$\frac{1}{2}m\overline{v^2} = \frac{3}{2}k_B T; \frac{1}{2}M_{mol}\overline{v^2} = \frac{3}{2}RT$; R=8.314 J/mol·K=0.08216L·atm/mol·K;

Molecular model of an ideal gas:

1. (3) In a 30.0s interval, 500 hailstones strike a glass window of area 0.600m^2 at an angle of 45° to the window surface. Each hailstone has a mass of 5.00g and moves with a speed of 8.00m/s. Assuming the collisions are elastic, find the average force and pressure on the window. (0.943N, 1.57Pa)
2. A sealed cubical container 20.0cm on a side contains three times Avogadro's number of molecules at a temperature of 20.0°C. Find the force exerted by the gas on one of the walls of the container. (3.65E4N).
3. (9) How many atoms of helium gas fill a balloon having a diameter of 30.0cm at 20.0°C and 1atm pressure. b) What is the average kinetic energy of the helium atoms? c) What is the rms speed of the helium atoms? (a) 3.54E23; b) 6.07E-21J c) 1.35km/s.
4. (11) A cylinder contains a mixture of helium and argon (39.9g/mol) gas in equilibrium at 150°C. a) What is the average kinetic energy of each gas molecule? c)What is the rms speed of each type of molecule? a) 8.76E-21J b)helium: 1.62km/s, argon: 514m/s.

Molar specific heat of an ideal gas: $Q_P = nC_P\Delta T; U = Q_V = nC_V\Delta T$

ideal gas monoatomic: $C_V = \frac{3}{2}R; C_P = C_V + R = \frac{5}{2}R;\ \gamma = \frac{C_P}{C_V}$ =1.67;

diatomic: $C_V = \frac{5}{2}R; C_P = C_V + R = \frac{7}{2}R; \gamma = 1.40$

5. (13) A 1.00 mol sample of hydrogen gas is heated at constant pressure from 300K to 420K. Draw a PV diagram. Calculate a) the energy transferred to the gas by heat, b) the increase in its internal energy, c) the work done on the gas. a) 3.46kJ, b) 2.45kJ, c) -1.01kJ.
6. (14) A house has well insulated walls. It contains a volume of 100m^3 of air at 300K. Calculate the energy required to increase the temperature of this diatomic ideal gas by 1.00C°. b) If this energy could be used to lift an object of mass m through a height of 2.00m, what is the value of m? a) 118kJ b)6.03E3kg.
7. A 1.00-mol sample of an ideal mono-atomic gas is at an initial temperature of 300K. The gas undergoes an iso-volumetric (isochoric) process acquiring 500J of energy by heat. It then undergoes an isobaric process losing this same amount of energy by heat. Determine a) the new temperature of the gas and b) the work done on the gas. a) 316K b) +200J.
8. (23) A container has a mixture of two gases: n_1 mol of gas 1 having molar specific heat C_1 and n_2 mol of gas 2 having specific heat C_2. a) Find the molar specific heat of the mixture. b) What is the molar specific heat of m gases with n_m moles having specific heats C_m? a) and b) $C = \frac{\sum_{i=1}^{m} n_i C_i}{\sum_{i=1}^{m} n_i}$

Adiabatic processes for an ideal gas $PV^{\gamma} = \text{constant}; TV^{\gamma-1} = \text{constant}$

9. (18) During the compression stroke of a certain gasoline engine, the pressure increases from 1.00 atm to 20.0 atm. If the process is adiabatic and the fuel-air mixture behaves like an ideal diatomic gas, by what factor does the volume change, and b) by what factor does the temperature change? c) Assuming that the compression starts with 0.016 mol of gas at 27.0°C, find the values for Q, W, and U that characterize the process. Draw a PV-diagram of the process. a)0.118 b) 2.35 c) Q=0, U=135J, W=+135J.
10. (21) Air in a thundercloud expands as it rises. If its initial temperature is 300K and no energy is lost by thermal conduction on expansion, what is its temperature when the initial volume has doubled? (227K)

The Equipartition of energy: $\frac{1}{2}k_BT$ per degree of freedom

11. (28) In a crude model of a rotating diatomic molecule of chlorine, the two Cl atoms are2.00E-10m apart and rotate about their center of mass with angular velocity ω=2.00E12/s. What is the rotational kinetic energy of one molecule which has a molar mass of 70.0g/mol? (2.33E-21J)

The Boltzmann distribution law: $\mathrm{v}_{\mathrm{avg}} = \sqrt{\frac{8k_BT}{\pi m}}$

12. (35) At what temperature would the average speed of helium atoms a) equal the escape speed from Earth, 1.12E4 m/s, and b)the escape speed from the moon, 2.37E3m/s. (a) 2.37E4 K, b)1.06E3 K.
13. (37) Assume that the Earth's atmosphere has a uniform temperature of 20°C and uniform composition, with an effective molar mass of 28.9g/mol. a) Show that the number density of molecules depends on height according to: $n_V(y) = n_0 e^{-\frac{mgy}{k_BT}}$. Find the ratio of the atmospheric density at a height of 11.0km to that at sea level with n_0. (0.278)
14. (38) The average height of a molecule in the Earth's atmosphere is given by

$$\bar{y} = n_0 \int_0^{\infty} y e^{-\frac{mgy}{k_BT}} dy = \frac{\int_0^{\infty} y e^{-\frac{mgy}{k_BT}} dy}{\int_0^{\infty} e^{-\frac{mgy}{k_BT}} dy}$$

a) Prove that this average height is equal to $\frac{k_BT}{mg}$ b) Calculate the height for T=10.0°C and molecular mass 28.9u. (a) b)8.31km.

Mean Free Path

$$\text{mean free path } \lambda = \frac{\text{average distance}}{\text{number of collisions}} = \frac{1}{\sqrt{2}\pi d^2 n_V}$$

$d = 2r = diameter$ of target cylinder; $n_V = \frac{N}{V}$ = number-density

number of collisions=$\sqrt{2}\pi d^2 n_V \bar{v}\Delta t$

15. In an ultra-high-vacuum system, the pressure is measured to be 1.00E-10torr (where 1 torr=133 Pa; 1 torr is the pressure corresponding to 1mm Hg; $\rho_{Hg} = 13.6\, g/cm^3$.). Assuming the molecular diameter is 3.00E-10m, the molecular speed is 500m/s, and the temperature is 300K, find a) the number of molecules in 1.00m^3, b)the mean free path of the molecules and c) the collision frequency. a) N=3.21E12 b) λ=779km; c) 6.42E-4Hz
16. (47) Show that the mean free path for the molecules of an ideal gas is:

$$\lambda = \frac{k_B T}{\sqrt{2}\pi d^2 P}$$

17. (49) The compressibility of a substance is the inverse of the bulk-modulus $B = \frac{1}{\kappa} = -V\frac{dP}{dV}$ a) Explain why the negative sign in this expression ensures that the bulk modulus and the compressibility are always positive. b) Show that if an ideal gas is compressed isothermally, B=P.

c) Show that if an ideal gas is compressed adiabatically B=γP d) Determine values for B for a mono-atomic gas at a pressure of 2.00atm.

18. (50) a) Show that the speed of sound in an ideal gas is v=

$$\sqrt{\frac{\gamma RT}{M}} = \sqrt{\frac{\gamma k_B T}{m}} = (\textit{for}\ \text{air})\ 331 m/s\sqrt{1+\frac{T(\textit{in}\ \text{Celsius})}{273}}$$

Start with v=$\sqrt{\frac{B}{\rho}}$