QUESTION 1: Ideal Gas Law (20 pts)

20 g of propane (C_3H_8) is in a 2 L container at 25°C.

a) what is the pressure in the container (in atm), assuming that propane behaves like an ideal gas ?

5.549 atm

b) assuming Van der Waals behavior, recalculate the pressure (a = 9.39 L^2 atm mol^{-1} and b=0.0905 L/mol) [4 pts]

5.182 atm

c) calculate the exact number of moles of oxygen needed to burn all the propane according to:

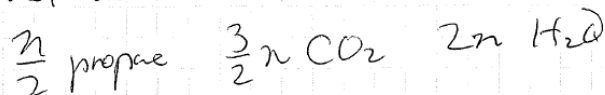$$C_3H_8 + 5O_2 = 3CO_2 + 4H_2O \ (g)$$ [2 pts]
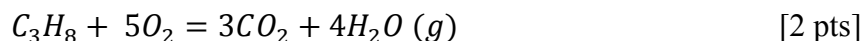
2.268 mol

d) If we add the exact number of moles of O_2 from part c) into the same 2L container, and assuming the reaction in part 1c) takes place completely, calculate the final pressure in the vessel assuming:
- ideal gas behavior
- the temperature rises to 150°C
- water remains as water vapor   [5 pts]

e) recalculate the answer in part d) if you start with only half the amount of oxygen calculated in part c), and also calculate (in addition to the total pressure) the partial pressures and mole fractions of all the remaining gasses. [7 pts]

QUESTION 2: First Law of Thermodynamics (20 pts)

A quantity of 0.45 mol of neon is confined in a container at 3.5 atm and 298 K and then allowed to expand under three different conditions.

(a) In the first process, the gas expands adiabatically and reversibly to 1.00 atm. Calculate the <u>final temperature</u> and the <u>work done</u>. [**6 pts**]

T = 180.5 K
W = -659J

(b) In the second process, the gas expands adiabatically against a constant pressure of 1.00 atm. Calculate the final temperature and the work done. [**6 pts**]

T = 212.9K   w = -478J

(a) In the third process, the gas expands isothermally and reversibly until its volume reaches the same value as the final volume in part (a). Determine the value of the final volume and the final pressure of this reversible isothermal expansion. [**4 pts**]

V = 6.67L   P = 1.65 atm

(d) On a P-V diagram, sketch the paths described in (a) and (c). In which process was more work performed? On the diagram, shade the area that represents the difference in the work done in process (a) and process (c) [**4 pts**]
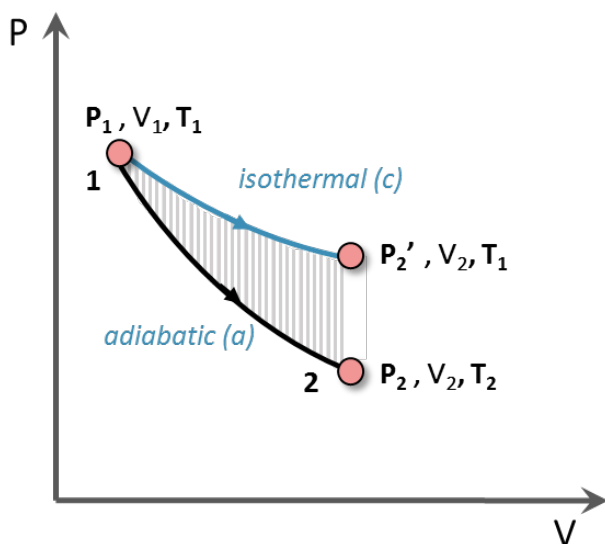
QUESTION 3: First Law of Thermodynamics (20 pts)

(a) The density of liquid water at 100 °C is 0.9584 g/cm^3, and that of steam at the same temperature is 0.000596 g/cm^3. If the enthalpy of evaporation of water at atmospheric pressure is 40.63 kJ/mol, what is ΔU? How much work is done by the system during the evaporation process? Hint: Consider calculating molar volumes first. [**5 pts**]

Work done by the system = 3.06 kJ (or w = -3.06 kJ)

$\Delta U = \Delta H - \Delta(PV) = 40.63$kJ /mol $- (1$atm$)(30.20$L$)(101.325$J / Latm$)(1$kJ /1000J$) = 37.6$kJ /mol

(b) Would you expect for the fusion process (ice to water) the difference between ΔU and ΔH to be larger or smaller than the one calculate in (a) for the vaporization process? Explain. [**3 pts**]

We would expect the difference between ΔU and ΔH to be really small, as the density difference between solid and liquid is much smaller than between liquid and gas. As such the difference between molar volumes of those two states would be much smaller, and thus work would be much smaller, leading to a negligable difference between ΔU and ΔH.

(c) How much heat is required to heat 2 moles of water (ice at -10℃) to gasous water vapour at 110℃? Sketch the process on a temperature vs heat graph. [**6 pts**]
    Given: ΔH_{fusion}=6. 01 kJ/mol, $\Delta H_{vapourization}$= 40.67 kJ/mol,
    $\overline{C_P}^{ice} = 2.11J/gK$ $\overline{C_P}^{water} = 4.18J/gK$ $\overline{C_P}^{vapour} = 2.08J/gK$

q = 109.9 kJ

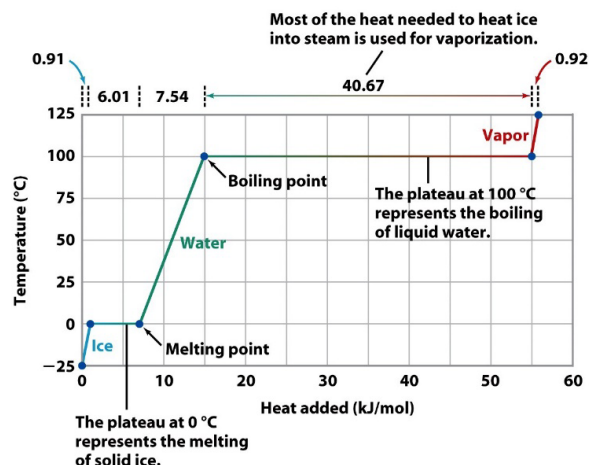Most of the heat needed to heat ice into steam is used for vaporization.

Figure 10-10 Chemistry, 5/e
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(d) A chunk of ice at 270 K, weighing 30 grams, is dropped into 300 g of liquid water at 300 K. Determine the final temperature of the system once equilibrium has been reached. Use any constants that you need from parth (c). [**6 pts**]

T 290.15K

Question 4: Thermochemistry

A table (4.1) with thermodynamic data is provided. The heat of combustion for formaldehyde (CH_2O) is -233 kJ (mol^{-1} CH_2O) at the standard state (298.15 K, 1 bar, products and reactants are both in the gas phase).
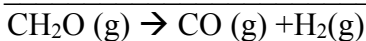a) Determine the heat of formation for formaldehyde (CH_2O) at standard state. [5 pts]

-116 kJ/mol

b) The heat of reaction for the reverse Water-Gas-Shift reaction (298.15 K, 1 bar) is:
    CO_2 (g) +H_2(g) → H_2O (l) +CO (g) $\Delta H^0_{RXN} = -288kJ\ (mol^{-1})$
    Determine the heat of reaction for the following reaction at standard state:

CH_2O (g) → CO (g) +H_2(g)
Show your work. [5 pts]

+6 kJ/mol

c) Determine the heat of combustion **(in kJ (mol^{-1} CH$_2$O))** for formaldehyde at 500 K. [4 pts]

-231.6 kJ/mol

d) Using Bond Enthalpy Table (Bond Dissociation Energies for the various bonds listed below), estimate the heat of reaction for the following reaction at the standard state. [4 pts]

+69 kJ/mol

e) The heat capacity for CO_2 (liquid) is HIGHER   than CO_2(gas) (circle one) [2 pts]

Question 5: Entropy

i) In a process taking place inside a system, 1.5 mole of a monoatomic ideal gas is expanded adiabatically from 500°C and 5 bar to a final pressure of 2 bar. Calculate ΔS_{system}, $\Delta S_{surroundings}$, and $\Delta S_{universe}$ for the following conditions:

a) if the process is reversible; [3 pts]
   no change in entropy

b) if the process is irreversible and expansion is made against vacuum. [4 pts]

$\Delta S_{sys} = 11.4 \ J/K$ $\Delta S_{surr} = 0$

c) if the process is irreversible and the work produced is 6000 J; [4 pts]

$\Delta S_{sys} = -5.28 \ J/K$ $\Delta S_{surr} = 0$

ii) Are the following statements true or false? [4 pts]
   Check one
   T   **F**

	☐ The entropy of a system cannot increase in any adiabatic process.
☐	ΔS (universe) for melting ice to water at 0 °C is ZERO.
	☐ It is possible to have the efficiency of the Carnot cycle equal to "1".
☐	In a process, «graphite» is transformed to «diamond». ΔS for this process is negative.

iii)

a) Calculate the change in the entropy when 20 g of solid mercury (Hg(s)) at -50°C and 1 bar transforms to gaseous mercury at its boiling point. Below are the required thermodynamic data (specific heat capacities, $C_{p,m}$, are independent of temperature): [3 pts]

ΔH_{fusion} = 2.33 kJ/mol
$\Delta H_{vaporization}$ = 59.11 kJ/mol
$C_{p,m\ Hg(s)}$ = 28.2 J/mol.K
$C_{p,m\ Hg(liq)}$ = 27.9 J/mol.K
Melting temperature = -39°C
Boiling temperature = 357°C

ΔS 13.3 J/K

b) Using the thermodynamic data provided in part (a), sketch a qualitative graph of the molar entropy of mercury (Hg) as a function of temperature in the range of 0 to 700 K at constant pressure. [2 pts]