2.2.3.2 Supplementary Equation for the Metastable-Vapour Region

Such as the basic equation $g_2(p,T)$, Eq. (2.6), the supplementary equation for a part of the metastable-vapour region is given in the dimensionless form of the specific Gibbs free energy, $\gamma = g/(RT)$, consisting of an ideal-gas part γ^{o} and a residual part γ^{r}, so that

$$\frac{g_{2,\mathrm{meta}}(p,T)}{RT} = \gamma(\pi,\tau) = \gamma^{\mathrm{o}}(\pi,\tau) + \gamma^{\mathrm{r}}(\pi,\tau) \;, \tag{2.9}$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $R = 0.461\,526\ \mathrm{kJ\ kg^{-1}\ K^{-1}}$ given by Eq. (1.1), and γ^{o} and γ^{r} according to Eqs. (2.7) and (2.10).

The equation for the ideal-gas part γ^{o} is identical with Eq. (2.7) except for the values of the two coefficients n_1^{o} and n_2^{o}, see Table 2.6. To use Eq. (2.7) as a part of Eq. (2.9), the coefficients n_1^{o} and n_2^{o} were slightly readjusted to meet the high consistency requirement between Eqs. (2.9) and (2.6) for the properties h and s along the saturated-vapour line, see below.

The equation for the residual part γ^{r} of Eq. (2.9) reads

$$\gamma^{\mathrm{r}}(\pi,\tau) = \sum_{i=1}^{13} n_i\, \pi^{I_i} (\tau - 0.5)^{J_i} \;, \tag{2.10}$$

where $\pi = p/p^*$ and $\tau = T^*/T$ with $p^* = 1$ MPa and $T^* = 540$ K. The coefficients n_i and exponents I_i and J_i of Eq. (2.10) are listed in Table 2.12. There are not any experimental data to which an equation can be fitted in the metastable-vapour region. Thus, Eq. (2.9) is only based on input values extrapolated from the stable single-phase region 2. These extrapolations were not performed with IAPWS-95 but with a special low-density gas equation [9].

Table 2.12 Coefficients and exponents of the residual part γ^{r}, Eq. (2.10)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	1	0	$-0.733\,622\,601\,865\,06 \times 10^{-2}$	8	3	4	$-0.634\,980\,376\,573\,13 \times 10^{-2}$
2	1	2	$-0.882\,238\,319\,431\,46 \times 10^{-1}$	9	3	16	$-0.860\,430\,930\,285\,88 \times 10^{-1}$
3	1	5	$-0.723\,345\,552\,132\,45 \times 10^{-1}$	10	4	7	$0.753\,215\,815\,227\,70 \times 10^{-2}$
4	1	11	$-0.408\,131\,785\,344\,55 \times 10^{-2}$	11	4	10	$-0.792\,383\,754\,461\,39 \times 10^{-2}$
5	2	1	$0.200\,978\,033\,802\,07 \times 10^{-2}$	12	5	9	$-0.228\,881\,607\,784\,47 \times 10^{-3}$
6	2	7	$-0.530\,459\,218\,986\,42 \times 10^{-1}$	13	5	10	$-0.264\,565\,014\,828\,10 \times 10^{-2}$
7	2	16	$-0.761\,904\,090\,869\,70 \times 10^{-2}$				

All thermodynamic properties can be derived from Eq. (2.9) by using the appropriate combinations of the ideal-gas part γ^{o}, Eq. (2.7), and the residual part γ^{r}, Eq. (2.10), of the dimensionless Gibbs free energy and their derivatives. The relations of the relevant thermodynamic properties to γ^{o} and γ^{r} and their derivatives are summarized in Table 2.8. Moreover, with the information given in Sec. 2.4, particularly with the formulas given in Sec. 2.4.1, all of the partial derivatives of the properties p, T, v, u, h, s, g, and f can be calculated easily. All of the required derivatives for the equations for γ^{o} and γ^{r} are explicitly given in Table 2.9 and Table 2.13, respectively.

Range of Validity. Equation (2.9) is valid in the metastable-vapour region from the saturated-vapour line to the 5% equilibrium moisture line (corresponding to the vapour fraction $x = 0.95$,