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EXAM I, ATMO 335, Feb 11, 2008. OPEN BOOK

1. A parcel of dry air has mass 2.8 kg, temperature 245 K. The parcel rests in the atmosphere at a height corresponding to a pressure of 500 hPa

   a) What is the volume of this parcel?
   $V = \frac{\mathcal{M}RT}{p} = 3.94\,\mathrm{m}^3$

   b) What is the internal energy of this parcel?

   $U = \mathcal{M}c_vT = 492\,\mathrm{k\,J}$

   c) One gram of water is evaporated into this parcel. How much thermal energy is removed as the parcel cools?

   $Q = \mathcal{M}_{water}L = 0.001 \times 2.5 \times 10^6$=2500 J

   d) How much does the internal energy change during this cooling?

   $\Delta T = \frac{Q}{\mathcal{M}_{air}c_p}$= 0.89 K; $\Delta U = \mathcal{M}_{air}c_v\Delta T = 1787\,\mathrm{J}$

2. Recall properties of the parcel in Problem 1 ($T = 245\,\mathrm{K}$, $p = 500\,\mathrm{hPa}$, $\mathcal{M} = 2.8\,\mathrm{kg}$).

   a) What is the number density n_0 in the parcel?

   $n_0 = \frac{p}{k_BT} = \frac{50000}{1.38\times10^{-23}\times245} = 1.48 \times 10^{25}\,\mathrm{molecules\,m^{-3}}$

   b) What is the mean free path in the parcel (use a reasonable value of σ_c)?

   Take σ_c=0.5 nm^2=0.5 $\times 10^{-18}$ m^2. Then $\lambda = \frac{1}{n_0\sigma_c}$ ≈135 nm

   c) What is the rms speed of a molecule in the parcel?

   $v_{rms} = \sqrt{3RT} = 459\,\mathrm{m\,s^{-1}}$, see Table 2.4

d) What is the speed of sound in this parcel?

$$v_{sound} = \sqrt{\gamma RT} = 0.683 v_{rms} = 314\,\mathrm{m\,s^{-1}} \quad (\gamma = \tfrac{c_p}{c_v} = \tfrac{7}{5})$$

3. A parcel of dry air is expanded adiabatically from $2.3\,\mathrm{m}^3$ to $5.4\,\mathrm{m}^3$. Its initial pressure is p= 500 hPa, and initial temperature $T = 245\,\mathrm{K}$.

a) What is the mass $\mathcal{M}$ of the parcel?

$$\mathcal{M} = \tfrac{pV}{RT} = \tfrac{50000\times 2.3}{287\times 245} = 1.64\,\mathrm{kg}$$

b) What is the final pressure?

$$p = p_0 \left(\tfrac{V_0}{V}\right)^{\gamma} = 50000 \left(\tfrac{2.3}{5.4}\right)^{1.400} = 151.4\,\mathrm{hPa}$$

c) What is the final Temperature?

$$T = T_0 \left(\tfrac{p}{p_0}\right)^{\kappa} = 245 \times \left(\tfrac{151}{500}\right)^{0.286} = 174.0\,\mathrm{K}$$

d) What is the change in enthalpy?

$$\Delta H = \mathcal{M} c_p \Delta T = 1.64 \times 1005 \times (174 - 245) = -117\,\mathrm{kJ}$$