

**Work independently. Do not look at others' exams.
Do not allow your exam responses to be shared.**

1. (45 points) For the following short answer questions, circle ALL correct answers

For a process that can be carried out by either a reversible or an irreversible path, the change in (**P, T, V, q, E, H, w**) must be the same for both paths.

P, T, V, E, H

(**ΔH , ΔS , ΔG , ΔE**) implies constant pressure.

H, G

A reversible process is one that proceeds by a succession of very small incremental steps, all of which are (**at equilibrium, spontaneous, enthalpically and entropically driven**).

At equilibrium

The heat needed to change the phase of a substance is typically (**smaller / larger**) than the heat needed to increase its temperature by 10 K.

Larger

H equals the heat transferred to the system under constant (**T, P, V**).

Pressure

The path which produces the maximum work is (**reversible / irreversible**).

reversible

An ideal gas expands isothermally against an external pressure of 2 atm. E for the system is (**greater than zero / equal to zero / less than zero**).

Zero

An ideal gas expands adiabatically against an external pressure of 2 atm. E for the system is (**greater than zero / equal to zero / less than zero**).

Less than zero

An ideal gas expands adiabatically into a vacuum. E for the system is (**greater than zero / equal to zero / less than zero**).

Zero

According to the 2nd law of thermodynamics, a spontaneous process, such as a balloon filled with a hot gas cooling to the surroundings at constant pressure, will always occur (**adiabatically, reversibly, irreversibly, without work done**).

Irreversibly

The internal energy of an ideal gas is a function of only (**T / P / V**).

T

For a sample of an ideal gas, the product PV remains constant as long as (**T / P / V**) is held constant.

T (PV=nRT)

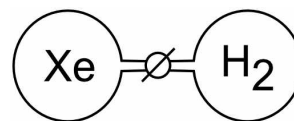
The 2nd law of thermodynamics states that the entropy of a (**closed / isolated / isothermal**) system always increases during a (**spontaneous / equilibrium / unfavorable**) process.

isolated

When a sample of liquid is converted reversibly to its vapor at its normal boiling point, (**q, w, ΔP , ΔV , ΔT , ΔE , ΔH , ΔS , ΔG**) is equal to zero for the system.

T, G

2. (25 points) Two 5 liter containers initially containing, respectively, H_2 and Xe gas, are separated by a valve. Considering the entire assembly to be the system, for each of the system variables below, indicate whether that value will be *less* than zero, *greater* than zero, or *equal* to zero, for the process which accompanies opening of the valve between the containers.



a)

| System variable | Circle correct answer | Assumptions/comments |
|-----------------|-----------------------|----------------------|
| G | < = > 0 | <0 |
| H | < = > 0 | =0 |
| S | < = > 0 | >0 |
| E | < = > 0 | =0 |
| q | < = > 0 | =0 |
| w | < = > 0 | =0 |

b) Explain in 30 words or less, your answer for E.

The system is the entire assembly. Since the total pressure and the total volume (of the system) do not change, $T = \frac{PV}{nR}$ does not change. Therefore E does not change

c) Explain in 40 words or less, your answer for S, focusing on the *molecular* explanation – what does it mean?

Although, the pressures don't change, in the original situation each gas was restricted to its own container. Afterwards, the gases have more places to be / ways to arrange themselves. Entropy goes up.

- 3a. (15 points) Calculate H and S when 2 moles of H_2O (g) is cooled irreversibly at constant P from 120°C to 100°C .

$$C = \frac{dq}{dT} \quad H = q_p = \int_{T_1}^{T_2} dq = \int_{T_1}^{T_2} n\bar{C}dT = n\bar{C} \int_{T_1}^{T_2} dT = n\bar{C}(T_2 - T_1)$$

$$H = (2\text{moles})(33.76 \text{ J K}^{-1} \text{ mol}^{-1})(373\text{K} - 393\text{K}) = -1350\text{J} = -1.35\text{kJ}$$

$$dS = \frac{dq_{rev}}{T} = \frac{CdT}{T} \quad C = \frac{dq}{dT}$$

$$\int_{S_1}^{S_2} dS = \int_{T_1}^{T_2} \frac{C dT}{T} = C \int_{T_1}^{T_2} \frac{dT}{T}$$

$$S_2 - S_1 = S = n\bar{C} \ln \frac{T_2}{T_1} = (2\text{moles})(33.76 \text{ J K}^{-1} \text{ mol}^{-1}) \ln \frac{373\text{K}}{393\text{K}} = -3.53\text{JK}^{-1}$$

- 3b. (15 points) Calculate q , w , E , T , and the final volume for the irreversible, isothermal expansion of 1 mole of H_2O (g) from an initial pressure of 1 atm and an initial volume of 1 L, to a final pressure of 0.1 atm.

$E = 0$ (isothermal)

$$n_1 = 1 \text{ mole} \quad P_1 = 1 \text{ atm} \quad V_1 = 1 \text{ L} \quad T_1 = \frac{PV_1}{n_1R} = \frac{(1\text{atm})(1\text{L})}{(1\text{mole})(0.08206 \text{ L atm K}^{-1} \text{ mole}^{-1})} = 12.2\text{K}$$

$$n_2 = 1 \text{ mole} \quad T_2 = T_1 \quad P_2 = 0.1 \text{ atm}$$

$$V_2 = \frac{n_2RT_2}{P_2} = \frac{(1\text{mole})(0.08206 \text{ L atm K}^{-1} \text{ mole}^{-1})(12.2\text{K})}{(0.1\text{atm})} = 10.0\text{L}$$

$$w = - \int_{V_1}^{V_2} PdV = -P \int_{V_1}^{V_2} dV = -P(V_2 - V_1) = -(0.1\text{atm})(10.0\text{L} - 1.0\text{L}) = -0.90\text{atm L}$$

$$w = -0.90\text{atm L} \frac{8.314 \text{ J K}^{-1} \text{ mol}^{-1}}{0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}} = -91.2\text{J}$$

$$q = -w = 91.2\text{J}$$