Revision of the "Revised Advisory Note No. 3: Thermodynamic Derivatives from IAPWS Formulations"

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Motivation and Aim of the Advisory Note No. 3

- Thermodynamic Derivatives as

$$\left(\frac{\partial h}{\partial p}\right)_v, \left(\frac{\partial u}{\partial p}\right)_v, \left(\frac{\partial s}{\partial p}\right)_v, \left(\frac{\partial T}{\partial p}\right)_h, \left(\frac{\partial T}{\partial p}\right)_s, \left(\frac{\partial v}{\partial h}\right)_p, \left(\frac{\partial v}{\partial s}\right)_p \ldots$$

  are used in:
  - Simulations of non-stationary processes;
  - Solving equation systems in comprehensive simulations of stationary heat cycles.

- All thermodynamic properties and derivatives can be calculated from precise fundamental equations.

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The aim of the IAPWS Advisory Note No. 3 is to describe how to form and calculate any thermodynamic derivative from IAPWS formulations.

History of the Advisory Note No. 3

- Adoption of the first version in 2007
- Issue of a revision in 2008

Contents of the Advisory Note No. 3

- Description of a formal method for determining any thermodynamic derivative from the formulations:
  - IAPWS-95
  - IAPWS-IF97
  - IAPWS-84 for heavy water
  - IAPWS-06 for ice
  - IAPWS-08 for seawater.

Reason for Revision in 2014

Elimination of a mistake

4.3 Determination of Partial Derivatives for IAPWS-IF97 Regions 2, 2 meta, and 5

The formulae for calculating the properties v, s, c_p, α_v, and κ_T of Table 2 from the dimensionless Gibbs free energy equations $\gamma(\pi,\tau)=\gamma^{\mathrm{o}}(\pi,\tau)+\gamma^{\mathrm{r}}(\pi,\tau)$ and its derivatives of regions 2, 2 meta, and 5 of the "IAPWS Industrial Formulation 1997 for the Thermodynamic Properties of Water and Steam" (IAPWS-IF97, Revision 2007) [3] are

$$v=\frac{RT}{p}\pi\left(\gamma^{\mathrm{o}}_{\pi}+\gamma^{\mathrm{r}}_{\pi}\right), \qquad s=R\left[\tau\left(\gamma^{\mathrm{o}}_{\tau}+\gamma^{\mathrm{r}}_{\tau}\right)-\left(\gamma^{\mathrm{o}}+\gamma^{\mathrm{r}}\right)\right],$$

$$c_p=-R\tau^2\left(\gamma^{\mathrm{o}}_{\tau\tau}+\gamma^{\mathrm{r}}_{\tau\tau}\right), \qquad \alpha_v=\frac{1}{T}\frac{\left(1+\pi\gamma^{\mathrm{r}}_{\pi}-\tau\pi\gamma^{\mathrm{r}}_{\pi\tau}\right)}{\left(1+\pi\gamma^{\mathrm{r}}_{\pi}\right)}, \qquad (7)$$

$$\kappa_T=\frac{1}{p}\frac{\left(1-\pi^2\gamma^{\mathrm{r}}_{\pi\pi}\right)}{\left(1+\pi\gamma^{\mathrm{r}}_{\pi}\right)},$$

where $\gamma=g/(RT)$, $\pi=p/p^*$, and $\tau=T^*/T$ with the specific gas constant R and the reducing parameters p^*, T^*. The equations $\gamma^{\mathrm{o}}(\pi,\tau)$, $\gamma^{\mathrm{r}}(\pi,\tau)$ and their derivatives which were abbreviated in Eq. (7) as follows:

$$\gamma^{\mathrm{o}}_{\pi}=\left(\frac{\partial\gamma^{\mathrm{o}}}{\partial\pi}\right)_{\tau}, \quad \gamma^{\mathrm{o}}_{\tau}=\left(\frac{\partial\gamma^{\mathrm{o}}}{\partial\tau}\right)_{\pi}, \quad \gamma^{\mathrm{o}}_{\tau\tau}=\left(\frac{\partial^2\gamma^{\mathrm{o}}}{\partial\tau^2}\right)_{\pi},$$

$$\gamma^{\mathrm{r}}_{\pi}=\left(\frac{\partial\gamma^{\mathrm{r}}}{\partial\pi}\right)_{\tau}, \quad \gamma^{\mathrm{r}}_{\pi\pi}=\left(\frac{\partial^2\gamma^{\mathrm{r}}}{\partial\pi^2}\right)_{\tau}, \quad \gamma^{\mathrm{r}}_{\tau}=\left(\frac{\partial\gamma^{\mathrm{r}}}{\partial\tau}\right)_{\pi}, \quad \gamma^{\mathrm{r}}_{\tau\tau}=\left(\frac{\partial^2\gamma^{\mathrm{r}}}{\partial\tau^2}\right)_{\pi}, \quad \gamma^{\mathrm{r}}_{\pi\tau}=\left(\frac{\partial^2\gamma^{\mathrm{r}}}{\partial\pi\,\partial\tau}\right),$$

where the value for R and the values for p^*, and T^* for each of the regions 2, 2 meta, and 5 are given in [3].

Extension and Revision in 2014

- Description for:
  - IAPWS Supplementary Release on a Formulation for Liquid Water for Oceanographic Use (2009)
  - IAPWS Advisory Note No. 5: Industrial Calculation of the Thermodynamic Properties of Seawater (2013).
- Update of the references