Week 5 Quiz

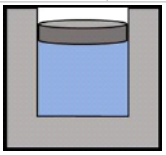
Thursday, February 4, 2021 10:46 AM

While developing a revolutionary prototype hydrogen fuel cell technology, Bernice performs an experiment with liquid water (H_2O). She starts with 3 mol of liquid water at 20 °C in a closed, rigid container with a moveable piston on top (pictured to the right). She adds heat to the H_2O until it is entirely steam at 100 °C. The piston is moved by Bernice to maintain exactly 1.0 atm of pressure.

The properties of water listed to the right might be useful.

(a) How much heat did Bernice add to the H_2O?

C (liquid)	4216 J / kg K
C (gas)	2028 J / kg K
L_V	2.26 x 10^6 J / kg
L_F	3.34 x 10^5 J / kg
mass	18 g / mol



$3\ mol = (3)\,18.3\ g = 54\ g = 0.054\ kg$

$Q = mC\Delta T + mL_v$

$= (0.054)(4216)(80) + (0.054)(2.26 \times 10^6)$

$= 18{,}213\ J + 122{,}040 = \boxed{140{,}000\ J}$

Rubric

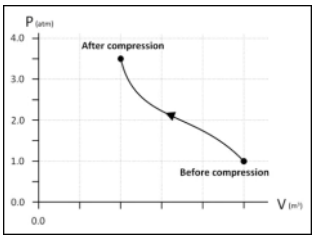
Part (a)

Problem Orientation
1 pt - Q = mCΔT eq.
1 pt - Q = mL_v eq.

Solution Exploration
1 pt - unit conversion

Solution Evaluation
0.5 pt - correct answer and unit

(b) Once the system has stabilized at 100 °C, Bernice compresses the water vapor in the container and obtains the pictured PV graph of the water vapor during the compression. Benny, as a misguided and unfunny prank, has erased some of the horizontal axis labels. If we treat the water vapor as a monatomic ideal gas, by what factor does the RMS average velocity of the water vapor molecules change?



$PV = nRT$

$P_f = 3.5\,P_i$

$V_f = \frac{2}{5}\,V_i$

$PV = nRT$

$P \times 3.5 \quad V \times \frac{2}{5} \quad nRT$ const $\times (3.5)(\frac{2}{5})$

$\Rightarrow$ Temp went up by $\frac{7}{5} \Rightarrow 373K \rightarrow 522\ K$

$\overline{KE} = \frac{3}{2}k_B T$

$\Rightarrow \frac{1}{2}\bar{m}v_{rms}^2 = \frac{3}{2}k_B T$

$v_{rms} = \sqrt{\frac{3k_B T}{\bar{m}}} \Rightarrow v_{rms}$ is proportional to $\sqrt{T}$

$v_{rms,f} = \sqrt{\frac{7}{5}}\,v_{rms,i} \Rightarrow v_{rms}$ increases by a factor of 1.18 (or 18% increase)

Part (b)

Problem Orientation
1 pt - PV=nRT eq.

Solution Exploration
0.5 pt - $P_f = 7/2\ P_i$
1 pt - $V_f = 2/5\ V_i$
1 pt - $1/2mv^2 = 3/2k_bT$ eq.

Solution Execution
1.5 pts - change in temperature
1 pt - finding v_{rms} factor

Solution Evaluation
0.5 pts - correct answer and units