Supporting Information:

An Analysis of the Critical Region of Multiparameter Equations of State †

Ian H. Bell,* Eric W. Lemmon, and Allan H. Harvey

Applied Chemicals and Materials Division, National Institute of Standards and Technology, Boulder, CO 80305, USA

E-mail: ian.bell@nist.gov

Contents

1 Numerical Critical Points

Table S1: Numerical critical points for fluids where the standard deviation of all valid obtained temperatures are less than 10^{-8} times the mean and the standard deviation of all valid obtained molar densities are less than 10^{-8} times the mean, or if only one cluster of numerical critical points is obtained by the clustering algorithm. If the fluid file in REFPROP 10.0 does not have a DOI for a publication documenting the EOS, the reference is not included in the table.

FLD	reference	$T_{\mathrm{crit,num}}$ / K	$\rho_{\mathrm{crit,num}}$ / mol/m^3
13BUTADIENE		425.135001516725	4530.000125563268
1BUTENE	Lemmon and Ihmels[S1]	419.290179672269	4240.060378624191
1BUTYNE		432.000004807970	4650.001137944028
1PENTENE		465.740005094924	3450.000491125145
22DIMETHYLBUTANE		490.000001301770	2780.013085631502
23DIMETHYLBUTANE		500.600001360633	2800.001093098367
3METHYLPENTANE		506.000000437214	2780.021595008656
ACETONE	Lemmon and Span[S2]	508.100009031149	4699.887637170586
ACETYLENE		308.300000541941	8830.015219977247
AMMONIA		405.559999973279	13695.999654455507
ARGON	Tegeler et al.[S3]	150.686999999886	13407.429652307319
BENZENE		562.020000354716	3900.999698733468
BUTANE	Bücker and Wagner[S4]	425.125000000014	3922.769613001141
C11	Aleksandrov et al.[S5]	638.800014467382	1514.900475944154
C12	Lemmon and Huber[S6]	658.100026858214	1330.349319849996
C16		722.099995323221	1000.000002644474
C1CC6		572.195852166207	2719.772044655079
C22		792.200035507396	722.996211226989
C2BUTENE	Lemmon and Ihmels[S1]	435.750076585240	4243.988811738827
C3CC6		630.800001098742	2060.000094878045
C4F10		386.326001674422	2636.999700803776
C5F12		421.000001315033	2169.999985856040
C6F14		448.000000604539	1825.000064527602
CF3I	Lemmon and Span[S7]	396.439690445971	4430.595539679294
CHLORINE		416.865404895758	7949.829189055028
CHLOROBENZENE		632.349998910651	3240.097046505090
CO	Lemmon and Span[S2]	132.859894633867	10850.163381508641
CO2	Span and Wagner[S8]	304.128199997469	10624.906288269034
COS	Lemmon and Span[S2]	378.770269705748	7409.848759557895
CYCLOBUTENE		448.000000503971	5170.000315944261
CYCLOHEX	Zhou et al.[S9]	553.600018855784	3223.997948889909
CYCLOPEN	Gedanitz et al.[S10]	511.720067256865	3920.019324850833

Continued on next page

Table S1: Numerical critical points for fluids where the standard deviation of all valid obtained temperatures are less than 10^{-8} times the mean and the standard deviation of all valid obtained molar densities are less than 10^{-8} times the mean, or if only one cluster of numerical critical points is obtained by the clustering algorithm. If the fluid file in REFPROP 10.0 does not have a DOI for a publication documenting the EOS, the reference is not included in the table.

FLD	reference	$T_{\mathrm{crit,num}}$ / K	$\rho_{\mathrm{crit,num}}$ / mol/m^3
CYCLOPRO		398.691400983772	6116.214614879299
D2	Richardson et al.[S11]	38.339999065746	17230.000189612478
D2O		643.846999983144	17775.533720792144
D4	Thol et al.[S12]	586.500003531823	1043.596585489433
D5		618.299999090851	819.990542602559
D6	Colonna et al.[S13]	645.758261242715	627.479822179235
DEA		736.499992565725	3300.000260856739
DECANE	Lemmon and Span[S2]	617.698845245878	1640.005187940962
DEE	Thol et al.[S14]	467.899640889919	3456.401580481182
DMC	Lemmon[S15]	557.000000018582	4000.051948173550
DME	Wu et al.[S16]	400.377999912190	5940.000177304969
EBENZENE	Zhou et al.[S17]	617.119999794919	2741.015958584866
EGLYCOL		718.999999997373	5879.999718142031
ETHANE	Bücker and Wagner[S18]	305.322000000025	6856.886685026533
ETHANOL	Schroeder et al.[S19]	514.709284881297	5930.686348980144
ETHYLENE	Smukala et al.[S20]	282.350000000002	7636.765980032601
ETHYLENEOXIDE	Thol et al.[S21]	468.920007690385	7170.345552856052
FLUORINE		144.414430811503	15602.990334978687
H2S	Lemmon and Span[S2]	373.100874713194	10188.086423476685
HCL	Thol et al.[S22]	324.680012793453	11870.000410277429
HELIUM		5.195300013639	17384.922905133368
HEPTANE		540.199122134419	2329.998122718437
HEXANE		507.819999883733	2705.767691516219
HYDROGEN	Leachman et al.[S23]	33.144332688313	15501.883353507348
IBUTENE	Lemmon and Ihmels[S1]	418.089802153580	4169.953751503084
IHEXANE	Lemmon and Span[S2]	497.700897751114	2714.958497780020
IOCTANE		543.999162645284	2120.057267707617
IPENTANE	Lemmon and Span[S2]	460.349794711447	3270.983543995838
ISOBUTAN	Bücker and Wagner[S4]	407.810000000007	3879.756787997491
KRYPTON	Lemmon and Span[S2]	209.479551797361	10847.443770773883
MD2M	Thol et al.[S24]	599.399201172128	863.999062714590
MD3M		628.959360982456	700.000693453590
MD4M		653.200003023893	570.004321940619
MDM	Thol et al.[S24]	565.360900931273	1133.987464259153

Continued on next page

Table S1: Numerical critical points for fluids where the standard deviation of all valid obtained temperatures are less than 10^{-8} times the mean and the standard deviation of all valid obtained molar densities are less than 10^{-8} times the mean, or if only one cluster of numerical critical points is obtained by the clustering algorithm. If the fluid file in REFPROP 10.0 does not have a DOI for a publication documenting the EOS, the reference is not included in the table.

FLD	reference	$T_{\mathrm{crit,num}}$ / K	$\rho_{\mathrm{crit,num}}$ / mol/m^3
MEA		671.400027007082	5390.001897330055
METHANE	Setzmann and Wagner [S25]	190.564002651289	10139.137654869055
METHANOL		513.379512723066	8785.166579439334
MLINOLEA	Huber et al. [S26]	799.000194539238	808.398599877921
MLINOLEN	Huber et al. [S26]	772.000002232016	847.300023899051
MM	Thol et al. [S27]	518.700125282309	1653.001461319927
MOLEATE	Huber et al. [S26]	782.000133205469	812.849810203212
MPALMITA	Huber et al. [S26]	755.000106138089	897.000004197855
MSTEARAT	Huber et al. [S26]	774.999985970041	794.299930049967
MXYLENE	Zhou et al. [S17]	616.890000360285	2664.961595780371
N2O	Lemmon and Span [S2]	309.520678231461	10290.903501226845
NEON		44.399999704987	24099.990089769854
NEOPENTN	Lemmon and Span [S2]	433.739591831346	3269.960036623968
NF3		234.000004095342	7920.004324184471
NONANE	Lemmon and Span [S2]	594.547813211921	1810.134951169471
NOVEC649	McLinden et al. [S28]	441.810014894905	1919.991245488947
OCTANE		568.739999945857	2031.019421928223
ORTHOHYD	Leachman et al. [S23]	33.219814621741	15443.851695476566
OXYGEN	Schmidt and Wagner [S29]	154.599389835297	13342.189355444723
OXYLENE	Zhou et al. [S17]	630.259003064435	2684.499182528047
PARAHYD	Leachman et al. [S23]	32.937855068916	15534.375068765861
PENTANE		469.699999871120	3209.991955032101
PROPADIENE		398.000002222070	5899.996558581693
PROPANE	Lemmon et al. [S30]	369.890008950966	5000.000623465764
PROPYLEN		364.211002591351	5456.982411756008
PROPYLENEOXIDE		488.110000201113	5154.994585612263
PROPYNE		402.701144274777	6208.426197699002
PXYLENE	Zhou et al. [S17]	616.168001941964	2693.916400807192
R11	Jacobsen et al. [S31]	471.109999998560	4032.962000003781
R1123		331.729982547725	5992.991677500096
R113		487.210000016661	2988.658995195607
R114		420.607725353667	3353.847329101395
R115	Lemmon and Span [S7]	353.101977538657	3979.968463559097
R116	Lemmon and Span [S2]	293.029792782694	4444.033365370853

Continued on next page

Table S1: Numerical critical points for fluids where the standard deviation of all valid obtained temperatures are less than 10^{-8} times the mean and the standard deviation of all valid obtained molar densities are less than 10^{-8} times the mean, or if only one cluster of numerical critical points is obtained by the clustering algorithm. If the fluid file in REFPROP 10.0 does not have a DOI for a publication documenting the EOS, the reference is not included in the table.

FLD	reference	$T_{\mathrm{crit,num}}$ / K	$\rho_{\mathrm{crit,num}}$ / mol/m^3
R12		385.119999768144	4672.781004502307
R1216		358.900001800403	3888.800590864051
R1224YDZ		428.690120670008	3558.159725664967
R123	Younglove and McLinden [S32]	456.830025813126	3596.477462782419
R1233ZDE	Mondéjar et al. [S33]	439.600833075670	3680.006518883804
R1234YF	Richter et al. [S34]	367.849988823419	4169.987458323874
R1234ZEE	Thol and Lemmon [S35]	382.513002604665	4289.757331198681
R1234ZEZ		423.270378395423	3999.982448012761
R124		395.427960773212	4098.136400891356
R1243ZF		376.930009838612	4300.345236139602
R125	Lemmon and Jacobsen [S36]	339.177282456107	4777.438522585501
R13	Magee [S37]	301.999999994203	5579.999999626142
R1336MZZZ		444.499991025335	3044.528760869529
R134A	Tillner-Roth and Baehr [S38]	374.211966584950	5017.495621784983
R14		227.396228531671	7124.455003395279
R141B	Lemmon and Span [S2]	477.500027705974	3921.075983637842
R142B	Lemmon and Span [S2]	410.260232652097	4438.068183579601
R143A	Lemmon and Jacobsen [S39]	345.857000867859	5128.454284175953
R150		561.580029067144	4330.813901171688
R152A	Outcalt and McLinden [S40]	386.411000000273	5571.450000765393
R161	Wu and Zhou [S41]	375.249995605452	6283.893183353822
R21		452.720164549304	5079.559327465906
R218	Lemmon and Span [S2]	345.019969014464	3339.957242333272
R22	Kamei et al. [S42]	369.295000008026	6058.220000737031
R227EA	Lemmon and Span [S7]	374.900103445253	3494.976825557756
R23	Penoncello et al. [S43]	299.293048971673	7519.973539479489
R236EA	Rui et al. [S44]	412.408990033871	3747.822841458774
R236FA	Pan et al. [S45]	398.070051605232	3626.014635848634
R245CA	Zhou and Lemmon [S46]	447.569995521968	3920.000023005454
R245FA	Akasaka et al. [S47]	427.009989695603	3873.872778950230
R32	Tillner-Roth and Yokozeki [S48]	351.255000449439	8150.083999393831
R365MFC	Lemmon and Span [S7]	460.003171675192	3199.420776086215
R40	Thol et al. [S14]	418.625652105875	6767.630586121616
R41	Lemmon and Span [S2]	317.279755849697	9299.974658863017

Continued on next page

Table S1: Numerical critical points for fluids where the standard deviation of all valid obtained temperatures are less than 10^{-8} times the mean and the standard deviation of all valid obtained molar densities are less than 10^{-8} times the mean, or if only one cluster of numerical critical points is obtained by the clustering algorithm. If the fluid file in REFPROP 10.0 does not have a DOI for a publication documenting the EOS, the reference is not included in the table.

FLD	reference	$T_{\mathrm{crit,num}}$ / K	$\rho_{\mathrm{crit,num}}$ / mol/m^3
RC318		388.371022245699	3099.525791352913
RE143A	Akasaka and Kayukawa [S49]	377.924817547696	4647.856430835564
RE245CB2		406.812993338169	3328.999369404063
RE245FA2		444.880001088672	3432.257186269010
RE347MCC		437.698314051319	2640.221415057733
SF6	Guder and Wagner [S50]	318.723199999987	5082.317411131595
SO2	Gao et al. [S51]	430.640000632067	8078.277631239390
T2BUTENE	Lemmon and Ihmels [S1]	428.610535765513	4212.918063787299
TOLUENE	Lemmon and Span [S2]	591.749078936290	3168.995782350518
VINYLCHLORIDE		424.964022730585	5620.139949551086
WATER	Wagner and Pruß [S52]	647.096000000005	17873.727849282910
XENON	Lemmon and Span [S2]	289.732568330720	8400.185085766099

Table S2: The multiple numerical critical points for nitrogen

FLD	reference	$T_{\mathrm{crit,num}}$ / K	$\rho_{\mathrm{crit,num}}$ / mol/m^3
NITROGEN	Span et al. [S53]	126.192000	11183.899999
NITROGEN	Span et al. [S53]	120.451816	16090.642727

2 Erroneous Critical Points

Table S4: Fluid files of REFPROP for which the numerical and published critical temperatures differ by more than 10^{-4} K or critical densities differ by more than 0.1 mol/m^3, sorted by error in critical temperature. The subscript of E indicates the value given by the EOS developers and the subscript of num the numerical value. A † indicates the reducing state is not the critical one

FLD	$\lvert\Delta T\rvert$ / K	$T_{\mathrm{crit,num}}$ / K	$T_{\mathrm{crit,E}}$ / K	$\lvert\Delta\rho\rvert$ / mol/m^3	$\rho_{\mathrm{crit,num}}$ / mol/m^3	$\rho_{\mathrm{crit,E}}$ / mol/m^3
R40	2.325652e+00	418.625652	416.3000	426.602414	6767.630586	7194.233000
R114	1.777725e+00	420.607725	418.8300	39.352671	3353.847329	3393.200000
R21	1.240165e+00	452.720165	451.4800	31.206273	5079.559327	5110.765600
DEE	1.199641e+00	467.899641	466.7000	105.298420	3456.401580	3561.700000†
METHANOL	7.795127e-01	513.379513	512.6000†	185.166579	8785.166579	8600.000000†
CYCLOPRO	3.914010e-01	398.691401	398.3000	26.685385	6116.214615	6142.900000†
PROPYNE	3.211443e-01	402.701144	402.3800	95.126198	6208.426198	6113.300000†
R14	1.137715e-01	227.396229	227.5100	15.035603	7124.455003	7109.419400
R236EA	3.100997e-02	412.408990	412.4400	31.656401	3747.822841	3716.166440
D6	2.173876e-02	645.758261	645.7800	0.191274	627.479822	627.288548
R150	1.997093e-02	561.580029	561.6000	0.813901	4330.813901	4330.000000
OXYGEN	1.838984e-02	154.599390	154.5810	287.810645	13342.189355	13630.000000
RC318	8.977754e-03	388.371022	388.3800	0.145791	3099.525791	3099.380000
R125	4.282456e-03	339.177282	339.1730	1.561477	4777.438523	4779.000000
C1CC6	4.147834e-03	572.195852	572.2000	0.227955	2719.772045	2720.000000
RE143A	3.817548e-03	377.924818	377.9210	0.284313	4647.856431	4648.140744
R365MFC	3.171675e-03	460.003172	460.0000	0.579224	3199.420776	3200.000000
R124	2.960773e-03	395.427961	395.4250	5.179199	4098.136401	4103.315600
NONANE	2.186788e-03	594.547813	594.5500	0.134951	1810.134951	1810.000000
R115	1.977539e-03	353.101978	353.1000	0.031536	3979.968464	3980.000000
R134A	1.966585e-03	374.211967	374.2100†	0.442622	5017.495622	5017.053000†
RE347MCC	1.685949e-03	437.698314	437.7000	0.221415	2640.221415	2640.000000
DECANE	1.154754e-03	617.698845	617.7000	0.005188	1640.005188	1640.000000
R123	9.741869e-04	456.830026	456.8310	0.060463	3596.477463	3596.417000

Continued on next page

Table S4: Fluid files of REFPROP for which the numerical and published critical temperatures differ by more than 10^{-4} K or critical densities differ by more than 0.1 mol/m^3, sorted by error in critical temperature. The subscript of E indicates the value given by the EOS developers and the subscript of num the numerical value. A † indicates the reducing state is not the critical one

FLD	$\lvert\Delta T\rvert$ / K	$T_{\mathrm{crit,num}}$ / K	$T_{\mathrm{crit,E}}$ / K	$\lvert\Delta\rho\rvert$ / mol/m^3	$\rho_{\mathrm{crit,num}}$ / mol/m^3	$\rho_{\mathrm{crit,E}}$ / mol/m^3
TOLUENE	9.210637e-04	591.749079	591.7500	0.004218	3168.995782	3169.000000
IHEXANE	8.977511e-04	497.700898	497.7000	0.041502	2714.958498	2715.000000
HEPTANE	8.778656e-04	540.199122	540.2000	0.001877	2329.998123	2330.000000
H2S	8.747132e-04	373.100875	373.1000	1.913577	10188.086423	10190.000000
IOCTANE	8.373547e-04	543.999163	544.0000	0.057268	2120.057268	2120.000000
R1233ZDE	8.330757e-04	439.600833	439.6000	0.006519	3680.006519	3680.000000
MD2M	7.988279e-04	599.399201	599.4000	0.000937	863.999063	864.000000
ETHANOL	7.151187e-04	514.709285	514.7100	0.686349	5930.686349	5930.000000
N2O	6.782315e-04	309.520678	309.5200	20.903501	10290.903501	10270.000000
HYDROGEN	6.673117e-04	33.144333	33.1450	6.116646	15501.883354	15508.000000
MD3M	6.390175e-04	628.959361	628.9600	0.000693	700.000693	700.000000
T2BUTENE	5.357655e-04	428.610536	428.6100	0.081936	4212.918064	4213.000000
KRYPTON	4.482026e-04	209.479552	209.4800	2.556229	10847.443771	10850.000000
XENON	4.316693e-04	289.732568	289.7330	0.185086	8400.185086	8400.000000
FLUORINE	4.308115e-04	144.414431	144.4140	0.009665	15602.990335	15603.000000
NEOPENTN	4.081687e-04	433.739592	433.7400	0.039963	3269.960037	3270.000000
R1234ZEZ	3.783954e-04	423.270378	423.2700	0.017552	3999.982448	4000.000000
CF3I	3.095540e-04	396.439690	396.4400	0.004460	4430.595540	4430.600000
COS	2.697057e-04	378.770270	378.7700	0.151240	7409.848760	7410.000000
R41	2.441503e-04	317.279756	317.2800	0.025341	9299.974659	9300.000000
R142B	2.326521e-04	410.260233	410.2600	0.068184	4438.068184	4438.000000
R116	2.072173e-04	293.029793	293.0300	0.033365	4444.033365	4444.000000
IPENTANE	2.052886e-04	460.349795	460.3500	0.016456	3270.983544	3271.000000
IBUTENE	1.978464e-04	418.089802	418.0900	0.046248	4169.953752	4170.000000

Continued on next page

Table S4: Fluid files of REFPROP for which the numerical and published critical temperatures differ by more than 10^{-4} K or critical densities differ by more than 0.1 mol/m^3, sorted by error in critical temperature. The subscript of E indicates the value given by the EOS developers and the subscript of num the numerical value. A † indicates the reducing state is not the critical one

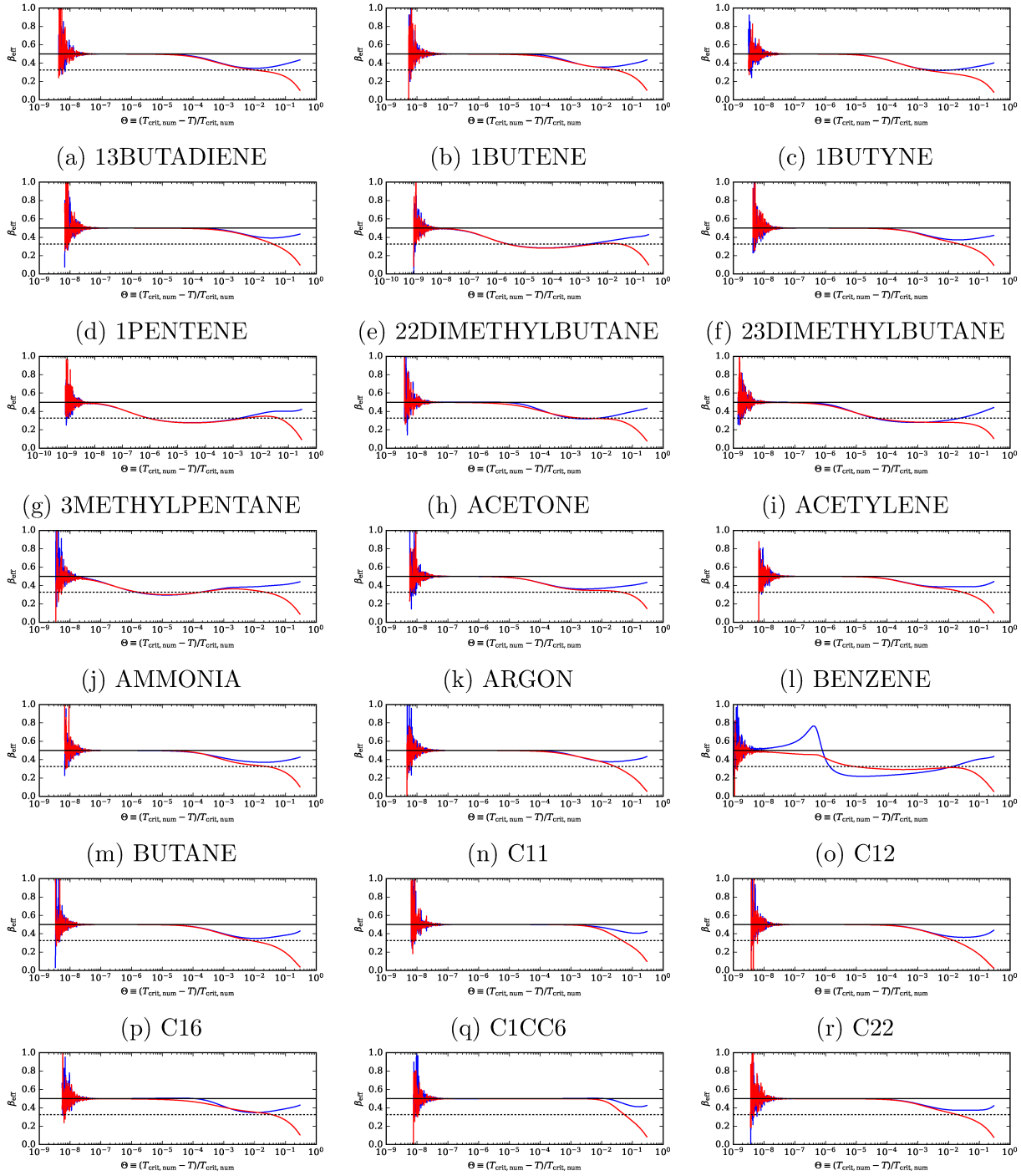
FLD	$\lvert\Delta T\rvert$ / K	$T_{\mathrm{crit,num}}$ / K	$T_{\mathrm{crit,E}}$ / K	$\lvert\Delta\rho\rvert$ / mol/m^3	$\rho_{\mathrm{crit,num}}$ / mol/m^3	$\rho_{\mathrm{crit,E}}$ / mol/m^3
MLINOLEA	1.945392e-04	799.000195	799.0000	0.001400	808.398600	808.400000
ORTHOHYD	1.853783e-04	33.219815	33.2200	1.148305	15443.851695	15445.000000
1BUTENE	1.796723e-04	419.290180	419.2900	0.060379	4240.060379	4240.000000
PARAHYD	1.449311e-04	32.937855	32.9380	3.624931	15534.375069	15538.000000
MOLEATE	1.332055e-04	782.000133	782.0000	0.000190	812.849810	812.850000
MM	1.252823e-04	518.700125	518.7000	0.001461	1653.001461	1653.000000
R1224YDZ	1.206700e-04	428.690121	428.6900	8.159726	3558.159726	3550.000000
MPALMITA	1.061381e-04	755.000106	755.0000	0.000004	897.000004	897.000000
CO	1.053661e-04	132.859895	132.8600	0.163382	10850.163382	10850.000000
R227EA	1.034453e-04	374.900103	374.9000	0.023174	3494.976826	3495.000000
C12	2.685821e-05	658.100027	658.1000	0.349320	1330.349320	1330.000000
VINYLCHLORIDE	2.273059e-05	424.964023	424.9640	0.139950	5620.139950	5620.000000
R1123	1.745227e-05	331.729983	331.7300	7.008322	5992.991678	6000.000000
R245FA	1.030440e-05	427.009990	427.0100	1.127221	3873.872779	3875.000000
R1243ZF	9.838612e-06	376.930010	376.9300	0.345236	4300.345236	4300.000000
ACETONE	9.031148e-06	508.100009	508.1000	0.112363	4699.887637	4700.000000
R1336MZZZ	8.974665e-06	444.499991	444.5000	0.528761	3044.528761	3044.000000
ETHYLENEOXIDE	7.690385e-06	468.920008	468.9200	0.345553	7170.345553	7170.000000
CHLORINE	4.895758e-06	416.865405	416.8654	110.170811	7949.829189	8060.000000
D4	3.531823e-06	586.500004	586.5000	0.596585	1043.596585	1043.000000
METHANE	2.651289e-06	190.564003	190.5640	0.137655	10139.137655	10139.000000†
R1234ZEE	2.604665e-06	382.513003	382.5130	0.242669	4289.757331	4290.000000
SO2	6.320671e-07	430.640001	430.6400	0.277631	8078.277631	8078.000000
HEXANE	1.162672e-07	507.820000	507.8200	0.232308	2705.767692	2706.000000

Continued on next page

Table S4: Fluid files of REFPROP for which the numerical and published critical temperatures differ by more than 10^{-4} K or critical densities differ by more than 0.1 mol/m^3, sorted by error in critical temperature. The subscript of E indicates the value given by the EOS developers and the subscript of num the numerical value. A † indicates the reducing state is not the critical one

FLD	$\lvert\Delta T\rvert$ / K	$T_{\mathrm{crit,num}}$ / K	$T_{\mathrm{crit,E}}$ / K	$\lvert\Delta\rho\rvert$ / mol/m^3	$\rho_{\mathrm{crit,num}}$ / mol/m^3	$\rho_{\mathrm{crit,E}}$ / mol/m^3
HELIUM	1.363893e-08	5.195300	5.1953	1.222905	17384.922905	17383.700000
ETHYLENE	2.273737e-12	282.350000	282.3500	0.234020	7636.765980	7637.000000†

3 All Fluids – Orthobaric Density



(a) 13BUTADIENE (b) 1BUTENE (c) 1BUTYNE

(d) 1PENTENE (e) 22DIMETHYLBUTANE (f) 23DIMETHYLBUTANE

(g) 3METHYLPENTANE (h) ACETONE (i) ACETYLENE

(j) AMMONIA (k) ARGON (l) BENZENE

(m) BUTANE (n) C11 (o) C12

(p) C16 (q) C1CC6 (r) C22

(s) C2BUTENE (t) C3CC6 (u) C4F10

Figure S1: Orthobaric scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

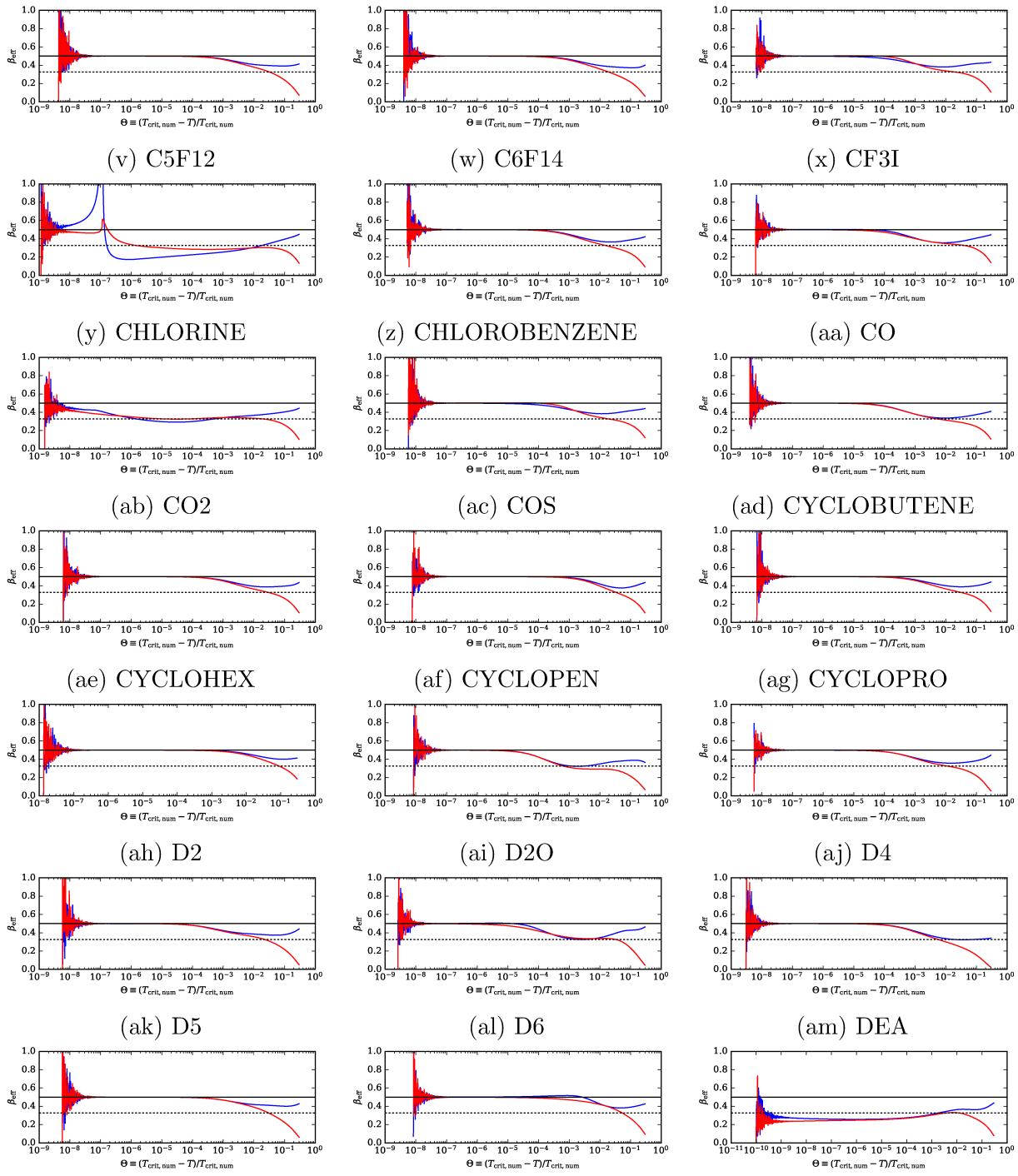


Figure S1: Orthobaric scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

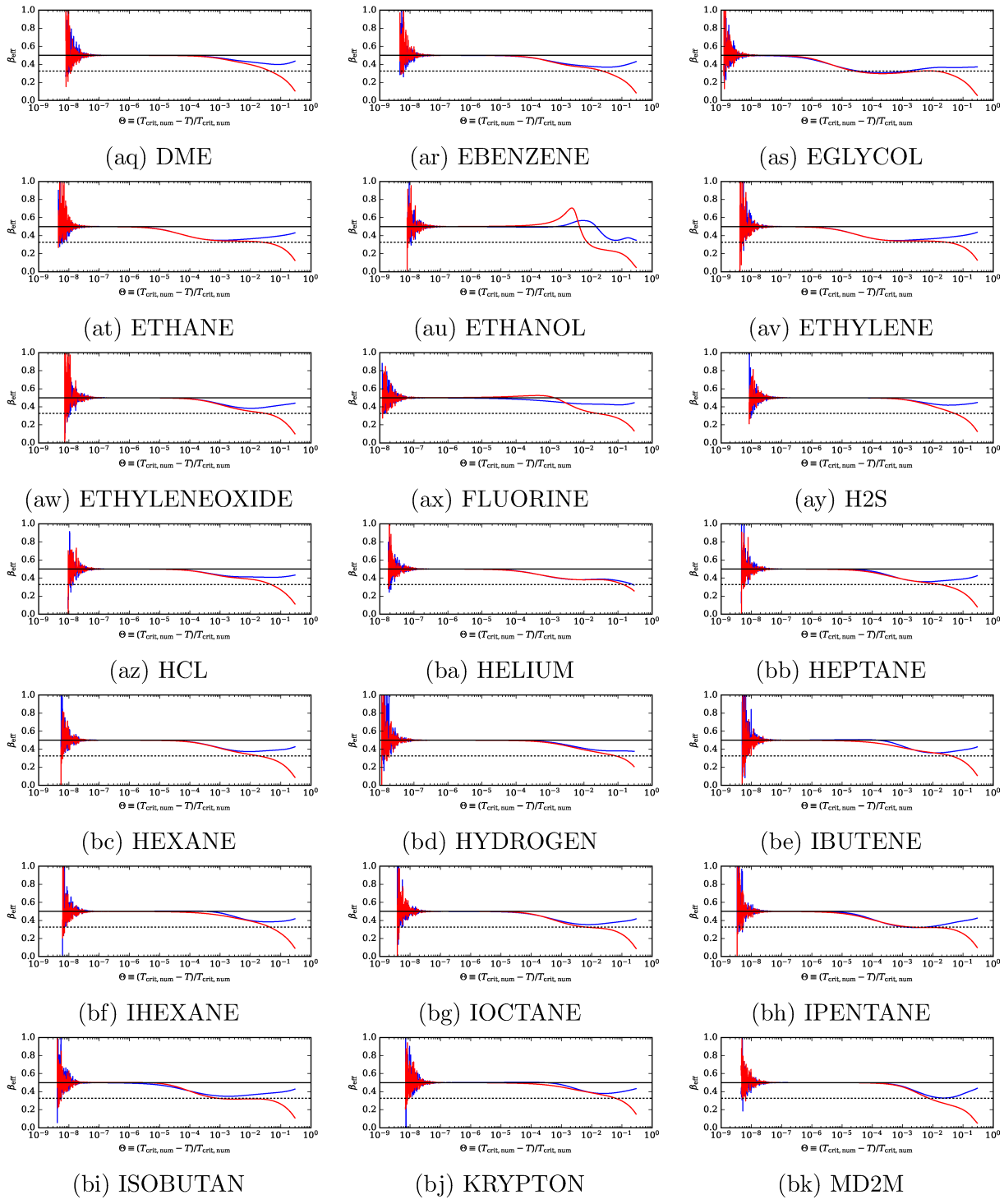


Figure S1: Orthobaric scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

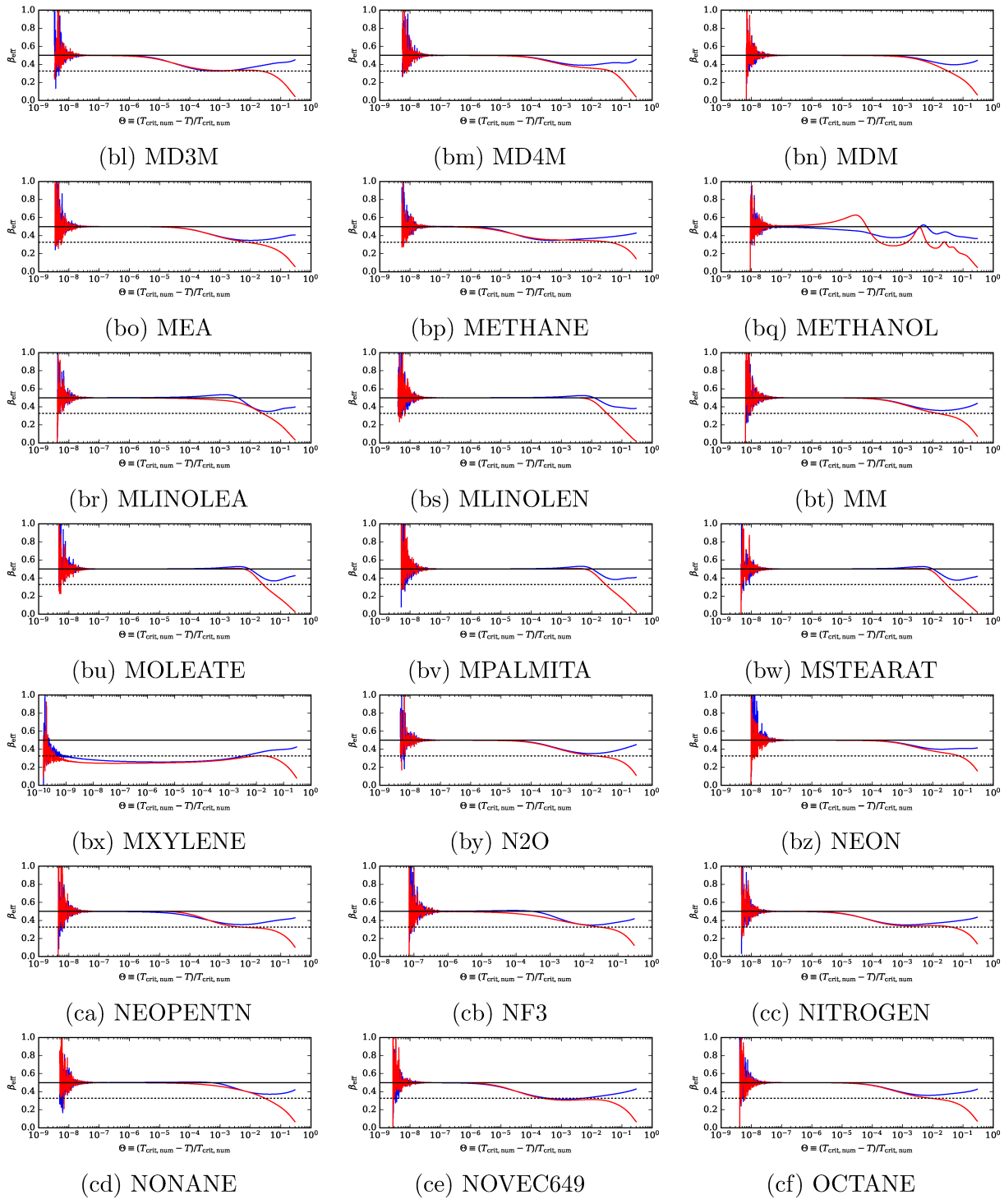


Figure S1: Orthobaric scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

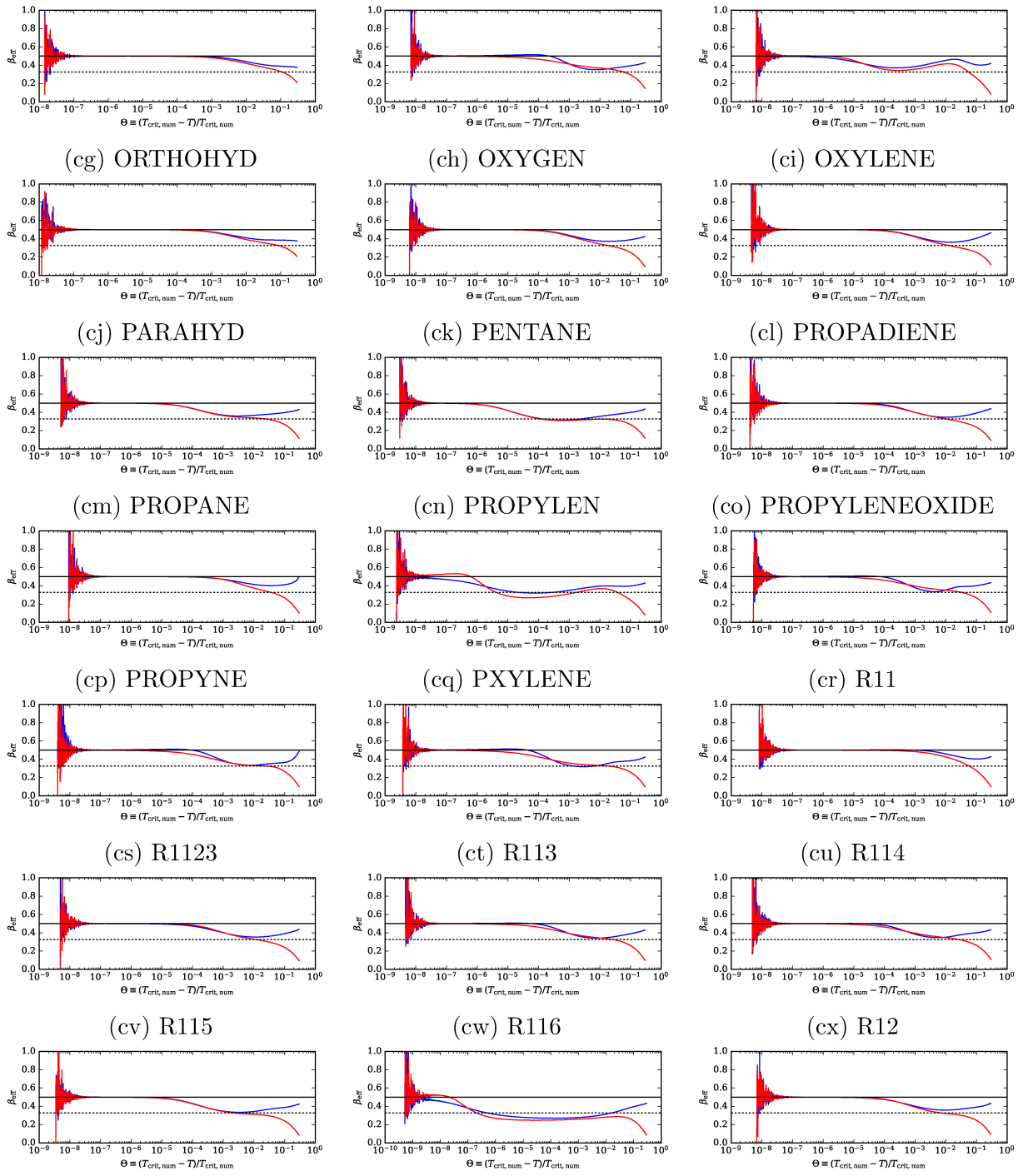
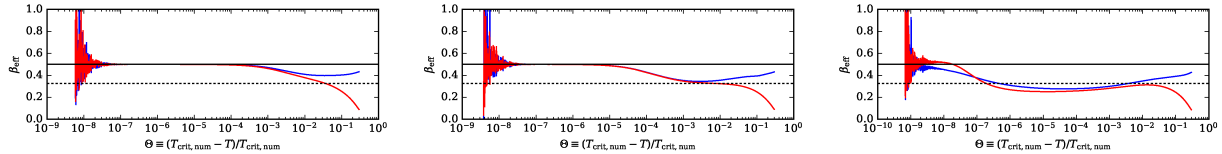


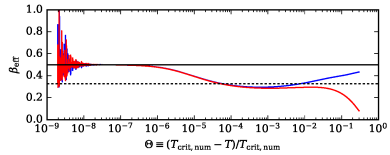
Figure S1: Orthobaric scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



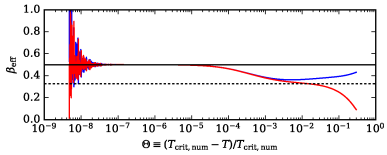
(db) R1233ZDE

(dc) R1234YF

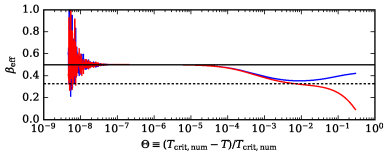
(dd) R1234ZEE



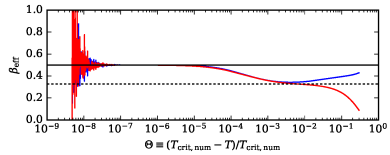
(de) R1234ZEZ



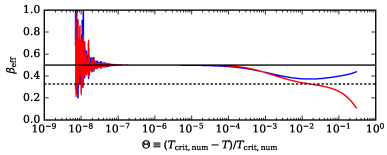
(df) R124



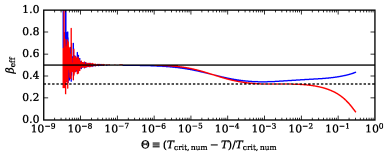
(dg) R1243ZF



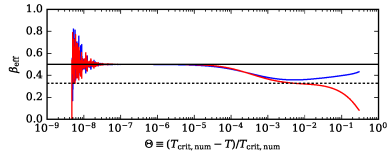
(dh) R125



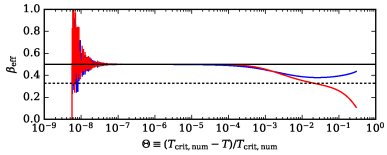
(di) R13



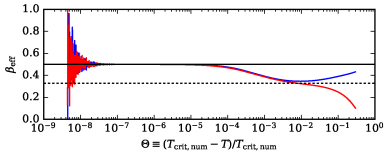
(dj) R1336MZZZ



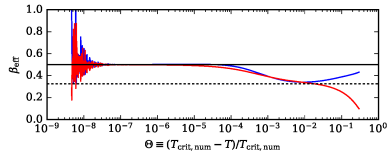
(dk) R134A



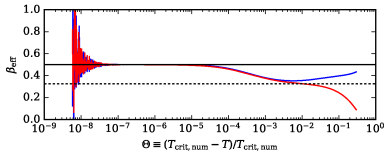
(dl) R14



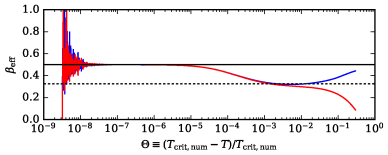
(dm) R141B



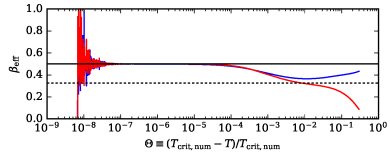
(dn) R142B



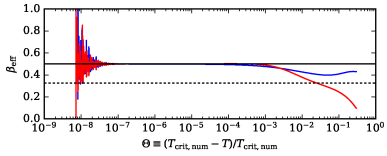
(do) R143A



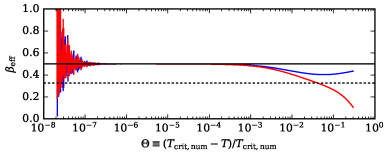
(dp) R150



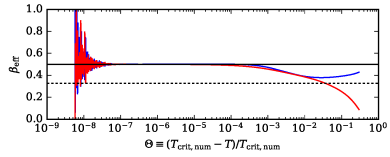
(dq) R152A



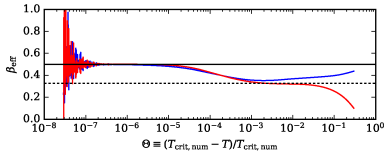
(dr) R161



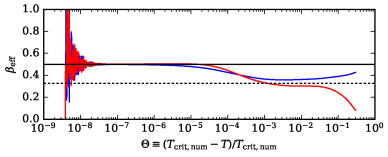
(ds) R21



(dt) R218



(du) R22



(dv) R227EA

Figure S1: Orthobaric scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

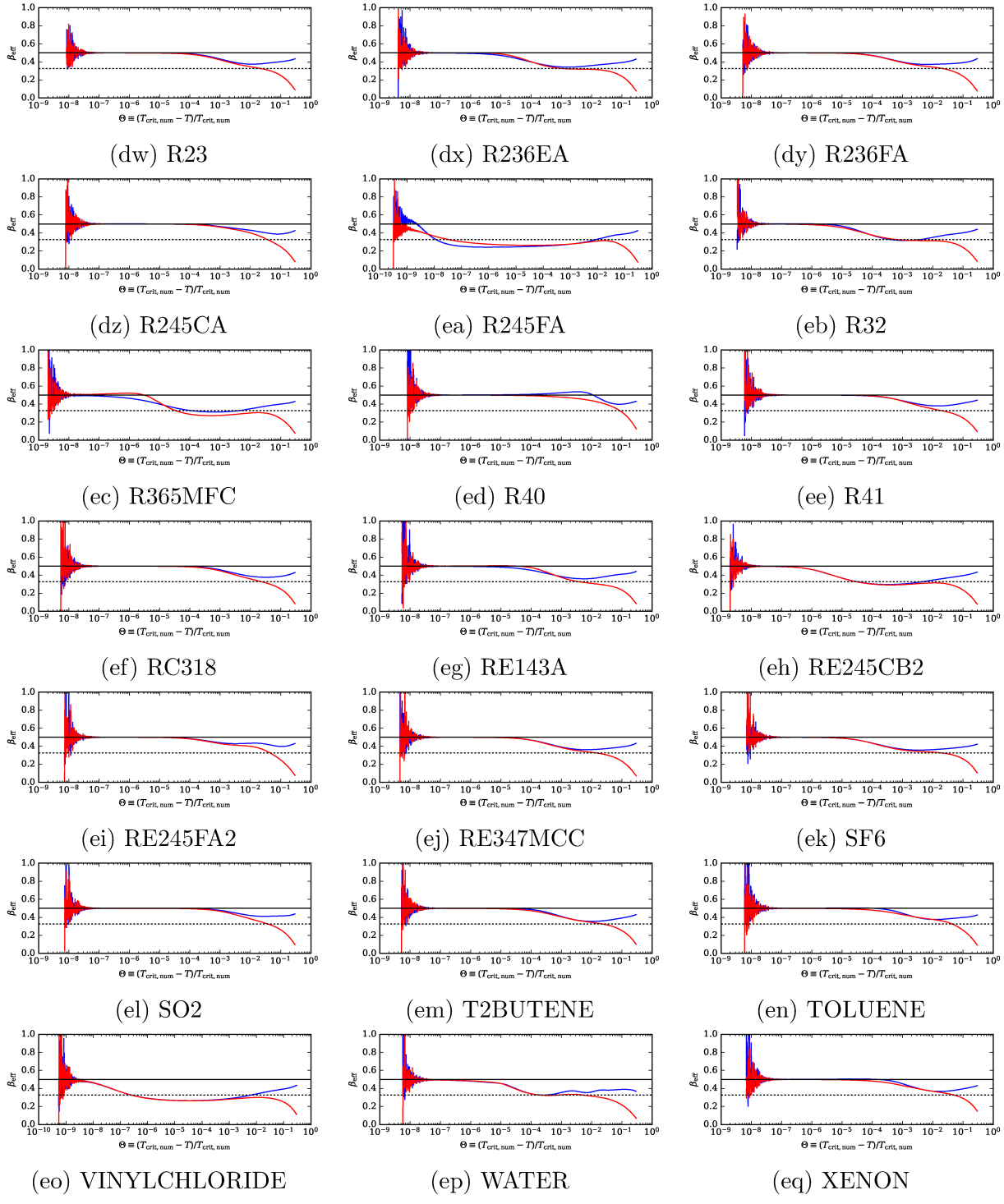
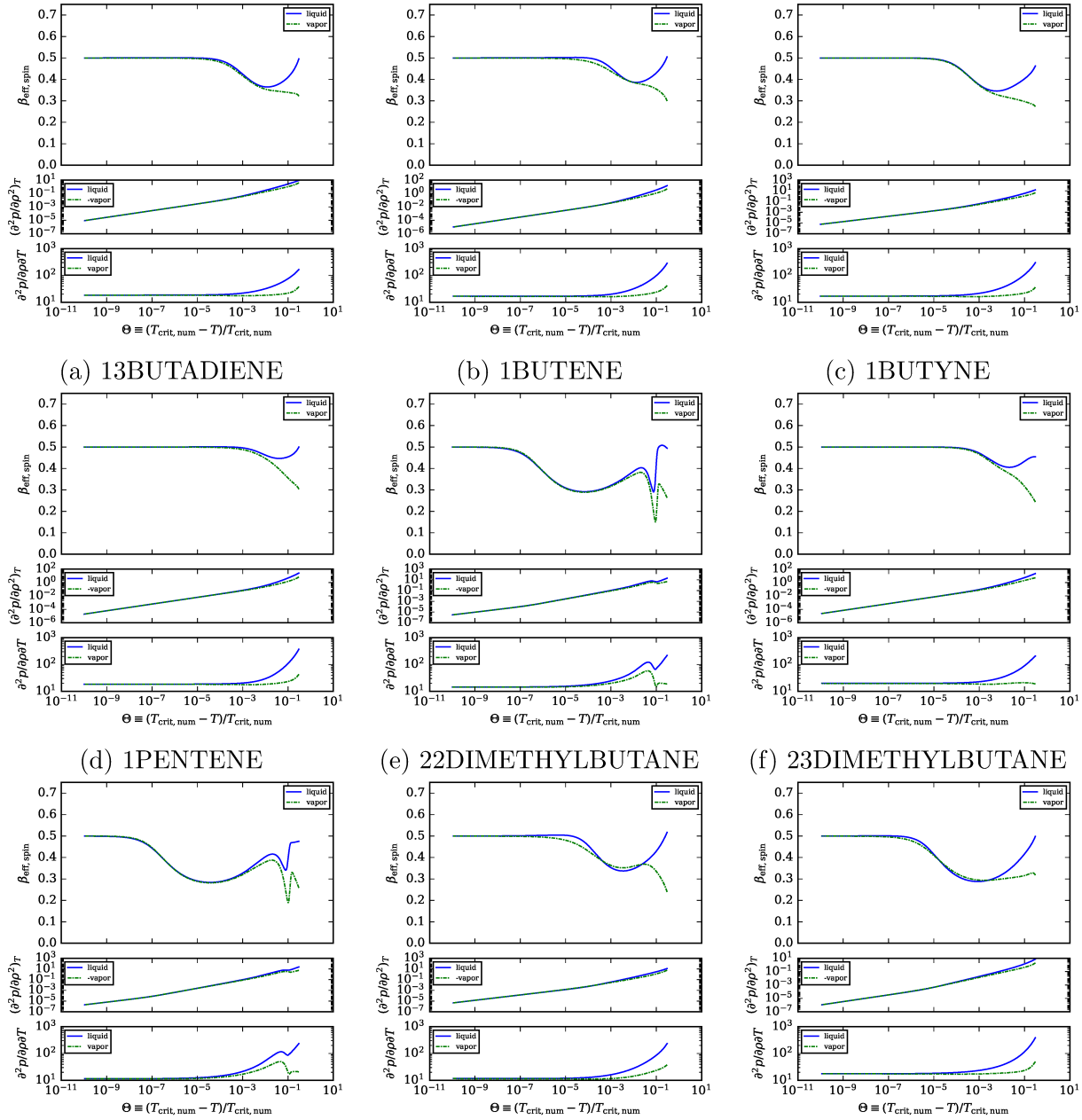


Figure S1: Orthobaric scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

4 All Fluids – Spinodal

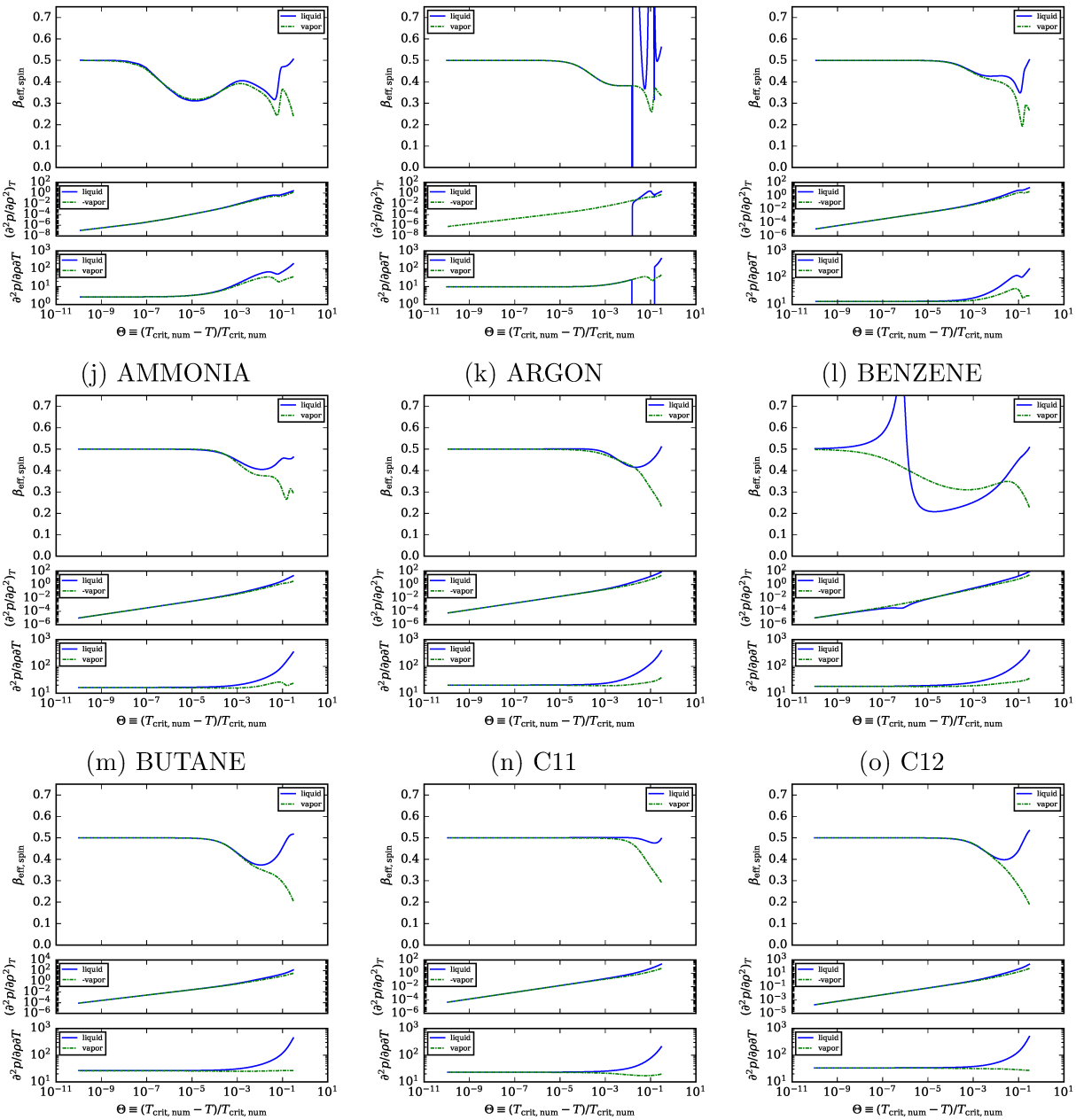


(a) 13BUTADIENE (b) 1BUTENE (c) 1BUTYNE

(d) 1PENTENE (e) 22DIMETHYLBUTANE (f) 23DIMETHYLBUTANE

(g) 3METHYLPENTANE (h) ACETONE (i) ACETYLENE

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

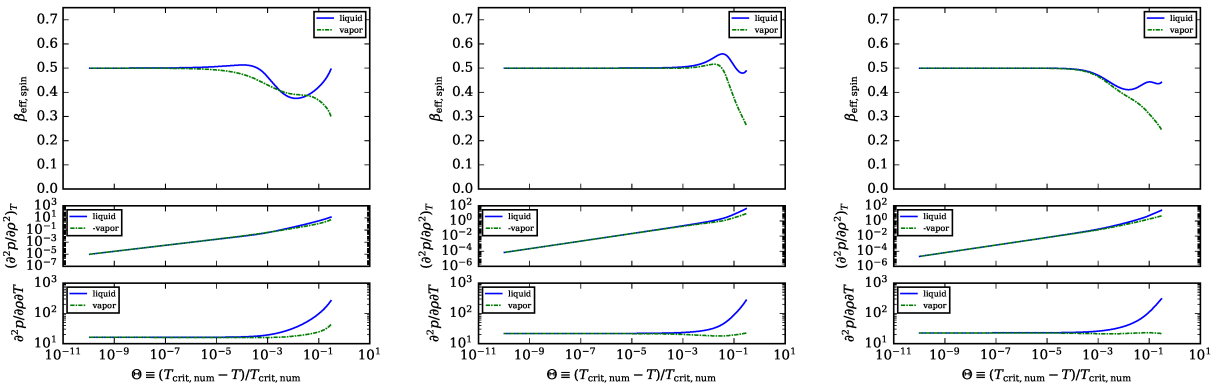


(j) AMMONIA (k) ARGON (l) BENZENE

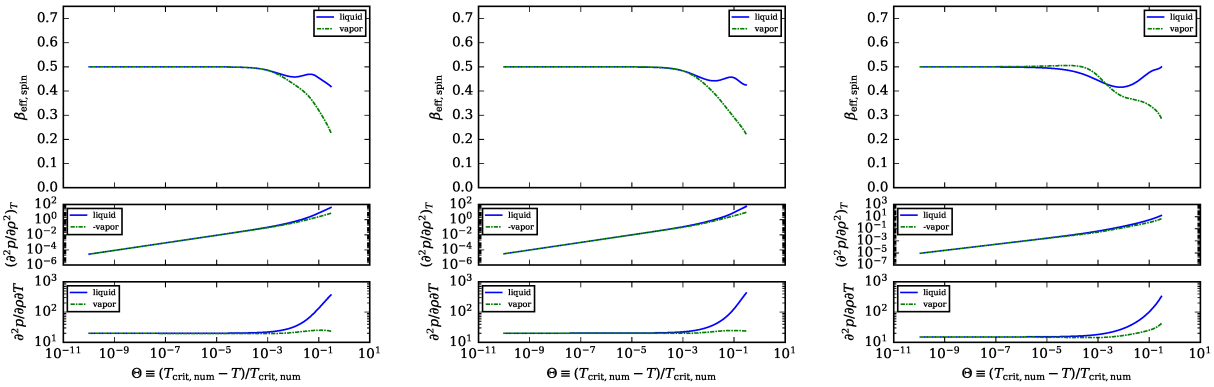
(m) BUTANE (n) C11 (o) C12

(p) C16 (q) C1CC6 (r) C22

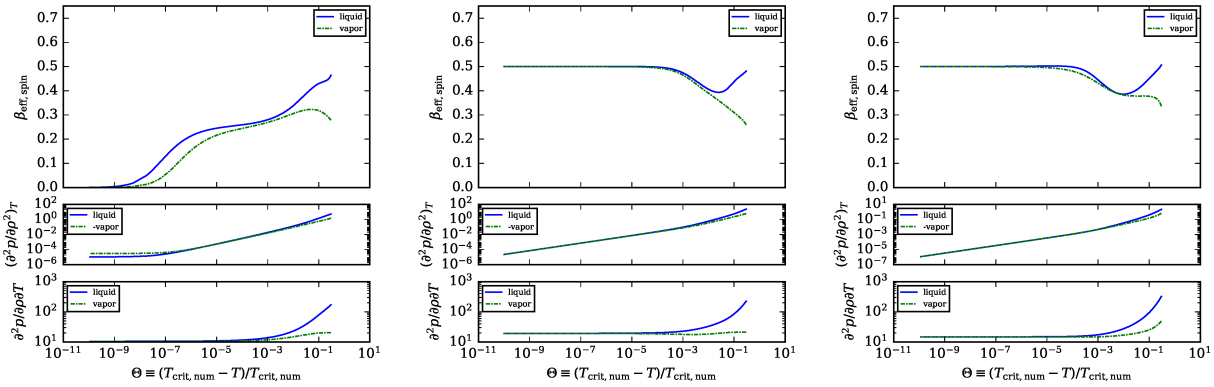
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(s) C2BUTENE (t) C3CC6 (u) C4F10

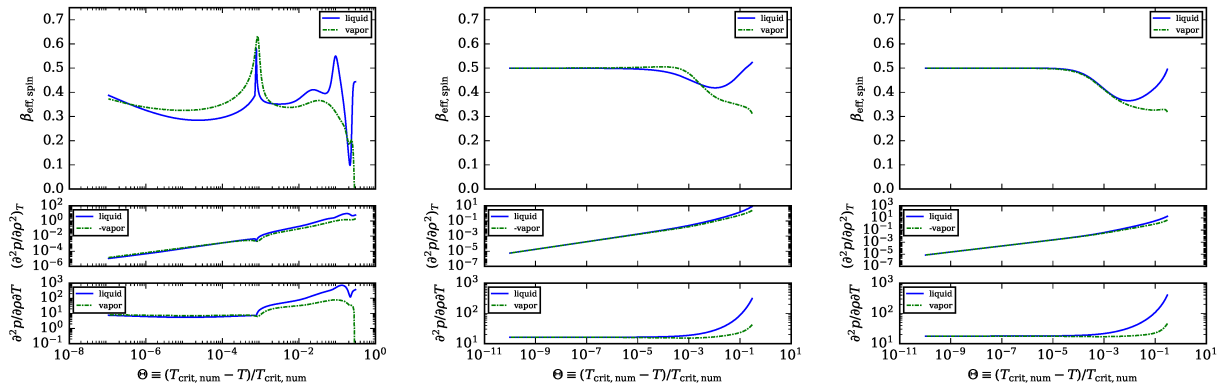


(v) C5F12 (w) C6F14 (x) CF3I

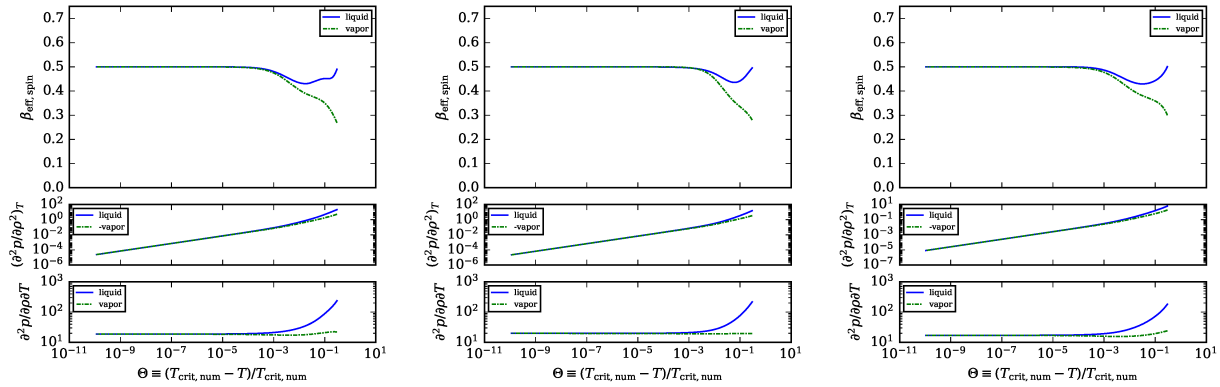


(y) CHLORINE (z) CHLOROBENZENE (aa) CO

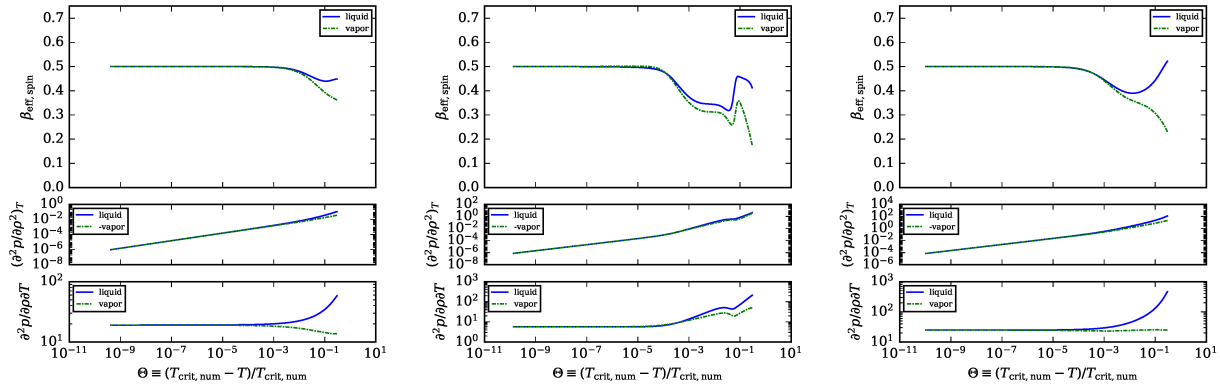
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(ab) CO2 (ac) COS (ad) CYCLOBUTENE

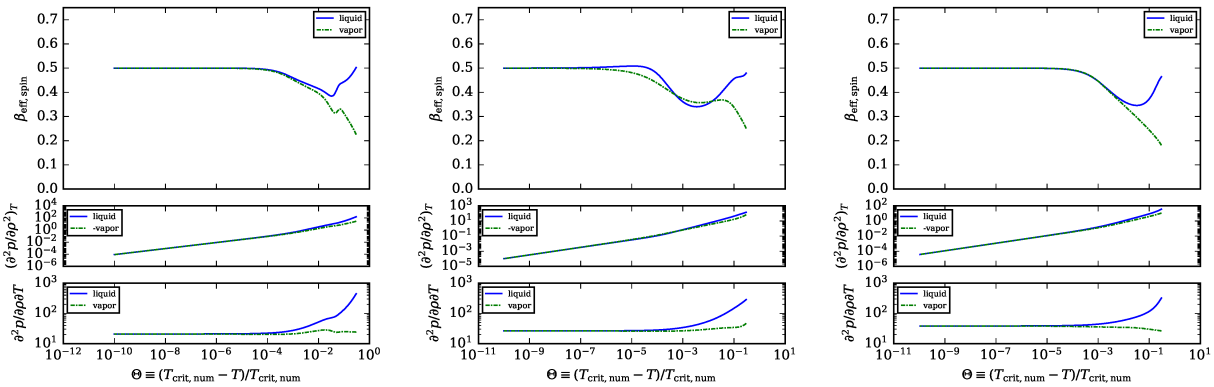


(ae) CYCLOHEX (af) CYCLOPEN (ag) CYCLOPRO

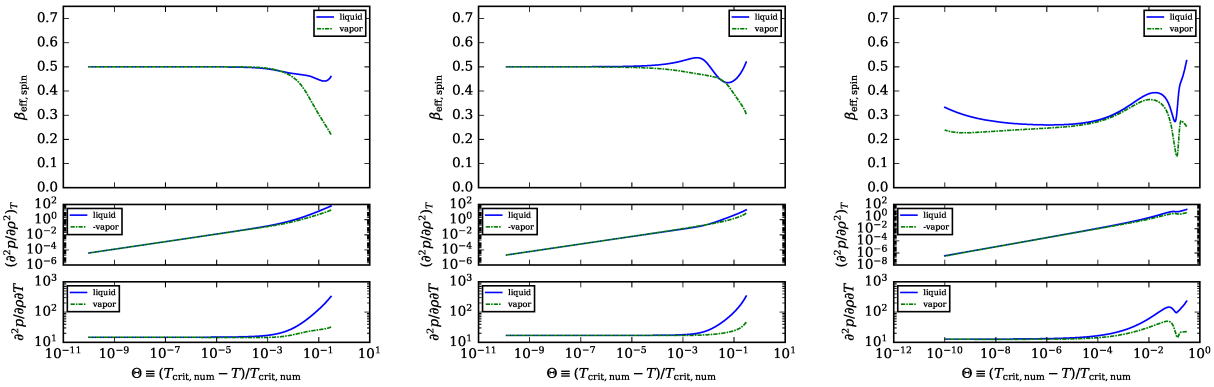


(ah) D2 (ai) D2O (aj) D4

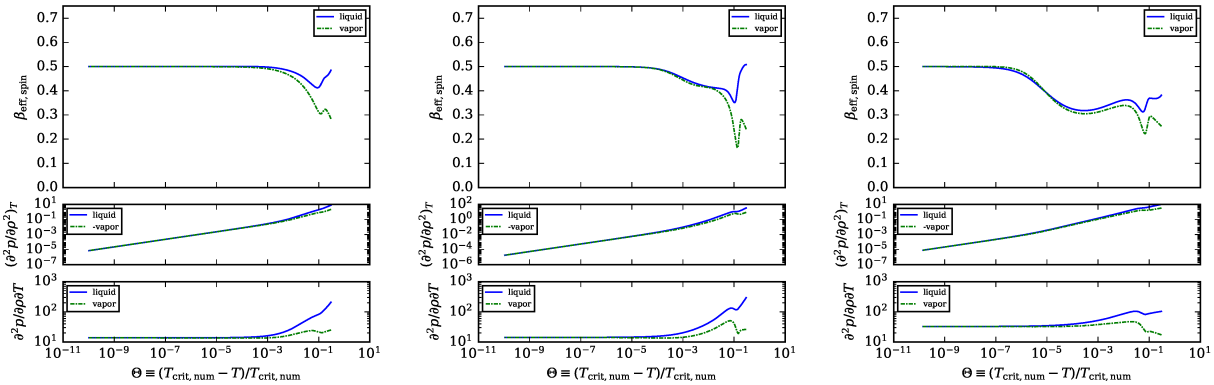
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(ak) D5 (al) D6 (am) DEA

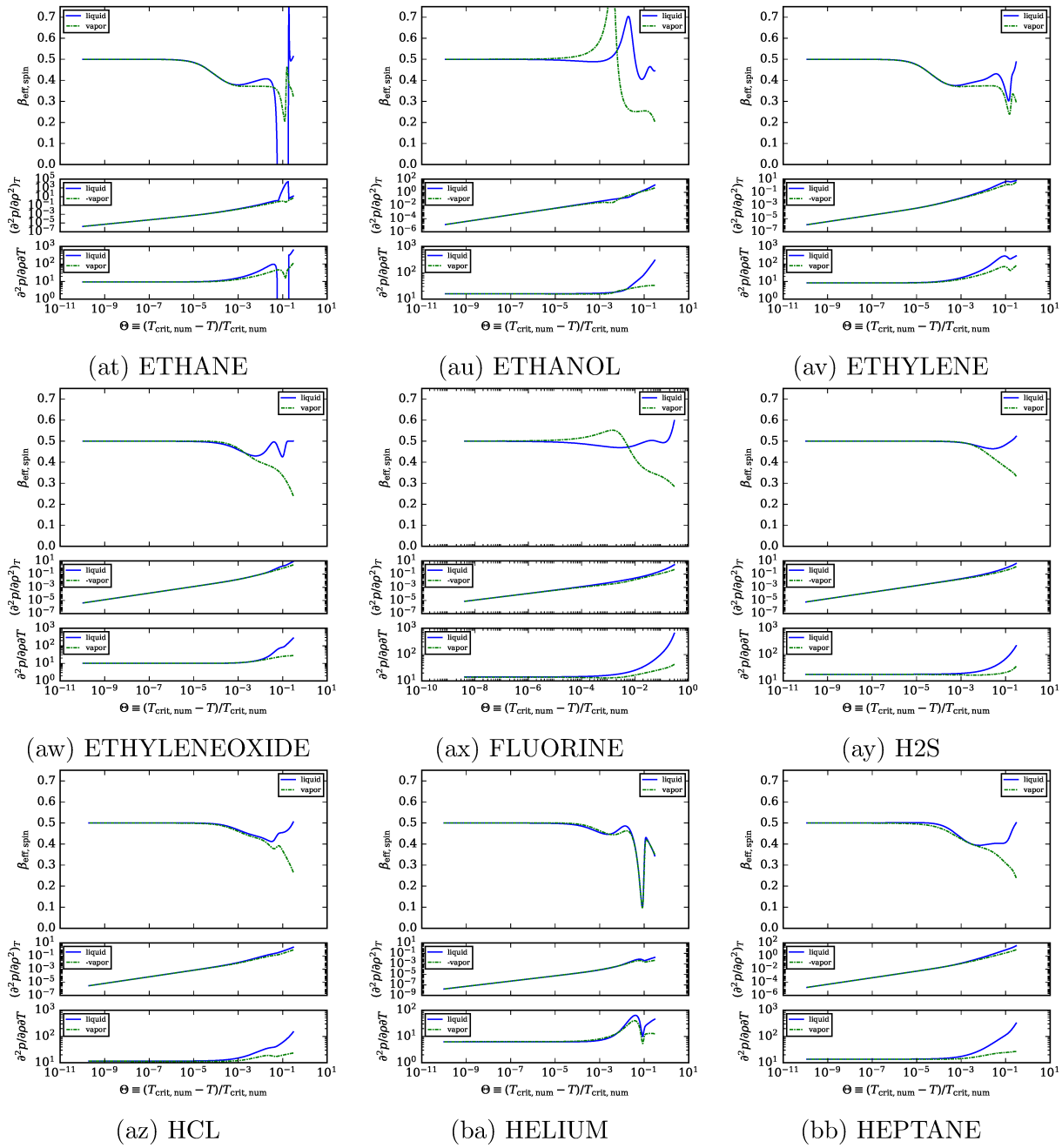


(an) DECANE (ao) DEE (ap) DMC



(aq) DME (ar) EBENZENE (as) EGLYCOL

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

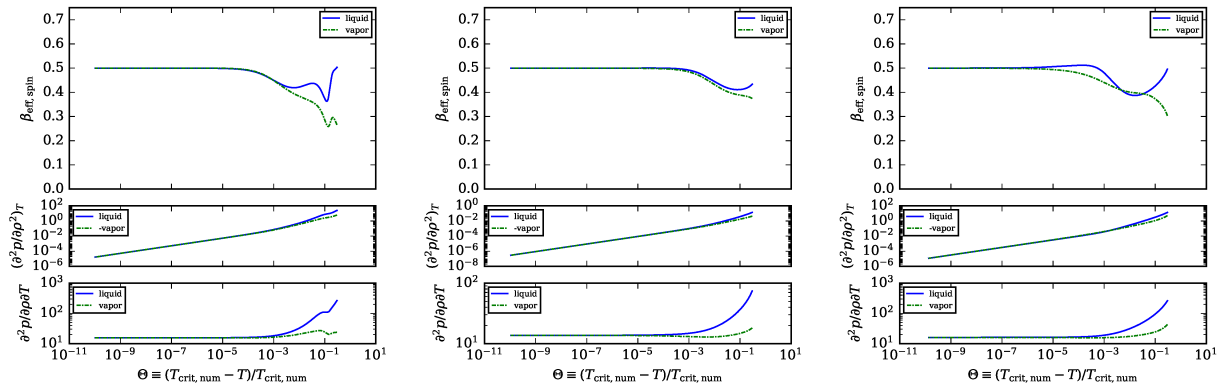


(at) ETHANE (au) ETHANOL (av) ETHYLENE

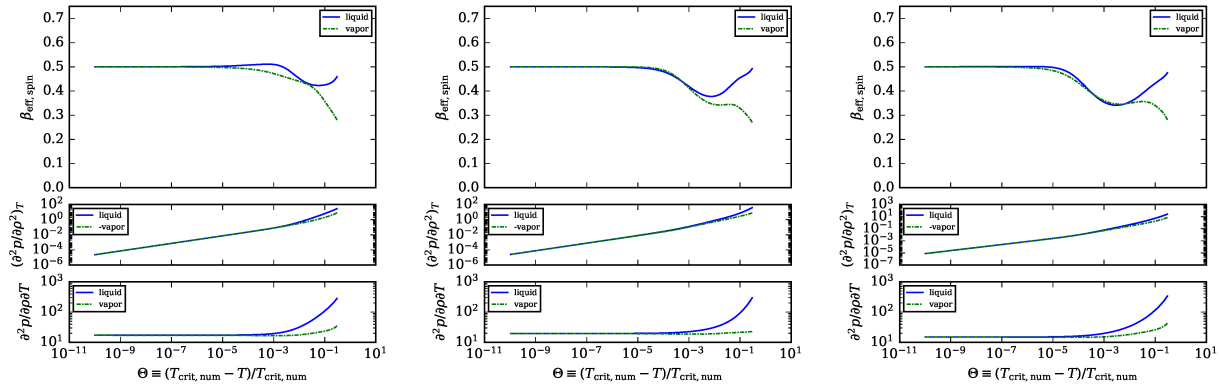
(aw) ETHYLENEOXIDE (ax) FLUORINE (ay) H2S

(az) HCL (ba) HELIUM (bb) HEPTANE

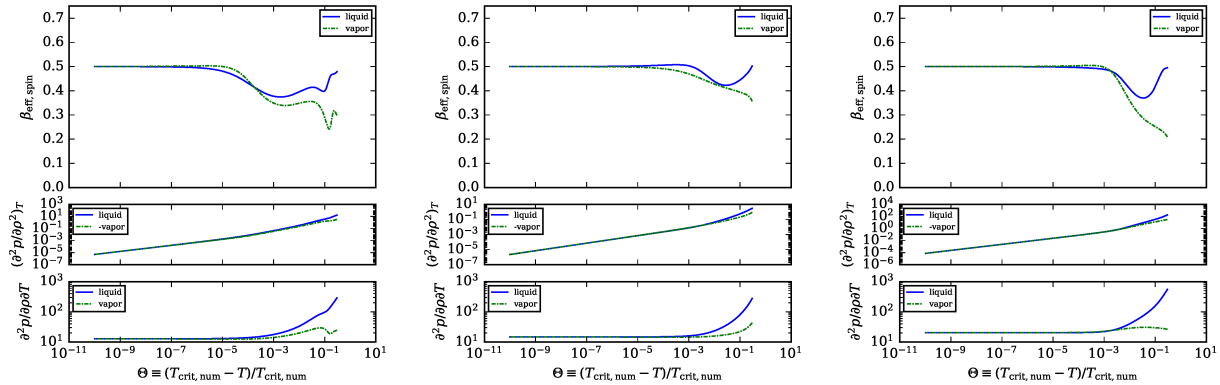
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(bc) HEXANE (bd) HYDROGEN (be) IBUTENE

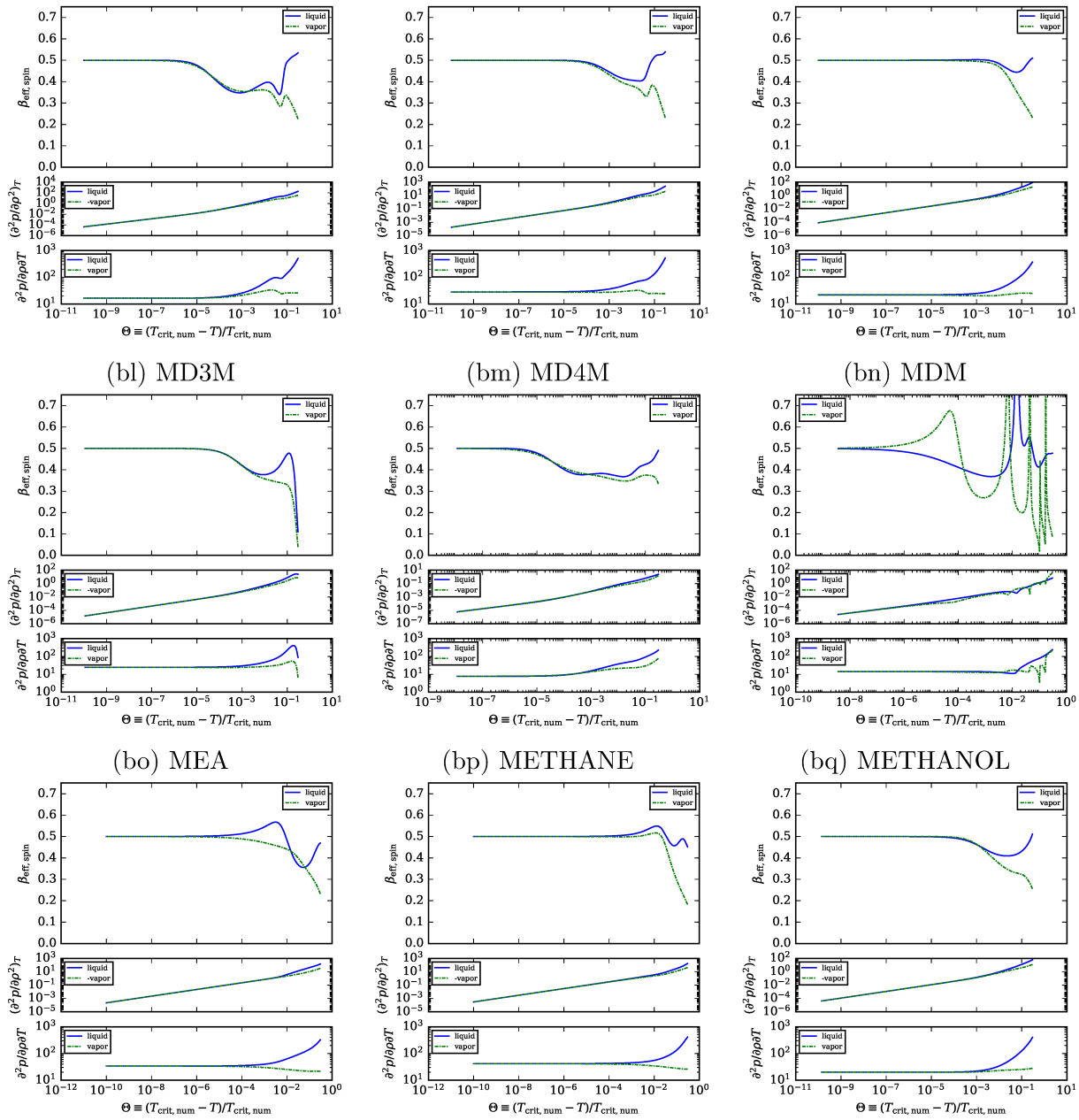


(bf) IHEXANE (bg) IOCTANE (bh) IPENTANE



(bi) ISOBUTAN (bj) KRYPTON (bk) MD2M

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

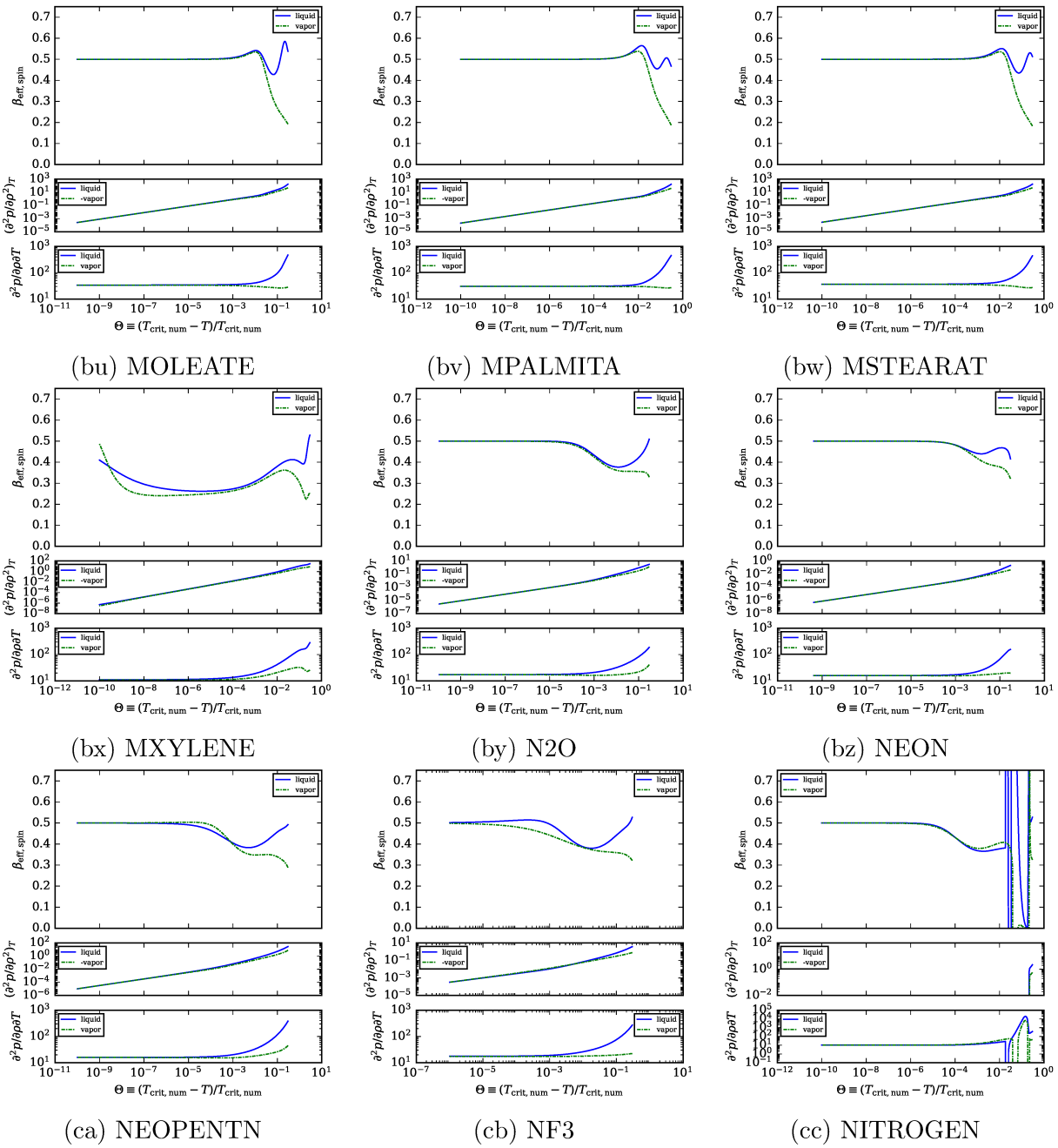


(bl) MD3M (bm) MD4M (bn) MDM

(bo) MEA (bp) METHANE (bq) METHANOL

(br) MLINOLEA (bs) MLINOLEN (bt) MM

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

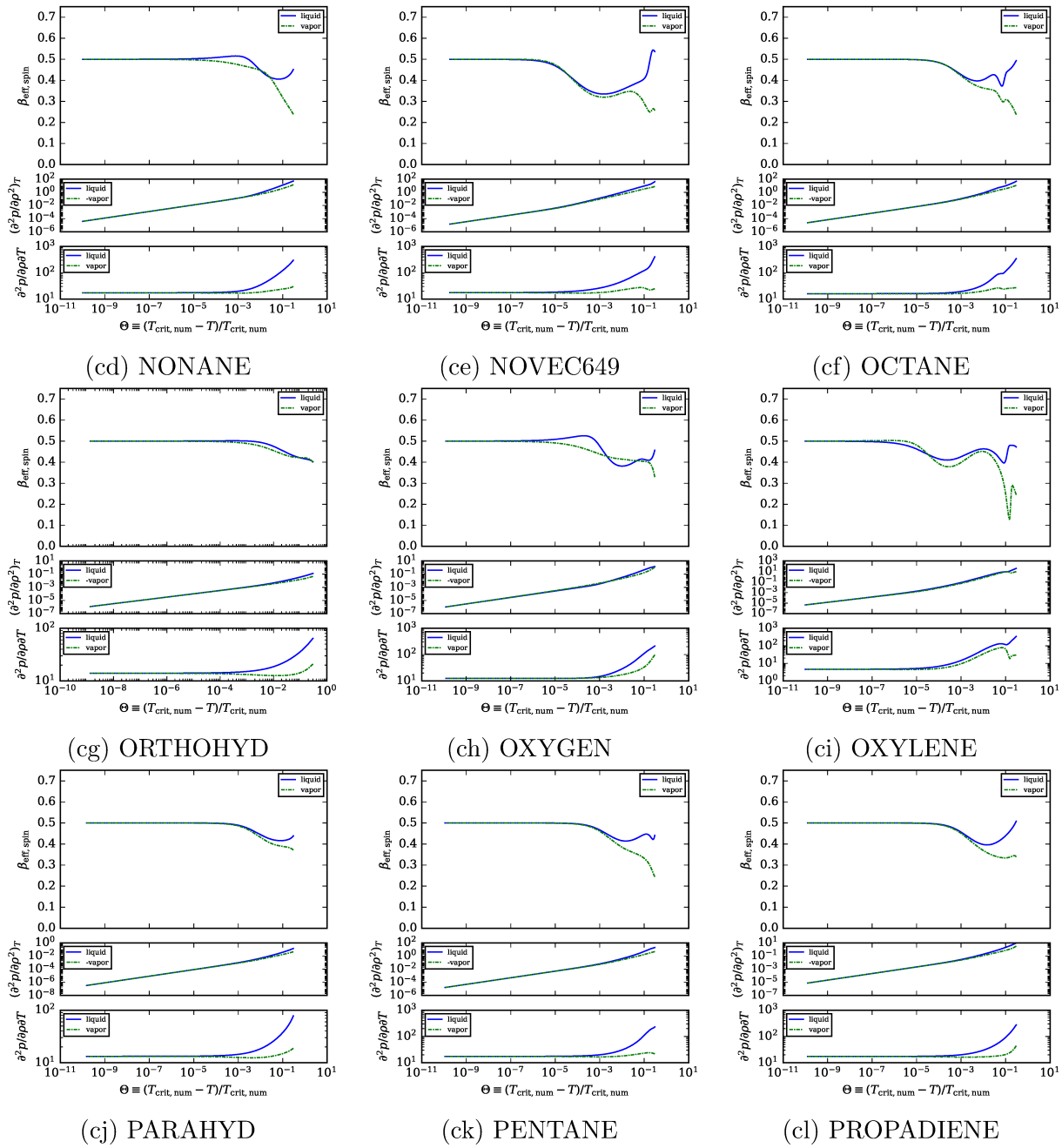


(bu) MOLEATE (bv) MPALMITA (bw) MSTEARAT

(bx) MXYLENE (by) N2O (bz) NEON

(ca) NEOPENTN (cb) NF3 (cc) NITROGEN

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

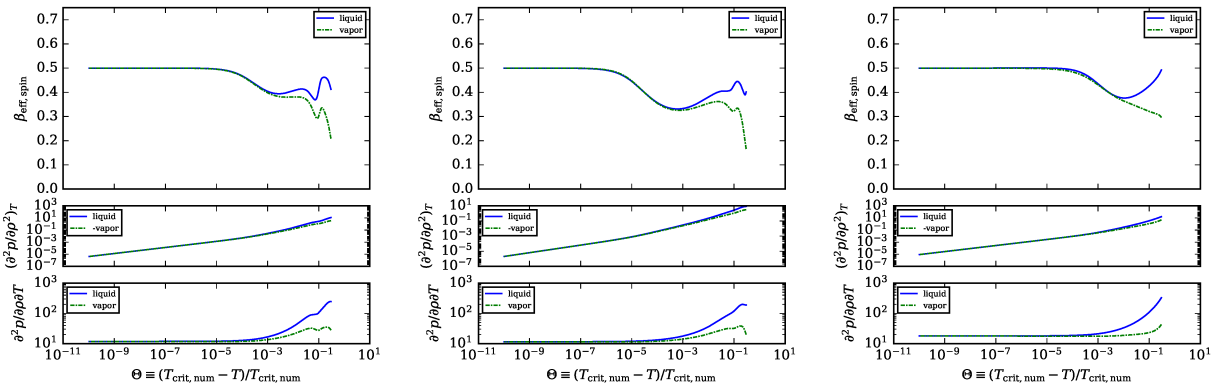


(cd) NONANE (ce) NOVEC649 (cf) OCTANE

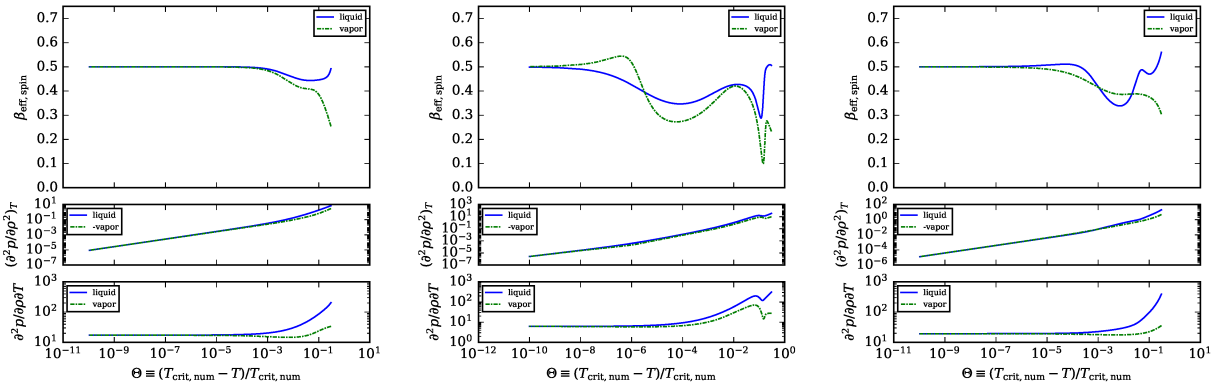
(cg) ORTHOHYD (ch) OXYGEN (ci) OXYLENE

(cj) PARAHYD (ck) PENTANE (cl) PROPADIENE

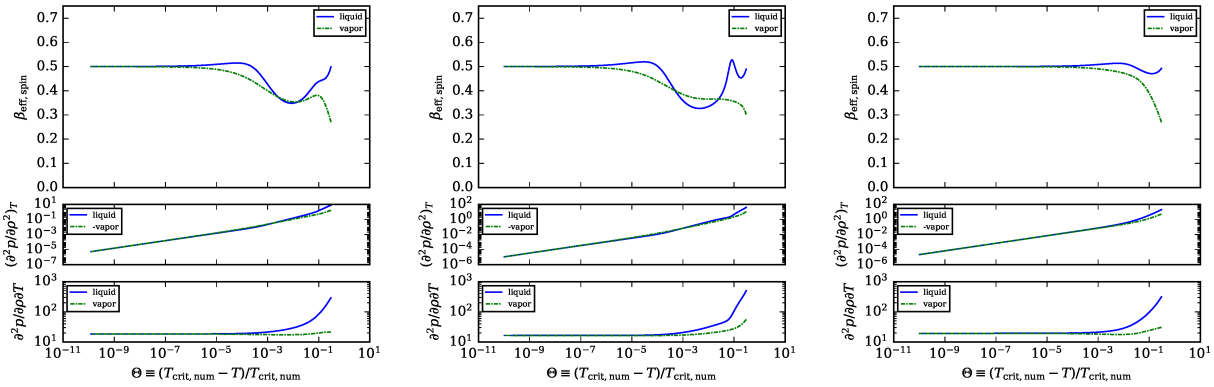
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(cm) PROPANE (cn) PROPYLEN (co) PROPYLENEOXIDE

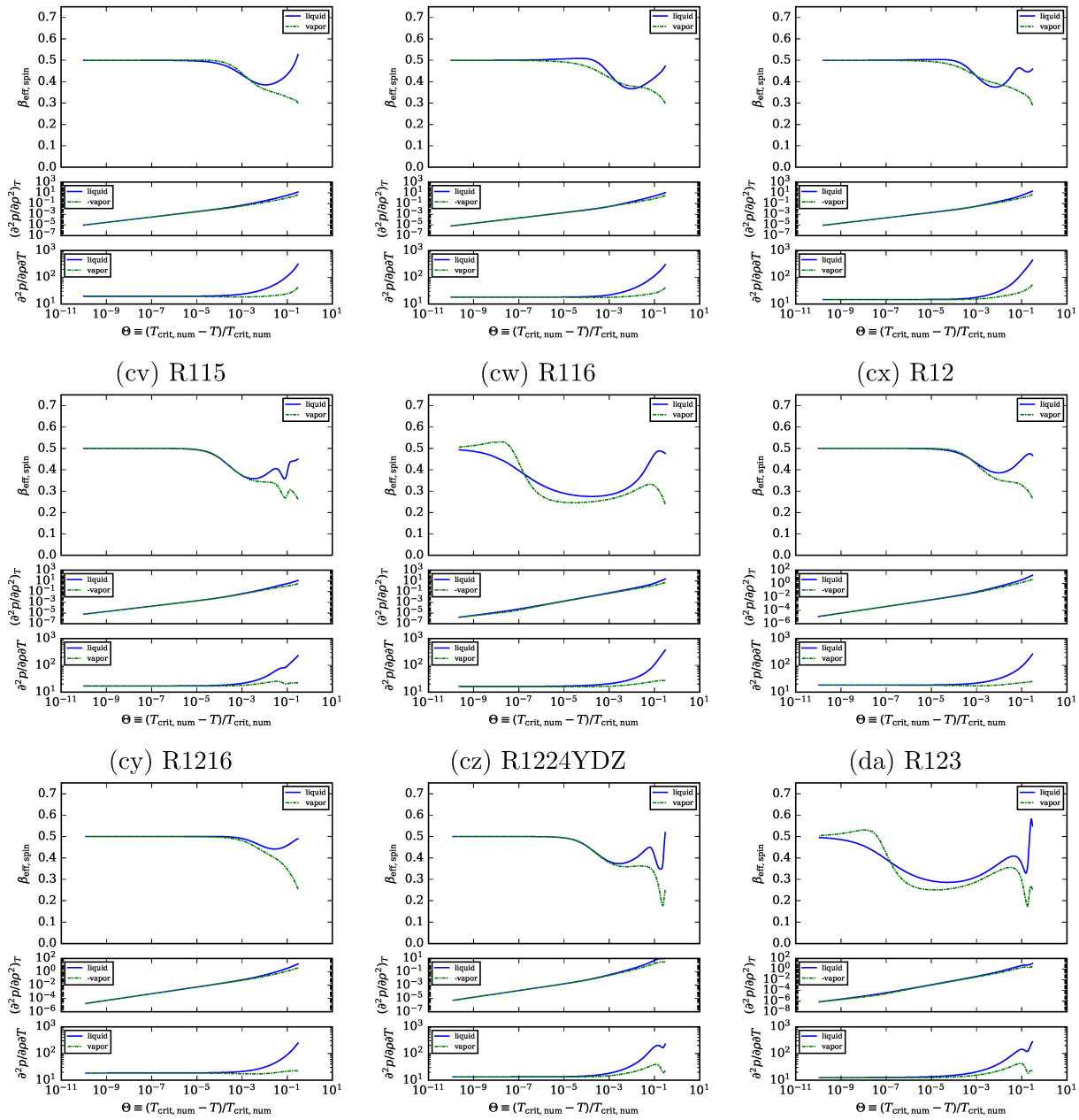


(cp) PROPYNE (cq) PXYLENE (cr) R11



(cs) R1123 (ct) R113 (cu) R114

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

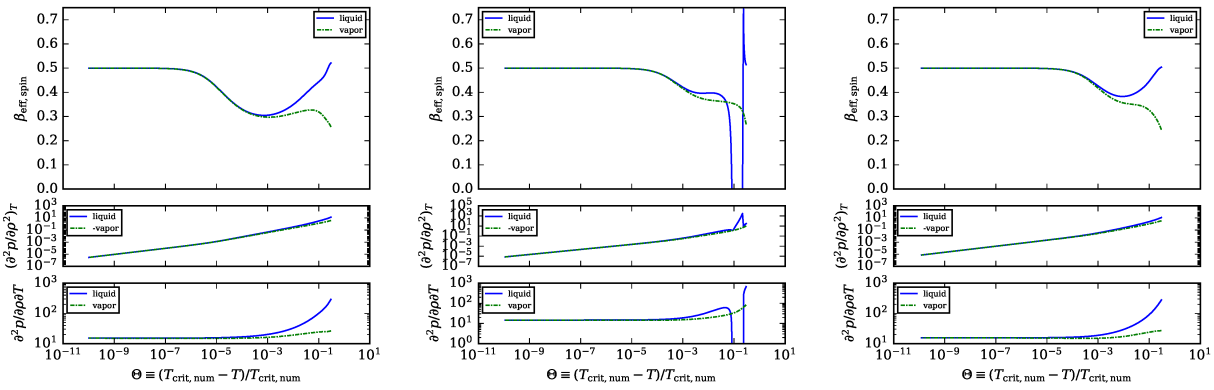


(cv) R115 (cw) R116 (cx) R12

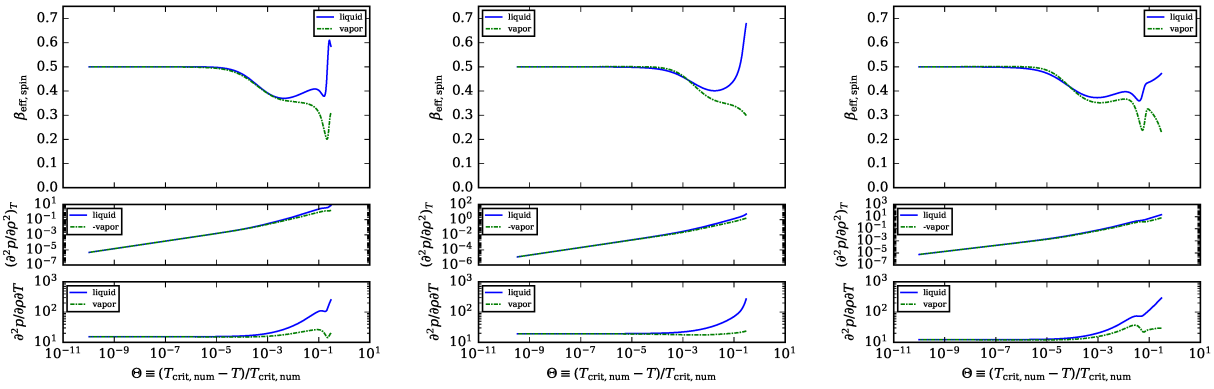
(cy) R1216 (cz) R1224YDZ (da) R123

(db) R1233ZDE (dc) R1234YF (dd) R1234ZEE

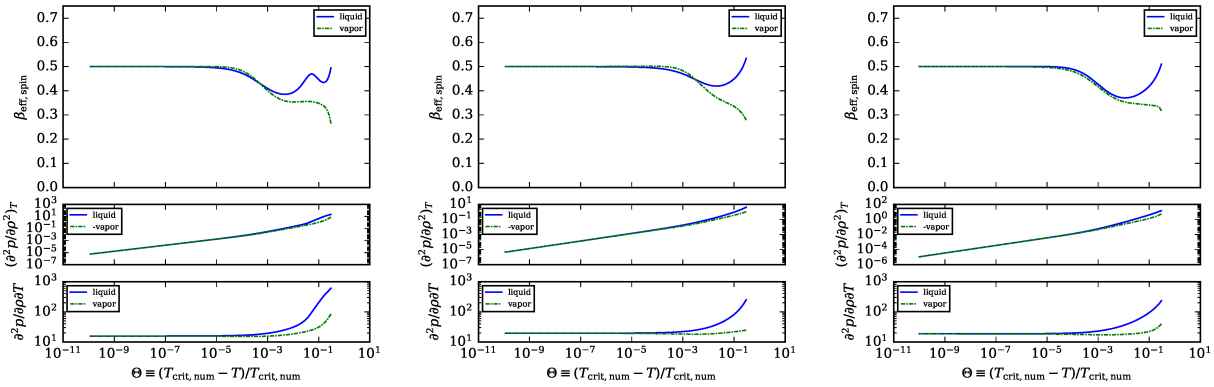
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(de) R1234ZEZ (df) R124 (dg) R1243ZF

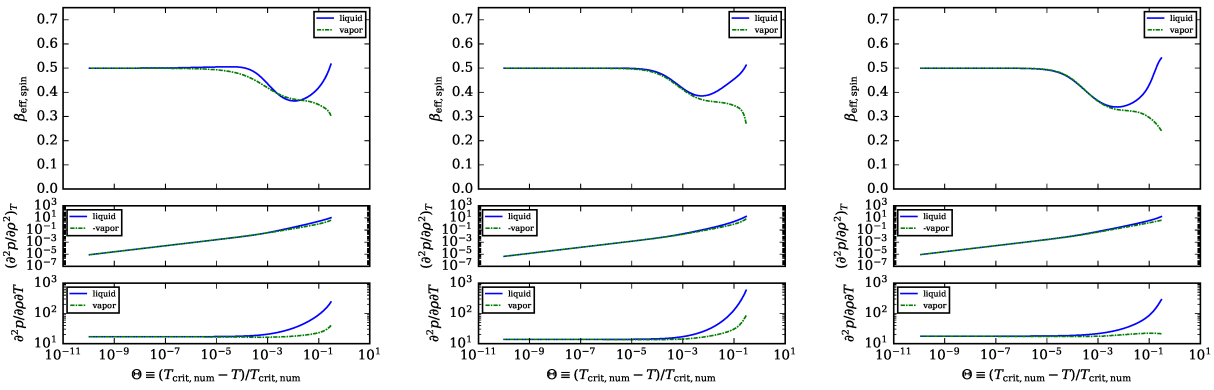


(dh) R125 (di) R13 (dj) R1336MZZZ

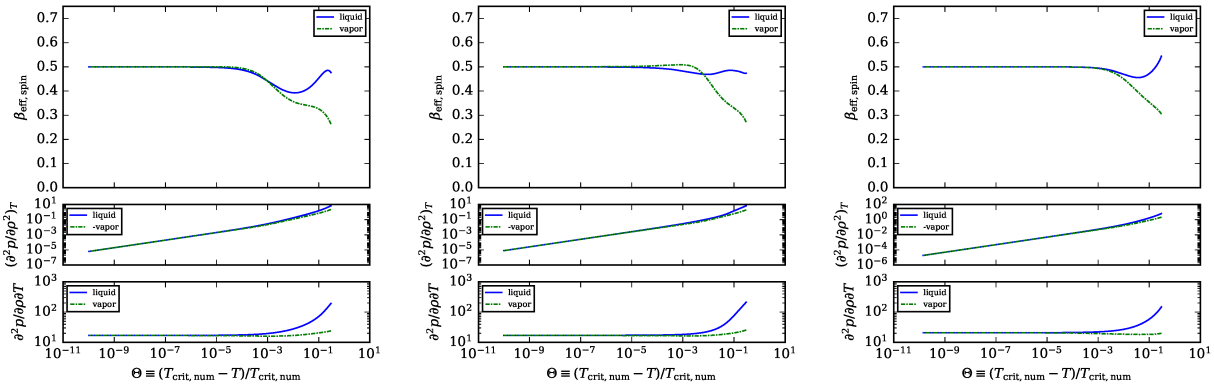


(dk) R134A (dl) R14 (dm) R141B

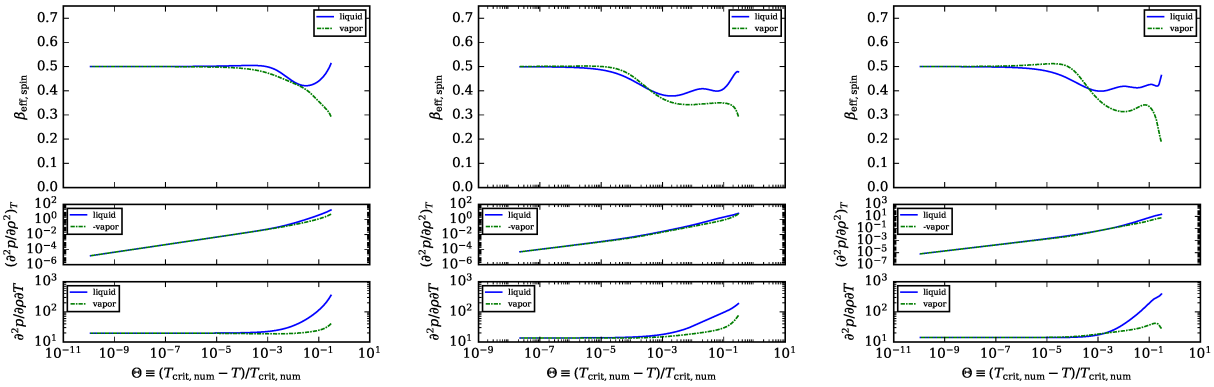
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(dn) R142B (do) R143A (dp) R150

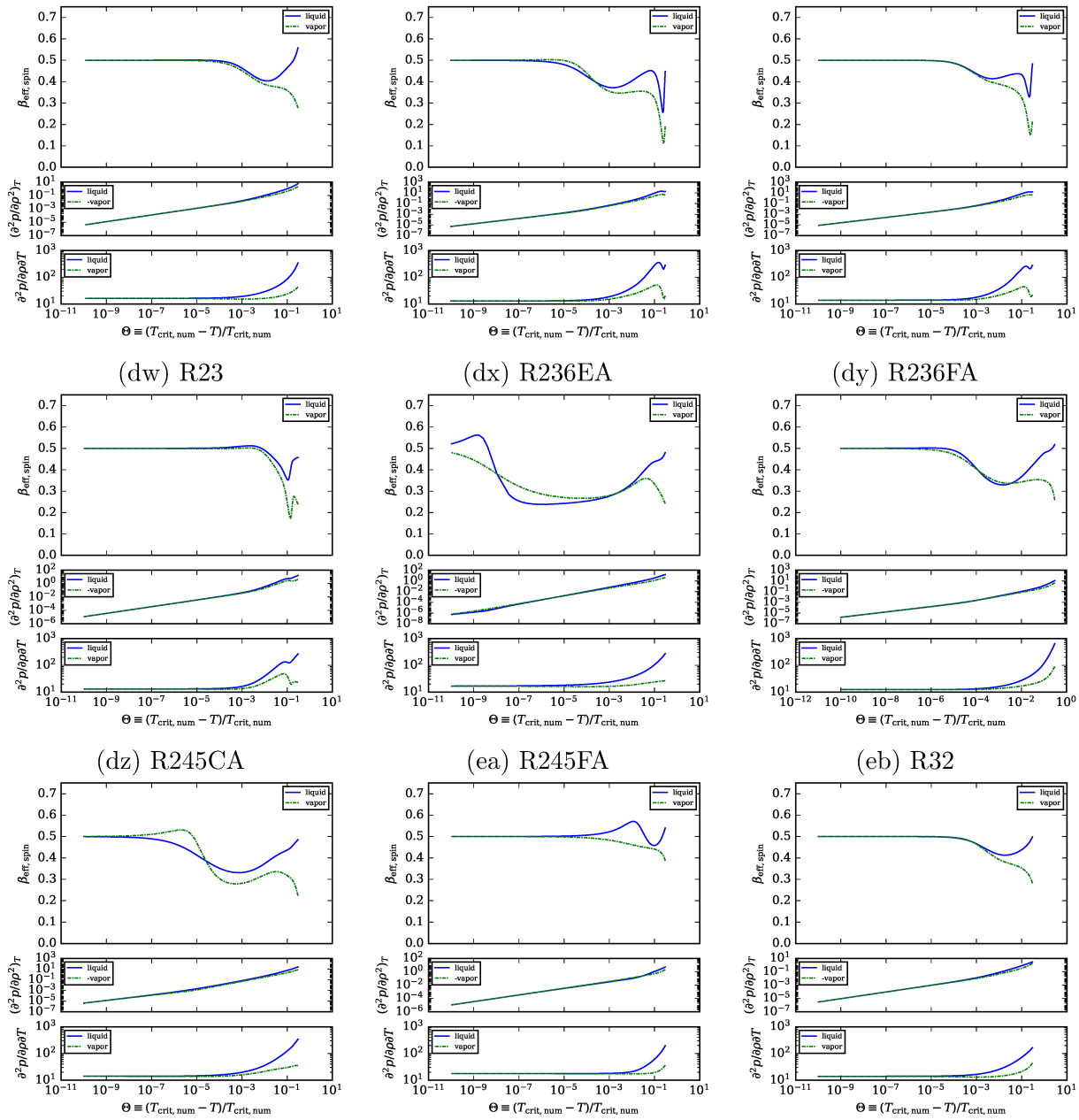


(dq) R152A (dr) R161 (ds) R21



(dt) R218 (du) R22 (dv) R227EA

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

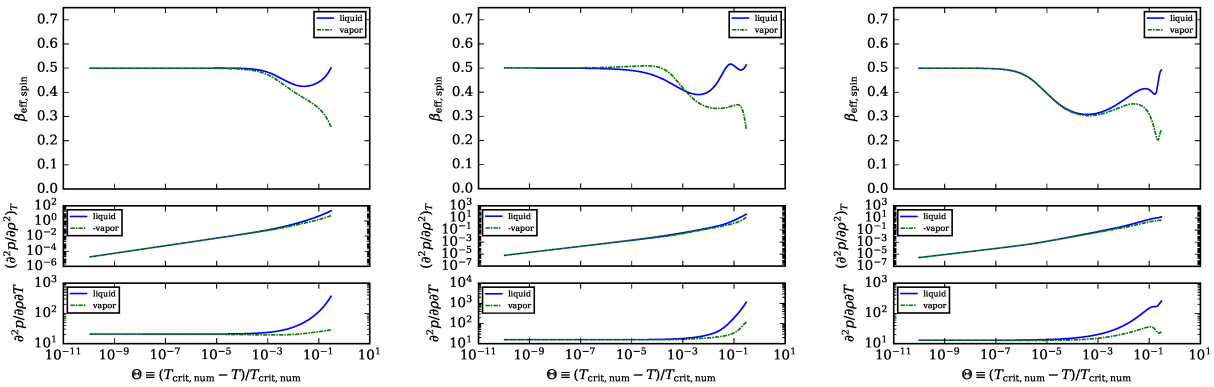


(dw) R23 (dx) R236EA (dy) R236FA

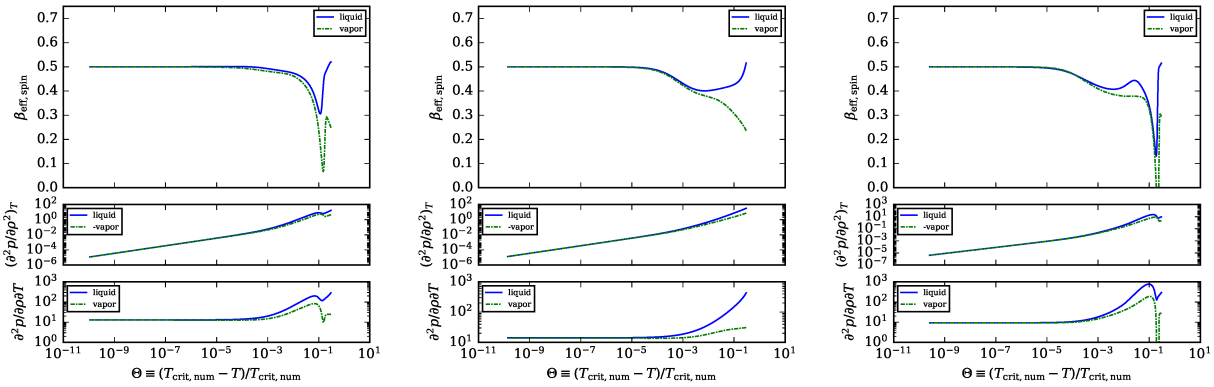
(dz) R245CA (ea) R245FA (eb) R32

(ec) R365MFC (ed) R40 (ee) R41

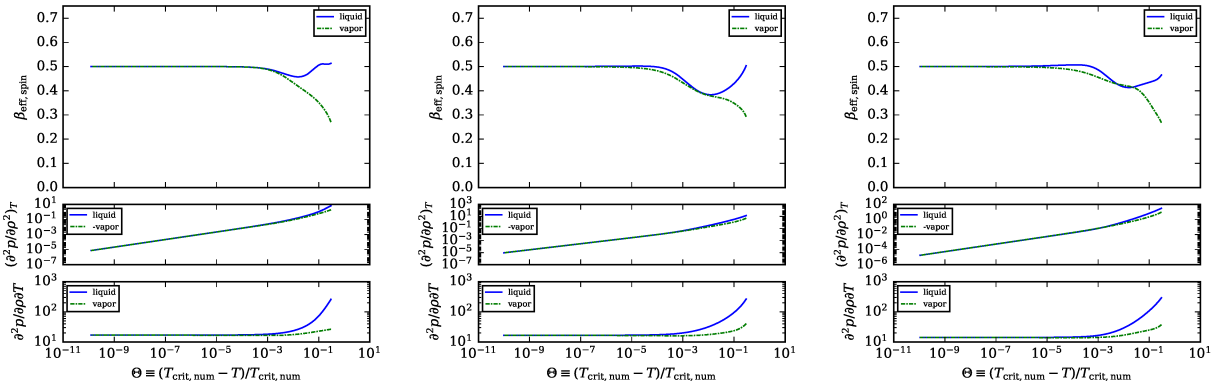
Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(ef) RC318 (eg) RE143A (eh) RE245CB2

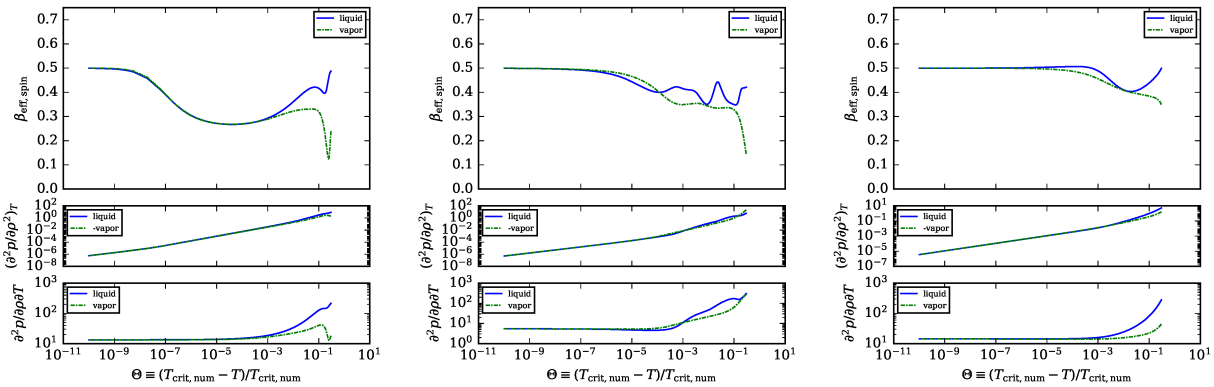


(ei) RE245FA2 (ej) RE347MCC (ek) SF6



(el) SO2 (em) T2BUTENE (en) TOLUENE

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.



(eo) VINYLCHLORIDE (ep) WATER (eq) XENON

Figure S2: Spinodal scaling curves for all fluids in REFPROP 10.0. Formatting follows similar figures in the main manuscript.

Literature Cited

(S1) Lemmon, E. W.; Ihmels, E. C. Thermodynamic properties of the butenes. *Fluid Phase Equilibria* **2005**, *228-229*, 173–187, DOI: 10.1016/j.fluid.2004.09.004.

(S2) Lemmon, E. W.; Span, R. Short Fundamental Equations of State for 20 Industrial Fluids. *Journal of Chemical and Engineering Data* **2006**, *51*, 785–850, DOI: 10.1021/je050186n.

(S3) Tegeler, C.; Span, R.; Wagner, W. A New Equation of State for Argon Covering the Fluid Region for Temperatures From the Melting Line to 700 K at Pressures up to 1000 MPa. *Journal of Physical and Chemical Reference Data* **1999**, *28*, 779–850, DOI: 10.1063/1.556037.

(S4) Bücker, D.; Wagner, W. Reference Equations of State for the Thermodynamic Properties of Fluid Phase n-Butane and Isobutane. *Journal of Physical and Chemical Reference Data* **2006**, *35*, 929–1019, DOI: 10.1063/1.1901687.

(S5) Aleksandrov, I. S.; Gerasimov, A. A.; Grigor'ev, B. A. Using fundamental equations of state for calculating the thermodynamic properties of normal undecane. *Thermal Engineering* **2011**, *58*, 691–698, DOI: 10.1134/s0040601511080027.

(S6) Lemmon, E. W.; Huber, M. L. Thermodynamic Properties of *n*-Dodecane. *Energy and Fuels* **2004**, *18*, 960–967, DOI: 10.1021/ef0341062.

(S7) Lemmon, E. W.; Span, R. Thermodynamic Properties of R-227ea, R-365mfc, R-115, and R-13I1. *Journal of Chemical and Engineering Data* **2015**, *60*, 3745–3758, DOI: 10.1021/acs.jced.5b00684.

(S8) Span, R.; Wagner, W. A New Equation of State for Carbon Dioxide Covering the Fluid Region from the Triple-Point Temperature to 1100 K at Pressures up to 800 MPa. *Journal of Physical and Chemical Reference Data* **1996**, *25*, 1509–1596, DOI: 10.1063/1.555991.

(S9) Zhou, Y.; Liu, J.; Penoncello, S. G.; Lemmon, E. W. An Equation of State for the Thermodynamic Properties of Cyclohexane. *Journal of Physical and Chemical Reference Data* **2014**, *43*, DOI: 10.1063/1.4900538.

(S10) Gedanitz, H.; Davila, M. J.; Lemmon, E. W. Speed of Sound Measurements and a Fundamental Equation of State for Cyclopentane. *Journal of Chemical and Engineering Data* **2015**, *60*, 1331–1337, DOI: 10.1021/je5010164.

(S11) Richardson, I. A.; Leachman, J. W.; Lemmon, E. W. Fundamental Equation of State for Deuterium. *Journal of Physical and Chemical Reference Data* **2014**, *43*, DOI: 10.1063/1.4864752.

(S12) Thol, M.; Rutkai, G.; Köster, A.; Dubberke, F. H.; Windmann, T.; Span, R.; Vrabec, J. Thermodynamic Properties of Octamethylcyclotetrasiloxane. *Journal of*

Chemical and Engineering Data **2016**, *61*, 2580–2595, DOI: 10.1021/acs.jced.6b00261.

(S13) Colonna, P.; Nannan, N.; Guardone, A. Multiparameter equations of state for siloxanes: [(CH3)3-Si-O1/2]2-[O-Si-(CH3)2]i=1,...,3, and [O-Si-(CH3)2]6. *Fluid Phase Equilibria* **2008**, *263*, 115–130, DOI: 10.1016/j.fluid.2007.10.001.

(S14) Thol, M.; Piazza, L.; Span, R. A New Functional Form for Equations of State for Some Weakly Associating Fluids. *International Journal of Thermophysics* **2014**, *35*, 783–811, DOI: 10.1007/s10765-014-1633-1.

(S15) Lemmon, E. W. Thermodynamic Properties of Dimethyl Carbonate. *Journal of Physical and Chemical Reference Data* **2011**, *40*, 043106, DOI: 10.1063/1.3664084.

(S16) Wu, J.; Zhou, Y.; Lemmon, E. W. An Equation of State for the Thermodynamic Properties of Dimethyl Ether. *Journal of Physical and Chemical Reference Data* **2011**, *40*, DOI: 10.1063/1.3582533.

(S17) Zhou, Y.; Wu, J.; Lemmon, E. W. Thermodynamic Properties of *o*-Xylene, *m*-Xylene, *p*-Xylene, and Ethylbenzene. *Journal of Physical and Chemical Reference Data* **2012**, *41*, 023103–023103–26, DOI: 10.1063/1.3703506.

(S18) Bücker, D.; Wagner, W. A Reference Equation of State for the Thermodynamic Properties of Ethane for Temperatures from the Melting Line to 675 K and Pressures up to 900 MPa. *Journal of Physical and Chemical Reference Data* **2006**, *35*, 205–266, DOI: 10.1063/1.1859286.

(S19) Schroeder, J. A.; Penoncello, S. G.; Schroeder, J. S. A Fundamental Equation of State for Ethanol. *Journal of Physical and Chemical Reference Data* **2014**, *43*, DOI: 10.1063/1.4895394.

(S20) Smukala, J.; Span, R.; Wagner, W. New Equation of State for Ethylene Covering the Fluid Region for Temperatures From the Melting Line to 450 K at Pressures up to 300 MPa. *Journal of Physical and Chemical Reference Data* **2000**, *29*, 1053–1121, DOI: 10.1063/1.1329318.

(S21) Thol, M.; Rutkai, G.; Köster, A.; Kortmann, M.; Span, R.; Vrabec, J. Fundamental equation of state for ethylene oxide based on a hybrid dataset. *Chemical Engineering Science* **2015**, *121*, 87–99, DOI: 10.1016/j.ces.2014.07.051.

(S22) Thol, M.; Dubberke, F. H.; Baumhögger, E.; Span, R.; Vrabec, J. Speed of Sound Measurements and a Fundamental Equation of State for Hydrogen Chloride. *Journal of Chemical and Engineering Data* **2018**, *63*, 2533–2547, DOI: 10.1021/acs.jced.7b01031.

(S23) Leachman, J. W.; Jacobsen, R. T.; Penoncello, S. G.; Lemmon, E. W. Fundamental Equations of State for Parahydrogen, Normal Hydrogen, and Orthohydrogen. *Journal of Physical and Chemical Reference Data* **2009**, *38*, 721–748, DOI: 10.1063/1.3160306.

(S24) Thol, M.; Dubberke, F. H.; Baumhögger, E.; Vrabec, J.; Span, R. Speed of Sound Measurements and Fundamental Equations of State for Octamethyltrisiloxane and Decamethyltetrasiloxane. *Journal of Chemical and Engineering Data* **2017**, *62*, 2633–2648, DOI: 10.1021/acs.jced.7b00092.

(S25) Setzmann, U.; Wagner, W. A New Equation of State and Tables of Thermodynamic Properties for Methane Covering the Range from the Melting Line to 625 K at Pressures up to 1000 MPa. *Journal of Physical and Chemical Reference Data* **1991**, *20*, 1061–1155, DOI: 10.1063/1.555898.

(S26) Huber, M. L.; Lemmon, E. W.; Kazakov, A.; Ott, L. S.; Bruno, T. J. Model for the Thermodynamic Properties of a Biodiesel Fuel. *Energy and Fuels* **2009**, *23*, 3790–3797, DOI: 10.1021/ef900159g.

(S27) Thol, M.; Dubberke, F.; Rutkai, G.; Windmann, T.; Köster, A.; Span, R.; Vrabec, J. Fundamental equation of state correlation for hexamethyldisiloxane based on experimental and molecular simulation data. *Fluid Phase Equilibria* **2016**, *418*, 133–151, DOI: 10.1016/j.fluid.2015.09.047.

(S28) McLinden, M. O.; Perkins, R. A.; Lemmon, E. W.; Fortin, T. J. Thermodynamic Properties of 1,1,1,2,2,4,5,5,5-Nonafluoro-4-(trifluoromethyl)-3-pentanone: Vapor Pressure, (p, ρ, T) Behavior, and Speed of Sound Measurements, and an Equation of State. *Journal of Chemical and Engineering Data* **2015**, *60*, 3646–3659, DOI: 10.1021/acs.jced.5b00623.

(S29) Schmidt, R.; Wagner, W. A new form of the equation of state for pure substances and its application to oxygen. *Fluid Phase Equilibria* **1985**, *19*, 175–200, DOI: 10.1016/0378-3812(85)87016-3.

(S30) Lemmon, E. W.; McLinden, M. O.; Wagner, W. Thermodynamic Properties of Propane. III. A Reference Equation of State for Temperatures from the Melting Line to 650 K and Pressures up to 1000 MPa. *Journal of Chemical and Engineering Data* **2009**, *54*, 3141–3180, DOI: 10.1021/je900217v.

(S31) Jacobsen, R.; Penoncello, S.; Lemmon, E. A fundamental equation for trichlorofluoromethane (R-11). *Fluid Phase Equilibria* **1992**, *80*, 45–56, DOI: 10.1016/0378-3812(92)87054-q.

(S32) Younglove, B. A.; McLinden, M. O. An International Standard Equation of State for the Thermodynamic Properties of Refrigerant 123 (2,2-Dichloro-1,1,1-Trifluoroethane). *Journal of Physical and Chemical Reference Data* **1994**, *23*, 731–779, DOI: 10.1063/1.555950.

(S33) Mondéjar, M. E.; McLinden, M. O.; Lemmon, E. W. Thermodynamic Properties of *trans*-1-Chloro-3,3,3-trifluoropropene (R1233zd(E)): Vapor Pressure, (p, ρ, T) Behavior, and Speed of Sound Measurements, and Equation of State. *Journal of Chemical and Engineering Data* **2015**, *60*, 2477–2489, DOI: 10.1021/acs.jced.5b00348.

(S34) Richter, M.; McLinden, M. O.; Lemmon, E. W. Thermodynamic Properties of 2,3,3,3-Tetrafluoroprop-1-ene (R1234yf): Vapor Pressure and p-ρ-T Measurements and an Equation of State. *Journal of Chemical and Engineering Data* **2011**, *56*, 3254–3264, DOI: 10.1021/je200369m.

(S35) Thol, M.; Lemmon, E. W. Equation of State for the Thermodynamic Properties of trans-1,3,3,3-Tetrafluoropropene [R-1234ze(E)]. *International Journal of Thermophysics* **2016**, *37*, DOI: 10.1007/s10765-016-2040-6.

(S36) Lemmon, E. W.; Jacobsen, R. T. A New Functional Form and New Fitting Techniques for Equations of State with Application to Pentafluoroethane (HFC-125). *Journal of Physical and Chemical Reference Data* **2005**, *34*, 69–108, DOI: 10.1063/1.1797813.

(S37) Magee, J. W. *International Journal of Thermophysics* **2000**, *21*, 1097–1121, DOI: 10.1023/a:1026446004383.

(S38) Tillner-Roth, R.; Baehr, H. D. An International Standard Formulation for the Thermodynamic Properties of 1,1,1,2-Tetrafluoroethane (HFC-134a) for Temperatures from 170 K to 455 K and Pressures up to 70 MPa. *Journal of Physical and Chemical Reference Data* **1994**, *23*, 657–729, DOI: 10.1063/1.555958.

(S39) Lemmon, E. W.; Jacobsen, R. T. An International Standard Formulation for the Thermodynamic Properties of 1,1,1-Trifluoroethane (HFC-143a) for Temperatures From 161 to 450 K and Pressures to 50 MPa. *Journal of Physical and Chemical Reference Data* **2000**, *29*, 521–552, DOI: 10.1063/1.1318909.

(S40) Outcalt, S. L.; McLinden, M. O. A Modified Benedict-Webb-Rubin Equation of State for the Thermodynamic Properties of R152a (1,1-difluoroethane). *Journal of Physical and Chemical Reference Data* **1996**, *25*, 605–636, DOI: 10.1063/1.555979.

(S41) Wu, J.; Zhou, Y. An Equation of State for Fluoroethane (R161). *International Journal of Thermophysics* **2012**, *33*, 220–234, DOI: 10.1007/s10765-011-1151-3.

(S42) Kamei, A.; Beyerlein, S. W.; Jacobsen, R. T. Application of nonlinear regression in the development of a wide range formulation for HCFC-22. *International Journal of Thermophysics* **1995**, *16*, 1155–1164, DOI: 10.1007/bf02081283.

(S43) Penoncello, S. G.; Lemmon, E. W.; Jacobsen, R. T.; Shan, Z. A Fundamental Equation for Trifluoromethane (R-23). *Journal of Physical and Chemical Reference Data* **2003**, *32*, 1473–1499, DOI: 10.1063/1.1559671.

(S44) Rui, X.; Pan, J.; Wang, Y. An equation of state for the thermodynamic properties of 1,1,1,2,3,3-hexafluoropropane (R236ea). *Fluid Phase Equilibria* **2013**, *341*, 78–85, DOI: 10.1016/j.fluid.2012.12.026.

(S45) Pan, J.; Rui, X.; Zhao, X.; Qiu, L. An equation of state for the thermodynamic properties of 1,1,1,3,3,3-hexafluoropropane (HFC-236fa). *Fluid Phase Equilibria* **2012**, *321*, 10–16, DOI: 10.1016/j.fluid.2012.02.012.

(S46) Zhou, Y.; Lemmon, E. W. Equation of State for the Thermodynamic Properties of 1,1,2,2,3-Pentafluoropropane (R-245ca). *International Journal of Thermophysics* **2016**, *37*, DOI: 10.1007/s10765-016-2039-z.

(S47) Akasaka, R.; Zhou, Y.; Lemmon, E. W. A Fundamental Equation of State for 1,1,1,3,3-Pentafluoropropane (R-245fa). *Journal of Physical and Chemical Reference Data* **2015**, *44*, DOI: 10.1063/1.4913493.

(S48) Tillner-Roth, R.; Yokozeki, A. An International Standard Equation of State for Difluoromethane (R-32) for Temperatures from the Triple Point at 136.34 K to 435 K and Pressures up to 70 MPa. *Journal of Physical and Chemical Reference Data* **1997**, *26*, 1273–1328, DOI: 10.1063/1.556002.

(S49) Akasaka, R.; Kayukawa, Y. A fundamental equation of state for trifluoromethyl methyl ether (HFE-143m) and its application to refrigeration cycle analysis. *International Journal of Refrigeration* **2012**, *35*, 1003–1013, DOI: 10.1016/j.ijrefrig.2012.01.003.

(S50) Guder, C.; Wagner, W. A Reference Equation of State for the Thermodynamic Properties of Sulfur Hexafluoride (SF6) for Temperatures from the Melting Line to 625K and Pressures up to 150MPa. *Journal of Physical and Chemical Reference Data* **2009**, *38*, 33–94, DOI: 10.1063/1.3037344.

(S51) Gao, K.; Wu, J.; Zhang, P.; Lemmon, E. W. A Helmholtz Energy Equation of State for Sulfur Dioxide. *Journal of Chemical and Engineering Data* **2016**, *61*, 2859–2872, DOI: 10.1021/acs.jced.6b00195.

(S52) Wagner, W.; Pruß, A. The IAPWS Formulation 1995 for the Thermodynamic Properties of Ordinary Water Substance for General and Scientific Use. *Journal of Physical and Chemical Reference Data* **2002**, *31*, 387–535, DOI: 10.1063/1.1461829.

(S53) Span, R.; Lemmon, E. W.; Jacobsen, R. T.; Wagner, W.; Yokozeki, A. A Reference Equation of State for the Thermodynamic Properties of Nitrogen for Temperatures from 63.151 to 1000 K and Pressures to 2200 MPa. *Journal of Physical and Chemical Reference Data* **2000**, *29*, 1361–1433, DOI: 10.1063/1.1349047.