YILDIZ TECHNICAL UNIVERSITY
FACULTY OF ELECTRICAL AND ELECTRONICS ENGINEERING
DEPARTMENT OF BIOMEDICAL ENGINEERING

BME 3711 – BIOTHERMODYNAMICS
2020 – FALL

MIDTERM

1. State whether the following phrases pertain to (A) the First Law of Thermodynamics, (B) the Second Law, (C) both the First and Second Law, or (D) neither of the Laws. Write A, B, C or D only. (10 points)

(i) For an isolated system the total energy is constant.

(ii) It is concerned with the transfer of heat and the performance of work.

(iii) It indicates whether a process will proceed quickly or slowly.

(iv) It predicts the direction of a reaction.

(v) It says that a quantity of heat cannot be converted into an equivalent amount of work.

(vi) It is a statement of the conservation of energy.

(vii) It says that the capacity to do work decreases as the organization of a system becomes more uniform.

(viii) It says that the capacity to do work decreases as objects come to the same temperature.

(ix) Every energy transfer that takes place reduce the amount of usable energy available to do work.

(x) At rest organisms have a basal metabolic rate.

2. Write two distinct efforts of human kind towards inventing an engine that violates a) the first law of thermodynamics and b) the second law of thermodynamics. **Explain** your reasoning giving information about the laws. (10 points)

3. Undernutrition may arise due to reduced dietary intake or reduced absorption of macro- and/or micronutrients from the intestine. It causes reduced muscle mass, fatigue and hypothermia. **Discuss** undernutrition and related complications in terms of the First and Second Laws of thermodynamics. (10 points)

4. Without performing a calculation, **predict** whether the standard entropies of the following reactions are positive or negative: (8 points)

a) Ala–Ser–Thr–Lys–Gly–Arg–Ser → Ala–Ser–Thr–Lys + Gly–Arg

b) $N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$

c) $4\ C_2H_5O_2N(s) + 9\ O_2(g) \rightarrow 8\ CO_2(g) + 10\ H_2O(l) + 2\ N_2(g)$

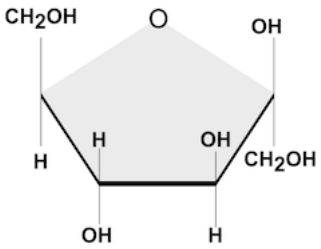
d) $NaNO_3(s) \longrightarrow Na^+(aq) + NO^{-3}(aq)$

5. The protein myoglobin unfolds at a transition temperature of 69.0°C, and the standard enthalpy of transition is 625 kJ mol^{-1}. Calculate the entropy of unfolding of myoglobin at 25.0°C, given that the difference in the constant-pressure heat capacities upon unfolding is 6.28 kJ K^{-1} mol^{-1} and can be assumed to be independent of temperature.

Hint: Imagine that the transition at 25.0°C occurs in three steps: (i) heating of the folded protein from 25.0°C to the transition temperature, (ii) unfolding at the transition temperature, and (iii) cooling of the unfolded protein to 25.0°C. (15 points)

6. Structure and the reaction of formation of fructose from CO_2 and H_2O is given below :

$$6\ CO_2\ (g) + 6\ H_2O\ (l) \rightarrow C_6H_{12}O_6\ (s) + 6\ O_2\ (g)$$



FRUCTOSE

a) Estimate the enthalpy of formation of fructose using the bond ethalpies. (Use tables given) (10 points)

b) Estimate the enthalpy of formation of fructose using standard enthalpy of formation of the reactants and products. (ΔH_f (CO_2) = -393.51 kJ/mol, ΔH_f (H_2O) = -285.83) (7 points)

c) Estimate the standard enthalpy of combustion of fructose without performing any calculation. (3 points)

7. A carnot engine operates between two reservoirs of 100 K and 300 K. The system contains 2.5 mol ideal Argon gas. Based on the pressure-volume diagram of a Carnot cycle calculate the following terms given that V_1 = 10 m^3, V_2 = 100 m^3, V_3 = 120 m^3, V_4 = 12 m^3. Use the formula $W = nC(T_f - T_i)$ for the adiabatic processes. [R = 8.314 J mol^{-1} K^{-1}, C_{Ar} = 20.79 J mol^{-1} K^{-1} (Heat capacity of Argon is constant over the temperature and volume changes)] (15 points)

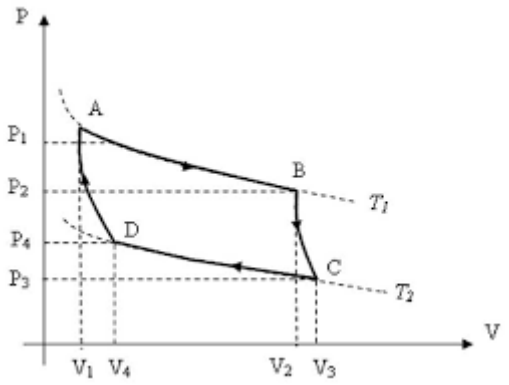
a) $W_{A\rightarrow B}$

b) $W_{B\rightarrow C}$

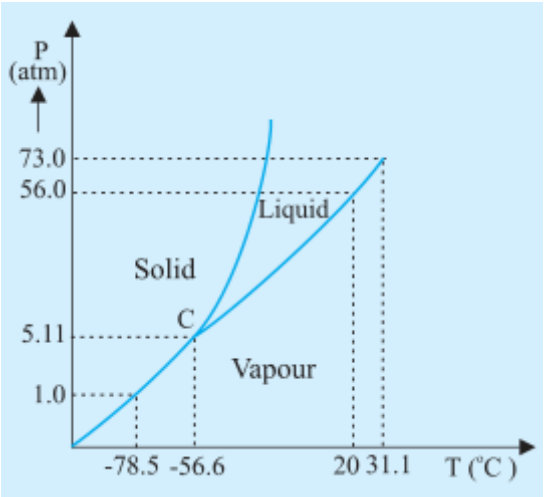
c) $W_{C\rightarrow D}$

d) $W_{D\rightarrow A}$

e) W_{total}. What does it mean?



8. Answer the following questions based on the below P-T phase diagram of carbon dioxide:



(a) Which temperature is the triple point for the CO_2. What happens at this temperature? (3 points)

b) What is the effect of decrease of pressure on the fusion and boiling point of CO_2? (3 points)

(c) What are the critical temperature and pressure for CO_2? What is their significance? (3 points)

(d) Is CO_2 solid, liquid or gas at (i) -70^oC under 1 atm, (ii) $-60°C$ under 10 atm, (iii) 15°C under 56 atm? (1 point each)

Table 1.4 Mean bond enthalpies, ΔH_B/(kJ mol^{-1})*

	H	C	N	O	F	Cl	Br	I	S	P	Si
H	436										
C	412	348 (1) 612 (2) 838 (3) 518 (a)†									
N	388	305 (1) 613 (2) 890 (3)	163 (1) 409 (2) 945 (3)								
O	463	360 (1) 743 (2)	157	146 (1) 97 (2)							
F	565	484	270	185	155						
Cl	431	338	200	203	254	242					
Br	366	276				219	193				
I	299	238				210	178	151			
S	338	259			496	250	212		264		
P	322									200	
Si	318		374	466							226

*Values are for single bonds except where otherwise stated (in parentheses).
†(a) Denotes aromatic.

You need to look at the interception of the elements in order to find the mean bond enthalpies. For example, mean bond enthalpy of C-C single bond is 348, double bond is 612. C-O single bond is 360.

Good Luck ☺

25.11.2020