ChemE 2200 - Physical Chemistry II for Engineers

Quiz 5 - February 26, 2025

Name:_____*Solution*_____

(A) The gas expands against a constant external pressure of 1.0 atm. Use the equation for work.

$$w_{1\to2} = -P_{ext}\Delta V = -(1.0 \text{ atm})(44.8 \text{ L} - 22.4 \text{ L}) = -22.4 \text{ L}\cdot\text{atm}\frac{0.101 \text{ kJ}}{1 \text{ L}\cdot\text{atm}} = -2.26 \text{ kJ}$$

(B) Because the volume does not change, $w_{2\to3} = 0$.

(C) Because the path is isothermal, $\Delta U_{3\to1} = 0$. Thus $w_{3\to1} = -q_{3\to1}$.

$$q_{3\to1} = -w_{3\to1} = -nRT\ln\frac{V_1}{V_3} = -(1.0 \text{ mol})(8.314 \text{ J}/(\text{K}\cdot\text{mol}))(273 \text{ K})\ln\frac{1 \text{ L}}{0.5 \text{ L}} = -1.57 \text{ kJ}$$

$$w_{3\to1} = +1.57 \text{ kJ}$$

(D) The net work is for the cycle is the sum of the paths.

$$w_{cycle} = w_{1\to2} + w_{2\to3} + w_{3\to1} = -2.27 + 0 + 1.57 = -0.70 \text{ kJ}$$

(E) $\Delta U_{cycle} = 0$ for the cycle because internal energy is a state function. Thus $q_{cycle} = -w_{cycle} = +0.70 \text{ kJ}$.

This reversible cycle converts 0.70 kJ of heat into 0.70 kJ of work.

Grading Rubric:

(A) +1 for correct setup : $w_{1\to2} = -P_{ext}\Delta V$
    +1 for correct answer with units : $-2.26 kJ$ or $-22.4 L\cdot atm$

(B) +1 for identifying an isochoric path ($\Delta V = 0$) has zero work
    +1 for correct answer: $w_{2\to3} = 0$

(C) +1 for correct setup: $\Delta U_{3\to1} = 0 \to q_{3\to1} = -w_{3\to1} = -nRT\ln\left(\frac{V_L}{V_3}\right)$
    +1 for correct answer with units: $w_{3\to1} = +1.57 kJ$ or $+15.5 L\cdot atm$

(D) +1 for correct setup: $w_{cycle} = w_{1\to2} + w_{2\to3} + w_{3\to1}$
    +1 for correct answer with units based on answers given in parts A,B,C (correct answer: $-0.70 kJ$ or $-6.9 L\cdot atm$)

(E) +1 for correct setup: $\Delta U_{cycle} = 0 = q_{cycle} + w_{cycle} \to q_{cycle} = -w_{cycle}$ or $q_{cycle} = q_{1\to2} + q_{2\to3} + q_{3\to1}$
    +1 for correct answer with units based on answers given in previous parts (correct answer: $+0.70 kJ$ or $+6.9 L\cdot atm$)