Chemistry 230 -- Quiz 3

September 19, 2001 — Tellinghuisen

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Note: If you want your paper returned folded (*i.e.*, score concealed), please print your name on the back.

1. (5) A mole of He gas initially at 155°C and 1.11 atm undergoes a cyclic process for which q = 129 J. Determine as many of the following as possible: ΔU, ΔH, ΔP, ΔT, w.

$$\Delta U = \Delta H = \Delta P = \Delta T = 0 \; ; \quad w = -q = -129\ \text{J}$$

2. (5) Briefly describe a possible process for taking liquid water from 25°C and 1.0 atm to 30°C and 1.0 atm, with $q < 0$.

First cool the water a bit ($q<0$). Then do stirring work to bring to 30°C ($q=0$, $w>0$).

3. (7) A hypothetical substance obeys the equation of state $PV_m = BT$, where B is a constant. The substance undergoes a change of state from (T_1, V_1) to (T_2, V_2), along a path where T varies quadratically with V, in accord with $T = c_1V^2 + c_2$ (where c_1 and c_2 are constants). Calculate the work w in terms of B, c_1, c_2, V_1, V_2, and the number of moles n.

$$w = -\int_{V_1}^{V_2} P\,dV \; ; \quad P = \frac{BT}{V_m} = \frac{nBT}{V} = \frac{nB}{V}\left[c_1V^2 + c_2\right]$$

$$w = -nB\left[c_1\int_{V_1}^{V_2} V\,dV + c_2\int_{V_1}^{V_2}\frac{dV}{V}\right]$$

$$= -nB\left[c_1\frac{V^2}{2} + c_2 \ln V\Big|_{V_1}^{V_2}\right] = nB\left[\frac{c_1}{2}\left(V_1^2 - V_2^2\right) + c_2\ln\frac{V_1}{V_2}\right]$$

4. (10) Suppose that the thermal expansivity of ethanol can be expressed as $\alpha = a + b\theta$ over the Celsius temperature range $0 \le \theta \le 40.0$°C, where a and b are constants. Further suppose that an ethanol thermometer has been calibrated to be correct at 0.0°C and at 40.0°C. Obtain an expression (in terms of the constants a and b) for the apparent temperature on this thermometer when the true temperature is θ = 25.0°C.

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p = a + b\theta \; ; \quad \theta = T - 273.15 \Rightarrow d\theta = dT$$

$$\Rightarrow \int_{V_0}^{V}\frac{dV'}{V'} = \int_0^{\theta}(a + b\theta')\,d\theta' \Rightarrow \ln\left(\frac{V}{V_0}\right) = a\theta + \frac{b}{2}\theta^2$$

$$\Rightarrow \boxed{V/V_0 = \exp\left[a\theta + \frac{b}{2}\theta^2\right]}$$

$$\text{apparent } T = \left(\frac{V_{25} - V_0}{V_{40} - V_0}\right) \times 40^\circ\text{C} = 40^\circ\text{C} \times \left(\frac{V_{25}/V_0 - 1}{V_{40}/V_0 - 1}\right)$$

Enter $\theta = 25^\circ$C & $\theta = 40^\circ$C to calculate the two ratios.