UMSO Thermodynamics Answer Sheet

Max Score : 70 points

1. **(+1 point total)** - Sadi Carnot **(1 point for full name)**

2. **(+4 points total)**
   a. Reversible Isothermal **(0.5 points for each)**
   b. Reversible Isentropic/Adiabatic **(0.5 points for each)**
   c. Reversible Isothermal **(0.5 points for each)**
   d. Reversible Isentropic/Adiabatic **(0.5 points for each)**

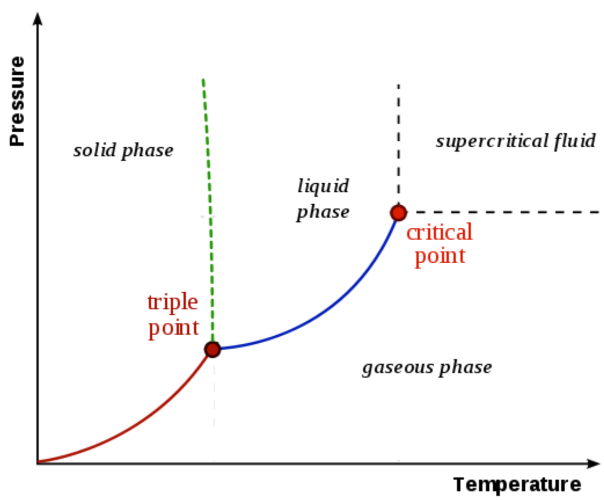
3. **(+3 points total)**
   a. -297.3 F **(1 point)**
   b. -182.9 C **(1 point)**
   c. 90.2 K **(1 point)**

4. **(+2 points total)**
   a. 200,000 calories **(1 point)**
   b. 836,800 joules **(1 point)**

5. **(+2 points total)**
   a. Isentropic **(1 point)**
   b. Rudolf Clausius **(1 point)**

6. **(+2 points total)**
   a. 0 K **(1 point)**
   b. Lord Kelvin/William Thompson **(1 point)**

7. **(+4 points total – 0.5 point per label, +1 point for identifying triple point for 3 phases)**



8. **(+4 points total)**
   a. High Temperatures **(1 point)**
      Low Pressures **(1 point)**
   b. At these conditions, intermolecular forces are less significant than the kinetic energy of the particles **(1 point)**. The molecule size is less significant than space between them **(1 point)**.

9. **(+4 points total)**
   a. A state variable is one that depends on the state of the system. They are not affected by their path and instead are described by the present state of the system **(2 points)**. Examples include: internal energy, enthalpy, entropy, mass, pressure, temperature, volume, density, fugacity, etc. **(1 point for each example)**

10. **(+2 points total)**
    a. The third law of thermodynamics states that : "The entropy of a perfect crystal at absolute zero is exactly equal to zero."**(+1 for analogous explanation)** It was developed by Walther Nernst **(+1 for full name)**.

11. **(+3 points total)**
    a. Heat capacity and specific heat both refer to the amount of heat required to raise the temperature **(+1 point)**. However, heat capacity refers to the amount of heat required to raise temperature with respect to its molar quantity **(+1 point)** and specific heat refers to the amount of heat required to raise the temperature with respect to its mass **(+1 point)**.

12. **(+3 points total)**
    a. $3\ ice\ cubes * \frac{30\ mL}{ice\ cube} * \frac{0.917g}{1mL} * \frac{334J}{g} * \frac{1kJ}{1000J}$ = 27.56 kJ
    (+1 points for volume conversion)
    (+1 points for latent heat)
    (+1 points for correct answer with units)

13. **(+3 points)**
    a. Decreases **(+1)**
    b. Increases **(+1)**
    c. 2^{nd} Law of Thermodynamics **(+1)**

14. **(+6 points total)**

a. Using the energy balance:

$$\hat{H} = \hat{U} + P\hat{V}$$

(+1 point for equation)

$$\hat{H} = 3800\frac{J}{mol} + (1\ atm)(24.63\frac{L}{mol})$$

(+1 point for plugging in numbers)

$$\hat{H} = 3800\frac{J}{mol} + (1\ atm)(24.63\frac{L}{mol})(8.314\frac{J}{K*mol})(\frac{1\ K*mol}{0.08206\ L*atm})$$

(+2 points for converting from atm *L to J)

$$\hat{H} = \frac{6295\frac{J}{mol}}{4.002\frac{g}{mol}} = 1572.96\frac{J}{g}$$

(+1 point correct answer, +1 point correct units)

15. **(+8 points total)**

a. **(+6 points)** Expansion work:

$$W = -\int_{V_1}^{V_f} P_{ex} dV$$

At a constant pressure, integral simplifies to:

$$W = -P_{ex}(\Delta V)$$

(+1 point for equation)

Solving for change in volume:

$$PV = nRT$$

(+1 point for using IGL)

$$(1\ atm) * (\Delta V) = (5\ mol)(0.08206\ \frac{L*atm}{K*mol})(15K)$$

(+1 point for plugging in numbers)

$$\Delta V = 6.155\ L = 0.00615\ m^3$$

(+1 point for correct volume)

$$1\ atm = 101325\ Pa$$

(+1 point for pressure conversion)

$$W = (101325\ \text{Pa}) * (0.00615\ \text{m}^3) = -623.6\ J$$

(+1 point for correct answer)

b. **(+2 points)** Depending on sign convention:

i. If the student uses:

$$W = -\int_{V_1}^{V_f} P_{ex} dV$$

Then W = (-) **(+1 point)** and work is being done by the system **(+1 point)**

ii. If the student uses:

$$W = \int_{V_1}^{V_f} P_{ex} dV$$

Then W = (+) **(+1 point)** and the work is being done by the system **(+1 point)**

16. **(+4 points)**

a. Carnot efficiency:

$$\eta = 1 - \frac{T_C}{T_H}$$

(+1 point for equation)

$$\eta = 1 - \frac{378K}{623K}$$

(+1 point for correct inputs)

$$\eta = 39.3\%$$

(+1 point for correct answer)

b. All the steps in the Carnot cycle are reversible, which means that no entropy is being generated through friction and other heat losses. **(+1 point for explanation)**

17. **(+8 points)**

a. Thermal Efficiency:

$$\eta = \frac{W_{out}}{Q_{in}}$$

(+1 point for equation)

$$\eta = \frac{600\ MW}{1900\ MW}$$

(+1 point for plugging numbers)

$$\eta = 31.5\%$$

(+1 point for correct answer)

b. Calculating for $\Delta T = 10°\text{C}$:

$$Q = mC_p\Delta T$$

(+1 point for equation)

$$(1900\ MW - 600MW) * 0.75 = m * 4.184 * 10$$

(+1 point for plugging numbers, +1 point for multiplying by 0.75)

$$975MW * \frac{10^6 \frac{J}{s}}{1MW} = m * 4.184 \frac{J}{°\text{C}g} * 10°\text{C}$$

$$m = 2.33 * 10^7 g * 1\frac{mL}{g} * 1\frac{L}{1000mL} * 1\frac{m^3}{1000L} = 23.3\frac{m^3}{s} * \frac{60\ s}{1\ min} * \frac{60\ min}{1\ hr} = 83{,}880\frac{m^3}{hr}$$

(+1 point for correct units, +1 point for correct answer)

18. **(+7 points)**

$$q_x = \frac{kA}{L}(T_1 - T_2)$$

(+1 point for equation)

Layer 1:

$$q_x = 200W = \frac{0.13\frac{W}{m*K}*1m^2}{0.20m}*(753K - T_{contact})$$

(+1 point for plugging in numbers)

$$T_{contact} = 445.3K$$

(+1 point for correct $T_{contact}$)

Layer 2:

$$q_x = 200W = \frac{1.1\frac{W}{m*K}*1m^2}{0.2m}*(445.3 - T_{outer\ wall})$$

(+1 point for plugging in numbers, +1 point for using $T_{contact}$)

$$T_{outer\ wall} = 408.9K = 135.9℃$$

(+1 point for correct answer)

This configuration is unsafe, additional insulation is required.

(+1 point for reasonable recommendation)