402975
3.003003003	1802.062301
2.915451895	3328.935464
2.83286119	5939.361846
2.754820937	10264.10434
2.680965147	17225.16494
2.610966057	28136.14584
2.544529262	44825.07016
2.421307506	106328.6326

Inverse Temp (1/K)	Cutoff Frequency (Hz)
5.780346821	5.54704277
5.464480874	24.0372885
5.18134715	89.47821607
4.926108374	292.6237475
4.694835681	856.2159177
4.484304933	2275.300464
4.291845494	5559.814071
4.115226337	12622.51381
3.95256917	26858.53882
3.802281369	53961.09712
3.663003663	103010.4954
3.533568905	187861.423
3.412969283	328837.2702
3.300330033	554721.9997
3.194888179	905021.5572

Inverse Temp (1/K)	Cutoff Frequency (Hz)
6.535947712	0.000330628
5.780346821	0.022647299
5.18134715	0.646013606
4.694835681	9.821666235
4.291845494	93.58794724
3.95256917	624.4052828
3.663003663	3154.601289
3.412969283	12775.69233
3.95256917	624.4052828
3.663003663	3154.601289
3.412969283	12775.69233
3.194888179	43270.9372
3.003003003	126580.584
2.83286119	327879.3022
2.680965147	766891.9223

Table S4-A. Simulation results of the time-averaged surface coverage of C* at temperatures of 273-353 K decreases in surface coverage of C* with increasing applied frequency. (α = 0.7, β = 0.7, δ = 0.1, ΔBE_C = 0.2 eV) Data points in Figure 8b.

Frequency (1/s)	273	293	313	333	353
0.01	0.499818215	0.499969119	0.499993426	0.499998316	0.4999995
0.03	0.499454645	0.499907357	0.499980278	0.499994949	0.499998492
0.06	0.498909289	0.499814714	0.499960556	0.499989898	0.4999970
0.1	0.498182149	0.49969119	0.49993426	0.499983163	0.4999950
0.3	0.494546446	0.499073569	0.49980278	0.499949489	0.499984919
0.6	0.489092892	0.498147138	0.49960556	0.499898977	0.4999698
1	0.481821486	0.496911897	0.4993426	0.499831628	0.4999497
3	0.445470472	0.49073569	0.498027799	0.499494885	0.499849186
6	0.392074332	0.481471381	0.496055598	0.498989771	0.4996984
10	0.330026514	0.469118971	0.493425996	0.498316285	0.4994973
30	0.173889946	0.407796595	0.480277988	0.494948854	0.498491864
60	0.100857375	0.327478497	0.460556119	0.489897708	0.4969837
100	0.065185018	0.253218301	0.43430	0.483162846	0.4949729
300	0.025016901	0.116127452	0.318879239	0.449491492	0.484918641
600	0.014210265	0.065084356	0.218256124	0.399749522	0.4698373
1000	0.009928079	0.042054797	0.152617791	0.340671972	0.4497317
3000	0.006595168	0.017396989	0.062899809	0.18546629	0.355028968
6000	0.006193156	0.011497458	0.035557457	0.110303446	0.2577407
10000	0.00610448	0.009713167	0.024027148	0.073111654	0.1868574
30000	0.006059738	0.00869217	0.013593089	0.030967438	0.081438192
60000	0.006055529	0.00859105	0.012100151	0.020441765	0.0475108
100000	0.006054631	0.008569348	0.011759519	0.01719152	0.0331549
300000	0.006054182	0.00855848	0.011585963	0.01531238	0.021114276
600000	0.00605414	0.008557461	0.011569578	0.01512542	0.0195691
1000000	0.006054131	0.008557243	0.01156608	0.015085275	0.0192247
k1,blue	8980.557485	37224.19001	128656.1856	383123.4537	1008198.799
k-1,blue	0.025972239	0.257102338	1.898759054	11.02873552	52.48111077
k2,green	0.000158122	0.002217269	0.022186333	0.168345114	1.015279823
k-2,green	54.67461546	321.024046	1503.302383	5848.083061	19504.23464

Table S4-B. Model results of the time-averaged surface coverage of C* at temperatures of 273-353 K decreases in surface coverage of C* with increasing applied frequency. ($\alpha = 0.7$, $\beta = 0.7$, $\delta = 0.1$, $\Delta BE_C = 0.2$ eV) Lines in Figure 8b.

Frequency (1/s)	Time (s)	273	293	313	333	353
0.01	100	0.4999989	0.5	0.5	0.5	0.5
0.02	50	0.4999958	0.5	0.5	0.5	0.5
0.03	33.33333	0.4999906	0.5	0.5	0.5	0.5
0.04	25	0.4999833	0.5	0.5	0.5	0.5
0.05	20	0.4999739	0.499999	0.5	0.5	0.5
0.06	16.66667	0.4999626	0.499999	0.5	0.5	0.5
0.07	14.28571	0.4999492	0.499999	0.5	0.5	0.5
0.08	12.5	0.4999339	0.499998	0.5	0.5	0.5
0.09	11.11111	0.4999166	0.499998	0.5	0.5	0.5
0.1	10	0.4998973	0.499997	0.5	0.5	0.5
0.2	5	0.4996007	0.499988	0.499999	0.5	0.5
0.3	3.333333	0.4991266	0.499973	0.499999	0.5	0.5
0.4	2.5	0.4984899	0.499952	0.499998	0.5	0.5
0.5	2	0.4977044	0.499926	0.499997	0.5	0.5
0.6	1.666667	0.4967827	0.499893	0.499995	0.5	0.5
0.7	1.428571	0.4957363	0.499856	0.499993	0.5	0.5
0.8	1.25	0.4945761	0.499812	0.499991	0.499999	0.5
0.9	1.111111	0.4933117	0.499764	0.499989	0.499999	0.5
1	1	0.4919523	0.499709	0.499986	0.499999	0.5
2	0.5	0.4746843	0.498892	0.499946	0.499996	0.5
3	0.333333	0.4540346	0.497622	0.499879	0.499992	0.499999
4	0.25	0.4326723	0.495962	0.499788	0.499986	0.499999
5	0.2	0.411828	0.493967	0.499672	0.499978	0.499998
6	0.166667	0.3920471	0.491685	0.499532	0.499968	0.499997
7	0.142857	0.3735386	0.489158	0.49937	0.499956	0.499996
8	0.125	0.3563444	0.486421	0.499186	0.499943	0.499995
9	0.111111	0.3404253	0.483507	0.49898	0.499928	0.499993
10	0.1	0.3257042	0.480443	0.498753	0.499912	0.499992
20	0.05	0.2256169	0.445628	0.49548	0.499656	0.499968
30	0.033333	0.1723457	0.410065	0.490743	0.499246	0.499929
40	0.025	0.1396949	0.377532	0.484955	0.498695	0.499875
50	0.02	0.1177059	0.348752	0.478427	0.498013	0.499806
60	0.016667	0.1019089	0.323534	0.471391	0.49721	0.499723
70	0.014286	0.0900181	0.301449	0.464021	0.496297	0.499625
80	0.0125	0.0807469	0.282047	0.45645	0.495282	0.499515
90	0.011111	0.0733168	0.264921	0.448777	0.494173	0.49939

Frequency (1/s)	Time (s)	273	293	313	333	353
100	0.01	0.06723	0.249723	0.441078	0.492978	0.499253
200	0.005	0.038157	0.159085	0.370165	0.477622	0.497236
300	0.003333	0.027813	0.117677	0.315345	0.458943	0.494226
400	0.0025	0.02251	0.094086	0.273902	0.439346	0.490446
500	0.002	0.019285	0.078867	0.241966	0.42	0.486071
600	0.001667	0.017117	0.068241	0.216763	0.40146	0.481241
700	0.001429	0.01556	0.060403	0.196429	0.383967	0.476069
800	0.00125	0.014387	0.054383	0.179707	0.367597	0.470644
900	0.001111	0.013471	0.049615	0.165726	0.352346	0.465038
1000	0.001	0.012737	0.045746	0.153872	0.338164	0.459312
2000	0.0005	0.009413	0.0277	0.091863	0.239929	0.402327
3000	0.000333	0.008297	0.021445	0.06745	0.186476	0.353628
4000	0.00025	0.007738	0.018271	0.054414	0.153348	0.314341
5000	0.0002	0.007402	0.016351	0.046307	0.130886	0.282665
6000	0.000167	0.007177	0.015065	0.040779	0.114677	0.256821
7000	0.000143	0.007017	0.014144	0.036769	0.102436	0.23543
8000	0.000125	0.006897	0.01345	0.033726	0.092869	0.217478
9000	0.000111	0.006803	0.01291	0.031339	0.085186	0.202222
10000	0.0001	0.006729	0.012478	0.029416	0.078883	0.18911
20000	0.00005	0.006392	0.010523	0.020615	0.04866	0.117875
30000	3.33E-05	0.006279	0.009869	0.017626	0.03786	0.088614
40000	0.000025	0.006223	0.009542	0.016121	0.032314	0.072707
50000	0.00002	0.006189	0.009345	0.015215	0.028938	0.062715
60000	1.67E-05	0.006167	0.009214	0.014609	0.026667	0.055858
70000	1.43E-05	0.006151	0.00912	0.014176	0.025035	0.050861
80000	1.25E-05	0.006139	0.00905	0.013851	0.023805	0.047058
90000	1.11E-05	0.006129	0.008995	0.013597	0.022846	0.044066
100000	0.00001	0.006122	0.008951	0.013395	0.022076	0.041652
200000	0.000005	0.006088	0.008754	0.012481	0.018588	0.030544
300000	3.33E-06	0.006077	0.008689	0.012175	0.017417	0.026752
400000	2.5E-06	0.006071	0.008656	0.012023	0.01683	0.024839
500000	0.000002	0.006068	0.008636	0.011931	0.016478	0.023685
600000	1.67E-06	0.006065	0.008623	0.01187	0.016242	0.022914
700000	1.43E-06	0.006064	0.008613	0.011826	0.016074	0.022362
800000	1.25E-06	0.006063	0.008606	0.011793	0.015948	0.021947
900000	1.11E-06	0.006062	0.008601	0.011768	0.015849	0.021624
1000000	0.000001	0.006061	0.008597	0.011748	0.015771	0.021365

Table S5-A. Simulation results of the time-averaged surface coverage of C* at temperatures of 273 K with varying duty cycle changes in surface coverage of C* with increasing applied frequency. (α = 0.78, β = 0.67 eV, $\gamma_{D/C}$ = 2.0, $\delta_{C\text{-}D}$ = 0.3, ΔBE_C = 0.6 eV) Data points in Figure 9a.

Duty Cycle	0.0001	0.001	0.01	0.1	0.5	0.9	0.99	0.999
Frequency (1/s)	**273**	**273**	**273**	**273**	**273**	**273**	**273**	**273**
0.01	0.14131	0.429201	0.492914	0.499291	0.499858	0.499922	0.499934	0.499985
0.03	0.054452	0.307651	0.478742	0.497874	0.499575	0.499765	0.499802	0.499955
0.06	0.028284	0.206003	0.457484	0.495749	0.49915	0.499531	0.499604	0.499911
0.1	0.017235	0.14131	0.429201	0.492915	0.498584	0.499218	0.49934	0.499851
0.3	0.005837	0.054452	0.307652	0.478744	0.495752	0.497655	0.498021	0.499554
0.6	0.002931	0.028284	0.206004	0.457488	0.491503	0.49531	0.496042	0.499108
1	0.001763	0.017235	0.141312	0.429207	0.485839	0.492183	0.493403	0.498513
3	0.00059	0.005837	0.054454	0.307664	0.457518	0.476548	0.480209	0.495539
6	0.000297	0.002932	0.028286	0.206019	0.415269	0.453096	0.460408	0.49101
10	0.000179	0.001763	0.017237	0.141329	0.362533	0.421941	0.433926	0.484349
30	6.17E-05	0.000591	0.005839	0.054473	0.206152	0.293338	0.317763	0.458436
60	3.23E-05	0.000297	0.002933	0.028305	0.122145	0.192906	0.219526	0.447512
100	2.06E-05	0.000179	0.00176	0.017257	0.078866	0.131405	0.158089	0.443965
300	8.79E-06	6.19E-05	0.000592	0.005859	0.028476	0.051068	0.089792	0.441781
600	5.85E-06	3.25E-05	0.000299	0.002953	0.014614	0.027303	0.077737	0.441545
1000	4.68E-06	2.07E-05	0.000181	0.001785	0.008916	0.017497	0.074615	0.441493
3000	3.5E-06	8.97E-06	6.37E-05	0.000612	0.00313	0.00894	0.072877	0.441466
6000	3.21E-06	6.03E-06	3.43E-05	0.000319	0.001709	0.007616	0.0727	0.441463
10000	3.09E-06	4.88E-06	2.28E-05	0.000205	0.001209	0.007282	0.072662	0.441463
30000	2.99E-06	3.9E-06	1.3E-05	0.00011	0.000855	0.007098	0.072642	0.441463
60000	2.98E-06	3.75E-06	1.15E-05	9.64E-05	0.00081	0.007079	0.07264	0.441463
100000	2.97E-06	3.71E-06	1.11E-05	9.29E-05	0.0008	0.007075	0.07264	0.441462
300000	2.97E-06	3.69E-06	1.09E-05	9.1E-05	0.000794	0.007073	0.07264	0.441463
600000	2.97E-06	3.68E-06	1.09E-05	9.09E-05	0.000794	0.007073	0.07264	0.441463
1000000	2.97E-06	3.68E-06	1.09E-05	9.08E-05	0.000794	0.007073	0.072651	0.441463
k1,blue	0.000204	0.000204	0.000204	0.000204	0.000204	0.000204	0.000204	0.000204
k-1,blue	70.56049	70.56049	70.56049	70.56049	70.56049	70.56049	70.56049	70.56049
k2,green	89183.85	89183.85	89183.85	89183.85	89183.85	89183.85	89183.85	89183.85
k-2,green	0.257924	0.257924	0.257924	0.257924	0.257924	0.257924	0.257924	0.257924

Table S5-B. Model results of the time-averaged surface coverage of C* at temperatures of 273 K with varying duty cycle changes in surface coverage of C* with increasing applied frequency. ($\alpha = 0.78$, $\beta = 0.67$ eV, $\gamma_{D/C} = 2.0$, $\delta_{C\text{-}D} = 0.3$, $\Delta BE_C = 0.6$ eV) Lines in Figure 9a.

Duty Cycle	0.0001	0.001	0.01	0.05	0.1	0.5	0.9	0.99	0.999
Frequency (1/s)	273	273	273	273	273	273	273	273	273
0.01	0.13871	0.434554	0.498561	0.499937	0.499984	0.499999	0.5	0.5	0.5
0.02	0.07777	0.358836	0.494815	0.499754	0.499937	0.499997	0.499999	0.499999	0.5
0.03	0.053996	0.301727	0.489437	0.499459	0.49986	0.499994	0.499998	0.499999	0.5
0.04	0.041348	0.259211	0.482917	0.499059	0.499754	0.49999	0.499997	0.499998	0.5
0.05	0.0335	0.22679	0.475614	0.498561	0.49962	0.499984	0.499995	0.499997	0.5
0.06	0.028156	0.201396	0.467792	0.497972	0.499459	0.499977	0.499993	0.499995	0.499999
0.07	0.024282	0.181025	0.459648	0.497297	0.499272	0.499969	0.499991	0.499993	0.499999
0.08	0.021345	0.164348	0.451326	0.496543	0.499059	0.49996	0.499988	0.499991	0.499999
0.09	0.019041	0.150455	0.442935	0.495714	0.498822	0.499949	0.499984	0.499989	0.499998
0.1	0.017187	0.13871	0.434555	0.494816	0.498561	0.499937	0.499981	0.499986	0.499998
0.2	0.008708	0.07777	0.358838	0.482918	0.494816	0.499755	0.499924	0.499945	0.499993
0.3	0.005832	0.053996	0.30173	0.467794	0.489439	0.49946	0.49983	0.499878	0.499984
0.4	0.004384	0.041349	0.259215	0.451329	0.48292	0.49906	0.499702	0.499786	0.499971
0.5	0.003512	0.033501	0.226793	0.434559	0.475618	0.498563	0.49954	0.499669	0.499955
0.6	0.00293	0.028156	0.2014	0.418053	0.467797	0.497975	0.499346	0.499529	0.499937
0.7	0.002513	0.024282	0.18103	0.402116	0.459654	0.497301	0.499121	0.499365	0.499915
0.8	0.002201	0.021345	0.164352	0.386902	0.451334	0.496548	0.498866	0.49918	0.49989
0.9	0.001957	0.019042	0.15046	0.372475	0.442944	0.49572	0.498581	0.498974	0.499862
1	0.001762	0.017188	0.138716	0.358848	0.434565	0.494823	0.498269	0.498746	0.499831
2	0.000884	0.008708	0.077776	0.259231	0.358861	0.482944	0.49383	0.495488	0.499392
3	0.00059	0.005832	0.054003	0.20142	0.301762	0.467843	0.487549	0.490815	0.498761
4	0.000444	0.004385	0.041356	0.164375	0.259253	0.451402	0.480036	0.485158	0.497997
5	0.000356	0.003513	0.033508	0.13874	0.226837	0.434657	0.471724	0.478828	0.49714
6	0.000297	0.002931	0.028163	0.119983	0.201448	0.418176	0.46292	0.472055	0.496224
7	0.000255	0.002514	0.024289	0.105676	0.181081	0.402263	0.453846	0.46501	0.495269
8	0.000223	0.002201	0.021352	0.094408	0.164406	0.387071	0.444661	0.457818	0.494293
9	0.000199	0.001958	0.019049	0.085308	0.150516	0.372666	0.435479	0.450572	0.49331
10	0.000179	0.001763	0.017195	0.077805	0.138773	0.359059	0.426382	0.44334	0.492328
20	9.12E-05	0.000885	0.008715	0.041387	0.077844	0.259592	0.34681	0.378205	0.483458
30	6.18E-05	0.000591	0.005839	0.028195	0.054074	0.201867	0.28921	0.329269	0.47677
40	4.71E-05	0.000444	0.004392	0.021384	0.041429	0.164878	0.247391	0.292926	0.471792
50	3.82E-05	0.000356	0.00352	0.017227	0.033582	0.139281	0.216034	0.265257	0.467997
60	3.24E-05	0.000298	0.002938	0.014425	0.028238	0.120552	0.19177	0.243611	0.465025
70	2.82E-05	0.000256	0.002521	0.012409	0.024365	0.106266	0.172483	0.226263	0.462641
80	2.5E-05	0.000224	0.002209	0.010889	0.021429	0.095016	0.156805	0.21207	0.460689
90	2.26E-05	0.0002	0.001965	0.009702	0.019126	0.085929	0.143819	0.200253	0.459063

Duty Cycle	0.0001	0.001	0.01	0.05	0.1	0.5	0.9	0.99	0.999
Frequency (1/s)	273	273	273	273	273	273	273	273	273
100	2.06E-05	0.00018	0.00177	0.008749	0.017272	0.078437	0.132892	0.190268	0.457689
200	1.18E-05	9.19E-05	0.000892	0.004425	0.008794	0.042074	0.07691	0.138523	0.450559
300	8.85E-06	6.25E-05	0.000598	0.002971	0.005918	0.028902	0.055378	0.118365	0.447778
400	7.38E-06	4.78E-05	0.000452	0.002242	0.004471	0.022101	0.04399	0.107648	0.446299
500	6.5E-06	3.9E-05	0.000363	0.001804	0.0036	0.01795	0.036946	0.100999	0.44538
600	5.91E-06	3.31E-05	0.000305	0.001511	0.003017	0.015153	0.032159	0.096472	0.444755
700	5.49E-06	2.89E-05	0.000263	0.001302	0.002601	0.01314	0.028694	0.093191	0.444302
800	5.18E-06	2.57E-05	0.000231	0.001145	0.002288	0.011622	0.02607	0.090705	0.443959
900	4.93E-06	2.33E-05	0.000207	0.001023	0.002045	0.010436	0.024014	0.088754	0.443689
1000	4.74E-06	2.13E-05	0.000187	0.000925	0.00185	0.009484	0.02236	0.087184	0.443472
2000	3.85E-06	1.25E-05	9.91E-05	0.000485	0.000971	0.005168	0.014807	0.080007	0.442481
3000	3.56E-06	9.56E-06	6.97E-05	0.000338	0.000678	0.003716	0.012249	0.077572	0.442144
4000	3.41E-06	8.09E-06	5.5E-05	0.000265	0.000531	0.002988	0.010963	0.076347	0.441975
5000	3.32E-06	7.21E-06	4.62E-05	0.000221	0.000443	0.00255	0.010189	0.07561	0.441873
6000	3.27E-06	6.62E-06	4.03E-05	0.000191	0.000385	0.002258	0.009671	0.075117	0.441805
7000	3.22E-06	6.2E-06	3.61E-05	0.00017	0.000343	0.002049	0.009301	0.074764	0.441756
8000	3.19E-06	5.89E-06	3.29E-05	0.000155	0.000311	0.001892	0.009024	0.0745	0.44172
9000	3.17E-06	5.64E-06	3.05E-05	0.000143	0.000287	0.00177	0.008808	0.074294	0.441691
10000	3.15E-06	5.45E-06	2.85E-05	0.000133	0.000267	0.001673	0.008635	0.074129	0.441668
20000	3.06E-06	4.57E-06	1.97E-05	8.86E-05	0.000179	0.001233	0.007855	0.073385	0.441566
30000	3.03E-06	4.27E-06	1.68E-05	7.39E-05	0.00015	0.001087	0.007594	0.073137	0.441531
40000	3.02E-06	4.13E-06	1.53E-05	6.66E-05	0.000135	0.001014	0.007464	0.073013	0.441514
50000	3.01E-06	4.04E-06	1.44E-05	6.22E-05	0.000126	0.00097	0.007386	0.072938	0.441504
60000	3E-06	3.98E-06	1.38E-05	5.92E-05	0.00012	0.00094	0.007334	0.072889	0.441497
70000	3E-06	3.94E-06	1.34E-05	5.71E-05	0.000116	0.000919	0.007297	0.072853	0.441492
80000	2.99E-06	3.9E-06	1.31E-05	5.56E-05	0.000113	0.000904	0.007269	0.072826	0.441488
90000	2.99E-06	3.88E-06	1.28E-05	5.43E-05	0.00011	0.000891	0.007247	0.072806	0.441485
100000	2.99E-06	3.86E-06	1.26E-05	5.34E-05	0.000108	0.000881	0.00723	0.072789	0.441483
200000	2.98E-06	3.77E-06	1.18E-05	4.89E-05	9.96E-05	0.000837	0.007151	0.072714	0.441473
300000	2.98E-06	3.74E-06	1.15E-05	4.75E-05	9.67E-05	0.000823	0.007125	0.07269	0.441469
400000	2.98E-06	3.73E-06	1.13E-05	4.67E-05	9.52E-05	0.000815	0.007112	0.072677	0.441468
500000	2.97E-06	3.72E-06	1.12E-05	4.63E-05	9.43E-05	0.000811	0.007104	0.07267	0.441467
600000	2.97E-06	3.71E-06	1.12E-05	4.6E-05	9.37E-05	0.000808	0.007099	0.072665	0.441466
700000	2.97E-06	3.71E-06	1.11E-05	4.58E-05	9.33E-05	0.000806	0.007095	0.072661	0.441465
800000	2.97E-06	3.71E-06	1.11E-05	4.56E-05	9.3E-05	0.000804	0.007093	0.072659	0.441465
900000	2.97E-06	3.7E-06	1.11E-05	4.55E-05	9.28E-05	0.000803	0.007091	0.072656	0.441465
1000000	2.97E-06	3.7E-06	1.11E-05	4.54E-05	9.26E-05	0.000802	0.007089	0.072655	0.441465

Table S5-C. Simulation results of the time-averaged surface coverage of C* at temperatures of 153 K with varying duty cycle changes in surface coverage of C* with increasing applied frequency. (α = 0.5, β = 0.375 eV, $\gamma_{D/C}$ = 2.0, $\delta_{C\text{-}D}$ = 0.25, ΔBE_C = 0.5 eV) Data points in Figure 9b.

Duty Cycle	0.0001	0.001	0.01	0.1	0.5	0.9	0.99	0.999	0.9999
Frequency (1/s)	153	153	153	153	153	153	153	153	153
0.01	0.49914	0.499914	0.499991	0.499999	0.5	0.500001	0.500009	0.500086	0.50086
0.03	0.497419	0.499742	0.499974	0.499998	0.5	0.500002	0.500026	0.500258	0.502581
0.06	0.494837	0.499484	0.499949	0.499995	0.5	0.500005	0.500051	0.500516	0.505163
0.1	0.491396	0.49914	0.499915	0.499992	0.5	0.500008	0.500085	0.50086	0.508604
0.3	0.474187	0.497421	0.499744	0.499977	0.5	0.500023	0.500256	0.502579	0.525813
0.6	0.448377	0.494842	0.499489	0.499954	0.5	0.500046	0.500511	0.505158	0.551623
1	0.414214	0.491403	0.499148	0.499924	0.5	0.500076	0.500852	0.508597	0.585786
3	0.279077	0.47421	0.497445	0.499771	0.5	0.500229	0.502555	0.52579	0.720923
6	0.179746	0.448424	0.494889	0.499541	0.5	0.500459	0.505111	0.551576	0.820254
10	0.120803	0.414288	0.491482	0.499235	0.5	0.500765	0.508518	0.585712	0.879197
30	0.045464	0.279222	0.474445	0.497705	0.5	0.502295	0.525555	0.720778	0.954536
60	0.023472	0.179924	0.44889	0.495411	0.5	0.504589	0.55111	0.820076	0.976528
100	0.014274	0.120999	0.41503	0.492351	0.5	0.507649	0.584972	0.879001	0.985726
300	0.004836	0.045679	0.280679	0.477053	0.5	0.522947	0.719321	0.954321	0.995164
600	0.002438	0.023692	0.181728	0.454064	0.5	0.545936	0.818272	0.976308	0.997562
1000	0.001475	0.014496	0.122973	0.423244	0.5	0.576756	0.877027	0.985504	0.998525
3000	0.000509	0.00506	0.04785	0.296878	0.5	0.703122	0.95215	0.99494	0.999491
6000	0.000269	0.002684	0.02612	0.203503	0.5	0.796497	0.97388	0.997316	0.999731
10000	0.00018	0.001797	0.017703	0.15355	0.5	0.84645	0.982297	0.998203	0.99982
30000	0.000113	0.001125	0.011216	0.108945	0.5	0.891055	0.988784	0.998875	0.999887
60000	0.000103	0.001035	0.010338	0.102501	0.5	0.897499	0.989662	0.998965	0.999897
100000	0.000101	0.001013	0.010127	0.100943	0.5	0.899057	0.989873	0.998987	0.999899
300000	0.0001	0.001002	0.010015	0.10011	0.5	0.89989	0.989985	0.998998	0.9999
600000	0.0001	0.001	0.010004	0.100028	0.5	0.899972	0.989996	0.999	0.9999
1000000	0.0001	0.001	0.010001	0.10001	0.5	0.89999	0.989999	0.999	0.9999
k1,blue	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338
k-1,blue	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76
k2,green	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76	58104.76
k-2,green	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338	0.000338

Table S5-D. Simulation results of the time-averaged surface coverage of C* at temperatures of 153 K with varying duty cycle changes in surface coverage of C* with increasing applied frequency. (α = 0.5, β = 0.375 eV, $\gamma_{D/C}$ = 2.0, $\delta_{C\text{-}D}$ = 0.25, ΔBE_C = 0.5 eV) Lines in Figure 9b.

Duty Cycle	0.0001	0.001	0.01	0.05	0.1	0.5	0.9	0.99	0.999	0.9999
Frequency (1/s)	273	273	273	273	273	273	273	273	273	273
0.01	0.49998	0.4999998	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.500023
0.02	0.49991	0.4999991	0.5	0.5	0.5	0.5	0.5	0.5	0.500001	0.500092
0.03	0.4998	0.4999979	0.5	0.5	0.5	0.5	0.5	0.5	0.500002	0.500205
0.04	0.49964	0.4999962	0.5	0.5	0.5	0.5	0.5	0.5	0.500004	0.500359
0.05	0.49945	0.4999941	0.4999999	0.5	0.5	0.5	0.5	0.5	0.500006	0.500554
0.06	0.49921	0.4999916	0.4999999	0.5	0.5	0.5	0.5	0.5	0.500008	0.500787
0.07	0.49894	0.4999885	0.4999999	0.5	0.5	0.5	0.5	0.5	0.500011	0.501057
0.08	0.49864	0.499985	0.4999999	0.5	0.5	0.5	0.5	0.5	0.500015	0.501362
0.09	0.4983	0.4999811	0.4999998	0.5	0.5	0.5	0.5	0.5	0.500019	0.501702
0.1	0.49793	0.4999767	0.4999998	0.5	0.5	0.5	0.5	0.5	0.500023	0.502074
0.2	0.49268	0.499908	0.4999991	0.5	0.5	0.5	0.5	0.500001	0.500092	0.507321
0.3	0.48535	0.4997957	0.4999979	0.5	0.5	0.5	0.5	0.500002	0.500204	0.514647
0.4	0.4767	0.4996416	0.4999963	0.5	0.5	0.5	0.5	0.500004	0.500358	0.523304
0.5	0.46722	0.4994475	0.4999942	0.5	0.5	0.5	0.5	0.500006	0.500553	0.532778
0.6	0.45729	0.4992149	0.4999917	0.5	0.5	0.5	0.5	0.500008	0.500785	0.542714
0.7	0.44714	0.4989453	0.4999887	0.5	0.5	0.5	0.5	0.500011	0.501055	0.552862
0.8	0.43695	0.4986404	0.4999853	0.499999	0.5	0.5	0.5	0.500015	0.50136	0.56305
0.9	0.42684	0.4983015	0.4999814	0.499999	0.5	0.5	0.5	0.500019	0.501699	0.573159
1	0.4169	0.49793	0.4999771	0.499999	0.5	0.5	0.5	0.500023	0.50207	0.583104
2	0.33226	0.4926917	0.4999096	0.499997	0.499999	0.5	0.500001	0.50009	0.507308	0.667744
3	0.27307	0.4853793	0.4997994	0.499992	0.499998	0.5	0.500002	0.500201	0.514621	0.726931
4	0.23097	0.4767379	0.4996481	0.499987	0.499997	0.5	0.500003	0.500352	0.523262	0.769025
5	0.19984	0.4672806	0.4994575	0.499979	0.499995	0.5	0.500005	0.500543	0.532719	0.800159
6	0.17598	0.457363	0.499229	0.49997	0.499993	0.5	0.500007	0.500771	0.542637	0.824017
7	0.15716	0.447233	0.4989644	0.499959	0.499991	0.5	0.500009	0.501036	0.552767	0.842844
8	0.14194	0.4370631	0.4986649	0.499947	0.499988	0.5	0.500012	0.501335	0.562937	0.858062
9	0.12939	0.4269732	0.4983321	0.499933	0.499985	0.5	0.500015	0.501668	0.573027	0.870611
10	0.11887	0.4170454	0.4979673	0.499917	0.499981	0.5	0.500019	0.502033	0.582955	0.88113
20	0.06551	0.3325584	0.4928235	0.499677	0.499926	0.5	0.500074	0.507176	0.667442	0.934493
30	0.04521	0.2734772	0.485643	0.499292	0.499836	0.5	0.500164	0.514357	0.726523	0.954791
40	0.03452	0.2314592	0.4771575	0.498774	0.499713	0.5	0.500287	0.522843	0.768541	0.965478
50	0.02793	0.2003816	0.4678707	0.498133	0.499557	0.5	0.500443	0.532129	0.799618	0.972072
60	0.02345	0.1765663	0.458132	0.49738	0.499371	0.5	0.500629	0.541868	0.823434	0.976546
70	0.02022	0.1577732	0.4481847	0.496523	0.499155	0.5	0.500845	0.551815	0.842227	0.979781
80	0.01777	0.1425822	0.4381983	0.49557	0.49891	0.5	0.50109	0.561802	0.857418	0.982229
90	0.01585	0.1300566	0.4282903	0.49453	0.498638	0.5	0.501362	0.57171	0.869943	0.984145

Duty Cycle	0.0001	0.001	0.01	0.05	0.1	0.5	0.9	0.99	0.999	0.9999
Frequency (1/s)	273	273	273	273	273	273	273	273	273	273
100	0.014313	0.119556	0.418542	0.493409	0.498341	0.5	0.501659	0.581458	0.880444	0.985687
200	0.007283	0.06629	0.335578	0.479022	0.494142	0.5	0.505858	0.664422	0.93371	0.992717
300	0.004906	0.046028	0.277563	0.46155	0.48828	0.5	0.51172	0.722437	0.953972	0.995094
400	0.003711	0.03536	0.236303	0.443243	0.481353	0.5	0.518647	0.763697	0.96464	0.996289
500	0.002992	0.028778	0.205786	0.425191	0.473772	0.5	0.526228	0.794214	0.971222	0.997008
600	0.002512	0.024312	0.1824	0.407907	0.465822	0.5	0.534178	0.8176	0.975688	0.997488
700	0.002168	0.021083	0.163946	0.391612	0.457702	0.5	0.542298	0.836054	0.978917	0.997832
800	0.00191	0.01864	0.149029	0.376375	0.44955	0.5	0.55045	0.850971	0.98136	0.99809
900	0.00171	0.016726	0.136729	0.362187	0.441461	0.5	0.558539	0.863271	0.983274	0.99829
1000	0.001549	0.015187	0.126418	0.349001	0.433503	0.5	0.566497	0.873582	0.984813	0.998451
2000	0.000825	0.00817	0.074112	0.257829	0.365778	0.5	0.634222	0.925888	0.99183	0.999175
3000	0.000584	0.005798	0.054216	0.208326	0.318419	0.5	0.681581	0.945784	0.994202	0.999416
4000	0.000463	0.004605	0.04374	0.177679	0.284737	0.5	0.715263	0.95626	0.995395	0.999537
5000	0.00039	0.003887	0.037277	0.156914	0.259825	0.5	0.740175	0.962723	0.996113	0.99961
6000	0.000342	0.003407	0.032891	0.141935	0.240735	0.5	0.759265	0.967109	0.996593	0.999658
7000	0.000307	0.003065	0.029721	0.130628	0.22567	0.5	0.77433	0.970279	0.996935	0.999693
8000	0.000281	0.002807	0.027321	0.121792	0.213493	0.5	0.786507	0.972679	0.997193	0.999719
9000	0.000261	0.002607	0.025443	0.114698	0.203452	0.5	0.796548	0.974557	0.997393	0.999739
10000	0.000245	0.002447	0.023931	0.108878	0.195035	0.5	0.804965	0.976069	0.997553	0.999755
20000	0.000173	0.001724	0.017041	0.080986	0.152336	0.5	0.847664	0.982959	0.998276	0.999827
30000	0.000148	0.001483	0.014711	0.071023	0.136094	0.5	0.863906	0.985289	0.998517	0.999852
40000	0.000136	0.001362	0.01354	0.065907	0.127543	0.5	0.872457	0.98646	0.998638	0.999864
50000	0.000129	0.00129	0.012835	0.062794	0.122267	0.5	0.877733	0.987165	0.99871	0.999871
60000	0.000124	0.001242	0.012364	0.0607	0.118687	0.5	0.881313	0.987636	0.998758	0.999876
70000	0.000121	0.001207	0.012027	0.059195	0.116099	0.5	0.883901	0.987973	0.998793	0.999879
80000	0.000118	0.001181	0.011775	0.058061	0.11414	0.5	0.88586	0.988225	0.998819	0.999882
90000	0.000116	0.001161	0.011578	0.057176	0.112606	0.5	0.887394	0.988422	0.998839	0.999884
100000	0.000115	0.001145	0.01142	0.056466	0.111373	0.5	0.888627	0.98858	0.998855	0.999885
200000	0.000107	0.001072	0.010711	0.053251	0.105748	0.5	0.894252	0.989289	0.998928	0.999893
300000	0.000105	0.001048	0.010474	0.052171	0.103846	0.5	0.896154	0.989526	0.998952	0.999895
400000	0.000104	0.001036	0.010356	0.05163	0.102889	0.5	0.897111	0.989644	0.998964	0.999896
500000	0.000103	0.001029	0.010285	0.051305	0.102314	0.5	0.897686	0.989715	0.998971	0.999897
600000	0.000102	0.001024	0.010237	0.051087	0.10193	0.5	0.89807	0.989763	0.998976	0.999898
700000	0.000102	0.001021	0.010203	0.050932	0.101655	0.5	0.898345	0.989797	0.998979	0.999898
800000	0.000102	0.001018	0.010178	0.050816	0.101449	0.5	0.898551	0.989822	0.998982	0.999898
900000	0.000102	0.001016	0.010158	0.050725	0.101288	0.5	0.898712	0.989842	0.998984	0.999898
1000000	0.000101	0.001015	0.010142	0.050653	0.10116	0.5	0.89884	0.989858	0.998985	0.999899

Table S6-A. Cutoff frequencies of three catalytic ratchets depicted in Figure 11d.

Temperature (K)	1/T*1000	fc,1 (Hz)	fc,2 (Hz)	fc,3 (Hz)
243	4.12	15	5	0.04
253	3.95	42	15	0.14
263	3.80	108	41	0.44
273	3.66	262	103	1.29
283	3.53	593	242	3.52
293	3.41	1272	535	9.00
303	3.30	2593	1122	22
313	3.19	5052	2245	49
323	3.10	9444	4303	106
333	3.00	17004	7933	218
343	2.92	29583	14112	431
353	2.83	49879	24298	819
363	2.75	81713	40602	1502
373	2.68	130367	66005	2667
383	2.61	202980	104611	4597
393	2.54	308996	161958	7706
403	2.48	460676	245361	12590
413	2.42	673657	364312	20087
423	2.36	967562	530915	31349
433	2.31	1366646	760365	47930
443	2.26	1900475	1071460	71888
453	2.21	2604628	1487146	105909
463	2.16	3521408	2035078	153442
473	2.11	4700554	2748200	218849
483	2.07	6199946	3665332	307583
493	2.03	8086283	4831752	426365
503	1.99	10435734	6299774	583395

Table S6-B. Dynamic turnover frequency (Fig. 11e) and surface coverage (Fig. 11g) at 303 K.

T, K	BEa [eV]	ΔBEa [eV]	f [1/s]	DC [%]	qdot [L/s]	Ca [%]	theta_*	theta_A*	theta_B*	theta_C*	theta_D*	A(g) [-]	D(g) [-]	r1 [1/s]	r2 [1/s]	r3 [1/s]	r4 [1/s]	r5 [1/s]	TOF [1/s]
303.15	2.5	-1.8	1.00E-06	50	1	0.01	4.64E-07	0.5	7.65E-08	0.5	1.26E-11	0.9999	0.0001	0.00017	0.00017	0.00017	0.00017	0.00017	0.00017
303.15	2.5	-1.8	1.00E-05	50	1	0.01	4.64E-07	0.5	7.89E-08	0.5	1.27E-11	0.9999	1.00E-04	0.000179	0.000179	0.000179	0.000179	0.000179	0.000179
303.15	2.5	-1.8	1.00E-04	50	1	0.01	4.64E-07	0.5	1.03E-07	0.5	1.31E-11	0.9999	0.0001	0.000269	0.000269	0.000269	0.000269	0.000269	0.000269
303.15	2.5	-1.8	0.001	50.00	1	9.99E-03	4.64E-07	0.5	3.42E-07	0.5	1.51E-11	0.9999	9.99E-05	0.001169	0.001169	0.001169	0.001169	0.001169	0.001169
303.15	2.5	-1.8	0.01	50.00	1	9.99E-03	4.64E-07	0.5	2.73E-06	0.5	3.25E-11	0.9999	9.99E-05	0.01017	0.01017	0.01017	0.01017	0.01017	0.01017
303.15	2.5	-1.8	0.1	50.00	1	1.00E-02	4.68E-07	0.5	2.66E-05	0.5	2.05E-10	0.9999	0.0001	0.1002	0.1002	0.1002	0.1002	0.1002	0.1002
303.15	2.5	-1.8	1	50.00	1	1.00E-02	5.04E-07	0.5001	2.66E-04	0.4996	1.93E-09	0.9999	0.0001	1	1	1	1	1	1
303.15	2.5	-1.8	10	50.00	1	1.00E-02	8.67E-07	0.5009	2.66E-03	0.4964	1.92E-08	0.9999	0.0001	10	10	10	10	10	10
303.15	2.5	-1.8	50	50.00	1	1.00E-02	2.48E-06	0.5047	1.33E-02	0.482	9.59E-08	0.9999	0.0001	50	50	50	50	50	50
303.15	2.5	-1.8	100	50.00	1	1.00E-02	4.50E-06	0.5094	2.66E-02	0.464	1.92E-07	0.9999	0.0001	100	100	100	100	100	100
303.15	2.5	-1.8	500	50.00	1	1.00E-02	2.06E-05	0.5472	1.27E-01	0.3254	9.57E-07	0.9999	1.00E-04	499.9	499.9	499.9	499.9	499.9	499.9
303.15	2.5	-1.8	1000	50.00	1	1.00E-02	4.02E-05	0.5932	1.97E-01	0.2099	1.89E-06	0.9999	0.0001	987.1	987.1	987.1	987.1	987.1	987.1
303.15	2.5	-1.8	10000	50.00	1	1.00E-02	0.000138	0.822	8.58E-02	0.09208	6.53E-06	0.9999	1.00E-04	3412	3412	3412	3412	3412	3412
303.15	2.5	-1.8	100000	50	1	0.00998	0.000149	0.848	0.009228	0.1426	7.46E-06	0.9999	9.98E-05	3688	3688	3688	3688	3688	3688
303.15	2.5	-1.8	1.00E+06	50	1	0.00999	0.000149	0.8483	0.000923	0.1506	1.07E-05	0.9999	9.99E-05	3691	3691	3691	3691	3691	3691
303.15	2.5	-1.8	1.00E+07	50	1	0.994	0.00015	0.8483	9.23E-05	0.1514	1.40E-05	0.9901	0.007657	3690	3690	3691	3690	3690	3690.2

Table S6-C. Static catalytic rates of the ratchet of Figure 11f at three temperatures

Temp, K	BEa [eV]	qdot [L/s]	Ca [%]	theta_*	theta_A*	theta_B*	theta_C*	theta_D*	A(g) [-]	D(g) [-]	r1 [1/s]	r2 [1/s]	r3 [1/s]	r4 [1/s]	r5 [1/s]	TOF [1/s]
263.15	2.5	3.34E-09	0.00999	5.60E-15	3.31E-10	1.35E-08	1	3.98E-13	0.9999	9.99E-05	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07	1.21E-07
263.15	2.3	4.70E-08	0.01	7.89E-14	4.23E-08	1.03E-09	1	2.89E-12	0.9999	0.0001	1.70E-06	1.70E-06	1.70E-06	1.70E-06	1.70E-06	1.70E-06
263.15	2.1	6.08E-06	0.103	1.11E-12	5.41E-06	1.21E-09	1	2.10E-11	0.999	9.84E-06	2.40E-05	2.40E-05	2.40E-05	2.40E-05	2.40E-05	2.40E-05
263.15	1.9	3.65E-05	0.0391	1.57E-11	6.91E-04	1.43E-09	0.9993	1.53E-10	0.9996	9.71E-05	3.38E-04	3.38E-04	3.38E-04	3.38E-04	3.38E-04	3.38E-04
263.15	1.7	0.000121	0.00997	2.03E-10	0.08385	1.60E-09	0.9162	1.02E-09	0.9999	9.97E-05	0.004371	0.004523	0.004523	0.004371	0.004371	4.43E-03
263.15	1.5	0.000151	0.00998	2.53E-10	0.9188	1.61E-10	0.0812	6.58E-10	0.9999	9.98E-05	0.005461	0.005465	0.005465	0.005461	0.005461	5.46E-03
263.15	1.3	1.92E-05	0.01	3.04E-11	0.9993	1.62E-12	0.000691	4.07E-11	0.9999	9.39E-05	0.000655	0.000655	0.000655	0.000655	0.000655	6.55E-04
263.15	1.1	2.06E-06	0.01	3.35E-12	1	1.50E-14	5.41E-06	2.32E-12	0.9999	9.66E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05	7.23E-05
263.15	0.9	2.24E-07	0.00999	3.06E-12	1	1.38E-16	4.23E-08	1.32E-13	0.9999	9.80E-05	7.97E-06	7.97E-06	7.97E-06	7.97E-06	7.97E-06	7.97E-06
263.15	0.7	2.43E-08	0.0101	1.82E-08	1	1.27E-18	3.31E-10	3.42E-13	0.9999	9.98E-05	8.79E-07	8.79E-07	8.79E-07	8.79E-07	8.79E-07	8.79E-07
303.15	2.5	1.68E-06	0.0101	2.06E-12	5.91E-09	1.52E-07	1	1.72E-11	0.9999	8.45E-05	5.13E-05	5.13E-05	5.13E-05	5.13E-05	5.13E-05	5.13E-05
303.15	2.3	1.67E-05	0.0101	2.05E-11	3.98E-07	1.58E-08	1	9.63E-11	0.9999	8.42E-05	0.00051	0.00051	0.00051	0.00051	0.00051	5.10E-04
303.15	2.1	0.00014	0.01	2.04E-10	2.68E-05	1.82E-08	1	5.39E-10	0.9999	0.0001	0.005073	0.005073	0.005073	0.005073	0.005073	5.07E-03
303.15	1.9	0.00139	0.01	2.02E-09	0.001804	2.09E-08	0.9982	3.01E-09	0.9999	1.00E-04	0.05035	0.05035	0.05035	0.05035	0.05035	5.04E-02
303.15	1.7	0.0123	0.01	1.80E-08	0.1086	2.16E-08	0.8914	1.51E-08	0.9999	0.0001	0.447	0.447	0.447	0.447	0.447	4.47E-01
303.15	1.5	0.0149	0.01	2.18E-08	0.8914	3.03E-09	0.1086	1.03E-08	0.9999	0.0001	0.5413	0.5413	0.5413	0.5413	0.5413	5.41E-01
303.15	1.3	0.00247	0.00999	3.59E-09	0.9982	5.82E-11	0.001804	9.56E-10	0.9999	9.99E-05	0.0894	0.0894	0.0894	0.0894	0.0894	8.94E-02
303.15	1.1	0.000365	0.00999	5.31E-10	1	9.98E-13	2.68E-05	7.95E-11	0.9999	9.99E-05	0.01321	0.01321	0.01321	0.01321	0.01321	1.32E-02
303.15	0.9	5.38E-05	0.00999	5.17E-10	1	1.71E-14	3.98E-07	6.61E-12	0.9999	1.00E-04	0.001948	0.001948	0.001948	0.001948	0.001948	1.95E-03
303.15	0.7	7.92E-06	0.00167	9.27E-07	1	2.93E-16	5.90E-09	1.29E-12	1	1.67E-05	0.000287	0.000287	0.000287	0.000287	0.000287	2.87E-04
343.15	2.5	0.000147	0.00998	1.89E-10	5.39E-08	9.87E-07	1	3.09E-10	0.9999	9.98E-05	0.005317	0.005317	0.005317	0.005317	0.005317	5.32E-03
343.15	2.3	0.00112	0.00997	1.44E-09	2.22E-06	1.28E-07	1	1.42E-09	0.9999	9.97E-05	0.04045	0.04045	0.04045	0.04045	0.04045	4.05E-02
343.15	2.1	0.00849	0.01	1.09E-08	9.15E-05	1.45E-07	0.9999	6.49E-09	0.9999	0.0001	0.3077	0.3077	0.3077	0.3077	0.3077	3.08E-01
343.15	1.9	0.0644	0.00999	8.28E-08	0.00376	1.64E-07	0.9962	2.96E-08	0.9999	9.99E-05	2.332	2.332	2.332	2.332	2.332	2.33E+00
343.15	1.7	0.425	0.01	5.47E-07	0.1347	1.62E-07	0.8653	1.18E-07	0.9999	0.0001	15.41	15.41	15.41	15.41	15.41	1.54E+01
343.15	1.5	0.503	0.01	6.48E-07	0.8653	2.86E-08	0.1347	8.40E-08	0.9999	0.0001	18.24	18.24	18.24	18.24	18.24	1.82E+01
343.15	1.3	0.107	0.00999	1.38E-07	0.9962	9.05E-10	0.003758	1.07E-08	0.9999	9.99E-05	3.872	3.872	3.872	3.872	3.872	3.87E+00
343.15	1.1	0.0198	0.00999	2.55E-08	0.9999	2.50E-11	9.14E-05	1.20E-09	0.9999	9.99E-05	0.7165	0.7165	0.7165	0.7165	0.7165	7.17E-01
343.15	0.9	0.00365	0.00999	2.62E-08	1	6.88E-13	2.22E-06	1.33E-10	0.9999	9.99E-05	0.1321	0.1321	0.1321	0.1321	0.1321	1.32E-01
343.15	0.7	0.000672	0.01	1.86E-05	1	1.89E-14	5.37E-08	4.65E-11	0.9999	0.0001	0.02435	0.02435	0.02435	0.02435	0.02435	2.44E-02