Question 1: Version J

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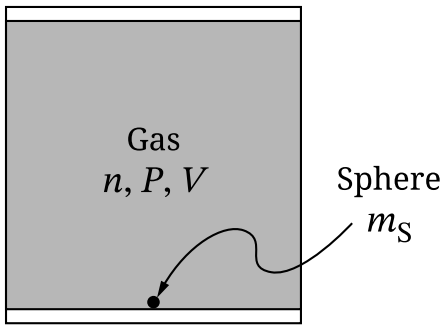
1. Part A

A sample of n moles of a monatomic, ideal gas is in a large, sealed, thermally conducting container with fixed volume. A small sphere of mass m_S is in the container. The volume of the sphere is much less than the volume of the container.

The gas is initially in State X with pressure P and volume V, as shown in Figure 1.

Figure 1



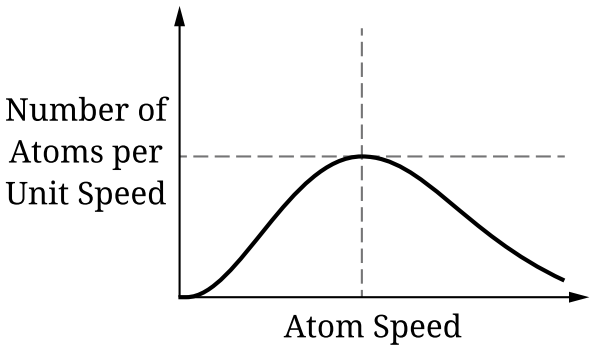
State X

Note: Figure not drawn to scale.

The sphere is initially in thermal equilibrium with the gas. The gas undergoes a heating process until the gas is in State Y with pressure $3P$ and the sphere is again in thermal equilibrium with the gas. The total energy transferred to the sphere during the heating process is Q_S.

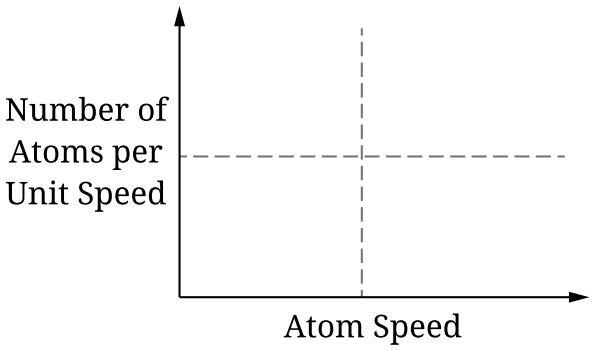
i. The graph in Figure 2 represents the number of atoms per unit speed as a function of atom speed for the gas when the gas is in State X. On Figure 3, **sketch** a curve that could represent the number of atoms per unit speed as a function of atom speed for the gas when the gas is in State Y.

Figure 2



State X

Figure 3



State Y

ii. **Derive** an expression for the change ΔT in temperature of the gas for the heating process that the gas undergoes as the gas changes from State X to State Y. Express your answer in terms of n, P, V, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

iii. **Derive** an expression for the specific heat c_S of the sphere. Express your answer in terms of n, m_S, P, V, Q_S, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

Part B

An insulated container is filled with a liquid of mass m_L and specific heat c_L. The original sphere is submerged in the liquid. The sphere has mass m_S, where $m_S < m_L$, and specific heat c_S, where $c_S < c_L$. The initial temperature of the sphere is greater than the initial temperature of the liquid. Later, the liquid and the sphere reach thermal equilibrium. The absolute values of the changes in the temperatures of the liquid and the sphere are $|\Delta T_L|$ and $|\Delta T_S|$, respectively.

Indicate whether $|\Delta T_S|$ is greater than, less than, or equal to $|\Delta T_L|$. Include one of the following relationships in your response.

- $|\Delta T_S| > |\Delta T_L|$
- $|\Delta T_S| < |\Delta T_L|$
- $|\Delta T_S| = |\Delta T_L|$

Justify your answer. Your justification may include expressions/equations but must include conceptual reasoning beyond algebraic solutions.