

SUPPLEMENTARY MATERIAL TO  
**High-temperature and high-pressure ( $p$ ,  $\rho$ ,  $T$ ) measurements  
and derived thermodynamic properties of 1-octyl-3-  
-methylimidazolium hexafluorophosphate**

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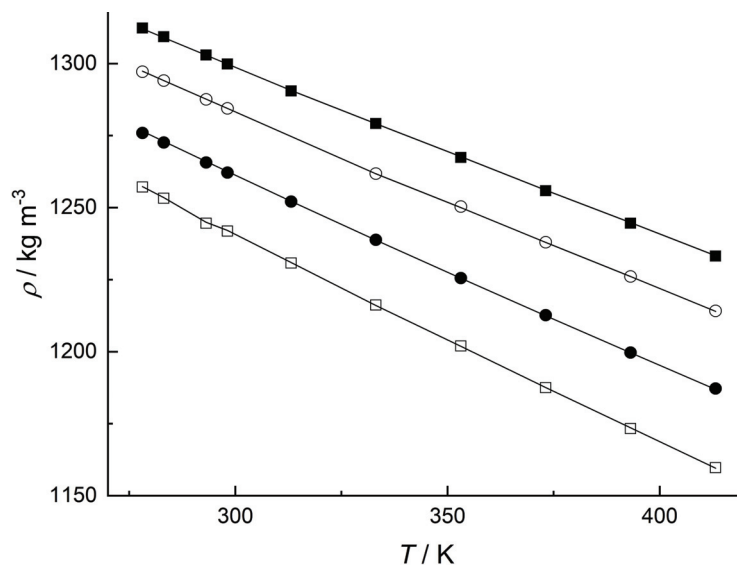


Fig. S-1. Measured densities of [OMIM][PF<sub>6</sub>] at high pressures as a function of temperature.  
□) 10, ●) 50, ○) 100 and ■) 140 MPa. Solid lines represent values calculated using the  
modified Tammann–Tait EOS.

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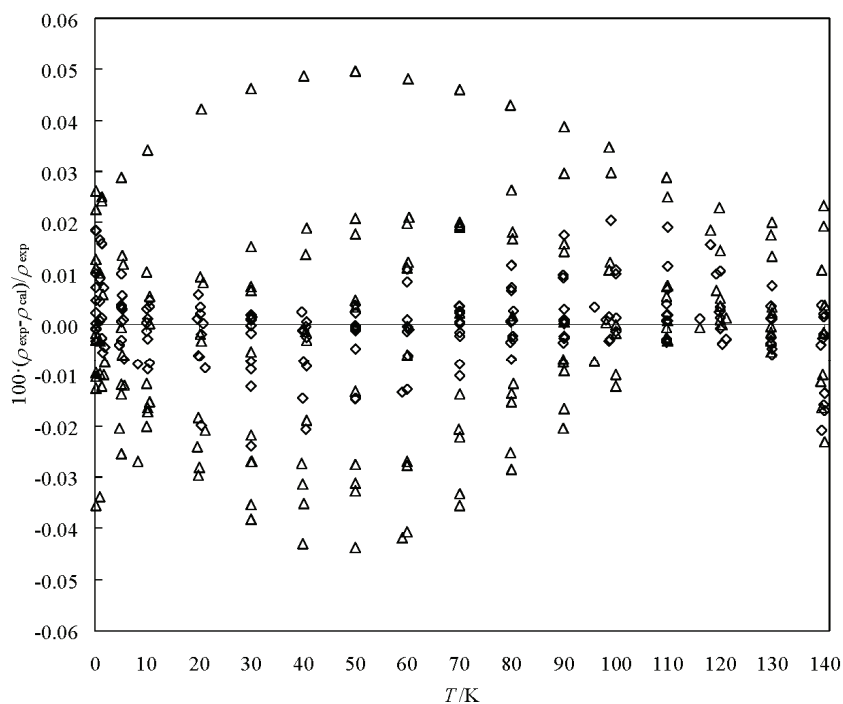


Fig. S-2. Deviations between experimental densities and values calculated using: ◇) multiparametric polynomial-type EOS (Eq. (2)) and △) the modified Tammann–Tait equation (Eq. (4)).

TABLE S-I. Summary of reported density data of [OMIM][PF<sub>6</sub>]

| First author           | Method <sup>a</sup> | Properties <sup>b</sup>                   | <i>T</i><br>K      | <i>p</i><br>MPa | Uncertainty            | Purity<br>mass % | Source                     |
|------------------------|---------------------|---|--------------------|-----------------|------------------------|------------------|----------------------------|
| Taguchi <sup>1</sup>   | BD                  | <i>p</i> , <i>ρ</i> , <i>T</i>            | 312.8–472.3        | 0.1–200         | 0.1 %                  | 98               | Acros Organics             |
| Gu <sup>2</sup>        | UHPD                | <i>p</i> , <i>ρ</i> , <i>T</i>            | 298.2–323.2        | 0.1–204         | 0.05–1.3 %             | 99.5             | SACHEM                     |
| Tomida <sup>3</sup>    | GP                  | <i>p</i> , <i>ρ</i> , <i>T</i> , <i>η</i> | 293.15–<br>–353.15 | 0.1–20          | 0.2 %                  | >99              | Prepared by the<br>authors |
| Gardas <sup>4</sup>    | VTD                 | <i>p</i> , <i>ρ</i> , <i>T</i>            | 293.15–<br>–393.15 | 0.1–10          | 1.0 kg·m <sup>-3</sup> | >98              | Solvent<br>Innovation      |
| Tomida <sup>5</sup>    | GP                  | <i>p</i> , <i>ρ</i> , <i>T</i> , <i>λ</i> | 295.1–335.2        | 0.1–20          | 0.2 %                  | >99              | Prepared by the<br>authors |
| Harris <sup>c,6</sup>  | FB                  | <i>p</i> , <i>ρ</i> , <i>T</i> , <i>η</i> | 273.15–<br>–353.15 | 0.1–176         | 0.5 %                  | >95              | Cannon                     |
| Safarov<br>(this work) | VTD                 | <i>p</i> , <i>ρ</i> , <i>T</i>            | 278.15–<br>–413.15 | 0.1–140         | 0.01–0.08 %            | 99               | Iolitech                   |

<sup>a</sup>BD – bellows dilatometer; UHPD – ultrahigh-pressure density apparatus; GP – glass piezometer; VTD – vibrating tube densimeter DMA 512P; FB – falling body; <sup>b</sup>*η*, viscosity; *λ*, thermal conductivity; <sup>c</sup>high pressure density values calculated from atmospheric pressure densities

TABLE S-II. Experimental values of pressure ( $p$ ), density ( $\rho$ ), temperature ( $T$ ), calculated values of isothermal compressibility ( $\kappa_T$ ), isobaric thermal expansibility ( $\alpha_p$ ), difference in isobaric and isochoric heat capacities ( $c_p-c_v$ ), thermal pressure coefficient ( $\gamma$ ), internal pressure ( $p_{int}$ ), isobaric heat capacity ( $c_p$ ), isochoric heat capacity ( $c_v$ ), speed of sound ( $u$ ) and isentropic exponent ( $\kappa_s$ ) of 1-octyl-3-methylimidazolium hexafluorophosphate [OMIM][PF<sub>6</sub>]

| $p$<br>MPa | $\rho$<br>kg m <sup>-3</sup> | $T$<br>K | $\kappa_T 10^6$<br>MPa <sup>-1</sup> | $\alpha_p \times 10^6$<br>K <sup>-1</sup> | $c_p-c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $\gamma$<br>MPa K <sup>-1</sup> | $p_{int}$<br>MPa | $c_p$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $u$<br>m s <sup>-1</sup> | $\kappa_s$ |
|------------|------------------------------|----------|--------------------------------------|---|---|---------------------------------|------------------|---|---|--------------------------|------------|
| 0.101      | 1252.21                      | 278.15   | 418.2                                | 636.2                                     | 215.04  | 1.5213                          | 423.1            | 1655.27                                     | 1440.23                                     | 1481.59                  | 27210.34   |
| 1.002      | 1252.66                      | 278.15   | 416.8                                | 634.5                                     | 214.51  | 1.5224                          | 422.4            | 1655.35                                     | 1440.84                                     | 1483.59                  | 2751.202   |
| 5.021      | 1254.66                      | 278.15   | 410.5                                | 626.8                                     | 212.19  | 1.5270                          | 419.7            | 1655.72                                     | 1443.53                                     | 1492.46                  | 556.541    |
| 10.003     | 1257.12                      | 278.15   | 402.9                                | 617.6                                     | 209.45  | 1.5327                          | 416.3            | 1656.18                                     | 1446.73                                     | 1503.33                  | 284.014    |
| 19.953     | 1261.96                      | 278.15   | 388.8                                | 600.4                                     | 204.33  | 1.5442                          | 409.6            | 1657.05                                     | 1452.71                                     | 1524.66                  | 147.031    |
| 29.957     | 1266.72                      | 278.15   | 375.7                                | 584.5                                     | 199.65  | 1.5559                          | 402.8            | 1657.84                                     | 1458.18                                     | 1545.62                  | 101.028    |
| 39.956     | 1271.38                      | 278.15   | 363.5                                | 569.8                                     | 195.38  | 1.5677                          | 396.1            | 1658.51                                     | 1463.13                                     | 1566.12                  | 78.057     |
| 49.928     | 1275.92                      | 278.15   | 352.1                                | 556.2                                     | 191.49  | 1.5796                          | 389.4            | 1659.04                                     | 1467.54                                     | 1586.15                  | 64.304     |
| 59.956     | 1280.39                      | 278.15   | 341.5                                | 543.6                                     | 187.93  | 1.5917                          | 382.8            | 1659.40                                     | 1471.47                                     | 1605.85                  | 55.077     |
| 70.006     | 1284.76                      | 278.15   | 331.5                                | 531.8                                     | 184.65  | 1.6040                          | 376.1            | 1659.57                                     | 1474.92                                     | 1625.24                  | 48.481     |
| 79.958     | 1288.99                      | 278.15   | 322.3                                | 520.9                                     | 181.68  | 1.6164                          | 369.6            | 1659.55                                     | 1477.87                                     | 1644.10                  | 43.579     |
| 89.925     | 1293.12                      | 278.15   | 313.5                                | 510.7                                     | 178.95  | 1.6289                          | 363.2            | 1659.31                                     | 1480.35                                     | 1662.66                  | 39.754     |
| 99.957     | 1297.17                      | 278.15   | 305.3                                | 501.2                                     | 176.44  | 1.6418                          | 356.7            | 1658.84                                     | 1482.40                                     | 1681.03                  | 36.672     |
| 109.953    | 1301.11                      | 278.15   | 297.5                                | 492.3                                     | 174.15  | 1.6548                          | 350.3            | 1658.13                                     | 1483.98                                     | 1699.03                  | 34.159     |
| 119.987    | 1304.96                      | 278.15   | 290.1                                | 483.9                                     | 172.05  | 1.6680                          | 344.0            | 1657.18                                     | 1485.13                                     | 1716.82                  | 32.056     |
| 129.953    | 1308.69                      | 278.15   | 283.2                                | 476.1                                     | 170.14  | 1.6814                          | 337.7            | 1655.98                                     | 1485.84                                     | 1734.23                  | 30.287     |
| 139.962    | 1312.32                      | 278.15   | 276.5                                | 468.7                                     | 168.39  | 1.6950                          | 331.5            | 1654.53                                     | 1486.13                                     | 1751.46                  | 28.763     |
| 0.101      | 1248.02                      | 283.15   | 428.0                                | 632.1                                     | 211.80  | 1.4769                          | 418.1            | 1665.26                                     | 1453.46                                     | 1464.55                  | 26503.93   |
| 1.023      | 1248.52                      | 283.15   | 426.4                                | 630.3                                     | 211.28  | 1.4780                          | 417.5            | 1665.35                                     | 1454.07                                     | 1466.67                  | 2625.304   |
| 5.021      | 1250.63                      | 283.15   | 419.8                                | 622.7                                     | 209.09  | 1.4831                          | 414.9            | 1665.73                                     | 1456.64                                     | 1475.78                  | 542.473    |
| 10.020     | 1253.24                      | 283.15   | 411.9                                | 613.5                                     | 206.48  | 1.4896                          | 411.8            | 1666.22                                     | 1459.74                                     | 1487.04                  | 276.573    |
| 19.925     | 1258.33                      | 283.15   | 397.1                                | 596.6                                     | 201.72  | 1.5025                          | 405.5            | 1667.20                                     | 1465.48                                     | 1508.97                  | 143.792    |
| 29.928     | 1263.19                      | 283.15   | 383.3                                | 580.9                                     | 197.39  | 1.5158                          | 399.3            | 1668.14                                     | 1470.75                                     | 1530.62                  | 98.883     |
| 39.954     | 1267.94                      | 283.15   | 370.4                                | 566.5                                     | 193.49  | 1.5294                          | 393.1            | 1669.01                                     | 1475.52                                     | 1551.86                  | 76.427     |
| 49.952     | 1272.57                      | 283.15   | 358.5                                | 553.3                                     | 189.99  | 1.5432                          | 387.0            | 1669.77                                     | 1479.78                                     | 1572.60                  | 63.005     |
| 59.986     | 1277.11                      | 283.15   | 347.4                                | 541.1                                     | 186.83  | 1.5574                          | 381.0            | 1670.41                                     | 1483.58                                     | 1593.02                  | 54.028     |
| 70.002     | 1281.53                      | 283.15   | 337.1                                | 529.8                                     | 184.00  | 1.5718                          | 375.1            | 1670.89                                     | 1486.89                                     | 1612.95                  | 47.626     |
| 79.924     | 1285.80                      | 283.15   | 327.4                                | 519.5                                     | 181.48  | 1.5864                          | 369.3            | 1671.21                                     | 1489.73                                     | 1632.38                  | 42.866     |
| 89.923     | 1289.99                      | 283.15   | 318.3                                | 509.8                                     | 179.21  | 1.6014                          | 363.5            | 1671.35                                     | 1492.15                                     | 1651.64                  | 39.129     |
| 99.957     | 1294.08                      | 283.15   | 309.7                                | 500.8                                     | 177.17  | 1.6168                          | 357.8            | 1671.30                                     | 1494.14                                     | 1670.63                  | 36.13      |
| 109.928    | 1298.04                      | 283.15   | 301.7                                | 492.4                                     | 175.36  | 1.6323                          | 352.3            | 1671.05                                     | 1495.69                                     | 1689.22                  | 33.69      |
| 119.953    | 1301.91                      | 283.15   | 294.0                                | 484.6                                     | 173.76  | 1.6483                          | 346.8            | 1670.59                                     | 1496.83                                     | 1707.61                  | 31.645     |
| 129.986    | 1305.67                      | 283.15   | 286.8                                | 477.4                                     | 172.35  | 1.6646                          | 341.4            | 1669.91                                     | 1497.56                                     | 1725.76                  | 29.913     |
| 139.954    | 1309.29                      | 283.15   | 280.0                                | 470.7                                     | 171.12  | 1.6812                          | 336.1            | 1669.01                                     | 1497.89                                     | 1743.53                  | 28.438     |
| 0.101      | 1240.23                      | 293.15   | 447.7                                | 624.4                                     | 205.85  | 1.3947                          | 408.8            | 1685.48                                     | 1479.63                                     | 1432.36                  | 25192.74   |
| 1.392      | 1240.92                      | 293.17   | 445.3                                | 621.8                                     | 205.16  | 1.3965                          | 408.0            | 1685.61                                     | 1480.45                                     | 1435.45                  | 1836.853   |
| 4.759      | 1242.71                      | 293.16   | 439.1                                | 615.4                                     | 203.45  | 1.4015                          | 406.1            | 1685.85                                     | 1482.40                                     | 1443.65                  | 544.248    |
| 8.248      | 1244.56                      | 293.15   | 432.8                                | 608.9                                     | 201.75  | 1.4068                          | 404.2            | 1686.11                                     | 1484.36                                     | 1452.08                  | 318.186    |
| 19.746     | 1250.75                      | 293.14   | 413.6                                | 589.1                                     | 196.68  | 1.4244                          | 397.8            | 1687.11                                     | 1490.43                                     | 1479.27                  | 138.606    |
| 30.203     | 1256.07                      | 293.14   | 397.7                                | 573.0                                     | 192.69  | 1.4409                          | 392.2            | 1688.10                                     | 1495.41                                     | 1503.36                  | 93.99      |
| 39.693     | 1260.75                      | 293.14   | 384.3                                | 559.7                                     | 189.53  | 1.4564                          | 387.2            | 1689.02                                     | 1499.48                                     | 1524.75                  | 73.841     |

TABLE S-II. Continued

| $p$<br>MPa | $\rho$<br>kg m <sup>-3</sup> | $T$<br>K | $\kappa_T 10^6$<br>MPa <sup>-1</sup> | $\alpha_p \times 10^6$<br>K <sup>-1</sup> | $c_p - c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $\gamma$<br>MPa K <sup>-1</sup> | $p_{\text{int}}$<br>MPa | $c_p$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $u$<br>m s <sup>-1</sup> | $\kappa_s$ |
|------------|------------------------------|----------|--------------------------------------|---|---|---------------------------------|-------------------------|---|---|--------------------------|------------|
| 49.997     | 1265.66                      | 293.14   | 370.9                                | 546.5                                     | 186.55  | 1.4737                          | 382.0                   | 1689.98                                     | 1503.44                                     | 1547.50                  | 60.621     |
| 58.939     | 1269.61                      | 293.13   | 360.0                                | 536.1                                     | 184.29  | 1.4891                          | 377.6                   | 1690.76                                     | 1506.47                                     | 1566.90                  | 52.894     |
| 69.996     | 1274.65                      | 293.14   | 347.5                                | 524.3                                     | 181.89  | 1.5087                          | 372.3                   | 1691.69                                     | 1509.80                                     | 1590.39                  | 46.064     |
| 79.792     | 1278.98                      | 293.15   | 337.2                                | 514.8                                     | 180.09  | 1.5264                          | 367.7                   | 1692.41                                     | 1512.32                                     | 1610.77                  | 41.59      |
| 89.997     | 1283.37                      | 293.15   | 327.2                                | 505.6                                     | 178.52  | 1.5456                          | 363.1                   | 1693.04                                     | 1514.53                                     | 1631.70                  | 37.967     |
| 99.996     | 1287.53                      | 293.15   | 317.9                                | 497.5                                     | 177.25  | 1.5648                          | 358.7                   | 1693.54                                     | 1516.29                                     | 1651.87                  | 35.134     |
| 109.993    | 1291.58                      | 293.15   | 309.2                                | 490.0                                     | 176.22  | 1.5846                          | 354.5                   | 1693.91                                     | 1517.68                                     | 1671.74                  | 32.816     |
| 119.993    | 1295.49                      | 293.15   | 301.0                                | 483.1                                     | 175.43  | 1.6048                          | 350.5                   | 1694.13                                     | 1518.71                                     | 1691.31                  | 30.884     |
| 129.998    | 1299.28                      | 293.15   | 293.3                                | 476.7                                     | 174.85  | 1.6256                          | 346.5                   | 1694.21                                     | 1519.37                                     | 1710.63                  | 29.248     |
| 140.001    | 1302.95                      | 293.15   | 285.9                                | 470.9                                     | 174.46  | 1.6469                          | 342.8                   | 1694.14                                     | 1519.68                                     | 1729.68                  | 27.847     |
| 0.101      | 1236.47                      | 298.15   | 457.7                                | 621.2                                     | 203.33  | 1.3573                          | 404.6                   | 1695.62                                     | 1492.29                                     | 1417.06                  | 24580.68   |
| 1.005      | 1236.97                      | 298.15   | 455.9                                | 619.4                                     | 202.86  | 1.3587                          | 404.1                   | 1695.66                                     | 1492.81                                     | 1419.33                  | 2479.267   |
| 5.023      | 1239.15                      | 298.15   | 448.1                                | 611.6                                     | 200.84  | 1.3649                          | 401.9                   | 1695.88                                     | 1495.03                                     | 1429.39                  | 504.021    |
| 10.006     | 1241.83                      | 298.15   | 438.8                                | 602.3                                     | 198.50  | 1.3727                          | 399.3                   | 1696.19                                     | 1497.68                                     | 1441.72                  | 257.972    |
| 19.924     | 1247.07                      | 298.16   | 421.5                                | 585.3                                     | 194.32  | 1.3887                          | 394.1                   | 1696.93                                     | 1502.61                                     | 1465.80                  | 134.49     |
| 30.002     | 1252.25                      | 298.15   | 405.3                                | 569.7                                     | 190.65  | 1.4057                          | 389.1                   | 1697.74                                     | 1507.09                                     | 1489.75                  | 92.642     |
| 40.001     | 1257.26                      | 298.15   | 390.6                                | 555.7                                     | 187.52  | 1.4230                          | 384.3                   | 1698.62                                     | 1511.10                                     | 1512.97                  | 71.953     |
| 50.006     | 1262.14                      | 298.13   | 376.9                                | 543.1                                     | 184.85  | 1.4410                          | 379.6                   | 1699.48                                     | 1514.63                                     | 1535.77                  | 59.533     |
| 59.924     | 1266.83                      | 298.15   | 364.4                                | 531.7                                     | 182.59  | 1.4591                          | 375.1                   | 1700.39                                     | 1517.80                                     | 1557.84                  | 51.306     |
| 69.928     | 1271.43                      | 298.15   | 352.6                                | 521.2                                     | 180.69  | 1.4782                          | 370.8                   | 1701.24                                     | 1520.55                                     | 1579.74                  | 45.373     |
| 79.941     | 1275.91                      | 298.14   | 341.6                                | 511.7                                     | 179.12  | 1.4979                          | 366.6                   | 1702.01                                     | 1522.90                                     | 1601.30                  | 40.923     |
| 89.924     | 1280.23                      | 298.15   | 331.4                                | 503.1                                     | 177.86  | 1.5179                          | 362.6                   | 1702.75                                     | 1524.89                                     | 1622.32                  | 37.467     |
| 99.924     | 1284.42                      | 298.15   | 321.8                                | 495.2                                     | 176.88  | 1.5387                          | 358.8                   | 1703.39                                     | 1526.51                                     | 1643.12                  | 34.7       |
| 109.925    | 1288.48                      | 298.12   | 312.8                                | 488.0                                     | 176.15  | 1.5601                          | 355.2                   | 1703.87                                     | 1527.72                                     | 1663.64                  | 32.439     |
| 119.957    | 1292.41                      | 298.15   | 304.3                                | 481.3                                     | 175.67  | 1.5819                          | 351.7                   | 1704.37                                     | 1528.70                                     | 1683.84                  | 30.546     |
| 129.953    | 1296.19                      | 298.15   | 296.3                                | 475.3                                     | 175.41  | 1.6044                          | 348.4                   | 1704.69                                     | 1529.29                                     | 1703.73                  | 28.954     |
| 139.924    | 1299.83                      | 298.15   | 288.7                                | 469.8                                     | 175.35  | 1.6274                          | 345.3                   | 1704.90                                     | 1529.55                                     | 1723.31                  | 27.592     |
| 0.101      | 1224.93                      | 313.15   | 488.8                                | 615.6                                     | 198.17  | 1.2593                          | 394.2                   | 1725.62                                     | 1527.45                                     | 1373.55                  | 22881.41   |
| 1.840      | 1225.95                      | 313.12   | 484.7                                | 611.9                                     | 197.28  | 1.2624                          | 393.4                   | 1725.47                                     | 1528.18                                     | 1378.42                  | 1266.009   |
| 5.531      | 1228.08                      | 313.14   | 476.3                                | 604.3                                     | 195.46  | 1.2686                          | 391.7                   | 1725.33                                     | 1529.88                                     | 1388.45                  | 428.069    |
| 10.195     | 1230.75                      | 313.15   | 466.1                                | 595.1                                     | 193.31  | 1.2767                          | 389.6                   | 1725.20                                     | 1531.89                                     | 1401.03                  | 236.981    |
| 21.171     | 1236.89                      | 313.18   | 443.9                                | 575.5                                     | 188.90  | 1.2964                          | 384.8                   | 1725.13                                     | 1536.23                                     | 1430.02                  | 119.484    |
| 29.997     | 1241.68                      | 313.17   | 427.6                                | 561.5                                     | 185.94  | 1.3131                          | 381.2                   | 1725.20                                     | 1539.26                                     | 1452.86                  | 87.379     |
| 40.566     | 1247.25                      | 313.16   | 409.7                                | 546.4                                     | 182.99  | 1.3338                          | 377.1                   | 1725.45                                     | 1542.47                                     | 1479.59                  | 67.311     |
| 49.996     | 1252.07                      | 313.16   | 395.0                                | 534.4                                     | 180.83  | 1.3529                          | 373.7                   | 1725.82                                     | 1544.98                                     | 1502.92                  | 56.565     |
| 59.861     | 1256.95                      | 313.17   | 380.8                                | 523.0                                     | 179.02  | 1.3735                          | 370.3                   | 1726.30                                     | 1547.28                                     | 1526.82                  | 48.944     |
| 69.994     | 1261.62                      | 313.16   | 367.3                                | 512.6                                     | 177.57  | 1.3956                          | 367.0                   | 1726.82                                     | 1549.25                                     | 1550.94                  | 43.356     |
| 80.400     | 1266.37                      | 313.16   | 354.5                                | 502.9                                     | 176.48  | 1.4189                          | 364.0                   | 1727.42                                     | 1550.94                                     | 1575.24                  | 39.083     |
| 89.996     | 1270.63                      | 313.15   | 343.4                                | 494.9                                     | 175.80  | 1.4412                          | 361.3                   | 1727.98                                     | 1552.19                                     | 1597.28                  | 36.02      |
| 95.950     | 1273.21                      | 313.15   | 336.9                                | 490.3                                     | 175.52  | 1.4553                          | 359.8                   | 1728.35                                     | 1552.83                                     | 1610.77                  | 34.428     |
| 109.806    | 1279.05                      | 313.15   | 322.8                                | 480.7                                     | 175.26  | 1.4890                          | 356.5                   | 1729.19                                     | 1553.93                                     | 1641.62                  | 31.39      |
| 119.272    | 1282.98                      | 313.16   | 313.9                                | 474.9                                     | 175.38  | 1.5128                          | 354.5                   | 1729.77                                     | 1554.39                                     | 1662.35                  | 29.722     |
| 129.807    | 1286.99                      | 313.16   | 304.6                                | 469.1                                     | 175.77  | 1.5401                          | 352.5                   | 1730.38                                     | 1554.61                                     | 1685.12                  | 28.155     |
| 139.445    | 1290.50                      | 313.16   | 296.5                                | 464.2                                     | 176.35  | 1.5657                          | 350.9                   | 1730.92                                     | 1554.57                                     | 1705.68                  | 26.93      |
| 0.101      | 1209.93                      | 333.15   | 534.6                                | 618.6                                     | 197.09  | 1.1571                          | 385.4                   | 1763.38                                     | 1566.30                                     | 1319.26                  | 20849.84   |

TABLE S-II. Continued

| $p$<br>MPa | $\rho$<br>kg m <sup>-3</sup> | $T$<br>K | $\kappa_T 10^6$<br>MPa <sup>-1</sup> | $\alpha_p \times 10^6$<br>K <sup>-1</sup> | $c_p - c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $\gamma$<br>MPa K <sup>-1</sup> | $p_{int}$<br>MPa | $c_p$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $u$<br>m s <sup>-1</sup> | $\kappa_s$ |
|------------|------------------------------|----------|--------------------------------------|---|---|---------------------------------|------------------|---|---|--------------------------|------------|
| 1.417      | 1210.75                      | 333.11   | 530.6                                | 615.4                                     | 196.36  | 1.1598                          | 384.9            | 1763.02                                     | 1566.67                                     | 1323.43                  | 1496.618   |
| 5.405      | 1213.36                      | 333.12   | 519.2                                | 606.2                                     | 194.27  | 1.1674                          | 383.5            | 1762.23                                     | 1567.96                                     | 1335.62                  | 400.458    |
| 9.966      | 1216.18                      | 333.14   | 506.9                                | 596.1                                     | 192.07  | 1.1762                          | 381.9            | 1761.42                                     | 1569.35                                     | 1349.37                  | 222.197    |
| 20.867     | 1222.73                      | 333.14   | 479.6                                | 574.6                                     | 187.55  | 1.1981                          | 378.3            | 1759.72                                     | 1572.17                                     | 1381.57                  | 111.845    |
| 29.997     | 1227.97                      | 333.15   | 459.0                                | 558.7                                     | 184.47  | 1.2170                          | 375.5            | 1758.61                                     | 1574.14                                     | 1407.81                  | 81.133     |
| 40.643     | 1233.74                      | 333.15   | 437.3                                | 542.3                                     | 181.56  | 1.2400                          | 372.5            | 1757.56                                     | 1576.00                                     | 1437.66                  | 62.746     |
| 49.996     | 1238.79                      | 333.15   | 419.9                                | 529.5                                     | 179.55  | 1.2609                          | 370.1            | 1756.85                                     | 1577.30                                     | 1463.27                  | 53.054     |
| 59.965     | 1243.99                      | 333.15   | 402.9                                | 517.3                                     | 177.89  | 1.2839                          | 367.8            | 1756.25                                     | 1578.36                                     | 1489.98                  | 46.052     |
| 69.995     | 1248.83                      | 333.15   | 387.2                                | 506.4                                     | 176.67  | 1.3077                          | 365.7            | 1755.81                                     | 1579.14                                     | 1516.30                  | 41.021     |
| 80.064     | 1253.62                      | 333.15   | 372.7                                | 496.6                                     | 175.85  | 1.3324                          | 363.8            | 1755.49                                     | 1579.65                                     | 1542.19                  | 37.239     |
| 89.993     | 1258.18                      | 333.15   | 359.5                                | 488.0                                     | 175.39  | 1.3574                          | 362.2            | 1755.29                                     | 1579.90                                     | 1567.25                  | 34.341     |
| 98.039     | 1261.78                      | 333.15   | 349.5                                | 481.6                                     | 175.26  | 1.3782                          | 361.1            | 1755.20                                     | 1579.94                                     | 1587.24                  | 32.424     |
| 109.797    | 1266.87                      | 333.15   | 335.8                                | 473.3                                     | 175.42  | 1.4094                          | 359.7            | 1755.16                                     | 1579.74                                     | 1615.98                  | 30.131     |
| 116.024    | 1269.50                      | 333.15   | 329.1                                | 469.3                                     | 175.66  | 1.4262                          | 359.1            | 1755.19                                     | 1579.53                                     | 1630.98                  | 29.106     |
| 129.796    | 1275.14                      | 333.15   | 315.1                                | 461.4                                     | 176.53  | 1.4644                          | 358.1            | 1755.35                                     | 1578.82                                     | 1663.60                  | 27.189     |
| 139.953    | 1279.17                      | 333.15   | 305.5                                | 456.2                                     | 177.46  | 1.4935                          | 357.6            | 1755.54                                     | 1578.08                                     | 1687.28                  | 26.02      |
| 0.101      | 1195.16                      | 353.15   | 586.1                                | 629.6                                     | 199.89  | 1.0742                          | 379.3            | 1797.87                                     | 1597.99                                     | 1267.46                  | 19006.01   |
| 1.356      | 1195.98                      | 353.18   | 581.5                                | 626.3                                     | 199.20  | 1.0769                          | 379.0            | 1797.56                                     | 1598.37                                     | 1271.70                  | 1426.142   |
| 5.209      | 1198.50                      | 353.15   | 567.7                                | 616.3                                     | 197.16  | 1.0857                          | 378.2            | 1796.45                                     | 1599.29                                     | 1284.94                  | 379.877    |
| 10.555     | 1201.95                      | 353.16   | 549.8                                | 603.5                                     | 194.62  | 1.0977                          | 377.1            | 1795.09                                     | 1600.47                                     | 1302.79                  | 193.291    |
| 20.386     | 1208.12                      | 353.18   | 519.7                                | 582.2                                     | 190.63  | 1.1203                          | 375.3            | 1792.82                                     | 1602.19                                     | 1334.88                  | 105.621    |
| 29.996     | 1213.97                      | 353.17   | 493.4                                | 563.9                                     | 187.47  | 1.1429                          | 373.7            | 1790.79                                     | 1603.32                                     | 1365.38                  | 75.467     |
| 40.360     | 1220.07                      | 353.17   | 468.1                                | 546.6                                     | 184.76  | 1.1679                          | 372.1            | 1788.84                                     | 1604.07                                     | 1397.29                  | 59.033     |
| 49.997     | 1225.54                      | 353.16   | 446.8                                | 532.4                                     | 182.81  | 1.1916                          | 370.8            | 1787.19                                     | 1604.38                                     | 1426.19                  | 49.866     |
| 60.201     | 1231.12                      | 353.15   | 426.4                                | 519.1                                     | 181.24  | 1.2173                          | 369.7            | 1785.60                                     | 1604.36                                     | 1456.03                  | 43.357     |
| 69.996     | 1236.27                      | 353.15   | 408.6                                | 507.6                                     | 180.17  | 1.2424                          | 368.8            | 1784.24                                     | 1604.07                                     | 1483.99                  | 38.895     |
| 79.895     | 1241.29                      | 353.15   | 392.1                                | 497.3                                     | 179.46  | 1.2684                          | 368.0            | 1782.98                                     | 1603.52                                     | 1511.62                  | 35.497     |
| 89.996     | 1246.19                      | 353.15   | 376.6                                | 487.8                                     | 179.09  | 1.2953                          | 367.4            | 1781.83                                     | 1602.74                                     | 1539.24                  | 32.802     |
| 98.966     | 1250.37                      | 353.15   | 363.9                                | 480.2                                     | 179.02  | 1.3197                          | 367.1            | 1780.90                                     | 1601.88                                     | 1563.30                  | 30.871     |
| 109.854    | 1255.22                      | 353.15   | 349.6                                | 471.9                                     | 179.24  | 1.3498                          | 366.8            | 1779.90                                     | 1600.65                                     | 1591.97                  | 28.953     |
| 118.122    | 1258.75                      | 353.16   | 339.5                                | 466.2                                     | 179.61  | 1.3730                          | 366.8            | 1779.23                                     | 1599.62                                     | 1613.37                  | 27.734     |
| 129.856    | 1263.50                      | 353.15   | 326.2                                | 458.8                                     | 180.40  | 1.4066                          | 366.9            | 1778.37                                     | 1597.98                                     | 1643.25                  | 26.274     |
| 139.988    | 1267.38                      | 353.15   | 315.5                                | 453.1                                     | 181.31  | 1.4362                          | 367.2            | 1777.76                                     | 1596.45                                     | 1668.61                  | 25.212     |
| 0.101      | 1179.97                      | 373.15   | 641.1                                | 635.7                                     | 199.37  | 0.9917                          | 369.9            | 1829.60                                     | 1630.23                                     | 1218.10                  | 17333.39   |
| 1.607      | 1181.09                      | 373.17   | 634.3                                | 631.6                                     | 198.74  | 0.9958                          | 370.0            | 1829.51                                     | 1630.77                                     | 1223.80                  | 1100.673   |
| 5.269      | 1183.79                      | 373.16   | 618.3                                | 622.1                                     | 197.32  | 1.0061                          | 370.2            | 1829.18                                     | 1631.86                                     | 1237.52                  | 344.055    |
| 10.434     | 1187.50                      | 373.16   | 597.3                                | 609.6                                     | 195.52  | 1.0206                          | 370.4            | 1828.70                                     | 1633.18                                     | 1256.51                  | 179.677    |
| 20.223     | 1194.24                      | 373.15   | 561.2                                | 588.2                                     | 192.66  | 1.0482                          | 370.9            | 1827.66                                     | 1635.00                                     | 1291.51                  | 98.498     |
| 29.997     | 1200.60                      | 373.15   | 529.5                                | 569.5                                     | 190.42  | 1.0757                          | 371.4            | 1826.50                                     | 1636.08                                     | 1325.25                  | 70.292     |
| 40.626     | 1207.16                      | 373.15   | 499.0                                | 551.7                                     | 188.58  | 1.1057                          | 372.0            | 1825.12                                     | 1636.55                                     | 1360.70                  | 55.015     |
| 49.997     | 1212.67                      | 373.15   | 475.0                                | 537.8                                     | 187.38  | 1.1323                          | 372.5            | 1823.83                                     | 1636.46                                     | 1391.02                  | 46.932     |
| 60.377     | 1218.50                      | 373.15   | 451.0                                | 524.0                                     | 186.45  | 1.1619                          | 373.2            | 1822.35                                     | 1635.89                                     | 1423.69                  | 40.907     |
| 69.994     | 1223.66                      | 373.15   | 431.0                                | 512.7                                     | 185.92  | 1.1893                          | 373.8            | 1820.94                                     | 1635.01                                     | 1453.07                  | 36.914     |
| 80.229     | 1228.94                      | 373.15   | 411.7                                | 501.7                                     | 185.65  | 1.2187                          | 374.5            | 1819.42                                     | 1633.76                                     | 1483.62                  | 33.718     |
| 89.996     | 1233.79                      | 373.15   | 394.8                                | 492.3                                     | 185.65  | 1.2469                          | 375.3            | 1817.97                                     | 1632.32                                     | 1512.09                  | 31.346     |

TABLE S-II. Continued

| $p$<br>MPa | $\rho$<br>kg m <sup>-3</sup> | $T$<br>K | $\kappa_T 10^6$<br>MPa <sup>-1</sup> | $\alpha_p \times 10^6$<br>K <sup>-1</sup> | $c_p - c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $\gamma$<br>MPa K <sup>-1</sup> | $p_{\text{int}}$<br>MPa | $c_p$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $c_v$<br>J kg <sup>-1</sup> K <sup>-1</sup> | $u$<br>m s <sup>-1</sup> | $\kappa_s$ |
|------------|------------------------------|----------|--------------------------------------|---|---|---------------------------------|-------------------------|---|---|--------------------------|------------|
| 98.774     | 1237.99                      | 373.15   | 380.8                                | 484.5                                     | 185.83  | 1.2724                          | 376.0                   | 1816.68                                     | 1630.85                                     | 1537.14                  | 29.615     |
| 109.807    | 1243.08                      | 373.16   | 364.6                                | 475.7                                     | 186.28  | 1.3046                          | 377.0                   | 1815.12                                     | 1628.84                                     | 1567.97                  | 27.833     |
| 120.387    | 1247.78                      | 373.17   | 350.4                                | 468.0                                     | 186.92  | 1.3356                          | 378.0                   | 1813.67                                     | 1626.75                                     | 1596.89                  | 26.432     |
| 129.806    | 1251.84                      | 373.16   | 338.6                                | 461.7                                     | 187.64  | 1.3635                          | 379.0                   | 1812.39                                     | 1624.75                                     | 1622.17                  | 25.378     |
| 139.394    | 1255.84                      | 373.16   | 327.5                                | 455.8                                     | 188.51  | 1.3920                          | 380.0                   | 1811.17                                     | 1622.65                                     | 1647.46                  | 24.453     |
| 0.101      | 1165.20                      | 393.15   | 691.5                                | 614.8                                     | 184.42  | 0.8890                          | 349.4                   | 1860.87                                     | 1676.45                                     | 1173.73                  | 15892.67   |
| 0.893      | 1165.82                      | 393.17   | 687.4                                | 613.0                                     | 184.38  | 0.8918                          | 349.7                   | 1861.38                                     | 1676.99                                     | 1176.94                  | 1808.296   |
| 5.065      | 1169.12                      | 393.15   | 666.0                                | 604.3                                     | 184.40  | 0.9074                          | 351.7                   | 1863.67                                     | 1679.28                                     | 1193.89                  | 328.998    |
| 10.495     | 1173.27                      | 393.15   | 640.3                                | 593.7                                     | 184.46  | 0.9272                          | 354.0                   | 1866.35                                     | 1681.88                                     | 1215.42                  | 165.14     |
| 20.293     | 1180.39                      | 393.15   | 598.7                                | 576.3                                     | 184.77  | 0.9626                          | 358.1                   | 1870.25                                     | 1685.48                                     | 1253.05                  | 91.329     |
| 29.996     | 1187.05                      | 393.14   | 562.9                                | 561.1                                     | 185.27  | 0.9969                          | 361.9                   | 1873.10                                     | 1687.83                                     | 1288.79                  | 65.731     |
| 40.382     | 1193.78                      | 393.14   | 529.1                                | 546.6                                     | 185.97  | 1.0331                          | 365.8                   | 1875.28                                     | 1689.31                                     | 1325.66                  | 51.952     |
| 49.996     | 1199.70                      | 393.14   | 501.5                                | 534.6                                     | 186.75  | 1.0660                          | 369.1                   | 1876.63                                     | 1689.88                                     | 1358.65                  | 44.295     |
| 59.923     | 1205.52                      | 393.15   | 475.9                                | 523.3                                     | 187.65  | 1.0996                          | 372.4                   | 1877.49                                     | 1689.84                                     | 1391.63                  | 38.962     |
| 69.995     | 1211.17                      | 393.14   | 452.5                                | 512.9                                     | 188.66  | 1.1333                          | 375.5                   | 1877.82                                     | 1689.16                                     | 1424.15                  | 35.096     |
| 80.176     | 1216.62                      | 393.14   | 431.2                                | 503.2                                     | 189.76  | 1.1669                          | 378.6                   | 1877.78                                     | 1688.02                                     | 1456.09                  | 32.174     |
| 89.996     | 1221.67                      | 393.14   | 412.6                                | 494.7                                     | 190.87  | 1.1990                          | 381.4                   | 1877.43                                     | 1686.55                                     | 1486.04                  | 29.978     |
| 98.911     | 1226.08                      | 393.14   | 397.1                                | 487.5                                     | 191.93  | 1.2278                          | 383.8                   | 1876.89                                     | 1684.96                                     | 1512.62                  | 28.363     |
| 109.816    | 1231.28                      | 393.14   | 379.6                                | 479.4                                     | 193.28  | 1.2628                          | 386.6                   | 1876.02                                     | 1682.74                                     | 1544.38                  | 26.743     |
| 121.147    | 1236.47                      | 393.14   | 363.1                                | 471.6                                     | 194.72  | 1.2987                          | 389.4                   | 1874.91                                     | 1680.19                                     | 1576.55                  | 25.369     |
| 129.816    | 1240.31                      | 393.14   | 351.4                                | 466.0                                     | 195.85  | 1.3260                          | 391.5                   | 1873.96                                     | 1678.11                                     | 1600.65                  | 24.48      |
| 139.721    | 1244.55                      | 393.15   | 339.0                                | 460.0                                     | 197.17  | 1.3570                          | 393.8                   | 1872.84                                     | 1675.67                                     | 1627.65                  | 23.598     |
| 0.101      | 1151.59                      | 413.15   | 722.5                                | 541.8                                     | 145.76  | 0.7499                          | 309.7                   | 1902.78                                     | 1757.02                                     | 1140.85                  | 14840.51   |
| 1.358      | 1152.62                      | 413.18   | 715.4                                | 540.7                                     | 146.49  | 0.7558                          | 310.9                   | 1905.06                                     | 1758.57                                     | 1146.18                  | 1115.08    |
| 4.968      | 1155.56                      | 413.17   | 695.7                                | 538.0                                     | 148.78  | 0.7734                          | 314.6                   | 1911.06                                     | 1762.29                                     | 1161.42                  | 313.764    |
| 10.185     | 1159.69                      | 413.16   | 669.2                                | 534.2                                     | 151.96  | 0.7984                          | 319.7                   | 1919.04                                     | 1767.08                                     | 1182.96                  | 159.344    |
| 20.328     | 1167.32                      | 413.16   | 623.3                                | 527.0                                     | 157.74  | 0.8456                          | 329.0                   | 1932.49                                     | 1774.75                                     | 1223.36                  | 85.944     |
| 29.994     | 1174.16                      | 413.15   | 585.3                                | 520.5                                     | 162.87  | 0.8893                          | 337.4                   | 1943.05                                     | 1780.18                                     | 1260.27                  | 62.177     |
| 40.069     | 1180.90                      | 413.15   | 550.5                                | 513.9                                     | 167.83  | 0.9335                          | 345.6                   | 1952.18                                     | 1784.34                                     | 1297.29                  | 49.601     |
| 49.996     | 1187.20                      | 413.15   | 520.2                                | 507.6                                     | 172.38  | 0.9758                          | 353.1                   | 1959.54                                     | 1787.16                                     | 1332.38                  | 42.155     |
| 60.072     | 1193.27                      | 413.15   | 492.9                                | 501.5                                     | 176.70  | 1.0176                          | 360.3                   | 1965.64                                     | 1788.94                                     | 1366.82                  | 37.11      |
| 69.993     | 1198.98                      | 413.15   | 468.7                                | 495.7                                     | 180.67  | 1.0577                          | 367.0                   | 1970.49                                     | 1789.82                                     | 1399.68                  | 33.56      |
| 79.817     | 1204.39                      | 413.15   | 447.1                                | 490.2                                     | 184.36  | 1.0964                          | 373.2                   | 1974.33                                     | 1789.97                                     | 1431.22                  | 30.909     |
| 89.996     | 1209.76                      | 413.15   | 426.8                                | 484.6                                     | 187.94  | 1.1355                          | 379.2                   | 1977.45                                     | 1789.51                                     | 1463.00                  | 28.771     |
| 98.652     | 1214.16                      | 413.15   | 410.9                                | 480.0                                     | 190.80  | 1.1681                          | 384.0                   | 1979.51                                     | 1788.71                                     | 1489.35                  | 27.3       |
| 109.797    | 1219.61                      | 413.15   | 392.2                                | 474.3                                     | 194.27  | 1.2092                          | 389.8                   | 1981.48                                     | 1787.21                                     | 1522.45                  | 25.746     |
| 119.806    | 1224.33                      | 413.13   | 376.9                                | 469.3                                     | 197.18  | 1.2452                          | 394.6                   | 1982.55                                     | 1785.37                                     | 1551.33                  | 24.593     |
| 129.797    | 1228.87                      | 413.14   | 362.7                                | 464.4                                     | 199.90  | 1.2803                          | 399.1                   | 1983.37                                     | 1783.47                                     | 1579.51                  | 23.619     |
| 139.562    | 1233.15                      | 413.15   | 350.0                                | 459.8                                     | 202.41  | 1.3139                          | 403.3                   | 1983.82                                     | 1781.41                                     | 1606.44                  | 22.801     |

\*Standard uncertainties  $u$  are:  $u(T) = 0.0075$  K;  $u(P) = 0.05$  %

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