

Supporting Information for Article

Thermal Decomposition Kinetics of Wood and Bark and their Torrefied Products

Energy & Fuels, **2017**, *31*, 4024-4034. doi: 10.1021/acs.energyfuels.6b03419)

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Keywords: Norway spruce; bark; torrefied wood; pyrolysis kinetics; thermogravimetry; distributed activation energy model.

Scope of this document: Expanding the corresponding journal article by an unabridged table of the obtained parameters and by a figure that shows the partial curves and the fit quality for the 36 experiments evaluated together in Evaluation 3.1.

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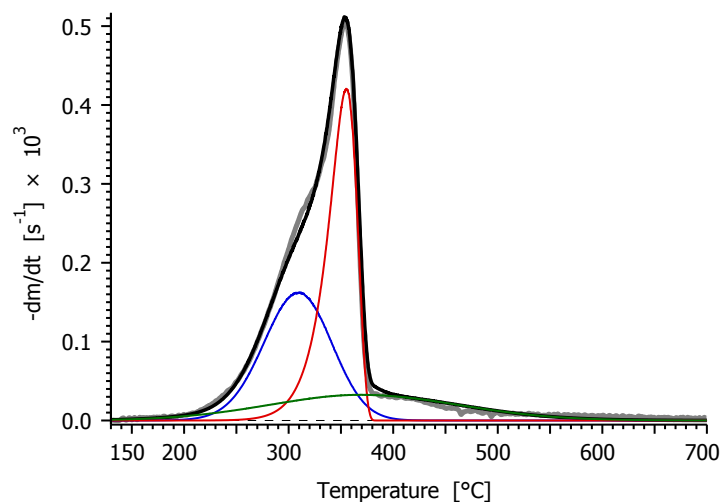
Table S1: The parameters resulting from the evaluations of the present study and from earlier works^a

Evaluation	Sample	E_1	E_2	E_3	$\log_{10} A_1$	$\log_{10} A_2$	$\log_{10} A_3$	n_2	z_2	σ_1	σ_3	c_1	c_2	c_3
1	(Each sample was evaluated separately)													
	Wood	179.3	173.8	194.8	13.22	11.67	13.50	0.770	0.860	8.59	24.58	0.336	0.327	0.170
	W225	157.0	168.0	268.3	11.34	11.19	18.59	0.858	0.679	4.20	35.65	0.272	0.424	0.149
	W275		179.1	207.8	—	12.29	13.52	0.933	1.215	—	25.77	—	0.521	0.233
	Bark	178.5	186.8	222.3	13.92	13.22	14.58	1.155	0.908	13.29	39.60	0.272	0.210	0.223
	B225	184.2	181.7	214.6	13.45	12.69	13.39	1.007	0.479	9.56	33.14	0.286	0.169	0.223
	B275		185.3	209.4	—	13.01	13.00	1.950	0.226	—	28.49	—	0.281	0.294
2	(Two groups of 18 experiments were evaluated)													
	Wood	176.8	175.3	201.2	13.13	11.85	13.42	0.835	1.249	8.28	28.44	0.305	0.370	0.182
	W225	176.8	175.3	201.2	13.13	11.84	13.42	0.835	1.249	5.05	28.44	0.247	0.437	0.161
	W275		175.3	201.2	—	11.96	13.42	0.835	1.249	—	28.44	—	0.509	0.250
	Bark	179.8	186.0	208.0	13.88	13.13	13.00	1.431	0.473	15.34	28.74	0.341	0.196	0.159
	B225	179.8	186.0	208.0	13.88	13.09	13.00	1.431	0.473	3.98	28.74	0.119	0.312	0.239
	B275		186.0	208.0	—	13.08	13.00	1.431	0.473	—	28.74	—	0.259	0.318
3.1	(all the 36 experiments were evaluated together)													
	Wood	177.4	175.7	209.1	13.16	11.87	14.05	0.849	1.123	8.46	29.64	0.313	0.365	0.179
	W225	177.4	175.7	209.1	13.16	11.86	14.05	0.849	1.123	5.10	29.64	0.251	0.433	0.160
	W275		175.7	209.1	—	11.98	14.05	0.849	1.123	—	29.64	—	0.507	0.251
	Bark	177.4	175.7	209.1	13.65	12.25	13.08	1.407	0.402	15.16	28.81	0.340	0.197	0.158
	B225	177.4	175.7	209.1	13.65	12.20	13.08	1.407	0.402	3.92	28.81	0.119	0.316	0.238
	B275		175.7	209.1	—	12.20	13.08	1.407	0.402	—	28.81	—	0.262	0.317
3.2	(all the 36 experiments were evaluated together)													
	Wood	177.9	176.1	207.4	13.26	11.90	13.79	1.022	0.796	8.35	30.95	0.304	0.388	0.168
	W225	177.9	176.1	207.4	13.26	11.89	13.79	1.022	0.796	4.57	30.95	0.239	0.462	0.142
	W275		176.1	207.4		12.01	13.79	1.022	0.796	—	30.95	—	0.528	0.233
	Bark	177.9	176.1	207.4	13.63	12.29	13.13	1.022	0.796	15.65	26.95	0.353	0.181	0.156
	B225	177.9	176.1	207.4	13.63	12.23	13.13	1.022	0.796	4.87	26.95	0.127	0.285	0.257
	B275		176.1	207.4		12.25	13.13	1.022	0.796	—	26.95	—	0.241	0.333
Earlier results for comparison														
2013^b	Norway spruce	168.5	169.1	230.0	12.62	11.55	16.11	0.726	1.258	8.64	34.15	0.344	0.342	0.167
2012^c	corn-cob	179.5	187.5	225.0	14.76	14.11	16.25	1	—	3.92	31.34	0.225	0.344	0.198
2011^d	corn stalk	175.6	185.4	195.4	14.64	13.86	14.68	1	—	5.84	36.58	0.107	0.279	0.317

^a The dimension of $E_{0,1}$, E_2 , $E_{0,3}$, σ_1 and σ_3 is kJ/mol. The dimension of A_1 , A_2 and A_3 is s^{-1} . n , z , c_1 , c_2 and c_3 are dimensionless. ^b From Table 3 of Tapasvi et al., *Energy Fuels* **2013**, 27, 6134-6145, doi: [10.1021/ef4016075](https://doi.org/10.1021/ef4016075).

^c From the 7th column in Table 3 of Trninić et al., *Energy Fuels*, **2012**, 26, 2005-2013, doi: [10.1021/ef3002668](https://doi.org/10.1021/ef3002668).

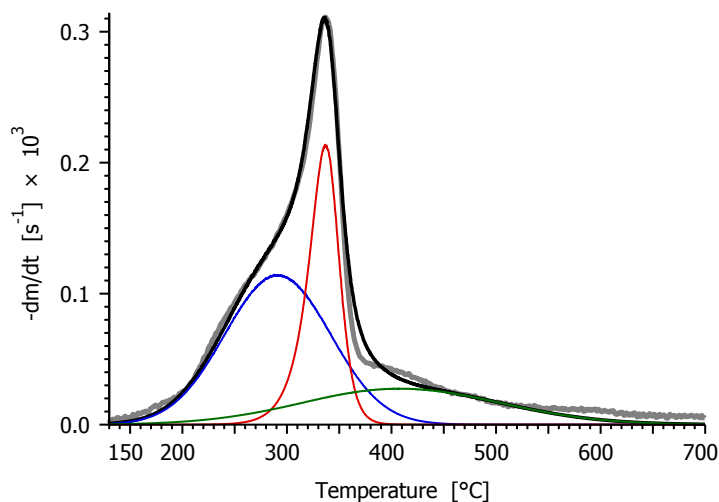
^d From the 1st column in Table 4 of Várhegyi et al., *Energy Fuels*, **2011**, 25, 24-32, doi: [10.1021/ef101079r](https://doi.org/10.1021/ef101079r).

**Wood 2.5°C/min 4mg**

Relative deviation: 1.45%, Deviation: 0.028 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$ 2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$ 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

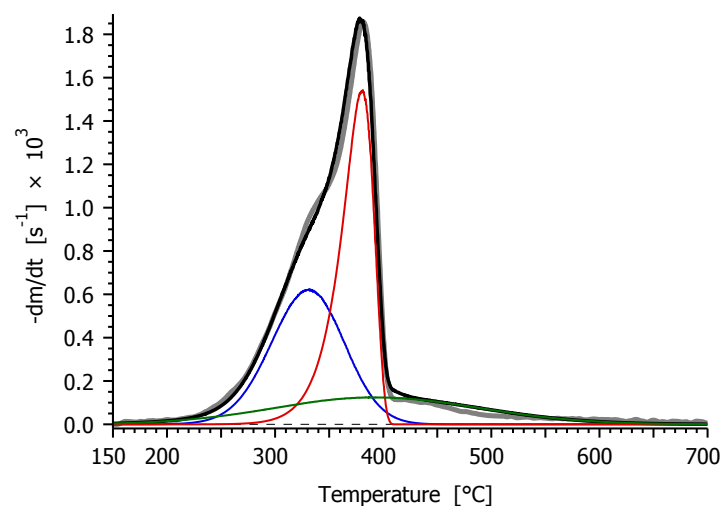
C: 31.3 36.5 17.9

**Bark 2.5°C/min 4mg**

Relative deviation: 2.02%, Deviation: 0.025 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$ 2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$ 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

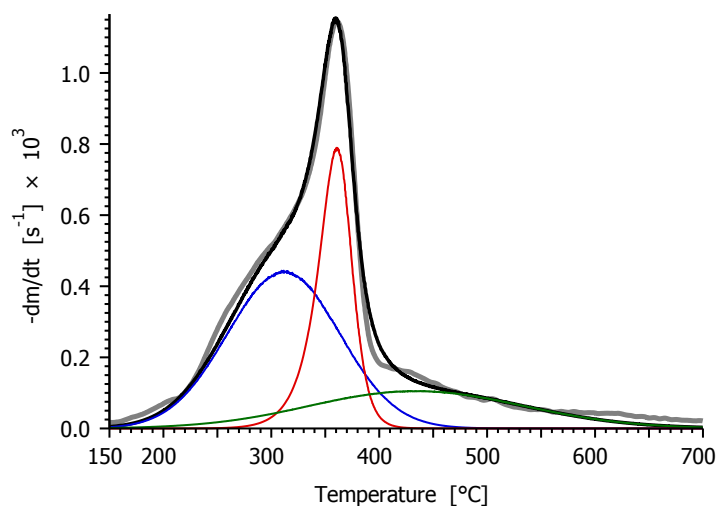
C: 34.0 19.7 15.8

**Wood 10°C/min 2mg**

Relative deviation: 1.82%, Deviation: 0.066 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$ 2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$ 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

C: 31.3 36.5 17.9

**Bark 10°C/min 2mg**

Relative deviation: 2.01%, Deviation: 0.050 µg/s

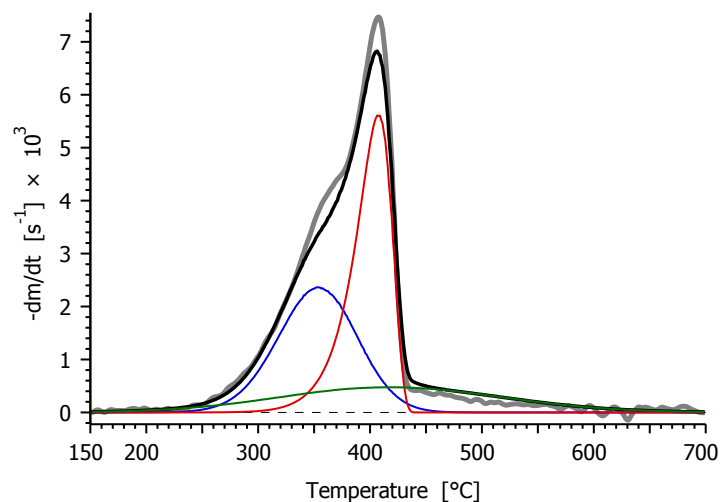
1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$ 2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$ 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

C: 34.0 19.7 15.8

Figure S1. Kinetic curve fitting for 36 experiments in Evaluation 3.1.Notation: - - - $T(t)$; — $-dm^{obs}/dt$; — $-dm^{calc}/dt$;

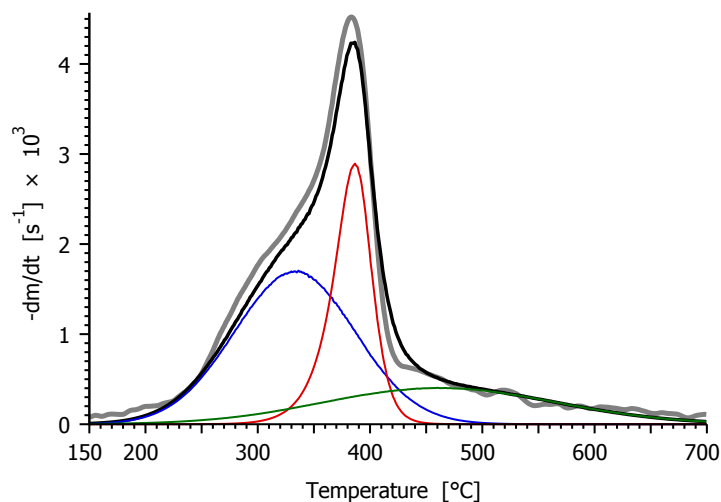
— — — mass loss rate curves of the pseudo-components.

(Continued in further pages.)

**Wood 40°C/min 0.5mg**

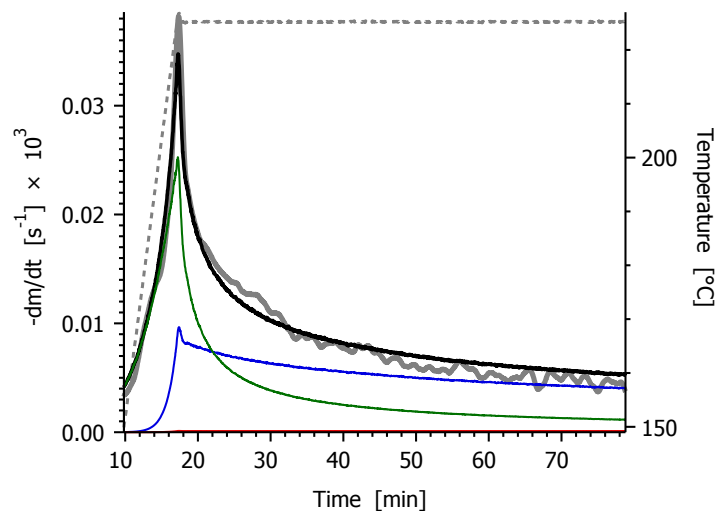
Relative deviation: 2.36%, Deviation: 0.081 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$
 2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$
 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$
 C: 31.3 36.5 17.9

**Bark 40°C/min 0.5mg**

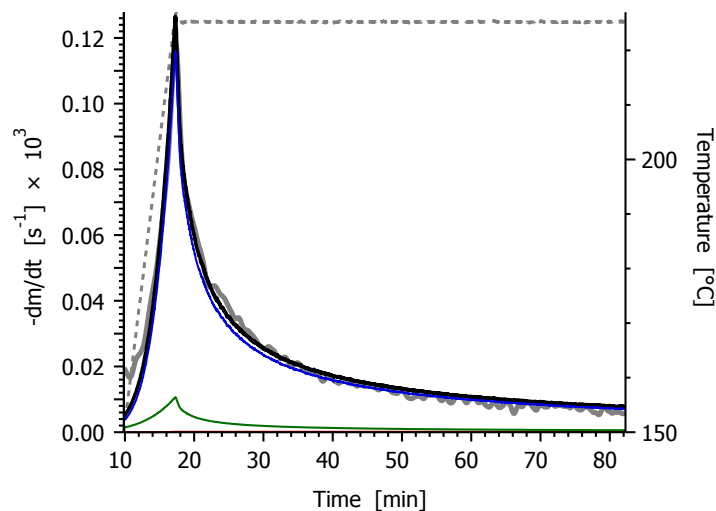
Relative deviation: 3.23%, Deviation: 0.075 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$
 2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$
 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$
 C: 34.0 19.7 15.8

**Wood 65min at 225°C 4mg**

Relative deviation: 2.80%, Deviation: 0.0044 µg/s

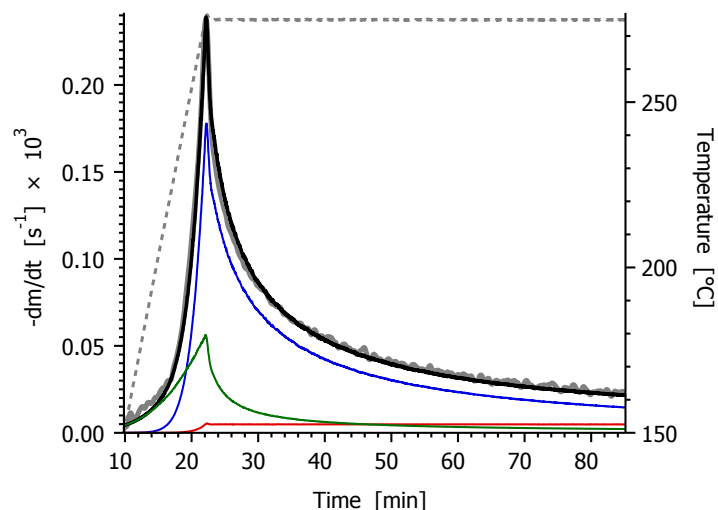
1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$
 2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$
 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$
 C: 31.3 36.5 17.9

**Bark 65min at 225°C 4mg**

Relative deviation: 2.37%, Deviation: 0.011 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$
 2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$
 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$
 C: 34.0 19.7 15.8

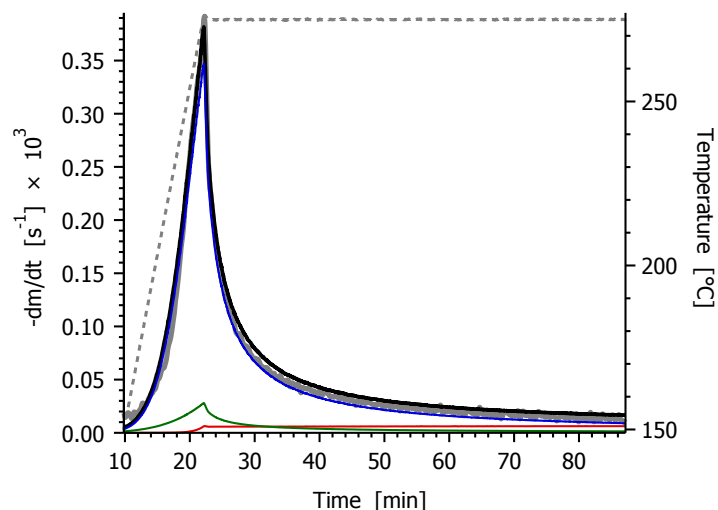
Figure S1, continued.

**Wood 65min at 275°C 4mg**

Relative deviation: 1.41%, Deviation: 0.011 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$ 2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$ 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

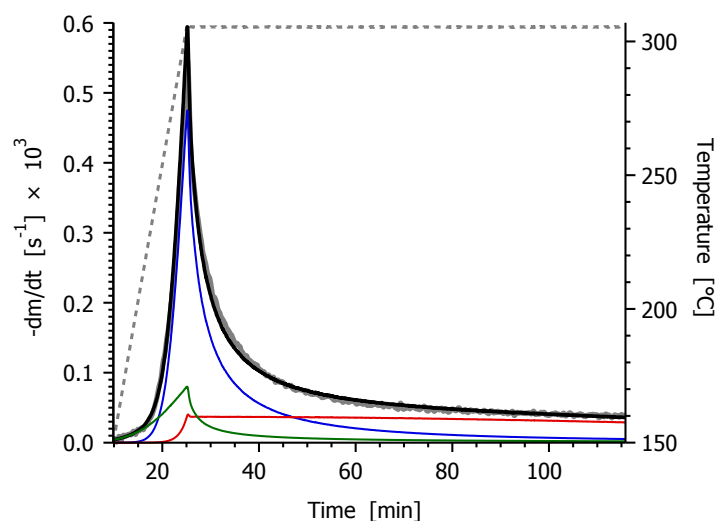
C: 31.3 36.5 17.9

**Bark 65min at 275°C 4mg**

Relative deviation: 1.98%, Deviation: 0.031 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$ 2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$ 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

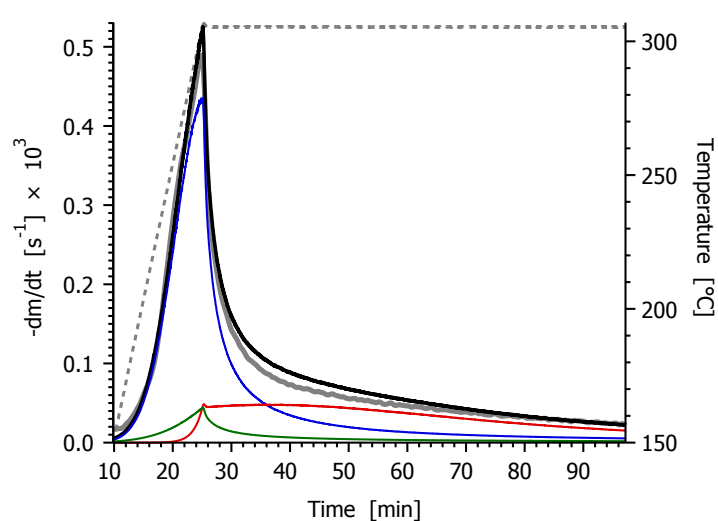
C: 34.0 19.7 15.8

**Wood 90min at 305°C 4mg**

Relative deviation: 1.43%, Deviation: 0.031 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$ 2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$ 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

C: 31.3 36.5 17.9

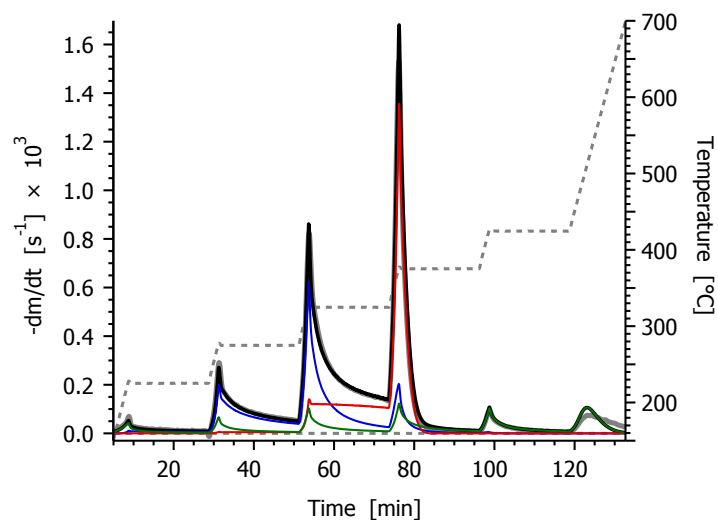
**Bark 65min at 305°C (10°C/min)**

Relative deviation: 2.14%, Deviation: 0.039 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$ 2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$ 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

C: 34.0 19.7 15.8

Figure S1, continued.



Wood stepwise A 4mg

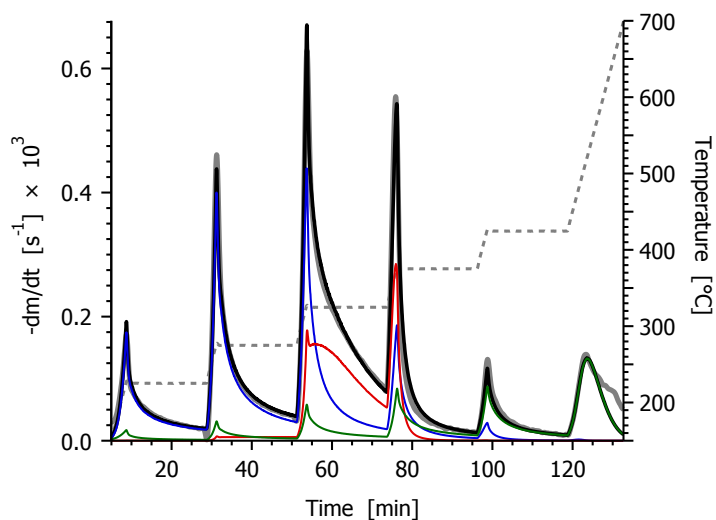
Relative deviation: 1.22%, Deviation: 0.072 $\mu\text{g/s}$

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$

2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$

3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

C: 31.3 36.5 17.9



Bark stepwise A 4mg

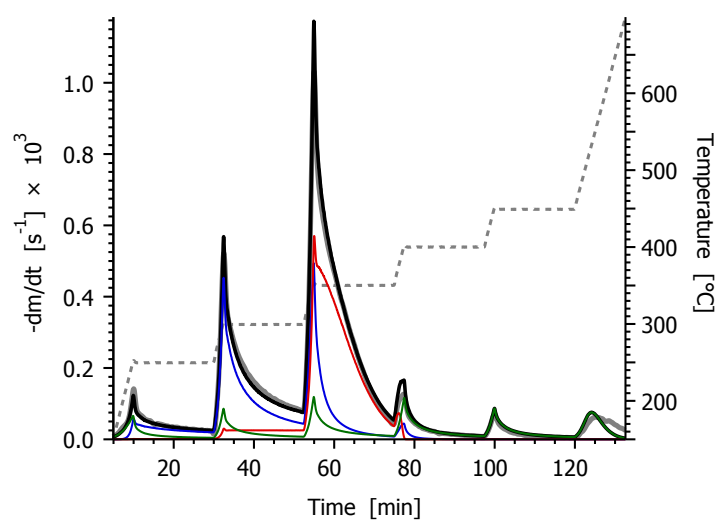
Relative deviation: 2.39%, Deviation: 0.061 $\mu\text{g/s}$

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$

2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$

3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

C: 34.0 19.7 15.8



Wood stepwise B 4mg

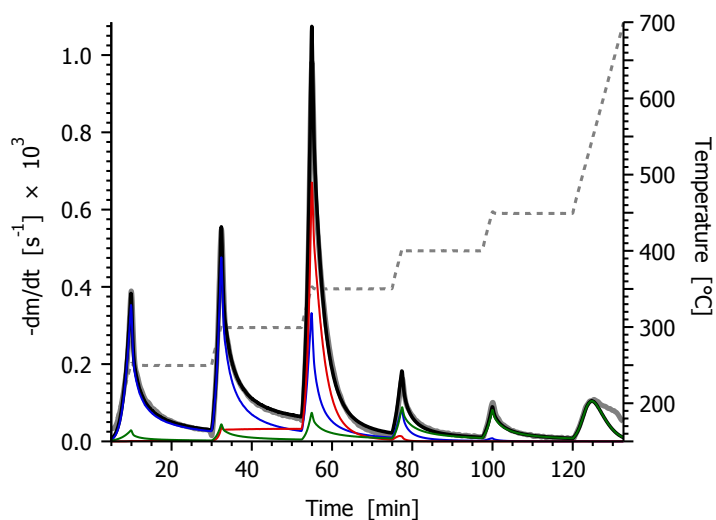
Relative deviation: 1.37%, Deviation: 0.061 $\mu\text{g/s}$

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=8.5$

2: $E=175.7$ $\log_{10} A=11.87$ $n=0.85$ $z=1.12$

3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

C: 31.3 36.5 17.9



Bark stepwise B 4mg

Relative deviation: 1.40%, Deviation: 0.056 $\mu\text{g/s}$

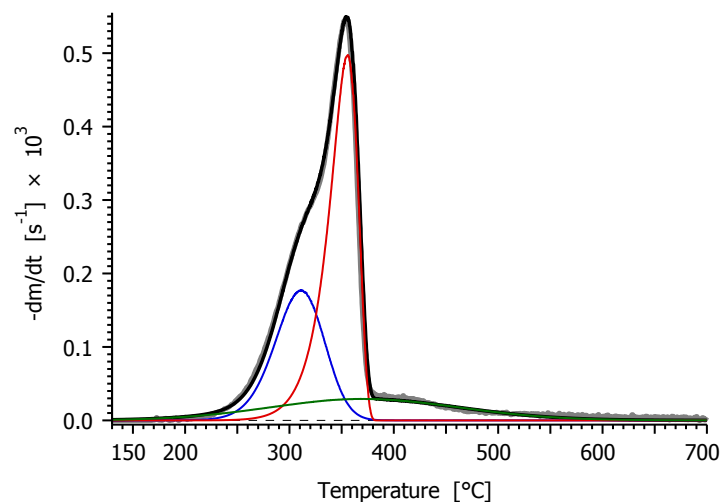
1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=15.2$

2: $E=175.7$ $\log_{10} A=12.25$ $n=1.41$ $z=0.402$

3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

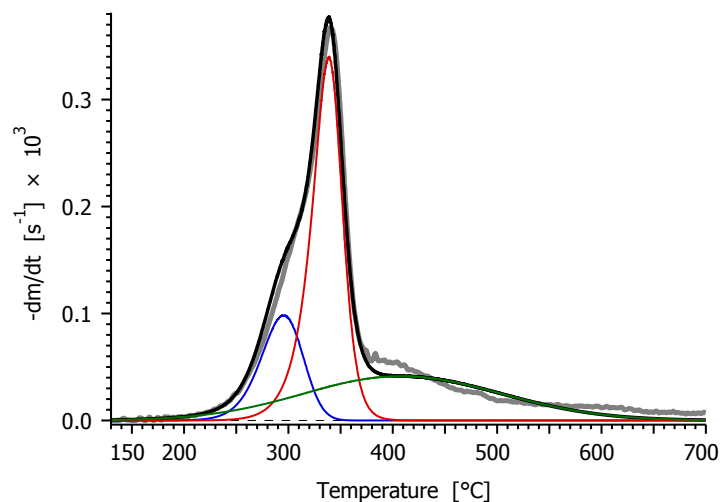
C: 34.0 19.7 15.8

Figure S1, continued.

**W225_60 2.5°C/min 4mg**

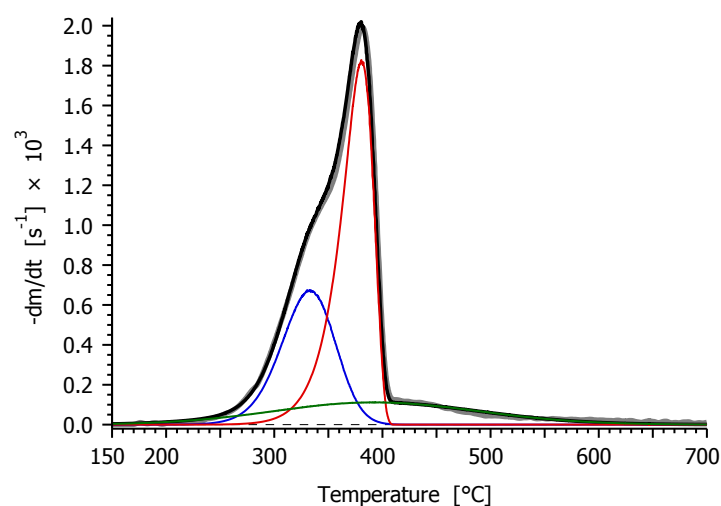
Relative deviation: 1.66%, Deviation: 0.037 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=5.1$
 2: $E=175.7$ $\log_{10} A=11.86$ $n=0.85$ $z=1.12$
 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$
 C: 25.1 43.3 16.0

**B225_60 2.5°C/min 4mg**

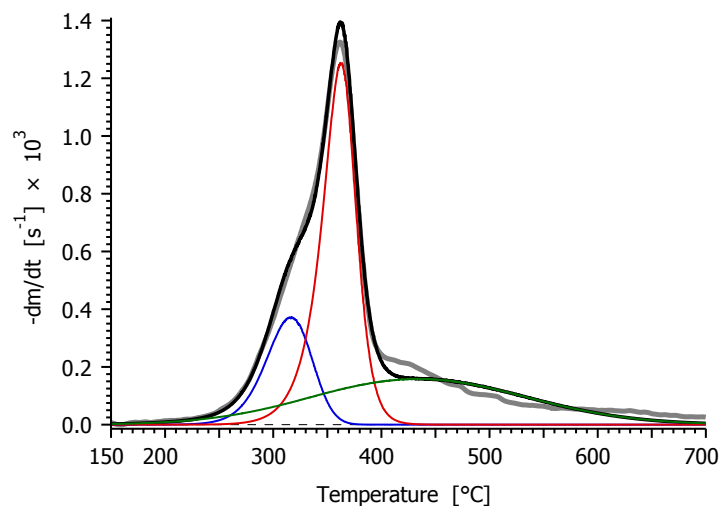
Relative deviation: 2.09%, Deviation: 0.030 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=3.9$
 2: $E=175.7$ $\log_{10} A=12.20$ $n=1.41$ $z=0.402$
 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$
 C: 11.9 31.5 23.8

**W225_60 10°C/min 2mg**

Relative deviation: 1.36%, Deviation: 0.054 µg/s

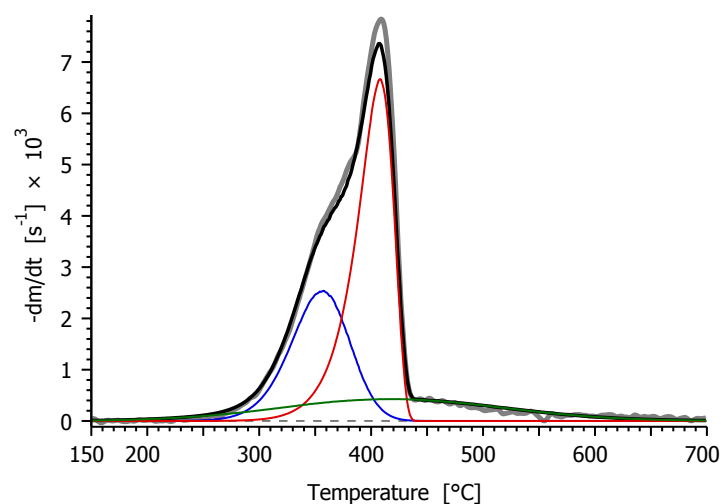
1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=5.1$
 2: $E=175.7$ $\log_{10} A=11.86$ $n=0.85$ $z=1.12$
 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$
 C: 25.1 43.3 16.0

**B225_60 10°C/min 2mg**

Relative deviation: 1.74%, Deviation: 0.046 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=3.9$
 2: $E=175.7$ $\log_{10} A=12.20$ $n=1.41$ $z=0.402$
 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$
 C: 11.9 31.5 23.8

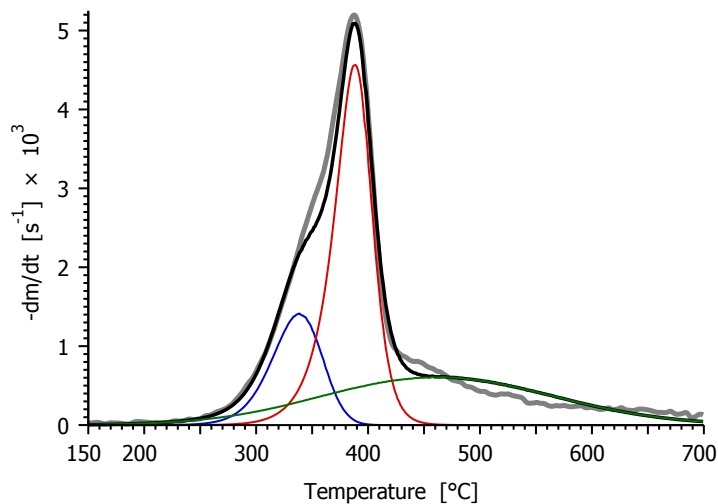
Figure S1, continued.

**W225_60 40°C/min 0.5mg**

Relative deviation: 1.83%, Deviation: 0.070 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=5.1$ 2: $E=175.7$ $\log_{10} A=11.86$ $n=0.85$ $z=1.12$ 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

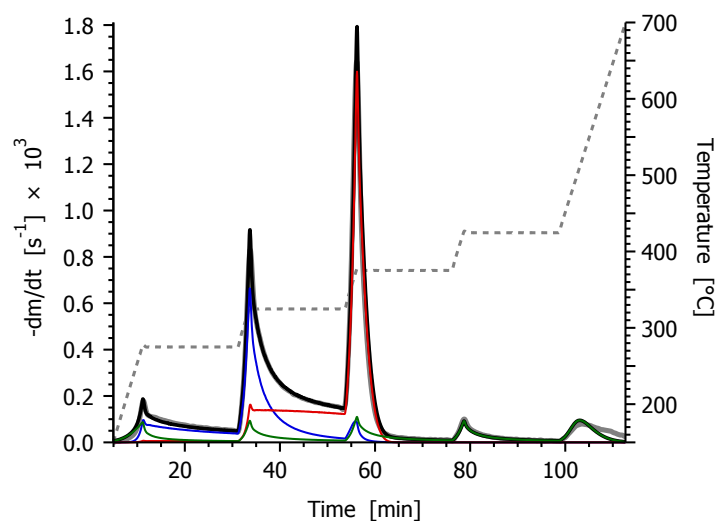
C: 25.1 43.3 16.0

**B225_60 40°C/min 0.6mg**

Relative deviation: 2.40%, Deviation: 0.070 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=3.9$ 2: $E=175.7$ $\log_{10} A=12.20$ $n=1.41$ $z=0.402$ 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

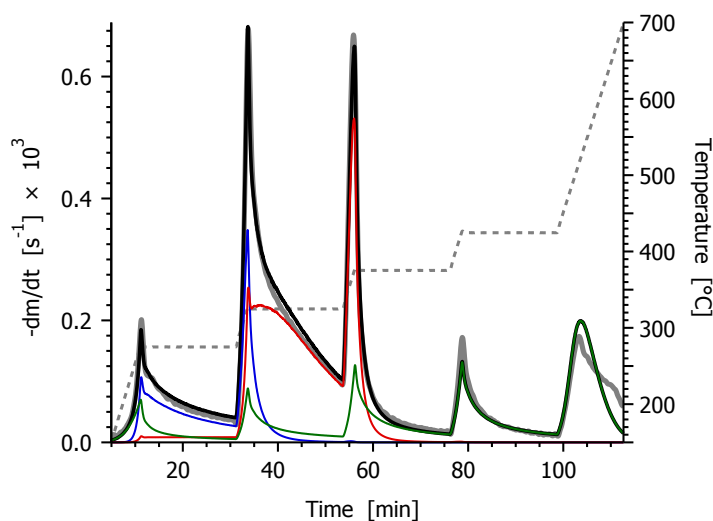
C: 11.9 31.5 23.8

**W225_60 stepwise A 4mg**

Relative deviation: 1.32%, Deviation: 0.084 µg/s

1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=5.1$ 2: $E=175.7$ $\log_{10} A=11.86$ $n=0.85$ $z=1.12$ 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

C: 25.1 43.3 16.0

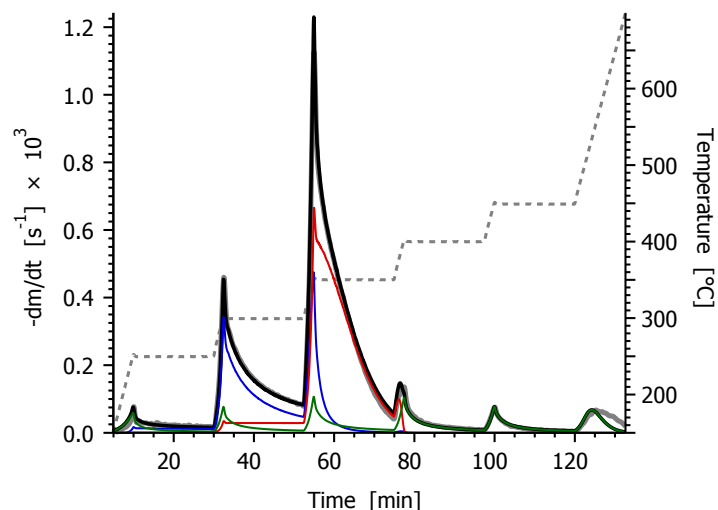
**B225_60 stepwise A 4mg**

Relative deviation: 2.37%, Deviation: 0.063 µg/s

1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=3.9$ 2: $E=175.7$ $\log_{10} A=12.20$ $n=1.41$ $z=0.402$ 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

C: 11.9 31.5 23.8

Figure S1, continued.


W225_60 stepwise B 4mg

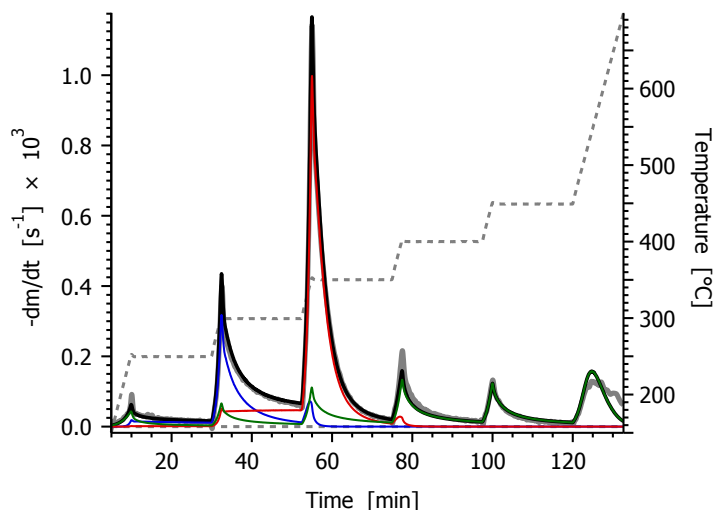
Relative deviation: 1.08%, Deviation: 0.049 µg/s

 1: $E_0=177.4$ $\log_{10} A=13.16$ $\sigma(E)=5.1$

 2: $E=175.7$ $\log_{10} A=11.86$ $n=0.85$ $z=1.12$

 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

C: 25.1 43.3 16.0


B225_60 stepwise B 4mg

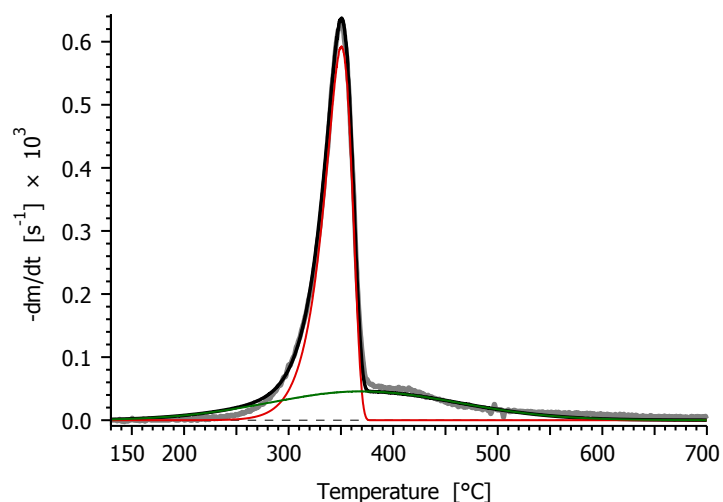
Relative deviation: 1.30%, Deviation: 0.062 µg/s

 1: $E_0=177.4$ $\log_{10} A=13.65$ $\sigma(E)=3.9$

 2: $E=175.7$ $\log_{10} A=12.20$ $n=1.41$ $z=0.402$

 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

C: 11.9 31.5 23.8


W275_60 2.5°C/min 4mg

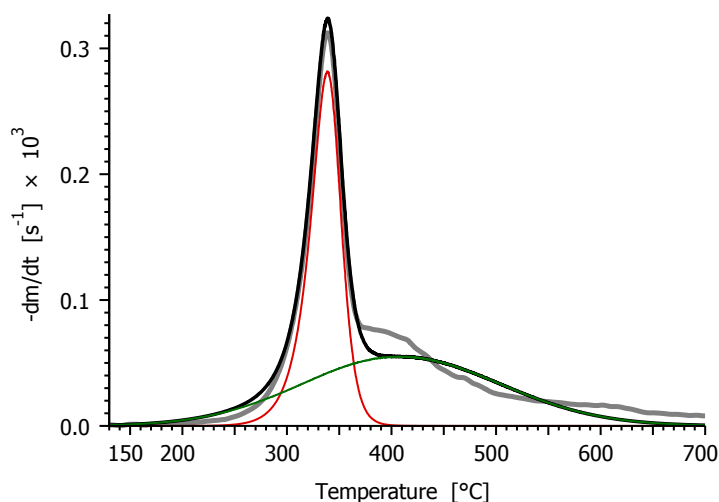
Relative deviation: 1.12%, Deviation: 0.031 µg/s

1: —

 2: $E=175.7$ $\log_{10} A=11.98$ $n=0.85$ $z=1.12$

 3: $E_0=209.1$ $\log_{10} A=14.05$ $\sigma(E)=29.6$

C: 0 50.7 25.1


B275_60 2.5°C/min 4mg

Relative deviation: 2.52%, Deviation: 0.032 µg/s

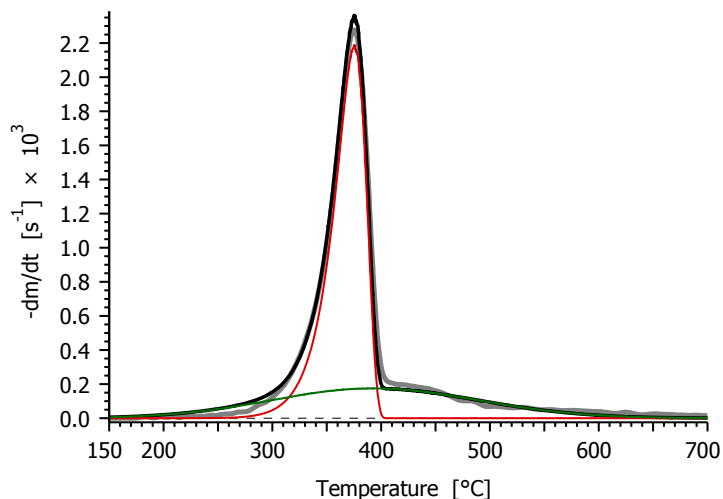
1: —

 2: $E=175.7$ $\log_{10} A=12.20$ $n=1.41$ $z=0.402$

 3: $E_0=209.1$ $\log_{10} A=13.08$ $\sigma(E)=28.8$

C: 0 26.2 31.6

Figure S1, continued.

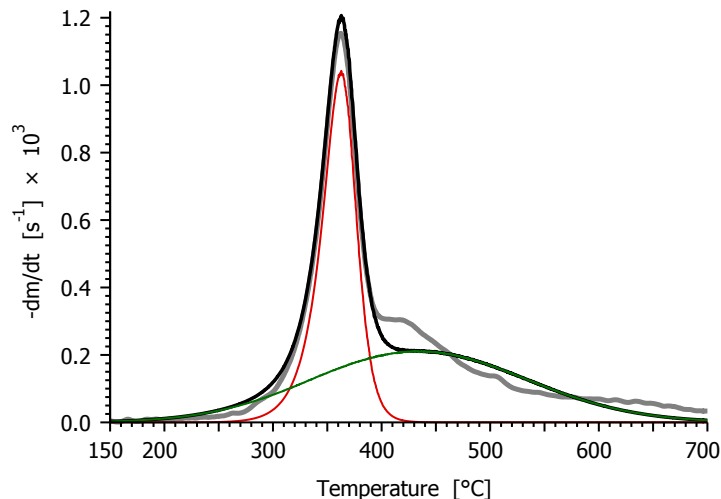
**W275_60 10°C/min 2mg**

Relative deviation: 1.45%, Deviation: 0.068 µg/s

1: —

2: $E = 175.7$ $\log_{10} A = 11.98$ $n = 0.85$ $z = 1.12$ 3: $E_0 = 209.1$ $\log_{10} A = 14.05$ $\sigma(E) = 29.6$

C: 0 50.7 25.1

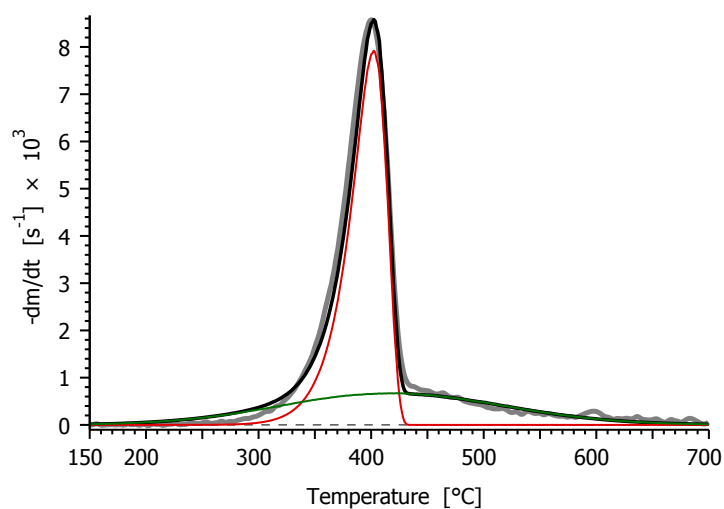
**B275_60 10°C/min 2mg**

Relative deviation: 2.72%, Deviation: 0.063 µg/s

1: —

2: $E = 175.7$ $\log_{10} A = 12.20$ $n = 1.41$ $z = 0.402$ 3: $E_0 = 209.1$ $\log_{10} A = 13.08$ $\sigma(E) = 28.8$

C: 0 26.2 31.6

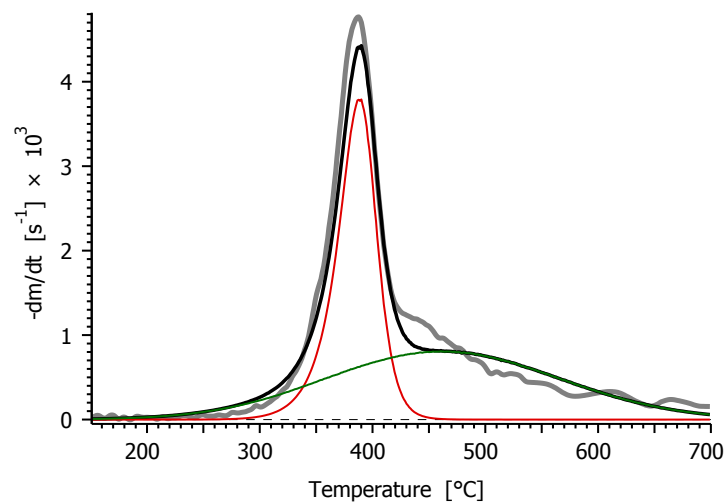
**W275_60 40°C/min 0.5mg**

Relative deviation: 2.18%, Deviation: 0.091 µg/s

1: —

2: $E = 175.7$ $\log_{10} A = 11.98$ $n = 0.85$ $z = 1.12$ 3: $E_0 = 209.1$ $\log_{10} A = 14.05$ $\sigma(E) = 29.6$

C: 0 50.7 25.1



B275_60 40°C/min 0.5mg

Relative deviation: 3.50%, Deviation: 0.081 µg/s

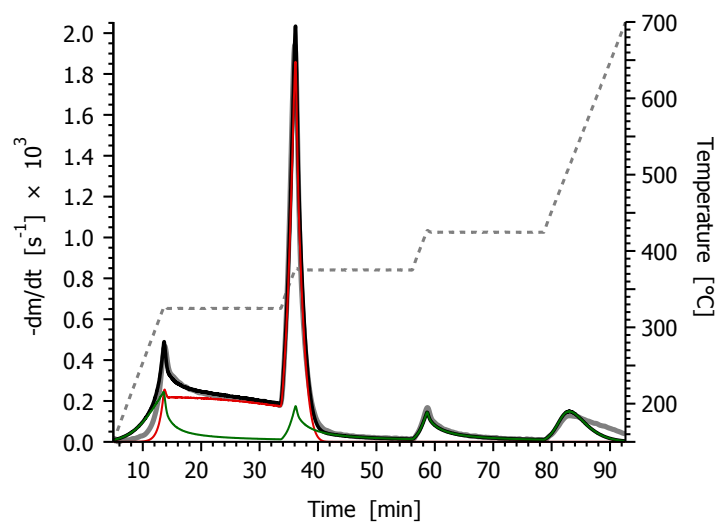
1: —

2: $E = 175.7$ $\log_{10} A = 12.20$ $n = 1.41$ $z = 0.402$

3: $E_0 = 209.1$ $\log_{10} A = 13.08$ $\sigma(E) = 28.8$

C: 0 26.2 31.6

Figure S1, continued.



W275_60 stepwise A 4mg

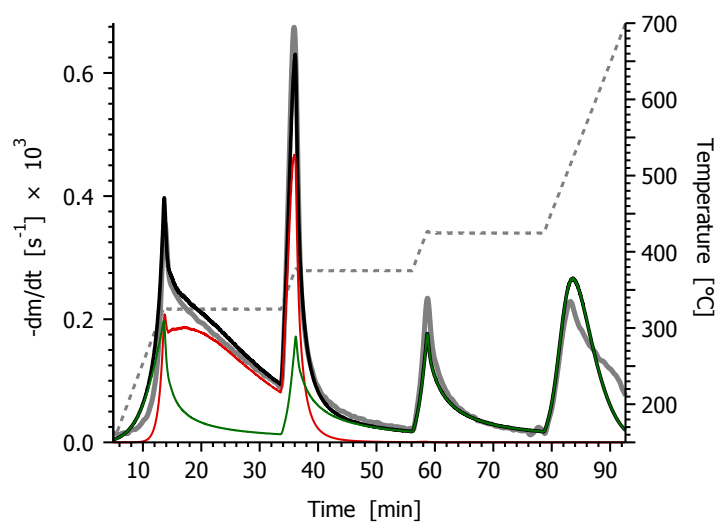
Relative deviation: 1.44%, Deviation: 0.11 µg/s

1: —

2: $E = 175.7$ $\log_{10} A = 11.98$ $n = 0.85$ $z = 1.12$

3: $E_0 = 209.1$ $\log_{10} A = 14.05$ $\sigma(E) = 29.6$

C: 0 50.7 25.1



B275_60 stepwise A 4mg

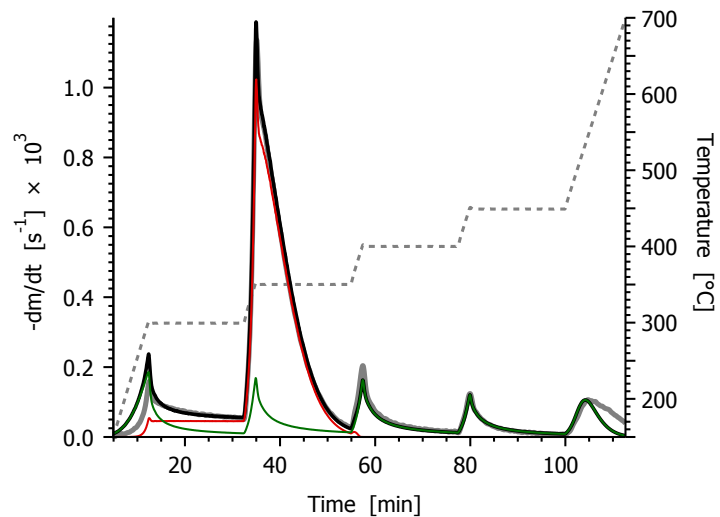
Relative deviation: 3.53%, Deviation: 0.099 µg/s

1: —

2: $E = 175.7$ $\log_{10} A = 12.20$ $n = 1.41$ $z = 0.402$

3: $E_0 = 209.1$ $\log_{10} A = 13.08$ $\sigma(E) = 28.8$

C: 0 26.2 31.6

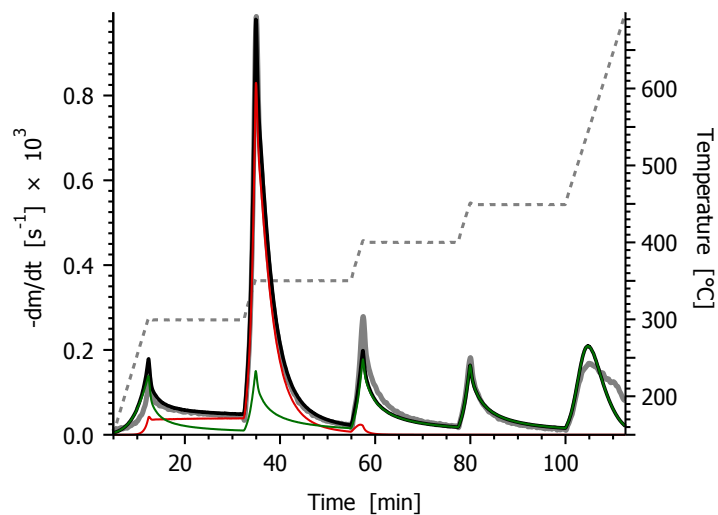
**W275_60 stepwise B 4mg**

Relative deviation: 1.86%, Deviation: 0.087 µg/s

1: —

2: $E = 175.7$ $\log_{10} A = 11.98$ $n = 0.85$ $z = 1.12$ 3: $E_0 = 209.1$ $\log_{10} A = 14.05$ $\sigma(E) = 29.6$

C: 0 50.7 25.1

**B275_60 stepwise B 4mg**

Relative deviation: 2.14%, Deviation: 0.086 µg/s

1: —

2: $E = 175.7$ $\log_{10} A = 12.20$ $n = 1.41$ $z = 0.402$ 3: $E_0 = 209.1$ $\log_{10} A = 13.08$ $\sigma(E) = 28.8$

C: 0 26.2 31.6

Figure S1, continued.