NAME:

1. (20 pts total)
a. (4pts) Indicate whether each of the following quantities is intensive, extensive, or neither:

P intensive

n extensive

PV ~~intens~~ extensive

$\overline{C}_p$ (molar heat capacity) intensive

b. (4pts) Which of the following are state variables:

Enthalpy, H state variable

Heat from reversible process, $q_{rev}$

Heat from irreversible process, $q_{irr}$

} not ⇒ path dependent

$q_{rev}/T$ $= S \Rightarrow$ state variable

c. (12pts) Consider a system in which liquid water freezes to ice at constant pressure. Describe what happens to the entropy of the system and the entropy of the universe. State the second law of thermodynamics and relate it to this problem in 20 words or less.

S system ↓ S universe ↑

2nd Law: $\Delta S_{universe} \geq 0$

even though the entropy of the system decreases, the overall entropy of the universe increases.

NAME:

2. (15 pts total) Consider the following reactions:

1) $H_2(g) + I_2(s) \rightarrow 2HI(g)$ $\Delta H^o_{298} = 52.96$ kJ/mol

2) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $\Delta H^o_{298} = -483.64$ kJ/mol

3) $4HI(g) + O_2(g) \rightarrow I_2(s) + 2H_2O(g)$

a. (5 pts) Calculate $\Delta H^o_{298}$ for reaction 3

$4HI(g) \rightarrow 2H_2(g) + 2I_2(s)$ $-2(52.96\ kJ/mol)$

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ $-483.64\ kJ/mol$

$4HI(g) + O_2(g) \rightarrow 2I_2(s) + 2H_2O(g)$ $\Delta H = -589.56\ kJ/mol$

b. (5 pts) Label the three reactions as either endothermic or exothermic (as written above)

1) endothermic

2) exothermic

3) exothermic

c. (5 pts) Calculate $\Delta E^o_{298}$ for reaction 3

$\Delta E = \Delta H - \Delta(pV)$

$= \Delta H - \Delta(nRT)$

$= -589.56\ kJ - (2-5)mol \cdot 8.314 \frac{J}{mol K}(298K)$

$= -582.1\ kJ/mol$

NAME:

3. (24 pts total) For each of the following processes, state whether each of the quantities ($q$, $w$, $\Delta T$, $\Delta E$, $\Delta H$, $\Delta S_{(system)}$) is positive, negative, zero, or undetermined.

a. (6pts) An ideal gas is compressed isothermally with an external pressure roughly equal to the internal pressure.

b. (6pts) Reversible adiabatic expansion of an unusual non-ideal gas following: $\left(P - a\left(\frac{n}{V}\right)^{2/3}\right)(V) = nRT$ (where $a$ is a **positive** constant)

c. (6pts) $H_2$ and $O_2$ react explosively to form $H_2O$ vapor in space (You may assume that $P_{ext} \sim 0$ and, since there is nowhere for the heat to go, the process adiabatic.

d. (6pts) Water boils into vapor at constant pressure (1atm) and T = 100 °C. ($\Delta H_{vap}$ = +40.66 kJ/mol)

Answer:

| | q | w | ΔT | ΔE | ΔH | $\Delta S_{(system)}$ |
|---|---|---|---|---|---|---|
| a. | − | + | 0 | 0 | 0 | − |
| b. | 0 | − | − | − | undetermined | 0 |
| c. | 0 | 0 | + | 0 | | |
| d. | + | − | 0 | + | + | + |

NAME:

4. (21 pts total) 1 mole of ideal gas at an initial temperature of 300K and an initial pressure of 10 atm, adiabatically and reversibly expands to the final pressure 1atm. (For 1 mole ideal gas, $C_v = 1.5R$, $C_p = 2.5R$.)

a) (5 pts) What is the initial volume $V_1$?

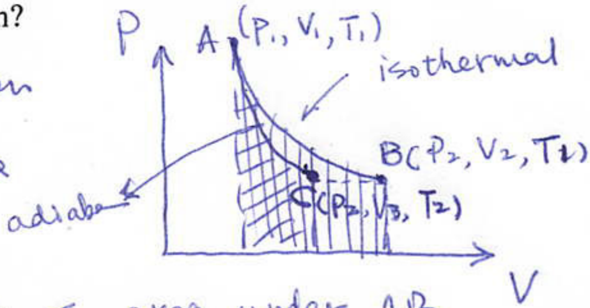
$$PV = nRT$$

$$V = \frac{nRT}{P} = \frac{1 \times 0.08206 \times 300}{10} = \boxed{2.46\ (L)}$$

b) (5 pts) What is the entropy change, $\Delta S$, of the ideal gas?

$$\Delta S = \int \frac{q_{rev}}{T}\, dT = 0$$

c) (6 pts) Compared with isothermal reversible expansion with the same initial state and final pressure as above, in which process, is the work, *w*, larger? Can you give your reason based on PV diagram?




isothermal reversible expansion has more work as the P-V diagram indicates:

The area under AC curve < area under AB.

(Note: $T\downarrow$, $V$ shrink for adiabatic process $\therefore V_3 <$

d) (5 pts) What is the final temperature for the adiabatic process?

(HINT: recall from Carnot cycle, we found $C_V \ln\left(\frac{T_2}{T_1}\right) = -nR\ln\left(\frac{V_2}{V_1}\right)$ for the adiabatic expansion of step II)

$$C_V \ln\left(\frac{T_2}{T_1}\right) = -nR \ln\left(\frac{V_2}{V_1}\right) \Rightarrow$$

$$\frac{T_2}{T_1} = \left(\frac{V_2}{V_1}\right)^{-\frac{nR}{C_V}} \quad \text{and} \quad V_2 = nRT_2/P_2. \quad V_1 = nRT_1/P_1$$

$$\Rightarrow \quad \frac{T_2}{T_1} = \left(\frac{T_2 P_1}{T_1 P_2}\right)^{-nR/C_V} \longrightarrow$$

$$\boxed{T_2 = 119.43\,K}$$

NAME:

5. (20 pts total) A spaceship cabin has dimension 2x2x2 meters = 8 $m^3$ volume.

a. (5 pts) If the air is at 1atm and 298K, suitable for a human, and it can be treated as an ideal gas, how many moles of "air molecules" are there (An "air molecule" is a molecule of any one of the gases that compose the air.)

$$8\,m^3 = 8\,(100cm)(100cm)(100cm) = 8{,}000{,}000\ cm^3 = 8\times10^6\,mL = 8\times10^3\,L$$

$$n = \frac{PV}{RT} = \frac{\cancel{1atm}\,(8{,}000\cancel{L})}{0.0821\frac{\cancel{Latm}}{\cancel{K}\,mol}\,298\cancel{K}} = 326.987\,mol = 327\,mol$$

b. (5 pts) A leak starts in the insulated (adiabatic) cabin allows one mole of air to escape against the vacuum per hour. Calculate the work and ΔE of this process over the first hour of the leak. (For this part of the problem, define all of the air as the system, including that portion that has escaped the spaceship and HINT: q = 0)

$q = 0$

$w = 0$, against vacuum

$\Delta E = w + q = 0$

c. (5 pts) What is the final temperature and pressure in the cabin?

ideal gas $\therefore \Delta E = 0 \Rightarrow \Delta T = 0$ $\quad T_F = 298K$

$$P = \frac{nRT}{V} = \frac{(326mol)(0.0821\frac{Latm}{Kmol})(298K)}{8{,}000L} = \frac{326}{327}\,1atm = 0.997atm$$

$\approx 1atm$

d. (5 pts) If we instead consider only the air in the cabin as the system, what is ΔE for the first hour of the leak?

$$\Delta E = \underbrace{E_{326mol,298K,1atm}}_{E_F} - \underbrace{E_{327mol,298K,1atm}}_{E_I}$$

$$= \frac{326}{327}E_I - E_I = \left(\frac{326}{327} - 1\right)E_I = \frac{-E_I}{327} < 0$$

loose matter, loose energy

at const P of 1atm →

$$E_I = \int_{0K}^{298K} nC_p\,dT = 327mol\left(\frac{5}{2}R\right)\int_{0K}^{298K} dT = 327mol\left(\frac{5}{2}R\right)298K = 2.025\times10$$

← at abs. 0, $E_{ideal\ gas} = 0$

or, since $E = n\frac{5}{2}RT$, $\quad \Delta E = \Delta n\frac{5}{2}RT = (-1mol)\frac{5}{2}RT = -6194J$