Tutorial 2

- Gibbs' phase rule and chemical potential;
- van der Waals equation of state of a real gas,
- critical constants;
- Maxwell-Boltzmann distribution of molecular velocities,
- transport phenomena,
- equipartition and virial theorems;

Q1:

The vapour pressure, in mm of Hg, of a substance in solid state is given by the relation $ln\ p = 23{\cdot}03 - \frac{3754}{T}$, where T is in Kelvin. The vapour pressure, in mm of Hg, of the substance in liquid state is given by the relation $ln\ p = 19{\cdot}49 - \frac{3063}{T}$. Calculate (i) the coordinates of the triple point, and (ii) the latent heat of vaporisation at the triple point. Take Gas constant $R = 8{\cdot}314\ J\ mol^{-1}\ K^{-1}$. *15*

2013

Q2:

The coefficient of viscosity of helium at 27°C is 2×10^{-5} kg $m^{-1}\ s^{-1}$. Calculate (i) the average speed and (ii) the diameter of a helium molecule, if it is assumed that the gas obeys Maxwell – Boltzmann distribution. Given Boltzmann constant $k_B = 1{\cdot}38 \times 10^{-23}\ J\ K^{-1}$ and mass of helium atom $= 6{\cdot}67 \times 10^{-27}$ kg. *10*

2013

Q3:

Define Enthalpy and show that it remains constant in a throttling process. ***10***

2014

Q4:

Consider a system of free gas particles having f degrees of freedom. Use equipartition theorem to establish the relation

$$f = \frac{2}{\left(\frac{C_p}{C_V} - 1\right)},$$

where C_p and C_V are molar specific heats at constant pressure and constant volume respectively. Obtain the values of $\frac{C_p}{C_V}$ for diatomic and triatomic gases. *15*

2014

Q5:

For a Van der Waals gas, write down the equation of state. Determine the coefficient of critical expansion β. *15*

2015

Q6:

The molecules of a gas obey Maxwell-Boltzmann distribution. Calculate the fraction of molecules of the gas within 1% of the most probable speed at STP. Interpret your result. 10

2016

Q7:

Write down van der Waals' equation of state for n moles of a gas and calculate the temperature at which 5 moles of the gas at 5 atm pressure will occupy a volume of 20 litres.
Given, $R = 8 \cdot 31 \times 10^7$ erg $\text{mol}^{-1}\ \text{K}^{-1}$, $a = 1 \cdot 34 \times 10^{12}$ dyne $\text{cm}^4\ \text{mol}^{-2}$, $b = 31 \cdot 2\ \text{cm}^3\ \text{mol}^{-1}$ and $1\ \text{atm} = 1 \cdot 013 \times 10^6$ dyne cm^{-2}. 10

2016

Q8:

What do you understand by the term 'phase transition'? Using Clausius-Clapeyron equation, show that for first-order phase transitions, vapour pressure decreases exponentially with temperature. You can assume that the vapour behaves like an ideal gas and latent heat remains constant with temperature. 15

2016

Q9:

The viscosity in a liquid arises due to friction between adjacent layers. What causes viscosity in a gas? Explain. 5

The molecules of a gas obeying Maxwell-Boltzmann distribution move with an average speed of 450 m s^{-1}. If the coefficient of viscosity of the gas η is $16 \cdot 6 \times 10^{-6}$ N s m^{-2}, density of the gas ρ is $1 \cdot 25$ kg m^{-3} and number density is $2 \cdot 7 \times 10^{25}$ m^{-3}, calculate the mean free path and diameter of the gas molecules. 10

2016

Q10:

Write and explain the Maxwell-Boltzmann distribution. Using this distribution, find the expressions for the most probable speed, mean speed and root-mean-square speed. 15

2017

Q11:

Calculate the critical temperature for helium, given the values for critical constants, $a = 6 \cdot 15 \times 10^{-5}$, $b = 9 \cdot 95 \times 10^{-4}$, where the unit of pressure is atm and the sample is kept at NTP. 10

2017

Q12:

One mole of a gas obeys the following equation of state :

$$\left(P + \frac{a}{v^2}\right)(v - b) = RT,$$

where v is the molar volume and, a and b are constants.
Show that internal energy of the gas increases as the volume increases, with the temperature remaining constant. *10*

2018

Q13:

At 4°C temperature, the density of water is found to be maximum. Prove that heat capacity at the constant pressure (c_p) is equal to the heat capacity at constant volume (c_v) for water at 4°C. *10*

2018

Q14:

What are the conditions for the change in temperature of a van der Waals gas passing through a porous plug ? Prove that the ideal gas passing through the porous plug does not show any change in temperature. *10*

2019

Q15:

What is Gibbs' phase rule ? Find the values of degrees of freedom when

(i) केवल तरल CO_2, गैसीय CO_2 के साथ संतुलन में है ।
only the liquid CO_2 is in equilibrium with the gaseous CO_2.

(ii) जल, वाष्प-तरल संतृप्ति क्षेत्र में है ।
water is in the vapour-liquid saturation region.

(iii) जल, एकल-प्रावस्था क्षेत्र में है ।
water is in a single-phase region.

(iv) जल, त्रिक (ट्रिपल) बिन्दु पर है ।
water is at the triple point. *15*

2019

Q16:

Starting from Maxwell-Boltzmann distribution for a free particle in 3-dimension, obtain the expression for root mean square (rms) speed of a particle. Calculate the rms speed of nitrogen (N_2) molecule at room temperature (27°C). *20*

2020

Q17:

Calculate the critical constants for CO_2 for which the Van der Waals constants are given by a = 0·0072 and b = 0·002. Also calculate the Boyle's temperature of CO_2. The unit of pressure is atmosphere and the unit of volume is that of a gm-mole of the gas at NTP. *10*

2021

Q18:

Assume that the Earth's atmosphere is pure nitrogen in thermodynamic equilibrium at a temperature of 300 K. Calculate the height above sea level at which the density of the atmosphere is one-half its sea level value. (Molecular weight of N_2 is 28 gm/mole) 10

2022

Q19:

One mole of gas obeys van der Waals equation of state. If its molar internal energy is given by $u = cT - a/V$ (in which V is the molar volume, a is one of the constants in the equation of state and c is a constant), calculate the molar heat capacities C_v and C_p. 10

2022

Q20:

Use the Maxwell-Boltzmann distribution to find the number of oxygen molecules whose velocities lie between 195 m/s and 205 m/s at 0°C. The given mass of oxygen gas is 0·1 kg. (Assume mass of proton to be $1{\cdot}66 \times 10^{-27}$ kg) *15*

2023

Q21.

A ternary system consists of three components (A, B and C) in equilibrium with two phases. Determine the number of degrees of freedom using the Gibb's phase rule and discuss the effect of pressure and temperature variations on the phase equilibrium. *15*

2025

Q22.

Discuss briefly the considerations which led Van der Waals to modify the gas equation. What are the critical constants of a gas ? Calculate the values of these constants in terms of the constants of the Van der Waals equation. *15*

2025

Q23.

Explain why, at equilibrium, the chemical potential of a component must be the same in all coexisting phases. Derive the equilibrium condition for a binary liquid-vapour system in terms of chemical potential. *15*

2025