Entropy as a function of mass

The Sackur-Tetrode formula,

$$S(E,V,N) = k_B N \left[\tfrac{3}{2} \ln \left(\frac{4\pi m E V^{2/3}}{3h_0^2 N^{5/3}} \right) + \tfrac{5}{2} \right],$$

predicts that

$$S_{\mathrm{Kr}} - S_{\mathrm{Ar}} = \tfrac{3}{2} k_B N \ln \left(\frac{m_{\mathrm{Kr}}}{m_{\mathrm{Ar}}} \right).$$

Meanwhile, the masses of a mole of Krypton and a mole of Argon are

$$m_{\mathrm{Kr}} N_A = 83.80 \text{ gr} \quad \text{and} \quad m_{\mathrm{Ar}} N_A = 39.948 \text{ gr},$$

where N_A is Avogadro's number. So the prediction is that

$$S_{\mathrm{Kr}} - S_{\mathrm{Ar}} = \tfrac{3}{2} k_B N (0.7409).$$

Or, if $\mathcal{S}$ represents the entropy per mole,

$$\mathcal{S}_{\mathrm{Kr}} - \mathcal{S}_{\mathrm{Ar}} = \tfrac{3}{2} k_B N_A (0.7409) = 9.239 \text{ J/K}.$$

The data in Ihsan Barin, *Thermochemical Data of Pure Substances*, third edition (VCH Publishers, New York, 1995), pages 76 and 924, are

temperature	$\mathcal{S}_{\mathrm{Kr}}$	$\mathcal{S}_{\mathrm{Ar}}$	$\mathcal{S}_{\mathrm{Kr}} - \mathcal{S}_{\mathrm{Ar}}$
300 K	164.213 J/K	154.974 J/K	9.239 J/K
2000 K	203.647 J/K	194.407 J/K	9.240 J/K