Pandemic Physics Lab 10: A day of thermodynamics problems

An ideal 3 dimensional **diatomic** gas (with translational and rotational realized) has the equation of state $PV = nRT$ where n is the number of moles and R=8.314 J/(K mol). Suppose that 1 mole of this ideal gas goes through an **isovolumeric** (V=constant) process. If the change is pressure is $\Delta P = 1 \times 10^5$ Pa, and the change in temperature is $\Delta T = 300$K, answer the following using correct SI units.

(a) What is the volume of the gas when the pressure is $P = 1 \times 10^5$ Pa and the temperature is T=300K?

(b) What are the values of c_v and c_p for this gas?

c_v=___________________________ c_p=___________________________

(c) What is the change in internal energy of the gas?

ΔU=________________

(d) How much heat was supplied (or evolved) from the gas?

Q=_________________

A copper cube with a density of 8960 kg/m^3 has a coefficient of linear expansion of $16.6x10^{-6}$ $/^0C$ and a specific heat of 385 $J/(kg\ ^0C)$. Suppose a 1 Kg block of copper is heated from a temperature of 0^0C to a temperature of 100^0C.
(a) if the cube is isotropic, what is the coefficient of volume expansion?

γ=____________
(b) How much heat is added to the system?

Q=_____________
(c) What is the change in volume of the cube?

ΔV=_____________
(d) If this expansion was in the presence of a pressure of $1x10^5 Pa$, how much work was done by the cube?

W=_____________
(e) What was the change in internal energy of the cube?

ΔU=_____________

A heat engine is observed to operate with 55% efficiency when a heat input of Q_H=100J is provided.

(a) What is the work that was measured from this engine?

(b) Suppose the engine went through a Carnot cycle with heat input was from a source which has a temperature of T_H=100 ^{0}C. What is the temperature (in K) of the colder reservoir?

An ideal 3 dimensional monotonic gas has the equation of state $PV=nRT$ where n is the number of moles and R=8.314 J/(K mol). For this gas, it is known that the molar specific heat at constant volume is $c_v= 3/2\ R$. You may assume n=1 mole here.

(a) Calculate c_p and the adiabatic coefficient γ for this gas.

C_p=____________________ γ=_______________________

(b) Suppose that the gas went through an **isobaric process ($P=P_i$)** which resulted in $\Delta V = 2V_i$ where V_i was the initial volume of the gas at the temperature T_i and pressure P_i. **In terms of P_i and V_i ,** calculate the following:

Q=___________________________

W=___________________________

ΔU=___________________________

(c) Suppose that the gas went through an **isothermal ($T=T_i$)** process which resulted in $\Delta V = 2V_i$ with P changing from P_i to P_f. Calculate the following **(in terms of the thermodynamic variable T_i):**

ΔU=_________________________

W=___________________________

Q=____________________________

An unknown solid material is observed to have a length of L_0=1 m at 0 ^{0}C and a length of L=1.01 m at 100 ^{0}C. **In your answers, be sure to use correct SI units.**

(a) Calculate the coefficient of linear expansion for this material.

α=___________

(b) Another material (not the same material as in part a) has a coefficient of linear expansion given by $\alpha=1\text{x}10^{-3}$ /C. Calculate the coefficient of volume expansion for this material assuming the material is isotropic.

γ=_________

(c) If a cube of the material in (b) above with a volume V_0=1 m^3 is heated from 0 ^{0}C to 100 ^{0}C, calculate the work done when it expands against a constant pressure of P=1x10^5 Pa.

W=_____________________

(d) Suppose the material in (b) above has a density of ρ=800 kg/m^3 and a specific heat at a constant pressure of c_p=2 J/(kg ^{0}C). Calculate the heat supplied to the system.

Q=________________________

(e) Calculate ΔU when the material in (b) above is expanded (as in c) and simultaneously heated (as in d).

ΔU=________________________

A heat engine is reported to operate with 75% efficiency when the cold reservoir is at 0^0 C.

(a) Assuming this engine follows the Carnot cycle, what is the temperature of the hot reservoir (in K)?

T_H=______________________

(b) Suppose the heat input to this engine was 50 J. Calculate the work done by this engine.

W=_________________________

(c) Suppose the heat input to this engine was 50J. Calculate the heat rejected by this engine.

For water, L_f=3.33x10^5 J/kg and c=4186 J/Kg ^{0}C.**In your answers, be sure to use correct SI units.**

(a) If 2 kg of water at 0^0C is mixed with 1 kg of water at 75^0C, calculate the final equilibrium temperature of the mixture.

T_f=______________________

(b) Calculate the change in entropy of the water as a result of the mixing described in part a, be sure to provide correct SI units.

ΔS=______________________

(c) If a 2 kg mass of water at 0^0C freezes to become ice at 0^0C, calculate the change in entropy of the ice.

ΔS=______________________

An ideal **3 dimensional diatomic gas with rotational modes realized but not vibrational modes** has the equation of state $PV=nRT$ where n is the number of moles. **You may assume n=2 moles for this entire problem.**

(a) Calculate c_v, c_p and the adiabatic coefficient γ for this gas, providing numerical answers with correct SI units.

c_v=________________ c_p=______________________

γ=_________________________

(b) Suppose that the ideal gas in (a) had an initial volume of $V_i=1\ m^3$ and went through an **isothermal process ($T=T_i=300$ K)** which resulted in $V_f=2m^3$. **Providing correct SI units, calculate the following:**

P_i=_______________________ Q=________________________ W=__________________

ΔU=_____________________

(c) Suppose that the same gas went through an **isovolumeric ($V=V_i$)** process which resulted in $T_f=600K$ where $T_i=200$ K with P changing from P_i to P_f. **Providing correct SI units, calculate the following:**

ΔU=___________________ W=_____________________________ Q=_____________________________

Constants: R=8.314 J/(K mol): water: c=4186 J/(^{0}C kg),$L_f=3.33\text{x}10^5$J/kg

An ideal 3 dimensional diatomic gas has the equation of state $PV = nRT$ where n is the number of moles and R=8.314 J/(K mol). You may assume n=1 mole here.

(a) Calculate c_p for this ideal gas when all 7 degrees of freedom are realized.

For the rest of this problem, assume c_v=3/2 R.
(b) Suppose n=1 moles of this gas went through an isothermal process at T=300K which resulted in $V_f = 3V_i$ with V_i being the initial volume of the gas. Calculate the following quantities:

$\Delta U =$ ____________________

$Q =$ _____________________

(c) Suppose n=1 moles of this gas went through an isobaric process at P=1.0×10^2 Pa and the volume changed from 1 m^3 to 3 m^3. Calculate the following quantities:

$\Delta T =$ _________________________

$\Delta U =$ _________________________