Tutorial 3

- Dulong-Petit, Einstein, and Debye's theories of specific heat of solids; Maxwell relations and applications;
- Clausius- Clapeyron equation;
- Adiabatic demagnetisation,
- Joule-Kelvin effect and liquefaction of gases.

Q1:

Explain the four thermodynamic relations of Maxwell. Using the same, obtain the Clausius-Clapeyron equation *15*

$$\frac{dP}{dT} = \frac{L}{T(V_2 - V_1)}.$$

2014

Q2:

A Van der Waals gas undergoes Joule-Kelvin expansion with a pressure drop of 50 atm. If its initial temperature is 300°K, determine its final temperature. (Given Van der Waals constant $a = 0{\cdot}136$ Pa m^6 mol^{-1}, $b = 36{\cdot}5 \times 10^{-6}$ m^3 mol^{-1}, $C_p = 30$ J K^{-1} mol^{-1}, $R = 8{\cdot}3$ J K^{-1} mol^{-1}) *10*

2015

Q3:

The vapour pressure of an organic substance is 50×10^3 Pa at 40°C. Its normal boiling point is 80°C. If the substance in vapour phase can be treated like an ideal gas, find the latent heat of vaporization of the substance. *15*

2015

Q4:

Derive Clausius-Clapeyron equation. How does it explain the effect of pressure on melting point of solids and boiling point of liquids? 10

2017

Q5:

Einstein's molar specific heat capacity of a solid is given by

$$C_V = 3R\left(\frac{\theta_E}{T}\right)^2 \frac{e^{\theta_E/T}}{(e^{\theta_E/T} - 1)^2},$$

where $\theta_E = \dfrac{\hbar\omega}{k_B}$

Obtain the expressions for the cases :

(i) when $T >> \theta_E$

(ii) when $T << \theta_E$

What is the discrepancy of Einstein model to explain the variation of specific heat capacities of solids with the temperature ?

The molar specific heat capacity of a solid at constant volume is $2{\cdot}77\ JK^{-1}$ at $36{\cdot}8$ K. Determine the Debye temperature of the solid. *20*

2019

Q6:

Explain the effect of pressure on the melting and boiling points of a substance using Clapeyron's latent heat equation.

Calculate under what pressure, water will boil at 120°C, if the change in specific volume when 1 gram of water is converted into steam is $1676\ cm^3$. Latent heat of steam = 540 cal/g, 1 atmospheric pressure = 10^6 dynes/cm^2. *15*

2019

Q7:

Discuss the principle of adiabatic demagnetization process to achieve low temperatures.

Determine the fall in temperature produced by adiabatic demagnetization of a paramagnetic material at initial temperature of 3 K when the magnetic field is switched off from 10,000 oersted to zero. Given : heat capacity at constant magnetic field = $0{\cdot}2\ J\ g^{-1}\ K^{-1}$ and Curie constant per gram mole per cm^3 = $0{\cdot}042$ erg $K^{-1}\ g^{-1}\ Oe^{-2}$. *15*

2020

Q8:

Obtain the Clausius-Clapeyron equation. Using this equation, show that for the phase boundary of the liquid and vapour phases, p–T relation can be written as $p = p_0\, e^{-L/kT}$. Here it has been assumed that the latent heat L is independent of temperature, that vapour is treated as an ideal gas and that $V_{vapour} = V >> V_{liquid}$ and that $p \to p_0$ as $T \to \infty$. *15*

2020

Q9:

(i) Define Joule-Kelvin coefficient. Write it in its mathematical form. *5*

(ii) Determine the Joule-Kelvin coefficient for a van der Waals gas. Hence, obtain an expression for temperature of inversion. Discuss the conditions under which heating or cooling is produced. *10*

2023

Q10.

Define internal energy *U*, Helmholtz's function *F*, enthalpy *H*, Gibbs' potential *G* and hence obtain the four Maxwell's thermodynamic relations. 20

2024