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1.1 (a) Thermostatic bath imposes its temperature T on the system.

(b) Container imposes constraint of constant volume. Thermal isolation implies that heat flow must be zero, while mechanical isolation (and constant volume) implies there is no work flow. Consequently there is no mechanism for adding or removing energy from the system. Thus, system volume and energy are constant.

(c) Thermally isolated $\Rightarrow$ adiabatic

Frictionless piston $\Rightarrow$ pressure of system equals ambient pressure (or ambient pressure + wg/A if piston-cylinder in vertical position. Here w = weight of piston, A = its area and g is the force of gravity.)

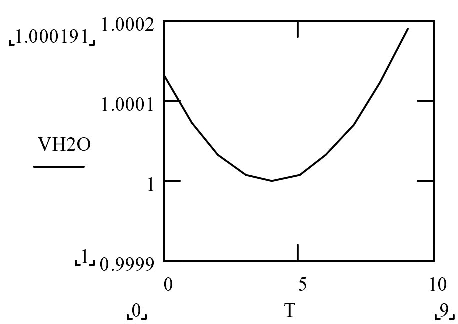
(d) Thermostatic bath $\Rightarrow$ constant temperature T.

Frictionless piston $\Rightarrow$ constant pressure (see part c above).

(e) Since pressure difference induces a mass flow, pressure equilibrates rapidly. Temperature equilibration, which is a result of heat conduction, occurs much more slowly. Therefore, if valve between tanks is opened for only a short time and then shut, the pressure in the two tanks will be the same, but *not* the temperatures.

1.2 (a) Water is inappropriate as a thermometric fluid between 0°C and 10°C, since the volume is not a unique function of temperature in this range, i.e., two temperatures will correspond to the same specific volume,

$\hat{V}(T = 1°\text{C}) \sim V(T = 7°\text{C})$; $\hat{V}(T = 2°\text{C}) \sim V(T = 6°\text{C})$; etc.



$[T \text{ in } ^{\circ}\text{C and } \hat{V} \text{ in cc/g}]$

Consequently, while T uniquely determines, $\hat{V}$, $\hat{V}$ does not uniquely determine T.

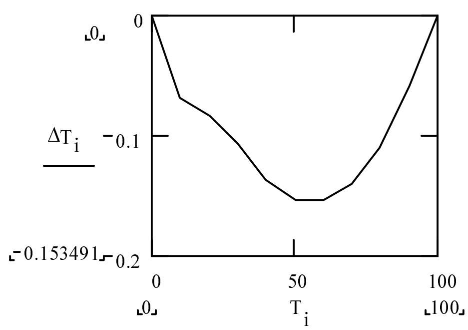
(b) Assuming that a mercury thermometer is calibrated at 0°C and 100°C, and that the specific volume of mercury varies linearly between these two temperatures yields

$$\hat{V}(T) = \hat{V}\left(0^\circ\mathrm{C}\right) + \frac{\hat{V}\left(T = 100^\circ\mathrm{C}\right) - \hat{V}\left(T = 0^\circ\mathrm{C}\right)}{100^\circ\mathrm{C} - 0^\circ\mathrm{C}}\left(T_\mathrm{s} - 0^\circ\mathrm{C}\right)$$
$$= 0.0735560 + 0.000013421\ T_\mathrm{s} \qquad (*)$$

where T is the actual temperature, and T_s is the temperature read on the thermometer scale. At 10°C, $\hat{V}_{\mathrm{exp}}(T = 10^\circ\mathrm{C}) = 0.0736893\ \mathrm{cc/g}$. However, the scale temperature for this specific volume is, from eqn. (*) above

$$T_\mathrm{s} = \frac{\hat{V}_{\mathrm{exp}}(T) - 0.0735560}{1.3421 \times 10^{-5}} = \frac{0.0736893 - 0.0735560}{1.3421 \times 10^{-5}} = 9.932^\circ\mathrm{C}$$

Thus, $T - T_\mathrm{s}$ at 10°C $= -0.068^\circ\mathrm{C}$. Repeating calculation at other temperatures yields figure below.



The temperature error plotted here results from the nonlinear dependence of the volume of mercury on temperature. In a real thermometer there will also be an error associated with the imperfect bore of the capillary tube.

(c) When we use a fluid-filled thermometer to measure ΔT we really measure ΔL, where

$$\Delta L = \frac{\Delta V}{A} = \frac{M\left(\partial\hat{V}/\partial T\right)\Delta T}{A}$$

A small area A and a large mass of fluid M magnifies ΔL obtained for a given ΔT. Thus, we use a capillary tube (small A) and bulb (large M) to get an accurate thermometer, since $\left(\partial\hat{V}/\partial T\right)$ is so small.