ECHE 363 – Thermodynamics of Chemical Systems
Quiz 1

Name Solutions

100 points total.

Be sure to show all work to obtain maximum credit. Closed book and no notes.

Equations that may or may not be needed.

First Law for closed systems:

$$dU + dE_k + dE_p = \delta Q + \delta W$$

$$\Delta U + \Delta E_k + \Delta E_p = Q + W$$

PV work:

$$\delta w_m = -P_E dv_m$$

Units and constants:

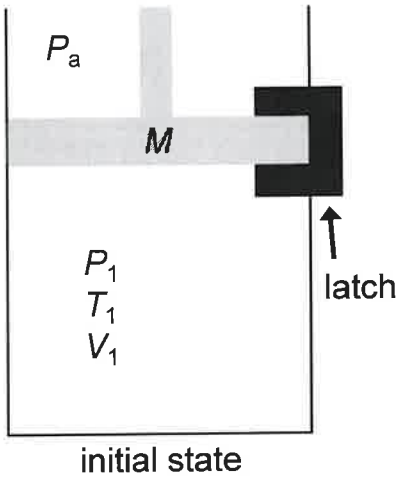
$R = 8.314$ J/(mol K)

$g = 9.8$ m/s^2

1 bar = 10^5 Pa = 10^5 kg/(m s^2)

For each of the following questions, consider the following process involving a piston–cylinder assembly:

The piston–cylinder assembly is well-insulated and initially contains an ideal gas at T_1, P_1, with an initial volume V_1. The piston has a mass M and cross-sectional area A, and is exposed to atmospheric pressure P_a. The piston is initially held in place by a latch that keeps it from moving. The latch is subsequently released, allowing the piston to move.



1. (30 points) Simplify the First Law balance associated with this process, canceling out all terms that you can approximate to be zero. You do not need to perform any calculations, but be clear about any assumptions.

$\Delta U + \Delta E_K + \Delta E_P = Q + W$

$= 0 \quad = 0 \quad = 0$

ignore KE, PE; insulated, adiabatic

$\boxed{\Delta U = W} \Rightarrow \Delta U = -\int_{V_1}^{V_2} P_E \, dV$ (only PV work)

2. (15 Points) In terms of the quantities provided, derive an expression for the external pressure P_E during the process.

$P_E = P_a + \frac{Mg}{A}$ (constant)

F_a ↓ on M; $\downarrow Mg = F_{piston}$

3. (10 Points) Provide an expression for the final pressure P_2 after the process has completed.

$P_2 = P_E = P_a + \frac{Mg}{A}$

(piston stops moving when mechanical equil is reached)

5. (5 points) At the end of the process, the piston will have: (circle one)

moved up

moved down

remained in its initial position

need more information

6. (5 Points) Briefly explain your answer to #5.

Do not know if P_E is $>$, $<$, or $=$ P_1!

7. (10 Points) Assuming that the piston does move during the process, would the expansion/compression be reversible or irreversible? Briefly explain.

Irreversible: $P_E \neq P$

8. (25 Points) Derive an expression for the work done during the expansion in terms of: P_1, P_a, V_1, V_2, M, g, and A. Clearly explain all assumptions and simplifications. Note: you may not need all of these terms.

$$W = -\int_{V_1}^{V_2} P_E \, dV$$

note: $P_E \neq P_{sys}$ (P)

$$W = -\int_{V_1}^{V_2} \left(P_a + \frac{Mg}{A}\right) dV$$

constant

$$\therefore \quad \boxed{W = -\left(P_a + \frac{Mg}{A}\right)(V_2 - V_1)}$$