NATIONAL OPEN UNIVERSITY OF NIGERIA PLOT 91, CADASTRAL ZONE, NNAMDI AZIKIWE EXPRESSWAY, JABI – ABUJA
FACULTY OF SCIENCES
DEPARTMENT OF CHEMISTRY
2025_1 EXAMINATION

COURSE CODE: CHM 405
COURSE TITLE: CHEMICAL THERMODYNAMICS
COURSE UNIT: 2
INSTRUCTION: Answer question one (1) and any other two questions
Time Allowed: Two (2) Hours

1 (a) A salt is composed of cation, M^+ and anion X^-, and perfectly dissociate when dissolved in water. 2.0 g of this salt was dissolved in 100 g of water. The freezing point of the salt solution was determined to be 1.3^{o}C. Calculate the formula mass of the solute if the molar freezing point depression is 1.24 Kkg/mol. (7 marks)
(b) Define Statistical thermodynamics (2 marks)
1 . (c) For a change in volume from 0.6 to 1.2 m^3 with a corresponding changes in pressure from 101325 to 65000 Pa, find the ratio of heat capacity at constant pressure to heat capacity at constant volume [redacted]. (10 marks)
(d) Show that the total entropy change in a Carnot cycle is zero (3 marks)
(e) Give the major differences between the following:
Extensive property and intensive property of a system (4 marks)
Constant chemical potential process and a constant particle number process
(4 marks)

2. (a) (i) Define Chemical potential - particle number (2 marks) (ii) describe the two classes of chemical-particle number process. (6 marks)
2. (b) Describe the Joule Thompson Experiment and write an expression for the Joule Thompson coefficient. (5 marks)
2. (c) The Table below shows the lattice enthalpy of sodium halides obtained from Born-Haber cycle and ionic model methods

Compound	Born-Haber	Ionic model	% Difference
NaI	705	682	3.3
NaBr	754	732	2.9

Explain why there is a difference between the lattice energies obtained from the two methods for of each compound. (4 marks)
From the Born Haber cycle values of lattice enthalpy, explain the reason why the lattice enthalpy of NaI is lesser than NaBr. (3 marks)

3. (a) Define the term 'enthalpy change of combustion'. (2 marks)
3. (b) What is the heat of combustion of ethanol when 0.55 g of ethanol was used to burn 250 g of water in the copper calorimeter resulting into a temperature of 10^{o}C, (Heat capacity of water = 4.18). (6 marks)
3.(c)(i) State the Carnot theorem. (2 marks)

(ii) Explain why the work done in a cyclic process is equal to the heat absorbed. (4 marks)
3. (d). From the first law of thermodynamics $\Delta U = q + W$, (i) show that the heat absorbed at constant pressure is equal to the change in enthalpy. Hint: W= -pdV (6 marks)

4. (a)(i) State the third law of thermodynamics and list the major limitations of the third law
(5 marks)
(a)(ii) State the zeroth law of thermodynamics (2 marks)
4. (b) What are Maxwell Equations? (2 marks)
4. (c) The following reaction occurs in the high-temperature preparation of titanium (IV) chloride.

$TiO_2(s) + C(s) + 2Cl_2(g) \rightarrow TiCl_4(l) + CO_2(g)$

Use the data given below to calculate the standard enthalpy change and the standard entropy change for this reaction. (6 marks)

Substance	$TiO_2(s)$	C(s)	$Cl_2(g)$	$TiCl_4(l)$	$CO_2(g)$
ΔH_f^o/ kJ mol^{-1}	–940	0	0	–804	–394
ΔS^o/ J $K^{-1}mol^{-1}$	49.9	5.7	223	252	

Calculate the temperature at which this reaction ceases to be feasible. (3 marks)
4. (d) What is the usefulness of Born-Haber cycle in thermochemistry? (2 marks)

5 (a) Define chemical potential (2 marks)
5.(b) The probability of finding a system in the ith quantum state with energy E_i is proportional to the Boltzman factor (exp(-E_i/kT)) and can be expressed as follows,

$$\boldsymbol{P_i = ce^{-E_{i/kT}}}$$

What does each term in the above equation represent and what is the value of k? (4 marks)
5.(c) State two (2) major difference between Maxwell-Boltzmann and Fermi-Dirac statistics. (4 marks)
5.(d) Given:

$$\Delta G_{mix} = n_A RT ln X_A + n_B RT ln X_B$$

Calculate the free energy of mixing gases A and B if their number of moles are 0.60 and 0.54 respectively. Hence state with reason, whether the mixing is spontaneous or not. (10 marks)