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Orthobaric densities and molar volumes of liquids

Part 2A

C_2 to C_{16} alkenes

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ORTHOBARIC DENSITIES AND MOLAR VOLUMES OF LIQUIDS

PART 2A: C₂ TO C₁₆ ALKENES

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ORTHOBARIC DENSITIES AND MOLAR VOLUMES OF LIQUIDS

PART 2A: C₂ TO C₁₆ ALKENES

1. INTRODUCTION

This Data Item presents orthobaric liquid densities and molar volumes of the C₂ to C₁₆ alkenes listed in Table 1 (pages 2 and 3), with alternative names, if any.

The values of density and molar volume given in the Tables have been obtained by evaluating, for each compound, an equation of the form

$$\ln(d/d_c) = -\ln(V/V_c) = a_1q + a_2q^2 + a_3q^3 + a_4q^4. \quad (1)$$

Equation (1) was fitted to the experimental data that had been selected and weighted in accordance with a critical assessment of all the data (see Sections A.2 and A.3). Table 2 gives the molecular weight, critical temperature, critical density and the coefficients a_1 , a_2 , a_3 and a_4 for each compound to be used in Equation (1).

Tables 3(D) to 11(D) present values of density in kg/m³ from the freezing point, T_f , to the critical point at intervals of 10°C. Tables 3(V) to 11(V) present molar volumes in cm³/mol over the same temperature range at intervals of 10 K.

The number of decimal places in each value of density and molar volume in the Tables indicates the reliability of the experimental data on which the values are based. Values with two decimal places are considered to have an uncertainty between 0.01 and 0.1 per cent. Values with one decimal place are considered to have an uncertainty between 0.1 and 1.0 per cent and values with no decimal places an uncertainty between 1 and 10 per cent.

The sources of experimental data for each compound, on which the tabulated values are based, and the calculation procedure are detailed in Appendix A which also contains a summary of the critical constants of all the compounds.

2. NOTATION

a_1, a_2, a_3, a_4	non-dimensional constants for each compound in Equation (1)	
d	density	kg/m ³
p	saturation pressure	kPa
q	$(1-T_r)^{1/3}$	
M	molecular weight (molar mass)	
R	gas constant, 8.3143	J/(mol K)
T	temperature on the International Practical Temperature Scale 1968, IPTS 68, (273.15 + °C)	K
t	Celsius temperature	°C
V_m	molar volume	cm ³ /mol
Z	compression factor ($pV/1000RT$)	
suffices		
c	denotes value at critical point	
f	denotes value at freezing point	
r	denotes reduced quantity, e.g. $T_r = T/T_c$	

TABLE 1
LIST of COMPOUNDS

The Empirical Formula, Name, Alternative Name, if any, and location of the Tables giving the Saturated Liquid Density, d , and the Saturated Liquid Molar Volume, V_m , for each compound considered in this Data Item are as follows.

No. Emp. Form.	Name	Alternative Names	Table Pages d V_m
C ₂ and C ₃ ALKENES			
1	C ₂ H ₄ Ethylene	Ethene	6 15
2	C ₃ H ₆ Propylene	Propene	6 15
C ₄ ALKENES			
3	C ₄ H ₈ But-1-ene	1-Butene	alpha-Butylene 6 15
4	cis-But-2-ene	cis-2-Butene	6 15
5	trans-But-2-ene	trans-2-Butene	6 15
6	2-Methylpropene	Isobutene	Isobutylene 6 15
C ₅ ALKENES			
7	C ₅ H ₁₀ Pent-1-ene	1-Pentene	alpha-Amylene 7 16
8	cis-Pent-2-ene	cis-2-Pentene	7 16
9	trans-Pent-2-ene	trans-2-Pentene	7 16
10	2-Methylbut-1-ene	2-Methyl-1-butene	7 16
11	3-Methylbut-1-ene	3-Methyl-1-butene	alpha-Isoamylene 7 16
12	2-Methylbut-2-ene	2-Methyl-2-butene	7 16
C ₆ ALKENES			
13	C ₆ H ₁₂ Hex-1-ene	1-Hexene	8 17
14	cis-Hex-2-ene	cis-2-Hexene	8 17
15	trans-Hex-2-ene	trans-2-Hexene	8 17
16	cis-Hex-3-ene	cis-3-Hexene	8 17
17	trans-Hex-3-ene	trans-3-Hexene	8 17
18	2-Methylpent-1-ene	2-Methyl-1-pentene	9 18
19	3-Methylpent-1-ene	3-Methyl-1-pentene	9 18
20	4-Methylpent-1-ene	4-Methyl-1-pentene	9 18
21	2-Methylpent-2-ene	2-Methyl-2-pentene	9 18
22	3-Methyl-cis-pent-2-ene	3-Methyl-cis-2-pentene	9 18
23	3-Methyl-trans-pent-2-ene	3-Methyl-trans-2-pentene	9 18
24	4-Methyl-cis-pent-2-ene	4-Methyl-cis-2-pentene	9 18
25	4-Methyl-trans-pent-2-ene	4-Methyl-trans-2-pentene	9 18
26	2-Ethylbut-1-ene	2-Ethyl-1-butene	10 19
27	2,3-Dimethylbut-1-ene	2,3-Dimethyl-1-butene	10 19
28	3,3-Dimethylbut-1-ene	3,3-Dimethyl-1-butene	10 19
29	2,3-Dimethylbut-2-ene	2,3-Dimethyl-2-butene	10 19
C ₇ ALKENES			
30	C ₇ H ₁₄ Hept-1-ene	1-Heptene	11 20
31	3-Methyl-cis-hex-3-ene	3-Methyl-cis-3-hexene	11 20
32	3-Methyl-trans-hex-3-ene	3-Methyl-trans-3-hexene	11 20
33	2,4-Dimethylpent-1-ene	2,4-Dimethyl-1-pentene	11 20
34	4,4-Dimethylpent-1-ene	4,4-Dimethyl-1-pentene	11 20
35	2,4-Dimethylpent-2-ene	2,4-Dimethyl-2-pentene	12 21
36	4,4-Dimethyl-cis-pent-2-ene	4,4-Dimethyl-cis-2-pentene	12 21
37	4,4-Dimethyl-trans-pent-2-ene	4,4-Dimethyl-trans-2-pentene	12 21
38	3-Methyl-2-ethylbut-1-ene	3-Methyl-2-ethyl-1-butene	12 21
39	2,3,3-Trimethylbut-1-ene	2,3,3-Trimethyl-1-butene	12 21

TABLE 1 continued

LIST of COMPOUNDS continued

The Empirical Formula, Name, Alternative Name, if any, and location of the Tables giving the Saturated Liquid Density, d , and the Saturated Liquid Molar Volume, V_m , for each compound considered in this Data Item are as follows.

No.	Emp. Form.	Name	Alternative Names	Table	
				Pages	d V_m
C ₈ ALKENES					
40	C ₈ H ₁₆	Oct-1-ene	1-Octene	13	22
41		2-Ethylhex-1-ene	2-Ethyl-1-hexene	13	22
42		2,2-Dimethyl-cis-hex-3-ene	2,2-Dimethyl-cis-3-hexene	13	22
43		2,2-Dimethyl-trans-hex-3-ene	2,2-Dimethyl-trans-3-hexene	13	22
44		2-Methyl-3-ethylpent-1-ene	2-Methyl-3-ethyl-1-pentene	13	22
45		2,4,4-Trimethylpent-1-ene	2,4,4-Trimethyl-1-pentene	13	22
46		2,4,4-Trimethylpent-2-ene	2,4,4-Trimethyl-2-pentene	13	22
C ₉ to C ₁₆ ALKENES					
47	C ₉ H ₁₈	Non-1-ene	1-Nonene	14	23
48	C ₁₀ H ₂₀	Dec-1-ene	1-Decene	14	23
49	C ₁₁ H ₂₂	Undec-1-ene	1-Undecene	14	23
50	C ₁₂ H ₂₄	Dodec-1-ene	1-Dodecene	14	23
51	C ₁₃ H ₂₆	Tridec-1-ene	1-Tridecene	14	23
52	C ₁₄ H ₂₈	Tetradec-1-ene	1-Tetradecene	14	23
53	C ₁₅ H ₃₀	Pentadec-1-ene	1-Pentadecene	14	23
54	C ₁₆ H ₃₂	Hexadec-1-ene	1-Hexadecene	14	23

TABLE 2

CONSTANTS in EQUATION (1)

This Table lists the constants for each compound that, when used in Equation (1) gives the Saturated Liquid Density, d , and the Saturated Liquid Molar Volume, V_m , given on pages 6 to 14 and pages 15 to 23 respectively.

No.	Name	T_c K	d_c kg/m ³	a_1	a_2	a_3	a_4
C₂ and C₃ ALKENES							
1	Ethylene	282.34	214.8	1.56028	-0.34759	-0.10133	0.17682
2	Propylene	365.57	229.0	1.61811	-0.35939	-0.22037	0.27819
C₄ ALKENES							
3	But-1-ene	419.95	236	1.65476	-0.34922	-0.34814	0.37545
4	cis-But-2-ene	435.58	242	1.65493	-0.34929	-0.34838	0.37568
5	trans-But-2-ene	428.63	239	1.63176	-0.33929	-0.31626	0.34489
6	2-Methylpropene	417.90	238	1.63935	-0.34259	-0.32677	0.35497
C₅ ALKENES							
7	Pent-1-ene	464.78	238	1.68963	-0.36426	-0.39648	0.42179
8	cis-Pent-2-ene	475.15	244	1.66747	-0.35470	-0.36576	0.39235
9	trans-Pent-2-ene	474.15	241	1.66165	-0.35218	-0.35769	0.38460
10	2-Methylbut-1-ene	470.15	240	1.74777	-0.38933	-0.47705	0.49904
11	3-Methylbut-1-ene	453.15	240	1.63896	-0.34239	-0.32624	0.35445
12	2-Methylbut-2-ene	481.15	240	1.71474	-0.37509	-0.43127	0.45515
C₆ ALKENES							
13	Hex-1-ene	504.03	240	1.70524	-0.37088	-0.41832	0.44264
14	cis-Hex-2-ene	511.15	246	1.67661	-0.35864	-0.37843	0.40449
15	trans-Hex-2-ene	510.15	243	1.67490	-0.35790	-0.37605	0.40220
16	cis-Hex-3-ene	508.15	240	1.72461	-0.37934	-0.44495	0.46826
17	trans-Hex-3-ene	509.15	237	1.74635	-0.38872	-0.47508	0.49715
18	2-Methylpent-1-ene	505.15	242	1.70687	-0.37168	-0.42037	0.44469
19	3-Methylpent-1-ene	495.15	242	1.67833	-0.35937	-0.38080	0.40676
20	4-Methylpent-1-ene	492.15	242	1.66881	-0.35527	-0.36762	0.39413
21	2-Methylpent-2-ene	513.15	242	1.71674	-0.37595	-0.43405	0.45781
22	3-Methyl-cis-pent-2-ene	515.15	248	1.68793	-0.36353	-0.39412	0.41953
23	3-Methyl-trans-pent-2-ene	519.15	245	1.69583	-0.36693	-0.40506	0.43002
24	4-Methyl-cis-pent-2-ene	496.15	240	1.70705	-0.37177	-0.42062	0.44494
25	4-Methyl-trans-pent-2-ene	500.15	237	1.73110	-0.38213	-0.45395	0.47689
26	2-Ethylbut-1-ene	511.15	242	1.73429	-0.38351	-0.45838	0.48113
27	2,3-Dimethylbut-1-ene	501.15	245	1.67264	-0.35692	-0.37293	0.39922
28	3,3-Dimethylbut-1-ene	480.15	243	1.64046	-0.34305	-0.32832	0.35644
29	2,3-Dimethylbut-2-ene	527.15	248	1.70483	-0.37081	-0.41754	0.44199
C₇ ALKENES							
30	Hept-1-ene	537.30	241	1.72155	-0.37802	-0.44071	0.46419
31	3-Methyl-cis-hex-3-ene	544.15	252	1.64479	-0.34491	-0.33433	0.36211
32	3-Methyl-trans-hex-3-ene	542.15	249	1.67009	-0.35582	-0.36938	0.39581
33	2,4-Dimethylpent-1-ene	526.15	249	1.63803	-0.34199	-0.32495	0.35322
34	4,4-Dimethylpent-1-ene	515.15	250	1.60111	-0.32608	-0.27378	0.30416
35	2,4-Dimethylpent-2-ene	526.15	249	1.64142	-0.34345	-0.32965	0.35773
36	4,4-Dimethyl-cis-pent-2-ene	527.15	253	1.61235	-0.33093	-0.28936	0.31930
37	4,4-Dimethyl-trans-pent-2-ene	521.15	250	1.61470	-0.33192	-0.29263	0.32222
38	3-Methyl-2-ethylbut-1-ene	537.15	249	1.67579	-0.35828	-0.37728	0.40339
39	2,3,3-Trimethylbut-1-ene	531.15	255	1.60263	-0.32672	-0.27589	0.30618

TABLE 2 continued

CONSTANTS in EQUATION (1) continued

This Table lists the constants for each compound that, when used in Equation (1) give the Saturated Liquid Density, d , and the Saturated Liquid Molar Volume, V_m , given on pages 6 to 14 and pages 15 to 23 respectively.

No.	Name	T_c K	d_c kg/m ³	a_1	a_2	a_3	a_4
C₈ ALKENES							
40	Oct-1-ene	566.65	242	1.72836	-0.38095	-0.45015	0.47324
41	2-Ethylhex-1-ene	569.15	246	1.72665	-0.38021	-0.44778	0.47097
42	2,2-Dimethyl-cis-hex-3-ene	548.15	256	1.59132	-0.32185	-0.26021	0.29115
43	2,2-Dimethyl-trans-hex-3-ene	546.15	253	1.59206	-0.32219	-0.26123	0.29214
44	2-Methyl-3-ethylpent-1-ene	561.15	250	1.68436	-0.36197	-0.38917	0.41478
45	2,4,4-Trimethylpent-1-ene	550.15	255	1.60869	-0.32934	-0.28429	0.31423
46	2,4,4-Trimethylpent-2-ene	555.15	255	1.62429	-0.33608	-0.30590	0.33496
C₉ to C₁₆ ALKENES							
47	Non-1-ene	592.15	242	1.75635	-0.41548	-0.49857	0.54667
48	Dec-1-ene	616.15	243	1.74865	-0.40356	-0.48427	0.52263
49	Undec-1-ene	638.15	244	1.73816	-0.38821	-0.46585	0.49203
50	Dodec-1-ene	657.15	244	1.75176	-0.40832	-0.48998	0.53221
51	Tridec-1-ene	675.15	244	1.76117	-0.42312	-0.50775	0.56215
52	Tetradec-1-ene	692.15	244	1.76761	-0.43349	-0.52019	0.58324
53	Pentadec-1-ene	707.15	244	1.77340	-0.44296	-0.53156	0.60254
54	Hexadec-1-ene	722.15	244	1.77639	-0.44788	-0.53746	0.61256

TABLE 3(D)

SATURATED LIQUID DENSITY of C₂ to C₄ ALKENESUnits: kg/m³ v. deg.C

No.	1	2	3	4	5	6
	C ₂ H ₄ Ethylene	C ₃ H ₆ Propylene	C ₄ H ₈ But-1-ene	C ₄ H ₈ cis-2-Butene	C ₄ H ₈ trans-2-Butene	C ₄ H ₈ Isobutylene
t _f (deg.C)	-169	-185	-185	-139	-105	-140
d _f (kg/m ³)	654.6	762.0	807.8	787.1	735.5	764.9
t deg.C	d kg/m ³					
-180		756.8	802.9			
-170		746.2	793.1			
-160	643.4	735.7	783.4			
-150	630.6	725.0	773.6			
-140	617.7	714.3	763.8			764.9
-130	604.4	703.5	754.0	778.4		755.1
-120	590.9	692.7	744.1	768.6		745.2
-110	577.0	681.7	734.2	758.9		735.3
-100	562.6	670.6	724.2	749.0	730.6	725.3
-90	547.8	659.3	714.2	739.2	720.9	715.3
-80	532.3	647.9	704.1	729.2	711.0	705.1
-70	516.0	636.2	693.9	719.2	701.1	694.9
-60	498.8	624.4	683.6	709.1	691.1	684.5
-50	480.5	612.2	673.2	698.9	681.0	674.0
-40	460.5	599.8	662.6	688.5	670.7	663.4
-30	438.4	587.0	651.8	678.1	660.2	652.6
-20	413.1	573.7	640.9	667.4	649.6	641.6
-10	382.5	560.0	629.7	656.6	638.8	630.3
0	340.7	545.6	618.3	645.5	627.7	618.8
10		530.5	606.6	634.2	616.4	607.0
20		514.6	594.5	622.7	604.8	594.8
30		497.5	582.0	610.8	592.8	582.1
40		478.9	569.1	598.5	580.4	569.0
50		458.4	555.6	585.7	567.4	555.3
60		435.0	541.3	572.5	553.9	540.9
70		407.1	526.3	558.6	539.8	525.6
80		370.8	510.2	543.9	524.7	509.2
90		306.1	492.9	528.4	508.6	491.4
100			474.	512.	491.	472.
110			452.	493.	472.	450.
120			427.	473.	450.	423.
130			395.	450.	424.	390.
140			349.	422.	392.	337.
150				386.	343.	
160				321.		
t _c (deg.C)	9.195	92.42	146.8	162.43	155.48	144.75
d _c (kg/m ³)	214.8	229.0	236.	242.	239.	238.

TABLE 4(D)

SATURATED LIQUID DENSITY of C₅ ALKENESUnits: kg/m³ v. deg.C

7	C ₅ H ₁₀	Pent-1-ene	1-Pentene		alpha-Amylene		
8		cis-Pent-2-ene	cis-2-Pentene				
9		trans-Pent-2-ene	trans-2-Pentene				
10		2-Methylbut-1-ene	2-Methyl-1-butene				
11		3-Methylbut-1-ene	3-Methyl-1-butene		alpha-Isoamylene		
12		2-Methylbut-2-ene	2-Methyl-2-butene				
No.		7	8	9	10	11	12
t _f (deg.C)		-165	-151	-140	-137	-168	-134
d _f (kg/m ³)		817.	820.	797.	819.	807.	808.
t							
deg.C					d		
					kg/m ³		
-160		813.				800.	
-150		803.	819.			791.	
-140		794.	810.	797.		781.	
-130		785.	800.	789.	812.	772.	804.
-120		776.	791.	780.	802.	763.	795.
-110		766.	782.	771.	792.	754.	786.
-100		757.	773.2	762.	783.	745.	777.
-90		748.	764.1	753.	773.	736.	767.
-80		739.	754.9	744.	763.	726.	758.
-70		729.	745.7	735.	754.	717.	749.
-60		720.	736.4	725.	744.	707.	739.
-50		710.	727.0	716.	734.	698.	730.
-40		701.	717.6	707.	724.	688.	721.
-30		691.	708.1	697.	714.	678.	711.
-20		681.	698.4	688.	704.	669.	702.
-10		671.	688.7	678.	694.	659.	692.
0		661.2	678.8	668.6	683.4	648.3	682.0
10		651.0	668.8	658.7	672.9	637.9	672.1
20		640.54	658.60	648.60	662.30	627.20	662.00
30		629.9	648.2	638.3	651.5	616.3	651.7
40		619.0	637.6	627.8	640.4	605.1	641.3
50		607.9	626.7	617.1	629.1	593.5	630.6
60		596.4	615.6	606.1	617.5	581.6	619.6
70		584.5	604.1	594.7	605.5	569.2	608.3
80		572.2	592.2	582.9	593.1	556.3	596.7
90		559.4	579.9	570.7	580.2	542.7	584.7
100		546.	567.	558.	567.	528.	572.
110		532.	553.	545.	553.	513.	559.
120		517.	539.	530.	537.	497.	545.
130		500.	524.	515.	521.	479.	531.
140		482.	508.	499.	504.	458.	515.
150		463.	490.	481.	485.	435.	498.
160		440.	470.	462.	463.	407.	480.
170		412.	447.	439.	437.	368.	459.
180		376.	420.	411.	405.	240.	434.
190		305.	384.	374.	358.		404.
200			316.	296.			361.
t _c (deg.C)		191.63	202	201	197	180	208
d _c (kg/m ³)		238.	244.	241.	240.	240.	240.

TABLE 5(D)

SATURATED LIQUID DENSITY of C₆ ALKENES-IUnits: kg/m³ v. deg.C

	13	14	15	16	17
	C ₆ H ₁₂	Hex-1-ene	1-Hexene		
		cis-Hex-2-ene	cis-2-Hexene		
		trans-Hex-2-ene	trans-2-Hexene		
		cis-Hex-3-ene	cis-3-Hexene		
		trans-Hex-3-ene	trans-3-Hexene		
No.	13	14	15	16	17
t _f (deg.C)	-140	-141	-133	-138	-113
d _f (kg/m ³)	816.	829.	811.	821.	797.
t			d		
deg.C			kg/m ³		
-140	816.	828.			
-130	807.	819.	809.	814.	
-120	798.	811.	800.	806.	
-110	790.	802.	792.	797.	794.
-100	781.	794.	783.	788.	785.
-90	772.	785.	775.	779.	776.
-80	763.	776.	766.	770.	768.
-70	755.	768.	758.	762.	759.
-60	746.	759.	749.	753.	750.
-50	737.0	750.3	740.3	743.9	740.9
-40	728.1	741.5	731.6	735.0	732.0
-30	719.2	732.7	722.9	726.0	723.0
-20	710.2	723.7	714.0	717.0	714.0
-10	701.1	714.8	705.2	707.8	704.9
0	691.9	705.7	696.2	698.7	695.7
10	682.6	696.5	687.1	689.4	686.4
20	673.21	687.19	677.88	679.96	677.03
30	663.68	677.76	668.55	670.44	667.54
40	654.0	668.2	659.1	660.8	657.9
50	644.1	658.4	649.4	650.9	648.1
60	634.1	648.5	639.6	640.9	638.2
70	623.8	638.4	629.6	630.7	628.0
80	613.3	628.0	619.3	620.2	617.6
90	602.4	617.4	608.7	609.5	606.9
100	591.	606.	598.	598.	596.
110	580.	595.	587.	587.	585.
120	568.	583.	575.	575.	573.
130	555.	571.	563.	563.	561.
140	542.	558.	550.	550.	548.
150	528.	545.	537.	536.	534.
160	513.	531.	523.	522.	520.
170	497.	515.	507.	506.	504.
180	480.	499.	491.	489.	488.
190	460.	481.	473.	470.	469.
200	437.	460.	452.	449.	448.
210	410.	436.	428.	423.	423.
220	373.	407.	398.	391.	392.
230	293.	364.	354.	340.	344.
t _c (deg.C)	230.88	238	237	235	236
d _c (kg/m ³)	240.	246.	243.	240.	237.