Motilal Nehru National Institute of Technology Allahabad
Department of Biotechnology
End semester (odd) examination 2017
Session: 2017-18
Programme: B.Tech, Semester: III
Course Name and code: Thermodynamics of biological systems (BT 1305)

Duration: 3 hrs **Max. Marks: 60**

Attempt any SIX QUESTIONS. Assume all gases are perfect unless stated otherwise. Theoretical answers should be supplemented with mathematical expressions wherever possible.

Q1) Write a brief note on the following: **(5x2 = 10)**

(i) Temperature and the Zeroth law of thermodynamics
(ii) Energy and Work
(iii) Systems and Surroundings
(iv) Maximum expansion work
(v) Heat capacity

Q2) Attempt all the five questions: **(5x2 = 10)**

(i) Calculate the work done by a system in which a reaction results in the formation of 1 mol CO_2 (g) at 25°C and 100 kPa.

(ii) A sample of methane of mass 4.50 g occupies 12.7 L at 310 K. (a) Calculate the work done when the gas expands isothermally against a constant external pressure of 30.0 kPa until its volume has increased by 3.3 L. (b) Calculate the work that would be done if the same expansion occurred isothermally and reversibly.

(iii) If an expansion is reversible but not isothermal and that the temperature decreases as the expansion proceeds, (a) find an expression for the work when $T = T_i - c(V - V_i)$, with c a positive constant. (b) Is the work greater or smaller than for isothermal expansion?

(iv) A typical human produces about 10 MJ of energy transferred as heat each day through metabolic activity. If a human body were an isolated system of mass 65 kg with the heat capacity of water ($C_{p,m}$ = 75 J K^{-1} mol^{-1}), what temperature rise would the body experience? Human bodies are actually open systems, and the main mechanism of heat loss is through the evaporation of water. What mass of water should be evaporated each day to maintain constant temperature? (Standard enthalpy of vaporization of water is 44 kJ i.e. the heat required to vaporize 1 mol H_2O (*l*) at 1 bar and 25°C)

(v) What will be the approximate increase in temperature of 100 mL of water sample when 1 kJ of energy is supplied by heating the sample free to expand?

Q3) Write a brief note on the following: **(5x2 = 10)**

(i) Internal energy and the First law of thermodynamics
(ii) Enthalpy and its variation with temperature
(iii) Types of Changes, Entropy and the Second law of thermodynamics
(iv) Entropy change accompanying heating
(v) The Third law of thermodynamics

(P.T.O.)

Q4) Attempt all the five questions. **(5x2 = 10)**

(i) What will be the change in enthalpy (ΔH) of a perfect gas when it undergoes expansion at (a) constant temperature, and (b) constant pressure with no non-expansion work?

(ii) Show that for a perfect gas, $C_p - C_v = nR$

(iii) Suppose that the internal energy (U) of a system could be expressed as a polynomial of temperature (T) as $U = a + bT + cT^2$, where a, b and c are constants. Find an expression for the constant-volume heat capacity (C_v) at temperature T. Derive an expression for the change in entropy (ΔS) of this system when its temperature changes from T_1 to T_2.

(iv) Suppose a small reptile beats its surroundings at a rate of 0.50 J s^{-1}. What entropy does it generate in the course of a day in the water in the lake that it inhabits, where the temperature is 15°C?

(v) For a reaction at 25°C and constant pressure, $\Delta S^\circ = -16.8$ J K^{-1} mol^{-1} and $\Delta H^\circ = -24.2$ kJ mol^{-1}. If the surroundings are maintained at 25°C, calculate the ΔS_{tot} and predict whether the reaction is spontaneous or not.

Q5) Attempt all the five questions **(5x2 = 10)**

(i) What is Gibbs free energy (G) and how it is related to the spontaneity of processes?

(ii) Show that maximum non-expansion work that can be obtained from a process at constant temperature and pressure is ΔG

(iii) Show that $\Delta G^\circ = -RT \ln K$, where K is the equilibrium constant

(iv) Explain how the non-spontaneous phosphorylation of glucose in the first step of Glycolysis is assisted by ATP hydrolysis. Why the hydrolysis of ATP in this first step cannot provide energy for other non-spontaneous reactions of the pathway?

(v) Explain the significance of biological oxidation-reduction reactions in cells. Calculate ΔG° for the reaction in which acetaldehyde is reduced by the biological electron carrier NADH:

$$\text{Acetaldehyde} + \text{NADH} + H^+ \rightarrow \text{ethanol} + \text{NAD}^+$$

$$\text{Acetaldehyde} + 2H^+ + 2e \rightarrow \text{ethanol} \qquad E^\circ = -0.197 \text{ V}$$

$$\text{NAD}^+ + 2H^+ + 2e \rightarrow \text{NADH} + H^+ \qquad E^\circ = -0.320 \text{ V}$$

Q6) Write a detailed note on the following: **(5X2 = 10)**

(i) Ideal and Non-ideal solutions

(ii) Fugacity

(iii) Chemical potential and phase equilibrium

(iv) Vapour-liquid equilibrium

(v) PVT behaviour of pure substances

Q7) Attempt all the five questions **(5x2 = 10)**

(i) Given that K (equilibrium constant) = 0.5 for the reaction

Glucose-6-phosphate ⇌ Fructose-6-phosphate

Calculate the concentration of Fructose-6-phosphate at the equilibrium if the initial concentrations of the reactant and the product are 1M

(ii) For the enzyme catalysed reaction given below, K = 19 at 25°C.

Glucose-1-phosphate ⇌ Glucose-6-phosphate

What will be the direction of reaction (forward or backward) if we start the reaction with (a) 1M of reactant and product, (b) 1mM G1P and 19 mM G6P, (c) 1mM G1P and 30 mM G6P

(iii) What are fluids and how they can be classified?

(iv) Derive Bernoulli's equation

(v) Differentiate between laminar and turbulent flow.