2016 SCORING GUIDELINES

Question 1

10 points total **Distribution of points**

(a)

i. 2 points

For showing the calculation of the force on the piston and a correct answer with units — 1 point

$F = PA = \left(1.0 \times 10^5 \text{ Pa}\right)\left(5 \times 10^{-3} \text{ m}^2\right) = 500 \text{ N}$

For explaining the force in terms of gas atom collisions — some change in the atoms' momentum or velocity must be identified to justify a force between atoms and piston — 1 point

Example: The collisions of the gas atoms with the container walls cause a change in the momentum of the gas atoms, which means forces are exerted between the atoms and the piston. Each gas molecule colliding with a wall experiences a force from the wall that changes the molecule's velocity or momentum.

ii. 2 points

For showing the calculation of the temperature and a correct answer with units — 1 point

$PV = nRT$

$T = PV/nR = \left(1.0 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3\right)/(2)(8.31 \text{ J/mol•K}) = 602 \text{ K}$

For indicating that temperature characterizes the average speed or average kinetic energy or RMS velocity of the molecules — 1 point

(b)

i. 2 points

For identifying that the temperature increases due to increasing volume and constant pressure — 1 point

For relating temperature change with internal energy change — 1 point

Example: Because the volume increases at a constant pressure, the temperature goes up because $PV = nRT$. Increasing temperature means increasing average kinetic energy or total internal energy.

ii. 3 points

For calculating the work done in process *ABC* (i.e., the area under the line) — 1 point

$W_{AB} = -\left(1.0 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3 - 0.04 \text{ m}^3\right) = -6000 \text{ J}$ and $W_{BC} = 0$

For calculating T_A and T_C (or ΔT between the states) and using them to determine internal energy change — 1 point

$T_A = P_A V_A / nR = \left(1.0 \times 10^5 \text{ Pa}\right)\left(0.04 \text{ m}^3\right)/(2 \text{ mol})(8.31 \text{ J/mol•K}) = 241 \text{ K}$

$T_C = P_C V_C / nR = \left(0.5 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3\right)/(2 \text{ mol})(8.31 \text{ J/mol•K}) = 301 \text{ K}$

$\Delta U = \Delta K_{\text{per molecule}}\, nN_0 = (3/2) k_B \Delta T n N_0$

$\Delta U = (3/2)\left(1.38 \times 10^{-23} \text{ J/K}\right)(301 \text{ K} - 241 \text{ K})(2 \text{ mol})\left(6.02 \times 10^{23}\right) = 1500 \text{ J}$

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Question 1 (continued)

Distribution of points

(b)

ii. (continued)

Alternately, ΔU can be calculated directly from the given data

$\Delta U = (3/2) nR\Delta T = (3/2)(P_C V_C - P_A V_A)$

$= (3/2)\left(\left(0.5 \times 10^5 \text{ Pa}\right)\left(0.10 \text{ m}^3\right) - \left(1.0 \times 10^5 \text{ Pa}\right)\left(0.04 \text{ m}^3\right)\right) = 1500 \text{ J}$

For substituting ΔU and W (whether correct or incorrect) into some form of the first law of thermodynamics to find Q and for including units in a numerical answer — 1 point

$Q = \Delta U - W = 1500 \text{ J} - (-6000 \text{ J})$

$Q = 7500 \text{ J}$

(c) 1 point

For recognizing that the change in kinetic energy for process *CA* has the same numerical value as ΔU from (b)ii but with the opposite sign OR for calculating ΔK using the correct temperature change or $\Delta K_{\text{total}} = (3/2) nR\,\Delta T$ as shown below — 1 point

$\Delta K_{\text{total}} = (3/2) k_B \Delta T n N_0$ or $\Delta K_{\text{total}} = (3/2) nR\,\Delta T$

$\Delta K_{\text{total}} = (3/2)\left(1.38 \times 10^{-23} \text{ J/K}\right)(241 \text{ K} - 301 \text{ K})(2 \text{ mol})\left(6.02 \times 10^{23} \text{ mol}^{-1}\right)$

$\Delta K_{\text{total}} = -1500 \text{ J}$