UNIVERSITY OF GHANA

FACULTY OF ENGINEERING SCIENCE

BSc. (Eng) MATERIALS SCIENCE AND ENGINEERING

SECOND SEMESTER EXAMINATIONS 2013/2014

MTEN 204-THERMODYNAMICS OF MATERIALS (2 CREDITS)

TIME- 2Hrs 30 min

ANSWER ALL QUESTIONS

1.

a) State and explain the three (3) laws of thermodynamics **(6 marks)**

b) Briefly discuss the following terms associated with thermodynamics: **(6 marks)**
(a) Internal energy, (b) Black body, (c) Thermal conductivity, (d) specific heat capacity, (e) Latent heat of fusion, and (f) Latent heat of vaporization.

c) Assuming that nitrogen behaves as a van der Waals gas with **a** = $(1.391)^2$ atm/mole^2 and **b** = 39.1 cm^3/mole, calculate the change in the Gibbs free energy and the change in entropy when the volume of 1 mole of nitrogen is increased from 1 to 2 litres at 400K. What will be the changes in Gibbs free energy and entropy if the nitrogen gas were to behave as an ideal gas? **(8 marks)**

d) A glass rod is heated and then blown by a glass blower. When it is at 185°C it is brought outside to cool. 3200 J of heat is transferred from the glass to the air, which is at 18°C. Find the change in entropy of the universe. **(5 marks)**

2.

a) Air is contained in an insulated, rigid volume at 20°C and 200 kPa. A paddle wheel, inserted in the volume, does 720 kJ of work on the air. If the volume is 2m^3, calculate the entropy increase assuming constant specific heats, a zero heat transfer and take the gas constant for air R_{air} = 0.287 kJ/kg. **(8 marks)**

b) Briefly explain the following terms: system, closed system and open system. **(6 marks)**

c) Given that the standard free energies of formation $\Delta G°_f$ of the following substances are $CH_4(g)$ = -50.5, $O_2(g)$ = 0.0, $CO_2(g)$ = -394.4, $H_2O(g)$ = -228.6, $O_3(g)$ = 163.2, calculate $\Delta G°$ at 25°C for the reaction $\mathbf{CH_{4(g)} + 8O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)} + 4\ O_{3(g)}}$ **(6 marks)**

d) A 2200-kg vehicle traveling at 90 km/h (25 m/s) hits the rear of a stationary, 1000-kg vehicle. After the collision the large vehicle slows to 50 km/h (13.89 m/s), and the smaller

vehicle now has a speed of 88 km/h (24.44 m/s). What has been the increase in internal energy, taking both vehicles as the system? **(5 marks)**

3.

a) Briefly describe with real life situations of the 3 main heat transfer processes. (6 marks)

b) State the energy balance law for a closed system. **(4 marks)**

c) An air tank with a volume of 20 m^3 is pressurized to 10 MPa. The tank eventually reaches room temperature of 25°C. If the air is allowed to escape with no heat transfer until $P_f = 200$ kPa, determine the mass of air remaining in the tank and the final temperature of air in the tank. **(8 marks)**

d) Under nonstandard conditions, $\Delta G = \Delta G^\circ + RT\ln Q$, where Q is the reaction quotient and the gas constant R = 8.314 J/K. Calculate ΔG at 427°C for the reaction below if the P_{N2} = 33.0 atm, P_{H2}= 99.0 atm, and P_{NH3}= 2.0 atm: $\mathbf{N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)}$.
Take the standard entropies S°, as: ($NH_3(g)$=192.8 J/mol·K, $N_2(g)$ =191.5 J/mol·K, $H_2(g)$ =130.58 J/mol·K), and the standard enthalpies H° as; $NH_3(g)$=-46.19 J, $N_2(g)$ =0 J, $H_2(g)$ =0 J/mol·K. **(7 marks)**

4.

a) Systems can be described from the macroscopic and microscopic points of view. Briefly discuss these 2 viewpoints. **(6 marks)**

b) Superman vaporizes an 1800 kg ice monster with his heat ray vision. The ice monster was at -20 °C. After being vaporized he is turned into steam at 135 °C. How much energy did Superman expend? Take the following into consideration:_Specific Heat capacity of (ice =2090 J/kg °C, liquid water = 4186 J/kg °C, steam = 1970 J/kg °C) and also take for water: $L_f = 3.33 \times 10^5$ J/Kg; $L_v = 2.26 \times 10^6$ J/Kg **(6 marks)**

c) Calculate ΔS° for the reaction;
$\mathbf{4NH_{3(g)} + 5O_{2(g)} \rightarrow 4NO_{(g)} + 6H_2O_{(l)}}$.
The standard entropies S°, are given as: $NH_3(g)$ =192.8 J/mol·K, $O_2(g)$ =205.2 J/mol·K, NO(g) =210.8 J/mol·K, $H_2O(g)$= 188.8 J/mol·K **(6 marks)**

d) The reactions $\mathbf{SO_{2(g)} + \frac{1}{2}\ O_{2(g)} \rightarrow SO_{3(g)}}$ has ΔH° = -98.9 kJ and ΔS° = -94.0 J/K at 25°C. Calculate ΔG° at 125°C and determine if it is spontaneous. **(7 marks)**

Examiner: Dr. David Dodoo-Arhin