

PH2610 Classical and Statistical Thermodynamics

Course Content

Section 1 Introduction to Classical Thermodynamics

1.1 Introduction – Macroscopic and microscopic descriptions

1.2 Systems and Variables

1.3 Thermodynamic Equilibrium

1.3.1 Equilibrium

1.3.2 Thermodynamic state

1.3.3 Functions of state

1.3.4 Reversible processes

1.3.5 Cyclic processes

1.3.6 Temperature, thermal equilibrium and the zeroth law of thermodynamics

1.3.7 Temperature scales

1.4 The First Law of Thermodynamics

1.5 Work

1.5.1 Expression for work

1.5.2 An example: work done on a gas

1.5.3 Other examples of expressions for work

Section 2 Introduction to Statistical Mechanics

2.1 Introducing entropy

2.1.1 Boltzmann's formula

2.2 The spin 1/2 paramagnet as a model system

2.2.1 Quantum states of a spin 1/2 paramagnet

2.2.2 The notion of a microstate

2.2.3 Counting the microstates

2.2.4 Distribution of particles among states

2.2.5 The average distribution and the most probable distribution

2.3 Entropy and the second law of thermodynamics

2.3.1 Order and entropy

2.3.2 The second law of thermodynamics

2.3.3 Thermal interaction between systems and temperature

2.4 More on the $S=1/2$ paramagnet

2.4.1 Energy distribution of the $S=1/2$ paramagnet

2.4.2 Magnetisation of $S = 1/2$ magnet — Curie's law

2.4.3 Entropy of $S = 1/2$ magnet

2.5 The Boltzmann distribution

2.5.1 Thermal interaction with the rest of the world – using a Gibbs ensemble

2.5.2 Most likely distribution

2.5.3 What are α and β ?

2.5.4 Link between the partition function and thermodynamic variables

2.5.5 Finding Thermodynamic Variables

2.6 Localised systems

- 2.6.1 Working in terms of the partition function of a single particle
- 2.6.2 Using the partition function I — the $S = 1/2$ paramagnet (again)
- 2.6.3 Using the partition function II — the Einstein model of a solid

Section 3 Entropy and Classical Thermodynamics

3.1 Entropy in thermodynamics and statistical mechanics

- 3.1.1 The Second Law of Thermodynamics
- 3.1.2 Restatement of the First Law
- 3.1.3 Microscopic interpretation of the first law
- 3.1.4 Entropy changes in irreversible processes

3.2 Alternative statements of the Second Law

- 3.2.1 Some statements of the Second Law
- 3.2.2 Demonstration that the law of increasing entropy implies statement 1a

3.3 The Carnot cycle

- 3.3.1 Introduction to Carnot cycles — Thermodynamic temperature
- 3.3.2 Efficiency of heat engines and heat pumps
- 3.3.3 Equivalence of ideal gas and thermodynamic temperatures

3.4 Thermodynamic potentials

- 3.4.1 Equilibrium states
- 3.4.2 Constant temperature (and volume): the Helmholtz potential
- 3.4.3 Constant pressure and energy: the Enthalpy function
- 3.4.4 Constant pressure and temperature: the Gibbs free energy
- 3.4.5 Differential expressions for the potentials
- 3.4.6 Natural variables and the Maxwell relations

3.5 Some applications

- 3.5.1 Entropy of an ideal gas
- 3.5.2 General expression for $C_p - C_V$
- 3.5.3 Joule Expansion – ideal gas
- 3.5.4 Joule Expansion – real non-ideal gas
- 3.5.5 Joule-Kelvin or Joule-Thomson process – Throttling
- 3.5.6 Joule-Thomson coefficient
- 3.5.7 Joule-Thomson effect for real and ideal gases
- 3.5.8 Inversion temperature and liquefaction of gases

Section 4 Statistical Thermodynamics of delocalised particles

4.1 Classical Ideal Gas

- 4.1.1 Indistinguishability
- 4.1.2 Classical approximation
- 4.1.3 Specifying the single-particle energy states
- 4.1.4 Density of states
- 4.1.5 Calculating the partition function
- 4.1.6 Thermodynamic properties
- 4.1.7 Thermal deBroglie wavelength
- 4.1.8 Breakdown of the classical approximation

4.2 Quantum statistics

- 4.2.2 Bosons and Fermions
- 4.2.3 The quantum distribution functions
- 4.2.4 The chemical potential
- 4.2.5 Methodology for quantum gases

4.3 The Fermi gas

- 4.3.1 The Fermi-Dirac distribution
- 4.3.2 Fermi gas at zero temperature
- 4.3.3 Fermi temperature and Fermi wavevector
- 4.3.4 Qualitative behaviour of a degenerate Fermi gas
- 4.3.5 Fermi gas at low temperatures – simple model
- 4.3.6 Internal energy and thermal capacity
- 4.3.6 Equation of state

4.4 The Bose gas

- 4.4.1 Generalisation of the density of states function
- 4.4.2 Examples of Bose systems
- 4.4.3 Helium-4
- 4.4.4 Phonons and photons — quantised waves
- 4.4.5 Photons in thermal equilibrium — black body radiation
- 4.4.6 The spectrum maximum
- 4.4.7 Internal energy and thermal capacity of a photon gas
- 4.4.8 Energy flux
- 4.4.9 Phonons — Debye model of a solid
- 4.4.10 Phonon internal energy and thermal capacity
- 4.4.11 Limiting forms at high and low temperatures

Section 5 Further Thermodynamics

5.1 Phase equilibrium

- 5.1.1 Conditions for equilibrium coexistence
- 5.1.2 The phase diagram
- 5.1.3 Clausius-Clapeyron equation
- 5.1.4 Saturated vapour pressure

5.2 The Third Law of thermodynamics

- 5.2.1 History
- 5.2.2 Entropy
- 5.2.3 Quantum viewpoint
- 5.2.4 Unattainability of absolute zero
- 5.2.5 Heat capacity at low temperatures
- 5.2.6 Other consequences of the Third Law
- 5.2.7 Pessimist's statement of the laws of thermodynamics