

The curve in Figure 16.11 of the text shows how the vibrational heat capacity depends on temperature. Note that even when the temperature is only slightly above the vibrational temperature, the heat capacity is close to its equipartition value.

The total heat capacity of a molecular substance is the sum of each contribution (Figure 16.12 of the text). When equipartition is valid (when the temperature is well above the characteristic temperature of the mode  $T \gg \theta_M$ ) we can estimate the heat capacity by counting the numbers of modes that are active. In gases, all three translational modes are always active and contribute  $\frac{3}{2}R$  to the molar heat capacity. If we denote the number of active rotational modes by  $\nu_R^\ddagger$  (so for most molecules at normal temperatures  $\nu_R^\ddagger = 2$  for linear molecules, and 3 for non-linear molecules), then

the total heat capacity is given by  $C_{V,m} = \frac{3}{2}R + \frac{\nu_R^\ddagger}{2}R + \frac{\nu_V}{2}R$ , where  $\nu_V$  is the number of active vibrational modes. In the equipartition limit  $\nu_V = 3N - 5$  for linear molecules and  $\nu_V = 3N - 6$  for non-linear molecules, where  $N$  is the number of atoms in the molecule.

$$C_{V,m} = \frac{3}{2}R + \frac{\nu_R^\ddagger}{2}R + \frac{\nu_V}{2}R$$

The equipartition value of  $C_{V,m}$  is the value that the heat capacity approaches as  $T \rightarrow \infty$ . The value of  $C_{V,m}$  at a given temperature is given by the sum of the equipartition value and the vibrational contribution. The vibrational contribution is given by  $\frac{\nu_V}{2}R$ , where  $\nu_V$  is the number of active vibrational modes. The number of active vibrational modes is given by  $\nu_V = 3N - 5$  for linear molecules and  $\nu_V = 3N - 6$  for non-linear molecules. The number of active vibrational modes is given by  $\nu_V = 3N - 5$  for linear molecules and  $\nu_V = 3N - 6$  for non-linear molecules.

### Solutions to exercises

The thermal energy is given by  $U = \frac{1}{2}k_B T$  per degree of freedom. When equipartition is valid, the thermal energy is given by  $U = \frac{1}{2}k_B T$  per degree of freedom.

$$U = \frac{1}{2}k_B T$$

At 298 K, the thermal energy is given by  $U = \frac{1}{2}k_B T$ .

$$U = \frac{1}{2}k_B T = \frac{1}{2}(1.38 \times 10^{-23} \text{ J K}^{-1})(298 \text{ K}) = 2.05 \times 10^{-21} \text{ J}$$

At 1000 K, the thermal energy is given by  $U = \frac{1}{2}k_B T$ .

$$U = \frac{1}{2}k_B T = \frac{1}{2}(1.38 \times 10^{-23} \text{ J K}^{-1})(1000 \text{ K}) = 6.90 \times 10^{-21} \text{ J}$$

$$C_{V,m} = \frac{3}{2}R + \frac{\nu_R^\ddagger}{2}R + \frac{\nu_V}{2}R$$

At 298 K, the thermal energy is given by  $U = \frac{1}{2}k_B T$ .

# Physical Chemistry 9th Edition Solutions

**Mary Burnham, Carol Hurd**



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The Encyclopaedia Britannica, 1929

Encyclopaedia Britannica, 1929

*The Encyclopedia Britannica* James Louis Garvin, Franklin Henry Hooper, Warren E. Cox, 1929

*Chemical Engineering Catalog*, 1918

**Physico-chemical Aspects of Textile Coloration** Stephen M. Burkinshaw, 2016-02-08 The production of textile materials comprises a very large and complex global industry that utilises a diverse range of fibre types and creates a variety of textile products As the great majority of such products are coloured predominantly using aqueous dyeing processes the coloration of textiles is a large scale global business in which complex procedures are used to apply different types of dye to the various types of textile material The development of such dyeing processes is the result of substantial research activity undertaken over many decades into the physico chemical aspects of dye adsorption and the establishment of dyeing theory which seeks to describe the mechanism by which dyes interact with textile fibres Physico Chemical Aspects of Textile Coloration provides a comprehensive treatment of the physical chemistry involved in the dyeing of the major types of natural man made and synthetic fibres with the principal types of dye The book covers fundamental aspects of the physical and chemical structure of both fibres and dyes together with the structure and properties of water in relation to dyeing dyeing as an area of study as well as the terminology employed in dyeing technology and science contemporary views of intermolecular forces and the nature of the interactions that can occur between dyes and fibres at a molecular level fundamental principles involved in dyeing theory as represented by the thermodynamics and kinetics of dye sorption detailed accounts of the

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*Bulletin of the Chemical Society of Japan* Nihon Kagakkai, 1986      **Chemical News and Journal of Physical Science**, 1888      Physical Chemistry for Schools Henry John Horstman Fenton, 1916      **Industrial & Engineering Chemistry**, 1923      *The United States Catalog* Mary Burnham, Carol Hurd, 1928      *The Journal of Industrial and Engineering Chemistry*, 1923      Physical Chemistry Keith James Laidler, John H. Meiser, 1982      **Laboratory Manual of Organic Chemistry** Harry Linn Fisher, 1924      **The Lancet**, 1927

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