



**NATIONAL OPEN UNIVERSITY OF NIGERIA**

14/16, Ahmadu Bello Way, Victoria Island

**SCHOOL OF SCIENCE AND TECHNOLOGY**

**October, 2013 Examination**

**Course Code: CHM 301**

**TIME: 3 Hours**

**Course Title: PHYSICAL CHEMISTRY III**

**Instruction: Answer any five questions**

1. (a) (i) What is a state property? (2 marks)
- (ii) Give four examples. ( $\frac{1}{2}$  mark each) (2 marks)
- (b) State the first law of thermodynamics (2 marks)
- (c) Describe briefly the types of system that exist in chemical thermodynamics. (6 marks)
- (d) A gas expands from  $10 \text{ m}^3$  to  $12 \text{ m}^3$  against a constant pressure of 1 bar ( $1 \times 10^5 \text{ N m}^{-2}$ ) at 298 K. What is the work done on the gas? (3 marks)
2. (a) Distinguish between an 'extensive variable' and an 'intensive variable'. (4 marks)
- (b) Write short notes on each of the followings: ( $1\frac{1}{2}$  marks each) ( $7\frac{1}{2}$  marks)
  - (i) Isothermal process
  - (ii) Adiabatic process
  - (iii) Isobaric process
  - (iv) Isochoric process
  - (v) Cyclic process
- (c) Calculate the work that must be done at S.T.P to make room for the products of octane combustion. G.M.V at S.T.P =  $22.4 \text{ dm}^3 \text{ mol}^{-1}$ . Standard pressure =  $1 \times 10^5 \text{ Nm}^{-2}$ . (3 marks)
3. (a) State the second law of thermodynamics (3 marks)
- (b) Calculate the change in the entropy of 100 g of water when it freezes at  $0^\circ \text{C}$  in a refrigerator ice tray.  $S^\circ (\text{ice}) = 43.2 \text{ J K}^{-1} \text{ mol}^{-1}$  and  $S^\circ (\text{water}) = 65.2 \text{ J K}^{-1} \text{ mol}^{-1}$ . (4 marks)
- (c) The enthalpy of vaporization of a substance is  $72 \text{ J mol}^{-1}$  and its boiling point is  $-73^\circ \text{C}$ . Calculate the entropy of vaporization. (3 marks)
- (d) Predict the sign of the entropy change for these processes: (1 mark each) (4 marks)
  - (i)  $\text{SF}_4(\text{g}) + \text{F}_2(\text{g}) \rightarrow \text{SF}_6(\text{g})$
  - (ii)  $\text{H}_2\text{S}(\text{g}) + \text{NH}_3(\text{g}) \rightarrow \text{NH}_4\text{HS}(\text{s})$
  - (iii)  $\text{O}_2(\text{g}) + (\text{at } 400 \text{ K}) \rightarrow \text{O}_2(\text{g}) (\text{at } 800 \text{ K})$
  - (iv)  $\text{CH}_3\text{OH}(\text{l}) \rightarrow \text{CH}_3\text{OH}(\text{g})$

4. (a) Define the term 'standard enthalpy of reaction'.  
(2 marks)
- (b) The combustion of propane is described by the equation  
(3 marks)  

$$\text{C}_3\text{H}_8(g) + 5\text{O}_2(g) \rightarrow 3\text{CO}_2(g) + 4\text{H}_2\text{O}(l) \Delta H = -2220 \text{ kJ}.$$
 Calculate the mass of propane that must be burned to obtain 350 kJ of heat.
- (c) Calculate  $\Delta H$  for the reaction:  $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ ; given the bond dissociation energies: N-  
 $\text{N} = 163 \text{ kJ mol}^{-1}$ ;  $\text{H-H} = 436 \text{ kJ mol}^{-1}$ ;  $\text{N-H} = 391 \text{ kJ mol}^{-1}$  (5 marks)
- (d) True or False? (1 mark each)  
 (4 mark)
- i) water flows down the hill spontaneously  
 ii) a gas cannot expand spontaneously into vacuum  
 iii) heat is conducted spontaneously from the hot end of a metal bar to the colder end until the temperature of the bar is same throughout  
 iv) a gas diffuses spontaneously into another gas.

5. (a) Given the following information: (1½ each) (3 marks)



Calculate  $\Delta H$  for the reactions: (i)  $\text{A} + \text{B} \rightarrow \text{E}$  (ii)  $\text{A} + \text{B} + \text{E} \rightarrow 2\text{C} + 2\text{D}$

- (b) Copy and complete the following table: (6 marks)

$\Delta H$	$\Delta S$	Temperature	Reaction
-	positive	Any temperature	Spontaneous
positive	negative	Any temperature	-
positive	positive	-	Spontaneous
positive	positive	-	Non-spontaneous
negative	negative	Low temperature	-
negative	negative	High temperature	-

- (c) Calculate the standard free energy of formation of  $\text{HI}(g)$  at  $25^\circ\text{C}$  from its standard entropy and its standard enthalpy of formation, given the following information:

$$\Delta H_f^\circ(\text{HI}, g) = 26.48 \text{ kJ}; \quad \Delta H_f^\circ(\text{H}_2, g) = 0; \quad \Delta H_f^\circ(\text{I}_2, g) = 0.$$

$$S^\circ(\text{HI}, g) = 206.6 \text{ J K}^{-1}; \quad S^\circ(\text{H}_2, g) = 130.7 \text{ J K}^{-1}; \quad S^\circ(\text{I}_2, g) = 116.1 \text{ J K}^{-1}.$$

(5 marks)

6. (a) Describe briefly what you understand by the term "Absolute zero (temperature)" (4 marks)

- (b) Answer these questions: (1 mark each) (5 marks)

(i) The total energy of the universe is constant. This is a statement of the \_\_\_\_\_ law of

thermodynamics

(ii) The change in entropy for any process is not dependent upon the pathway by which the

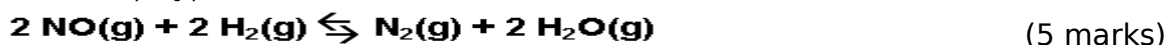
process occurs. In other words, the change in entropy for any process is a function

(iii) Refractive index is an intensive property. True or false

(iv) The energy required to cook your meals is an extensive property. True or false

(v) In a closed system, heat neither leaves nor enters. True or false

(c) Initially, a mixture of 0.100 M NO, 0.050 M H<sub>2</sub>, 0.100 M H<sub>2</sub>O was allowed to reach equilibrium (initially there was no N<sub>2</sub>). At equilibrium the concentration of NO was found to be 0.062 M. Determine the value of the equilibrium constant, K<sub>c</sub>, for the reaction:



7. (a) (i) What are colligative properties? (3 marks)

(ii) Give two examples of colligative properties (2 marks)

(b) What is the total volume of the solution, when 3.80 mol of water is mixed with 0.500 mol of ethanol? The partial molar volumes of water and ethanol at this composition are  $1.80 \times 10^{-5} \text{ m}^3 \text{ mol}^{-1}$  and  $5.34 \times 10^{-5} \text{ m}^3 \text{ mol}^{-1}$ , respectively.

(4 marks)

(c) Calculate the molecular mass of 9.21g non-volatile organic compound, dissolved in 50g

of pure water at 25°C, which depresses the vapour pressure of the water from  $3.16 \times 10^3$  to  $3.10 \times 10^3 \text{ Nm}^{-2}$ . (5 marks)