CHAPTER 18
THERMAL PROPERTIES OF MATTER

Discussion Questions

Q18.1 The equation of state expressed in Eq.(18.1) shows that in general the volume V depends on the temperature and pressure. An equation of state of this form applies only to a single phase of material, either solid, liquid or gas. Different behavior is found during phase changes.

Q18.2 No, the Celsius temperature could not be used. Converting from Kelvin to Celsius is not done just by multiplying by a conversion factor. You can see that Celsius temperatures can't work because Celsius temperatures can be negative and negative T in Eq.(18.3) doesn't make sense.

Q18.3 The temperature of the air inside the tires increases and this causes the pressure to increase. You should not let air out of the tires to reduce the pressure, they would then be under-inflated when they cool. The recommended inflation pressure for tires are always given as cold-inflation values.

Q18.4 The increase in pressure raises the boiling point of the coolant and prevents it from boiling. If the system were sealed too great of an engine temperature could result in a coolant pressure that would damage engine parts and coolant hoses.

Q18.5 The frozen water in the food undergoes sublimation.

Q18.6 The air pressure at the higher elevation of the slopes was much less than at sea level where the bags were filled and sealed. The pressure difference between the air inside and outside the bags caused them to burst.

Q18.7 At low pressures where the ideal gas law applies the number of atoms per cm^3 is still quite large.

Q18.8 The distribution of speeds of the gas molecules doesn't change when they move through the hole into the other half of the container. Therefore, the total translational kinetic energy of the gas doesn't change and the final temperature will be T_0. The volume doubles and the temperature doesn't change, so $pV = nRT$ says that the pressure is halved. The new pressure is $p_0 / 2$.

Q18.9 (a) A kilogram of each has the same mass. One mole of each has the same number of atoms. The mass of one mole is much larger for lead so one kilogram of lead is fewer moles than one kilogram of hydrogen and therefore has fewer atoms. (b) If we have a mole of hydrogen atoms each has the same number of atoms, equal to Avogadro's number. If we instead have a mole of hydrogen molecules, there are more hydrogen atoms than lead atoms since each hydrogen molecule has two atoms. One mole of lead has more mass than one mole of hydrogen since one lead atom has more mass than either a hydrogen atom or a hydrogen molecule.

Q18.10 (a) Adding heat to the gas increases the average kinetic energy of each gas atom. This increases their average speed and therefore they exert a greater force in collisions with the walls of the container. The increased average speed also means that collisions with the wall are more frequent. (b) Constant temperature means the average kinetic energy of each atom and also the average speed don't change. But with a smaller volume collisions with the walls are more frequent and this increases the average force on the walls.

Q18.11 The mass of a nitrogen molecule is less than the mass of an oxygen molecule so I would expect the proportion of oxygen to be less at higher altitudes, since at a given altitude the gravitational potential energy of an oxygen atom would be greater.

Q18.12 This statement is incorrect. In thermal equilibrium the two gases have the same average kinetic energy per atom. The average speeds will then be inversely proportional to the square root of the masses of the atoms.

Q18.13 The assumption of elastic collisions with the walls in equivalent to assuming that the walls are at the same temperature as the gas. If the walls are hotter or colder than the gas, the gas atoms will gain or lose energy when they collide with the walls.

Q18.14 Temperature is related to the average kinetic energy of the random motion of the atoms. The collective motion of the entire gas does not affect the temperature.

Q18.15 The average translational kinetic energy of one atom of the gas depends on the temperature of the gas. If the volume is also kept constant then the temperature increases when the pressure increases. But if both pressure and volume change such as to keep their product pV constant then the temperature doesn't change and the average translational kinetic energy of the atoms remains constant.

Q18.16 It is justified if the difference in gravitational potential energy of an atom at the top and at the bottom of the container is much smaller than the average kinetic energy of the atoms. Let the container height be h. Then $\Delta U = mgh$. $K_{\text{tr}} = \frac{1}{2}mv_{\text{rms}}^2$. The ratio of these energies is $\Delta U / K_{\text{tr}} = 2gh / v_{\text{rms}}^2$. Example 18.6 shows that $v_{\text{rms}} \approx 500$ m/s so for $h = 1$ m this ratio is very small and neglect of gravitational potential energy changes is justified.

Q18.17 The average speed of the air molecules inside the house would decrease and this would lower the temperature of the air in the house.

Q18.18 The lighter gas atoms have a larger v_{rms} and exit through the hole more frequently.

Q18.19 Eq.(18.14) says that the total average translational kinetic energy of the gas depends on the number of moles and on the Kelvin temperature. For the same total mass, there will be more moles of gas B so specimen B will have more total kinetic energy. We must use the molecular mass of the gas in the analysis.

Q18.20 To double the average translational kinetic energy of each gas atom you must double the Kelvin temperature. 25° C = 298 K and 50° C = 323 K so this temperature does not double the Kelvin temperature. The final temperature would have to be 2(298 K) = 596 K = 323°C to double the average translational kinetic energy per atom.

Q18.21 Eq.(18.19) shows that v_{rms} is directly proportional to the square root of the Kelvin temperature of the gas, so to double v_{rms} the Kelvin temperature T must be increased by a factor of 4.

Q18.22 (a) $Q = nC_V\Delta T$ and $\Delta T = \dfrac{Q}{nC_V}$. C_V is smaller for the monatomic gas so the monatomic gas will increase more in temperature than the diatomic gas. (b) Since the diatomic gas has internal degrees of freedom (rotation and vibration) not all the energy that flows into the gas goes into increasing the translational kinetic energy K_{tr}. Some goes into increasing the rotational and vibrational energy. But only K_{tr} determines the temperature.

Q18.23 No. All ideal diatomic gases have the same molar heat capacity C_V. Therefore, if the same amount of heat flows into 1.00 mol of any diatomic ideal gas, the temperature will increase the same amount. But the number of moles that corresponds to 1.00 g of gas depends on the molecular mass and that will be different for different gases. That is, in $\Delta T = \dfrac{Q}{nC_V}$, C_V will be the same but n will be different and therefore ΔT will be different.

Q18.24 The only thing we can say is that for small Δv the number of molecules having speeds between v and $v + \Delta v$ is $Nf(v)\Delta v$. So, neither statement in the question is correct.

Q18.25 There is no liquid phase below the triple point pressure. Table 18.3 gives the triple point pressure to be 610 Pa for water and 5.17×10^5 Pa for CO_2. The atmospheric pressure is below the triple point pressure of water, and there can be no liquid water on Mars. The same holds true for CO_2. On earth $p_{\text{atm}} = 1.01 \times 10^5\ \text{Pa}$ so on the surface of the earth there can be liquid water but not liquid CO_2.

Q18.26 The water boils when the vapor pressure of the liquid equals the applied pressure, which is being reduced. When the water boils the molecules at the surface with the greatest translational speed escape from the liquid. This reduces the average translational kinetic energy of the molecules remaining in the liquid, and this lowers the temperature of the liquid.

Q18.27 The melting temperature of the ice increases when the applied pressure increases. This is because the volume decreases when ice changes phase to liquid.

Q18.28 The water doesn't boil because the large hydrostatic pressure at this depth increases the boiling point to above this temperature.

Q18.29 Atmospheric pressure on the moon is very small so any liquid water on the surface would boil away.

Q18.30 The boiling point temperature is lower at the lower air pressure at high altitudes. So, the boiling water at high altitudes has a lower temperature.