# Thermodynamics

*Do two of the following three problems, each on a separate page (or pages) and write your name on every page you turn in.*

## Problem 1

Estimate the constant-volume specific heat capacity $C_V$ of benzene ($C_6H_6$), in units of the ideal gas constant $R$. See the image of benzene structure below. Explain your estimate in detail. Recall that for a monatomic ideal gas, $C_V = \frac{3}{2}R$.

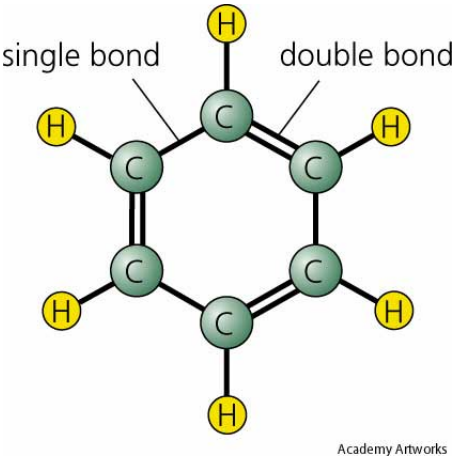


Figure 1: Benzene molecule

## Problem 2

An interstellar gas cloud consists of atomic hydrogen with density $n_{\rm H} = 10^4\,{\rm cm}^{-3}$. At what temperature would the thermal (kinetic) pressure of the gas be equal to the radiation pressure of the photons emitted by the gas?

# Problem 3

One kilomole of a monatomic ideal gas follows the reversible closed cycle shown in the figure below. Here, $P_1 = 10$ atm, $V_1 = 2$ m$^3$, and $V_2 = 4$ m$^3$. The segment of the cycle from point 1 to point 2 is adiabatic. Calculate the change in entropy for each segment of the cycle. What is the sum of entropy changes over the complete cycle?

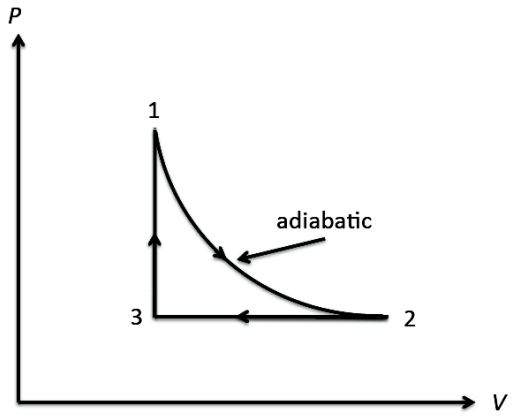


Figure 2: Thermal cycle

Useful constants:
Stefan-Boltzmann constant $\sigma = 5.67 \times 10^{-8} \mathrm{W\,m^{-2}K^{-4}}$
Ideal gas constant: $R = 8.314\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro's number: $N_A = 6.022 \times 10^{23}$
Boltzmann constant: $k_B = 1.381 \times 10^{-23}\,\mathrm{J\,K^{-1}}$