



Hochschule  
Zittau/Görlitz  
UNIVERSITY OF APPLIED SCIENCES

# **Stoffwertsammlung**

## **Technische Thermodynamik und Wärmeübertragung**

**Fakultät Maschinenwesen**  
**Fachgebiet Technische Thermodynamik**

von  
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## Stoffwertsammlung

### Technische Thermodynamik, Wärme- und Stoffübertragung

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## Periodensystem der Elemente

|                                 |                                |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                |                                |                                  |                                 |                                  |                                 |                        |    |    |    |    |
|---------------------------------|--------------------------------|-------------------------------|-----------------------------------|------------------------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|----------------------------------|--------------------------------|----------------------------------|--------------------------------|--------------------------------|----------------------------------|---------------------------------|----------------------------------|---------------------------------|------------------------|----|----|----|----|
| 1                               |                                |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                |                                |                                  |                                 |                                  |                                 |                        |    |    |    | 18 |
| 1                               |                                |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                |                                |                                  |                                 |                                  |                                 | 2                      |    |    |    |    |
| H<br>Wasser-<br>stoff<br>1,0079 |                                |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                |                                |                                  |                                 |                                  |                                 | He<br>Helium<br>4,0026 |    |    |    |    |
|                                 |                                |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                |                                |                                  |                                 |                                  | 13                              | 14                     | 15 | 16 | 17 |    |
| 3                               | 4                              |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                | 5                              | 6                                | 7                               | 8                                | 9                               | 10                     |    |    |    |    |
| Li<br>Lithium<br>6,941          | Be<br>Beryllium<br>9,0122      |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                | B<br>Bor<br>10,811             | C<br>Kohlen-<br>stoff<br>12,011  | N<br>Stickstoff<br>14,007       | O<br>Sauer-<br>stoff<br>15,999   | F<br>Fluor<br>18,988            | Ne<br>Neon<br>20,180   |    |    |    |    |
| 11                              | 12                             |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                | 13                             | 14                               | 15                              | 16                               | 17                              | 18                     |    |    |    |    |
| Na<br>Natrium<br>22,990         | Mg<br>Magne-<br>sium<br>24,305 |                               |                                   |                              |                                |                                |                                |                                |                                  |                                |                                  |                                | Al<br>Alu-<br>minium<br>26,982 | Si<br>Silicium<br>28,086         | P<br>Phosphor<br>30,974         | S<br>Schwefel<br>32,065          | Cl<br>Chlor<br>35,453           | Ar<br>Argon<br>39,948  |    |    |    |    |
| 19                              | 20                             | 21                            | 22                                | 23                           | 24                             | 25                             | 26                             | 27                             | 28                               | 29                             | 30                               | 31                             | 32                             | 33                               | 34                              | 35                               | 36                              |                        |    |    |    |    |
| K<br>Kalium<br>39,098           | Ca<br>Calcium<br>40,078        | Sc<br>Scan-<br>dium<br>44,956 | Ti<br>Titan<br>47,867             | V<br>Vana-<br>dium<br>50,942 | Cr<br>Chrom<br>51,996          | Mn<br>Mangan<br>54,938         | Fe<br>Eisen<br>55,845          | Co<br>Cobalt<br>58,933         | Ni<br>Nickel<br>58,693           | Cu<br>Kupfer<br>63,546         | Zn<br>Zink<br>65,38              | Ga<br>Gallium<br>69,723        | Ge<br>Germa-<br>nium<br>72,64  | As<br>Arsen<br>74,922            | Se<br>Selen<br>78,96            | Br<br>Brom<br>79,904             | Kr<br>Krypton<br>83,798         |                        |    |    |    |    |
| 37                              | 38                             | 39                            | 40                                | 41                           | 42                             | 43                             | 44                             | 45                             | 46                               | 47                             | 48                               | 49                             | 50                             | 51                               | 52                              | 53                               | 54                              |                        |    |    |    |    |
| Rb<br>Rubidium<br>85,468        | Sr<br>Strontium<br>87,62       | Y<br>Yttrium<br>88,906        | Zr<br>Zirkonium<br>91,224         | Nb<br>Niob<br>92,906         | Mo<br>Molybdän<br>95,96        | Tc<br>Tech-<br>netium<br>95,96 | Ru<br>Ruthe-<br>nium<br>101,07 | Rh<br>Rhodium<br>102,91        | Pd<br>Palladium<br>106,42        | Ag<br>Silber<br>107,87         | Cd<br>Cadmium<br>112,41          | In<br>Indium<br>114,82         | Sn<br>Zinn<br>118,71           | Sb<br>Antimon<br>121,76          | Te<br>Tellur<br>127,60          | I<br>Iod<br>126,90               | Xe<br>Xenon<br>131,29           |                        |    |    |    |    |
| 55                              | 56                             | 57-71                         | 72                                | 73                           | 74                             | 75                             | 76                             | 77                             | 78                               | 79                             | 80                               | 81                             | 82                             | 83                               | 84                              | 85                               | 86                              |                        |    |    |    |    |
| Cs<br>Cäsium<br>132,91          | Ba<br>Barium<br>137,33         | folgende<br>Seite             | Hf<br>Hafnium<br>178,49           | Ta<br>Tantal<br>180,95       | W<br>Wolfram<br>183,84         | Re<br>Rhenium<br>186,21        | Os<br>Osmium<br>190,23         | Ir<br>Iridium<br>192,22        | Pt<br>Platin<br>195,08           | Au<br>Gold<br>196,97           | Hg<br>Queck-<br>silber<br>200,59 | Tl<br>Thallium<br>204,38       | Pb<br>Blei<br>207,2            | Bi<br>Bismut<br>208,98           | Po<br>Polonium<br>209,98        | At<br>Astat<br>(210)             | Rn<br>Radon<br>(222)            |                        |    |    |    |    |
| 87                              | 88                             | 89-103                        | 104                               | 105                          | 106                            | 107                            | 108                            | 109                            | 110                              | 111                            | 112                              | 113                            | 114                            | 115                              | 116                             | 117                              | 118                             |                        |    |    |    |    |
| Fr<br>Francium<br>(223)         | Ra<br>Radium<br>226,03         | folgende<br>Seite             | Rf<br>Ruther-<br>fordium<br>(261) | Db<br>Dubnium<br>(262)       | Sg<br>Sea-<br>borgium<br>(263) | Bh<br>Bohrium<br>(262)         | Hs<br>Hassium<br>(265)         | Mt<br>Meit-<br>nerium<br>(266) | Ds<br>Darm-<br>stadtium<br>(269) | Rg<br>Rönt-<br>genium<br>(272) | Cn<br>Coperni-<br>cium<br>(277)  | Uut<br>Unun-<br>trium<br>(287) | Fl<br>Flerovium<br>(289)       | Uup<br>Unun-<br>pentium<br>(288) | Lv<br>Liver-<br>morium<br>(289) | Uus<br>Unun-<br>septium<br>(293) | Uuo<br>Unun-<br>octium<br>(294) |                        |    |    |    |    |

Symbol

Name

Ordnungszahl

Atomgewicht

1

H

Wasser-  
stoff  
1,0079

Symbol — 1 — Ordnungszahl  
Name — H — Atomgewicht  
Wasser-  
stoff  
1,0079

## Periodensystem der Elemente (Fortsetzung)

|             |                                                                                      |                                                                                      |                                                                                            |                                                                                     |                                                                                          |                                                                                        |                                                                                        |                                                                                         |                                                                                      |                                                                                          |                                                                                      |                                                                                     |                                                                                      |                                                                                        |                                                                                       |
|-------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Lanthanoide | <div> <div>57</div> <div><b>La</b></div> <div>Lanthan</div> <div>138,91</div> </div> | <div> <div>58</div> <div><b>Ce</b></div> <div>Cer</div> <div>140,12</div> </div>     | <div> <div>59</div> <div><b>Pr</b></div> <div>Pra-seodym</div> <div>140,91</div> </div>    | <div> <div>60</div> <div><b>Nd</b></div> <div>Neodym</div> <div>144,24</div> </div> | <div> <div>61</div> <div><b>Pm</b></div> <div>Pro-methium</div> <div>146,90</div> </div> | <div> <div>62</div> <div><b>Sm</b></div> <div>Samarium</div> <div>150,36</div> </div>  | <div> <div>63</div> <div><b>Eu</b></div> <div>Europium</div> <div>151,96</div> </div>  | <div> <div>64</div> <div><b>Gd</b></div> <div>Gadolinium</div> <div>157,25</div> </div> | <div> <div>65</div> <div><b>Tb</b></div> <div>Terbium</div> <div>158,93</div> </div> | <div> <div>66</div> <div><b>Dy</b></div> <div>Dyspro-sium</div> <div>162,50</div> </div> | <div> <div>67</div> <div><b>Ho</b></div> <div>Holmium</div> <div>164,93</div> </div> | <div> <div>68</div> <div><b>Er</b></div> <div>Erbium</div> <div>167,26</div> </div> | <div> <div>69</div> <div><b>Tm</b></div> <div>Thulium</div> <div>168,93</div> </div> | <div> <div>70</div> <div><b>Yb</b></div> <div>Ytterbium</div> <div>173,05</div> </div> | <div> <div>71</div> <div><b>Lu</b></div> <div>Lutetium</div> <div>174,97</div> </div> |
| Actinoide   | <div> <div>89</div> <div><b>Ac</b></div> <div>Actinium (227)</div> </div>            | <div> <div>90</div> <div><b>Th</b></div> <div>Thorium</div> <div>232,04</div> </div> | <div> <div>91</div> <div><b>Pa</b></div> <div>Pro-taktinium</div> <div>231,04</div> </div> | <div> <div>92</div> <div><b>U</b></div> <div>Uran</div> <div>238,03</div> </div>    | <div> <div>93</div> <div><b>Np</b></div> <div>Nep-tunium</div> <div>237,05</div> </div>  | <div> <div>94</div> <div><b>Pu</b></div> <div>Plutonium</div> <div>244,10</div> </div> | <div> <div>95</div> <div><b>Am</b></div> <div>Americium</div> <div>243,10</div> </div> | <div> <div>96</div> <div><b>Cm</b></div> <div>Curium</div> <div>247,10</div> </div>     | <div> <div>97</div> <div><b>Bk</b></div> <div>Berkelium (247,10)</div> </div>        | <div> <div>98</div> <div><b>Cf</b></div> <div>Califor-nium (251,10)</div> </div>         | <div> <div>99</div> <div><b>Es</b></div> <div>Ein-steinium (254,10)</div> </div>     | <div> <div>100</div> <div><b>Fm</b></div> <div>Fermium (257,10)</div> </div>        | <div> <div>101</div> <div><b>Md</b></div> <div>Mende-levium (258)</div> </div>       | <div> <div>102</div> <div><b>No</b></div> <div>Nobelium (259)</div> </div>             | <div> <div>103</div> <div><b>Lr</b></div> <div>Law-rencium (260)</div> </div>         |

**Tab. 0 Umrechnung englischer Einheiten in SI-Einheiten**

| Maßeinheit                                 | Umrechnung                                              |   |            |                                     |
|--------------------------------------------|---------------------------------------------------------|---|------------|-------------------------------------|
| Inch                                       | 1 in (")                                                | = | 0,0254     | m                                   |
| Foot (12 in)                               | 1 ft                                                    | = | 0,3048     | m                                   |
| Yard (3 ft)                                | 1 yd                                                    | = | 0,9144     | m                                   |
| Mile                                       | 1 mile                                                  | = | 1609,344   | m                                   |
| Nautical mile                              | 1 nmile                                                 | = | 1852       | m                                   |
| Gallon (U.S.)                              | 1 gal                                                   | = | 0,00378541 | m <sup>3</sup>                      |
| Gallon (U.K.)                              | 1 gal                                                   | = | 0,00454609 | m <sup>3</sup>                      |
| Barrel (U.S.)                              | 1 barrel                                                | = | 0,1156     | m <sup>3</sup>                      |
| Barrel Petrol (U.S.)                       | 1 barrel Petrol                                         | = | 0,1589873  | m <sup>3</sup>                      |
| Barrel (U.K.)                              | 1 barrel                                                | = | 0,1637     | m <sup>3</sup>                      |
| Foot per minute                            | 1 ft min <sup>-1</sup>                                  | = | 0,00508    | m s <sup>-1</sup>                   |
| Yard per second                            | 1 yd s <sup>-1</sup>                                    | = | 0,9144     | m s <sup>-1</sup>                   |
| Mile per hour                              | 1 mile h <sup>-1</sup>                                  | = | 1,6093     | km h <sup>-1</sup>                  |
| Pound                                      | 1 lb                                                    | = | 0,4535924  | kg                                  |
| Cubic foot per pound                       | 1 ft <sup>3</sup> lb <sup>-1</sup>                      | = | 0,0624280  | m <sup>3</sup> kg <sup>-1</sup>     |
| Pound per cubic foot                       | 1 lb ft <sup>-3</sup>                                   | = | 16,01846   | kg m <sup>-3</sup>                  |
| Pound-force per square inch                | 1 psi (1 lbf in <sup>-2</sup> )                         | = | 6,894757   | kPa                                 |
| Horsepower hour                            | 1 hp h                                                  | = | 2684,52    | kJ                                  |
| Horsepower                                 | 1 hp                                                    | = | 0,74570    | kW                                  |
| British thermal unit (International Table) | 1 Btu                                                   | = | 1,055056   | kJ                                  |
| Btu per hour                               | 1 Btu h <sup>-1</sup>                                   | = | 0,2930711  | W                                   |
| Btu per pound                              | 1 Btu lb <sup>-1</sup>                                  | = | 2,326      | kJ kg <sup>-1</sup>                 |
| Btu per cubic foot                         | 1 Btu ft <sup>-3</sup>                                  | = | 37,25895   | kJ m <sup>-3</sup>                  |
| Btu per pound and Rankine                  | 1 Btu lb <sup>-1</sup> °R <sup>-1</sup>                 | = | 4,1868     | kJ kg <sup>-1</sup> K <sup>-1</sup> |
| Btu per hour, foot, and Rankine            | 1 Btu h <sup>-1</sup> ft <sup>-1</sup> °R <sup>-1</sup> | = | 1,730735   | W m <sup>-1</sup> K <sup>-1</sup>   |
| Btu per hour, square foot, and Rankine     | 1 Btu h <sup>-1</sup> ft <sup>-2</sup> °R <sup>-1</sup> | = | 5,678263   | W m <sup>-2</sup> K <sup>-1</sup>   |

**Tab. 1 Physikalische Konstanten**

|                                               |                                                                                                                                                                |
|-----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Universelle (molare) Gaskonstante             | $\bar{R} = R_m = 8,314472 \text{ kJ kmol}^{-1} \text{ K}^{-1}$<br>(aktueller Wert: $\bar{R}^{14} = R_m^{14} = 8,3144598 \text{ kJ kmol}^{-1} \text{ K}^{-1}$ ) |
| AVOGADRO-Konstante                            | $N_A = 6,022140857 \cdot 10^{26} \text{ kmol}^{-1}$                                                                                                            |
| Erdfallbeschleunigung                         | $g = 9,80665 \text{ m s}^{-2}$                                                                                                                                 |
| Lichtgeschwindigkeit im Vakuum                | $c_0 = 299,792458 \cdot 10^6 \text{ m s}^{-1}$                                                                                                                 |
| Strahlungskoeffizient des Schwarzen Strahlers | $C_s = 5,67051 \text{ W m}^{-2} \text{ K}^{-4}$<br>(aktueller Wert: $C_s^{14} = 5,670367 \text{ W m}^{-2} \text{ K}^{-4}$ )                                    |

**Tab. 2 Allgemeine stoffspezifische Konstanten**

| Fluid               | Summenformel                                 | $M$<br>kg kmol <sup>-1</sup> | $R$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | Daten am kritischen Punkt |              |                                |
|---------------------|----------------------------------------------|------------------------------|--------------------------------------------|---------------------------|--------------|--------------------------------|
|                     |                                              |                              |                                            | $T_c$<br>K                | $p_c$<br>MPa | $\rho_c$<br>kg m <sup>-3</sup> |
| Wasser              | H <sub>2</sub> O                             | 18,015                       | 0,46153                                    | 647,096                   | 22,064       | 322,0                          |
| Stickstoffmonoxid   | NO                                           | 30,006                       | 0,27709                                    | 180,2                     | 6,485        | 520                            |
| Stickstoffdioxid    | NO <sub>2</sub>                              | 46,01                        | 0,18071                                    | 431,35                    | 10,13        | 550                            |
| Kohlenmonoxid       | CO                                           | 28,01                        | 0,29684                                    | 132,91                    | 3,499        | 301                            |
| Kohlendioxid        | CO <sub>2</sub>                              | 44,01                        | 0,18892                                    | 304,21                    | 7,3825       | 466,1                          |
| Schwefeldioxid      | SO <sub>2</sub>                              | 64,065                       | 0,12978                                    | 430,7                     | 7,88         | 525                            |
| Schwefeltrioxid     | SO <sub>3</sub>                              | 80,06                        | 0,10385                                    | 491,45                    | 8,44         | 633                            |
| Luft (trocken)      |                                              | 28,960                       | 0,28710                                    | 132,507                   | 3,766        | 313                            |
| Ammoniak            | NH <sub>3</sub>                              | 17,031                       | 0,48821                                    | 405,60                    | 11,30        | 235                            |
| R12                 | CCl <sub>2</sub> F <sub>2</sub>              | 120,92                       | 0,068760                                   | 385,16                    | 4,16         | 558                            |
| R22                 | CHF <sub>2</sub> Cl                          | 86,469                       | 0,096156                                   | 369,33                    | 4,990        | 513                            |
| R23                 | CHF <sub>3</sub>                             | 70,01                        | 0,11876                                    | 298,75                    | 4,75         | 500                            |
| R123                | CHCl <sub>2</sub> CF <sub>3</sub>            | 152,93                       | 0,054368                                   | 456,94                    | 3,674        | 549,9                          |
| R134a               | CH <sub>2</sub> FCF <sub>3</sub>             | 102,03                       | 0,081490                                   | 374,3                     | 4,064        | 508                            |
| R142b               | CH <sub>3</sub> CF <sub>2</sub> Cl           | 100,50                       | 0,082734                                   | 410,3                     | 4,123        | 435                            |
| R152a               | CH <sub>3</sub> CHF <sub>2</sub>             | 66,05                        | 0,12588                                    | 386,7                     | 4,49         | 365                            |
| R227                | CF <sub>3</sub> CHFCF <sub>3</sub>           | 170,03                       | 0,048900                                   | 375,05                    | 2,952        | 592                            |
| R502                |                                              | 111,6                        | 0,074502                                   | 355,36                    | 4,08         | 561                            |
| Helium              | He                                           | 4,003                        | 2,0771                                     | 5,201                     | 0,2275       | 69,64                          |
| Neon                | Ne                                           | 20,179                       | 0,41204                                    | 44,40                     | 2,654        | 483,5                          |
| Argon               | Ar                                           | 39,948                       | 0,20813                                    | 150,8                     | 4,8979       | 535,7                          |
| Stickstoff          | N <sub>2</sub>                               | 28,013                       | 0,29681                                    | 126,20                    | 3,400        | 314                            |
| Wasserstoff         | H <sub>2</sub>                               | 2,016                        | 4,1242                                     | 33,24                     | 1,296        | 30,1                           |
| Sauerstoff          | O <sub>2</sub>                               | 31,999                       | 0,25984                                    | 154,576                   | 5,043        | 436,1                          |
| Fluor               | F <sub>2</sub>                               | 37,997                       | 0,21882                                    | 144,30                    | 5,215        | 574                            |
| Chlor               | Cl <sub>2</sub>                              | 70,906                       | 0,11726                                    | 417,0                     | 7,70         | 573                            |
| Ozon                | O <sub>3</sub>                               | 47,998                       | 0,17323                                    | 261,1                     | 5,53         | 537                            |
| Methan              | CH <sub>4</sub>                              | 16,043                       | 0,51826                                    | 190,555                   | 4,595        | 162,2                          |
| Ethylen (Ethen)     | C <sub>2</sub> H <sub>4</sub>                | 28,054                       | 0,29637                                    | 282,37                    | 5,02         | 218                            |
| Ethan               | C <sub>2</sub> H <sub>6</sub>                | 30,069                       | 0,27651                                    | 305,32                    | 4,872        | 206,18                         |
| Propylen            | C <sub>3</sub> H <sub>6</sub>                | 42,08                        | 0,19759                                    | 365,57                    | 4,6646       | 223,4                          |
| Propan              | C <sub>3</sub> H <sub>8</sub>                | 44,096                       | 0,18856                                    | 369,89                    | 4,2512       | 220,478                        |
| Butan               | C <sub>4</sub> H <sub>10</sub>               | 58,122                       | 0,14305                                    | 425,125                   | 3,796        | 228,0                          |
| Isobutan            | C <sub>4</sub> H <sub>10</sub>               | 58,122                       | 0,14305                                    | 407,81                    | 3,629        | 225,5                          |
| Benzol              | C <sub>6</sub> H <sub>6</sub>                | 78,11                        | 0,10645                                    | 562,09                    | 4,898        | 309                            |
| Diphenyl            | C <sub>12</sub> H <sub>10</sub>              | 154,20                       | 0,053920                                   | 788,65                    | 3,8          | 343                            |
| Methanol            | CH <sub>3</sub> OH                           | 32,04                        | 0,25950                                    | 512,58                    | 8,092        | 272                            |
| Ethanol             | C <sub>2</sub> H <sub>5</sub> OH             | 46,07                        | 0,18047                                    | 516,25                    | 6,379        | 275,5                          |
| Propanol            | C <sub>3</sub> H <sub>7</sub> OH             | 60,09                        | 0,13837                                    | 508,40                    | 4,764        | 272,7                          |
| Butanol             | C <sub>4</sub> H <sub>9</sub> OH             | 74,12                        | 0,11218                                    | 562,98                    | 4,413        | 269,9                          |
| Glyzerin            | C <sub>2</sub> H <sub>8</sub> O <sub>3</sub> | 92,09                        | 0,090287                                   | 850,0                     | 7,5          | 332                            |
| Aceton              | C <sub>3</sub> H <sub>6</sub> O              | 58,08                        | 0,14316                                    | 509,45                    | 4,78         | 278                            |
| Phenol              | C <sub>6</sub> H <sub>6</sub> O              | 94,11                        | 0,088349                                   | 694,25                    | 6,13         | 401                            |
| Formaldehyd         | CH <sub>2</sub> O                            | 30,03                        | 0,27687                                    | 402                       | 6,7          | 266                            |
| Schwefelhexafluorid | SF <sub>6</sub>                              | 146,05                       | 0,056929                                   | 318,729                   | 3,7545       | 742                            |

**Tab. 3-1 Fluide im Idealgaszustand**

Werte nach VDI-Richtlinie 4670

| $\vartheta$<br>°C | Luft (trocken)                               |                                                            |                            |                                              | Wasserdampf - H <sub>2</sub> O               |                                                            |                            |                                              |
|-------------------|----------------------------------------------|------------------------------------------------------------|----------------------------|----------------------------------------------|----------------------------------------------|------------------------------------------------------------|----------------------------|----------------------------------------------|
|                   | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p \Big _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p \Big _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> |
| -70               | 1,0026                                       | 1,0030                                                     | -70,213                    | -0,13501                                     | 1,8511                                       | 1,8542                                                     | 2371,14                    | 8,6070                                       |
| -50               | 1,0028                                       | 1,0032                                                     | -50,159                    | -0,04086                                     | 1,8523                                       | 1,8553                                                     | 2408,17                    | 8,7808                                       |
| -40               | 1,0029                                       | 1,0033                                                     | -40,130                    | 0,00310                                      | 1,8533                                       | 1,8559                                                     | 2426,70                    | 8,8621                                       |
| -30               | 1,0030                                       | 1,0034                                                     | -30,101                    | 0,04522                                      | 1,8545                                       | 1,8565                                                     | 2445,24                    | 8,9399                                       |
| -20               | 1,0032                                       | 1,0035                                                     | -20,070                    | 0,08565                                      | 1,8558                                       | 1,8573                                                     | 2463,79                    | 9,0147                                       |
| -10               | 1,0035                                       | 1,0036                                                     | -10,036                    | 0,12452                                      | 1,8572                                       | 1,8580                                                     | 2482,35                    | 9,0866                                       |
| $\vartheta_o = 0$ | 1,0038                                       | 1,0038                                                     | $h_o = 0$                  | $s_o = 0,16196$                              | 1,8589                                       | 1,8589                                                     | $h_o = 2500,93$            | $s_o = 9,1559$                               |
| 10                | 1,0042                                       | 1,0040                                                     | 10,040                     | 0,19805                                      | 1,8608                                       | 1,8598                                                     | 2519,53                    | 9,2228                                       |
| 20                | 1,0046                                       | 1,0042                                                     | 20,084                     | 0,23291                                      | 1,8629                                       | 1,8608                                                     | 2538,15                    | 9,2874                                       |
| 25                | 1,0048                                       | 1,0043                                                     | 25,107                     | 0,24991                                      | 1,8641                                       | 1,8614                                                     | 2547,47                    | 9,3189                                       |
| 30                | 1,0051                                       | 1,0044                                                     | 30,132                     | 0,26662                                      | 1,8654                                       | 1,8619                                                     | 2556,79                    | 9,3499                                       |
| 40                | 1,0057                                       | 1,0046                                                     | 40,186                     | 0,29925                                      | 1,8681                                       | 1,8631                                                     | 2575,46                    | 9,4105                                       |
| 50                | 1,0063                                       | 1,0049                                                     | 50,245                     | 0,33087                                      | 1,8711                                       | 1,8644                                                     | 2594,15                    | 9,4693                                       |
| 60                | 1,0070                                       | 1,0052                                                     | 60,311                     | 0,36155                                      | 1,8743                                       | 1,8658                                                     | 2612,88                    | 9,5264                                       |
| 70                | 1,0077                                       | 1,0055                                                     | 70,385                     | 0,39134                                      | 1,8779                                       | 1,8673                                                     | 2631,64                    | 9,5818                                       |
| 80                | 1,0085                                       | 1,0058                                                     | 80,466                     | 0,42030                                      | 1,8816                                       | 1,8688                                                     | 2650,44                    | 9,6358                                       |
| 90                | 1,0094                                       | 1,0062                                                     | 90,556                     | 0,44847                                      | 1,8856                                       | 1,8705                                                     | 2669,28                    | 9,6884                                       |
| 100               | 1,0104                                       | 1,0066                                                     | 100,66                     | 0,47591                                      | 1,8898                                       | 1,8722                                                     | 2688,15                    | 9,7397                                       |
| 120               | 1,0126                                       | 1,0074                                                     | 120,89                     | 0,52872                                      | 1,8988                                       | 1,8759                                                     | 2726,04                    | 9,8386                                       |
| 140               | 1,0151                                       | 1,0083                                                     | 141,16                     | 0,57902                                      | 1,9084                                       | 1,8798                                                     | 2764,11                    | 9,9331                                       |
| 160               | 1,0180                                       | 1,0093                                                     | 161,49                     | 0,62708                                      | 1,9186                                       | 1,8840                                                     | 2802,38                    | 10,0235                                      |
| 180               | 1,0211                                       | 1,0105                                                     | 181,88                     | 0,67310                                      | 1,9292                                       | 1,8885                                                     | 2840,86                    | 10,1104                                      |
| 200               | 1,0245                                       | 1,0117                                                     | 202,34                     | 0,71727                                      | 1,9402                                       | 1,8931                                                     | 2879,55                    | 10,1939                                      |
| 250               | 1,0341                                       | 1,0152                                                     | 253,80                     | 0,82065                                      | 1,9690                                       | 1,9053                                                     | 2977,27                    | 10,3902                                      |
| 300               | 1,0449                                       | 1,0192                                                     | 305,77                     | 0,91552                                      | 1,9993                                       | 1,9185                                                     | 3076,47                    | 10,5713                                      |
| 350               | 1,0565                                       | 1,0237                                                     | 358,30                     | 1,00339                                      | 2,0308                                       | 1,9322                                                     | 3177,22                    | 10,7398                                      |
| 400               | 1,0684                                       | 1,0286                                                     | 411,42                     | 1,08538                                      | 2,0633                                       | 1,9466                                                     | 3279,57                    | 10,8978                                      |
| 450               | 1,0805                                       | 1,0337                                                     | 465,14                     | 1,16236                                      | 2,0968                                       | 1,9614                                                     | 3383,57                    | 11,0468                                      |
| 500               | 1,0924                                       | 1,0389                                                     | 519,47                     | 1,23499                                      | 2,1310                                       | 1,9767                                                     | 3489,26                    | 11,1881                                      |
| 550               | 1,1040                                       | 1,0443                                                     | 574,38                     | 1,30381                                      | 2,1659                                       | 1,9923                                                     | 3596,68                    | 11,3227                                      |
| 600               | 1,1151                                       | 1,0498                                                     | 629,86                     | 1,36923                                      | 2,2013                                       | 2,0082                                                     | 3705,86                    | 11,4515                                      |
| 650               | 1,1258                                       | 1,0552                                                     | 685,88                     | 1,43162                                      | 2,2371                                       | 2,0244                                                     | 3816,82                    | 11,5750                                      |
| 700               | 1,1358                                       | 1,0606                                                     | 742,42                     | 1,49127                                      | 2,2729                                       | 2,0409                                                     | 3929,57                    | 11,6940                                      |
| 750               | 1,1454                                       | 1,0659                                                     | 799,46                     | 1,54842                                      | 2,3088                                       | 2,0576                                                     | 4044,11                    | 11,8088                                      |
| 800               | 1,1543                                       | 1,0712                                                     | 856,95                     | 1,60328                                      | 2,3446                                       | 2,0744                                                     | 4160,45                    | 11,9198                                      |
| 850               | 1,1627                                       | 1,0763                                                     | 914,88                     | 1,65604                                      | 2,3800                                       | 2,0913                                                     | 4278,57                    | 12,0273                                      |
| 900               | 1,1706                                       | 1,0813                                                     | 973,21                     | 1,70685                                      | 2,4149                                       | 2,1083                                                     | 4398,44                    | 12,1318                                      |
| 950               | 1,1779                                       | 1,0862                                                     | 1031,93                    | 1,75586                                      | 2,4494                                       | 2,1254                                                     | 4520,05                    | 12,2333                                      |
| 1000              | 1,1848                                       | 1,0910                                                     | 1091,00                    | 1,80320                                      | 2,4831                                       | 2,1424                                                     | 4643,37                    | 12,3321                                      |
| 1050              | 1,1913                                       | 1,0956                                                     | 1150,40                    | 1,84896                                      | 2,5161                                       | 2,1594                                                     | 4768,35                    | 12,4284                                      |
| 1100              | 1,1974                                       | 1,1001                                                     | 1210,12                    | 1,89326                                      | 2,5483                                       | 2,1764                                                     | 4894,96                    | 12,5223                                      |
| 1150              | 1,2031                                       | 1,1045                                                     | 1270,14                    | 1,93619                                      | 2,5797                                       | 2,1932                                                     | 5023,17                    | 12,6140                                      |
| 1200              | 1,2084                                       | 1,1087                                                     | 1330,42                    | 1,97782                                      | 2,6101                                       | 2,2100                                                     | 5152,91                    | 12,7036                                      |
| 1250              | 1,2134                                       | 1,1128                                                     | 1390,97                    | 2,01824                                      | 2,6396                                       | 2,2266                                                     | 5284,16                    | 12,7912                                      |
| 1300              | 1,2182                                       | 1,1167                                                     | 1451,76                    | 2,05751                                      | 2,6681                                       | 2,2430                                                     | 5416,86                    | 12,8769                                      |
| 1350              | 1,2227                                       | 1,1206                                                     | 1512,79                    | 2,09570                                      | 2,6957                                       | 2,2593                                                     | 5550,96                    | 12,9608                                      |
| 1400              | 1,2270                                       | 1,1243                                                     | 1574,03                    | 2,13286                                      | 2,7223                                       | 2,2753                                                     | 5686,41                    | 13,0430                                      |
| 1450              | 1,2310                                       | 1,1279                                                     | 1635,48                    | 2,16905                                      | 2,7479                                       | 2,2912                                                     | 5823,17                    | 13,1235                                      |
| 1500              | 1,2348                                       | 1,1314                                                     | 1697,12                    | 2,20431                                      | 2,7726                                       | 2,3068                                                     | 5961,19                    | 13,2025                                      |
| 1550              | 1,2385                                       | 1,1348                                                     | 1758,96                    | 2,23870                                      | 2,7964                                       | 2,3222                                                     | 6100,41                    | 13,2799                                      |
| 1600              | 1,2420                                       | 1,1381                                                     | 1820,97                    | 2,27226                                      | 2,8192                                       | 2,3374                                                     | 6240,81                    | 13,3559                                      |
| 1650              | 1,2454                                       | 1,1413                                                     | 1883,16                    | 2,30502                                      | 2,8412                                       | 2,3524                                                     | 6382,32                    | 13,4305                                      |
| 1700              | 1,2486                                       | 1,1444                                                     | 1945,51                    | 2,33703                                      | 2,8623                                       | 2,3670                                                     | 6524,92                    | 13,5037                                      |

$$c_p \Big|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$s_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

**Tab. 3-2 Fluide im Idealgaszustand**

Werte nach VDI-Richtlinie 4670

| $\vartheta$<br>°C | Sauerstoff O <sub>2</sub>                    |                                                       |                            |                                              | Stickstoff N <sub>2</sub>                    |                                                       |                            |                                              |
|-------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|
|                   | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> |
| -70               | 0,91030                                      | 0,91203                                               | -63,842                    | -0,27000                                     | 1,0391                                       | 1,0392                                                | -72,742                    | -0,30767                                     |
| -50               | 0,91095                                      | 0,91261                                               | -45,630                    | -0,18450                                     | 1,0392                                       | 1,0392                                                | -51,958                    | -0,21009                                     |
| -40               | 0,91147                                      | 0,91296                                               | -36,519                    | -0,14455                                     | 1,0391                                       | 1,0392                                                | -41,566                    | -0,16454                                     |
| -30               | 0,91211                                      | 0,91336                                               | -27,401                    | -0,10626                                     | 1,0391                                       | 1,0392                                                | -31,175                    | -0,12090                                     |
| -20               | 0,91287                                      | 0,91379                                               | -18,276                    | -0,06948                                     | 1,0391                                       | 1,0392                                                | -20,784                    | -0,07902                                     |
| -10               | 0,91377                                      | 0,91427                                               | -9,143                     | -0,03410                                     | 1,0392                                       | 1,0392                                                | -10,392                    | -0,03876                                     |
| $\vartheta_o = 0$ | 0,91480                                      | 0,91480                                               | $h_o = 0$                  | $s_o = 0$                                    | 1,0393                                       | 1,0393                                                | $h_o = 0$                  | $s_o = 0$                                    |
| 10                | 0,91599                                      | 0,91539                                               | 9,154                      | 0,03291                                      | 1,0394                                       | 1,0394                                                | 10,394                     | 0,03737                                      |
| 20                | 0,91734                                      | 0,91602                                               | 18,320                     | 0,06473                                      | 1,0396                                       | 1,0394                                                | 20,789                     | 0,07345                                      |
| 25                | 0,91808                                      | 0,91636                                               | 22,909                     | 0,08025                                      | 1,0397                                       | 1,0395                                                | 25,987                     | 0,09103                                      |
| 30                | 0,91885                                      | 0,91671                                               | 27,501                     | 0,09552                                      | 1,0398                                       | 1,0395                                                | 31,186                     | 0,10833                                      |
| 40                | 0,92052                                      | 0,91745                                               | 36,698                     | 0,12537                                      | 1,0400                                       | 1,0396                                                | 41,585                     | 0,14207                                      |
| 50                | 0,92235                                      | 0,91824                                               | 45,912                     | 0,15433                                      | 1,0403                                       | 1,0397                                                | 51,986                     | 0,17477                                      |
| 60                | 0,92433                                      | 0,91909                                               | 55,145                     | 0,18247                                      | 1,0406                                       | 1,0398                                                | 62,391                     | 0,20648                                      |
| 70                | 0,92646                                      | 0,91999                                               | 64,399                     | 0,20984                                      | 1,0409                                       | 1,0400                                                | 72,798                     | 0,23726                                      |
| 80                | 0,92873                                      | 0,92094                                               | 73,675                     | 0,23649                                      | 1,0413                                       | 1,0401                                                | 83,209                     | 0,26717                                      |
| 90                | 0,93113                                      | 0,92194                                               | 82,974                     | 0,26245                                      | 1,0418                                       | 1,0403                                                | 93,625                     | 0,29625                                      |
| 100               | 0,93365                                      | 0,92298                                               | 92,298                     | 0,28778                                      | 1,0423                                       | 1,0405                                                | 104,045                    | 0,32456                                      |
| 120               | 0,93900                                      | 0,92520                                               | 111,024                    | 0,33666                                      | 1,0436                                       | 1,0409                                                | 124,904                    | 0,37901                                      |
| 140               | 0,94470                                      | 0,92757                                               | 129,860                    | 0,38340                                      | 1,0452                                       | 1,0414                                                | 145,791                    | 0,43083                                      |
| 160               | 0,95068                                      | 0,93009                                               | 148,814                    | 0,42819                                      | 1,0471                                       | 1,0420                                                | 166,713                    | 0,48028                                      |
| 180               | 0,95685                                      | 0,93272                                               | 167,889                    | 0,47124                                      | 1,0493                                       | 1,0426                                                | 187,676                    | 0,52759                                      |
| 200               | 0,96315                                      | 0,93544                                               | 187,089                    | 0,51270                                      | 1,0519                                       | 1,0434                                                | 208,688                    | 0,57297                                      |
| 250               | 0,97909                                      | 0,94258                                               | 235,645                    | 0,61025                                      | 1,0597                                       | 1,0459                                                | 261,471                    | 0,67901                                      |
| 300               | 0,99477                                      | 0,94998                                               | 284,993                    | 0,70033                                      | 1,0692                                       | 1,0490                                                | 314,688                    | 0,77615                                      |
| 350               | 1,00973                                      | 0,95746                                               | 335,110                    | 0,78415                                      | 1,0799                                       | 1,0526                                                | 368,412                    | 0,86601                                      |
| 400               | 1,02373                                      | 0,96488                                               | 385,951                    | 0,86262                                      | 1,0915                                       | 1,0567                                                | 422,694                    | 0,94980                                      |
| 450               | 1,03665                                      | 0,97214                                               | 437,465                    | 0,93644                                      | 1,1035                                       | 1,0613                                                | 477,567                    | 1,02843                                      |
| 500               | 1,04848                                      | 0,97920                                               | 489,598                    | 1,00614                                      | 1,1156                                       | 1,0661                                                | 533,043                    | 1,10260                                      |
| 550               | 1,05925                                      | 0,98599                                               | 542,295                    | 1,07218                                      | 1,1276                                       | 1,0711                                                | 589,125                    | 1,17288                                      |
| 600               | 1,06903                                      | 0,99251                                               | 595,506                    | 1,13494                                      | 1,1394                                       | 1,0763                                                | 645,802                    | 1,23972                                      |
| 650               | 1,07792                                      | 0,99874                                               | 649,183                    | 1,19471                                      | 1,1507                                       | 1,0816                                                | 703,057                    | 1,30349                                      |
| 700               | 1,08600                                      | 1,0047                                                | 703,284                    | 1,25178                                      | 1,1616                                       | 1,0870                                                | 760,868                    | 1,36447                                      |
| 750               | 1,09337                                      | 1,0104                                                | 757,771                    | 1,30638                                      | 1,1720                                       | 1,0923                                                | 819,210                    | 1,42293                                      |
| 800               | 1,10013                                      | 1,0158                                                | 812,611                    | 1,35871                                      | 1,1817                                       | 1,0976                                                | 878,054                    | 1,47908                                      |
| 850               | 1,10635                                      | 1,0209                                                | 867,775                    | 1,40895                                      | 1,1909                                       | 1,1028                                                | 937,373                    | 1,53311                                      |
| 900               | 1,11212                                      | 1,0258                                                | 923,239                    | 1,45727                                      | 1,1996                                       | 1,1079                                                | 997,139                    | 1,58517                                      |
| 950               | 1,11751                                      | 1,0305                                                | 978,981                    | 1,50380                                      | 1,2077                                       | 1,1130                                                | 1057,322                   | 1,63540                                      |
| 1000              | 1,12256                                      | 1,0350                                                | 1034,984                   | 1,54867                                      | 1,2153                                       | 1,1179                                                | 1117,898                   | 1,68394                                      |
| 1050              | 1,12735                                      | 1,0393                                                | 1091,233                   | 1,59200                                      | 1,2224                                       | 1,1227                                                | 1178,841                   | 1,73089                                      |
| 1100              | 1,13191                                      | 1,0434                                                | 1147,716                   | 1,63390                                      | 1,2290                                       | 1,1274                                                | 1240,126                   | 1,77635                                      |
| 1150              | 1,13628                                      | 1,0473                                                | 1204,421                   | 1,67447                                      | 1,2352                                       | 1,1319                                                | 1301,731                   | 1,82042                                      |
| 1200              | 1,14051                                      | 1,0511                                                | 1261,342                   | 1,71378                                      | 1,2409                                       | 1,1364                                                | 1363,635                   | 1,86317                                      |
| 1250              | 1,14461                                      | 1,0548                                                | 1318,470                   | 1,75191                                      | 1,2464                                       | 1,1407                                                | 1425,820                   | 1,90468                                      |
| 1300              | 1,14861                                      | 1,0583                                                | 1375,801                   | 1,78895                                      | 1,2514                                       | 1,1448                                                | 1488,266                   | 1,94502                                      |
| 1350              | 1,15253                                      | 1,0617                                                | 1433,329                   | 1,82495                                      | 1,2562                                       | 1,1489                                                | 1550,957                   | 1,98425                                      |
| 1400              | 1,15638                                      | 1,0650                                                | 1491,052                   | 1,85997                                      | 1,2606                                       | 1,1528                                                | 1613,878                   | 2,02243                                      |
| 1450              | 1,16019                                      | 1,0683                                                | 1548,967                   | 1,89408                                      | 1,2648                                       | 1,1566                                                | 1677,015                   | 2,05961                                      |
| 1500              | 1,16396                                      | 1,0714                                                | 1607,071                   | 1,92732                                      | 1,2687                                       | 1,1602                                                | 1740,355                   | 2,09585                                      |
| 1550              | 1,16770                                      | 1,0744                                                | 1665,362                   | 1,95974                                      | 1,2725                                       | 1,1638                                                | 1803,886                   | 2,13118                                      |
| 1600              | 1,17141                                      | 1,0774                                                | 1723,840                   | 1,99138                                      | 1,2759                                       | 1,1672                                                | 1867,597                   | 2,16566                                      |
| 1650              | 1,17511                                      | 1,0803                                                | 1782,503                   | 2,02229                                      | 1,2792                                       | 1,1706                                                | 1931,478                   | 2,19931                                      |
| 1700              | 1,17878                                      | 1,0831                                                | 1841,350                   | 2,05249                                      | 1,2824                                       | 1,1738                                                | 1995,519                   | 2,23219                                      |

$$c_p|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$s_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

**Tab. 3-3 Fluide im Idealgaszustand**

Werte nach VDI-Richtlinie 4670

| $\vartheta$<br>°C | Kohlenmonoxid CO                             |                                                       |                            |                                              | Kohlendioxid CO <sub>2</sub>                 |                                                       |                            |                                              |
|-------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|
|                   | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> |
| -70               | 1,0390                                       | 1,0391                                                | -72,738                    | -0,30765                                     | 0,73892                                      | 0,77822                                               | -54,476                    | -0,22984                                     |
| -50               | 1,0390                                       | 1,0391                                                | -51,957                    | -0,21009                                     | 0,76134                                      | 0,78947                                               | -39,474                    | -0,15942                                     |
| -40               | 1,0390                                       | 1,0392                                                | -41,567                    | -0,16454                                     | 0,77265                                      | 0,79509                                               | -31,804                    | -0,12580                                     |
| -30               | 1,0391                                       | 1,0392                                                | -31,177                    | -0,12091                                     | 0,78394                                      | 0,80069                                               | -24,021                    | -0,09312                                     |
| -20               | 1,0392                                       | 1,0393                                                | -20,786                    | -0,07903                                     | 0,79516                                      | 0,80626                                               | -16,125                    | -0,06130                                     |
| -10               | 1,0393                                       | 1,0393                                                | -10,393                    | -0,03876                                     | 0,80628                                      | 0,81178                                               | -8,118                     | -0,03028                                     |
| $\vartheta_o = 0$ | 1,0394                                       | 1,0394                                                | $h_o = 0$                  | $s_o = 0$                                    | 0,81726                                      | 0,81726                                               | $h_o = 0$                  | $s_o = 0$                                    |
| 10                | 1,0396                                       | 1,0395                                                | 10,395                     | 0,03738                                      | 0,82807                                      | 0,82268                                               | 8,227                      | 0,02958                                      |
| 20                | 1,0399                                       | 1,0396                                                | 20,793                     | 0,07346                                      | 0,83869                                      | 0,82804                                               | 16,561                     | 0,05850                                      |
| 25                | 1,0400                                       | 1,0397                                                | 25,993                     | 0,09105                                      | 0,84393                                      | 0,83069                                               | 20,767                     | 0,07273                                      |
| 30                | 1,0402                                       | 1,0398                                                | 31,193                     | 0,10835                                      | 0,84911                                      | 0,83333                                               | 25,000                     | 0,08681                                      |
| 40                | 1,0405                                       | 1,0399                                                | 41,597                     | 0,14211                                      | 0,85932                                      | 0,83856                                               | 33,542                     | 0,11453                                      |
| 50                | 1,0410                                       | 1,0401                                                | 52,004                     | 0,17483                                      | 0,86932                                      | 0,84371                                               | 42,186                     | 0,14170                                      |
| 60                | 1,0415                                       | 1,0403                                                | 62,416                     | 0,20656                                      | 0,87910                                      | 0,84880                                               | 50,928                     | 0,16834                                      |
| 70                | 1,0420                                       | 1,0405                                                | 72,833                     | 0,23737                                      | 0,88867                                      | 0,85381                                               | 59,767                     | 0,19448                                      |
| 80                | 1,0427                                       | 1,0407                                                | 83,257                     | 0,26731                                      | 0,89803                                      | 0,85876                                               | 68,701                     | 0,22015                                      |
| 90                | 1,0434                                       | 1,0410                                                | 93,687                     | 0,29644                                      | 0,90718                                      | 0,86363                                               | 77,727                     | 0,24535                                      |
| 100               | 1,0443                                       | 1,0413                                                | 104,126                    | 0,32479                                      | 0,91612                                      | 0,86844                                               | 86,844                     | 0,27011                                      |
| 120               | 1,0463                                       | 1,0419                                                | 125,031                    | 0,37936                                      | 0,93342                                      | 0,87784                                               | 105,340                    | 0,31840                                      |
| 140               | 1,0486                                       | 1,0427                                                | 145,979                    | 0,43134                                      | 0,94997                                      | 0,88697                                               | 124,176                    | 0,36512                                      |
| 160               | 1,0514                                       | 1,0436                                                | 166,979                    | 0,48097                                      | 0,96581                                      | 0,89584                                               | 143,335                    | 0,41041                                      |
| 180               | 1,0546                                       | 1,0447                                                | 188,038                    | 0,52850                                      | 0,98099                                      | 0,90446                                               | 162,804                    | 0,45434                                      |
| 200               | 1,0581                                       | 1,0458                                                | 209,165                    | 0,57412                                      | 0,99555                                      | 0,91285                                               | 182,570                    | 0,49703                                      |
| 250               | 1,0683                                       | 1,0493                                                | 262,318                    | 0,68091                                      | 1,02945                                      | 0,93284                                               | 233,209                    | 0,59874                                      |
| 300               | 1,0800                                       | 1,0534                                                | 316,020                    | 0,77894                                      | 1,06019                                      | 0,95154                                               | 285,463                    | 0,69411                                      |
| 350               | 1,0927                                       | 1,0581                                                | 370,334                    | 0,86978                                      | 1,08815                                      | 0,96909                                               | 339,182                    | 0,78395                                      |
| 400               | 1,1058                                       | 1,0632                                                | 425,295                    | 0,95462                                      | 1,11363                                      | 0,98559                                               | 394,236                    | 0,86892                                      |
| 450               | 1,1191                                       | 1,0687                                                | 480,918                    | 1,03432                                      | 1,13690                                      | 1,0011                                                | 450,508                    | 0,94955                                      |
| 500               | 1,1321                                       | 1,0744                                                | 537,200                    | 1,10957                                      | 1,15817                                      | 1,0158                                                | 507,893                    | 1,02627                                      |
| 550               | 1,1448                                       | 1,0802                                                | 594,125                    | 1,18091                                      | 1,17762                                      | 1,0296                                                | 566,295                    | 1,09946                                      |
| 600               | 1,1569                                       | 1,0861                                                | 651,671                    | 1,24877                                      | 1,19543                                      | 1,0427                                                | 625,627                    | 1,16943                                      |
| 650               | 1,1684                                       | 1,0920                                                | 709,808                    | 1,31352                                      | 1,21174                                      | 1,0551                                                | 685,812                    | 1,23646                                      |
| 700               | 1,1793                                       | 1,0979                                                | 768,502                    | 1,37543                                      | 1,22668                                      | 1,0668                                                | 746,778                    | 1,30077                                      |
| 750               | 1,1894                                       | 1,1036                                                | 827,722                    | 1,43477                                      | 1,24039                                      | 1,0779                                                | 808,460                    | 1,36257                                      |
| 800               | 1,1989                                       | 1,1093                                                | 887,432                    | 1,49175                                      | 1,25298                                      | 1,0885                                                | 870,799                    | 1,42206                                      |
| 850               | 1,2077                                       | 1,1148                                                | 947,599                    | 1,54655                                      | 1,26454                                      | 1,0985                                                | 933,741                    | 1,47938                                      |
| 900               | 1,2159                                       | 1,1202                                                | 1008,192                   | 1,59933                                      | 1,27517                                      | 1,1080                                                | 997,238                    | 1,53469                                      |
| 950               | 1,2235                                       | 1,1255                                                | 1069,181                   | 1,65024                                      | 1,28496                                      | 1,1171                                                | 1061,244                   | 1,58812                                      |
| 1000              | 1,2306                                       | 1,1305                                                | 1130,536                   | 1,69940                                      | 1,29398                                      | 1,1257                                                | 1125,721                   | 1,63978                                      |
| 1050              | 1,2372                                       | 1,1355                                                | 1192,232                   | 1,74693                                      | 1,30230                                      | 1,1339                                                | 1190,631                   | 1,68979                                      |
| 1100              | 1,2433                                       | 1,1402                                                | 1254,246                   | 1,79293                                      | 1,30999                                      | 1,1418                                                | 1255,941                   | 1,73824                                      |
| 1150              | 1,2490                                       | 1,1448                                                | 1316,553                   | 1,83750                                      | 1,31711                                      | 1,1492                                                | 1321,621                   | 1,78522                                      |
| 1200              | 1,2543                                       | 1,1493                                                | 1379,136                   | 1,88072                                      | 1,32370                                      | 1,1564                                                | 1387,643                   | 1,83081                                      |
| 1250              | 1,2592                                       | 1,1536                                                | 1441,974                   | 1,92267                                      | 1,32983                                      | 1,1632                                                | 1453,983                   | 1,87510                                      |
| 1300              | 1,2638                                       | 1,1577                                                | 1505,051                   | 1,96342                                      | 1,33552                                      | 1,1697                                                | 1520,618                   | 1,91814                                      |
| 1350              | 1,2682                                       | 1,1617                                                | 1568,352                   | 2,00303                                      | 1,34081                                      | 1,1759                                                | 1587,528                   | 1,96001                                      |
| 1400              | 1,2722                                       | 1,1656                                                | 1631,863                   | 2,04157                                      | 1,34576                                      | 1,1819                                                | 1654,694                   | 2,00077                                      |
| 1450              | 1,2760                                       | 1,1694                                                | 1695,571                   | 2,07908                                      | 1,35038                                      | 1,1877                                                | 1722,099                   | 2,04047                                      |
| 1500              | 1,2796                                       | 1,1730                                                | 1759,464                   | 2,11563                                      | 1,35470                                      | 1,1932                                                | 1789,727                   | 2,07915                                      |
| 1550              | 1,2830                                       | 1,1765                                                | 1823,532                   | 2,15127                                      | 1,35876                                      | 1,1984                                                | 1857,564                   | 2,11688                                      |
| 1600              | 1,2862                                       | 1,1799                                                | 1887,764                   | 2,18602                                      | 1,36257                                      | 1,2035                                                | 1925,599                   | 2,15370                                      |
| 1650              | 1,2893                                       | 1,1831                                                | 1952,152                   | 2,21995                                      | 1,36616                                      | 1,2084                                                | 1993,818                   | 2,18964                                      |
| 1700              | 1,2921                                       | 1,1863                                                | 2016,688                   | 2,25308                                      | 1,36955                                      | 1,2131                                                | 2062,212                   | 2,22475                                      |

$$c_p|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$s_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

**Tab. 3-4 Fluide im Idealgaszustand**

Werte nach VDI-Richtlinie 4670

| $\vartheta$<br>°C | Argon Ar                                     |                                                            |                            |                                              | Neon Ne                                      |                                                            |                            |                                              |
|-------------------|----------------------------------------------|------------------------------------------------------------|----------------------------|----------------------------------------------|----------------------------------------------|------------------------------------------------------------|----------------------------|----------------------------------------------|
|                   | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p \Big _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p \Big _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> |
| -70               | 0,52033                                      | 0,52033                                                    | -36,423                    | -0,15406                                     | 1,0301                                       | 1,0301                                                     | -72,104                    | -0,30497                                     |
| -50               | 0,52033                                      | 0,52033                                                    | -26,017                    | -0,10520                                     | 1,0301                                       | 1,0301                                                     | -51,503                    | -0,20825                                     |
| -40               | 0,52033                                      | 0,52033                                                    | -20,813                    | -0,082389                                    | 1,0301                                       | 1,0301                                                     | -41,202                    | -0,16310                                     |
| -30               | 0,52033                                      | 0,52033                                                    | -15,610                    | -0,060537                                    | 1,0301                                       | 1,0301                                                     | -30,902                    | -0,11984                                     |
| -20               | 0,52033                                      | 0,52033                                                    | -10,407                    | -0,039565                                    | 1,0301                                       | 1,0301                                                     | -20,601                    | -0,07832                                     |
| -10               | 0,52033                                      | 0,52033                                                    | -5,203                     | -0,019407                                    | 1,0301                                       | 1,0301                                                     | -10,301                    | -0,03842                                     |
| $\vartheta_o = 0$ | 0,52033                                      | 0,52033                                                    | $h_o = 0$                  | $s_o = 0$                                    | 1,0301                                       | 1,0301                                                     | $h_o = 0$                  | $s_o = 0$                                    |
| 10                | 0,52033                                      | 0,52033                                                    | 5,203                      | 0,018709                                     | 1,0301                                       | 1,0301                                                     | 10,301                     | 0,03704                                      |
| 20                | 0,52033                                      | 0,52033                                                    | 10,407                     | 0,036768                                     | 1,0301                                       | 1,0301                                                     | 20,601                     | 0,07279                                      |
| 25                | 0,52033                                      | 0,52033                                                    | 13,008                     | 0,045568                                     | 1,0301                                       | 1,0301                                                     | 25,751                     | 0,09021                                      |
| 30                | 0,52033                                      | 0,52033                                                    | 15,610                     | 0,054222                                     | 1,0301                                       | 1,0301                                                     | 30,902                     | 0,10734                                      |
| 40                | 0,52033                                      | 0,52033                                                    | 20,813                     | 0,071109                                     | 1,0301                                       | 1,0301                                                     | 41,202                     | 0,14077                                      |
| 50                | 0,52033                                      | 0,52033                                                    | 26,017                     | 0,087465                                     | 1,0301                                       | 1,0301                                                     | 51,503                     | 0,17315                                      |
| 60                | 0,52033                                      | 0,52033                                                    | 31,220                     | 0,10332                                      | 1,0301                                       | 1,0301                                                     | 61,803                     | 0,20454                                      |
| 70                | 0,52033                                      | 0,52033                                                    | 36,423                     | 0,11871                                      | 1,0301                                       | 1,0301                                                     | 72,104                     | 0,23500                                      |
| 80                | 0,52033                                      | 0,52033                                                    | 41,626                     | 0,13366                                      | 1,0301                                       | 1,0301                                                     | 82,404                     | 0,26459                                      |
| 90                | 0,52033                                      | 0,52033                                                    | 46,830                     | 0,14819                                      | 1,0301                                       | 1,0301                                                     | 92,705                     | 0,29335                                      |
| 100               | 0,52033                                      | 0,52033                                                    | 52,033                     | 0,16232                                      | 1,0301                                       | 1,0301                                                     | 103,01                     | 0,32134                                      |
| 120               | 0,52033                                      | 0,52033                                                    | 62,440                     | 0,18949                                      | 1,0301                                       | 1,0301                                                     | 123,61                     | 0,37511                                      |
| 140               | 0,52033                                      | 0,52033                                                    | 72,846                     | 0,21531                                      | 1,0301                                       | 1,0301                                                     | 144,21                     | 0,42623                                      |
| 160               | 0,52033                                      | 0,52033                                                    | 83,253                     | 0,23991                                      | 1,0301                                       | 1,0301                                                     | 164,81                     | 0,47492                                      |
| 180               | 0,52033                                      | 0,52033                                                    | 93,660                     | 0,26339                                      | 1,0301                                       | 1,0301                                                     | 185,41                     | 0,52142                                      |
| 200               | 0,52033                                      | 0,52033                                                    | 104,066                    | 0,28587                                      | 1,0301                                       | 1,0301                                                     | 206,01                     | 0,56590                                      |
| 250               | 0,52033                                      | 0,52033                                                    | 130,083                    | 0,33814                                      | 1,0301                                       | 1,0301                                                     | 257,51                     | 0,66938                                      |
| 300               | 0,52033                                      | 0,52033                                                    | 156,099                    | 0,38563                                      | 1,0301                                       | 1,0301                                                     | 309,02                     | 0,76340                                      |
| 350               | 0,52033                                      | 0,52033                                                    | 182,116                    | 0,42915                                      | 1,0301                                       | 1,0301                                                     | 360,52                     | 0,84955                                      |
| 400               | 0,52033                                      | 0,52033                                                    | 208,132                    | 0,46931                                      | 1,0301                                       | 1,0301                                                     | 412,02                     | 0,92905                                      |
| 450               | 0,52033                                      | 0,52033                                                    | 234,149                    | 0,50659                                      | 1,0301                                       | 1,0301                                                     | 463,52                     | 1,0029                                       |
| 500               | 0,52033                                      | 0,52033                                                    | 260,165                    | 0,54138                                      | 1,0301                                       | 1,0301                                                     | 515,03                     | 1,0717                                       |
| 550               | 0,52033                                      | 0,52033                                                    | 286,182                    | 0,57399                                      | 1,0301                                       | 1,0301                                                     | 566,53                     | 1,1363                                       |
| 600               | 0,52033                                      | 0,52033                                                    | 312,199                    | 0,60467                                      | 1,0301                                       | 1,0301                                                     | 618,03                     | 1,1970                                       |
| 650               | 0,52033                                      | 0,52033                                                    | 338,215                    | 0,63364                                      | 1,0301                                       | 1,0301                                                     | 669,54                     | 1,2544                                       |
| 700               | 0,52033                                      | 0,52033                                                    | 364,232                    | 0,66109                                      | 1,0301                                       | 1,0301                                                     | 721,04                     | 1,3087                                       |
| 750               | 0,52033                                      | 0,52033                                                    | 390,248                    | 0,68716                                      | 1,0301                                       | 1,0301                                                     | 772,54                     | 1,3603                                       |
| 800               | 0,52033                                      | 0,52033                                                    | 416,265                    | 0,71199                                      | 1,0301                                       | 1,0301                                                     | 824,04                     | 1,4095                                       |
| 850               | 0,52033                                      | 0,52033                                                    | 442,281                    | 0,73568                                      | 1,0301                                       | 1,0301                                                     | 875,55                     | 1,4564                                       |
| 900               | 0,52033                                      | 0,52033                                                    | 468,298                    | 0,75834                                      | 1,0301                                       | 1,0301                                                     | 927,05                     | 1,5012                                       |
| 950               | 0,52033                                      | 0,52033                                                    | 494,314                    | 0,78006                                      | 1,0301                                       | 1,0301                                                     | 978,55                     | 1,5442                                       |
| 1000              | 0,52033                                      | 0,52033                                                    | 520,331                    | 0,80091                                      | 1,0301                                       | 1,0301                                                     | 1030,05                    | 1,5855                                       |
| 1050              | 0,52033                                      | 0,52033                                                    | 546,347                    | 0,82095                                      | 1,0301                                       | 1,0301                                                     | 1081,56                    | 1,6252                                       |
| 1100              | 0,52033                                      | 0,52033                                                    | 572,364                    | 0,84025                                      | 1,0301                                       | 1,0301                                                     | 1133,06                    | 1,6634                                       |
| 1150              | 0,52033                                      | 0,52033                                                    | 598,381                    | 0,85886                                      | 1,0301                                       | 1,0301                                                     | 1184,56                    | 1,7002                                       |
| 1200              | 0,52033                                      | 0,52033                                                    | 624,397                    | 0,87683                                      | 1,0301                                       | 1,0301                                                     | 1236,06                    | 1,7358                                       |
| 1250              | 0,52033                                      | 0,52033                                                    | 650,414                    | 0,89420                                      | 1,0301                                       | 1,0301                                                     | 1287,57                    | 1,7702                                       |
| 1300              | 0,52033                                      | 0,52033                                                    | 676,430                    | 0,91100                                      | 1,0301                                       | 1,0301                                                     | 1339,07                    | 1,8034                                       |
| 1350              | 0,52033                                      | 0,52033                                                    | 702,447                    | 0,92728                                      | 1,0301                                       | 1,0301                                                     | 1390,57                    | 1,8357                                       |
| 1400              | 0,52033                                      | 0,52033                                                    | 728,463                    | 0,94307                                      | 1,0301                                       | 1,0301                                                     | 1442,08                    | 1,8669                                       |
| 1450              | 0,52033                                      | 0,52033                                                    | 754,480                    | 0,95839                                      | 1,0301                                       | 1,0301                                                     | 1493,58                    | 1,8972                                       |
| 1500              | 0,52033                                      | 0,52033                                                    | 780,496                    | 0,97327                                      | 1,0301                                       | 1,0301                                                     | 1545,08                    | 1,9267                                       |
| 1550              | 0,52033                                      | 0,52033                                                    | 806,513                    | 0,98774                                      | 1,0301                                       | 1,0301                                                     | 1596,58                    | 1,9554                                       |
| 1600              | 0,52033                                      | 0,52033                                                    | 832,529                    | 1,00182                                      | 1,0301                                       | 1,0301                                                     | 1648,09                    | 1,9832                                       |
| 1650              | 0,52033                                      | 0,52033                                                    | 858,546                    | 1,01553                                      | 1,0301                                       | 1,0301                                                     | 1699,59                    | 2,0104                                       |
| 1700              | 0,52033                                      | 0,52033                                                    | 884,563                    | 1,02888                                      | 1,0301                                       | 1,0301                                                     | 1751,09                    | 2,0368                                       |

$$c_p \Big|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$s_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

**Tab. 3-5 Fluide im Idealgaszustand**

 Werte SO<sub>2</sub> nach VDI-Richtlinie 4670, Werte NO nach ASME

| $\vartheta$<br>°C | Schwefeldioxid SO <sub>2</sub>               |                                                       |                            |                                              | Stickstoffoxid NO                            |                                                       |                            |                                              |
|-------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|
|                   | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> |
| -70               | 0,56956                                      | 0,58862                                               | -41,203                    | -0,17400                                     | 1,0136                                       | 1,00477                                               | -70,334                    | -0,29761                                     |
| -50               | 0,58036                                      | 0,59409                                               | -29,705                    | -0,12002                                     | 1,0080                                       | 1,00239                                               | -50,119                    | -0,20269                                     |
| -40               | 0,58583                                      | 0,59684                                               | -23,874                    | -0,09446                                     | 1,0054                                       | 1,00131                                               | -40,052                    | -0,15856                                     |
| -30               | 0,59132                                      | 0,59960                                               | -17,988                    | -0,06974                                     | 1,0032                                       | 1,00032                                               | -30,010                    | -0,11639                                     |
| -20               | 0,59683                                      | 0,60236                                               | -12,047                    | -0,04580                                     | 1,0011                                       | 0,99942                                               | -19,988                    | -0,07600                                     |
| -10               | 0,60236                                      | 0,60513                                               | -6,051                     | -0,02257                                     | 0,9994                                       | 0,99860                                               | -9,986                     | -0,03724                                     |
| $\vartheta_o = 0$ | 0,60791                                      | 0,60791                                               | $h_o = 0$                  | $s_o = 0$                                    | 0,9979                                       | 0,99786                                               | $h_o = 0$                  | $s_o = 0$                                    |
| 10                | 0,61349                                      | 0,61070                                               | 6,107                      | 0,02196                                      | 0,9966                                       | 0,99722                                               | 9,972                      | 0,03586                                      |
| 20                | 0,61908                                      | 0,61349                                               | 12,270                     | 0,04335                                      | 0,9956                                       | 0,99666                                               | 19,933                     | 0,07043                                      |
| 25                | 0,62188                                      | 0,61489                                               | 15,372                     | 0,05384                                      | 0,9952                                       | 0,99641                                               | 24,910                     | 0,08726                                      |
| 30                | 0,62469                                      | 0,61629                                               | 18,489                     | 0,06421                                      | 0,9949                                       | 0,99618                                               | 29,885                     | 0,10381                                      |
| 40                | 0,63030                                      | 0,61909                                               | 24,764                     | 0,08457                                      | 0,9943                                       | 0,99578                                               | 39,831                     | 0,13609                                      |
| 50                | 0,63590                                      | 0,62189                                               | 31,095                     | 0,10447                                      | 0,9940                                       | 0,99546                                               | 49,773                     | 0,16734                                      |
| 60                | 0,64150                                      | 0,62469                                               | 37,482                     | 0,12394                                      | 0,9940                                       | 0,99521                                               | 59,713                     | 0,19763                                      |
| 70                | 0,64706                                      | 0,62749                                               | 43,924                     | 0,14299                                      | 0,9941                                       | 0,99504                                               | 69,653                     | 0,22703                                      |
| 80                | 0,65260                                      | 0,63028                                               | 50,423                     | 0,16166                                      | 0,9944                                       | 0,99494                                               | 79,595                     | 0,25559                                      |
| 90                | 0,65809                                      | 0,63307                                               | 56,976                     | 0,17996                                      | 0,9950                                       | 0,99491                                               | 89,542                     | 0,28337                                      |
| 100               | 0,66353                                      | 0,63584                                               | 63,584                     | 0,19791                                      | 0,9957                                       | 0,99495                                               | 99,495                     | 0,31040                                      |
| 120               | 0,67423                                      | 0,64135                                               | 76,962                     | 0,23283                                      | 0,9976                                       | 0,99522                                               | 119,43                     | 0,36243                                      |
| 140               | 0,68464                                      | 0,64680                                               | 90,551                     | 0,26654                                      | 1,0001                                       | 0,99572                                               | 139,40                     | 0,41199                                      |
| 160               | 0,69472                                      | 0,65216                                               | 104,346                    | 0,29914                                      | 1,0031                                       | 0,99645                                               | 159,43                     | 0,45934                                      |
| 180               | 0,70443                                      | 0,65743                                               | 118,338                    | 0,33072                                      | 1,0066                                       | 0,99738                                               | 179,53                     | 0,50469                                      |
| 200               | 0,71377                                      | 0,66260                                               | 132,520                    | 0,36135                                      | 1,0105                                       | 0,99849                                               | 199,70                     | 0,54825                                      |
| 250               | 0,73539                                      | 0,67504                                               | 168,760                    | 0,43414                                      | 1,0216                                       | 1,00198                                               | 250,49                     | 0,65029                                      |
| 300               | 0,75457                                      | 0,68673                                               | 206,019                    | 0,50214                                      | 1,0341                                       | 1,00628                                               | 301,88                     | 0,74410                                      |
| 350               | 0,77144                                      | 0,69765                                               | 244,178                    | 0,56597                                      | 1,0472                                       | 1,01119                                               | 353,92                     | 0,83113                                      |
| 400               | 0,78624                                      | 0,70782                                               | 283,128                    | 0,62608                                      | 1,0605                                       | 1,01652                                               | 406,61                     | 0,91246                                      |
| 450               | 0,79920                                      | 0,71727                                               | 322,772                    | 0,68288                                      | 1,0735                                       | 1,02213                                               | 459,96                     | 0,98891                                      |
| 500               | 0,81056                                      | 0,72604                                               | 363,022                    | 0,73670                                      | 1,0859                                       | 1,02789                                               | 513,95                     | 1,0611                                       |
| 550               | 0,82054                                      | 0,73419                                               | 403,805                    | 0,78781                                      | 1,0975                                       | 1,03370                                               | 568,53                     | 1,1295                                       |
| 600               | 0,82934                                      | 0,74176                                               | 445,056                    | 0,83646                                      | 1,1084                                       | 1,03947                                               | 623,68                     | 1,1945                                       |
| 650               | 0,83711                                      | 0,74880                                               | 486,721                    | 0,88286                                      | 1,1184                                       | 1,04517                                               | 679,36                     | 1,2565                                       |
| 700               | 0,84401                                      | 0,75536                                               | 528,753                    | 0,92720                                      | 1,1279                                       | 1,05074                                               | 735,52                     | 1,3158                                       |
| 750               | 0,85016                                      | 0,76148                                               | 571,110                    | 0,96964                                      | 1,1368                                       | 1,05618                                               | 792,14                     | 1,3725                                       |
| 800               | 0,85566                                      | 0,76720                                               | 613,758                    | 1,01034                                      | 1,1449                                       | 1,06148                                               | 849,18                     | 1,4270                                       |
| 850               | 0,86061                                      | 0,77255                                               | 656,667                    | 1,04942                                      | 1,1523                                       | 1,06661                                               | 906,62                     | 1,4793                                       |
| 900               | 0,86507                                      | 0,77757                                               | 699,810                    | 1,08700                                      | 1,1592                                       | 1,07156                                               | 964,41                     | 1,5296                                       |
| 950               | 0,86911                                      | 0,78228                                               | 743,167                    | 1,12319                                      | 1,1655                                       | 1,07634                                               | 1022,52                    | 1,5781                                       |
| 1000              | 0,87279                                      | 0,78672                                               | 786,716                    | 1,15808                                      | 1,1713                                       | 1,08095                                               | 1080,95                    | 1,6249                                       |
| 1050              | 0,87615                                      | 0,79090                                               | 830,441                    | 1,19177                                      | 1,1767                                       | 1,08538                                               | 1139,65                    | 1,6701                                       |
| 1100              | 0,87923                                      | 0,79484                                               | 874,326                    | 1,22433                                      | 1,1816                                       | 1,08964                                               | 1198,60                    | 1,7139                                       |
| 1150              | 0,88206                                      | 0,79857                                               | 918,360                    | 1,25582                                      | 1,1863                                       | 1,09374                                               | 1257,80                    | 1,7562                                       |
| 1200              | 0,88468                                      | 0,80211                                               | 962,529                    | 1,28633                                      | 1,1906                                       | 1,09769                                               | 1317,23                    | 1,7973                                       |
| 1250              | 0,88710                                      | 0,80546                                               | 1006,824                   | 1,31590                                      | 1,1946                                       | 1,10149                                               | 1376,86                    | 1,8371                                       |
| 1300              | 0,88934                                      | 0,80864                                               | 1051,236                   | 1,34458                                      | 1,1983                                       | 1,10514                                               | 1436,68                    | 1,8757                                       |
| 1350              | 0,89144                                      | 0,81167                                               | 1095,756                   | 1,37244                                      | 1,2018                                       | 1,10866                                               | 1496,68                    | 1,9133                                       |
| 1400              | 0,89339                                      | 0,81456                                               | 1140,378                   | 1,39952                                      | 1,2051                                       | 1,11204                                               | 1556,86                    | 1,9498                                       |
| 1450              | 0,89523                                      | 0,81731                                               | 1185,094                   | 1,42585                                      | 1,2082                                       | 1,11530                                               | 1617,19                    | 1,9853                                       |
| 1500              | 0,89695                                      | 0,81993                                               | 1229,899                   | 1,45148                                      | 1,2110                                       | 1,11845                                               | 1677,67                    | 2,0199                                       |
| 1550              | 0,89857                                      | 0,82244                                               | 1274,787                   | 1,47645                                      | 1,2138                                       | 1,12148                                               | 1738,29                    | 2,0536                                       |
| 1600              | 0,90011                                      | 0,82485                                               | 1319,755                   | 1,50078                                      | 1,2163                                       | 1,12440                                               | 1799,04                    | 2,0865                                       |
| 1650              | 0,90156                                      | 0,82715                                               | 1364,797                   | 1,52451                                      | 1,2187                                       | 1,12723                                               | 1859,92                    | 2,1186                                       |
| 1700              | 0,90295                                      | 0,82936                                               | 1409,910                   | 1,54767                                      | 1,2210                                       | 1,12995                                               | 1920,92                    | 2,1499                                       |

$$c_p \Big|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$s_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

**Tab. 3-6 Fluide im Idealgaszustand**

 Werte Methan nach IUPAC, Werte Ethan nach *Bücker* (2003)

| $\vartheta$<br>°C | Methan CH <sub>4</sub>                       |                                                       |                            |                                              | Ethan C <sub>2</sub> H <sub>6</sub>          |                                                       |                            |                                              |
|-------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|
|                   | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $S_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $S_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> |
| -70               | 2,0907                                       | 2,1246                                                | -148,72                    | -0,62845                                     | 1,4161                                       | 1,5261                                                | -106,828                   | -0,45016                                     |
| -50               | 2,1053                                       | 2,1355                                                | -106,77                    | -0,43151                                     | 1,4750                                       | 1,5585                                                | -77,927                    | -0,31451                                     |
| -40               | 2,1151                                       | 2,1418                                                | -85,67                     | -0,33901                                     | 1,5068                                       | 1,5755                                                | -63,020                    | -0,24917                                     |
| -30               | 2,1269                                       | 2,1488                                                | -64,46                     | -0,24995                                     | 1,5400                                       | 1,5929                                                | -47,787                    | -0,18520                                     |
| -20               | 2,1405                                       | 2,1565                                                | -43,13                     | -0,16396                                     | 1,5746                                       | 1,6108                                                | -32,215                    | -0,12245                                     |
| -10               | 2,1561                                       | 2,1647                                                | -21,65                     | -0,08074                                     | 1,6106                                       | 1,6290                                                | -16,290                    | -0,06075                                     |
| $\vartheta_o = 0$ | 2,1737                                       | 2,1737                                                | $h_o = 0$                  | $s_o = 0$                                    | 1,6477                                       | 1,6477                                                | $h_o = 0$                  | $s_o = 0$                                    |
| 10                | 2,1932                                       | 2,1833                                                | 21,83                      | 0,07850                                      | 1,6860                                       | 1,6667                                                | 16,667                     | 0,05992                                      |
| 20                | 2,2145                                       | 2,1935                                                | 43,87                      | 0,15498                                      | 1,7252                                       | 1,6861                                                | 33,722                     | 0,11911                                      |
| 25                | 2,2258                                       | 2,1988                                                | 54,97                      | 0,19253                                      | 1,7451                                       | 1,6959                                                | 42,398                     | 0,14846                                      |
| 30                | 2,2376                                       | 2,2043                                                | 66,13                      | 0,22964                                      | 1,7653                                       | 1,7058                                                | 51,174                     | 0,17765                                      |
| 40                | 2,2624                                       | 2,2157                                                | 88,63                      | 0,30266                                      | 1,8061                                       | 1,7258                                                | 69,030                     | 0,23560                                      |
| 50                | 2,2887                                       | 2,2276                                                | 111,38                     | 0,37418                                      | 1,8476                                       | 1,7460                                                | 87,298                     | 0,29302                                      |
| 60                | 2,3165                                       | 2,2401                                                | 134,41                     | 0,44435                                      | 1,8895                                       | 1,7664                                                | 105,983                    | 0,34996                                      |
| 70                | 2,3457                                       | 2,2531                                                | 157,72                     | 0,51329                                      | 1,9319                                       | 1,7870                                                | 125,090                    | 0,40647                                      |
| 80                | 2,3760                                       | 2,2665                                                | 181,32                     | 0,58110                                      | 1,9746                                       | 1,8078                                                | 144,623                    | 0,46257                                      |
| 90                | 2,4075                                       | 2,2804                                                | 205,24                     | 0,64788                                      | 2,0175                                       | 1,8287                                                | 164,584                    | 0,51830                                      |
| 100               | 2,4400                                       | 2,2948                                                | 229,48                     | 0,71372                                      | 2,0606                                       | 1,8497                                                | 184,974                    | 0,57369                                      |
| 120               | 2,5074                                       | 2,3246                                                | 278,95                     | 0,84284                                      | 2,1466                                       | 1,8921                                                | 227,046                    | 0,68350                                      |
| 140               | 2,5776                                       | 2,3557                                                | 329,79                     | 0,96898                                      | 2,2324                                       | 1,9346                                                | 270,837                    | 0,79213                                      |
| 160               | 2,6499                                       | 2,3879                                                | 382,06                     | 1,09252                                      | 2,3172                                       | 1,9771                                                | 316,335                    | 0,89965                                      |
| 180               | 2,7235                                       | 2,4211                                                | 435,80                     | 1,21377                                      | 2,4009                                       | 2,0195                                                | 363,519                    | 1,00613                                      |
| 200               | 2,7981                                       | 2,4551                                                | 491,01                     | 1,33300                                      | 2,4832                                       | 2,0618                                                | 412,363                    | 1,11160                                      |
| 250               | 2,9860                                       | 2,5424                                                | 635,61                     | 1,62336                                      | 2,6819                                       | 2,1661                                                | 541,535                    | 1,37095                                      |
| 300               | 3,1730                                       | 2,6320                                                | 789,60                     | 1,90434                                      | 2,8695                                       | 2,2679                                                | 680,365                    | 1,62427                                      |
| 350               | 3,3563                                       | 2,7224                                                | 952,85                     | 2,17732                                      | 3,0460                                       | 2,3666                                                | 828,297                    | 1,87162                                      |
| 400               | 3,5345                                       | 2,8129                                                | 1125,14                    | 2,44319                                      | 3,2120                                       | 2,4620                                                | 984,792                    | 2,11311                                      |
| 450               | 3,7068                                       | 2,9027                                                | 1306,20                    | 2,70257                                      | 3,3681                                       | 2,5541                                                | 1149,336                   | 2,34883                                      |
| 500               | 3,8726                                       | 2,9914                                                | 1495,71                    | 2,95590                                      | 3,5148                                       | 2,6429                                                | 1321,447                   | 2,57891                                      |
| 550               | 4,0316                                       | 3,0788                                                | 1693,34                    | 3,20354                                      | 3,6527                                       | 2,7285                                                | 1500,670                   | 2,80349                                      |
| 600               | 4,1836                                       | 3,1646                                                | 1898,75                    | 3,44576                                      | 3,7821                                       | 2,8110                                                | 1686,574                   | 3,02270                                      |
| 650               | 4,3287                                       | 3,2486                                                | 2111,59                    | 3,68275                                      | 3,9036                                       | 2,8904                                                | 1878,751                   | 3,23669                                      |
| 700               | 4,4668                                       | 3,3307                                                | 2331,51                    | 3,91472                                      | 4,0176                                       | 2,9669                                                | 2076,812                   | 3,44561                                      |
| 750               | 4,5981                                       | 3,4109                                                | 2558,16                    | 4,14181                                      | 4,1243                                       | 3,0405                                                | 2280,388                   | 3,64958                                      |
| 800               | 4,7226                                       | 3,4890                                                | 2791,20                    | 4,36417                                      | 4,2242                                       | 3,1114                                                | 2489,129                   | 3,84875                                      |
| 850               | 4,8406                                       | 3,5651                                                | 3030,31                    | 4,58192                                      | 4,3177                                       | 3,1797                                                | 2702,704                   | 4,04326                                      |
| 900               | 4,9522                                       | 3,6391                                                | 3275,15                    | 4,79519                                      | 4,4052                                       | 3,2453                                                | 2920,801                   | 4,23323                                      |
| 950               | 5,0579                                       | 3,7110                                                | 3525,43                    | 5,00409                                      | 4,4869                                       | 3,3086                                                | 3143,125                   | 4,41880                                      |
| 1000              | 5,1578                                       | 3,7808                                                | 3780,84                    | 5,20874                                      | 4,5633                                       | 3,3694                                                | 3369,401                   | 4,60010                                      |
| 1050              | 5,2522                                       | 3,8487                                                | 4041,11                    | 5,40924                                      | 4,6347                                       | 3,4280                                                | 3599,371                   | 4,77727                                      |
| 1100              | 5,3414                                       | 3,9145                                                | 4305,98                    | 5,60572                                      | 4,7015                                       | 3,4844                                                | 3832,794                   | 4,95042                                      |
| 1150              | 5,4257                                       | 3,9784                                                | 4575,17                    | 5,79827                                      | 4,7639                                       | 3,5386                                                | 4069,445                   | 5,11969                                      |
| 1200              | 5,5055                                       | 4,0404                                                | 4848,47                    | 5,98700                                      | 4,8223                                       | 3,5909                                                | 4309,115                   | 5,28520                                      |
| 1250              | 5,5809                                       | 4,1005                                                | 5125,65                    | 6,17202                                      | 4,8769                                       | 3,6413                                                | 4551,609                   | 5,44708                                      |
| 1300              | 5,6523                                       | 4,1588                                                | 5406,50                    | 6,35344                                      | 4,9280                                       | 3,6898                                                | 4796,746                   | 5,60543                                      |
| 1350              | 5,7200                                       | 4,2154                                                | 5690,82                    | 6,53136                                      | 4,9760                                       | 3,7366                                                | 5044,359                   | 5,76037                                      |
| 1400              | 5,7841                                       | 4,2703                                                | 5978,44                    | 6,70588                                      | 5,0209                                       | 3,7816                                                | 5294,291                   | 5,91203                                      |
| 1450              | 5,8449                                       | 4,3236                                                | 6269,17                    | 6,87709                                      | 5,0630                                       | 3,8251                                                | 5546,399                   | 6,06049                                      |
| 1500              | 5,9027                                       | 4,3753                                                | 6562,88                    | 7,04511                                      | 5,1025                                       | 3,8670                                                | 5800,548                   | 6,20588                                      |
| 1550              | 5,9576                                       | 4,4254                                                | 6859,40                    | 7,21002                                      | 5,1397                                       | 3,9075                                                | 6056,613                   | 6,34830                                      |
| 1600              | 6,0099                                       | 4,4741                                                | 7158,60                    | 7,37192                                      | 5,1746                                       | 3,9465                                                | 6314,479                   | 6,48783                                      |
| 1650              | 6,0598                                       | 4,5214                                                | 7460,35                    | 7,53089                                      | 5,2075                                       | 3,9843                                                | 6574,039                   | 6,62458                                      |
| 1700              | 6,1073                                       | 4,5674                                                | 7764,54                    | 7,68704                                      | 5,2384                                       | 4,0207                                                | 6835,193                   | 6,75864                                      |

$$c_p|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$S_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

**Tab. 3-7 Fluide im Idealgaszustand**

 Werte H<sub>2</sub> nach *Leachman et al.* (2009), Werte He nach GERG 2008

| $\vartheta$<br>°C | Wasserstoff H <sub>2</sub>                   |                                                       |                            |                                              | Helium He                                    |                                                       |                            |                                              |
|-------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|----------------------------------------------|-------------------------------------------------------|----------------------------|----------------------------------------------|
|                   | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $c_p _{T_o}^T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $h$<br>kJ kg <sup>-1</sup> | $s_T$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> |
| -70               | 13,574                                       | 13,9316                                               | -975,21                    | -4,1203                                      | 5,193                                        | 5,193                                                 | -363,52                    | -1,5376                                      |
| -50               | 13,813                                       | 14,0249                                               | -701,24                    | -2,8342                                      | 5,193                                        | 5,193                                                 | -259,66                    | -1,0499                                      |
| -40               | 13,911                                       | 14,0654                                               | -562,61                    | -2,2265                                      | 5,193                                        | 5,193                                                 | -207,73                    | -0,8223                                      |
| -30               | 13,997                                       | 14,1022                                               | -423,07                    | -1,6405                                      | 5,193                                        | 5,193                                                 | -155,80                    | -0,6042                                      |
| -20               | 14,072                                       | 14,1357                                               | -282,71                    | -1,0748                                      | 5,193                                        | 5,193                                                 | -103,86                    | -0,3949                                      |
| -10               | 14,137                                       | 14,16612                                              | -141,66                    | -0,5283                                      | 5,193                                        | 5,193                                                 | -51,93                     | -0,1937                                      |
| $\vartheta_o = 0$ | 14,194                                       | 14,19370                                              | $h_o = 0$                  | $s_o = 0$                                    | 5,193                                        | 5,193                                                 | $h_o = 0$                  | $s_o = 0$                                    |
| 10                | 14,242                                       | 14,21870                                              | 142,19                     | 0,5112                                       | 5,193                                        | 5,193                                                 | 51,93                      | 0,1867                                       |
| 20                | 14,284                                       | 14,24134                                              | 284,83                     | 1,0063                                       | 5,193                                        | 5,193                                                 | 103,86                     | 0,3670                                       |
| 25                | 14,303                                       | 14,25185                                              | 356,30                     | 1,2480                                       | 5,193                                        | 5,193                                                 | 129,83                     | 0,4548                                       |
| 30                | 14,320                                       | 14,26184                                              | 427,86                     | 1,4861                                       | 5,193                                        | 5,193                                                 | 155,80                     | 0,5412                                       |
| 40                | 14,351                                       | 14,28038                                              | 571,22                     | 1,9513                                       | 5,193                                        | 5,193                                                 | 207,73                     | 0,7097                                       |
| 50                | 14,377                                       | 14,29716                                              | 714,86                     | 2,4029                                       | 5,193                                        | 5,193                                                 | 259,66                     | 0,8730                                       |
| 60                | 14,399                                       | 14,31232                                              | 858,74                     | 2,8414                                       | 5,193                                        | 5,193                                                 | 311,59                     | 1,0312                                       |
| 70                | 14,417                                       | 14,32604                                              | 1002,82                    | 3,2675                                       | 5,193                                        | 5,193                                                 | 363,52                     | 1,1848                                       |
| 80                | 14,433                                       | 14,33845                                              | 1147,08                    | 3,6818                                       | 5,193                                        | 5,193                                                 | 415,45                     | 1,3340                                       |
| 90                | 14,446                                       | 14,34967                                              | 1291,47                    | 4,0850                                       | 5,193                                        | 5,193                                                 | 467,39                     | 1,4790                                       |
| 100               | 14,457                                       | 14,35984                                              | 1435,98                    | 4,4776                                       | 5,193                                        | 5,193                                                 | 519,32                     | 1,6201                                       |
| 120               | 14,473                                       | 14,37743                                              | 1725,29                    | 5,2328                                       | 5,193                                        | 5,193                                                 | 623,18                     | 1,8912                                       |
| 140               | 14,485                                       | 14,39197                                              | 2014,88                    | 5,9513                                       | 5,193                                        | 5,193                                                 | 727,05                     | 2,1489                                       |
| 160               | 14,493                                       | 14,40411                                              | 2304,66                    | 6,6362                                       | 5,193                                        | 5,193                                                 | 830,91                     | 2,3944                                       |
| 180               | 14,499                                       | 14,41435                                              | 2594,58                    | 7,2906                                       | 5,193                                        | 5,193                                                 | 934,77                     | 2,6288                                       |
| 200               | 14,505                                       | 14,42312                                              | 2884,62                    | 7,9169                                       | 5,193                                        | 5,193                                                 | 1038,64                    | 2,8531                                       |
| 250               | 14,518                                       | 14,44077                                              | 3610,19                    | 9,3747                                       | 5,193                                        | 5,193                                                 | 1298,30                    | 3,3748                                       |
| 300               | 14,536                                       | 14,45510                                              | 4336,53                    | 10,7006                                      | 5,193                                        | 5,193                                                 | 1557,95                    | 3,8488                                       |
| 350               | 14,561                                       | 14,4683                                               | 5063,92                    | 11,9174                                      | 5,193                                        | 5,193                                                 | 1817,61                    | 4,2832                                       |
| 400               | 14,593                                       | 14,4818                                               | 5792,72                    | 13,0424                                      | 5,193                                        | 5,193                                                 | 2077,27                    | 4,6840                                       |
| 450               | 14,633                                       | 14,4963                                               | 6523,33                    | 14,0893                                      | 5,193                                        | 5,193                                                 | 2336,93                    | 5,0561                                       |
| 500               | 14,680                                       | 14,5122                                               | 7256,12                    | 15,0691                                      | 5,193                                        | 5,193                                                 | 2596,59                    | 5,4033                                       |
| 550               | 14,736                                       | 14,5300                                               | 7991,49                    | 15,9907                                      | 5,193                                        | 5,193                                                 | 2856,25                    | 5,7287                                       |
| 600               | 14,799                                       | 14,5497                                               | 8729,83                    | 16,8615                                      | 5,193                                        | 5,193                                                 | 3115,91                    | 6,0349                                       |
| 650               | 14,869                                       | 14,5715                                               | 9471,50                    | 17,6875                                      | 5,193                                        | 5,193                                                 | 3375,57                    | 6,3241                                       |
| 700               | 14,947                                       | 14,5955                                               | 10216,88                   | 18,4738                                      | 5,193                                        | 5,193                                                 | 3635,23                    | 6,5980                                       |
| 750               | 15,031                                       | 14,6217                                               | 10966,31                   | 19,2247                                      | 5,193                                        | 5,193                                                 | 3894,89                    | 6,8582                                       |
| 800               | 15,121                                       | 14,6501                                               | 11720,09                   | 19,9440                                      | 5,193                                        | 5,193                                                 | 4154,54                    | 7,1060                                       |
| 850               | 15,216                                       | 14,6806                                               | 12478,50                   | 20,6347                                      | 5,193                                        | 5,193                                                 | 4414,20                    | 7,3425                                       |
| 900               | 15,316                                       | 14,7131                                               | 13241,78                   | 21,2996                                      | 5,193                                        | 5,193                                                 | 4673,86                    | 7,5687                                       |
| 950               | 15,419                                       | 14,7475                                               | 14010,14                   | 21,9410                                      | 5,193                                        | 5,193                                                 | 4933,52                    | 7,7854                                       |
| 1000              | 15,525                                       | 14,7837                                               | 14783,73                   | 22,5608                                      | 5,193                                        | 5,193                                                 | 5193,18                    | 7,9935                                       |
| 1050              | 15,633                                       | 14,8216                                               | 15562,69                   | 23,1610                                      | 5,193                                        | 5,193                                                 | 5452,84                    | 8,1936                                       |
| 1100              | 15,743                                       | 14,8610                                               | 16347,09                   | 23,7429                                      | 5,193                                        | 5,193                                                 | 5712,50                    | 8,3862                                       |
| 1150              | 15,854                                       | 14,9017                                               | 17137,01                   | 24,3079                                      | 5,193                                        | 5,193                                                 | 5972,16                    | 8,5719                                       |
| 1200              | 15,964                                       | 14,9437                                               | 17932,45                   | 24,8572                                      | 5,193                                        | 5,193                                                 | 6231,82                    | 8,7512                                       |
| 1250              | 16,075                                       | 14,9867                                               | 18733,43                   | 25,3919                                      | 5,193                                        | 5,193                                                 | 6491,48                    | 8,9246                                       |
| 1300              | 16,184                                       | 15,0307                                               | 19539,90                   | 25,9128                                      | 5,193                                        | 5,193                                                 | 6751,14                    | 9,0923                                       |
| 1350              | 16,293                                       | 15,0754                                               | 20351,82                   | 26,4209                                      | 5,193                                        | 5,193                                                 | 7010,79                    | 9,2548                                       |
| 1400              | 16,399                                       | 15,1208                                               | 21169,12                   | 26,9168                                      | 5,193                                        | 5,193                                                 | 7270,45                    | 9,4124                                       |
| 1450              | 16,504                                       | 15,1667                                               | 21991,73                   | 27,4013                                      | 5,193                                        | 5,193                                                 | 7530,11                    | 9,5653                                       |
| 1500              | 16,607                                       | 15,2130                                               | 22819,53                   | 27,8748                                      | 5,193                                        | 5,193                                                 | 7789,77                    | 9,7138                                       |
| 1550              | 16,708                                       | 15,2596                                               | 23652,44                   | 28,3381                                      | 5,193                                        | 5,193                                                 | 8049,43                    | 9,8582                                       |
| 1600              | 16,807                                       | 15,3065                                               | 24490,33                   | 28,7914                                      | 5,193                                        | 5,193                                                 | 8309,09                    | 9,9987                                       |
| 1650              | 16,903                                       | 15,3534                                               | 25333,08                   | 29,2354                                      | 5,193                                        | 5,193                                                 | 8568,75                    | 10,1355                                      |
| 1700              | 16,996                                       | 15,4003                                               | 26180,56                   | 29,6705                                      | 5,193                                        | 5,193                                                 | 8828,41                    | 10,2688                                      |

$$c_p|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$s_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

**Tab. 4 Stoffwerte von Wasserflüssigkeit (inkompressibel)**

Werte auf Siedelinie nach IAPWS-IF97

| $\vartheta$     | $\rho$            | $c_p$                              | $c_p \Big _{T_o}^T$                | $h$                | $s_T$                              | $\beta = \alpha_v$                  | $\lambda$                                             | $\eta$                                                | $\nu$                                              | $Pr$    |
|-----------------|-------------------|------------------------------------|------------------------------------|--------------------|------------------------------------|-------------------------------------|-------------------------------------------------------|-------------------------------------------------------|----------------------------------------------------|---------|
| °C              | kgm <sup>-3</sup> | kJkg <sup>-1</sup> K <sup>-1</sup> | kJkg <sup>-1</sup> K <sup>-1</sup> | kJkg <sup>-1</sup> | kJkg <sup>-1</sup> K <sup>-1</sup> | 10 <sup>-3</sup><br>K <sup>-1</sup> | 10 <sup>-3</sup><br>W m <sup>-1</sup> K <sup>-1</sup> | 10 <sup>-6</sup><br>kgm <sup>-1</sup> s <sup>-1</sup> | 10 <sup>-6</sup><br>m <sup>2</sup> s <sup>-1</sup> | -       |
| $\vartheta_o=0$ | 999,79            | 4,2199                             | 4,2199                             | $h_o = 0$          | $s_o = 0$                          | -0,068073                           | 561,97                                                | 1792,0                                                | 1,7923                                             | 13,456  |
| 2               | 999,89            | 4,2134                             | 4,1958                             | 8,3916             | 0,030606                           | -0,032744                           | 566,17                                                | 1673,7                                                | 1,6739                                             | 12,455  |
| 4               | 999,93            | 4,2078                             | 4,2032                             | 16,813             | 0,061101                           | 0,000267                            | 570,26                                                | 1567,4                                                | 1,5676                                             | 11,566  |
| 6               | 999,89            | 4,2031                             | 4,2039                             | 25,224             | 0,091340                           | 0,031229                            | 574,25                                                | 1471,6                                                | 1,4718                                             | 10,771  |
| 8               | 999,80            | 4,1992                             | 4,2033                             | 33,626             | 0,12133                            | 0,060370                            | 578,13                                                | 1384,8                                                | 1,3851                                             | 10,059  |
| 10              | 999,65            | 4,1958                             | 4,2021                             | 42,021             | 0,15109                            | 0,087889                            | 581,92                                                | 1306,0                                                | 1,3064                                             | 9,4166  |
| 12              | 999,45            | 4,1930                             | 4,2008                             | 50,410             | 0,18061                            | 0,11396                             | 585,61                                                | 1234,1                                                | 1,2348                                             | 8,8363  |
| 14              | 999,20            | 4,1905                             | 4,1995                             | 58,794             | 0,20990                            | 0,13873                             | 589,21                                                | 1168,4                                                | 1,1693                                             | 8,3098  |
| 16              | 998,90            | 4,1884                             | 4,1983                             | 67,173             | 0,23898                            | 0,16233                             | 592,72                                                | 1108,1                                                | 1,1094                                             | 7,8306  |
| 18              | 998,55            | 4,1866                             | 4,1971                             | 75,548             | 0,26785                            | 0,18487                             | 596,14                                                | 1052,7                                                | 1,0542                                             | 7,3931  |
| 20              | 998,16            | 4,1851                             | 4,1960                             | 83,920             | 0,29650                            | 0,20646                             | 599,47                                                | 1001,6                                                | 1,0035                                             | 6,9926  |
| 22              | 997,73            | 4,1838                             | 4,1950                             | 92,289             | 0,32495                            | 0,22718                             | 602,73                                                | 954,42                                                | 0,95659                                            | 6,6250  |
| 24              | 997,25            | 4,1827                             | 4,1940                             | 100,66             | 0,35320                            | 0,24711                             | 605,90                                                | 910,70                                                | 0,91320                                            | 6,2868  |
| 25              | 997,00            | 4,1822                             | 4,1935                             | 104,84             | 0,36726                            | 0,25680                             | 607,46                                                | 890,04                                                | 0,89271                                            | 6,1276  |
| 26              | 996,74            | 4,1817                             | 4,1931                             | 109,02             | 0,38126                            | 0,26631                             | 609,00                                                | 870,12                                                | 0,87296                                            | 5,9748  |
| 28              | 996,19            | 4,1809                             | 4,1923                             | 117,38             | 0,40912                            | 0,28486                             | 612,01                                                | 832,38                                                | 0,83556                                            | 5,6864  |
| 30              | 995,61            | 4,1803                             | 4,1915                             | 125,75             | 0,43679                            | 0,30280                             | 614,95                                                | 797,22                                                | 0,80074                                            | 5,4193  |
| 32              | 994,99            | 4,1798                             | 4,1908                             | 134,11             | 0,46428                            | 0,32018                             | 617,82                                                | 764,41                                                | 0,76826                                            | 5,1715  |
| 34              | 994,34            | 4,1794                             | 4,1902                             | 142,47             | 0,49158                            | 0,33704                             | 620,61                                                | 733,72                                                | 0,73790                                            | 4,9411  |
| 36              | 993,65            | 4,1791                             | 4,1896                             | 150,82             | 0,51871                            | 0,35343                             | 623,33                                                | 704,99                                                | 0,70949                                            | 4,7265  |
| 38              | 992,93            | 4,1789                             | 4,1890                             | 159,18             | 0,54566                            | 0,36938                             | 625,98                                                | 678,03                                                | 0,68286                                            | 4,5264  |
| 40              | 992,18            | 4,1788                             | 4,1885                             | 167,54             | 0,57243                            | 0,38492                             | 628,56                                                | 652,72                                                | 0,65786                                            | 4,3394  |
| 42              | 991,40            | 4,1788                             | 4,1881                             | 175,90             | 0,59903                            | 0,40008                             | 631,08                                                | 628,91                                                | 0,63436                                            | 4,1645  |
| 44              | 990,60            | 4,1789                             | 4,1877                             | 184,26             | 0,62547                            | 0,41488                             | 633,52                                                | 606,48                                                | 0,61224                                            | 4,0006  |
| 46              | 989,76            | 4,1791                             | 4,1873                             | 192,62             | 0,65174                            | 0,42936                             | 635,90                                                | 585,34                                                | 0,59139                                            | 3,8468  |
| 48              | 988,90            | 4,1794                             | 4,1870                             | 200,98             | 0,67785                            | 0,44353                             | 638,21                                                | 565,37                                                | 0,57172                                            | 3,7024  |
| 50              | 988,01            | 4,1798                             | 4,1867                             | 209,34             | 0,70379                            | 0,45742                             | 640,46                                                | 546,50                                                | 0,55314                                            | 3,5666  |
| 55              | 985,67            | 4,1811                             | 4,1862                             | 230,24             | 0,76798                            | 0,49100                             | 645,81                                                | 503,61                                                | 0,51093                                            | 3,2605  |
| 60              | 983,18            | 4,1829                             | 4,1859                             | 251,15             | 0,83122                            | 0,52317                             | 650,76                                                | 466,02                                                | 0,47400                                            | 2,9955  |
| 65              | 980,53            | 4,1853                             | 4,1858                             | 272,08             | 0,89354                            | 0,55416                             | 655,35                                                | 432,89                                                | 0,44149                                            | 2,7646  |
| 70              | 977,75            | 4,1882                             | 4,1860                             | 293,02             | 0,95499                            | 0,58413                             | 659,57                                                | 403,54                                                | 0,41272                                            | 2,5625  |
| 75              | 974,83            | 4,1917                             | 4,1863                             | 313,97             | 1,0156                             | 0,61327                             | 663,44                                                | 377,41                                                | 0,38715                                            | 2,3845  |
| 80              | 971,78            | 4,1956                             | 4,1869                             | 334,95             | 1,0754                             | 0,64172                             | 666,96                                                | 354,04                                                | 0,36433                                            | 2,2272  |
| 85              | 968,60            | 4,2001                             | 4,1876                             | 355,95             | 1,1344                             | 0,66960                             | 670,15                                                | 333,07                                                | 0,34387                                            | 2,0875  |
| 90              | 965,30            | 4,2051                             | 4,1885                             | 376,97             | 1,1927                             | 0,69704                             | 673,00                                                | 314,17                                                | 0,32546                                            | 1,9630  |
| 95              | 961,89            | 4,2106                             | 4,1897                             | 398,02             | 1,2502                             | 0,72414                             | 675,54                                                | 297,09                                                | 0,30886                                            | 1,8517  |
| 100             | 958,35            | 4,2166                             | 4,1910                             | 419,10             | 1,3070                             | 0,75101                             | 677,76                                                | 281,59                                                | 0,29382                                            | 1,7519  |
| 110             | 950,95            | 4,2304                             | 4,1942                             | 461,36             | 1,4187                             | 0,80442                             | 681,28                                                | 254,61                                                | 0,26775                                            | 1,5810  |
| 120             | 943,11            | 4,2464                             | 4,1982                             | 503,78             | 1,5278                             | 0,85798                             | 683,61                                                | 232,03                                                | 0,24603                                            | 1,4413  |
| 130             | 934,83            | 4,2648                             | 4,2030                             | 546,39             | 1,6346                             | 0,91238                             | 684,80                                                | 212,94                                                | 0,22778                                            | 1,3262  |
| 140             | 926,13            | 4,2860                             | 4,2086                             | 589,20             | 1,7393                             | 0,96829                             | 684,87                                                | 196,64                                                | 0,21233                                            | 1,2306  |
| 150             | 917,01            | 4,3103                             | 4,2150                             | 632,25             | 1,8420                             | 1,0264                              | 683,86                                                | 182,61                                                | 0,19914                                            | 1,1510  |
| 160             | 907,45            | 4,3379                             | 4,2223                             | 675,57             | 1,9428                             | 1,0875                              | 681,80                                                | 170,43                                                | 0,18781                                            | 1,0844  |
| 170             | 897,45            | 4,3695                             | 4,2306                             | 719,21             | 2,0419                             | 1,1522                              | 678,71                                                | 159,78                                                | 0,17803                                            | 1,0286  |
| 180             | 887,01            | 4,4056                             | 4,2399                             | 763,19             | 2,1395                             | 1,2217                              | 674,60                                                | 150,38                                                | 0,16954                                            | 0,98210 |
| 190             | 876,08            | 4,4468                             | 4,2503                             | 807,57             | 2,2358                             | 1,2968                              | 669,49                                                | 142,05                                                | 0,16214                                            | 0,94347 |
| 200             | 864,67            | 4,4940                             | 4,2620                             | 852,39             | 2,3308                             | 1,3788                              | 663,38                                                | 134,59                                                | 0,15565                                            | 0,91175 |

$$c_p \Big|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

$$s_T = s_o + \int_{T_o}^T \frac{c_p}{T} dT$$

↑  
kinematische  
Viskosität

**Tab. 5 Stoffwerte von Luft (trocken) als reales Fluid bei  $p = 0,101325$  MPa**

Werte nach Lemmon et al. (2000, 2004)

| $\vartheta$       | $\rho$            | $c_p$                              | $c_p _{T_o}^T$                     | $h$                | $\beta = \alpha_v$                  | $\lambda$                                             | $\eta$                                                | $\nu$                                              | $Pr$    |
|-------------------|-------------------|------------------------------------|------------------------------------|--------------------|-------------------------------------|-------------------------------------------------------|-------------------------------------------------------|----------------------------------------------------|---------|
| °C                | kgm <sup>-3</sup> | kJkg <sup>-1</sup> K <sup>-1</sup> | kJkg <sup>-1</sup> K <sup>-1</sup> | kJkg <sup>-1</sup> | 10 <sup>-3</sup><br>K <sup>-1</sup> | 10 <sup>-3</sup><br>W m <sup>-1</sup> K <sup>-1</sup> | 10 <sup>-6</sup><br>kgm <sup>-1</sup> s <sup>-1</sup> | 10 <sup>-6</sup><br>m <sup>2</sup> s <sup>-1</sup> | -       |
| -30               | 1,4530            | 1,0058                             | 1,0058                             | -30,174            | 4,13316                             | 21,810                                                | 15,670                                                | 10,785                                             | 0,72267 |
| -25               | 1,4236            | 1,0058                             | 1,0058                             | -25,145            | 4,04874                             | 22,178                                                | 15,934                                                | 11,193                                             | 0,72260 |
| -20               | 1,3953            | 1,0058                             | 1,0058                             | -20,116            | 3,96773                             | 22,543                                                | 16,195                                                | 11,607                                             | 0,72255 |
| -15               | 1,3682            | 1,0058                             | 1,0058                             | -15,088            | 3,88993                             | 22,905                                                | 16,454                                                | 12,026                                             | 0,72250 |
| -10               | 1,3421            | 1,0058                             | 1,0059                             | -10,059            | 3,81515                             | 23,265                                                | 16,711                                                | 12,452                                             | 0,72246 |
| -5                | 1,3170            | 1,0059                             | 1,0059                             | -5,029             | 3,74321                             | 23,623                                                | 16,967                                                | 12,883                                             | 0,72242 |
| $\vartheta_o = 0$ | 1,2928            | 1,0059                             | 1,0059                             | $h_o = 0,000$      | 3,67396                             | 23,979                                                | 17,220                                                | 13,320                                             | 0,72239 |
| 5                 | 1,2694            | 1,0060                             | 1,0060                             | 5,030              | 3,60725                             | 24,332                                                | 17,472                                                | 13,763                                             | 0,72237 |
| 10                | 1,2470            | 1,0061                             | 1,0060                             | 10,060             | 3,54293                             | 24,683                                                | 17,722                                                | 14,212                                             | 0,72236 |
| 15                | 1,2252            | 1,0062                             | 1,0061                             | 15,091             | 3,48088                             | 25,032                                                | 17,970                                                | 14,666                                             | 0,72234 |
| 20                | 1,2043            | 1,0064                             | 1,0061                             | 20,123             | 3,42099                             | 25,379                                                | 18,216                                                | 15,126                                             | 0,72234 |
| 25                | 1,1840            | 1,0065                             | 1,0062                             | 25,155             | 3,36313                             | 25,724                                                | 18,461                                                | 15,591                                             | 0,72234 |
| 30                | 1,1645            | 1,0067                             | 1,0063                             | 30,188             | 3,30721                             | 26,068                                                | 18,704                                                | 16,062                                             | 0,72234 |
| 35                | 1,1455            | 1,0069                             | 1,0063                             | 35,222             | 3,25313                             | 26,409                                                | 18,945                                                | 16,539                                             | 0,72235 |
| 40                | 1,1272            | 1,0072                             | 1,0064                             | 40,257             | 3,20080                             | 26,749                                                | 19,185                                                | 17,020                                             | 0,72236 |
| 45                | 1,1094            | 1,0074                             | 1,0065                             | 45,294             | 3,15014                             | 27,087                                                | 19,423                                                | 17,507                                             | 0,72238 |
| 50                | 1,0922            | 1,0077                             | 1,0066                             | 50,331             | 3,10107                             | 27,423                                                | 19,660                                                | 18,000                                             | 0,72240 |
| 60                | 1,0594            | 1,0083                             | 1,0069                             | 60,411             | 3,00739                             | 28,092                                                | 20,129                                                | 19,000                                             | 0,72245 |
| 70                | 1,0284            | 1,0089                             | 1,0071                             | 70,497             | 2,91923                             | 28,754                                                | 20,592                                                | 20,022                                             | 0,72252 |
| 80                | 0,99928           | 1,0097                             | 1,0074                             | 80,590             | 2,83611                             | 29,411                                                | 21,049                                                | 21,064                                             | 0,72261 |
| 90                | 0,97172           | 1,0105                             | 1,0077                             | 90,691             | 2,75762                             | 30,064                                                | 21,501                                                | 22,126                                             | 0,72271 |
| 100               | 0,94565           | 1,0115                             | 1,0080                             | 100,801            | 2,68337                             | 30,711                                                | 21,947                                                | 23,209                                             | 0,72283 |
| 110               | 0,92093           | 1,0125                             | 1,0084                             | 110,921            | 2,61302                             | 31,354                                                | 22,388                                                | 24,310                                             | 0,72296 |
| 120               | 0,89748           | 1,0136                             | 1,0088                             | 121,051            | 2,54629                             | 31,994                                                | 22,825                                                | 25,432                                             | 0,72310 |
| 130               | 0,87520           | 1,0148                             | 1,0092                             | 131,193            | 2,48288                             | 32,629                                                | 23,256                                                | 26,572                                             | 0,72326 |
| 140               | 0,85400           | 1,0160                             | 1,0096                             | 141,347            | 2,42257                             | 33,262                                                | 23,683                                                | 27,732                                             | 0,72343 |
| 150               | 0,83380           | 1,0174                             | 1,0101                             | 151,514            | 2,36513                             | 33,891                                                | 24,105                                                | 28,910                                             | 0,72361 |
| 160               | 0,81453           | 1,0188                             | 1,0106                             | 161,694            | 2,31035                             | 34,517                                                | 24,523                                                | 30,107                                             | 0,72381 |
| 170               | 0,79614           | 1,0203                             | 1,0111                             | 171,890            | 2,25807                             | 35,141                                                | 24,937                                                | 31,322                                             | 0,72402 |
| 180               | 0,77856           | 1,0219                             | 1,0117                             | 182,100            | 2,20810                             | 35,762                                                | 25,346                                                | 32,555                                             | 0,72423 |
| 190               | 0,76174           | 1,0235                             | 1,0122                             | 192,327            | 2,16030                             | 36,381                                                | 25,752                                                | 33,807                                             | 0,72446 |
| 200               | 0,74563           | 1,0252                             | 1,0129                             | 202,571            | 2,11453                             | 36,998                                                | 26,153                                                | 35,075                                             | 0,72470 |
| 250               | 0,67434           | 1,0347                             | 1,0162                             | 254,062            | 1,91203                             | 40,055                                                | 28,107                                                | 41,680                                             | 0,72602 |
| 300               | 0,61550           | 1,0454                             | 1,0202                             | 306,058            | 1,74498                             | 43,074                                                | 29,977                                                | 48,703                                             | 0,72750 |
| 350               | 0,56611           | 1,0568                             | 1,0246                             | 358,611            | 1,60480                             | 46,059                                                | 31,774                                                | 56,127                                             | 0,72907 |
| 400               | 0,52406           | 1,0688                             | 1,0294                             | 411,750            | 1,48550                             | 49,011                                                | 33,507                                                | 63,937                                             | 0,73067 |
| 450               | 0,48783           | 1,0808                             | 1,0344                             | 465,489            | 1,38272                             | 51,928                                                | 35,182                                                | 72,120                                             | 0,73226 |
| 500               | 0,45629           | 1,0927                             | 1,0397                             | 519,827            | 1,29325                             | 54,806                                                | 36,806                                                | 80,665                                             | 0,73381 |
| 550               | 0,42857           | 1,1043                             | 1,0450                             | 574,752            | 1,21466                             | 57,645                                                | 38,384                                                | 89,562                                             | 0,73530 |
| 600               | 0,40404           | 1,1154                             | 1,0504                             | 630,246            | 1,14508                             | 60,441                                                | 39,920                                                | 98,802                                             | 0,73670 |
| 650               | 0,38216           | 1,1260                             | 1,0558                             | 686,284            | 1,08305                             | 63,192                                                | 41,417                                                | 108,378                                            | 0,73802 |
| 700               | 0,36253           | 1,1361                             | 1,0612                             | 742,839            | 1,02739                             | 65,900                                                | 42,880                                                | 118,282                                            | 0,73925 |
| 750               | 0,34481           | 1,1456                             | 1,0665                             | 799,884            | 0,977175                            | 68,562                                                | 44,311                                                | 128,508                                            | 0,74039 |
| 800               | 0,32875           | 1,1545                             | 1,0717                             | 857,390            | 0,931643                            | 71,180                                                | 45,713                                                | 139,052                                            | 0,74146 |
| 850               | 0,31412           | 1,1629                             | 1,0769                             | 915,328            | 0,890166                            | 73,756                                                | 47,089                                                | 149,907                                            | 0,74244 |
| 900               | 0,30073           | 1,1708                             | 1,0819                             | 973,671            | 0,852226                            | 76,289                                                | 48,439                                                | 161,070                                            | 0,74336 |
| 950               | 0,28844           | 1,1781                             | 1,0867                             | 1032,395           | 0,817389                            | 78,783                                                | 49,767                                                | 172,535                                            | 0,74420 |
| 1000              | 0,27712           | 1,1850                             | 1,0915                             | 1091,475           | 0,785288                            | 81,238                                                | 51,073                                                | 184,301                                            | 0,74499 |

$$c_p|_{T_o}^T = \frac{1}{T - T_o} \cdot \int_{T_o}^T c_p dT = \frac{h - h_o}{T - T_o}$$

↑  
kinematische  
Viskosität

**Tab. 6 Spezifisches Volumen von Luft (trocken) als reales Fluid**

Werte nach Lemmon et al. (2000)

| $\vartheta$        | $v$ in $\text{m}^3 \text{kg}^{-1}$ |         |         |         |         |         |         |         |         |         |         |
|--------------------|------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                    | $p$                                |         |         |         |         |         |         |         |         |         |         |
|                    | MPa                                |         |         |         |         |         |         |         |         |         |         |
| $^{\circ}\text{C}$ | 0,1                                | 0,5     | 1       | 1,5     | 2       | 2,5     | 3       | 3,5     | 4       | 4,5     | 5       |
| -30                | 0,69737                            | 0,13888 | 0,06908 | 0,04582 | 0,03420 | 0,02723 | 0,02259 | 0,01928 | 0,01680 | 0,01487 | 0,01333 |
| -20                | 0,72619                            | 0,14473 | 0,07206 | 0,04784 | 0,03574 | 0,02849 | 0,02365 | 0,02020 | 0,01762 | 0,01561 | 0,01401 |
| -10                | 0,75500                            | 0,15057 | 0,07503 | 0,04985 | 0,03727 | 0,02973 | 0,02470 | 0,02112 | 0,01843 | 0,01634 | 0,01468 |
| 0                  | 0,78379                            | 0,15640 | 0,07798 | 0,05185 | 0,03879 | 0,03096 | 0,02575 | 0,02202 | 0,01923 | 0,01707 | 0,01534 |
| 5                  | 0,79819                            | 0,15931 | 0,07946 | 0,05285 | 0,03955 | 0,03158 | 0,02627 | 0,02247 | 0,01963 | 0,01743 | 0,01566 |
| 10                 | 0,81259                            | 0,16222 | 0,08093 | 0,05385 | 0,04031 | 0,03219 | 0,02678 | 0,02292 | 0,02003 | 0,01778 | 0,01599 |
| 15                 | 0,82698                            | 0,16513 | 0,08241 | 0,05484 | 0,04106 | 0,03280 | 0,02730 | 0,02337 | 0,02042 | 0,01814 | 0,01631 |
| 20                 | 0,84137                            | 0,16803 | 0,08388 | 0,05583 | 0,04182 | 0,03341 | 0,02781 | 0,02381 | 0,02082 | 0,01849 | 0,01663 |
| 25                 | 0,85576                            | 0,17094 | 0,08535 | 0,05682 | 0,04257 | 0,03402 | 0,02832 | 0,02426 | 0,02121 | 0,01884 | 0,01695 |
| 30                 | 0,87015                            | 0,17384 | 0,08682 | 0,05781 | 0,04332 | 0,03462 | 0,02883 | 0,02470 | 0,02160 | 0,01919 | 0,01727 |
| 35                 | 0,88454                            | 0,17675 | 0,08828 | 0,05880 | 0,04407 | 0,03523 | 0,02934 | 0,02514 | 0,02199 | 0,01954 | 0,01759 |
| 40                 | 0,89892                            | 0,17965 | 0,08975 | 0,05979 | 0,04481 | 0,03583 | 0,02985 | 0,02558 | 0,02238 | 0,01989 | 0,01790 |
| 45                 | 0,91331                            | 0,18255 | 0,09121 | 0,06078 | 0,04556 | 0,03644 | 0,03036 | 0,02602 | 0,02276 | 0,02024 | 0,01822 |
| 50                 | 0,92769                            | 0,18545 | 0,09268 | 0,06176 | 0,04631 | 0,03704 | 0,03086 | 0,02645 | 0,02315 | 0,02058 | 0,01853 |
| 60                 | 0,95646                            | 0,19124 | 0,09560 | 0,06373 | 0,04779 | 0,03824 | 0,03187 | 0,02733 | 0,02392 | 0,02127 | 0,01915 |
| 70                 | 0,98522                            | 0,19704 | 0,09852 | 0,06569 | 0,04928 | 0,03944 | 0,03288 | 0,02819 | 0,02468 | 0,02196 | 0,01977 |
| 80                 | 1,01398                            | 0,20283 | 0,10144 | 0,06765 | 0,05076 | 0,04063 | 0,03388 | 0,02906 | 0,02545 | 0,02264 | 0,02039 |
| 90                 | 1,04274                            | 0,20861 | 0,10435 | 0,06961 | 0,05224 | 0,04182 | 0,03488 | 0,02992 | 0,02620 | 0,02332 | 0,02101 |
| 100                | 1,07149                            | 0,21439 | 0,10727 | 0,07156 | 0,05371 | 0,04301 | 0,03587 | 0,03078 | 0,02696 | 0,02399 | 0,02162 |
| 120                | 1,12899                            | 0,22595 | 0,11308 | 0,07546 | 0,05666 | 0,04538 | 0,03786 | 0,03249 | 0,02847 | 0,02534 | 0,02284 |
| 140                | 1,18648                            | 0,23750 | 0,11889 | 0,07936 | 0,05959 | 0,04774 | 0,03984 | 0,03419 | 0,02996 | 0,02667 | 0,02404 |
| 160                | 1,24396                            | 0,24905 | 0,12469 | 0,08324 | 0,06252 | 0,05009 | 0,04181 | 0,03589 | 0,03145 | 0,02800 | 0,02525 |
| 180                | 1,30144                            | 0,26058 | 0,13048 | 0,08712 | 0,06544 | 0,05244 | 0,04377 | 0,03758 | 0,03294 | 0,02933 | 0,02644 |
| 200                | 1,35891                            | 0,27212 | 0,13627 | 0,09100 | 0,06836 | 0,05478 | 0,04573 | 0,03926 | 0,03442 | 0,03065 | 0,02764 |
| 250                | 1,50257                            | 0,30093 | 0,15073 | 0,10066 | 0,07563 | 0,06062 | 0,05061 | 0,04346 | 0,03810 | 0,03393 | 0,03060 |
| 300                | 1,64620                            | 0,32972 | 0,16516 | 0,11031 | 0,08289 | 0,06644 | 0,05547 | 0,04764 | 0,04176 | 0,03719 | 0,03354 |
| 350                | 1,78983                            | 0,35849 | 0,17958 | 0,11994 | 0,09013 | 0,07224 | 0,06031 | 0,05180 | 0,04541 | 0,04044 | 0,03647 |
| 400                | 1,93344                            | 0,38726 | 0,19399 | 0,12956 | 0,09735 | 0,07803 | 0,06515 | 0,05595 | 0,04905 | 0,04368 | 0,03939 |
| 450                | 2,07704                            | 0,41601 | 0,20838 | 0,13918 | 0,10457 | 0,08381 | 0,06997 | 0,06009 | 0,05268 | 0,04691 | 0,04230 |
| 500                | 2,22063                            | 0,44476 | 0,22278 | 0,14878 | 0,11179 | 0,08959 | 0,07479 | 0,06423 | 0,05630 | 0,05014 | 0,04520 |
| 550                | 2,36422                            | 0,47350 | 0,23716 | 0,15838 | 0,11899 | 0,09536 | 0,07961 | 0,06836 | 0,05992 | 0,05335 | 0,04810 |
| 600                | 2,50781                            | 0,50224 | 0,25154 | 0,16798 | 0,12620 | 0,10113 | 0,08442 | 0,07248 | 0,06353 | 0,05657 | 0,05100 |
| 650                | 2,65139                            | 0,53097 | 0,26592 | 0,17757 | 0,13340 | 0,10689 | 0,08922 | 0,07660 | 0,06714 | 0,05978 | 0,05389 |
| 700                | 2,79496                            | 0,55970 | 0,28029 | 0,18716 | 0,14059 | 0,11265 | 0,09403 | 0,08072 | 0,07075 | 0,06299 | 0,05678 |
| 750                | 2,93854                            | 0,58843 | 0,29467 | 0,19675 | 0,14779 | 0,11841 | 0,09883 | 0,08484 | 0,07435 | 0,06619 | 0,05966 |
| 800                | 3,08211                            | 0,61715 | 0,30904 | 0,20633 | 0,15498 | 0,12417 | 0,10363 | 0,08896 | 0,07795 | 0,06940 | 0,06255 |
| 850                | 3,22568                            | 0,64588 | 0,32340 | 0,21591 | 0,16217 | 0,12992 | 0,10842 | 0,09307 | 0,08155 | 0,07260 | 0,06543 |
| 900                | 3,36925                            | 0,67460 | 0,33777 | 0,22549 | 0,16936 | 0,13567 | 0,11322 | 0,09718 | 0,08515 | 0,07580 | 0,06831 |
| 950                | 3,51282                            | 0,70332 | 0,35214 | 0,23507 | 0,17654 | 0,14143 | 0,11801 | 0,10129 | 0,08875 | 0,07900 | 0,07119 |
| 1000               | 3,65639                            | 0,73204 | 0,36650 | 0,24465 | 0,18373 | 0,14718 | 0,12281 | 0,10540 | 0,09235 | 0,08219 | 0,07407 |
| 1050               | 3,79995                            | 0,76076 | 0,38086 | 0,25423 | 0,19091 | 0,15293 | 0,12760 | 0,10951 | 0,09594 | 0,08539 | 0,07695 |
| 1100               | 3,94352                            | 0,78948 | 0,39522 | 0,26381 | 0,19810 | 0,15867 | 0,13239 | 0,11362 | 0,09954 | 0,08859 | 0,07983 |
| 1150               | 4,08708                            | 0,81820 | 0,40959 | 0,27338 | 0,20528 | 0,16442 | 0,13718 | 0,11772 | 0,10313 | 0,09178 | 0,08270 |
| 1200               | 4,23064                            | 0,84691 | 0,42395 | 0,28296 | 0,21246 | 0,17017 | 0,14197 | 0,12183 | 0,10673 | 0,09498 | 0,08558 |
| 1250               | 4,37421                            | 0,87563 | 0,43831 | 0,29253 | 0,21965 | 0,17591 | 0,14676 | 0,12594 | 0,11032 | 0,09817 | 0,08845 |
| 1300               | 4,51777                            | 0,90434 | 0,45267 | 0,30211 | 0,22683 | 0,18166 | 0,15155 | 0,13004 | 0,11391 | 0,10137 | 0,09133 |
| 1350               | 4,66133                            | 0,93306 | 0,46703 | 0,31168 | 0,23401 | 0,18741 | 0,15634 | 0,13415 | 0,11750 | 0,10456 | 0,09420 |
| 1400               | 4,80489                            | 0,96177 | 0,48138 | 0,32125 | 0,24119 | 0,19315 | 0,16113 | 0,13825 | 0,12109 | 0,10775 | 0,09708 |
| 1450               | 4,94845                            | 0,99049 | 0,49574 | 0,33083 | 0,24837 | 0,19890 | 0,16591 | 0,14235 | 0,12469 | 0,11094 | 0,09995 |
| 1500               | 5,09201                            | 1,01920 | 0,51010 | 0,34040 | 0,25555 | 0,20464 | 0,17070 | 0,14646 | 0,12828 | 0,11414 | 0,10282 |
| 1550               | 5,23557                            | 1,04791 | 0,52446 | 0,34997 | 0,26273 | 0,21038 | 0,17549 | 0,15056 | 0,13187 | 0,11733 | 0,10570 |
| 1600               | 5,37914                            | 1,07663 | 0,53882 | 0,35954 | 0,26991 | 0,21613 | 0,18027 | 0,15467 | 0,13546 | 0,12052 | 0,10857 |
| 1650               | 5,52270                            | 1,10534 | 0,55317 | 0,36912 | 0,27709 | 0,22187 | 0,18506 | 0,15877 | 0,13905 | 0,12371 | 0,11144 |
| 1700               | 5,66625                            | 1,13405 | 0,56753 | 0,37869 | 0,28427 | 0,22762 | 0,18985 | 0,16287 | 0,14264 | 0,12690 | 0,11431 |

**Tab. 7 Spezifische isobare Wärmekapazität von Luft (trocken) als reales Fluid**

Werte nach Lemmon et al. (2000)

| $\vartheta$<br>°C | $c_p$ in $\text{kJkg}^{-1}\text{K}^{-1}$ |        |        |        |        |        |        |        |        |        |        |
|-------------------|------------------------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
|                   | $p$<br>MPa                               |        |        |        |        |        |        |        |        |        |        |
|                   | 0,1                                      | 0,5    | 1      | 1,5    | 2      | 2,5    | 3      | 3,5    | 4      | 4,5    | 5      |
| -30               | 1,0058                                   | 1,0164 | 1,0300 | 1,0440 | 1,0582 | 1,0727 | 1,0876 | 1,1026 | 1,1179 | 1,1334 | 1,1490 |
| -20               | 1,0057                                   | 1,0154 | 1,0276 | 1,0401 | 1,0527 | 1,0656 | 1,0787 | 1,0919 | 1,1053 | 1,1188 | 1,1325 |
| -10               | 1,0058                                   | 1,0145 | 1,0256 | 1,0368 | 1,0482 | 1,0597 | 1,0713 | 1,0831 | 1,0949 | 1,1068 | 1,1188 |
| 0                 | 1,0059                                   | 1,0139 | 1,0239 | 1,0341 | 1,0443 | 1,0547 | 1,0651 | 1,0756 | 1,0862 | 1,0968 | 1,1075 |
| 5                 | 1,0060                                   | 1,0136 | 1,0232 | 1,0329 | 1,0426 | 1,0525 | 1,0624 | 1,0724 | 1,0824 | 1,0925 | 1,1025 |
| 10                | 1,0061                                   | 1,0134 | 1,0225 | 1,0318 | 1,0411 | 1,0505 | 1,0599 | 1,0694 | 1,0789 | 1,0884 | 1,0980 |
| 15                | 1,0062                                   | 1,0132 | 1,0220 | 1,0308 | 1,0397 | 1,0486 | 1,0576 | 1,0666 | 1,0757 | 1,0847 | 1,0938 |
| 20                | 1,0064                                   | 1,0130 | 1,0215 | 1,0299 | 1,0384 | 1,0469 | 1,0555 | 1,0641 | 1,0727 | 1,0813 | 1,0899 |
| 25                | 1,0065                                   | 1,0129 | 1,0210 | 1,0291 | 1,0372 | 1,0454 | 1,0536 | 1,0618 | 1,0700 | 1,0782 | 1,0863 |
| 30                | 1,0067                                   | 1,0129 | 1,0206 | 1,0284 | 1,0362 | 1,0440 | 1,0518 | 1,0596 | 1,0674 | 1,0752 | 1,0830 |
| 35                | 1,0069                                   | 1,0128 | 1,0203 | 1,0277 | 1,0352 | 1,0427 | 1,0501 | 1,0576 | 1,0651 | 1,0726 | 1,0800 |
| 40                | 1,0071                                   | 1,0128 | 1,0200 | 1,0271 | 1,0343 | 1,0415 | 1,0486 | 1,0558 | 1,0630 | 1,0701 | 1,0772 |
| 45                | 1,0074                                   | 1,0129 | 1,0197 | 1,0266 | 1,0335 | 1,0404 | 1,0473 | 1,0541 | 1,0610 | 1,0678 | 1,0746 |
| 50                | 1,0077                                   | 1,0129 | 1,0196 | 1,0262 | 1,0328 | 1,0394 | 1,0460 | 1,0526 | 1,0591 | 1,0657 | 1,0722 |
| 60                | 1,0082                                   | 1,0132 | 1,0193 | 1,0254 | 1,0316 | 1,0377 | 1,0438 | 1,0499 | 1,0559 | 1,0619 | 1,0679 |
| 70                | 1,0089                                   | 1,0135 | 1,0192 | 1,0249 | 1,0306 | 1,0363 | 1,0419 | 1,0476 | 1,0532 | 1,0588 | 1,0643 |
| 80                | 1,0097                                   | 1,0140 | 1,0193 | 1,0246 | 1,0299 | 1,0352 | 1,0405 | 1,0457 | 1,0509 | 1,0561 | 1,0612 |
| 90                | 1,0105                                   | 1,0145 | 1,0195 | 1,0245 | 1,0295 | 1,0344 | 1,0393 | 1,0442 | 1,0490 | 1,0538 | 1,0586 |
| 100               | 1,0115                                   | 1,0152 | 1,0199 | 1,0246 | 1,0292 | 1,0338 | 1,0384 | 1,0429 | 1,0475 | 1,0519 | 1,0564 |
| 120               | 1,0136                                   | 1,0169 | 1,0210 | 1,0252 | 1,0292 | 1,0333 | 1,0373 | 1,0413 | 1,0453 | 1,0492 | 1,0531 |
| 140               | 1,0160                                   | 1,0190 | 1,0227 | 1,0263 | 1,0300 | 1,0336 | 1,0371 | 1,0407 | 1,0442 | 1,0477 | 1,0511 |
| 160               | 1,0188                                   | 1,0214 | 1,0247 | 1,0280 | 1,0313 | 1,0345 | 1,0377 | 1,0408 | 1,0440 | 1,0471 | 1,0501 |
| 180               | 1,0218                                   | 1,0242 | 1,0272 | 1,0302 | 1,0331 | 1,0360 | 1,0388 | 1,0417 | 1,0445 | 1,0473 | 1,0500 |
| 200               | 1,0252                                   | 1,0274 | 1,0301 | 1,0327 | 1,0354 | 1,0380 | 1,0405 | 1,0431 | 1,0456 | 1,0482 | 1,0507 |
| 250               | 1,0347                                   | 1,0364 | 1,0385 | 1,0406 | 1,0427 | 1,0448 | 1,0468 | 1,0488 | 1,0508 | 1,0528 | 1,0548 |
| 300               | 1,0454                                   | 1,0467 | 1,0485 | 1,0502 | 1,0519 | 1,0535 | 1,0552 | 1,0568 | 1,0584 | 1,0600 | 1,0616 |
| 350               | 1,0568                                   | 1,0580 | 1,0594 | 1,0608 | 1,0622 | 1,0636 | 1,0649 | 1,0663 | 1,0676 | 1,0689 | 1,0703 |
| 400               | 1,0688                                   | 1,0697 | 1,0709 | 1,0721 | 1,0732 | 1,0744 | 1,0755 | 1,0767 | 1,0778 | 1,0789 | 1,0800 |
| 450               | 1,0808                                   | 1,0816 | 1,0826 | 1,0836 | 1,0846 | 1,0856 | 1,0865 | 1,0875 | 1,0884 | 1,0894 | 1,0903 |
| 500               | 1,0927                                   | 1,0934 | 1,0942 | 1,0951 | 1,0959 | 1,0968 | 1,0976 | 1,0984 | 1,0992 | 1,1000 | 1,1008 |
| 550               | 1,1043                                   | 1,1049 | 1,1056 | 1,1063 | 1,1071 | 1,1078 | 1,1085 | 1,1092 | 1,1099 | 1,1106 | 1,1113 |
| 600               | 1,1154                                   | 1,1159 | 1,1166 | 1,1172 | 1,1178 | 1,1185 | 1,1191 | 1,1197 | 1,1203 | 1,1209 | 1,1215 |
| 650               | 1,1260                                   | 1,1265 | 1,1270 | 1,1276 | 1,1282 | 1,1287 | 1,1292 | 1,1298 | 1,1303 | 1,1308 | 1,1314 |
| 700               | 1,1361                                   | 1,1365 | 1,1370 | 1,1375 | 1,1380 | 1,1385 | 1,1389 | 1,1394 | 1,1399 | 1,1403 | 1,1408 |
| 750               | 1,1456                                   | 1,1459 | 1,1464 | 1,1468 | 1,1473 | 1,1477 | 1,1481 | 1,1485 | 1,1489 | 1,1494 | 1,1498 |
| 800               | 1,1545                                   | 1,1548 | 1,1552 | 1,1556 | 1,1560 | 1,1564 | 1,1568 | 1,1571 | 1,1575 | 1,1579 | 1,1582 |
| 850               | 1,1629                                   | 1,1632 | 1,1635 | 1,1639 | 1,1642 | 1,1646 | 1,1649 | 1,1652 | 1,1656 | 1,1659 | 1,1662 |
| 900               | 1,1708                                   | 1,1710 | 1,1713 | 1,1716 | 1,1719 | 1,1722 | 1,1725 | 1,1728 | 1,1731 | 1,1734 | 1,1737 |
| 950               | 1,1781                                   | 1,1783 | 1,1786 | 1,1789 | 1,1792 | 1,1794 | 1,1797 | 1,1800 | 1,1803 | 1,1805 | 1,1808 |
| 1000              | 1,1850                                   | 1,1852 | 1,1855 | 1,1857 | 1,1860 | 1,1862 | 1,1865 | 1,1867 | 1,1869 | 1,1872 | 1,1874 |
| 1050              | 1,1915                                   | 1,1916 | 1,1919 | 1,1921 | 1,1923 | 1,1926 | 1,1928 | 1,1930 | 1,1932 | 1,1934 | 1,1937 |
| 1100              | 1,1975                                   | 1,1977 | 1,1979 | 1,1981 | 1,1983 | 1,1985 | 1,1987 | 1,1989 | 1,1991 | 1,1993 | 1,1995 |
| 1150              | 1,2032                                   | 1,2034 | 1,2035 | 1,2037 | 1,2039 | 1,2041 | 1,2043 | 1,2045 | 1,2047 | 1,2048 | 1,2050 |
| 1200              | 1,2086                                   | 1,2087 | 1,2089 | 1,2090 | 1,2092 | 1,2094 | 1,2096 | 1,2097 | 1,2099 | 1,2101 | 1,2102 |
| 1250              | 1,2136                                   | 1,2137 | 1,2139 | 1,2141 | 1,2142 | 1,2144 | 1,2145 | 1,2147 | 1,2148 | 1,2150 | 1,2151 |
| 1300              | 1,2184                                   | 1,2185 | 1,2186 | 1,2188 | 1,2189 | 1,2191 | 1,2192 | 1,2193 | 1,2195 | 1,2196 | 1,2198 |
| 1350              | 1,2229                                   | 1,2230 | 1,2231 | 1,2233 | 1,2234 | 1,2235 | 1,2236 | 1,2238 | 1,2239 | 1,2240 | 1,2242 |
| 1400              | 1,2271                                   | 1,2272 | 1,2274 | 1,2275 | 1,2276 | 1,2277 | 1,2279 | 1,2280 | 1,2281 | 1,2282 | 1,2283 |
| 1450              | 1,2312                                   | 1,2313 | 1,2314 | 1,2315 | 1,2316 | 1,2317 | 1,2318 | 1,2320 | 1,2321 | 1,2322 | 1,2323 |
| 1500              | 1,2350                                   | 1,2351 | 1,2352 | 1,2353 | 1,2354 | 1,2355 | 1,2356 | 1,2358 | 1,2359 | 1,2360 | 1,2361 |
| 1550              | 1,2387                                   | 1,2388 | 1,2389 | 1,2390 | 1,2391 | 1,2392 | 1,2393 | 1,2394 | 1,2395 | 1,2396 | 1,2396 |
| 1600              | 1,2422                                   | 1,2423 | 1,2424 | 1,2425 | 1,2426 | 1,2426 | 1,2427 | 1,2428 | 1,2429 | 1,2430 | 1,2431 |
| 1650              | 1,2456                                   | 1,2456 | 1,2457 | 1,2458 | 1,2459 | 1,2460 | 1,2460 | 1,2461 | 1,2462 | 1,2463 | 1,2464 |
| 1700              | 1,2488                                   | 1,2488 | 1,2489 | 1,2490 | 1,2491 | 1,2491 | 1,2492 | 1,2493 | 1,2494 | 1,2494 | 1,2495 |

**Tab. 8 Spezifische Enthalpie von Luft (trocken) als reales Fluid**

Werte nach Lemmon et al. (2000)

| $\vartheta$<br>°C | $h$ in $\text{kJkg}^{-1}$ |         |         |         |         |         |         |         |         |         |         |
|-------------------|---------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                   | $p$<br>MPa                |         |         |         |         |         |         |         |         |         |         |
|                   | 0,1                       | 0,5     | 1       | 1,5     | 2       | 2,5     | 3       | 3,5     | 4       | 4,5     | 5       |
| -30               | -30,170                   | -31,539 | -33,247 | -34,952 | -36,653 | -38,350 | -40,041 | -41,727 | -43,406 | -45,077 | -46,738 |
| -20               | -20,112                   | -21,380 | -22,960 | -24,533 | -26,099 | -27,659 | -29,211 | -30,756 | -32,292 | -33,818 | -35,334 |
| -10               | -10,055                   | -11,231 | -12,694 | -14,149 | -15,596 | -17,034 | -18,463 | -19,882 | -21,292 | -22,691 | -24,079 |
| 0                 | 0,004                     | -1,089  | -2,447  | -3,795  | -5,134  | -6,462  | -7,781  | -9,090  | -10,388 | -11,674 | -12,949 |
| 5                 | 5,033                     | 3,979   | 2,671   | 1,372   | 0,084   | -1,195  | -2,463  | -3,720  | -4,966  | -6,201  | -7,425  |
| 10                | 10,063                    | 9,047   | 7,785   | 6,534   | 5,293   | 4,063   | 2,843   | 1,634   | 0,437   | -0,749  | -1,924  |
| 15                | 15,094                    | 14,113  | 12,896  | 11,690  | 10,495  | 9,311   | 8,137   | 6,974   | 5,823   | 4,683   | 3,556   |
| 20                | 20,126                    | 19,179  | 18,005  | 16,842  | 15,690  | 14,549  | 13,420  | 12,301  | 11,194  | 10,098  | 9,015   |
| 25                | 25,158                    | 24,243  | 23,111  | 21,989  | 20,879  | 19,780  | 18,692  | 17,616  | 16,551  | 15,497  | 14,455  |
| 30                | 30,191                    | 29,308  | 28,215  | 27,133  | 26,063  | 25,004  | 23,956  | 22,919  | 21,894  | 20,880  | 19,878  |
| 35                | 35,225                    | 34,372  | 33,317  | 32,273  | 31,241  | 30,220  | 29,211  | 28,212  | 27,225  | 26,250  | 25,286  |
| 40                | 40,260                    | 39,437  | 38,418  | 37,410  | 36,415  | 35,430  | 34,457  | 33,496  | 32,545  | 31,606  | 30,679  |
| 45                | 45,296                    | 44,501  | 43,517  | 42,545  | 41,584  | 40,635  | 39,697  | 38,770  | 37,855  | 36,951  | 36,058  |
| 50                | 50,334                    | 49,565  | 48,615  | 47,677  | 46,750  | 45,834  | 44,930  | 44,037  | 43,155  | 42,285  | 41,425  |
| 60                | 60,413                    | 59,696  | 58,809  | 57,935  | 57,071  | 56,219  | 55,379  | 54,549  | 53,730  | 52,922  | 52,125  |
| 70                | 70,499                    | 69,829  | 69,002  | 68,186  | 67,382  | 66,589  | 65,807  | 65,036  | 64,275  | 63,525  | 62,786  |
| 80                | 80,592                    | 79,966  | 79,195  | 78,434  | 77,685  | 76,946  | 76,219  | 75,502  | 74,795  | 74,099  | 73,413  |
| 90                | 90,693                    | 90,109  | 89,389  | 88,680  | 87,982  | 87,294  | 86,617  | 85,951  | 85,294  | 84,648  | 84,012  |
| 100               | 100,80                    | 100,26  | 99,586  | 98,925  | 98,275  | 97,635  | 97,005  | 96,386  | 95,776  | 95,177  | 94,587  |
| 120               | 121,05                    | 120,58  | 119,99  | 119,42  | 118,86  | 118,30  | 117,76  | 117,23  | 116,70  | 116,19  | 115,68  |
| 140               | 141,35                    | 140,94  | 140,43  | 139,94  | 139,45  | 138,97  | 138,50  | 138,05  | 137,60  | 137,15  | 136,72  |
| 160               | 161,70                    | 161,34  | 160,90  | 160,48  | 160,06  | 159,65  | 159,25  | 158,86  | 158,48  | 158,10  | 157,73  |
| 180               | 182,10                    | 181,80  | 181,42  | 181,06  | 180,70  | 180,35  | 180,01  | 179,68  | 179,36  | 179,04  | 178,73  |
| 200               | 202,57                    | 202,31  | 202,00  | 201,69  | 201,39  | 201,09  | 200,81  | 200,53  | 200,26  | 199,99  | 199,74  |
| 250               | 254,06                    | 253,90  | 253,70  | 253,51  | 253,33  | 253,15  | 252,98  | 252,82  | 252,66  | 252,51  | 252,36  |
| 300               | 306,06                    | 305,97  | 305,87  | 305,78  | 305,69  | 305,60  | 305,52  | 305,45  | 305,38  | 305,32  | 305,26  |
| 350               | 358,61                    | 358,59  | 358,57  | 358,55  | 358,53  | 358,53  | 358,52  | 358,52  | 358,53  | 358,54  | 358,55  |
| 400               | 411,75                    | 411,78  | 411,82  | 411,87  | 411,92  | 411,97  | 412,03  | 412,10  | 412,16  | 412,23  | 412,31  |
| 450               | 465,49                    | 465,56  | 465,66  | 465,76  | 465,86  | 465,97  | 466,08  | 466,20  | 466,32  | 466,44  | 466,56  |
| 500               | 519,83                    | 519,94  | 520,08  | 520,23  | 520,38  | 520,53  | 520,69  | 520,84  | 521,01  | 521,17  | 521,34  |
| 550               | 574,75                    | 574,90  | 575,08  | 575,26  | 575,45  | 575,64  | 575,84  | 576,03  | 576,23  | 576,44  | 576,64  |
| 600               | 630,25                    | 630,42  | 630,63  | 630,85  | 631,08  | 631,30  | 631,53  | 631,76  | 631,99  | 632,22  | 632,46  |
| 650               | 686,28                    | 686,48  | 686,73  | 686,98  | 687,23  | 687,48  | 687,74  | 688,00  | 688,26  | 688,52  | 688,78  |
| 700               | 742,84                    | 743,06  | 743,33  | 743,61  | 743,88  | 744,16  | 744,45  | 744,73  | 745,01  | 745,30  | 745,59  |
| 750               | 799,88                    | 800,12  | 800,42  | 800,72  | 801,02  | 801,32  | 801,62  | 801,93  | 802,24  | 802,55  | 802,86  |
| 800               | 857,39                    | 857,64  | 857,96  | 858,28  | 858,60  | 858,92  | 859,25  | 859,57  | 859,90  | 860,23  | 860,56  |
| 850               | 915,33                    | 915,59  | 915,93  | 916,27  | 916,61  | 916,95  | 917,29  | 917,63  | 917,98  | 918,33  | 918,67  |
| 900               | 973,67                    | 973,95  | 974,30  | 974,66  | 975,01  | 975,37  | 975,73  | 976,09  | 976,45  | 976,81  | 977,17  |
| 950               | 1032,4                    | 1032,7  | 1033,1  | 1033,4  | 1033,8  | 1034,2  | 1034,5  | 1034,9  | 1035,3  | 1035,7  | 1036,0  |
| 1000              | 1091,5                    | 1091,8  | 1092,2  | 1092,5  | 1092,9  | 1093,3  | 1093,7  | 1094,1  | 1094,5  | 1094,9  | 1095,2  |
| 1050              | 1150,9                    | 1151,2  | 1151,6  | 1152,0  | 1152,4  | 1152,8  | 1153,2  | 1153,6  | 1154,0  | 1154,4  | 1154,8  |
| 1100              | 1210,6                    | 1210,9  | 1211,3  | 1211,7  | 1212,1  | 1212,6  | 1213,0  | 1213,4  | 1213,8  | 1214,2  | 1214,6  |
| 1150              | 1270,6                    | 1271,0  | 1271,4  | 1271,8  | 1272,2  | 1272,6  | 1273,0  | 1273,5  | 1273,9  | 1274,3  | 1274,7  |
| 1200              | 1330,9                    | 1331,3  | 1331,7  | 1332,1  | 1332,5  | 1333,0  | 1333,4  | 1333,8  | 1334,2  | 1334,7  | 1335,1  |
| 1250              | 1391,5                    | 1391,8  | 1392,3  | 1392,7  | 1393,1  | 1393,6  | 1394,0  | 1394,4  | 1394,9  | 1395,3  | 1395,7  |
| 1300              | 1452,3                    | 1452,6  | 1453,1  | 1453,5  | 1454,0  | 1454,4  | 1454,8  | 1455,3  | 1455,7  | 1456,2  | 1456,6  |
| 1350              | 1513,3                    | 1513,7  | 1514,1  | 1514,6  | 1515,0  | 1515,5  | 1515,9  | 1516,4  | 1516,8  | 1517,3  | 1517,7  |
| 1400              | 1574,6                    | 1574,9  | 1575,4  | 1575,8  | 1576,3  | 1576,7  | 1577,2  | 1577,7  | 1578,1  | 1578,6  | 1579,0  |
| 1450              | 1636,0                    | 1636,4  | 1636,9  | 1637,3  | 1637,8  | 1638,2  | 1638,7  | 1639,2  | 1639,6  | 1640,1  | 1640,5  |
| 1500              | 1697,7                    | 1698,1  | 1698,5  | 1699,0  | 1699,4  | 1699,9  | 1700,4  | 1700,8  | 1701,3  | 1701,8  | 1702,2  |
| 1550              | 1759,5                    | 1759,9  | 1760,4  | 1760,8  | 1761,3  | 1761,8  | 1762,3  | 1762,7  | 1763,2  | 1763,7  | 1764,1  |
| 1600              | 1821,6                    | 1821,9  | 1822,4  | 1822,9  | 1823,4  | 1823,8  | 1824,3  | 1824,8  | 1825,3  | 1825,7  | 1826,2  |
| 1650              | 1883,7                    | 1884,1  | 1884,6  | 1885,1  | 1885,6  | 1886,0  | 1886,5  | 1887,0  | 1887,5  | 1888,0  | 1888,4  |
| 1700              | 1946,1                    | 1946,5  | 1947,0  | 1947,5  | 1947,9  | 1948,4  | 1948,9  | 1949,4  | 1949,9  | 1950,4  | 1950,8  |

**Tab. 9 Spezifische Entropie von Luft (trocken) als reales Fluid**

Werte nach Lemmon et al. (2000)

| $\vartheta$        | s in $\text{kJkg}^{-1}\text{K}^{-1}$ |         |         |         |         |         |         |         |         |         |         |
|--------------------|--------------------------------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|
|                    | $p$<br>MPa                           |         |         |         |         |         |         |         |         |         |         |
| $^{\circ}\text{C}$ | 0,1                                  | 0,5     | 1       | 1,5     | 2       | 2,5     | 3       | 3,5     | 4       | 4,5     | 5       |
| -30                | 0,0486                               | -0,4179 | -0,6224 | -0,7444 | -0,8325 | -0,9021 | -0,9600 | -1,0098 | -1,0537 | -1,0931 | -1,1288 |
| -20                | 0,0891                               | -0,3770 | -0,5810 | -0,7024 | -0,7900 | -0,8590 | -0,9164 | -0,9656 | -1,0089 | -1,0477 | -1,0829 |
| -10                | 0,1281                               | -0,3377 | -0,5412 | -0,6622 | -0,7493 | -0,8179 | -0,8747 | -0,9235 | -0,9663 | -1,0046 | -1,0393 |
| 0                  | 0,1656                               | -0,2998 | -0,5030 | -0,6235 | -0,7103 | -0,7784 | -0,8349 | -0,8832 | -0,9256 | -0,9635 | -0,9977 |
| 5                  | 0,1838                               | -0,2814 | -0,4844 | -0,6048 | -0,6913 | -0,7593 | -0,8156 | -0,8637 | -0,9060 | -0,9436 | -0,9777 |
| 10                 | 0,2018                               | -0,2634 | -0,4662 | -0,5864 | -0,6728 | -0,7406 | -0,7967 | -0,8447 | -0,8867 | -0,9242 | -0,9581 |
| 15                 | 0,2194                               | -0,2456 | -0,4483 | -0,5684 | -0,6546 | -0,7222 | -0,7782 | -0,8260 | -0,8678 | -0,9052 | -0,9389 |
| 20                 | 0,2367                               | -0,2282 | -0,4307 | -0,5506 | -0,6367 | -0,7042 | -0,7600 | -0,8076 | -0,8494 | -0,8865 | -0,9201 |
| 25                 | 0,2537                               | -0,2111 | -0,4135 | -0,5332 | -0,6191 | -0,6865 | -0,7421 | -0,7897 | -0,8312 | -0,8683 | -0,9017 |
| 30                 | 0,2704                               | -0,1942 | -0,3965 | -0,5161 | -0,6019 | -0,6691 | -0,7246 | -0,7720 | -0,8135 | -0,8504 | -0,8837 |
| 35                 | 0,2869                               | -0,1777 | -0,3798 | -0,4993 | -0,5850 | -0,6521 | -0,7074 | -0,7547 | -0,7960 | -0,8328 | -0,8660 |
| 40                 | 0,3031                               | -0,1614 | -0,3634 | -0,4828 | -0,5683 | -0,6353 | -0,6905 | -0,7377 | -0,7789 | -0,8156 | -0,8486 |
| 45                 | 0,3191                               | -0,1453 | -0,3472 | -0,4665 | -0,5519 | -0,6188 | -0,6739 | -0,7210 | -0,7621 | -0,7986 | -0,8316 |
| 50                 | 0,3348                               | -0,1295 | -0,3313 | -0,4505 | -0,5358 | -0,6026 | -0,6576 | -0,7046 | -0,7456 | -0,7820 | -0,8149 |
| 60                 | 0,3655                               | -0,0987 | -0,3002 | -0,4192 | -0,5044 | -0,5709 | -0,6258 | -0,6725 | -0,7133 | -0,7496 | -0,7822 |
| 70                 | 0,3953                               | -0,0687 | -0,2701 | -0,3889 | -0,4739 | -0,5403 | -0,5949 | -0,6415 | -0,6821 | -0,7182 | -0,7507 |
| 80                 | 0,4243                               | -0,0396 | -0,2408 | -0,3595 | -0,4443 | -0,5105 | -0,5650 | -0,6114 | -0,6519 | -0,6878 | -0,7202 |
| 90                 | 0,4525                               | -0,0112 | -0,2124 | -0,3309 | -0,4155 | -0,4816 | -0,5360 | -0,5823 | -0,6226 | -0,6584 | -0,6906 |
| 100                | 0,4800                               | 0,0163  | -0,1847 | -0,3030 | -0,3876 | -0,4535 | -0,5078 | -0,5539 | -0,5941 | -0,6298 | -0,6619 |
| 120                | 0,5329                               | 0,0694  | -0,1314 | -0,2495 | -0,3338 | -0,3996 | -0,4536 | -0,4995 | -0,5395 | -0,5749 | -0,6068 |
| 140                | 0,5832                               | 0,1199  | -0,0807 | -0,1986 | -0,2827 | -0,3483 | -0,4021 | -0,4479 | -0,4877 | -0,5229 | -0,5546 |
| 160                | 0,6313                               | 0,1681  | -0,0323 | -0,1501 | -0,2340 | -0,2994 | -0,3531 | -0,3987 | -0,4383 | -0,4734 | -0,5049 |
| 180                | 0,6774                               | 0,2143  | 0,0140  | -0,1036 | -0,1874 | -0,2527 | -0,3062 | -0,3517 | -0,3912 | -0,4261 | -0,4575 |
| 200                | 0,7216                               | 0,2586  | 0,0584  | -0,0591 | -0,1428 | -0,2079 | -0,2613 | -0,3067 | -0,3460 | -0,3809 | -0,4122 |
| 250                | 0,8250                               | 0,3622  | 0,1623  | 0,0450  | -0,0384 | -0,1033 | -0,1565 | -0,2016 | -0,2408 | -0,2754 | -0,3065 |
| 300                | 0,9199                               | 0,4573  | 0,2576  | 0,1404  | 0,0572  | -0,0076 | -0,0606 | -0,1055 | -0,1445 | -0,1790 | -0,2099 |
| 350                | 1,0078                               | 0,5453  | 0,3457  | 0,2287  | 0,1456  | 0,0809  | 0,0281  | -0,0167 | -0,0556 | -0,0900 | -0,1208 |
| 400                | 1,0899                               | 0,6274  | 0,4279  | 0,3110  | 0,2280  | 0,1634  | 0,1106  | 0,0659  | 0,0272  | -0,0071 | -0,0378 |
| 450                | 1,1669                               | 0,7044  | 0,5050  | 0,3882  | 0,3053  | 0,2408  | 0,1881  | 0,1435  | 0,1048  | 0,0706  | 0,0400  |
| 500                | 1,2395                               | 0,7771  | 0,5778  | 0,4611  | 0,3781  | 0,3138  | 0,2611  | 0,2165  | 0,1779  | 0,1438  | 0,1132  |
| 550                | 1,3083                               | 0,8460  | 0,6467  | 0,5300  | 0,4472  | 0,3828  | 0,3302  | 0,2857  | 0,2471  | 0,2130  | 0,1825  |
| 600                | 1,3738                               | 0,9115  | 0,7122  | 0,5956  | 0,5128  | 0,4485  | 0,3959  | 0,3514  | 0,3128  | 0,2788  | 0,2483  |
| 650                | 1,4362                               | 0,9739  | 0,7747  | 0,6581  | 0,5753  | 0,5110  | 0,4585  | 0,4140  | 0,3755  | 0,3415  | 0,3111  |
| 700                | 1,4958                               | 1,0336  | 0,8344  | 0,7178  | 0,6351  | 0,5708  | 0,5183  | 0,4739  | 0,4354  | 0,4014  | 0,3710  |
| 750                | 1,5530                               | 1,0908  | 0,8916  | 0,7751  | 0,6923  | 0,6281  | 0,5756  | 0,5312  | 0,4927  | 0,4588  | 0,4284  |
| 800                | 1,6079                               | 1,1457  | 0,9465  | 0,8300  | 0,7473  | 0,6831  | 0,6306  | 0,5862  | 0,5477  | 0,5138  | 0,4834  |
| 850                | 1,6606                               | 1,1985  | 0,9993  | 0,8828  | 0,8001  | 0,7359  | 0,6835  | 0,6391  | 0,6006  | 0,5667  | 0,5364  |
| 900                | 1,7115                               | 1,2493  | 1,0502  | 0,9337  | 0,8510  | 0,7868  | 0,7344  | 0,6900  | 0,6516  | 0,6177  | 0,5873  |
| 950                | 1,7605                               | 1,2983  | 1,0992  | 0,9827  | 0,9000  | 0,8359  | 0,7834  | 0,7391  | 0,7007  | 0,6668  | 0,6365  |
| 1000               | 1,8078                               | 1,3457  | 1,1466  | 1,0301  | 0,9474  | 0,8833  | 0,8308  | 0,7865  | 0,7481  | 0,7142  | 0,6839  |
| 1050               | 1,8536                               | 1,3914  | 1,1924  | 1,0759  | 0,9932  | 0,9291  | 0,8767  | 0,8324  | 0,7939  | 0,7601  | 0,7298  |
| 1100               | 1,8979                               | 1,4358  | 1,2367  | 1,1202  | 1,0376  | 0,9734  | 0,9210  | 0,8767  | 0,8383  | 0,8044  | 0,7741  |
| 1150               | 1,9408                               | 1,4787  | 1,2796  | 1,1632  | 1,0805  | 1,0164  | 0,9640  | 0,9197  | 0,8813  | 0,8474  | 0,8171  |
| 1200               | 1,9825                               | 1,5203  | 1,3213  | 1,2048  | 1,1222  | 1,0581  | 1,0057  | 0,9614  | 0,9230  | 0,8891  | 0,8588  |
| 1250               | 2,0229                               | 1,5608  | 1,3617  | 1,2453  | 1,1626  | 1,0985  | 1,0461  | 1,0018  | 0,9635  | 0,9296  | 0,8993  |
| 1300               | 2,0622                               | 1,6001  | 1,4010  | 1,2846  | 1,2019  | 1,1378  | 1,0854  | 1,0411  | 1,0028  | 0,9689  | 0,9386  |
| 1350               | 2,1004                               | 1,6382  | 1,4392  | 1,3228  | 1,2401  | 1,1760  | 1,1237  | 1,0794  | 1,0410  | 1,0072  | 0,9769  |
| 1400               | 2,1375                               | 1,6754  | 1,4764  | 1,3599  | 1,2773  | 1,2132  | 1,1608  | 1,1166  | 1,0782  | 1,0444  | 1,0141  |
| 1450               | 2,1737                               | 1,7116  | 1,5126  | 1,3961  | 1,3135  | 1,2494  | 1,1971  | 1,1528  | 1,1144  | 1,0806  | 1,0503  |
| 1500               | 2,2090                               | 1,7469  | 1,5479  | 1,4314  | 1,3488  | 1,2847  | 1,2323  | 1,1881  | 1,1497  | 1,1159  | 1,0856  |
| 1550               | 2,2434                               | 1,7813  | 1,5823  | 1,4658  | 1,3832  | 1,3191  | 1,2668  | 1,2225  | 1,1841  | 1,1503  | 1,1200  |
| 1600               | 2,2770                               | 1,8149  | 1,6158  | 1,4994  | 1,4168  | 1,3527  | 1,3003  | 1,2561  | 1,2177  | 1,1839  | 1,1536  |
| 1650               | 2,3097                               | 1,8476  | 1,6486  | 1,5322  | 1,4496  | 1,3855  | 1,3331  | 1,2888  | 1,2505  | 1,2167  | 1,1864  |
| 1700               | 2,3417                               | 1,8796  | 1,6806  | 1,5642  | 1,4816  | 1,4175  | 1,3651  | 1,3209  | 1,2825  | 1,2487  | 1,2184  |

**Tab. 10 Stoffwerte von flüssigen Metallen**

| Metall            | $\vartheta$<br>°C | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $\rho$<br>kg m <sup>-3</sup> | $\lambda$<br>W m <sup>-1</sup> K <sup>-1</sup> | $\eta$<br>10 <sup>-6</sup><br>kg m <sup>-1</sup> s <sup>-1</sup> | $\nu$<br>10 <sup>-9</sup><br>m <sup>2</sup> s <sup>-1</sup> | $Pr$<br>- |
|-------------------|-------------------|----------------------------------------------|------------------------------|------------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------|-----------|
| Quecksilber<br>Hg | 0                 | 0,1400                                       | 13590                        | 7,80                                           | 1685                                                             | 124                                                         | 0,0302    |
|                   | 100               | 0,1370                                       | 13350                        | 9,08                                           | 1255                                                             | 94                                                          | 0,0189    |
|                   | 200               | 0,1370                                       | 13130                        | 10,35                                          | 1065                                                             | 80                                                          | 0,0139    |
|                   | 300               | 0,1370                                       | 12880                        | 11,63                                          | 914                                                              | 71                                                          | 0,0108    |
|                   | 400               | 0,1375                                       | 12700                        | 12,62                                          | 838                                                              | 66                                                          | 0,0091    |
|                   | 500               | 0,1380                                       | 12480                        | 13,35                                          | 774                                                              | 62                                                          | 0,0080    |
| Zinn<br>Sn        | 240               | 0,2550                                       | 6985                         | 30,50                                          | 1907                                                             | 273                                                         | 0,0160    |
|                   | 300               | 0,2550                                       | 6940                         | 31,60                                          | 1673                                                             | 241                                                         | 0,0135    |
|                   | 400               | 0,2550                                       | 6865                         | 33,60                                          | 1380                                                             | 201                                                         | 0,0105    |
|                   | 500               | 0,2550                                       | 6790                         | 35,50                                          | 1181                                                             | 174                                                         | 0,0085    |
|                   | 600               | 0,2550                                       | 6720                         | 37,40                                          | 1048                                                             | 156                                                         | 0,0072    |
|                   | 700               | 0,2550                                       | 6640                         | 39,40                                          | 950                                                              | 143                                                         | 0,0062    |
| Natrium<br>Na     | 100               | 1,385                                        | 928                          | 86,1                                           | 715                                                              | 770                                                         | 0,0115    |
|                   | 200               | 1,325                                        | 903                          | 81,6                                           | 457                                                              | 506                                                         | 0,0074    |
|                   | 300               | 1,280                                        | 878                          | 75,5                                           | 346                                                              | 394                                                         | 0,0059    |
|                   | 400               | 1,270                                        | 854                          | 68,8                                           | 282                                                              | 330                                                         | 0,0052    |
|                   | 500               | 1,270                                        | 829                          | 63,9                                           | 240                                                              | 289                                                         | 0,0048    |
|                   | 600               | 1,275                                        | 805                          | 60,6                                           | 207                                                              | 257                                                         | 0,0044    |
|                   | 700               | 1,275                                        | 780                          | 59,1                                           | 181                                                              | 232                                                         | 0,0039    |
| Kalium<br>K       | 100               | 0,817                                        | 818                          | 46,5                                           | 459                                                              | 561                                                         | 0,0081    |
|                   | 200               | 0,792                                        | 795                          | 46,0                                           | 340                                                              | 428                                                         | 0,0059    |
|                   | 300               | 0,775                                        | 773                          | 43,11                                          | 272                                                              | 352                                                         | 0,0049    |
|                   | 400               | 0,766                                        | 750                          | 39,6                                           | 224                                                              | 298                                                         | 0,0043    |
|                   | 500               | 0,766                                        | 727                          | 34,9                                           | 187                                                              | 257                                                         | 0,0041    |
|                   | 600               | 0,770                                        | 704                          | 31,0                                           | 156                                                              | 221                                                         | 0,0039    |
|                   | 700               | 0,775                                        | 681                          | 28,3                                           | 140                                                              | 205                                                         | 0,0038    |
| Blei<br>Pb        | 400               | 0,1480                                       | 10582                        | 15,12                                          | 2222                                                             | 210                                                         | 0,0218    |
|                   | 500               | 0,1480                                       | 10476                        | 15,45                                          | 1833                                                             | 175                                                         | 0,0175    |
|                   | 600               | 0,1480                                       | 10360                        | 15,95                                          | 1585                                                             | 153                                                         | 0,0147    |
|                   | 700               | 0,1480                                       | 10242                        | 17,70                                          | 1403                                                             | 137                                                         | 0,0117    |
|                   | 800               | 0,1480                                       | 10125                        | 19,80                                          | 1266                                                             | 125                                                         | 0,0095    |

↑  
kinematische  
Viskosität

**Tab. 11 Transporteigenschaften ausgewählter Feststoffe (Mittelwerte)**

| Stoff                     | $\rho$<br>kg m <sup>-3</sup> | $c_p$<br>kJ kg <sup>-1</sup> K <sup>-1</sup> | $\lambda$<br>W m <sup>-1</sup> K <sup>-1</sup> | $a$<br>10 <sup>-6</sup> m <sup>2</sup> s <sup>-1</sup> |
|---------------------------|------------------------------|----------------------------------------------|------------------------------------------------|--------------------------------------------------------|
| Aluminium                 | 2700                         | 0,897                                        | 209                                            | 86,296                                                 |
| Blei                      | 11340                        | 0,129                                        | 34                                             | 23,242                                                 |
| Stahl                     | 7850                         | 0,460                                        | 50                                             | 13,847                                                 |
| Chromnickelstahl          | 7900                         | 0,477                                        | 14,5                                           | 3,8479                                                 |
| Schmiedeeisen             | 7800                         | 0,460                                        | 58                                             | 16,165                                                 |
| Eisen                     | 7200                         | 0,540                                        | 54                                             | 13,889                                                 |
| Gußeisen                  | 7280                         | 0,536                                        | 60                                             | 15,376                                                 |
| Gold                      | 19290                        | 0,1295                                       | 311                                            | 124,50                                                 |
| Kupfer                    | 8300                         | 0,4186                                       | 372                                            | 107,07                                                 |
| Messing                   | 8600                         | 0,381                                        | 98                                             | 29,909                                                 |
| Platin                    | 21400                        | 0,133                                        | 70,4                                           | 24,735                                                 |
| Silber                    | 10500                        | 0,234                                        | 418                                            | 170,13                                                 |
| Zinn                      | 7280                         | 0,227                                        | 63                                             | 38,123                                                 |
| Kalkstein                 | 2650                         | 0,840                                        | 2,2                                            | 0,98832                                                |
| Sandstein                 | 2225                         | 0,710                                        | 1,87                                           | 1,1837                                                 |
| Porzellan                 | 2290                         | 0,800                                        | 1,17                                           | 0,63865                                                |
| Schamottestein            | 1850                         | 0,840                                        | 0,71                                           | 0,45688                                                |
| Verputz                   | 1690                         | 0,840                                        | 0,79                                           | 0,55649                                                |
| Leichtbausteine           | 600                          |                                              | 0,407                                          |                                                        |
| Ziegelstein               | 1700                         | 0,840                                        | 0,45                                           | 0,31513                                                |
| Beton                     | 2100                         | 0,880                                        | 1,1                                            | 0,59524                                                |
| Fensterglas               | 2400                         | 0,816                                        | 1,16                                           | 0,59232                                                |
| Fliesen/Kacheln           | 2000                         | 1,05                                         | 1,51                                           | 0,71905                                                |
| Holz                      |                              |                                              | 0,14                                           |                                                        |
| Dachpappe                 |                              |                                              | 0,25                                           |                                                        |
| Dampfsperrfolie           |                              |                                              | 0,2                                            |                                                        |
| Styropor                  | 22                           | 1,38                                         | 0,038                                          | 1,2516                                                 |
| Steinwolle                | 200                          | 0,84                                         | 0,041                                          | 0,24405                                                |
| Glaswolle                 | 50                           | 0,660                                        | 0,037                                          | 1,1212                                                 |
| Mineralwolle              |                              |                                              | 0,04                                           |                                                        |
| Asphalt                   | 2120                         | 0,920                                        | 0,7                                            | 0,35890                                                |
| Kesselstein,<br>gipsreich | 2350                         |                                              | 1,51                                           |                                                        |
| kalkreich                 | 1750                         |                                              | 0,65                                           |                                                        |
| siliziumreich             | 750                          |                                              | 0,15                                           |                                                        |
| Kieselgurstein            | 300                          | 0,7                                          | 0,08                                           | 0,38095                                                |
| Gips                      | 800                          | 1,09                                         | 0,31                                           | 0,35551                                                |
| Schlacke                  | 725                          | 0,84                                         | 0,33                                           | 0,54187                                                |
| Quarzglas                 | 2210                         | 0,730                                        | 1,36                                           | 0,84299                                                |
| Hartgummi                 | 1200                         | 1,420                                        | 0,157                                          | 0,092136                                               |
| Kork                      | 275                          | 2,030                                        | 0,051                                          | 0,091357                                               |
| Leder                     | 1000                         | 1,500                                        | 0,16                                           | 0,10667                                                |
| Papier                    | 700                          | 1,200                                        | 0,14                                           | 0,16667                                                |
| menschliche Haut          | 1030                         | 2,5                                          | 0,37                                           | 0,14369                                                |
| Eis bei 0°C               | 917                          | 2,09                                         | 2,21                                           | 1,1531                                                 |

**Tab. 12 Gesamtemissionsverhältnisse  $\varepsilon$  ausgewählter Stoffe (Mittelwerte)**

| Stoff bzw. Oberfläche               | $\varepsilon$ |
|-------------------------------------|---------------|
| Kupfer, poliert                     | 0,030         |
| Kupfer, poliert , leicht angelaufen | 0,037         |
| Kupfer, geschabt                    | 0,070         |
| Kupfer, schwarz oxidiert            | 0,78          |
| Kupfer, oxidiert                    | 0,76          |
| Aluminium, walzblank                | 0,039         |
| Aluminiumbronzeanstrich             | 0,3           |
| Nickel, blank matt                  | 0,041         |
| Nickel, poliert                     | 0,045         |
| Chrom, poliert                      | 0,058         |
| Eisen, blank geätzt                 | 0,128         |
| Eisen, blank abgeschmiegelt         | 0,24          |
| Gußeisen                            | 0,80          |
| Stahl und Eisen mit Walzhaut        | 0,77          |
| Stahl und Eisen verrostet           | 0,70          |
| Stahl und Eisen stark verrostet     | 0,85          |
| Stahl und Eisen verzinkt            | 0,23          |
| Zink                                | 0,23          |
| Zink, grau oxidiert                 | 0,25          |
| Blei, grau oxidiert                 | 0,28          |
| Messing, blankpoliert               | 0,205         |
| Zinn                                | 0,15          |
| Platin, poliert                     | 0,081         |
| Gold, poliert                       | 0,025         |
| Silber, poliert                     | 0,026         |
| Korund - Schmirgel, rau             | 0,855         |
| Heizkörperlack                      | 0,925         |
| Mennigeanstrich                     | 0,93          |
| Emaile                              | 0,92          |
| Ziegelsteine                        | 0,93          |
| Mörtel, Verputz                     | 0,93          |
| Beton, rau                          | 0,94          |
| Kacheln                             | 0,74          |
| Marmor, hellgrau, poliert           | 0,72          |
| Glas                                | 0,954         |
| Glas, blank versilbert              | 0,015         |
| Holz                                | 0,936         |
| Dachpappe                           | 0,93          |
| Ton, gebrannt                       | 0,91          |
| Gips                                | 0,92          |
| Porzellan                           | 0,94          |
| Papier                              | 0,94          |
| Schnee                              | 0,82          |
| Eis, glatt                          | 0,986         |
| Eis, rauher Reifbelag               | 0,928         |
| Wasser                              | 0,94          |

**Tab. 13 Heizwerte und Brennwerte (Mittelwerte)**bezogen auf den Standard-Zustand  $\vartheta_{\text{sd}} = 25\text{ °C}$ ,  $T_{\text{sd}} = 298,15\text{ K}$ ,  $p_{\text{sd}} = p_n = 0,101325\text{ MPa}$ 

|                                                                                                                              | <b>Heizwert</b><br>$\Delta_H h (H_U)$ |                      | <b>Brennwert</b><br>$\Delta_B h (H_O)$ |                      |
|------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|----------------------|----------------------------------------|----------------------|
| <b>Feste Brennstoffe</b>                                                                                                     | $\text{kJ kg}^{-1}$                   |                      | $\text{kJ kg}^{-1}$                    |                      |
| Torf, 55% Wassergehalt                                                                                                       | 7800                                  |                      | 10400                                  |                      |
| Rohbraunkohle, Rheinland                                                                                                     | 9500                                  |                      | 12000                                  |                      |
| Rohbraunkohle, Mitteldeutschland                                                                                             | 10000                                 |                      | 12560                                  |                      |
| Rohbraunkohle, Lausitz                                                                                                       | 8500                                  |                      | 11000                                  |                      |
| Braunkohlenbriketts                                                                                                          | 18500                                 |                      | -                                      |                      |
| Braunkohlenkoks                                                                                                              | 29300                                 |                      | -                                      |                      |
| Steinkohle, Ruhrgebiet                                                                                                       | 27500                                 |                      | 29000                                  |                      |
| Steinkohle, Australien                                                                                                       | 29000                                 |                      | 30350                                  |                      |
| Steinkohle, Südafrika                                                                                                        | 25500                                 |                      | 26740                                  |                      |
| Anthrazit                                                                                                                    | 31000                                 |                      | 31900                                  |                      |
| Bagasse (Zuckerrohr), 49% Wassergehalt                                                                                       | 7650                                  |                      | 10300                                  |                      |
| Stroh / Schilf, 9% Wassergehalt                                                                                              | 15000                                 |                      | 16700                                  |                      |
| Holz, frisch, 37% Wassergehalt                                                                                               | 10500                                 |                      | 12800                                  |                      |
| Holz, trocken, 15% Wassergehalt                                                                                              | 15490                                 |                      | 17400                                  |                      |
| Holzkohle                                                                                                                    | -                                     |                      | 29700                                  |                      |
| Papier, 6% Wassergehalt                                                                                                      | 13500                                 |                      | 13650                                  |                      |
| Hausmüll, 3% Wassergehalt                                                                                                    | 8400                                  |                      | 10080                                  |                      |
| Klärschlamm, 7% Wassergehalt                                                                                                 | 10000                                 |                      | 11600                                  |                      |
| <b>Flüssige Brennstoffe</b>                                                                                                  | $\text{kJ kg}^{-1}$                   |                      | $\text{kJ kg}^{-1}$                    |                      |
| Dieselöl                                                                                                                     | 41650                                 |                      | 44800                                  |                      |
| Benzin                                                                                                                       | 42500                                 |                      | 46700                                  |                      |
| Heizöl EL                                                                                                                    | 42700                                 |                      | 45400                                  |                      |
| Heizöl S                                                                                                                     | 40200                                 |                      | 42300                                  |                      |
| Methanol                                                                                                                     | 19510                                 |                      | 22310                                  |                      |
| <b>Gasförmige Brennstoffe</b>                                                                                                | $\text{kJ kg}^{-1}$                   | $\text{kJ m}_n^{-3}$ | $\text{kJ kg}^{-1}$                    | $\text{kJ m}_n^{-3}$ |
| Stadtgas                                                                                                                     | 23600                                 | 13900                | 26600                                  | 15700                |
| Erdgas L                                                                                                                     | 38610                                 | 31950                | 42480                                  | 35150                |
| Erdgas H                                                                                                                     | 47550                                 | 37500                | 52110                                  | 41100                |
| Methan $\text{CH}_4$                                                                                                         | 50010                                 | 35880                | 55500                                  | 39820                |
| Ethan $\text{C}_2\text{H}_6$                                                                                                 | 47490                                 | 64345                | 51880                                  | 70290                |
| Propan $\text{C}_3\text{H}_8$                                                                                                | 46350                                 | 93210                | 50340                                  | 101240               |
| n-Butan $\text{C}_4\text{H}_{10}$                                                                                            | 45715                                 | 123810               | 49500                                  | 134060               |
| Wasserstoff $\text{H}_2$                                                                                                     | 119970                                | 10780                | 141800                                 | 12745                |
| Generatorgas                                                                                                                 | -                                     | 4900                 | -                                      | -                    |
| Deponiegas                                                                                                                   | -                                     | 19800                | -                                      | -                    |
| Klärgas                                                                                                                      | -                                     | 22000                | -                                      | -                    |
| Biogas                                                                                                                       | -                                     | 23400                | -                                      | -                    |
| $\text{kJ m}_n^{-3}$ - bezogen auf $1\text{ m}^3$ im Normzustand bei $p_n = 0,101325\text{ MPa}$ und $T_n = 273,15\text{ K}$ |                                       |                      |                                        |                      |

**Tab. 14 Diffusionskoeffizienten  $D_{AB}$  von Dampf-Luft-Gemischen  
bei 0,101325 MPa und 25 °C**

| Gemisch A-B                  | $D_{AB}$<br>$10^{-6} \text{ m}^2 \text{ s}^{-1}$ |
|------------------------------|--------------------------------------------------|
| Wasserstoff - Luft           | 67,39                                            |
| Sauerstoff - Luft            | 19,61                                            |
| Wasserdampf - Luft           | 24,19                                            |
| Kohlenstoffdioxid - Luft     | 1,525                                            |
| Ammoniak - Luft              | 18,75                                            |
| Schwefelkohlenstoff - Luft   | 9,78                                             |
| Tetrachlorkohlenstoff - Luft | 8,28                                             |
| Methanol - Luft              | 15,20                                            |
| Trichlorethylen - Luft       | 8,75                                             |
| Essigsäure - Luft            | 12,35                                            |
| Ethanol - Luft               | 11,28                                            |
| Aceton - Luft                | 10,49                                            |
| Propanol - Luft              | 9,93                                             |
| Isopropanol - Luft           | 10,13                                            |
| Butan - Luft                 | 9,64                                             |
| Butanol - Luft               | 8,61                                             |
| Benzen - Luft                | 8,47                                             |
| Anilin - Luft                | 7,35                                             |
| Toluen - Luft                | 8,49                                             |

**Tab. 15 Diffusionskoeffizienten  $D_{AB}$  von Dampf-Dampf-Gemischen  
bei 0,101325 MPa und 25 °C**

| Gemisch A-B                             | $D_{AB}$<br>$10^{-6} \text{ m}^2 \text{ s}^{-1}$ |
|-----------------------------------------|--------------------------------------------------|
| Stickstoff - Wasserdampf                | 24,0                                             |
| Stickstoff - Ethen                      | 16,0                                             |
| Stickstoff - Ethan                      | 14,97                                            |
| Sauerstoff - Methan                     | 23,0                                             |
| Sauerstoff - Wasserdampf                | 28,97                                            |
| Wasserdampf - Methan                    | 28,0                                             |
| Wasserdampf - Ethen                     | 19,97                                            |
| Kohlenstoffdioxid - Ethen               | 14,97                                            |
| Kohlenstoffdioxid - Methan              | 17,97                                            |
| Kohlenstoffdioxid - Wasserdampf         | 19,0                                             |
| Kohlenstoffdioxid - Schwefelkohlenstoff | 7,39                                             |
| Kohlenstoffmonoxid - Ethen              | 12,97                                            |
| Schwefeldioxid - Rauchgas (bei 60 °C)   | 15,4                                             |

**Tab. 16 Diffusionskoeffizienten  $D_{AB}$  von binären Flüssigkeitsgemischen bei 0,101325 MPa und 25 °C**

| Gemisch A-B                         | $D_{AB}$<br>$10^{-9} \text{ m}^2 \text{ s}^{-1}$ |
|-------------------------------------|--------------------------------------------------|
| Ammoniak - Wasser                   | 2,0                                              |
| Essigsäure - Wasser                 | 1,27                                             |
| Kohlenstoffdioxid - Wasser          | 1,95                                             |
| Methanol - Wasser                   | 1,6                                              |
| Sauerstoff - Wasser                 | 2,51                                             |
| Stickstoff - Wasser                 | 2,34                                             |
| Ethanol - Wasser                    | 1,24                                             |
| Chloroform - Tetrachlorkohlenstoff  | 1,66                                             |
| Tetrachlorkohlenstoff - Methanol    | 2,55                                             |
| Schwefeldioxid - Wasser (bei 60 °C) | 0,23                                             |

**Tab. 17 Faktoren für Äquivalente Luftschichtdicken  $\mu$  (Mittelwerte)  
zur Berechnung der Wasserdampfdiffusion (DIN 4108)**

| Stoff             | $\mu$   |
|-------------------|---------|
| Verputz           | 25      |
| Beton             | 110     |
| Ziegelstein       | 7       |
| Leichtbaustein    | 8       |
| Kalkstein         | 15      |
| Glaswolle         | 1       |
| Steinwolle        | 1       |
| Mineralwolle      | 1       |
| Styropor          | 40      |
| Polystyrol        | 35      |
| PUR-Schaum        | 65      |
| Kork              | 8       |
| Gips              | 7       |
| Holzschalung      | 40      |
| PVC-Folie         | 35 000  |
| Polyethylen-Folie | 100 000 |
| Bitumenpappe      | 45 000  |
| Dachpappe         | 40 000  |
| Bitumenanstrich   | 740     |
| Dampfsperrfolie   | 100 000 |

**Tab. 18 Sättigungsdruck von Wasser**

| Dampfdruck            |              | Sublimationsdruck     |                  |
|-----------------------|--------------|-----------------------|------------------|
| $\vartheta$<br>°C     | $p_s$<br>kPa | $\vartheta$<br>°C     | $p_{sub}$<br>kPa |
| 0                     | 0,611213     | −1                    | 0,56266          |
| 0,01                  | 0,611657     | −2                    | 0,51770          |
| 1                     | 0,657088     | −3                    | 0,47604          |
| 2                     | 0,705988     | −4                    | 0,43745          |
| 3                     | 0,758082     | −5                    | 0,40174          |
| 4                     | 0,813549     | −6                    | 0,36871          |
| 5                     | 0,872575     | −7                    | 0,33817          |
| 6                     | 0,935353     | −8                    | 0,30995          |
| 7                     | 1,00209      | −9                    | 0,28391          |
| 8                     | 1,07299      | −10                   | 0,25987          |
| 9                     | 1,14828      | −11                   | 0,23771          |
| 10                    | 1,22818      | −12                   | 0,21729          |
| 11                    | 1,31295      | −13                   | 0,19849          |
| 12                    | 1,40282      | −14                   | 0,18119          |
| 13                    | 1,49806      | −15                   | 0,16527          |
| 14                    | 1,59894      | −16                   | 0,15065          |
| 15                    | 1,70574      | −17                   | 0,13722          |
| 16                    | 1,81876      | −18                   | 0,12490          |
| 17                    | 1,93829      | −19                   | 0,11361          |
| 18                    | 2,06466      | −20                   | 0,10324          |
| 19                    | 2,19818      | −21                   | 0,093755         |
| 20                    | 2,33921      | −22                   | 0,085077         |
| 21                    | 2,48810      | −23                   | 0,077142         |
| 22                    | 2,64521      | −24                   | 0,069893         |
| 23                    | 2,81092      | −25                   | 0,063274         |
| 24                    | 2,98563      | −26                   | 0,057235         |
| 25                    | 3,16975      | −27                   | 0,051731         |
| 26                    | 3,36369      | −28                   | 0,046717         |
| 27                    | 3,56789      | −29                   | 0,042155         |
| 28                    | 3,78281      | −30                   | 0,038005         |
| 29                    | 4,00892      | −31                   | 0,034235         |
| 30                    | 4,24669      | −32                   | 0,030812         |
| 35                    | 5,62862      | −33                   | 0,027707         |
| 40                    | 7,38443      | −34                   | 0,024893         |
| Werte nach IAPWS-IF97 |              | Werte nach IAPWS 2008 |                  |