Answers to Exercise 9.4
Kinetic Molecular Theory

1. Each of the following statements assumes that there is no change to any property not specifically mentioned in the statement.

(a) Pressure is force applied to an area: $P = \frac{F}{A}$. In the context of gases, pressure is a measure of the force exerted by gas particles as they collide with the sides of their container.

Note that the term "sides of the container" is being used very generally here. If I stand inside a room, the walls, ceiling and floor are sides of the container – but so am I. Because the gas particles cannot travel through me, I will experience air pressure too.

(b) As the number of gas particles increases, the frequency of collisions between gas particles and the sides of the container increases. More collisions = more net force applied to the container = higher pressure.

(c) As the mass of each particle increases, the force it applies to the container with each collision increases. (Recall from physics that force = mass × acceleration.)

(d) As the speed of the gas particles increases, the force they apply to the container with each collision increases.

(e) As the volume of the container decreases, there is less empty space for the gas particles to travel through. They therefore encounter (and collide with) the sides of the container more frequently. More collisions = more net force applied to the container = higher pressure.

(f) Temperature is directly proportional to kinetic energy and, therefore, if the mass of the gas particles does not change (because the identity of the gas does not change), the speed of the particles must increase as temperature increases: $\frac{3}{2}RT = \frac{1}{2}mv_{rms}^2 = \overline{E_k}$

Therefore, the particles apply greater force to the container with each collision.

2.

(a) The root-mean-square speed is slightly larger than the most probable speed. This is because no gas particle can have a speed smaller than 0 m/s, but there is no upper limit on speed. Also, squaring large values increases them more than squaring small values, so the higher speeds contribute more to the root-mean-square speed, making it slightly higher than either a straight average or the observed most probable speed.

(b) The four noble gases have different molar masses. At any given temperature, the average kinetic energy is the same for all gases, but kinetic energy is a function of both mass and speed ($\overline{E_k} = \frac{1}{2}mv^2$). Thus, gases with smaller molar masses will have higher speeds at any given temperature. This is consistent with the graph which shows that He has the highest root-mean-square speed – followed by Ne then Ar then Xe.