P-CHEM: A TALE OF TWO APPROACHES

Most P-chem problems have one right answer but multiple ways to reach it. The following has a mathematical approach and a theoretical approach. See which works best for you.

The problem
A piston filled with 0.0400 moles of a perfect gas expands reversibly from 50.0 mL to 375 mL at a constant temperature of 37.0 °C. As it does so, it absorbs 208 J of heat from the surroundings. Calculate $q$, $w$, $\Delta H$, and $\Delta U$ for this process.

Define trigger words and phrases
» Perfect gas: The equation of state is $PV = nRT$.
» Reversibly: Infinitesimally small changes, meaning you may need to use calculus.
» Constant temperature: $\Delta T = 0$, which is important because it relates to the change in internal energy, $\Delta U$.
» Absorbs 208 J of heat: Heat ($q$) for this process is a positive value.

What you know:
» $n = 0.0400$ moles of gas
» $V_i = 50.0$ mL
» $V_f = 375$ mL
» $T = 37.0$ °C = 310 K

What you need to find:
» $q$ (heat)
» $w$ (work)
» $\Delta H$ (change in enthalpy)
» $\Delta U$ (change in internal energy)

Theoretical approach
» You are given the value of $q$ and know that $\Delta T = 0$.
» No change in temperature leads you to determine that $\Delta U = 0$, because for perfect gases, the internal energy $U$ is only concerned with kinetic energy. (If the average kinetic energy of the system—the temperature—remains constant, so will $U$)
» Because $\Delta U = q + w$, and you already know that $\Delta U = 0$, $w$ must be equal to $-q$ (simple algebraic rearrangements are all you need so far). From the problem, $q = +208$ J. Thus, $w = -208$ J.
» Solve for $\Delta H$ using $\Delta H = \Delta U + \Delta(PV)$. You already know that $\Delta U = 0$. The change in $PV$ would be final minus initial. Using the perfect gas law, $PV = nRT$, you realize that because there was no change either in temperature $T$ or in the number of moles $n$, $\Delta(PV) = 0$, and thus $\Delta H = 0$.

Mathematical approach
» The problem gives you the value of heat ($q = +208$ J)
» Derive the equation for work ($w$) for an isothermal reversible expansion of a perfect gas, and calculate $w$.
» Add together the values for $q$ and $w$ to get $\Delta U$.
» For $\Delta H$, you have $\Delta U$ and now need to find $\Delta(PV)$. Use the perfect gas law to find the pressure for the final and initial states in atm.
» Keep as many digits in the calculator as possible when you multiply the pressures and volumes, to ensure that you get the correct value for $\Delta H$ (i.e., zero). Rounding too soon introduces errors that will result in an incorrect answer.

Answers (the same for either approach)
$q = +208$ J  $w = -208$ J  $\Delta H = 0$ J  $\Delta U = 0$ J