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Volumetric behaviour of the ternary liquid system composed of methyl *tert*-butyl ether, toluene, and isooctane at temperatures from (298.15 to 328.15) K: Experimental data and correlation

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1. Introduction

Research activities of our laboratory comprise, among others, the systematic measurement of volumetric properties of different groups of organic compounds. Our present project is devoted to the systematic study of liquid systems modelling liquid engine fuels. After measuring (cyclohexane + alkane) at normal pressure and temperature 298.15 K [1], (cyclohexane + nonane) at temperatures from (298.15 to 328.15) K and at pressures up to 40 MPa [2] (octane + benzene, or +toluene, or +1,3-xylene, or +1,3,5-trimethylbenzene) at temperatures between (298.15 and 328.15) K [3], and (octane + benzene) at temperatures from (298.15 to 328.15) K and at pressures up to 40 MPa [4], the binary [5] and ternary systems containing methyl tert-butyl ether (MTBE) have been studied with the aim to decide what and how many ternary constants, in addition to the binary constants, are needed to fit the ternary data to Redlich-Kister equation within the error of experimental results. This measurement is also of practical importance with respect to use of MTBE as the liquid fuel antiknock additive.

ABSTRACT

The densities and speeds of sound of (methyl *tert*-butyl ether {MTBE} + toluene + isooctane) were measured at four temperatures over the range (298.15 to 328.15) K and the respective values of excess volumes V_m^E and adiabatic compressibility κ_s were calculated. The V_m^E and κ_s values for the ternary and corresponding binaries were fitted to the Redlich–Kister equation considering various numbers of ternary constants. The necessary number of ternary constants needed to describe the system is discussed. © 2010 Elsevier Ltd. All rights reserved.

> The thorough literature search showed that there exist no ternary data for this system. However, to be able to do the test, we needed a most accurate and mutually consistent binary (and ternary) data. Not finding such data sets, we decided to measure the title binary systems [5] as the first step followed by the ternary data measurements described in this work.

> The densities and excess volumes of the investigated liquids and their mixtures are required, for instance, for relating excess enthalpy and excess Gibbs energy values. From a practical point of view, the data are useful for the design of mixing, storage, and process equipment. Last but not least, the data measured reflect interactions between the molecules of the mixtures studied and can serve for testing the theories of the liquid state.

2. Experimental

2.1. Materials

The chemicals used in the experiments were the following products from Fluka: MTBE (methyl *tert*-butyl ether, methyl 1,1-dimethylethyl ether), puriss., g.c. mass fraction purity ≥ 0.95 , toluene, RdH, for chromatography, g.c. mass fraction purity ≥ 0.995 , isooctane (2,2,4-trimethylpentane), RdH puriss. p.a., g.c. mass fraction purity ≥ 0.995 . The substances were used without further



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TABLE 1

Densities ρ and refractive index values n_D at T = 298.15 K of the pure components, and their comparison with literature; w is the mass fraction purity as determined by g.l.c.

| Component | $\rho/(g \cdot cm^{-3})$ | $\rho/(g \cdot cm^{-3})$ | | | n _D | | |
|-----------|--------------------------|--------------------------|-----------|--------------|----------------|-----------|--------|
| | Experimental | Literature | Reference | Experimental | Literature | Reference | |
| Toluene | 0.86219 | 0.8623 | [5] | 1.4941 | 1.49414 | [5] | 0.9995 |
| Isooctane | 0.68779 | 0.68781 | [5] | 1.38905 | 1.38898 | [5] | 0.9996 |
| MTBE | 0.73527 | 0.7353 | [6] | 1.36648 | 1.3664 | [6] | 0.9989 |

TABLE 2

Experimental values of density ρ , calculated excess molar volume V_m^E , speed of sound u and adiabatic compressibility κ_5 for (x_1 MTBE + x_2 toluene + x_3 isooctane) at temperature T and atmospheric pressure; $x_3 = 1 - x_1 - x_2$.

| | x_2/x_3 | <i>x</i> ₁ | <i>x</i> ₂ | $ ho/(g \cdot cm^{-3})$ | $V_{\rm m}^{\rm E}/({\rm cm^3\cdot mol^{-1}})$ | $u/(\mathbf{m} \cdot \mathbf{s}^{-1})$ | $10^4 \kappa_{\rm S}/{ m MPa^{-1}}$ |
|---|-----------|-----------------------|-----------------------|-------------------------|--|--|--------------------------------------|
| 2.88855 0.0000 0.41365 0.8002 0.659 1242.3 8.77 0.01062 0.6592 0.7838 0033 1242.3 8.73 0.291.43 0.29643 0.2962 0.7838 0033 113.04 9.74 0.421.43 0.22647 0.7832 0142 113.04 9.74 0.69137 0.22647 0.77542 0174 10733 11.07 0.8938 0.41675 0.77562 0174 10733 11.07 0.8938 0.41675 0.74252 0033 11.62.0 8.81 0.8939 0.44567 0.74252 0037 11.83 10.07 0.29311 0.39347 0.75123 0.053 11.83 10.07 0.29311 0.39347 0.75123 0.053 11.28 10.34 0.29311 0.39477 0.73742 0.007 1092.8 11.02 0.29311 0.39477 0.73743 0.007 1093.8 11.02 0.29311 | | | | T = 298.1 | 5 K | | |
| 0.1002 0.65025 0.78450 -0.033 1285.6 9.77 0.20785 0.58962 0.78122 -0.142 1171.0 9.31 0.445.31 0.42527 0.778122 -0.142 1151.0 8.74 0.4011 0.22687 0.77812 -0.142 1151.0 8.74 0.0011 0.22687 0.77928 -0.174 1093.1 11.07 0.89853 0.14575 0.74923 -0.174 1093.4 12.266 0.89857 0.73527 0.000 1165.0 12.06 12.06 0.89857 0.73527 0.000 1162.0 13.13 10.07 0.20508 0.4650 0.7313.2 0.033 13.13 10.27 0.40500 0.2391.0 0.73847 -0.014 1076.2 11.44 0.50068 0.24740 -0.007 1004.5 11.20 11.20 0.50068 0.24740 -0.014 1076.2 11.44 11.31 0.50068 0.24957 0.2727 </th <td>2.89955</td> <td>0.00000</td> <td>0.74356</td> <td>0.80092</td> <td>0.059</td> <td>1221.3</td> <td>8.37</td> | 2.89955 | 0.00000 | 0.74356 | 0.80092 | 0.059 | 1221.3 | 8.37 |
| 0.297850.288020.78838-0.0331135.60.020.291430.528620.77542-0.1741131.00.31610.13100.316130.77543-0.1741131.110.160.13110.316130.77543-0.1741133.110.160.13110.316130.77542-0.1741133.110.160.89380.140750.77542-0.0831156.712.060.89390.140750.77542-0.0831153.810.010.89390.495050.751330.00331123.810.0270.298400.205110.393470.751230.0531135.310.270.205110.393470.751230.0531143.810.070.205310.235230.744620.017114410.770.205320.246650.77343-0.0171162.211.840.407040.295240.77743-0.0171062.211.840.707980.44650.74747-0.0171062.211.840.707980.245110.77743-0.0171062.211.840.707980.228120.7784-0.1311118.211.370.999510.229110.77970.1331167.111.460.999760.229770.1381079.111.470.999780.229780.77970.1381167.111.470.999780.229710.7397.40.13111.62.212.280.999780.26972 </th <td></td> <td>0.10802</td> <td>0.66325</td> <td>0.79450</td> <td>-0.033</td> <td>1202.9</td> <td>8.70</td> | | 0.10802 | 0.66325 | 0.79450 | -0.033 | 1202.9 | 8.70 |
| 0.29143 0.25827 -0.142 1171.0 9.31 0.40525 0.46237 0.7589 -0.174 115.0 9.75 0.51144 0.36357 0.7689 -0.194 113.3 10.65 0.40137 0.27565 -0.194 113.3 10.65 0.7133 0.27463 0.7555 -0.073 1005.4 12.65 0.80000 0.40500 0.7527 0.000 105.64 12.65 0.28012 0.80899 0.45560 0.7518 0.078 115.18 10.01 0.20511 0.3944 0.7512 0.003 115.18 10.01 0.20511 0.3944 0.7462 0.017 114.4 10.49 0.40704 0.23958 0.20068 0.7462 0.017 116.24 11.62 0.20511 0.34431 0.74757 0.000 1075.2 11.64 0.40706 0.4456 0.7417 -0.049 1075.2 11.64 0.407076 0.1152 0.1256 | | 0.20785 | 0.58902 | 0.78838 | -0.093 | 1185.6 | 9.02 |
| 040256 04223 0.7794 -0.74 11504 974 0.51104 0.63017 0.25507 0.76288 -0.194 1131.3 10.56 0.71135 0.2463 0.7566 -0.174 1093.3 11.54 0.80307 0.07327 0.000 1095.4 12.26 0.80000 0.4500 0.7544 0.101 116.2.0 9.81 0.80000 0.4500 0.7318 0.073 117.3 10.04 0.80000 0.4500 0.7318 0.073 117.4 10.07 0.8000 0.4500 0.7318 0.077 10.04 10.7 0.26368 0.24716 0.7463 0.007 11.44 10.7 0.26368 0.24716 0.7467 0.007 10.06.8 11.30 0.77756 0.14456 0.7477 0.017 11.44 10.7 0.26368 0.27416 0.7397 0.017 11.43 11.2 0.77756 0.132 11.27 11.44 | | 0.29143 | 0.52687 | 0.78322 | -0.142 | 1171.0 | 9.31 |
| 0.5104 0.2637 0.7609 -0.194 111.1 10.16 0.71135 0.21463 0.7556 -0.174 1093.3 11.07 0.8038 0.4757 0.7425 -0.083 1057.5 1246 0.8038 0.4757.5 0.7425 -0.083 1057.5 1246 0.8038 0.45500 0.7544 0.000 106.4 1246 0.26511 0.39347 0.7523 0.003 113.5 10.01 0.26514 0.34841 0.7464 0.017 114.4 10.77 0.26614 0.4456 0.7474 0.017 114.4 10.77 0.26613 0.24574 0.2477 0.017 116.4 10.77 0.26633 0.04576 0.73747 -0017 1062 11.64 0.81430 0.04576 0.73743 -0007 1063 12.31 0.10000 0.73743 -0017 1062 11.41 0.81430 0.04571 0.7377 0.0103 11.11 <th></th> <th>0.40526</th> <th>0.44223</th> <th>0.77594</th> <th>-0.174</th> <th>1150.4</th> <th>9.74</th> | | 0.40526 | 0.44223 | 0.77594 | -0.174 | 1150.4 | 9.74 |
| 060317 0.25907 0.7528 -0.194 113.9 10.56 0.71135 0.2163 0.7523 -0.134 1075.2 11.34 0.80398 0.1475 0.7425 -0.083 1075.2 11.34 0.80807 0.07520 0.73327 0.000 1075.4 12.66 0.98020 0.00000 0.4550 0.75318 0.073 115.8 10.01 0.20511 0.3947 0.75123 0.033 118.53 10.01 0.20511 0.39481 0.24661 0.0731 112.4 11.67 0.20518 0.24615 0.7400 0.007 10908 11.30 0.20756 0.14465 0.7374 -0.017 1062.2 11.90 0.73757 0.030 0.4655 0.2311 11.12 11.13 0.90603 0.46451 0.7374 -0.017 1062.2 11.90 0.73757 0.133 10161 11.22 11.22 11.22 0.90603 0.46651 < | | 0.51104 | 0.36357 | 0.76909 | -0.194 | 1131.1 | 10.16 |
| 0.1135 0.000000.21463 0.075420.7566 0.74223-0.174 0.08331093 1055.71.154 1.2660.98020 0.000000.49500 0.075420.74250 0.0203-0.083 0.07531165.7 12.0612.060.98020 0.025110.39347 0.0251310.075 0.075330.073 0.07331135.5 10.0110.01 1162.09.81 0.0730.20511 0.0296310.39347 0.0293220.74762 0.0170.017 1114.410.77 10.02661.04 0.023311.02 11.020.20561 0.0296300.20008 0.0446010.0074 0.007441005.2 11.0211.92 11.920.30963 0.046510.27347 0.0007-0.0071095.8 11.3411.34 1.020.39926 0.000000.246510.73747 0.73747-0.0071095.8 11.3411.37 1.020.39926 0.0000010.2233220.73527 0.737470.0061045.5 1.361.36 1.360.39926 0.0000010.233220.7357 0.737470.10111.82 1.3611.37 1.360.39926 0.0200340.04617 0.737470.131 0.13111.64 1.56 1.361.36 1.360.39926 0.0200440.239347 0.027370.138 0.131106.65 1.361.36 1.360.39926 0.0200540.06975 0.027070.138 0.13111.62 1.361.36 1.36 1.360.39926 0.0200540.06975 0.027070.138 0.131106.65 1.361.36 1.36 1.360.49927 0.020050.66225 0.027070 | | 0.60317 | 0.29507 | 0.76298 | -0.194 | 1113.9 | 10.56 |
| 88029 0.14675 0.7423 -0.134 10752 11.54 0.98020 0.08989 0.74259 -0.083 1036.4 12.66 0.08989 0.45050 0.7518 0.078 1151.8 10.01 0.20511 0.39381 0.7462 0.033 1127.8 10.47 0.20514 0.34831 0.74654 0.033 1127.8 10.47 0.40704 0.23522 0.74762 0.017 114.8 10.67 0.50808 0.24716 0.7487 0.002 1102.8 11.30 0.50958 0.20061 0.73747 -0.017 116.2 11.31 0.50958 0.20071 0.038 11.32 11.31 0.14455 0.74173 -0.017 10635 12.31 0.10000 0.23322 0.71851 0.101 1118.2 11.31 0.1101 11182 11.31 1.326 11.32 0.13926 0.23322 0.7387 0.131 11.62 11.32 | | 0.71135 | 0.21463 | 0.75566 | -0.174 | 1093.3 | 11.07 |
| 0.389270.075420.74259-0.0831065712.660.880200.055180.011115.09.810.280110.393470.751230.073113.510.010.295140.393470.751230.073113.510.270.295140.393470.751230.073113.510.270.295140.393470.74620.073114.410.770.295630.20080.747620.017114.410.770.50060.247620.747620.0071090.811.320.5035900.20080.74400-0.0071090.81.330.7079500.14650.73743-0.0171062.211.840.814630.091760.73743-0.009103.412.860.392660.000000.233220.718510.1011110.211.720.039510.228110.719670.1311110.211.720.999510.228110.719670.1331102.212.860.239260.000500.15820.17331077.911.870.499330.126860.725250.1731077.911.870.499330.126860.725270.1331061.612.180.499350.126860.725270.1331064.512.860.499350.49580.728770.1331064.512.860.499350.495760.75947-0.1331064.512.860.499950.495760.7594 | | 0.80398 | 0.14575 | 0.74923 | -0.134 | 1075.2 | 11.54 |
| 0.38020 0.00000 1036.4 12.66 0.38020 0.000089 0.45050 0.75131 0.078 1151.8 10.01 0.29134 0.34831 0.74054 0.033 1122.8 10.47 0.20151 0.34831 0.74052 0.013 1122.8 10.47 0.20568 0.24716 0.74752 0.017 1102.8 11.27 0.20588 0.20088 0.74762 0.014 10752.2 11.84 0.20795 0.14456 0.7473 -0.014 10752.2 11.84 0.80603 0.46651 0.73743 -0.009 1045.5 12.31 0.3926 0.20000 0.23322 0.73527 0.0001 11.82 11.37 0.3926 0.26944 0.72951 0.151 11.91 11.82 11.37 0.3926 0.06000 0.25332 0.7207 0.153 1065.1 12.36 0.39392 0.12686 0.72328 0.059 1145.4 3.45 0.49932 | | 0.89857 | 0.07542 | 0.74259 | -0.083 | 1056.7 | 12.06 |
| 0.980200.000000.495000.754640.1011162.09.810.000000.025110.293470.751380.00331138.510.270.205110.293470.751230.0331138.510.270.205630.201060.744520.0071102.811.020.500580.241650.745720.0071090.811.020.500580.200060.74407-0.0071090.211.640.707960.14650.74737-0.0171062.211.640.814630.091760.73737-0.0071096.312.310.390200.096010.255320.718510.101118.211.370.0909510.228110.719670.1311110.211.270.197780.228110.729760.1311110.211.560.4999210.12850.721720.1311102.911.600.4999230.12860.722770.1551065.911.520.4999230.12860.722770.1551064.912.660.4999230.128690.72870.0901064.912.660.4999230.128690.72870.0901164.99.450.4999230.128690.72870.0901164.99.450.4999230.128690.72870.0901164.99.450.4999230.128690.72870.0901164.99.450.4999230.128690.72870.1311161.212.66< | | 1.00000 | | 0.73527 | 0.000 | 1036.4 | 12.66 |
| 0.488890.450500.735130.0781151.810.010.205110.29340.248310.749640.0331127.810.490.407040.295320.747620.0021102.811.020.500680.247160.745870.0021102.811.020.595800.20080.74400-0.0071090.811.300.595800.20080.74400-0.0141076.211.640.595800.00680.74173-0.0141076.211.640.596300.046510.73734-0.0091095.512.311.00000.253320.718570.1011118.211.131.00000.253520.71870.131110.211.270.999510.2210.719670.131110211.270.191780.204740.722190.1711094.511.560.400450.151880.723720.1751085.911.720.400450.151880.723720.1331061.612.180.606220.099750.727070.1581069.112.030.6967680.752850.727070.1381061.612.180.809830.048170.739384-0.0591164.49.450.209440.15880.722920.1001052.212.360.209550.727070.1581069.612.1811.640.42950.424570.47343-0.0591164.49.450.209450.42457 | 0.98020 | 0.00000 | 0.49500 | 0.75464 | 0.101 | 1162.0 | 9.81 |
| 0.29510.293470.71230.0331138.510.270.296340.34810.748640.0331137.810.490.497040.293520.747620.0171114.410.770.500680.270080.74407-0.0071090.811.300.570560.148650.74173-0.0171062.211.940.91630.04550.73747-0.0171062.211.940.91630.0291760.73743-0.0071064.512.310.906910.025320.718510.1011118.211.130.909510.222110.718510.101118.211.370.909510.222110.718510.1011102.911.400.490230.126860.723720.1731065.911.720.490230.126860.723720.1731075.911.870.696720.097580.727070.1581069.912.360.490230.126860.728720.1731075.911.870.696720.02780.728770.1331061.612.860.898250.027680.728770.1331061.612.860.898250.025780.72874-0.0591163.412.660.180020.639760.72874-0.0591163.412.660.180020.639760.72874-0.0251169.515.650.180030.442730.7644-0.2051166.916.750.180040.5357 <t< th=""><td></td><td>0.08989</td><td>0.45050</td><td>0.75318</td><td>0.078</td><td>1151.8</td><td>10.01</td></t<> | | 0.08989 | 0.45050 | 0.75318 | 0.078 | 1151.8 | 10.01 |
| 0.429634 0.34831 0.74962 0.033 112.78 10.49 0.450704 0.23952 0.74762 0.017 111.44 10.77 0.55958 0.2008 0.74400 -0.007 1092.8 11.30 0.57956 0.14456 0.74173 -0.014 1062.2 11.91 0.81633 0.019176 0.73743 -0.009 1045.5 12.31 1.0000 0.23332 0.71851 0.101 1118.2 11.13 0.09963 0.23322 0.71851 0.101 1118.2 11.13 0.09951 0.22811 0.71976 0.13 1110.2 11.27 0.09953 0.19788 0.72219 0.17 1108.5 11.56 0.19178 0.20474 0.72081 0.152 1102.9 11.87 0.40945 0.15188 0.72377 0.138 1065.1 12.03 0.606762 0.09975 0.72707 0.158 1061.6 12.18 0.606762 0.09975 0 | | 0.20511 | 0.39347 | 0.75123 | 0.053 | 1138.5 | 10.27 |
| 0.40704 0.23352 0.74762 0.017 1114.4 10.77 0.50068 0.24716 0.74587 0.02 1102.8 11.02 0.57076 0.14456 0.74173 -0.017 106.82 11.30 0.81463 0.09176 0.73733 -0.007 109.85 12.31 0.0000 0.25332 0.73577 0.000 103.64 12.66 0.0000 0.25332 0.71851 0.101 118.2 11.31 0.0000 0.25332 0.72197 0.131 1110.2 11.72 0.01951 0.22811 0.71967 0.131 1102.9 11.40 0.49923 0.12686 0.72377 0.133 1061.6 12.18 0.40045 0.17815 0.72707 0.133 1061.6 12.18 0.40045 0.07658 0.72807 0.133 1061.6 12.18 0.40045 0.07658 0.72807 0.133 1061.6 12.18 0.406052 0.02458 0.72807 | | 0.29634 | 0.34831 | 0.74964 | 0.033 | 1127.8 | 10.49 |
| 0.50088 0.24716 0.74487 0.002 1102.8 11.02 0.50580 0.20008 0.74400 0.077 1090.8 11.30 0.70796 0.14456 0.71373 0.014 10762 11.94 0.90603 0.04651 0.73373 0.009 10455 12.31 0.00900 0.25332 0.71851 0.101 11182 11.13 0.03951 0.22811 0.71967 0.131 11102 11.27 0.111 0.1182 0.12332 0.173 10029 11.46 0.22654 0.12353 0.72219 0.173 10845 11.56 0.40923 0.12686 0.72527 0.103 1065.1 12.03 0.40923 0.12686 0.7257 0.133 1061.6 12.18 0.40923 0.02578 0.72897 0.103 1052.2 12.36 0.40923 0.02578 0.73527 0.000 1036.4 12.66 0.108000 0.74356 0.73547< | | 0.40704 | 0.29352 | 0.74762 | 0.017 | 1114.4 | 10.77 |
| 8,59580 0.20008 0.74400 -0.0074 1090.8 11.30 0.70795 0.14456 0.73173 -0.0174 1062.2 11.99 0.90600 0.04651 0.73737 -0.009 1049.5 12.31 1.00000 0.25332 0.71851 0.101 1118.2 11.32 0.09951 0.22811 0.71957 0.131 1102.9 11.40 0.19178 0.20474 0.72081 0.152 1002.9 11.40 0.29534 0.17835 0.72219 0.171 1064.5 11.56 0.40045 0.15188 0.72372 0.175 1085.9 11.72 0.40045 0.15188 0.72377 0.133 1061.6 12.18 0.60622 0.09975 0.73077 0.158 109.12 12.38 0.8083 0.04817 0.73087 0.0059 1044.8 2.50 0.11802 0.66325 0.75842 -0.059 1064.9 9.58 0.11902 0.66325 0 | | 0.50068 | 0.24716 | 0.74587 | 0.002 | 1102.8 | 11.02 |
| 0.3926 0.014456 0.71733 -0.017 10622 11.99 0.30603 0.04651 0.73733 -0.009 1036.4 12.31 0.33926 0.00000 0.25332 0.71851 0.101 1118.2 11.39 0.33926 0.00900 0.25332 0.71851 0.101 1118.2 11.31 0.1971 0.22811 0.71897 0.131 1110.2 11.27 0.1977 0.23954 0.1783 0.72219 0.1715 1084.3 11.56 0.49923 0.12686 0.72370 0.158 1061.6 12.18 0.69768 0.07638 0.72370 0.158 1063.1 12.03 0.69768 0.07638 0.72370 0.158 1061.6 12.18 0.69768 0.02578 0.73287 0.100 1052.2 12.36 0.10602 0.66325 0.78542 -0.025 1166.4 9.45 0.20755 0.58902 0.77917 -0.118 1142.8 9.36 | | 0.59580 | 0.20008 | 0.74400 | -0.007 | 1090.8 | 11.30 |
| 83463 0.09176 0.73947 -0.017 1062.2 11.99 0.0000 0.73527 0.000 1036.4 12.66 0.33926 0.0000 0.25332 0.71831 0.101 1118.2 11.37 0.0951 0.22811 0.71957 0.131 1102.9 11.40 0.29392 0.1978 0.72219 0.171 1094.5 11.56 0.40045 0.15188 0.72372 0.175 1085.9 11.72 0.40045 0.15188 0.72377 0.133 1061.6 12.18 0.69622 0.09975 0.72707 0.158 1069.1 12.03 0.8983 0.04817 0.73907 0.100 1052.2 12.36 0.8983 0.04817 0.73907 0.100 1054.4 12.69 1.00000 0.74356 0.72807 0.7352 0.000 1160.4 9.45 0.29850 0.62780 0.73527 0.000 1161.4 9.45 0.20805 0.44816 | | 0.70796 | 0.14456 | 0.74173 | -0.014 | 1076.2 | 11.64 |
| 0.00603 0.04651 0.73743 -0.009 1049.5 12.31 0.33926 0.00000 0.25332 0.71851 0.101 1118.2 11.13 0.13926 0.009951 0.22811 0.71967 0.131 1110.2 11.27 0.1978 0.20474 0.7201 0.152 1102.9 11.40 0.40953 0.1758 0.72219 0.175 1085.9 11.72 0.40952 0.12686 0.72525 0.173 1077.9 11.87 0.60672 0.09975 0.128 1066.1 12.18 0.60978 0.07588 0.72877 0.133 1061.6 12.18 0.80893 0.04817 0.73907 0.100 1052.2 12.36 0.80825 0.02578 0.73277 0.138 1164.9 9.45 0.1000 0.74355 0.7527 0.030 1054.4 12.66 0.20785 0.58902 0.7917 -0.118 1142.8 9.83 0.20785 0.58902 <td></td> <td>0.81463</td> <td>0.09176</td> <td>0.73947</td> <td>-0.017</td> <td>1062.2</td> <td>11.99</td> | | 0.81463 | 0.09176 | 0.73947 | -0.017 | 1062.2 | 11.99 |
| 1.0000 0.73527 0.000 1036.4 12.66 0.33926 0.00000 0.25332 0.71851 0.101 1118.2 11.13 0.43926 0.09951 0.22811 0.71957 0.131 1102.9 11.40 0.25594 0.17835 0.72219 0.171 1094.5 11.56 0.40045 0.15188 0.72272 0.173 1077.9 11.87 0.40045 0.15188 0.722707 0.158 1066.1 12.18 0.60622 0.09975 0.72707 0.133 1061.6 12.18 0.80983 0.04817 0.73997 0.100 1052.2 12.36 0.80983 0.04817 0.73927 0.100 1054.4 12.66 0.80993 0.04817 0.73927 0.100 1054.4 12.66 0.80983 0.04817 0.73927 0.100 1054.4 12.66 0.80993 0.2045 0.79920 0.744 0.205 10.616 12.18 0.20143< | | 0.90603 | 0.04651 | 0.73743 | -0.009 | 1049.5 | 12.31 |
| 0.33926 0.00000 0.23322 0.71851 0.01 11182 11.13 0.19178 0.22811 0.72957 0.1311 1110.2 11.27 0.29594 0.17835 0.72219 0.171 1094.5 11.56 0.40045 0.13188 0.72372 0.173 1087.9 11.87 0.40045 0.13886 0.72575 0.173 1077.9 11.87 0.60622 0.09975 0.72077 0.158 1069.1 12.03 0.60622 0.02578 0.72877 0.130 1061.6 12.18 0.80983 0.04817 0.73288 0.090 1048.8 12.60 0.89825 0.02578 0.78542 -0.000 1064 266 0.20785 0.58902 0.77117 -0.118 1142.8 9.83 0.20785 0.58902 0.77917 -0.172 1127.9 10.16 0.20785 0.5897 0.7324 -0.226 1106.9 10.65 0.20143 0.52687 </th <td></td> <td>1.00000</td> <td></td> <td>0.73527</td> <td>0.000</td> <td>1036.4</td> <td>12.66</td> | | 1.00000 | | 0.73527 | 0.000 | 1036.4 | 12.66 |
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| 0.29594 0.17335 0.72219 0.171 1094,5 1.56 0.49045 0.15188 0.72372 0.175 1085,9 11.72 0.69622 0.09975 0.72707 0.158 1069,1 12.03 0.69768 0.07658 0.72877 0.133 1061,6 12.18 0.8983 0.04817 0.73997 0.100 1052,2 12.36 0.89825 0.02578 0.73288 0.059 10444.8 12.50 0.10000 0.74356 0.7900 0.048 1179,2 9.08 0.10802 0.66325 0.78542 -0.050 1160,4 9.45 0.20785 0.58902 0.7717 -0.118 1142,8 9.83 0.21433 0.52687 0.77389 -0.172 1127.9 10.16 0.40526 0.44223 0.76544 -0.205 1106,9 10.65 0.51104 0.36357 0.75942 -0.220 1069,5 11.61 0.71135 0.21463 0.7465 | | 0.19178 | 0.20474 | 0.72081 | 0.152 | 1102.9 | 11.40 |
| 0.40045 0.15188 0.72372 0.175 1085.9 11.72 0.49023 0.12666 0.72255 0.173 1077.9 1.187 0.690768 0.07658 0.72877 0.133 1061.6 1.2.18 0.699788 0.04817 0.73097 0.100 1052.2 1.2.36 0.898825 0.02578 0.73288 0.099 1044.8 1.2.50 0.0000 0.73527 0.000 1036.4 1.266 2.89955 0.00000 0.74356 0.79200 -0.048 1179.2 9.08 0.10802 0.66325 0.77817 -0.118 1142.8 9.43 0.20785 0.58802 0.77917 -0.118 1142.8 9.43 0.21743 0.52687 0.77389 -0.172 1127.9 10.16 0.40526 0.44223 0.76644 -0.226 1087.2 11.41 0.40526 0.44251 0.73905 -0.151 1030.3 12.27 0.50988 0.14675 < | | 0.29594 | 0.17835 | 0.72219 | 0.171 | 1094.5 | 11.56 |
| 0.49923 0.12686 0.72525 0.173 1077.9 11.87 0.696768 0.07958 0.72877 0.133 1061.6 12.03 0.69768 0.07658 0.72877 0.133 1061.6 12.18 0.80983 0.04817 0.73097 0.100 1052.2 12.36 0.80983 0.02578 0.73288 0.059 1044.8 12.50 0.1000 0.74356 0.79200 0.000 1036.4 12.66 0.10802 0.66325 0.78542 -0.050 1160.4 9.45 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.20785 0.58902 0.77917 -0.120 106.95 10.65 0.40526 0.44223 0.76644 -0.220 1069.5 11.61 0.40526 0.49237 0.75942 -0.220 1069.5 11.61 0.71135 0.21463 0. | | 0.40045 | 0.15188 | 0.72372 | 0.175 | 1085.9 | 11.72 |
| 0.60622 0.09975 0.72707 0.158 1066.1 12.03 0.60768 0.07658 0.72877 0.133 106.6 12.18 0.80893 0.04817 0.73097 0.100 1052.2 12.36 0.89825 0.02578 0.73288 0.059 1044.8 12.60 0.80000 0.74356 0.79200 0.048 1179.2 9.08 0.10802 0.66325 0.78542 -0.050 1160.4 9.45 0.2075 0.58902 0.77917 -0.118 142.8 9.83 0.29143 0.52687 0.77393 -0.172 1127.9 10.16 0.40526 0.44223 0.7664 -0.220 1069.5 11.61 0.7135 0.21463 0.74565 -0.188 1048.7 12.19 0.7135 0.21463 0.74565 -0.198 1048.7 12.19 0.40527 0.73905 -0.151 1030.3 12.75 0.80388 0.14575 0.73905 -0.151< | | 0.49923 | 0.12686 | 0.72525 | 0.173 | 1077.9 | 11.87 |
| 0.69768 0.07658 0.72877 0.133 1061.6 12.18 0.89825 0.02578 0.73097 0.100 1052.2 12.36 0.89825 0.02578 0.73288 0.000 1044.8 12.50 1.00000 0.74356 0.79200 1036.4 9.66 0.18802 0.66325 0.78542 -0.050 1160.4 9.45 0.20785 0.58802 0.77319 -0.118 1142.8 9.83 0.20785 0.58802 0.77319 -0.118 1142.8 9.83 0.20785 0.58870 0.77319 -0.118 1142.8 9.83 0.40526 0.44223 0.76644 -0.205 1065 11.61 0.40526 0.44223 0.75514 -0.202 1069.5 11.61 0.71355 0.2163 0.77390 -0.151 103.3 12.75 0.80886 0.44555 0.73905 -0.151 103.3 12.75 0.808857 0.73202 0.018 1048.7 | | 0.60622 | 0.09975 | 0.72707 | 0.158 | 1069.1 | 12.03 |
| 0.89983 0.04817 0.7397 0.100 1052.2 12.36 0.89825 0.02578 0.73282 0.009 1044.8 12.50 1.0000 0.73527 0.009 1044.8 12.50 2.89955 0.0000 0.74356 0.79200 0.048 1179.2 9.08 0.10802 0.66325 0.78542 -0.0118 1142.8 9.83 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.20785 0.63357 0.75942 -0.226 1087.2 11.14 0.60317 0.29507 0.75314 -0.220 1069.5 11.61 0.60317 0.29507 0.75314 -0.220 1089.5 12.75 0.80388 0.14575 0.73922 -0.091 101.4 13.35 0.80388 0.4565 0.73830 -0.020 109.7 12.19 0.80388 0.4565 0.73830 -0.021 101.4 13.35 0.80398 0.45650 0.73830 | | 0.69768 | 0.07658 | 0.72877 | 0.133 | 1061.6 | 12.18 |
| 0.88825 1.0000 0.02578 0.73288 0.73227 0.059 0.000 1044.8 10.000 12.50 12.66 2.89955 0.00000 0.74356 0.79200 0.048 1179.2 9.08 0.10802 0.66325 0.78542 -0.050 1160.4 9.45 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.40526 0.44223 0.76644 -0.205 1106.9 10.65 0.51104 0.36357 0.73924 -0.226 1087.2 11.14 0.071135 0.21463 0.74565 -0.198 1045.7 12.19 0.71135 0.21463 0.74565 -0.198 1045.7 12.19 0.80398 0.44570 0.73222 -0.091 1011.4 13.35 1.0000 0.74400 0.662 1109.7 10.91 0.20511 0.39347 0.7427 0.033 1096.0 11.21 0.40505 | | 0.80983 | 0.04817 | 0.73097 | 0.100 | 1052.2 | 12.36 |
| 1,0000 0,73527 0,000 1036.4 12.66 2.89955 0,0000 0,74356 0,79200 0.048 1179.2 9.08 2.89955 0,0000 0,64325 0,78542 -0.050 1160.4 9.45 0,20785 0,58902 0,77917 -0.118 1142.8 9.83 0,29143 0,52687 0,77389 -0.172 1127.9 10.165 0,6526 0.44223 0,7644 -0.205 1186.7 11.61 0,65114 0,36357 0,75942 -0.226 1887.2 11.14 0,71135 0,21463 0,74565 -0.198 1048.7 12.19 0,80388 0,14575 0,73905 -0.151 1030.3 12.75 0,803857 0,07542 0,72472 0.000 990.8 14.06 0,98857 0,07440 0.087 1120.2 10.68 0,40500 0,74400 0.687 1109.1 11.14 0,20511 0,39347 0,74227 0.033 | | 0.89825 | 0.02578 | 0.73288 | 0.059 | 1044.8 | 12.50 |
| 38.75 K 2.89955 0.0000 0.74356 0.79200 0.048 1179.2 9.08 0.10802 0.66325 0.78542 -0.050 1160.4 9.45 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.29143 0.52667 0.77389 -0.172 1127.9 10.16 0.40526 0.44223 0.76644 -0.205 1069.5 11.61 0.40526 0.44223 0.76644 -0.205 1087.2 11.14 0.60317 0.29507 0.73942 -0.202 1069.5 11.61 0.71135 0.21463 0.74555 -0.198 1048.7 12.19 0.80388 0.14575 0.73905 -0.151 1030.3 12.75 0.89850 0.45050 0.74440 0.662 1109.7 10.91 0.20511 0.39347 0.7427 0.033 1064.5 11.47 0.40704 0.29352 0.73830 -0.002 1071.1 11.81 | | 1.00000 | | 0.73527 | 0.000 | 1036.4 | 12.66 |
| 2.89955 0.0000 0.74356 0.79200 0.048 1179.2 9.08 0.10802 0.66325 0.78542 -0.050 1160.4 9.45 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.29143 0.52687 0.77389 -0.172 1127.9 10.16 0.40526 0.44223 0.76544 -0.205 1069.9 10.65 0.51104 0.36357 0.75942 -0.226 1087.2 11.14 0.60317 0.29507 0.7314 -0.220 1069.5 11.61 0.80398 0.14575 0.73905 -0.151 1030.3 12.75 0.80398 0.14575 0.73922 -0.091 101.4 13.35 0.10000 0.49500 0.74600 0.087 1120.2 10.68 0.98820 0.00000 0.49500 0.74400 0.062 1109.7 10.91 0.29634 0.34831 0.74252 0.014 1084.9 11.47 0.2 | | | | 308.15 | К | | |
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| 0.20785 0.58902 0.77917 -0.118 1142.8 9.83 0.29143 0.52687 0.77389 -0.172 1127.9 10.165 0.40526 0.44223 0.76644 -0.205 1106.9 10.65 0.51104 0.36357 0.75942 -0.226 1087.2 11.14 0.60317 0.29507 0.75314 -0.220 1069.5 11.61 0.71135 0.21463 0.74565 -0.198 1048.7 12.19 0.80388 0.14575 0.73905 -0.151 1030.3 12.75 0.89857 0.07542 0.73222 -0.091 1011.4 13.35 1.0000 0.49500 0.74400 0.062 1109.7 10.91 0.20511 0.39347 0.74227 0.033 1096.0 11.21 0.2068 0.24716 0.73637 -0.014 1084.9 11.47 0.2068 0.24716 0.73637 -0.014 1059.1 12.11 0.50568 0.24716 <t< th=""><td></td><td>0.10802</td><td>0.66325</td><td>0.78542</td><td>-0.050</td><td>1160.4</td><td>9.45</td></t<> | | 0.10802 | 0.66325 | 0.78542 | -0.050 | 1160.4 | 9.45 |
| 0.29143 0.52687 0.77389 -0.172 1127.9 10.16 0.40526 0.44223 0.76644 -0.205 1106.9 10.65 0.51104 0.36357 0.75942 -0.226 1087.2 11.14 0.60317 0.29507 0.75314 -0.220 1069.5 11.61 0.71135 0.21463 0.74565 -0.198 1048.7 12.19 0.80398 0.14575 0.73905 -0.151 1030.3 12.75 0.89857 0.07542 0.73222 -0.091 1011.4 1335 1.0000 -0.25511 0.39347 0.74207 0.000 990.8 14.06 0.98020 0.00000 0.45050 0.74400 0.062 1109.7 10.91 0.20511 0.39347 0.74227 0.033 1096.0 11.21 0.205634 0.34831 0.74052 0.014 1084.9 11.47 0.40704 0.29352 0.73830 -0.002 1071.1 11.81 <t< th=""><td></td><td>0.20785</td><td>0.58902</td><td>0.77917</td><td>-0.118</td><td>1142.8</td><td>9.83</td></t<> | | 0.20785 | 0.58902 | 0.77917 | -0.118 | 1142.8 | 9.83 |
| 0.40526 0.44223 0.76644 -0.205 1106.9 10.65 0.51104 0.36357 0.75942 -0.226 1087.2 11.14 0.60317 0.29507 0.75314 -0.220 10695 11.61 0.71135 0.21463 0.74565 -0.198 1048.7 12.19 0.80398 0.14575 0.73905 -0.151 1030.3 12.75 0.89857 0.07542 0.72472 0.000 990.8 14.06 0.98020 0.0000 0.49500 0.74600 0.087 1120.2 10.68 0.29634 0.48957 0.73222 0.004 1096.0 11.21 0.29634 0.34831 0.74052 0.014 1084.9 11.47 0.40704 0.29352 0.73830 -0.002 1071.1 11.81 0.50668 0.24716 0.73637 -0.014 1059.1 12.11 0.50568 0.24076 0.72930 -0.021 1046.8 12.43 0.75956 | | 0.29143 | 0.52687 | 0.77389 | -0.172 | 1127.9 | 10.16 |
| 0.51104 0.36357 0.75942 -0.226 1087.2 11.14 0.60317 0.29507 0.75314 -0.220 1069.5 11.61 0.71135 0.21463 0.74565 -0.198 1048.7 12.19 0.80398 0.14575 0.73905 -0.151 1030.3 12.75 0.89857 0.07542 0.73222 -0.091 1011.4 13.35 1.0000 0.49500 0.74600 0.887 1120.2 10.68 0.98020 0.00000 0.49500 0.74600 0.087 1120.2 10.68 0.20511 0.39347 0.74227 0.0033 1096.0 11.21 0.29634 0.34831 0.74052 0.014 1084.9 11.47 0.40704 0.29352 0.73830 -0.002 1071.1 11.81 0.50586 0.24716 0.73432 -0.021 1046.8 12.43 0.50585 0.20008 0.73432 -0.021 1046.8 12.43 0.59586 < | | 0.40526 | 0.44223 | 0.76644 | -0.205 | 1106.9 | 10.65 |
| 0.60317 0.29507 0.75314 -0.220 1069.5 11.61 0.71135 0.21463 0.74565 -0.198 1048.7 12.19 0.80398 0.14575 0.73905 -0.151 1030.3 12.75 0.8857 0.07542 0.091 1011.4 13.35 1.0000 0.72472 0.000 990.8 14.06 0.98020 0.00000 0.49500 0.74600 0.087 1120.2 10.68 0.20511 0.39347 0.74227 0.003 1096.0 11.21 0.20514 0.34831 0.74525 0.014 1084.9 11.47 0.40704 0.29352 0.73830 -0.002 1071.1 11.81 0.50586 0.24716 0.73637 -0.014 1059.1 12.14 0.59580 0.20088 0.73432 -0.021 1046.8 12.43 0.70796 0.14456 0.73180 -0.023 1031.7 12.84 0.81463 0.09176 0.72930 - | | 0.51104 | 0.36357 | 0.75942 | -0.226 | 1087.2 | 11.14 |
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| | | 0.19178 | 0.20474 | 0.71206 | 0.142 | 1060.5 | 12.49 |

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