

Physics 425, Spring 2009

Quiz 2 – February 5

Name: _____ ID: _____

(books and notes are not allowed)

Planck constant: $h = 6.63 \times 10^{-34}$ J s, Boltzmann constant: $k = 1.38 \times 10^{-23}$ J/K
Avogadro number: $N_a = 6.02 \times 10^{23}$, $1 \text{ eV} = 1.6 \times 10^{-19}$ J, $T \text{ (K)} = T \text{ (}^\circ\text{C)} + 273.16$
 $E = f/2 \text{ kT}$, $\Delta E = Q - W$

Note:

- Not all the above constants and relations are useful.
- Briefly explain how the result is obtained. Generous partial credit will be given to correct steps and explanations even if the final result may be erroneous.

For a particular ideal gas system it has been determined that the internal energy is given by $E = 2.5PV + C$, where P is the pressure, V is the volume, and C is a constant. The system is initially in the state $P = 2 \times 10^5$ Pa, $V = 0.01 \text{ m}^3$, and evolves quasi-statically to a final state of $V = 0.03 \text{ m}^3$ along the path $P = 10^5 + 10^9 (V - 0.02)^2$. (Note: $1 \text{ J} = 1 \text{ Pa} \cdot \text{m}^3$)

- Calculate work W . Is the work done by the system or on the system?
- Calculate heat Q . Does the system absorb or release heat?
- Suppose that the gas has 2×10^{24} degrees of freedom, how much does the gas temperature change?

Key:

$$(a) W = \int_i^f P dV = \int_{V_i=0.01}^{V_f=0.03} [10^5 + 10^9 (V - 0.02)^2] dV = 10^5 (V_f - V_i) + \frac{10^9}{3} [(V_f - 0.02)^3 - (V_i - 0.02)^3] = 2.67 \times 10^3 \text{ J}$$

W is positive, and also the system is expanding, so the work is done by the system.

$$(b) Q = \Delta E + W$$

$$\Delta E = E_f - E_i = 2.5(P_f V_f - P_i V_i)$$

$$\text{As } P_f = 10^5 + 10^9 (V_f - 0.02)^2 = 2.00 \times 10^5 \text{ Pa,}$$

$$\Delta E = 2.5(P_f V_f - P_i V_i) = 1. \times 10^4 \text{ J}$$

$$Q = \Delta E + W = 1.27 \times 10^4 \text{ J}$$

$Q > 0$, the system absorbs heat to do work as well as increase its internal energy.

$$(c) E = \frac{1}{2} f k T, \Delta E = \frac{1}{2} f k \Delta T, \text{ so } \Delta T = \frac{2 \Delta E}{f k} = 725 \text{ K}$$