MCQs on Laws of Thermodynamics

◆ Zeroth Law of Thermodynamics

1. Zeroth law of thermodynamics establishes the concept of:
A) Heat
B) Work
C) Temperature
D) Energy
Answer: C

2. If body A is in thermal equilibrium with B, and B with C, then A is in thermal equilibrium with C. This statement represents:
A) First Law
B) Zeroth Law
C) Second Law
D) Third Law
Answer: B

3. The physical quantity that determines thermal equilibrium is:
A) Pressure
B) Volume
C) Temperature
D) Entropy
Answer: C

◆ First Law of Thermodynamics

4. First law of thermodynamics is based on conservation of:
A) Mass
B) Momentum
C) Energy
D) Entropy
Answer: C

5. Mathematical form of first law is:
A) $Q = W$
B) $\Delta Q = \Delta W$
C) $Q = \Delta U + W$
D) $Q = \Delta U - W$
Answer: C

6. Internal energy of an ideal gas depends only on:
A) Pressure
B) Volume
C) Temperature
D) Entropy
Answer: C

7. If heat supplied equals work done, change in internal energy is:
A) Positive
B) Negative
C) Zero
D) Infinite
Answer: C

8. Unit of internal energy is:
A) Joule
B) Watt
C) Kelvin
D) Pascal
Answer: A

◆ **Thermodynamic Processes**

9. In isothermal process, temperature remains:
A) Constant
B) Zero
C) Increasing
D) Decreasing
Answer: A

10. In adiabatic process:
A) $Q = 0$
B) $W = 0$
C) $\Delta U = 0$
D) $T =$ constant
Answer: A

11. For isothermal process of ideal gas, PV =
A) Constant
B) Zero
C) γ
D) T
Answer: A

12. For adiabatic process:
A) PV = constant
B) PV^γ = constant
C) P/T = constant
D) V/T = constant
Answer: B

13. In isochoric process:
A) Pressure constant
B) Volume constant
C) Temperature constant
D) Heat zero
Answer: B

14. In isobaric process:
A) P constant
B) V constant
C) T constant
D) Q constant
Answer: A

◆ **Relation Between CP and CV**

15. CP – CV equals:
A) γ
B) R
C) PV
D) T
Answer: B

16. γ (gamma) is defined as:
A) CP – CV
B) CP + CV
C) CP/CV
D) CV/CP
Answer: C

17. For monoatomic gas, γ equals:
A) 1
B) 1.4
C) 1.67
D) 1.33
Answer: C

◆ **Work Done**

18. Work done in isothermal process is:
A) PV
B) nRT ln(V2/V1)
C) γPV
D) Zero
Answer: B

19. Work done in adiabatic process depends on:
A) Temperature only
B) Pressure only
C) Initial and final states
D) Heat supplied
Answer: C

20. In free expansion of gas, work done is:
A) Maximum
B) Minimum
C) Zero
D) Infinite
Answer: C

◆ **Compressibility & Expansion Coefficient**

21. Coefficient of volume expansion is:
A) (1/V)(dV/dT)
B) (1/P)(dP/dT)
C) (1/T)(dT/dV)
D) (1/V)(dT/dV)
Answer: A

22. Compressibility is defined as:
A) (1/V)(dV/dP)
B) (1/P)(dP/dV)
C) (1/T)(dT/dP)
D) (1/V)(dP/dV)
Answer: A

◆ **Reversible & Irreversible Processes**

23. Reversible process occurs:
A) Rapidly
B) Slowly
C) Suddenly
D) Spontaneously
Answer: B

24. Entropy change in reversible process is:
A) Maximum
B) Minimum
C) Zero
D) Negative
Answer: C

25. Free expansion is an example of:
A) Reversible
B) Irreversible
C) Isothermal
D) Adiabatic reversible
Answer: B

◆ Second Law of Thermodynamics

26. Second law introduces the concept of:
A) Heat
B) Work
C) Entropy
D) Temperature
Answer: C

27. Kelvin-Planck statement is related to:
A) First law
B) Heat engine
C) Entropy
D) Temperature
Answer: B

28. Clausius statement deals with:
A) Heat flow
B) Work
C) Pressure
D) Volume
Answer: A

29. Heat cannot flow from cold to hot body without:
A) Temperature
B) Pressure
C) External work
D) Entropy
Answer: C

◆ **Carnot Cycle & Theorem**

30. Carnot engine efficiency depends on:
A) Working substance
B) Temperature of reservoirs
C) Pressure
D) Volume
Answer: B

31. Carnot efficiency =
A) 1 – T2/T1
B) T2/T1
C) T1/T2
D) 1 + T2/T1
Answer: A

32. Carnot cycle consists of:
A) 2 processes
B) 3 processes
C) 4 processes
D) 5 processes
Answer: C

33. Carnot engine is:
A) Irreversible
B) Real engine
C) Ideal reversible engine
D) Diesel engine
Answer: C

◆ **Entropy**

34. Entropy is a measure of:
A) Energy
B) Disorder

C) Pressure
D) Volume
Answer: B

35. Unit of entropy is:
A) Joule
B) J/K
C) Watt
D) Pascal
Answer: B

36. Entropy change formula is:
A) $\Delta S = Q$
B) $\Delta S = Q/T$
C) $\Delta S = T/Q$
D) $\Delta S = W/T$
Answer: B

37. Entropy of isolated system always:
A) Decreases
B) Increases
C) Constant
D) Zero
Answer: B

38. Entropy-temperature diagram represents:
A) P-V graph
B) T-S graph
C) P-T graph
D) V-T graph
Answer: B

◆ Third Law of Thermodynamics

39. Third law states that entropy at absolute zero is:
A) Infinite
B) Zero
C) Maximum
D) Undefined
Answer: B

40. Absolute zero temperature is:
A) 0°C
B) 273 K

C) –273°C
D) 100 K
Answer: C

41. Unattainability principle states:
A) 0 K cannot be reached
B) Heat cannot convert fully
C) Work cannot be zero
D) Entropy decreases
Answer: A

◆ **Mixed Conceptual Questions**

42. Efficiency of 100% is impossible due to:
A) First law
B) Second law
C) Zeroth law
D) Third law
Answer: B

43. In adiabatic process temperature:
A) Constant
B) Changes
C) Zero
D) Infinite
Answer: B

44. For ideal gas, internal energy change in isothermal process is:
A) Positive
B) Negative
C) Zero
D) Infinite
Answer: C

45. Entropy change in irreversible process is:
A) Zero
B) Negative
C) Positive
D) Constant
Answer: C

46. Most efficient engine is:
A) Diesel
B) Petrol

C) Carnot
D) Steam
Answer: C

47. Work done is maximum in:
A) Reversible process
B) Irreversible process
C) Isochoric process
D) Free expansion
Answer: A

48. In isochoric process work done is:
A) Maximum
B) Zero
C) Minimum
D) Infinite
Answer: B

49. CP is always:
A) Equal to CV
B) Less than CV
C) Greater than CV
D) Zero
Answer: C

50. Entropy is constant in:
A) Irreversible process
B) Adiabatic reversible process
C) Free expansion
D) Heat transfer
Answer: B

MCQs on Thermodynamical Potentials (Q.51–100)

🔷 Thermodynamic Potentials

51. Enthalpy (H) is defined as:
A) U – PV
B) U + PV
C) PV – U
D) T – S
Answer: B

52. Helmholtz free energy (F or A) is given by:
A) U + TS
B) U – TS
C) H – TS
D) H + TS
Answer: B

53. Gibbs free energy (G) is defined as:
A) U + PV
B) H – TS
C) U – TS
D) PV – TS
Answer: B

54. Internal energy is a function of:
A) T and V
B) P and V
C) T and P
D) S only
Answer: A

55. Enthalpy is most useful in processes at constant:
A) Volume
B) Temperature
C) Pressure
D) Entropy
Answer: C

56. Gibbs free energy is minimum at equilibrium for:
A) Constant T and P
B) Constant T and V
C) Constant S and V
D) Constant P and V
Answer: A

57. Helmholtz free energy is minimum at equilibrium for:
A) Constant T and P
B) Constant T and V
C) Constant P and V
D) Constant S
Answer: B

58. Natural variables of Gibbs function are:
A) T, V
B) S, V
C) T, P

D) P, V
Answer: C

59. Natural variables of Helmholtz function are:
A) T, V
B) T, P
C) S, P
D) S, V
Answer: A

60. dG equals:
A) SdT – VdP
B) –SdT + VdP
C) TdS – PdV
D) PdV – TdS
Answer: B

🔷 Maxwell's Relations

61. Number of Maxwell relations are:
A) 2
B) 3
C) 4
D) 5
Answer: C

62. Maxwell relations are derived from:
A) First law
B) Second law
C) Exact differentials
D) Zeroth law
Answer: C

63. One Maxwell relation is:
A) $(\partial T/\partial V)_s = -(\partial P/\partial S)_v$
B) $(\partial T/\partial V)_p = (\partial P/\partial T)_v$
C) $(\partial S/\partial V)_T = (\partial P/\partial T)_V$
D) $(\partial S/\partial T)_V = (\partial P/\partial V)_T$
Answer: C

64. Maxwell relations are useful to:
A) Measure entropy experimentally
B) Define temperature
C) Calculate work

D) Define heat
Answer: A

65. Maxwell relations connect thermodynamic:
A) Constants
B) Variables
C) Units
D) Laws
Answer: B

🔷 Joule-Thomson Effect

66. Joule-Thomson process occurs at constant:
A) Volume
B) Temperature
C) Enthalpy
D) Entropy
Answer: C

67. Joule-Thomson coefficient is:
A) $(\partial T/\partial P)H$
B) $(\partial P/\partial T)H$
C) $(\partial V/\partial T)P$
D) $(\partial S/\partial T)V$
Answer: A

68. For ideal gas, Joule-Thomson coefficient is:
A) Positive
B) Negative
C) Zero
D) Infinite
Answer: C

69. Inversion temperature is the temperature at which:
A) $\mu JT = 0$
B) $P = 0$
C) $V = 0$
D) $S = 0$
Answer: A

70. Joule-Thomson effect is used in:
A) Engines
B) Refrigeration
C) Heating

D) Combustion
Answer: B

◆ Clausius-Clapeyron Equation

71. Clausius-Clapeyron equation is used for:
A) Ideal gas law
B) Phase transition
C) Entropy change
D) Work calculation
Answer: B

72. It relates pressure with:
A) Volume
B) Temperature
C) Entropy
D) Energy
Answer: B

73. Latent heat appears in:
A) Maxwell relation
B) Joule law
C) Clausius-Clapeyron equation
D) First law
Answer: C

74. dP/dT equals:
A) $L / T\Delta V$
B) $T\Delta V / L$
C) $L\Delta V$
D) T/L
Answer: A

75. Clausius-Clapeyron equation is derived from:
A) First law
B) Second law
C) Third law
D) Zeroth law
Answer: B

🔷 Expression for (CP – CV)

76. CP – CV for ideal gas equals:
A) γ
B) R
C) PV
D) T
Answer: B

77. CP is always:
A) < CV
B) > CV
C) = CV
D) 0
Answer: B

78. Ratio CP/CV is denoted by:
A) R
B) μ
C) γ
D) β
Answer: C

79. For diatomic gas, γ ≈
A) 1.67
B) 1.4
C) 1
D) 2
Answer: B

80. Expression of CP – CV involves:
A) Compressibility
B) Expansion coefficient
C) Both A and B
D) None
Answer: C

🔷 TdS Equations

81. First TdS equation is:
A) TdS = dU + PdV
B) TdS = dU – PdV
C) TdS = dH + VdP

D) TdS = PdV
Answer: A

82. Second TdS equation is:
A) TdS = dH – VdP
B) TdS = dH + VdP
C) TdS = dU
D) TdS = PdV
Answer: A

83. TdS equations are derived using:
A) First and Second law
B) Zeroth law
C) Third law
D) Boyle’s law
Answer: A

84. TdS equations are useful in finding:
A) Entropy change
B) Pressure
C) Volume
D) Work
Answer: A

🔷 Mixed Conceptual Questions

85. Gibbs free energy change at equilibrium is:
A) Positive
B) Negative
C) Zero
D) Infinite
Answer: C

86. If G decreases, process is:
A) Non-spontaneous
B) Spontaneous
C) Reversible
D) Isothermal
Answer: B

87. Helmholtz energy is useful in:
A) Open system
B) Closed system
C) Constant volume system

D) Constant pressure system
Answer: C

88. Enthalpy change at constant pressure equals:
A) Work
B) Heat
C) Entropy
D) Volume
Answer: B

89. Maxwell relations reduce number of:
A) Equations
B) Experiments
C) Variables
D) Laws
Answer: B

90. Joule-Thomson cooling occurs when μJT is:
A) Zero
B) Positive
C) Negative
D) Infinite
Answer: B

91. Gibbs energy is minimum for stable:
A) Non-equilibrium
B) Equilibrium
C) Isothermal
D) Adiabatic
Answer: B

92. Clapeyron equation applies to:
A) Chemical reaction
B) Phase equilibrium
C) Gas laws
D) Heat engine
Answer: B

93. Natural variables of enthalpy are:
A) S, P
B) T, V
C) T, P
D) S, V
Answer: A

94. dU equals:
A) TdS – PdV
B) TdS + PdV
C) PdV
D) TdS
Answer: A

95. Joule-Thomson effect is significant for:
A) Ideal gas
B) Real gas
C) Vacuum
D) Plasma
Answer: B

96. Maxwell relations are based on equality of:
A) Mixed partial derivatives
B) Temperature
C) Pressure
D) Heat
Answer: A

97. Gibbs free energy is also called:
A) Available energy
B) Internal energy
C) Heat energy
D) Potential energy
Answer: A

98. Entropy remains constant in:
A) Irreversible adiabatic
B) Reversible adiabatic
C) Isothermal
D) Isochoric
Answer: B

99. At absolute zero, entropy is:
A) Maximum
B) Zero (perfect crystal)
C) Infinite
D) Negative
Answer: B

100. Thermodynamic potentials help determine:
A) Direction of process
B) Color of gas
C) Density only

D) Pressure only
Answer: A

MCQs on Kinetic Theory of Gases (101–150)

🔷 Maxwell's Distribution of Velocities

101. Maxwell's law describes distribution of:
A) Pressure
B) Energy
C) Molecular velocities
D) Temperature
Answer: C

102. Maxwell distribution is valid for:
A) Solids
B) Liquids
C) Ideal gases
D) Plasma only
Answer: C

103. The most probable speed corresponds to:
A) Maximum area
B) Peak of distribution curve
C) Minimum speed
D) Zero speed
Answer: B

104. Most probable speed (vp) is proportional to:
A) $\sqrt{T}$
B) T
C) 1/T
D) T^2
Answer: A

105. Maxwell distribution curve shifts towards right when:
A) Temperature decreases
B) Temperature increases
C) Pressure increases
D) Volume decreases
Answer: B

106. Area under Maxwell distribution curve represents:
A) Temperature

B) Pressure
C) Total number of molecules
D) Density
Answer: C

107. RMS speed is given by:
A) $\sqrt{(2RT/M)}$
B) $\sqrt{(3RT/M)}$
C) $\sqrt{(RT/M)}$
D) $3RT/M$
Answer: B

108. Relation between speeds is:
A) $v_p < v_{avg} < v_{rms}$
B) $v_{rms} < v_{avg} < v_p$
C) $v_{avg} < v_p < v_{rms}$
D) $v_p = v_{rms}$
Answer: A

109. Average speed is:
A) $\sqrt{(8RT/\pi M)}$
B) $\sqrt{(3RT/M)}$
C) $\sqrt{(2RT/M)}$
D) RT/M
Answer: A

110. Experimental verification of Maxwell distribution was done by:
A) Joule
B) Maxwell
C) Stern
D) Clausius
Answer: C

🔷 Mean Free Path (Zeroth Order)

111. Mean free path is average distance between:
A) Two collisions
B) Two temperatures
C) Two pressures
D) Two volumes
Answer: A

112. Mean free path is inversely proportional to:
A) Temperature

B) Pressure
C) Volume
D) Speed
Answer: B

113. Formula for mean free path is:
A) $1/(\sqrt{2}\,\pi\,d^2\,n)$
B) $\pi\,d^2\,n$
C) $\sqrt{2}\,\pi\,d^2$
D) $1/n$
Answer: A

114. If pressure increases, mean free path:
A) Increases
B) Decreases
C) Constant
D) Infinite
Answer: B

115. Larger molecular diameter results in:
A) Larger mean free path
B) Smaller mean free path
C) No change
D) Infinite path
Answer: B

🔷 Transport Phenomena – Viscosity

116. Viscosity in gases is due to:
A) Collisions
B) Gravity
C) Pressure
D) Temperature only
Answer: A

117. Coefficient of viscosity depends on:
A) Temperature
B) Pressure
C) Volume
D) Density only
Answer: A

118. Viscosity of gas increases with:
A) Decrease in temperature

B) Increase in temperature
C) Increase in pressure
D) Decrease in density
Answer: B

119. Unit of viscosity is:
A) Pascal
B) Pascal-second
C) Joule
D) Watt
Answer: B

120. Viscosity arises due to transfer of:
A) Mass
B) Energy
C) Momentum
D) Heat
Answer: C

🔷 Conduction of Heat

121. Heat conduction in gases occurs due to:
A) Molecular collisions
B) Radiation
C) Convection only
D) Pressure difference
Answer: A

122. Thermal conductivity increases with:
A) Temperature
B) Pressure
C) Volume
D) Density
Answer: A

123. Unit of thermal conductivity is:
A) W/mK
B) J
C) Pascal
D) m^2
Answer: A

124. Conduction is transfer of:
A) Momentum

B) Mass
C) Heat
D) Volume
Answer: C

🔷 Diffusion (Vertical Case)

125. Diffusion is due to:
A) Pressure difference
B) Concentration difference
C) Temperature only
D) Volume change
Answer: B

126. Rate of diffusion is inversely proportional to:
A) √Density
B) Density
C) Pressure
D) Volume
Answer: A

127. Lighter gases diffuse:
A) Slowly
B) Faster
C) Same
D) Zero
Answer: B

128. Graham's law relates diffusion with:
A) Pressure
B) Temperature
C) Density
D) Volume
Answer: C

129. Diffusion involves transfer of:
A) Energy
B) Mass
C) Momentum
D) Heat
Answer: B

◆ Equipartition of Energy

130. Law of equipartition states each degree of freedom contributes:
A) kT
B) ½kT
C) 2kT
D) 3kT
Answer: B

131. Monoatomic gas has degrees of freedom:
A) 2
B) 3
C) 5
D) 6
Answer: B

132. Internal energy of monoatomic gas per mole is:
A) 3/2 RT
B) 5/2 RT
C) 7/2 RT
D) RT
Answer: A

133. Diatomic gas (at moderate temperature) has degrees of freedom:
A) 3
B) 5
C) 6
D) 7
Answer: B

134. Internal energy of diatomic gas is:
A) 3/2 RT
B) 5/2 RT
C) 7/2 RT
D) 2RT
Answer: B

135. Specific heat at constant volume for monoatomic gas is:
A) 3/2 R
B) 5/2 R
C) 7/2 R
D) R
Answer: A

136. Specific heat ratio γ for monoatomic gas is:
A) 1.4

B) 1.67
C) 1.33
D) 1
Answer: B

137. Specific heat ratio γ for diatomic gas is approximately:
A) 1.67
B) 1.4
C) 1.2
D) 2
Answer: B

◆ Mixed Conceptual Questions

138. RMS speed increases with:
A) Molecular mass
B) Temperature
C) Pressure
D) Density
Answer: B

139. Heavier molecules have:
A) Higher speed
B) Lower speed
C) Same speed
D) Infinite speed
Answer: B

140. Mean free path increases when density:
A) Increases
B) Decreases
C) Constant
D) Doubles
Answer: B

141. Transport phenomena are due to molecular:
A) Rest
B) Collisions
C) Size
D) Shape
Answer: B

142. Maxwell distribution becomes broader at:
A) Low temperature

B) High temperature
C) Zero temperature
D) Constant pressure
Answer: B

143. Equipartition law fails at:
A) High temperature
B) Low temperature
C) Room temperature
D) Constant pressure
Answer: B

144. Thermal conductivity depends on:
A) Mean free path
B) Temperature
C) Molecular speed
D) All of these
Answer: D

145. Viscosity is independent of:
A) Pressure (at low pressure)
B) Temperature
C) Collisions
D) Speed
Answer: A

146. Maxwell distribution is a plot of:
A) Number vs Speed
B) Pressure vs Volume
C) Temperature vs Time
D) Energy vs Volume
Answer: A

147. Diffusion is fastest in:
A) Solids
B) Liquids
C) Gases
D) Plasma
Answer: C

148. Internal energy depends on:
A) Pressure
B) Volume
C) Temperature
D) Density
Answer: C

149. Equipartition theorem is based on:
A) Classical mechanics
B) Quantum mechanics
C) Relativity
D) Thermodynamics only
Answer: A

150. Kinetic theory successfully explains:
A) Gas pressure
B) Temperature
C) Specific heat
D) All of these
Answer: D

MCQs on Theory of Radiation (151–200)

🔷 Blackbody Radiation

151. A perfect blackbody is one which:
A) Reflects all radiation
B) Absorbs all incident radiation
C) Transmits all radiation
D) Emits no radiation
Answer: B

152. A good approximation of blackbody is:
A) Polished metal
B) Hollow cavity with small hole
C) Transparent glass
D) Ice surface
Answer: B

153. Blackbody radiation depends only on:
A) Nature of material
B) Temperature
C) Pressure
D) Volume
Answer: B

154. Emissive power of a blackbody is:
A) Minimum
B) Zero
C) Maximum

D) Infinite
Answer: C

155. At higher temperature, peak of blackbody spectrum shifts towards:
A) Longer wavelength
B) Shorter wavelength
C) Infrared only
D) Constant value
Answer: B

156. Unit of energy density is:
A) J
B) J/m^3
C) W/m^2
D) K
Answer: B

🔷 Spectral Distribution

157. Spectral distribution shows variation of energy with:
A) Pressure
B) Volume
C) Wavelength/Frequency
D) Time
Answer: C

158. The area under spectral curve represents:
A) Temperature
B) Total emitted energy
C) Pressure
D) Density
Answer: B

159. With increase in temperature, total energy emitted:
A) Decreases
B) Increases
C) Constant
D) Zero
Answer: B

160. Spectral energy density is denoted by:
A) $u(\lambda)$
B) P
C) V

D) T
Answer: A

Planck's Law

161. Planck introduced the concept of:
A) Continuous energy
B) Energy quanta
C) Heat waves
D) Ether
Answer: B

162. Energy of photon is given by:
A) $E = mc^2$
B) $E = h\nu$
C) $E = RT$
D) $E = PV$
Answer: B

163. Planck's constant is:
A) 6.67×10^{-11} Js
B) 3×10^{8} m/s
C) 6.626×10^{-34} Js
D) 1.38×10^{-23} J/K
Answer: C

164. Planck's law successfully explains:
A) Only low frequency region
B) Only high frequency region
C) Entire spectrum
D) Visible region only
Answer: C

165. Planck's radiation formula reduces to Wien's law at:
A) Low frequency
B) High frequency
C) Zero frequency
D) Constant frequency
Answer: B

166. Planck's law reduces to Rayleigh-Jeans law at:
A) High frequency
B) Low frequency
C) Zero temperature

D) Infinite wavelength
Answer: B

167. Quantization of energy was proposed in year:
A) 1900
B) 1850
C) 1920
D) 1930
Answer: A

🔷 Wien's Distribution Law

168. Wien's distribution law is valid at:
A) Low frequency
B) High frequency
C) All frequencies
D) Zero temperature
Answer: B

169. Wien's law fails at:
A) High frequency
B) Low frequency
C) High temperature
D) Zero wavelength
Answer: B

170. Wien's law was derived before:
A) Rayleigh law
B) Planck law
C) Newton law
D) Stefan law
Answer: B

🔷 Rayleigh-Jeans Law

171. Rayleigh-Jeans law is based on:
A) Quantum theory
B) Classical physics
C) Relativity
D) Thermodynamics only
Answer: B

172. Rayleigh-Jeans law is valid for:
A) High frequency
B) Low frequency
C) All frequencies
D) Zero temperature
Answer: B

173. Rayleigh-Jeans law leads to:
A) Photoelectric effect
B) Ultraviolet catastrophe
C) Compton effect
D) Doppler effect
Answer: B

174. Ultraviolet catastrophe refers to:
A) Infinite energy at low frequency
B) Infinite energy at high frequency
C) Zero energy
D) Negative energy
Answer: B

🔷 Stefan-Boltzmann Law

175. Stefan-Boltzmann law states that total energy emitted is proportional to:
A) T
B) T^2
C) T^3
D) T^4
Answer: D

176. Mathematical form is:
A) $E = \sigma T^2$
B) $E = \sigma T^4$
C) $E = T^4$
D) $E = \sigma T$
Answer: B

177. Stefan's constant value is approximately:
A) 5.67×10^{-8} W/m²K⁴
B) 6.63×10^{-34}
C) 1.38×10^{-23}
D) 3×10^{8}
Answer: A

178. Stefan-Boltzmann law can be derived from:
A) Wien's law
B) Rayleigh law
C) Planck's law
D) Newton law
Answer: C

🔷 Wien's Displacement Law

179. Wien's displacement law states:
A) λmax T = constant
B) λ/T = constant
C) T/λ = constant
D) λ = constant
Answer: A

180. Value of displacement constant is approximately:
A) 2.9×10^{-3} mK
B) 6.63×10^{-34}
C) 5.67×10^{-8}
D) 1.38×10^{-23}
Answer: A

181. As temperature increases, λmax:
A) Increases
B) Decreases
C) Constant
D) Infinite
Answer: B

182. Wien's displacement law can be derived from:
A) Rayleigh law
B) Planck's law
C) Stefan law
D) Newton law
Answer: B

🔷 Energy Density Concept

183. Energy density is energy per unit:
A) Area
B) Volume

C) Length
D) Mass
Answer: B

184. Energy density increases with:
A) Temperature
B) Pressure
C) Volume
D) Density
Answer: A

185. Total energy density is proportional to:
A) T
B) T^2
C) T^3
D) T^4
Answer: D

🔷 Mixed Conceptual Questions

186. Blackbody radiation confirms:
A) Classical theory
B) Quantum theory
C) Relativity
D) Newton law
Answer: B

187. Peak wavelength of Sun lies in:
A) Infrared
B) Visible region
C) Microwave
D) X-ray
Answer: B

188. At absolute zero, radiation energy is:
A) Maximum
B) Infinite
C) Zero
D) Constant
Answer: C

189. Rayleigh-Jeans law agrees with experiment at:
A) High frequency
B) Low frequency

C) All frequencies
D) Zero frequency only
Answer: B

190. Planck resolved ultraviolet catastrophe by introducing:
A) Wave theory
B) Energy quantization
C) Classical theory
D) Heat law
Answer: B

191. Frequency and wavelength relation is:
A) $c = \lambda\nu$
B) $c = \nu/\lambda$
C) $\lambda = c\nu$
D) $\nu = c\lambda$
Answer: A

192. Radiation pressure is due to:
A) Mass
B) Momentum of photons
C) Temperature
D) Gravity
Answer: B

193. Blackbody emits radiation at:
A) One wavelength
B) All wavelengths
C) No wavelength
D) Visible only
Answer: B

194. Planck's theory marked beginning of:
A) Classical physics
B) Quantum physics
C) Relativity
D) Thermodynamics
Answer: B

195. Stefan-Boltzmann law applies to:
A) Ideal gas
B) Blackbody
C) Solid only
D) Liquid only
Answer: B

196. Wien's law gives position of:
A) Maximum intensity
B) Minimum intensity
C) Zero intensity
D) Infinite intensity
Answer: A

197. Energy density inside cavity is independent of:
A) Material
B) Temperature
C) Frequency
D) Wavelength
Answer: A

198. Higher temperature objects appear:
A) Red
B) Blue
C) Black
D) Invisible
Answer: B

199. Total emissive power of blackbody is proportional to:
A) λ
B) T^4
C) T
D) ν
Answer: B

200. Theory of radiation mainly supports:
A) Classical mechanics
B) Quantum mechanics
C) Fluid mechanics
D) Electromagnetism only
Answer: B

MCQs on Statistical Mechanics (201–250)

🔷 Maxwell–Boltzmann Statistics

201. Maxwell–Boltzmann statistics is applicable to:
A) Photons
B) Fermions
C) Classical particles

D) Electrons only
Answer: C

202. Maxwell–Boltzmann distribution assumes particles are:
A) Indistinguishable
B) Identical and indistinguishable
C) Distinguishable
D) Bosons
Answer: C

203. Maxwell–Boltzmann statistics obeys:
A) Pauli exclusion principle
B) Bose condensation
C) Classical mechanics
D) Uncertainty principle
Answer: C

204. Distribution function in MB statistics depends on:
A) Energy and temperature
B) Pressure only
C) Volume only
D) Density only
Answer: A

205. MB statistics is valid at:
A) Very low temperature
B) High temperature & low density
C) Absolute zero
D) High density
Answer: B

206. Maxwell velocity distribution curve is:
A) Linear
B) Parabolic
C) Bell-shaped
D) Rectangular
Answer: C

207. In MB distribution, probability decreases exponentially with:
A) Temperature
B) Energy
C) Volume
D) Pressure
Answer: B

208. Partition function is important in:
A) Classical thermodynamics
B) Statistical mechanics
C) Fluid mechanics
D) Optics
Answer: B

🔷 Phase Space

209. Phase space is defined as space of:
A) Position only
B) Momentum only
C) Position and momentum
D) Energy only
Answer: C

210. For one particle in 3D, phase space dimension is:
A) 3
B) 6
C) 9
D) 12
Answer: B

211. Volume element in phase space is:
A) dx
B) dp
C) $d^3x\, d^3p$
D) dE
Answer: C

212. Each point in phase space represents:
A) Many states
B) One microstate
C) One macrostate
D) Temperature
Answer: B

213. Liouville's theorem is related to conservation of:
A) Energy
B) Phase space density
C) Mass
D) Pressure
Answer: B

🔷 Quantum Statistics

214. Quantum statistics applies to particles that are:
A) Macroscopic
B) Classical
C) Indistinguishable
D) Massive only
Answer: C

215. There are mainly how many types of quantum statistics?
A) 1
B) 2
C) 3
D) 4
Answer: B

216. Fermions obey:
A) Maxwell-Boltzmann
B) Bose-Einstein
C) Fermi-Dirac
D) Classical law
Answer: C

217. Bosons obey:
A) Fermi-Dirac
B) Bose-Einstein
C) Maxwell
D) Newton
Answer: B

218. Pauli exclusion principle applies to:
A) Bosons
B) Fermions
C) Photons
D) Gas molecules
Answer: B

🔷 Fermi–Dirac Statistics

219. Fermi–Dirac distribution function is:
A) $1 / (e^{E/kT} – 1)$
B) $1 / (e^{E/kT} + 1)$

C) $e^{(-E/kT)}$
D) kT/E
Answer: B

220. Electrons in metals form:
A) Photon gas
B) Classical gas
C) Electron gas
D) Boson gas
Answer: C

221. Fermi energy is energy at:
A) Absolute zero
B) Infinite temperature
C) Room temperature
D) Zero pressure
Answer: A

222. At $T = 0$ K, states below Fermi energy are:
A) Empty
B) Partially filled
C) Completely filled
D) Half filled
Answer: C

223. Fermi-Dirac statistics is important in:
A) Semiconductor physics
B) Fluid mechanics
C) Optics only
D) Relativity
Answer: A

224. Fermions have spin:
A) Integer
B) Half-integer
C) Zero
D) Infinite
Answer: B

225. Example of fermion:
A) Photon
B) Electron
C) Phonon
D) Gluon
Answer: B

🔷 Bose–Einstein Statistics

226. Bose–Einstein distribution function is:
A) 1 / (e^(E/kT) – 1)
B) 1 / (e^(E/kT) + 1)
C) e^(–E/kT)
D) E/kT
Answer: A

227. Bosons have spin:
A) Half-integer
B) Integer
C) Negative
D) Fractional
Answer: B

228. Example of boson:
A) Electron
B) Proton
C) Photon
D) Neutron
Answer: C

229. Photon gas obeys:
A) Fermi-Dirac
B) Maxwell
C) Bose-Einstein
D) Classical law
Answer: C

230. Bose-Einstein condensation occurs at:
A) High temperature
B) Low temperature
C) Infinite temperature
D) Room temperature
Answer: B

231. Chemical potential for photon gas is:
A) Positive
B) Negative
C) Zero
D) Infinite
Answer: C

232. Bosons can occupy:
A) One particle per state
B) Infinite particles per state
C) No state
D) Two only
Answer: B

🔷 Electron Gas

233. Electron gas in metals behaves as:
A) Ideal boson gas
B) Ideal fermion gas
C) Classical gas
D) Photon gas
Answer: B

234. Degeneracy pressure arises due to:
A) Temperature
B) Pauli exclusion principle
C) Gravity
D) Density only
Answer: B

235. At high temperature, Fermi-Dirac reduces to:
A) Bose law
B) Maxwell-Boltzmann
C) Wien law
D) Rayleigh law
Answer: B

🔷 Comparison of Three Statistics

236. Maxwell-Boltzmann applies to:
A) Classical distinguishable particles
B) Indistinguishable particles
C) Fermions only
D) Bosons only
Answer: A

237. Fermi-Dirac statistics obeys exclusion principle?
A) Yes
B) No

C) Sometimes
D) Rarely
Answer: A

238. Bose-Einstein statistics allows:
A) One particle per state
B) Two per state
C) Many particles per state
D) No particles
Answer: C

239. At high temperature all three statistics approach:
A) Fermi-Dirac
B) Bose-Einstein
C) Maxwell-Boltzmann
D) Quantum limit
Answer: C

240. Photon gas differs from electron gas because photon has:
A) Mass
B) Charge
C) Zero rest mass
D) Spin ½
Answer: C

🔷 Mixed Conceptual Questions

241. Distribution functions depend on:
A) Energy
B) Temperature
C) Chemical potential
D) All of these
Answer: D

242. Microstate means:
A) Bulk property
B) Single configuration
C) Average state
D) Temperature
Answer: B

243. Macrostate depends on:
A) Few parameters
B) All particles individually

C) Momentum only
D) Position only
Answer: A

244. Density of states is important in:
A) Quantum statistics
B) Fluid flow
C) Classical mechanics
D) Heat conduction
Answer: A

245. At absolute zero, Bose distribution shows:
A) No particles
B) Condensation in ground state
C) Infinite energy
D) Zero density
Answer: B

246. Fermi temperature is related to:
A) Fermi energy
B) Pressure
C) Volume
D) Radiation
Answer: A

247. Phase space volume element is divided by h^3 due to:
A) Relativity
B) Uncertainty principle
C) Thermodynamics
D) Optics
Answer: B

248. Statistical mechanics links:
A) Microscopic and macroscopic properties
B) Heat and work
C) Pressure and volume
D) Temperature and entropy
Answer: A

249. Bose-Einstein statistics was proposed by:
A) Einstein and Bose
B) Planck
C) Newton
D) Maxwell
Answer: A

250. Statistical mechanics provides foundation for:
A) Thermodynamics
B) Fluid mechanics
C) Optics
D) Relativity
Answer: A

LAWS OF THERMODYNAMICS & THERMODYNAMICAL POTENTIALS

75 Questions with Answers

🔷 Zeroth Law & Temperature

1. State Zeroth Law of Thermodynamics.
Answer: If two systems are separately in thermal equilibrium with a third system, they are in thermal equilibrium with each other.

2. What concept is established by Zeroth law?
Answer: Temperature.

3. What is thermal equilibrium?
Answer: A state in which no heat flows between systems in contact.

4. Define temperature.
Answer: Temperature is a measure of the degree of hotness or coldness of a body.

5. Why is Zeroth law important?
Answer: It forms the basis of temperature measurement.

🔷 First Law & Internal Energy

6. State the First Law of Thermodynamics.
Answer: Heat supplied to a system equals increase in internal energy plus work done ($Q = \Delta U + W$).

7. Define internal energy.
Answer: Total energy possessed by molecules of a system due to motion and interactions.

8. What is the mathematical form of First Law?
Answer: $dQ = dU + dW$.

9. What happens if Q = W?
Answer: $\Delta U = 0$.

10. Define heat engine.
Answer: A device that converts heat into work.

🔷 Thermodynamic Processes

11. Define isothermal process.
Answer: Process at constant temperature.

12. Define adiabatic process.
Answer: Process in which no heat exchange occurs ($Q = 0$).

13. Define isobaric process.
Answer: Process at constant pressure.

14. Define isochoric process.
Answer: Process at constant volume.

15. Write condition for adiabatic process.
Answer: PV^γ = constant.

16. Work done in isothermal process (ideal gas)?
Answer: $W = nRT \ln(V_2/V_1)$.

17. Work done in isochoric process?
Answer: Zero.

18. Which process has maximum work output?
Answer: Reversible process.

🔷 CP and CV

19. Define CP.
Answer: Specific heat at constant pressure.

20. Define CV.
Answer: Specific heat at constant volume.

21. Relation between CP and CV (ideal gas)?
Answer: $CP - CV = R$.

22. Define γ.
Answer: $\gamma = C_P/C_V$.

23. Value of γ for monoatomic gas?
Answer: 1.67.

◆ Compressibility & Expansion

24. Define coefficient of volume expansion.
Answer: $(1/V)(\partial V/\partial T)_p$.

25. Define compressibility.
Answer: $(1/V)(\partial V/\partial P)_t$.

26. How does compressibility vary with pressure?
Answer: Decreases with increase in pressure.

◆ Reversible & Irreversible Process

27. Define reversible process.
Answer: Process that can be reversed without net change in system and surroundings.

28. Define irreversible process.
Answer: Process that cannot be reversed exactly.

29. Entropy change in reversible adiabatic process?
Answer: Zero.

◆ Second Law & Entropy

30. State Kelvin-Planck statement.
Answer: It is impossible to convert all heat into work in a cyclic process.

31. State Clausius statement.
Answer: Heat cannot flow from cold to hot body without external work.

32. Define entropy.
Answer: Measure of disorder or randomness.

33. Unit of entropy?
Answer: J/K.

34. Entropy change formula?
Answer: $dS = dQrev / T$.

35. Entropy of isolated system always?
Answer: Increases.

🔷 Carnot Cycle

36. What is Carnot cycle?
Answer: Ideal reversible cycle with two isothermal and two adiabatic processes.

37. Efficiency of Carnot engine?
Answer: $\eta = 1 - T_2/T_1$.

38. On what does Carnot efficiency depend?
Answer: Temperature of reservoirs.

39. State Carnot theorem.
Answer: No engine is more efficient than Carnot engine.

🔷 Entropy Changes

40. Entropy change in irreversible process?
Answer: Positive.

41. What is T-S diagram?
Answer: Graph between temperature and entropy.

42. Area under T-S curve represents?
Answer: Heat.

🔷 Third Law

43. State Third Law.
Answer: Entropy of perfect crystal at absolute zero is zero.

44. What is absolute zero?
Answer: 0 K or –273°C.

45. What is unattainability principle?
Answer: Absolute zero cannot be reached.

◆ Thermodynamical Potentials

🔷 Internal Energy & Enthalpy

46. Define enthalpy.
Answer: H = U + PV.

47. At constant pressure, heat equals?
Answer: Change in enthalpy.

48. Define Helmholtz free energy.
Answer: F = U – TS.

49. Define Gibbs free energy.
Answer: G = H – TS.

50. Condition for spontaneity (G)?
Answer: $\Delta G < 0$.

🔷 Maxwell Relations

51. How many Maxwell relations are there?
Answer: Four.

52. Maxwell relations are derived from?
Answer: Equality of mixed partial derivatives.

53. Write one Maxwell relation.
Answer: $(\partial S/\partial V)_T = (\partial P/\partial T)_V$.

🔷 Joule–Thomson Effect

54. Define Joule–Thomson effect.
Answer: Temperature change during adiabatic throttling at constant enthalpy.

55. Joule–Thomson coefficient is?
Answer: $\mu JT = (\partial T/\partial P)H$.

56. Value of μJT for ideal gas?
Answer: Zero.

🔷 Clausius–Clapeyron Equation

57. Write Clausius–Clapeyron equation.
Answer: $dP/dT = L / T\Delta V$.

58. It applies to?
Answer: Phase equilibrium.

🔷 CP – CV Expression

59. CP – CV equals?
Answer: R (for ideal gas).

60. CP is always greater than CV because?
Answer: Work is done at constant pressure.

🔷 TdS Equations

61. First TdS equation?
Answer: $TdS = dU + PdV$.

62. Second TdS equation?
Answer: $TdS = dH – VdP$.

🔷 Advanced Conceptual Questions

63. Natural variables of G?
Answer: T and P.

64. Natural variables of F?
Answer: T and V.

65. Condition of equilibrium (G)?
Answer: dG = 0.

66. In adiabatic reversible process, entropy is?
Answer: Constant.

67. Why is entropy maximum at equilibrium?
Answer: System reaches most probable state.

68. Which potential is useful for chemical reactions?
Answer: Gibbs free energy.

69. What is latent heat?
Answer: Heat absorbed/released during phase change without temperature change.

70. Why Carnot cycle is ideal?
Answer: It is completely reversible.

71. Entropy change for free expansion?
Answer: Positive.

72. Internal energy of ideal gas depends on?
Answer: Temperature only.

73. Which process has no work done?
Answer: Isochoric.

74. Which law introduces entropy?
Answer: Second Law.

75. Which law defines absolute zero entropy?
Answer: Third Law.

SHORT QUESTIONS WITH ANSWERS (76–150)

◆ KINETIC THEORY OF GASES

◆ Maxwell's Distribution of Velocities

76. What does Maxwell's law describe?
Answer: Distribution of molecular velocities in a gas.

77. On what does Maxwell distribution depend?
Answer: Temperature and molecular mass.

78. What is most probable speed?
Answer: Speed corresponding to maximum molecules in distribution curve.

79. Expression for most probable speed?
Answer: vp=2RTMv_p = \sqrt{\frac{2RT}{M}}vp=M2RT

80. Expression for RMS speed?
Answer: vrms=3RTMv_{rms} = \sqrt{\frac{3RT}{M}}vrms=M3RT

81. Expression for average speed?
Answer: vavg=8RTπMv_{avg} = \sqrt{\frac{8RT}{\pi M}}vavg=πM8RT

82. Relation between speeds?
Answer: vp<vavg<vrmsv_p < v_{avg} < v_{rms}vp<vavg<vrms

83. Shape of Maxwell distribution curve?
Answer: Bell-shaped.

84. What happens to curve at higher temperature?
Answer: Broadens and shifts right.

85. Who verified Maxwell distribution experimentally?
Answer: Stern.

◆ Mean Free Path

86. Define mean free path.
Answer: Average distance travelled between collisions.

87. Formula for mean free path?
Answer: λ=12πd2n\lambda = \frac{1}{\sqrt{2}\pi d^2 n}λ=2πd2n1

88. Mean free path is inversely proportional to?
Answer: Pressure.

89. Effect of molecular diameter on mean free path?
Answer: Larger diameter → smaller mean free path.

90. What happens to mean free path at low pressure?
Answer: It increases.

◆ Transport Phenomena

91. What is viscosity in gases?
Answer: Transfer of momentum between layers.

92. Viscosity increases with?
Answer: Temperature.

93. Define thermal conductivity.
Answer: Transfer of heat due to molecular motion.

94. Unit of thermal conductivity?
Answer: W/mK.

95. What is diffusion?
Answer: Transfer of mass due to concentration difference.

96. Diffusion rate depends on?
Answer: Molecular mass.

97. Graham's law states?
Answer: Rate of diffusion ∝ 1/√density.

98. Which gas diffuses faster: H_2 or O_2?
Answer: H_2.

99. Viscosity arises due to transfer of?
Answer: Momentum.

100. Conduction arises due to transfer of?
Answer: Energy.

◆ Equipartition of Energy

101. State equipartition theorem.
Answer: Each degree of freedom contributes ½kT energy.

102. Degrees of freedom of monoatomic gas?
Answer: 3.

103. Internal energy of monoatomic gas?
Answer: 32RT\frac{3}{2}RT23RT

104. Degrees of freedom of diatomic gas (moderate T)?
Answer: 5.

105. Internal energy of diatomic gas?
Answer: 52RT\frac{5}{2}RT25RT

106. γ for monoatomic gas?
Answer: 1.67.

107. γ for diatomic gas?
Answer: 1.4.

108. Equipartition theorem fails at?
Answer: Low temperatures.

109. Specific heat at constant volume (monoatomic)?
Answer: 32R\frac{3}{2}R23R

110. Specific heat at constant pressure (diatomic)?
Answer: 72R\frac{7}{2}R27R

◆ THEORY OF RADIATION

◆ Blackbody Radiation

111. Define blackbody.
Answer: Perfect absorber and emitter of radiation.

112. Example of blackbody?
Answer: Hollow cavity with small hole.

113. Blackbody radiation depends on?
Answer: Temperature only.

114. What is spectral distribution?
Answer: Distribution of energy with wavelength.

115. Area under spectral curve represents?
Answer: Total emitted energy.

◆ Planck's Law

116. State Planck's energy formula.
Answer: E=hνE = h\nuE=hν

117. Value of Planck's constant?
Answer: 6.626×10^{-34} Js.

118. Planck resolved which problem?
Answer: Ultraviolet catastrophe.

119. Planck's law reduces to Wien's law at?
Answer: High frequency.

120. Planck's law reduces to Rayleigh-Jeans law at?
Answer: Low frequency.

◆ Rayleigh-Jeans & Wien's Law

121. Rayleigh-Jeans law is based on?
Answer: Classical theory.

122. Rayleigh-Jeans law fails at?
Answer: High frequency.

123. Wien's displacement law formula?
Answer: λmaxT=constant\lambda_{max}T = constantλmaxT=constant

124. Wien's law gives?
Answer: Position of maximum intensity.

125. Stefan-Boltzmann law states?
Answer: Energy $\propto T^4$.

126. Value of Stefan constant?
Answer: 5.67×10^{-8} W/m^2K^4.

127. Energy density is energy per unit?
Answer: Volume.

128. Total energy density is proportional to?
Answer: T^4.

129. Wien’s law derived from?
Answer: Planck’s law.

130. Radiation pressure arises due to?
Answer: Photon momentum.

◆ STATISTICAL MECHANICS

◆ Maxwell-Boltzmann Statistics

131. MB statistics applies to?
Answer: Classical distinguishable particles.

132. MB distribution valid at?
Answer: High temperature, low density.

133. MB distribution function decreases with?
Answer: Increasing energy.

134. What is phase space?
Answer: Space of position and momentum coordinates.

135. Dimension of phase space (1 particle in 3D)?
Answer: 6.

◆ Quantum Statistics

136. Fermions obey?
Answer: Fermi-Dirac statistics.

137. Bosons obey?
Answer: Bose-Einstein statistics.

138. Pauli exclusion principle applies to?
Answer: Fermions.

139. Fermi-Dirac distribution formula?
Answer: 1e(E−μ)/kT+1\frac{1}{e^{(E-\mu)/kT}+1}e(E−μ)/kT+11

140. Bose-Einstein distribution formula?
Answer: 1e(E−μ)/kT−1\frac{1}{e^{(E-\mu)/kT}-1}e(E−μ)/kT−11

◆ Electron Gas & Photon Gas

141. Electron gas behaves as?
Answer: Ideal fermion gas.

142. Fermi energy defined at?
Answer: Absolute zero.

143. Photon gas obeys?
Answer: Bose-Einstein statistics.

144. Chemical potential of photon gas?
Answer: Zero.

145. Bosons can occupy?
Answer: Same quantum state.

◆ Comparison of Statistics

146. MB statistics assumes particles are?
Answer: Distinguishable.

147. FD statistics allows how many particles per state?
Answer: One.

148. BE statistics allows?
Answer: Many particles per state.

149. At high temperature all statistics approach?
Answer: Maxwell-Boltzmann.

150. Statistical mechanics connects?
Answer: Microscopic and macroscopic properties.

LAWS OF THERMODYNAMICS & THERMODYNAMICAL POTENTIALS

35 Mid-Size Questions (10 Marks)

🔷 LAWS OF THERMODYNAMICS

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1. State and explain Zeroth Law of Thermodynamics. Discuss its importance.

Answer:
Zeroth Law states that if two systems are separately in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.
It establishes the concept of temperature and forms the basis of thermometry. It allows comparison of temperatures using a thermometer.

---

2. State and derive the First Law of Thermodynamics.

Answer:
First Law: Energy can neither be created nor destroyed.
For a small change:

$$dQ=dU+dWdQ = dU + dWdQ=dU+dW$$

For reversible work: $dW=PdVdW = PdVdW=PdV$
So,

$$dQ=dU+PdVdQ = dU + PdVdQ=dU+PdV$$

It expresses conservation of energy in thermodynamic systems.

---

3. Explain internal energy and show that it is a state function.

Answer:
Internal energy is total microscopic energy of molecules.
Since change in internal energy depends only on initial and final states and not on path, it is a state function.

---

4. Derive work done in an isothermal expansion of ideal gas.

Answer:
For isothermal process:

PV=nRTPV = nRTPV=nRT

Work done:

W=∫V1V2PdVW = \int_{V_1}^{V_2} PdVW=∫V1V2PdV =nRT∫V1V2dVV= nRT \int_{V_1}^{V_2} \frac{dV}{V}=nRT∫V1V2VdV W=nRTln⁡V2V1W = nRT \ln \frac{V_2}{V_1}W=nRTlnV1V2

---

5. Derive work done in adiabatic expansion.

Answer:
For adiabatic process:

PVγ=constantPV^\gamma = constantPVγ=constant

Work done:

W=P1V1−P2V2γ−1W = \frac{P_1V_1 - P_2V_2}{\gamma -1}W=γ−1P1V1−P2V2

---

6. Derive relation between CP and CV for ideal gas.

Answer:
From first law:

dQ=dU+PdVdQ = dU + PdVdQ=dU+PdV

At constant pressure:

CPdT=CVdT+RdTC_P dT = C_V dT + RdTCPdT=CVdT+RdT

Hence,

CP−CV=RC_P - C_V = RCP−CV=R

---

7. Explain reversible and irreversible processes with examples.

Answer:
Reversible process: Infinitely slow, system remains in equilibrium.
Irreversible process: Rapid, involves friction, heat loss etc.
Example: Free expansion is irreversible.

---

8. State and explain Second Law of Thermodynamics.

Answer:
Kelvin-Planck: Impossible to convert all heat into work.
Clausius: Heat cannot flow from cold to hot without work.

---

9. Define entropy and derive entropy change in reversible process.

Answer:
Entropy:

$$dS = \frac{dQ_{rev}}{T}$$

For isothermal process:

$$\Delta S = \frac{Q_{rev}}{T}$$

---

10. Derive entropy change for ideal gas in isothermal expansion.

Answer:

$$\Delta S = nR \ln \frac{V_2}{V_1}$$

---

11. Explain Carnot cycle with diagram and derive efficiency.

Answer:
Carnot cycle has:

- Two isothermal processes
- Two adiabatic processes

Efficiency:

$$\eta = 1 - \frac{T_2}{T_1}$$

---

12. State and prove Carnot theorem.

Answer:
No engine working between two temperatures is more efficient than Carnot engine.
Proof is based on second law and reversibility argument.

---

13. Discuss entropy change in irreversible process.

Answer:
For irreversible process:

$$\Delta S > \frac{Q}{T}$$

Entropy of isolated system always increases.

---

14. Explain T-S diagram and its significance.

Answer:
T-S diagram plots temperature vs entropy.
Area under curve = Heat absorbed.

---

15. State and explain Third Law of Thermodynamics.

Answer:
Entropy of perfect crystal at absolute zero is zero.

---

16. Explain unattainability of absolute zero.

Answer:
Absolute zero cannot be reached in finite steps due to decreasing entropy change near 0K.

---

17. Define coefficient of compressibility and expansion.

Answer:

β=1V(∂V∂T)P\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_Pβ=V1(∂T∂V)P
κ=−1V(∂V∂P)T\kappa = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_Tκ=−V1(∂P∂V)T

◆ THERMODYNAMICAL POTENTIALS

---

18. Define thermodynamic potentials and explain their importance.

Answer:
U, H, F, G are thermodynamic potentials used to determine equilibrium and spontaneity.

---

19. Define enthalpy and derive its differential form.

Answer:

H=U+PVH = U + PVH=U+PV dH=dU+PdV+VdPdH = dU + PdV + VdPdH=dU+PdV+VdP

---

20. Define Helmholtz free energy and derive its natural variables.

Answer:

F=U−TSF = U - TSF=U−TS dF=−SdT−PdVdF = -SdT - PdVdF=−SdT−PdV

Natural variables: T, V.

---

21. Define Gibbs free energy and derive its differential form.

Answer:

G=H−TSG = H - TSG=H−TS dG=−SdT+VdPdG = -SdT + VdPdG=−SdT+VdP

22. Discuss conditions of equilibrium using Gibbs free energy.

Answer:
At constant T and P:

dG=0dG = 0dG=0

Minimum G indicates equilibrium.

---

23. Derive Maxwell's relations.

Answer:
From thermodynamic potentials and equality of mixed partial derivatives.
Example:

(∂S∂V)T=(∂P∂T)V\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V(∂V∂S)T=(∂T∂P)V

---

24. Discuss applications of Maxwell relations.

Answer:
Used to calculate entropy, specific heat, and compressibility from measurable quantities.

---

25. Explain Joule-Thomson effect.

Answer:
Temperature change during adiabatic throttling at constant enthalpy.

---

26. Define Joule-Thomson coefficient and explain inversion temperature.

Answer:

μJT=(∂T∂P)H\mu_{JT} = \left(\frac{\partial T}{\partial P}\right)_HμJT=(∂P∂T)H

Inversion temperature: Temperature where μJT = 0.

---

27. Derive Clausius-Clapeyron equation.

Answer:

dPdT=LTΔV\frac{dP}{dT} = \frac{L}{T\Delta V}dTdP=TΔVL

---

28. Explain physical meaning of Clausius-Clapeyron equation.

Answer:
It gives rate of change of pressure with temperature during phase change.

---

29. Derive expression for CP – CV using thermodynamic identities.

Answer:

CP−CV=TVα2κTC_P - C_V = \frac{TV\alpha^2}{\kappa_T}CP−CV=κTTVα2

---

30. Define ratio CP/CV and explain its importance.

Answer:

γ=CPCV\gamma = \frac{C_P}{C_V}γ=CVCP

Important in adiabatic processes.

---

31. Derive first TdS equation.

Answer:

TdS=dU+PdVTdS = dU + PdVTdS=dU+PdV

---

32. Derive second TdS equation.

Answer:

$$TdS = dH - VdP$$

---

33. Discuss spontaneity criteria using Helmholtz energy.

Answer:
At constant T and V:

$$dF < 0$$

---

34. Compare all four thermodynamic potentials.

Answer:

Potential	Expression	Natural Variables
U	U	S, V
H	U + PV	S, P
F	U – TS	T, V
G	H – TS	T, P

---

35. Show how entropy, temperature and pressure are interrelated using Maxwell relations.

Answer:
Using:

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V$$

This relates entropy change to measurable P–T relations.

◆ KINETIC THEORY OF GASES

---

36. Derive Maxwell's law of distribution of molecular velocities.

Answer:
Assuming isotropic distribution and independence of velocity components:

f(vx)=Ae−mvx2/2kTf(v_x) = Ae^{-mv_x^2/2kT}f(vx)=Ae−mvx2/2kT

Total velocity distribution:

f(v)=4π(m2πkT)3/2v2e−mv2/2kTf(v) = 4\pi \left(\frac{m}{2\pi kT}\right)^{3/2} v^2 e^{-mv^2/2kT}f(v)=4π(2πkTm)3/2v2e−mv2/2kT

This is Maxwell's velocity distribution law.

---

37. Discuss experimental verification of Maxwell's distribution.

Answer:
Otto Stern experimentally verified Maxwell distribution using molecular beam method.
Measured molecular speeds matched theoretical curve.

---

38. Obtain expressions for most probable, average and RMS speeds.

Answer:

vp=2kTmv_p = \sqrt{\frac{2kT}{m}}vp=m2kT vavg=8kTπmv_{avg} = \sqrt{\frac{8kT}{\pi m}}vavg =πm8kT vrms=3kTmv_{rms} = \sqrt{\frac{3kT}{m}}vrms=m3kT

Relation: vp<vavg<vrmsv_p < v_{avg} < v_{rms}vp<vavg<vrms

---

39. Derive expression for mean free path (zeroth order approximation).

Answer:

λ=12πd2n\lambda = \frac{1}{\sqrt{2}\pi d^2 n}λ=2πd2n1

Where
d = molecular diameter
n = number density

---

40. Discuss dependence of mean free path on pressure and temperature.

Answer:

$$\lambda \propto \frac{T}{P}$$

Increases with temperature and decreases with pressure.

---

41. Explain viscosity in gases using kinetic theory.

Answer:
Viscosity arises due to transfer of momentum between gas layers.

$$\eta = \frac{1}{3}\rho \bar{v}\lambda$$

---

42. Derive expression for thermal conductivity of gases.

Answer:
Thermal conductivity:

$$K = \frac{1}{3} C_v \rho \bar{v}\lambda$$

Represents energy transfer due to molecular motion.

---

43. Explain diffusion in gases (vertical case).

Answer:
Diffusion occurs due to concentration gradient.
Fick's law:

$$J = -D \frac{dn}{dx}$$

---

44. State and explain law of equipartition of energy.

Answer:
Each degree of freedom contributes $\frac{1}{2}kT$ energy per molecule.

---

45. Apply equipartition theorem to monoatomic gas.

Answer:
Degrees of freedom = 3

U=32RTU = \frac{3}{2}RTU=23RT CV=32RC_V = \frac{3}{2}RCV=23R

---

46. Apply equipartition theorem to diatomic gas.

Answer:
Degrees of freedom = 5

U=52RTU = \frac{5}{2}RTU=25RT CV=52RC_V = \frac{5}{2}RCV=25R

---

47. Discuss limitations of equipartition theorem.

Answer:
Fails at low temperatures due to quantum effects.

◆ THEORY OF RADIATION

---

48. Define blackbody and explain its characteristics.

Answer:
A blackbody absorbs and emits all radiation.
Energy depends only on temperature.

---

49. Explain spectral distribution of blackbody radiation.

Answer:
Shows variation of intensity with wavelength.
Peak shifts toward shorter wavelengths with temperature.

---

50. Define energy density of radiation.

Answer:
Energy per unit volume inside cavity.

$$u \propto T^4$$

---

51. Derive Planck's radiation law.

Answer:
Using quantization:

$$E = h\nu$$

Energy density:

$$u(\nu) = \frac{8\pi h\nu^3}{c^3}\frac{1}{e^{h\nu/kT}-1}$$

---

52. Show that Planck's law reduces to Wien's law at high frequency.

Answer:
For $h\nu >> kT$:

$$u(\nu) \approx \frac{8\pi h\nu^3}{c^3} e^{-h\nu/kT}$$

Which is Wien's law.

---

53. Show that Planck's law reduces to Rayleigh–Jeans law at low frequency.

Answer:
For $h\nu << kT$:

$$u(\nu) = \frac{8\pi \nu^2 kT}{c^3}$$

---

54. Explain ultraviolet catastrophe.

Answer:
Classical Rayleigh–Jeans law predicted infinite energy at high frequency.

---

55. Derive Stefan–Boltzmann law from Planck's law.

Answer:
Integrating Planck's law over all frequencies:

E=σT4E = \sigma T^4E=σT4

---

56. Derive Wien's displacement law from Planck's law.

Answer:
Differentiating Planck's formula and setting maximum:

λmaxT=constant\lambda_{max}T = constantλmaxT=constant

◆ STATISTICAL MECHANICS

---

57. Explain Maxwell–Boltzmann statistics.

Answer:
Applies to classical distinguishable particles.
Distribution:

f(E)=Ae−E/kTf(E) = Ae^{-E/kT}f(E)=Ae−E/kT

---

58. Derive Maxwell–Boltzmann velocity distribution.

Answer:
Probability proportional to e−mv2/2kTe^{-mv^2/2kT}e−mv2/2kT.
Full distribution includes spherical factor 4πv24\pi v^24πv2.

---

59. Define phase space and explain its significance.

Answer:
Space of position and momentum coordinates.
Each point represents one microstate.

---

60. Discuss quantum statistics.

Answer:
Applies to indistinguishable particles.
Two types: Fermi–Dirac and Bose–Einstein.

---

61. Derive Fermi–Dirac distribution law.

Answer:

f(E)=1e(E−μ)/kT+1f(E) = \frac{1}{e^{(E-\mu)/kT}+1}f(E)=e(E−μ)/kT+11

Obeys Pauli exclusion principle.

---

62. Explain concept of Fermi energy.

Answer:
Highest occupied energy at absolute zero.

---

63. Discuss properties of electron gas.

Answer:
Electrons behave as ideal fermion gas.
Exhibits degeneracy pressure.

---

64. Derive Bose–Einstein distribution law.

Answer:

f(E)=1e(E−μ)/kT−1f(E) = \frac{1}{e^{(E-\mu)/kT}-1}f(E)=e(E−μ)/kT−11

---

65. Explain photon gas.

Answer:
Photon gas obeys BE statistics with $\mu = 0$.

---

66. Discuss Bose–Einstein condensation.

Answer:
At low temperature, particles occupy ground state.

---

67. Compare Maxwell–Boltzmann, Fermi–Dirac and Bose–Einstein statistics.

Property	MB	FD	BE
Particle Type	Classical	Fermions	Bosons
Exclusion Principle	No	Yes	No
Occupancy	Unlimited	One per state	Many per state

---

68. Show that FD and BE reduce to MB at high temperature.

Answer:
When e(E−μ)/kT>>1e^{(E-\mu)/kT} >> 1e(E−μ)/kT>>1,
FD and BE approximate to MB distribution.

---

69. Explain density of states.

Answer:
Number of states per unit energy interval.

---

70. Discuss application of FD statistics in metals.

Answer:
Explains electrical conductivity and heat capacity.

---

71. Discuss application of BE statistics in radiation theory.

Answer:
Planck's radiation law derived using BE statistics.

---

72. Derive relation between entropy and distribution function.

Answer:
Entropy linked with number of microstates:

S=klnWS = k \ln WS=klnW

---

73. Explain degeneracy pressure.

Answer:
Pressure due to Pauli exclusion even at 0 K.

---

74. Discuss limitations of classical statistics.

Answer:
Fails at low temperature and high density.

---

75. Explain how statistical mechanics connects microscopic and macroscopic properties.

Answer:
By averaging over microstates, macroscopic thermodynamic quantities are derived.

LONG QUESTIONS WITH 15 MARKS ANSWERS

---

1. State and explain Zeroth Law of Thermodynamics. Discuss its significance.

Answer:
Zeroth Law states that if two systems are separately in thermal equilibrium with a third system, then they are in thermal equilibrium with each other.

If system A is in equilibrium with system C and system B is also in equilibrium with system C, then A and B are in equilibrium with each other.

This establishes the concept of temperature as a measurable property. It forms the basis of thermometers. Without Zeroth law, temperature comparison would not be logically possible.

Its significance:

1. Defines temperature.
2. Provides foundation for thermometry.
3. Establishes transitive nature of thermal equilibrium.

---

2. State and derive the First Law of Thermodynamics.

Answer:
First Law states that energy can neither be created nor destroyed, only transformed.

For a small change:
$dQ = dU + dW$

For reversible process:
$dW = PdV$

Therefore:
$dQ = dU + PdV$

For cyclic process:
$\oint dQ = \oint dW$

This law expresses conservation of energy. It explains conversion of heat into work but does not specify direction of process.

Limitations:

1. Does not explain spontaneity.
2. Does not give efficiency limit of engines.

---

3. Define internal energy and show it is a state function.

Answer:
Internal energy is total microscopic energy of molecules including translational, rotational and vibrational energies.

Mathematically:
$dU = dQ - dW$

For ideal gas:
U depends only on temperature.

Since change in internal energy depends only on initial and final states and not on path, it is a state function.

Proof: For cyclic process $\Delta U = 0$.

---

4. Derive work done in isothermal expansion of ideal gas.

Answer:
For isothermal process:
$PV = nRT$

Work done:
$W = \int PdV$

Substitute $P = nRT/V$

$W = nRT \int (dV/V)$

$W = nRT \ln(V2/V1)$

Thus work depends logarithmically on volume ratio.

---

5. Derive work done in adiabatic expansion.

Answer:
For adiabatic process:
PV^gamma = constant

Work:
W = ∫ PdV

Using P = constant / V^gamma

After integration:

W = (P1V1 − P2V2) / (gamma − 1)

Adiabatic work is greater than isothermal work between same volumes.

---

6. Derive relation between Cp and Cv for ideal gas.

Answer:
From first law:
dQ = dU + PdV

At constant volume:
Cv = (dU/dT)

At constant pressure:
Cp = (dQ/dT)

Using ideal gas equation:
PdV = RdT

Therefore:
Cp dT = Cv dT + R dT

So:
Cp − Cv = R

---

7. Derive general expression Cp − Cv = TV alpha^2 / kappa_T.

Answer:
Using thermodynamic identities:

$Cp - Cv = T (\partial P/\partial T)V (\partial V/\partial T)P$

Using definitions:
alpha = $(1/V)(\partial V/\partial T)P$
kappa_T = $-(1/V)(\partial V/\partial P)T$

Final relation:
Cp − Cv = TV alpha^2 / kappa_T

---

8. Explain reversible and irreversible processes.

Answer:
Reversible process:

1. Infinitely slow.
2. System remains in equilibrium.
3. Maximum work output.

Irreversible process:

1. Finite rate.
2. Involves friction or heat loss.
3. Entropy increases.

Example:
Free expansion is irreversible.

---

9. State and explain Second Law of Thermodynamics.

Answer:

Kelvin Planck statement:
Impossible to convert all heat into work in cyclic process.

Clausius statement:
Heat cannot flow from cold to hot without external work.

Second law introduces entropy and direction of processes.

---

10. Define entropy and derive entropy change in isothermal process.

Answer:
Entropy:
dS = dQrev / T

For isothermal process:
Qrev = nRT ln(V2/V1)

Therefore:
Delta S = nR ln(V2/V1)

Entropy increases in expansion.

---

11. Explain Carnot cycle and derive efficiency.

Answer:
Carnot cycle consists of:

1. Isothermal expansion at T1
2. Adiabatic expansion
3. Isothermal compression at T2
4. Adiabatic compression

Efficiency:
eta = 1 − T2/T1

Depends only on reservoir temperatures.

---

12. Prove Carnot theorem.

Answer:
Carnot theorem states no engine operating between two temperatures can be more efficient than Carnot engine.

Proof:
Assume more efficient engine exists. It would violate second law by producing net work without heat exchange. Hence impossible.

---

13. Explain T S diagram and Carnot cycle representation.

Answer:
T S diagram plots temperature vs entropy.

Area under curve equals heat absorbed.

Carnot cycle appears as rectangle in T S diagram.

---

14. State and explain Third Law of Thermodynamics.

Answer:
Entropy of perfect crystal at 0 K is zero.

Implications:

1. Absolute entropy can be calculated.
2. Heat capacities approach zero at 0 K.

---

15. Explain unattainability of absolute zero.

Answer:
Absolute zero cannot be reached in finite steps.

As temperature approaches zero, entropy change becomes extremely small.

Practical cooling methods become ineffective near 0 K.

THERMODYNAMICAL POTENTIALS

---

16. Define and derive enthalpy.

Answer:
H = U + PV

Differentiating:
dH = dU + PdV + VdP

At constant pressure:
$dH = dQ$

---

17. Define Helmholtz free energy.

Answer:
$F = U - TS$

$dF = -S\,dT - P\,dV$

Natural variables: T and V.

Condition for spontaneity:
$dF < 0$ at constant T and V.

---

18. Define Gibbs free energy.

Answer:
$G = H - TS$

$dG = -S\,dT + V\,dP$

Natural variables: T and P.

Condition for spontaneity:
Delta $G < 0$.

---

19. Derive Maxwell relations.

Answer:
From differential forms:

$dU = T\,dS - P\,dV$

Using equality of mixed partial derivatives:

$(\partial T/\partial V)_S = -(\partial P/\partial S)_V$

Similarly four Maxwell relations obtained.

---

20. Discuss applications of Maxwell relations.

Answer:
Used to:

1. Calculate entropy from measurable quantities.
2. Derive Cp − Cv relation.
3. Determine compressibility and expansion coefficients.

---

21. Explain Joule Thomson effect.

Answer:
Temperature change during adiabatic throttling at constant enthalpy.

Coefficient:
muJT = (∂T/∂P)H

For ideal gas muJT = 0.

---

22. Explain inversion temperature.

Answer:
Temperature at which muJT = 0.

Above inversion temperature gas heats on expansion.

Below inversion temperature gas cools.

---

23. Derive Clausius Clapeyron equation.

Answer:
At phase equilibrium:

dP/dT = L / T (V2 − V1)

Describes variation of pressure with temperature during phase change.

---

24. Derive first and second TdS equations.

Answer:
From first law:

$dU = T\,dS - P\,dV$

So:
$T\,dS = dU + P\,dV$

Second:
$T\,dS = dH - V\,dP$

Useful in thermodynamic calculations.

---

25. Compare all thermodynamic potentials.

Answer:

Internal Energy U: Natural variables S, V
Enthalpy H: Natural variables S, P
Helmholtz F: Natural variables T, V
Gibbs G: Natural variables T, P

They help determine equilibrium and spontaneity under different constraints.

LONG QUESTIONS WITH ANSWERS (15 MARKS)

(Q.26 – Q.50)

◆ KINETIC THEORY OF GASES

---

26. Derive Maxwell law of distribution of molecular velocities.

Answer:
Maxwell assumed that gas molecules move randomly and velocity components are independent.

Probability of a molecule having velocity components vx, vy, vz:

f(vx) proportional to e^(-mvx^2 / 2kT)

Similarly for vy and vz.

Total distribution:

$f(v_x, v_y, v_z) = A e^{[-m(v_x^2 + v_y^2 + v_z^2)/2kT]}$

Since $v^2 = v_x^2 + v_y^2 + v_z^2$,

Transforming to spherical coordinates and multiplying by $4\pi v^2$:

$f(v) = 4\pi (m/2\pi kT)^{(3/2)} v^2 e^{(-mv^2/2kT)}$

This is Maxwell velocity distribution law.

---

27. Discuss experimental verification of Maxwell distribution.

Answer:
Maxwell distribution was verified by Otto Stern using molecular beam experiments.

Method:

1. A beam of gas molecules was passed through rotating slits.
2. Deflection measured molecular speeds.
3. Observed distribution matched theoretical curve.

This confirmed:

1. Existence of most probable speed.
2. Temperature dependence of velocity.

---

28. Obtain expressions for most probable, average and RMS speeds.

Answer:

Most probable speed:
$v_p = \sqrt{(2kT/m)}$

Average speed:
$v_{avg} = \sqrt{(8kT/\pi m)}$

RMS speed:
$v_{rms} = \sqrt{(3kT/m)}$

Relation:
$vp < vavg < vrms$

All speeds increase with temperature and decrease with molecular mass.

---

29. Derive expression for mean free path in zeroth order approximation.

Answer:
Mean free path is average distance between successive collisions.

Consider molecule diameter d and number density n.

Collision cross section = πd^2

Mean free path:

$\lambda = 1 / (\sqrt{2}\, \pi\, d^2\, n)$

It is inversely proportional to pressure.

---

30. Discuss temperature and pressure dependence of mean free path.

Answer:

Since n proportional to P/T,

lambda proportional to T/P

Therefore:

1. Increases with temperature.
2. Decreases with pressure.
3. Larger molecular size reduces mean free path.

---

31. Explain viscosity of gases using kinetic theory.

Answer:
Viscosity arises due to transfer of momentum between adjacent layers.

Coefficient of viscosity:

eta = (1/3) rho vbar lambda

Where:
rho = density
vbar = average speed
lambda = mean free path

Viscosity increases with temperature and is nearly independent of pressure at low pressure.

---

32. Derive expression for thermal conductivity of gases.

Answer:
Thermal conductivity represents energy transport.

From kinetic theory:

K = (1/3) Cv rho vbar lambda

It increases with temperature and depends on molecular motion.

---

33. Explain diffusion in gases for vertical case.

Answer:
Diffusion is mass transport due to concentration gradient.

According to Fick law:

J = −D dn/dx

Diffusion coefficient:

D = (1/3) vbar lambda

Lighter gases diffuse faster.

---

34. State and explain law of equipartition of energy.

Answer:
Each degree of freedom contributes (1/2)kT energy per molecule.

For one mole:

Each degree contributes (1/2)RT.

Valid at moderate temperatures for classical gases.

---

35. Apply equipartition theorem to monoatomic and diatomic gases.

Answer:

Monoatomic gas:
Degrees of freedom = 3

U = (3/2)RT
Cv = (3/2)R
Cp = (5/2)R
gamma = 5/3

Diatomic gas:
Degrees of freedom = 5

U = (5/2)RT
Cv = (5/2)R
Cp = (7/2)R
gamma = 7/5

◆ THEORY OF RADIATION

---

36. Define blackbody radiation and explain its properties.

Answer:
A blackbody absorbs all incident radiation.

Properties:

1. Emission depends only on temperature.
2. Emits continuous spectrum.
3. Total energy proportional to T^4.

Example: cavity with small hole.

---

37. Explain spectral distribution of blackbody radiation.

Answer:
Spectral distribution shows variation of energy with wavelength.

Characteristics:

1. Continuous curve.
2. Peak shifts to shorter wavelength with rise in temperature.
3. Area under curve gives total energy.

---

38. Derive Planck radiation law.

Answer:
Planck assumed energy quantization:

E = nhnu

Average energy:

Eavg = hnu / (e^(hnu/kT) − 1)

Energy density:

u(nu) = (8πhnu^3 / c^3) [1 / (e^(hnu/kT) − 1)]

This matches experimental data.

---

39. Deduce Wien distribution law from Planck law.

Answer:
For high frequency:

hnu >> kT

Exponential term dominates:

u(nu) proportional to nu^3 e^(−hnu/kT)

This is Wien distribution law.

---

40. Derive Rayleigh Jeans law and explain ultraviolet catastrophe.

Answer:
From classical equipartition:

Each mode has energy kT.

Energy density:

u(nu) = (8πnu^2 kT) / c^3

Fails at high frequency predicting infinite energy.

This failure is ultraviolet catastrophe.

---

41. Derive Stefan Boltzmann law from Planck law.

Answer:
Integrating Planck law over all frequencies:

Total energy density proportional to T^4

Radiated power:

E = sigma T^4

Where sigma is Stefan constant.

---

42. Derive Wien displacement law from Planck law.

Answer:
Differentiating Planck function with respect to wavelength and setting derivative zero gives:

lambda max T = constant

Shows peak shifts inversely with temperature.

◆ STATISTICAL MECHANICS

---

43. Explain Maxwell Boltzmann statistics and its assumptions.

Answer:
Applies to classical distinguishable particles.

Assumptions:

1. Particles independent.
2. No quantum restrictions.
3. Low density.

Distribution:

f(E) proportional to $e^{(-E/kT)}$

---

44. Derive Maxwell Boltzmann velocity distribution.

Answer:
Probability proportional to $e^{(-mv^2/2kT)}$.

Including spherical factor:

f(v) proportional to $v^2 e^{(-mv^2/2kT)}$

Same as Maxwell distribution.

---

45. Define phase space and explain its significance.

Answer:
Phase space is space of position and momentum coordinates.

For one particle in 3D:
6 dimensional space.

Each point represents a microstate.

---

46. Derive Fermi Dirac distribution law.

Answer:
Using Pauli exclusion principle:

f(E) = 1 / [e^((E − mu)/kT) + 1]

At T = 0:
All states below Fermi energy filled.

---

47. Explain electron gas model.

Answer:
Electrons in metal behave as ideal Fermi gas.

Properties:

1. Fermi energy defined.
2. Degeneracy pressure exists.
3. Explains electrical conductivity.

---

48. Derive Bose Einstein distribution law.

Answer:
For bosons without exclusion:

f(E) = 1 / [e^((E − mu)/kT) − 1]

Allows multiple occupancy of same state.

---

49. Explain photon gas and its properties.

Answer:
Photon gas obeys Bose Einstein statistics.

Chemical potential mu = 0.

Energy density derived from BE statistics leads to Planck law.

---

50. Compare Maxwell Boltzmann, Fermi Dirac and Bose Einstein statistics.

Answer:

Maxwell Boltzmann:
Classical, distinguishable particles.

Fermi Dirac:
Fermions, obey exclusion principle.

Bose Einstein:
Bosons, multiple occupancy allowed.

At high temperature, all reduce to Maxwell Boltzmann statistics.