

Supplementary Information of

Probing Structure-Functionality Relationships of Catalytic Bimetallic Pt-Ru Nanoparticles Associated with Improved Sulfur Resistance

Jessica N. G. Stanley, Paul Benndorf, Falk Heinroth, Anthony F. Masters, and
Thomas Maschmeyer*

Laboratory of Advanced Catalysis for Sustainability

School of Chemistry, F11 The University of Sydney, Sydney, NSW 2006 Australia

*thomas.maschmeyer@sydney.edu.au

Models

Pt foil. Based on fcc structure.

$$\begin{aligned}N(1) &= 12 \\x(1) &= (1/2 \times 3.909) = 1.9545 \\y(1) &= (1/2 \times 3.909) = 1.9545 \\z(1) &= 0\end{aligned}$$

$$\begin{aligned}N(2) &= 6 \\x(2) &= 3.909 \\y(2) &= 0 \\z(2) &= 0\end{aligned}$$

$$\begin{aligned}N(3) &= 24 \\x(3) &= 3.909 \\y(3) &= (1/2 \times 3.909) = 1.9545 \\z(3) &= -(1/2 \times 3.909) = -1.9545\end{aligned}$$

$$\begin{aligned}N(4) &= 12 \\x(4) &= 3.909 \\y(4) &= 3.909 \\z(4) &= 0\end{aligned}$$

Ru foil. Based on hcp structure.

$$N(1) = 12$$

$$x(1) = (1/3 \times 2.31) = 0.77$$

$$y(1) = (2.67 / 2) = 1.335$$

$$z(1) = (4.27 / 2) = 2.135$$

$$N(2) = 6$$

$$x(2) = (2.31 + (1/3 \times 2.31)) = 3.08$$

$$y(2) = 0$$

$$z(2) = 2.135$$

$$N(3) = 2$$

$$x(3) = 0$$

$$y(3) = 0$$

$$z(3) = 4.27$$

$$N(4) = 18$$

$$x(4) = 4.67$$

$$y(4) = 0$$

$$z(4) = 0$$

$$N(5) = 12$$

$$x(5) = (2.67 / 2) = 2.31$$

$$y(5) = (2.67 / 2) = 1.335$$

$$z(5) = 4.27$$

$$N(6) = 16$$

$$x(6) = 4.67$$

$$y(6) = 2.67$$

$$z(6) = 0$$

Best-Fit Parameters for Fresh, Poisoned and Regenerated Samples

Pt₁Ru₃

Pt L _{III} -edge											
Pt ₁ Ru ₃ fresh				Pt ₁ Ru ₃ poisoned				Pt ₁ Ru ₃ regenerated			
	<i>R</i> (Å)	<i>N</i>	σ ² (Å ²)		<i>R</i> (Å)	<i>N</i>	σ ² (Å ²)		<i>R</i> (Å)	<i>N</i>	σ ² (Å ²)
Pt-Pt	2.75	3.1	0.001	Pt-Pt	2.76	3.8	0.001 _f	Pt-Pt	2.75	2.4	0.001 _f
Pt-Pt	3.90	1.7	0.003	Pt-Pt	3.91	2.8	0.003 _f	Pt-Pt	3.91	1.5	0.003 _f
Pt-Pt	4.78	3.0	0.0009	Pt-Pt	4.79	3.8	0.0009 _f	Pt-Pt	4.77	2.1	0.0009 _f
Pt-Pt	5.53	0.4	0.001	Pt-Pt	5.54	0.4	0.001 _f	Pt-Pt	5.53	0.2	0.001 _f
Pt-Ru	2.70	2.6	0.002	Pt-Ru	2.70	2.2	0.002 _f	Pt-Ru	2.71	2.8	0.002 _f
Pt-Ru	3.79	0.7	0.0009	Pt-Ru	3.79	0.3	0.0009 _f	Pt-Ru	3.79	0.3	0.0009 _f
Pt-Ru	4.70	4.7	0.007	Pt-Ru	4.70	3.9	0.007 _f	Pt-Ru	4.70	6.6	0.007 _f
Pt-Ru	5.41	2.6	0.005	Pt-Ru	5.40	2.2	0.005 _f	Pt-Ru	5.40	2.8	0.005 _f
<i>R</i> -factor = 9.67 %		Chi ² = 2.41		<i>R</i> -factor = 9.56 %		Chi ² = 1.73		<i>R</i> -factor = 13.2 %		Chi ² = 5.09	

Pt₁Ru₃

Ru K-edge											
Pt ₁ Ru ₃ fresh				Pt ₁ Ru ₃ poisoned				Pt ₁ Ru ₃ regenerated			
	<i>R</i> (Å)	<i>N</i>	σ ² (Å ²)		<i>R</i> (Å)	<i>N</i>	σ ² (Å ²)		<i>R</i> (Å)	<i>N</i>	σ ² (Å ²)
Ru-Ru	2.67	8.5	0.003	Ru-Ru	2.67	8.5	0.003 _f	Ru-Ru	2.68	8.5	0.003 _f
Ru-Ru	2.79	2.8	0.0007	Ru-Ru	2.79	2.4	0.0007 _f	Ru-Ru	3.79	2.8	0.0007 _f
Ru-Ru	4.29	3.1	0.001	Ru-Ru	4.29	2.6	0.001 _f	Ru-Ru	4.30	2.3	0.001 _f
Ru-Ru	4.67	6.2	0.0009	Ru-Ru	4.67	5.6	0.0009 _f	Ru-Ru	4.67	5.5	0.0009 _f
Ru-Ru	5.08	12.2	0.004	Ru-Ru	5.08	12.3	0.004 _f	Ru-Ru	5.08	12.5	0.004 _f
Ru-Ru	5.34	9.4	0.002	Ru-Ru	5.34	8.0	0.002 _f	Ru-Ru	5.33	7.9	0.002 _f
Ru-Pt	2.70	0.2	0.001	Ru-Pt	2.70	0.1	0.001 _f	Ru-Pt	2.72	0.2	0.001 _f
<i>R</i> -factor = 6.17 %		Chi ² = 1.74		<i>R</i> -factor = 6.59 %		Chi ² = 2.09		<i>R</i> -factor = 7.46 %		Chi ² = 1.30	

Pt_{1.5}Ru₁

Pt L _{III} -edge											
Pt _{1.5} Ru ₁ fresh				Pt ₁ Ru ₃ poisoned				Pt ₁ Ru ₃ regenerated			
	<i>R</i> (Å)	<i>N</i>	σ^2 (Å ²)		<i>R</i> (Å)	<i>N</i>	σ^2 (Å ²)		<i>R</i> (Å)	<i>N</i>	σ^2 (Å ²)
Pt-Pt	2.76	9.9	0.0008	Pt-Pt	2.76	10.1	0.0008 _f	Pt-Pt	2.76	7.6	0.0008 _f
Pt-Pt	3.91	4.9	0.001	Pt-Pt	3.91	5.1	0.001 _f	Pt-Pt	3.92	3.6	0.001 _f
Pt-Pt	4.80	16.6	0.001	Pt-Pt	4.80	17.6	0.001 _f	Pt-Pt	4.80	12.3	0.001 _f
Pt-Pt	5.53	9.9	0.003	Pt-Pt	5.53	10.4	0.003 _f	Pt-Pt	5.54	7.6	0.003 _f
Pt-Ru	2.72	1.2	0.009	Pt-Ru	2.72	1.0	0.009 _f				
<i>R</i> -factor = 4.96 %		Chi ² = 1.45		<i>R</i> -factor = 5.44 %		Chi ² = 1.30		<i>R</i> -factor = 7.59 %		Chi ² = 4.41	

Pt_{1.5}Ru₁

Ru K-edge											
Pt _{1.5} Ru ₁ fresh				Pt ₁ Ru ₃ poisoned				Pt ₁ Ru ₃ regenerated			
	<i>R</i> (Å)	<i>N</i>	σ^2 (Å ²)		<i>R</i> (Å)	<i>N</i>	σ^2 (Å ²)		<i>R</i> (Å)	<i>N</i>	σ^2 (Å ²)
Ru-Ru	2.68	7.8	0.003	Ru-Ru	2.68	7.8	0.003 _f	Ru-Ru	2.68	5.6	0.003 _f
Ru-Ru	3.79	2.4	0.0008	Ru-Ru	3.78	2.3	0.0008 _f	Ru-Ru	3.79	2.3	0.0008 _f
Ru-Ru	4.26	0.2	0.001	Ru-Ru	4.24	0.4	0.001 _f	Ru-Ru	4.27	0.7	0.001 _f
Ru-Ru	4.68	7.0	0.002	Ru-Ru	4.68	7.5	0.002 _f	Ru-Ru	4.68	7.7	0.002 _f
Ru-Ru	5.05	4.1	0.0008	Ru-Ru	5.05	3.8	0.0008 _f	Ru-Ru	5.05	4.8	0.0008 _f
Ru-Ru	5.34	4.2	0.0006	Ru-Ru	5.34	4.9	0.0006 _f	Ru-Ru	5.34	4.7	0.0006 _f
Ru-Pt	2.72	2.3	0.005	Ru-Pt	2.72	1.8	0.005 _f	Ru-Pt	2.73	3.1	0.005 _f
<i>R</i> -factor = 5.84 %		Chi ² = 0.64		<i>R</i> -factor = 7.72 %		Chi ² = 0.88		<i>R</i> -factor = 7.15 %		Chi ² = 1.12	

Lists of Restraints

Pt L_{III} Edge

Pt foil

$s_1 > 0.001 \{0.001\}$
 $s_2 > 0.001 \{0.001\}$
 $s_3 > 0.001 \{0.001\}$
 $s_4 > 0.001 \{0.001\}$
 $s_1 < 0.01 \{0.001\}$
 $s_2 < 0.01 \{0.001\}$
 $s_3 < 0.01 \{0.001\}$
 $s_4 < 0.01 \{0.001\}$
 $S_{O2} \sim 0.85 \{0.2\}$
 $E_0 < -1 \{0.5\}$
 $|(v_1 - v_0)| \sim 2.76 \{0.01\}$
 $|(v_2 - v_0)| \sim 3.91 \{0.01\}$
 $|(v_3 - v_0)| \sim 4.79 \{0.01\}$
 $|(v_4 - v_0)| \sim 5.53 \{0.01\}$
 $s_1 \sim s_2 \{0.015\}$
 $s_2 \sim s_3 \{0.015\}$
 $s_3 \sim s_4 \{0.015\}$
 $|(v_2 - v_1)| \sim 2.765 \{0.05\}$
 $|(v_3 - v_2)| \sim 2.765 \{0.05\}$
 $|(v_4 - v_3)| \sim 2.765 \{0.05\}$
 $|(v_3 - v_1)| \sim 2.765 \{0.05\}$
 $|(v_1 - v_4)| \sim 2.765 \{0.05\}$

Pt catalyst

$s_1 > 0.001 \{0.001\}$
 $s_2 > 0.001 \{0.001\}$
 $s_3 > 0.001 \{0.001\}$
 $s_4 > 0.001 \{0.001\}$
 $s_1 < 0.01 \{0.001\}$
 $s_2 < 0.01 \{0.001\}$
 $s_3 < 0.01 \{0.001\}$
 $s_4 < 0.01 \{0.001\}$
 $S_{O2} \sim 0.85 \{0.2\}$

$E_0 < -1 \{0.5\}$
 $s_1 \approx s_2 \{0.015\}$
 $s_2 \approx s_3 \{0.015\}$
 $s_3 \approx s_4 \{0.015\}$
 $|(v_2 - v_1)| \approx 2.765 \{0.05\}$
 $|(v_3 - v_2)| \approx 2.765 \{0.05\}$
 $|(v_4 - v_3)| \approx 2.765 \{0.05\}$
 $|(v_3 - v_1)| \approx 2.765 \{0.05\}$
 $|(v_1 - v_0)| \approx 2.76 \{0.05\}$
 $|(v_2 - v_0)| \approx 3.91 \{0.05\}$
 $|(v_3 - v_0)| \approx 4.79 \{0.05\}$
 $|(v_4 - v_0)| \approx 5.53 \{0.05\}$

Pt₁Ru₃ catalyst (fresh, poisoned, regenerated)

$s_1 > 0.001 \{0.001\}$
 $s_2 > 0.001 \{0.001\}$
 $s_3 > 0.001 \{0.001\}$
 $s_4 > 0.001 \{0.001\}$
 $s_1 < 0.01 \{0.001\}$
 $s_2 < 0.01 \{0.001\}$
 $s_3 < 0.01 \{0.001\}$
 $s_4 < 0.01 \{0.001\}$
 $S_{O_2} \approx 0.85 \{0.2\}$
 $E_0 < -1 \{0.5\}$
 $|(v_1 - v_0)| \approx 2.76 \{0.01\}$
 $|(v_2 - v_0)| \approx 3.91 \{0.01\}$
 $|(v_3 - v_0)| \approx 4.79 \{0.01\}$
 $|(v_4 - v_0)| \approx 5.53 \{0.01\}$
 $s_1 \approx s_2 \{0.015\}$
 $s_2 \approx s_3 \{0.015\}$
 $s_3 \approx s_4 \{0.015\}$
 $|(v_2 - v_1)| \approx 2.765 \{0.05\}$
 $|(v_3 - v_2)| \approx 2.765 \{0.05\}$
 $|(v_4 - v_3)| \approx 2.765 \{0.05\}$
 $|(v_3 - v_1)| \approx 2.765 \{0.05\}$
 $|(v_1 - v_4)| \approx 2.765 \{0.05\}$
 $s_5 \approx s_1 \{0.015\}$
 $s_5 > 0.001 \{0.001\}$
 $s_5 < 0.01 \{0.001\}$
 $|(v_6 - v_0)| \approx 3.79 \{0.01\}$
 $|(v_6 - v_5)| \approx 2.7 \{0.05\}$
 $|(v_5 - v_0)| \approx 2.7 \{0.01\}$
 $s_6 > 0.001 \{0.001\}$
 $s_6 < 0.01 \{0.001\}$

$|(v7 - v0)| \approx 4.7 \{0.01\}$
 $|(v7 - v6)| \approx 2.7 \{0.05\}$
 $|(v7 - v5)| \approx 2.7 \{0.05\}$
 $s7 > 0.001 \{0.001\}$
 $s7 < 0.01 \{0.001\}$
 $|(v8 - v0)| \approx 5.4 \{0.01\}$
 $s8 > 0.001 \{0.001\}$
 $s8 < 0.01 \{0.001\}$
 $s5 \approx s6 \{0.015\}$
 $s6 \approx s7 \{0.015\}$
 $s7 \approx s8 \{0.015\}$
 $|(v8 - v7)| \approx 2.7 \{0.05\}$
 $|(v8 - v5)| \approx 2.7 \{0.05\}$

Pt_{1.5}Ru₁ catalyst (fresh, poisoned, regenerated)

$s1 > 0.001 \{0.001\}$
 $s2 > 0.001 \{0.001\}$
 $s3 > 0.001 \{0.001\}$
 $s4 > 0.001 \{0.001\}$
 $s1 < 0.01 \{0.001\}$
 $s2 < 0.01 \{0.001\}$
 $s3 < 0.01 \{0.001\}$
 $s4 < 0.01 \{0.001\}$
 $S02 \approx 0.85 \{0.2\}$
 $E0 < -1 \{0.5\}$
 $|(v1 - v0)| \approx 2.76 \{0.01\}$
 $|(v2 - v0)| \approx 3.91 \{0.01\}$
 $|(v3 - v0)| \approx 4.79 \{0.01\}$
 $|(v4 - v0)| \approx 5.53 \{0.01\}$
 $s1 \approx s2 \{0.015\}$
 $s2 \approx s3 \{0.015\}$
 $s3 \approx s4 \{0.015\}$
 $|(v2 - v1)| \approx 2.765 \{0.05\}$
 $|(v3 - v2)| \approx 2.765 \{0.05\}$
 $|(v4 - v3)| \approx 2.765 \{0.05\}$
 $|(v3 - v1)| \approx 2.765 \{0.05\}$
 $|(v1 - v4)| \approx 2.765 \{0.05\}$
 $s5 \approx s1 \{0.015\}$
 $s5 > 0.001 \{0.001\}$
 $s5 < 0.01 \{0.001\}$
 $|(v5 - v0)| \approx 2.72 \{0.01\}$

Pt₁Ru_{1.5} catalyst

s1 > 0.001 {0.001}
s2 > 0.001 {0.001}
s3 > 0.001 {0.001}
s4 > 0.001 {0.001}
s1 < 0.01 {0.001}
s2 < 0.01 {0.001}
s3 < 0.01 {0.001}
s4 < 0.01 {0.001}
S02 ≈ 0.85 {0.2}
E0 < -1 {0.5}
|(v1 - v0)| ≈ 2.76 {0.01}
|(v2 - v0)| ≈ 3.91 {0.01}
|(v3 - v0)| ≈ 4.79 {0.01}
|(v4 - v0)| ≈ 5.53 {0.01}
s1 ≈ s2 {0.015}
s2 ≈ s3 {0.015}
s3 ≈ s4 {0.015}
|(v2 - v1)| ≈ 2.765 {0.05}
|(v3 - v2)| ≈ 2.765 {0.05}
|(v4 - v3)| ≈ 2.765 {0.05}
|(v3 - v1)| ≈ 2.765 {0.05}
|(v1 - v4)| ≈ 2.765 {0.05}
s1 ≈ s5 {0.015}
|(v5 - v0)| ≈ 2.7 {0.01}
s5 > 0.001 {0.001}
s5 < 0.01 {0.001}

Ru K Edge

Ru foil

s1 > 0.001 {0.001}
s2 > 0.001 {0.001}
s3 > 0.001 {0.001}
s4 > 0.001 {0.001}
s1 < 0.01 {0.001}
s2 < 0.01 {0.001}
s3 < 0.01 {0.001}
s4 < 0.01 {0.001}
S02 ≈ 0.85 {0.2}
E0 < -1 {0.5}
s1 ≈ s2 {0.015}
s2 ≈ s3 {0.015}
s3 ≈ s4 {0.015}
|(v1 - v0)| ≈ 2.67 {0.05}
|(v2 - v0)| ≈ 3.78 {0.05}

$|(v2 - v1)| \approx 2.67 \{0.05\}$
 $|(v3 - v0)| \approx 4.27 \{0.05\}$
 $|(v3 - v1)| \approx 2.67 \{0.05\}$
 $|(v4 - v0)| \approx 4.67 \{0.05\}$
 $|(v4 - v2)| \approx 2.67 \{0.05\}$
 $|(v5 - v0)| \approx 5.06 \{0.05\}$
 $|(v5 - v3)| \approx 2.67 \{0.05\}$
 $|(v5 - v2)| \approx 2.67 \{0.05\}$
 $|(v5 - v1)| \approx 2.67 \{0.05\}$
 $s5 > 0.001 \{0.001\}$
 $s5 < 0.01 \{0.001\}$
 $s4 \approx s5 \{0.015\}$
 $|(v6 - v0)| \approx 5.33 \{0.05\}$
 $|(v6 - v4)| \approx 2.67 \{0.05\}$
 $s6 > 0.001 \{0.001\}$
 $s6 < 0.01 \{0.001\}$
 $s6 \approx s5 \{0.015\}$

Ru catalyst

$s1 > 0.001 \{0.001\}$
 $s2 > 0.001 \{0.001\}$
 $s3 > 0.001 \{0.001\}$
 $s4 > 0.001 \{0.001\}$
 $s1 < 0.01 \{0.001\}$
 $s2 < 0.01 \{0.001\}$
 $s3 < 0.01 \{0.001\}$
 $s4 < 0.01 \{0.001\}$
 $S02 \approx 0.85 \{0.2\}$
 $E0 < -1 \{0.5\}$
 $s1 \approx s2 \{0.015\}$
 $s2 \approx s3 \{0.015\}$
 $s3 \approx s4 \{0.015\}$
 $|(v1 - v0)| \approx 2.67 \{0.05\}$
 $|(v2 - v0)| \approx 3.78 \{0.05\}$
 $|(v2 - v1)| \approx 2.67 \{0.05\}$
 $|(v3 - v0)| \approx 4.27 \{0.05\}$
 $|(v3 - v1)| \approx 2.67 \{0.05\}$
 $|(v4 - v0)| \approx 4.67 \{0.05\}$
 $|(v4 - v2)| \approx 2.67 \{0.05\}$
 $|(v5 - v0)| \approx 5.06 \{0.05\}$
 $|(v5 - v3)| \approx 2.67 \{0.05\}$
 $|(v5 - v2)| \approx 2.67 \{0.05\}$
 $|(v5 - v1)| \approx 2.67 \{0.05\}$
 $s5 > 0.001 \{0.001\}$
 $s5 < 0.01 \{0.001\}$
 $s4 \approx s5 \{0.015\}$

$|(v6 - v0)| \approx 5.33 \{0.05\}$
 $|(v6 - v4)| \approx 2.67 \{0.05\}$
 $s6 > 0.001 \{0.001\}$
 $s6 < 0.01 \{0.001\}$
 $s6 \approx s5 \{0.015\}$
 $N5 < 12 \{2\}$

Pt₁Ru₃ catalyst (fresh, poisoned, regenerated)

$s1 > 0.001 \{0.001\}$
 $s2 > 0.001 \{0.001\}$
 $s3 > 0.001 \{0.001\}$
 $s4 > 0.001 \{0.001\}$
 $s1 < 0.01 \{0.001\}$
 $s2 < 0.01 \{0.001\}$
 $s3 < 0.01 \{0.001\}$
 $s4 < 0.01 \{0.001\}$
 $S02 \approx 0.85 \{0.2\}$
 $E0 < -1 \{0.5\}$
 $s1 \approx s2 \{0.015\}$
 $s2 \approx s3 \{0.015\}$
 $s3 \approx s4 \{0.015\}$
 $|(v1 - v0)| \approx 2.67 \{0.05\}$
 $|(v2 - v0)| \approx 3.78 \{0.05\}$
 $|(v2 - v1)| \approx 2.67 \{0.05\}$
 $|(v3 - v0)| \approx 4.27 \{0.05\}$
 $|(v3 - v1)| \approx 2.67 \{0.05\}$
 $|(v4 - v0)| \approx 4.67 \{0.05\}$
 $|(v4 - v2)| \approx 2.67 \{0.05\}$
 $|(v5 - v0)| \approx 5.06 \{0.05\}$
 $|(v5 - v3)| \approx 2.67 \{0.05\}$
 $|(v5 - v2)| \approx 2.67 \{0.05\}$
 $|(v5 - v1)| \approx 2.67 \{0.05\}$
 $s5 > 0.001 \{0.001\}$
 $s5 < 0.01 \{0.001\}$
 $s4 \approx s5 \{0.015\}$
 $|(v6 - v0)| \approx 5.33 \{0.05\}$
 $|(v6 - v4)| \approx 2.67 \{0.05\}$
 $s6 > 0.001 \{0.001\}$
 $s6 < 0.01 \{0.001\}$
 $s7 > 0.001 \{0.001\}$
 $s7 < 0.01 \{0.001\}$
 $|(v7 - v0)| \approx 2.7 \{0.05\}$
 $N5 < 12 \{2\}$

Pt_{1.5}Ru₁ catalyst (fresh, poisoned, regenerated)

s1 > 0.001 {0.001}
s2 > 0.001 {0.001}
s3 > 0.001 {0.001}
s4 > 0.001 {0.001}
s1 < 0.01 {0.001}
s2 < 0.01 {0.001}
s3 < 0.01 {0.001}
s4 < 0.01 {0.001}
S02 ≈ 0.85 {0.2}
E0 < -1 {0.5}
s1 ≈ s2 {0.015}
s2 ≈ s3 {0.015}
s3 ≈ s4 {0.015}
|(v1 - v0)| ≈ 2.67 {0.05}
|(v2 - v0)| ≈ 3.78 {0.05}
|(v2 - v1)| ≈ 2.67 {0.05}
|(v3 - v0)| ≈ 4.27 {0.05}
|(v3 - v1)| ≈ 2.67 {0.05}
|(v4 - v0)| ≈ 4.67 {0.05}
|(v4 - v2)| ≈ 2.67 {0.05}
|(v5 - v0)| ≈ 5.06 {0.05}
|(v5 - v3)| ≈ 2.67 {0.05}
|(v5 - v2)| ≈ 2.67 {0.05}
|(v5 - v1)| ≈ 2.67 {0.05}
s5 > 0.001 {0.001}
s5 < 0.01 {0.001}
s4 ≈ s5 {0.015}
|(v6 - v0)| ≈ 5.33 {0.05}
|(v6 - v4)| ≈ 2.67 {0.05}
s6 > 0.001 {0.001}
s6 < 0.01 {0.001}
|(v7 - v0)| ≈ 2.72 {0.01}
s7 > 0.001 {0.001}
s7 < 0.01 {0.001}

Pt₁Ru_{1.5} catalyst

s1 > 0.001 {0.001}
s2 > 0.001 {0.001}
s3 > 0.001 {0.001}
s4 > 0.001 {0.001}
s1 < 0.01 {0.001}
s2 < 0.01 {0.001}
s3 < 0.01 {0.001}

$s_4 < 0.01 \{0.001\}$
 $S_{02} \approx 0.85 \{0.2\}$
 $E_0 < -1 \{0.5\}$
 $s_1 \approx s_2 \{0.015\}$
 $s_2 \approx s_3 \{0.015\}$
 $s_3 \approx s_4 \{0.015\}$
 $|(v_1 - v_0)| \approx 2.67 \{0.05\}$
 $|(v_2 - v_0)| \approx 3.78 \{0.05\}$
 $|(v_2 - v_1)| \approx 2.67 \{0.05\}$
 $|(v_3 - v_0)| \approx 4.27 \{0.05\}$
 $|(v_3 - v_1)| \approx 2.67 \{0.05\}$
 $|(v_4 - v_0)| \approx 4.67 \{0.05\}$
 $|(v_4 - v_2)| \approx 2.67 \{0.05\}$
 $|(v_5 - v_0)| \approx 5.06 \{0.05\}$
 $|(v_5 - v_3)| \approx 2.67 \{0.05\}$
 $|(v_5 - v_2)| \approx 2.67 \{0.05\}$
 $|(v_5 - v_1)| \approx 2.67 \{0.05\}$
 $s_5 > 0.001 \{0.001\}$
 $s_5 < 0.01 \{0.001\}$
 $s_4 \approx s_5 \{0.015\}$
 $|(v_6 - v_0)| \approx 5.33 \{0.05\}$
 $|(v_6 - v_4)| \approx 2.67 \{0.05\}$
 $s_6 > 0.001 \{0.001\}$
 $s_6 < 0.01 \{0.001\}$
 $s_7 > 0.001 \{0.001\}$
 $s_7 < 0.01 \{0.001\}$
 $|(v_8 - v_0)| \approx 2.7 \{0.01\}$
 $|(v_7 - v_0)| \approx 2 \{0.01\}$
 $s_7 \approx s_8 \{0.015\}$
 $s_8 > 0.001 \{0.001\}$
 $s_8 < 0.01 \{0.001\}$
 $|(v_9 - v_0)| \approx 3.91 \{0.01\}$
 $s_8 \approx s_9 \{0.015\}$
 $s_9 > 0.001 \{0.001\}$
 $s_9 < 0.01 \{0.001\}$
 $|(v_9 - v_0)| \approx 3.79 \{0.01\}$
 $|(v_9 - v_8)| \approx 2.7 \{0.05\}$