**ISOTHERMAL VERSUS ADIABATIC EXPANSION OF AN IDEAL GAS BUBBLE**

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As a simple example of isothermal versus adiabatic expansion of an ideal gas, suppose that two identical bubbles form at the bottom of a lake. Bubble A rises quickly so that no heat is exchanged with the surrounding water, while bubble B rises slowly (bumping off the leaves of some lakeweed, for example) so that its temperature remains constant (assuming that the lake’s water temperature is the same everywhere).

Bubble A experiences adiabatic expansion, so it obeys the relation

\[ PV^\gamma = A \]  

for some constant \( A \). Bubble B expands isothermally, so

\[ PV = NkT = \text{constant} \]  

The initial volumes \( V_0 \) and pressures \( P_0 \) of the two bubbles are the same so

\[ A = P_0 V_0^\gamma \]  

\[ NkT = P_0 V_0 \]  

When the bubbles reach the surface of the lake, the pressure has reduced to \( P_1 \) so the volumes of the bubbles are

\[ V_A = \left( \frac{P_0}{P_1} \right)^{1/\gamma} V_0 \]  

\[ V_B = \frac{P_0}{P_1} V_0 \]  

Since \( \gamma = (f+2)/f > 1 \) where \( f \) is the number of degrees of freedom and \( P_0 > P_1 \)

\[ \left( \frac{P_0}{P_1} \right)^{1/\gamma} < \frac{P_0}{P_1} \]
so $V_B > V_A$. That is, the bubble that rises slowly will be larger than the bubble that rises quickly when they reach the surface.