

SPAThermo FRO1

a) $PV = NKT$

$\therefore T = \frac{PV}{NK}$

$$T_a = \frac{(4 \times 10^5)(0.01)}{(6.02 \times 10^{23})(1.38 \times 10^{-23})} = \frac{4 \times 10^3}{8.31} = 481 \text{ K}$$

$$T_b = \frac{(1 \times 10^5)(0.04)}{8.31} = 481 \text{ K}$$

$$T_c = \frac{(1 \times 10^5)(0.01)}{8.31} = 120 \text{ K}$$

b) $E = \frac{3}{2}NKT$ or $E = \frac{3}{2}PV$

$$E_a = \frac{3}{2}(4 \times 10^5)(0.01)$$

$$E_a = 6000 \text{ J}$$

$$E_b = 6000 \text{ J}$$

$$E_c = 1500 \text{ J}$$

c) $\Delta E = 0$ for one complete cycle. The gas ends up in the same state that it started in.

d) $\Delta E = Q - W$ $W_{ab} = 0$

$$\Delta E = E_a - E_c = Q_{ca}$$

$$\Delta E = 6000 \text{ J} - 1500 \text{ J} = 4500 \text{ J}$$

$$\therefore Q_{ca} = 4500 \text{ J}$$

e) $W_{bc} = \text{integral}$

$$= (1 \times 10^5 \text{ Pa})(0.03 \text{ m}^3)$$

= 3000 J. This is work done ON the gas. W is work done BY gas

$\therefore W = -3000 \text{ J}$. (Rather than losing energy by working our gas gains E.)

$$f) W = \int_a^b PdV = \int_a^b \frac{NKT}{V} dV = NKT \ln \frac{V_b}{V_a} = (6.02 \times 10^{23})(1.38 \times 10^{-23})(481 \text{ K}) \ln \left(\frac{0.04}{0.01} \right)$$

$$= 5540 \text{ J} \approx 5500 \text{ J (rounded off)}$$

g) $\Delta E = Q - W = 0$ for entire cycle. $\therefore W = Q$ so $W = 2500 \text{ J}$

h) isothermal $PV = \text{constant}$ throughout process.

i) $\Delta E_{ab} = 0$, therefore $Q_{ab} = W_{ab} = 5500 \text{ J}$

$$e = 1 - \frac{T_c}{T_H} = 1 - \frac{120}{481} = 0.75 = 75\%$$

Ch 15 Bank #8

a) i) $W = \int_V^V P dV = P \Delta V$
 $= (600 \frac{N}{m^2})(9m^3 - 3m^3)$
 $= 3600 J$

ii) $\Delta E = Q - W$, but this is not the easiest calculation. We know W from i), but we don't know Q .

$$E = \frac{3}{2}(NkT) = \frac{3}{2}(PV)$$

$$E_A = \frac{3}{2}(600 \frac{N}{m^2})(3m^3) = 2700 J$$

$$E_B = \frac{3}{2}(600 \frac{N}{m^2})(9m^3) = 8100 J$$

$$\Delta E = 5400 J$$

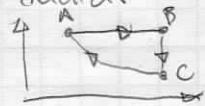
iii) $\Delta E = Q - W$ (First Law of Thermodynamics)

$$5400 J = Q - 3600 J$$

$$Q = 9000 J$$

This is added to the gas. The gas loses 3600 J by working, but it ends up with a net gain of 5400 J. This is due to the 9000 J of heat added.

b) & c) i) Refer to graph on the problem statement sheet.



ii) To figure out if heat is added to or removed from the gas we can ask ourselves, what would happen if ZERO heat was gained or lost during a compression. The answer is that it would become warmer due to the work done ON the gas by whatever is compressing it. But in an isothermal compression, the gas does not warm up. Therefore, we can infer that the gas must lose energy through heating.

Another way to say this is that the energy of a gas does not change in an isothermic process. ($E = \frac{3}{2}NkT$) If work is done on the gas in compression, which is always the case, then it has to lose that energy through heating to remain at the same energy.

Q115. a) $PV = NkT$

③ $T = \frac{PV}{Nk}$ $N = \text{constant}$ $K = \text{Boltzmann's Constant}$

∴ PV will help us rank the temperatures. PV is our surrogate for T.

i) $\left. \begin{array}{l} \text{Point A: } PV = P_0V_0 \\ \text{Point B: } PV = 3P_0V_0 \\ \text{Point C: } PV = 12P_0V_0 \\ \text{Point D: } PV = 4P_0V_0 \end{array} \right\} \text{Ranking from low to high: } A < B < D < C$

ii) $T = \frac{PV}{Nk}$

$T_D = \frac{4P_0V_0}{Nk}$ at point D

b) Process A → B: No work. (Integral $W = \int_{V_A}^{V_B} P dV = 0$)

Process B → C: Gas expands (pushes outward), $W > 0$
Work is done by gas ON surroundings (usually the atmosphere)

Process C → D: No work ($W = \int_{V_C}^{V_D} P dV = 0$)

Process D → A: Gas is compressed; surroundings do work ON gas, therefore, W is negative. The gas gains energy.

Answer: Check only process B → C (i.e. "BC")

c) During process A → B, the temperature of the gas goes from

$T_A = P_0V_0$ to $T_B = 3P_0V_0$ $E_{\text{GAS}} = \frac{3}{2}NkT$

The gas has more energy in state B than in state A. Because no work is done on the gas during process AB, the gain in energy can be attributed only to heating, Q. $\Delta E = Q - W$. ($\Delta E = Q - 0$)

∴ Q is positive.

d) The "area" within ABCD is the work done by the gas during one cycle.

Integral = $3P_0 \cdot (4V_0 - V_0) - P_0(4V_0 - V_0)$

Integral = $6P_0V_0 = W$

Ch 15 Bank #4

4) a) $PV = NkT$

$N = 0.1 \text{ mole} = 0.1 \times 6.02 \times 10^{23} = 6.02 \times 10^{22}$

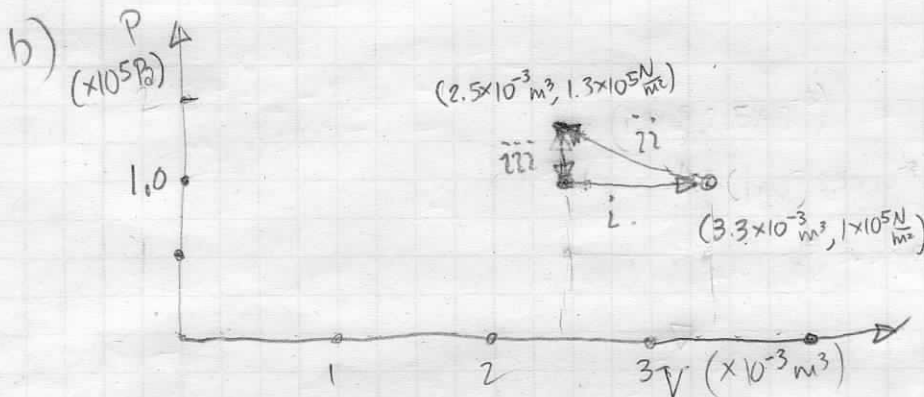
$V = \frac{NkT}{P}$

$V_0 = \frac{(6.02 \times 10^{22})(1.38 \times 10^{-23} \frac{\text{J}}{\text{K}})(300\text{K})}{1 \times 10^5 \frac{\text{N}}{\text{m}^2}}$

$V_0 = 0.00249 \text{ m}^3$

$V_1 = \frac{(6.02 \times 10^{22})(1.38 \times 10^{-23} \frac{\text{J}}{\text{K}})(400\text{K})}{1 \times 10^5}$

$V_1 = 0.00332 \text{ m}^3$



c) $E = \frac{3}{2} NkT = \frac{3}{2} PV$

$E_0 = \frac{3}{2} (6.02 \times 10^{22})(1.38 \times 10^{-23} \frac{\text{J}}{\text{K}})(300\text{K})$

$E_0 = 374 \text{ J}$

$E_1 = \frac{3}{2} PV$

$= \frac{3}{2} (1 \times 10^5 \frac{\text{N}}{\text{m}^2})(3.3 \times 10^{-3} \text{ m}^3)$

$E_1 = 495 \text{ J}$

$\Delta E = E_1 - E_0$

$= 495 \text{ J} - 374 \text{ J}$

$\Delta E = 121 \text{ J}$

d) $\Delta E = Q - W$ $W = \text{integral } P dV = P \Delta V = (1 \times 10^5 \frac{\text{N}}{\text{m}^2})(0.00083 \text{ m}^3) = 83 \text{ J}$

$121 \text{ J} = Q - 83 \text{ J} \Rightarrow Q = 204 \text{ J}$

e) "Area" represents work done on the gas by the surroundings.