Chemistry 236
Thermal Expansivity Lab Study Problems -- Answers

1. $\ell = \ell_r \exp[\alpha_\ell(T\text{-}T_r)] \approx \ell_r (1 + \alpha_\ell \Delta T)$ (for small ΔT).

   $V = \ell^3 = \ell_r^{\,3} \exp[3\alpha_\ell(T\text{-}T_r)] \approx \ell_r^{\,3}(1 + 3\alpha_\ell \Delta T)$.

   $(1 + \alpha_\ell \Delta T)^3 = 1 + 3\alpha_\ell \Delta T + 3\alpha_\ell^2 \Delta T^2 + \alpha_\ell^3 \Delta T^3 \approx 1 + 3\alpha_\ell \Delta T$.

2. V of the water = 50.000 mL @ 20.0˚C = 49.9103$_5$ g → 50.3016$_5$ mL @ 40.0˚C.

   (a) V_{cap} = 0.3016$_5$ mL @ 40.0˚C neglecting bulb expansion.

   (b) V_{bulb} = 50.00975 mL @ 40.0˚C → V_{cap} = 0.2919 mL.

   Answer (a) is higher by 0.00975 mL, or 3.3$_4$%; the capillary length for 0.00975 mL is 15.3 mm, which is easily measured. Hence this error is significant.

3. The relative change is $V_{25}/V_{40} = \rho_{40}/\rho_{25}$ = 0.99510. The error is thus -0.49%. Since the assumption that the whole capillary is at 25˚C is an extreme one, this problem may not be significant in typical situations. Still, the maximum error would be a measurable 0.7 mm on the capillary.

4. Since $T = t + 273.15$, $dV/dT = dV/dt$. Thus $\alpha = (a_1 + 2a_2t + 3a_3t^2 + 4a_4t^3 + 5a_5t^4)/\mathrm{V}(t)$. At 32.5°C V = 1.00516 g/mL and $\alpha = 3.248\times10^{-4}\ \mathrm{K}^{-1}$.

5. (a) 50.127 g H_2O (b) V = 50.217$_1$ mL

   (c) 37.788 g alcohol (d) ρ_{alc} = 0.75249 g/mL.

   air buoyancy = 0.062 g

   (a') 50.065 g (b') 50.1550 mL

   (c') 37.726 g alc. (d') ρ_{alc} = 0.75219 g/mL (0.040% error)

   The error vanishes if the density of the unknown is the same as that of water.

6. For an ideal gas, $PV = nRT$, and $\alpha = 1/T$.

7. (a) $x = t - 50°\mathrm{C} = T - 323.15\ \mathrm{K}$, so $d\rho/dT = d\rho/dx$, so $\alpha = -(b + 2cx + 3dx^2)$.
   (b) $\rho(30°\mathrm{C}) = 0.78062\ \mathrm{g/cm^3}$; $\alpha(30°\mathrm{C}) = 0.001106\ \mathrm{K}^{-1}$.
   (c) No.

8. All but mass.