Chapter 13: temperature, kinetic theory, and the gas laws

# 13.1 temperature

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| 1. | *What is the Fahrenheit temperature of a person with a  fever?* |
| Solution |  |
| 2. | *Frost damage to most plants occurs at temperatures of  or lower. What is this temperature on the Kelvin scale?* |
| Solution | To convert from Fahrenheit to Kelvin, first convert to Celsius:  Then convert to Kelvin: |
| 3. | *To conserve energy, room temperatures are kept at  in the winter and  in the summer. What are these temperatures on the Celsius scale?* |
| Solution |  |
| 4. | *A tungsten light bulb filament may operate at 2900 K. What is its Fahrenheit temperature? What is this on the Celsius scale?* |
| Solution | This is a two step process. First we convert Kelvin to Celsius then to Fahrenheit: |
| 5. | *The surface temperature of the Sun is about 5750 K. What is this temperature on the Fahrenheit scale?* |
| Solution | This is a two step process but we can do it in one step by combining the conversion equations for Kelvin to Celsius and Celsius to Fahrenheit. |
| 6. | *One of the hottest temperatures ever recorded on the surface of Earth was  in Death Valley, CA. What is this temperature in Celsius degrees? What is this temperature in Kelvin?* |
| Solution |  |
| 7. | *(a) Suppose a cold front blows into your locale and drops the temperature by 40.0 Fahrenheit degrees. How many degrees Celsius does the temperature decrease when there is a  decrease in temperature? (b) Show that any change in temperature in Fahrenheit degrees is nine-fifths the change in Celsius degrees.* |
| Solution | (a)  (b) We know that . We also know that  and . So, substituting, we have . Partially solving and rearranging the equation, we have . Therefore, |
| 8. | *(a) At what temperature do the Fahrenheit and Celsius scales have the same numerical value? (b) At what temperature do the Fahrenheit and Kelvin scales have the same numerical value?* |
| Solution | (a) To answer this we need to set , using  so  Solving gives: , or  . At this temperature, the Fahrenheit and Celsius scales have the same value.  (b) For this part, we need to let . Using an equation from part (a),  , and substituting in  along with  , we have: |
| 13.2 thermal expansion of solids and liquids | |
| 9. | *The height of the Washington Monument is measured to be 170 m on a day when the temperature is . What will its height be on a day when the temperature falls to ? Although the monument is made of limestone, assume that its thermal coefficient of expansion is the same as marble’s.* |
| Solution | Using Table 13.2 to find the thermal coefficient of expansion of marble:    (Answer rounded to five significant figures to show the slight difference in height.). |
| 10. | *How much taller does the Eiffel Tower become at the end of a day when the temperature has increased by ? Its original height is 321 m and you can assume it is made of steel.* |
| Solution | Using Table 13.2 to find the thermal coefficient of expansion of steel: |
| 11. | *What is the change in length of a 3.00-cm-long column of mercury if its temperature changes from  to* *, assuming the mercury is unconstrained?* |
| Solution | Using Table 13.2 to find the thermal coefficient of expansion of mercury: |
| 12. | *How large an expansion gap should be left between steel railroad rails if they may reach a maximum temperature  greater than when they were laid? Their original length is 10.0 m.* |
| Solution | Using Table 13.2 to find the thermal coefficient of expansion of steel: |
| 13. | *You are looking to purchase a small piece of land in Hong Kong. The price is “only” $60,000 per square meter! The land title says the dimensions are* . *By how much would the total price change if you measured the parcel with a steel tape measure on a day when the temperature was  above normal?* |
| Solution | On the warmer day, our tape measure will expand linearly. Therefore, we will measure each dimension to be smaller than its actual size. (Note that the parcel of land does not actually change, so we do not use the equation for thermal expansion in two dimensions.) Calling these new dimensions  and , we will find a new area, . Let’s calculate these new dimensions:      Because the area gets smaller, the price of the land DECREASES by ~$17,000. |
| 14. | *Global warming will produce rising sea levels partly due to melting ice caps but also due to the expansion of water as average ocean temperatures rise. To get some idea of the size of this effect, calculate the change in length of a column of water 1.00 km high for a temperature increase of  Note that this calculation is only approximate because ocean warming is not uniform with depth.* |
| Solution | To deal with volume increase, we need to use the equation  (We need to divide  by three because we are looking for the change in length, not volume.) Use Table 13.2 to find water’s coefficient of volume expansion: |
| 15. | *Show that 60.0 L of gasoline originally at  will expand to 61.1 L when it warms to*  *as claimed in Example 13.4.* |
| Solution |  |
| 16. | *(a) Suppose a meter stick made of steel and one made of invar (an alloy of iron and nickel) are the same length at . What is their difference in length at ? (b) Repeat the calculation for two 30.0-m-long surveyor’s tapes.* |
| Solution | (a)  (b) |
| 17. | *(a) If a 500-mL glass beaker is filled to the brim with ethyl alcohol at a temperature of  how much will overflow when its temperature reaches ? (b) How much less water would overflow under the same conditions?* |
| Solution | Assume that the glass beaker is initially at room temperature (), so that its temperature does not change.  (a) Ethyl alcohol:  (b) Water: |
| 18. | *Most automobiles have a coolant reservoir to catch radiator fluid that may overflow when the engine is hot. A radiator is made of copper and is filled to its 16.0-L capacity when at  What volume of radiator fluid will overflow when the radiator and fluid reach their  operating temperature, given that the fluid’s volume coefficient of expansion is ? Note that this coefficient is approximate, because most car radiators have operating temperatures of greater than* |
| Solution |  |
| 19. | *A physicist makes a cup of instant coffee and notices that, as the coffee cools, its level drops 3.00 mm in the glass cup. Show that this decrease cannot be due to thermal contraction by calculating the decrease in level if the  of coffee is in a 7.00-cm-diameter cup and decreases in temperature from  to  (Most of the drop in level is actually due to escaping bubbles of air.)* |
| Solution | The work shows that the change in volume (from thermal expansion) of the coffee and the cup does not account for all of the level drop. Thus, other factors must be held accountable (such as escaping bubbles of air). |
| 20. | *(a) The density of water at  is very nearly  (it is actually ), whereas the density of ice at  is . Calculate the pressure necessary to keep ice from expanding when it freezes, neglecting the effect such a large pressure would have on the freezing temperature. (This problem gives you only an indication of how large the forces associated with freezing water might be.) (b) What are the implications of this result for biological cells that are frozen?* |
| Solution | (a) If we start with the freezing of water, then it would expand to  of ice.    (b) Biological cells that are frozen must be left free to expand when they are unfrozen, otherwise they will undergo extreme pressures and probably be destroyed. In the freezing process, the cells experience large outward pressures. If they don’t have room to expand, they will likely be destroyed. |
| 21. | *Show that*  *by calculating the change in volume  of a cube with sides of length* |
| Solution | From the equation  we know that length changes with temperature. We also know that the volume of a cube is related to its length by  . Using the equation  and substituting for the sides we get . Then we replace  to get . Since  is small, we can use the binomial expansion to get . Rewriting the length terms in terms of volume gives . By comparing forms we get  . Thus,. |
| 13.3 the ideal gas law | |
| 22. | *The gauge pressure in your car tires is*  *at a temperature of  when you drive it onto a ferry boat to Alaska. What is their gauge pressure later, when their temperature has dropped to ?* |
| Solution | since |
| 23. | *Convert an absolute pressure of*  *to gauge pressure in*  *(This value was stated to be just less than*  *in Example 13.9. Is it?)* |
| Solution |  |
| 24. | *Suppose a gas-filled incandescent light bulb is manufactured so that the gas inside the bulb is at atmospheric pressure when the bulb has a temperature of . (a) Find the gauge pressure inside such a bulb when it is hot, assuming its average temperature is  (an approximation) and neglecting any change in volume due to thermal expansion or gas leaks. (b) The actual final pressure for the light bulb will be less than calculated in part (a) because the glass bulb will expand. What will the actual final pressure be, taking this into account? Is this a negligible difference?* |
| Solution | (a)  (b) First, let = the final pressure without glass bulb expansion,  = the final pressure with glass bulb expansion, and = the final temperature of the light bulb. Also, let  = the final volume pressure with glass bulb expansion.      The difference between this value and the value from part (a) is negligible. |
| 25. | *Large helium-filled balloons are used to lift scientific equipment to high altitudes. (a) What is the pressure inside such a balloon if it starts out at sea level with a temperature of  and rises to an altitude where its volume is twenty times the original volume and its temperature is ? (b) What is the gauge pressure? (Assume atmospheric pressure is constant.)* |
| Solution | (a)  (b) Gauge pressure = |
| 26. | *Confirm that the units of  are those of energy for each value of : (a) , (b) , and (c) .* |
| Solution | (a)  (b)  (c) |
| 27. | *In the text, it was shown that  for gas at STP. (a) Show that this quantity is equivalent to  as stated. (b) About how many atoms are there in one  (a cubic micrometer) at STP? (c) What does your answer to part (b) imply about the separation of atoms and molecules?* |
| Solution | (a)  (b)  (c) This says that the average volume of atoms and molecules must be on the order of  Or the average length of an atom is less than approximately  Since atoms are widely spaced, the average length is probably more on the order of 0.3 nm. |
| 28. | *Calculate the number of moles in the 2.00-L volume of air in the lungs of the average person. Note that the air is at  (body temperature).* |
| Solution |  |
| 29. | *An airplane passenger has*  *of air in his stomach just before the plane takes off from a sea-level airport. What volume will the air have at cruising altitude if cabin pressure drops to* *?* |
| Solution |  |
| 30. | *(a) What is the volume (in ) of Avogadro’s number of sand grains if each grain is a cube and has sides that are 1.0 mm long? (b) How many kilometers of beaches in length would this cover if the beach averages 100 m in width and 10.0 m in depth? Neglect air spaces between grains.* |
| Solution | (a)  (b) |
| 31. | *An expensive vacuum system can achieve a pressure as low as*  *at . How many atoms are there in a cubic centimeter at this pressure and temperature?* |
| Solution |  |
| 32. | *The number density of gas atoms at a certain location in the space above our planet is about  and the pressure is  in this space. What is the temperature there?* |
| Solution | (which seems reasonable) |
| 33. | *A bicycle tire has a pressure of*  *at a temperature of  and contains 2.00 L of gas. What will its pressure be if you let out an amount of air that has a volume of*  *at atmospheric pressure? Assume tire temperature and volume remain constant.* |
| Solution | Then, we need to determine how many molecules were removed from the tire:    We can now determine how many molecules remain after the gas is released:    Finally, the final pressure is: |
| 34. | *A high-pressure gas cylinder contains 50.0 L of toxic gas at a pressure of*  *and a temperature of . Its valve leaks after the cylinder is dropped. The cylinder is cooled to dry ice temperature*  *to reduce the leak rate and pressure so that it can be safely repaired. (a) What is the final pressure in the tank, assuming a negligible amount of gas leaks while being cooled and that there is no phase change? (b) What is the final pressure if one-tenth of the gas escapes? (c) To what temperature must the tank be cooled to reduce the pressure to 1.00 atm (assuming the gas does not change phase and that there is no leakage during cooling)? (d) Does cooling the tank appear to be a practical solution?* |
| Solution | (a) Assume , then since  and    (b) So, we now we know that , and    (c)  (d) No. The final temperature needed is much too low to be easily achieved for a large object. |
| 35. | *Find the number of moles in 2.00 L of gas at  and under*  *of pressure.* |
| Solution |  |
| 36. | *Calculate the depth to which Avogadro’s number of table tennis balls would cover Earth. Each ball has a diameter of 3.75 cm. Assume the space between balls adds an extra 25.0% to their volume and assume they are not crushed by their own weight.* |
| Solution | Let  = the radius of Earth,  = the radius of the ping pong balls, and  = the radius to the top of the ping pong balls measured from Earth’s center. Then |
| 37. | *(a) What is the gauge pressure in a  car tire containing 3.60 mol of gas in a 30.0 L volume? (b) What will its gauge pressure be if you add 1.00 L of gas originally at atmospheric pressure and ? Assume the temperature returns to  and the volume remains constant.* |
| Solution | (a)  (b) |
| 38. | *(a) In the deep space between galaxies, the density of atoms is as low as  and the temperature is a frigid 2.7 K. What is the pressure? (b) What volume (in ) is occupied by 1 mol of gas? (c) If this volume is a cube, what is the length of its sides in kilometers?* |
| Solution | (a)  (b)  (c) |
| 13.4 kinetic theory: atomic and molecular explanation of pressure and temperature | |
| 39. | *Some incandescent light bulbs are filled with argon gas. What is  for argon atoms near the filament, assuming their temperature is 2500 K?* |
| Solution |  |
| 40. | *Average atomic and molecular speeds  are large, even at low temperatures. What is  for helium atoms at 5.00 K, just one degree above helium’s liquefaction temperature?* |
| Solution |  |
| 41. | *(a) What is the average kinetic energy in joules of hydrogen atoms on the  surface of the Sun? (b) What is the average kinetic energy of helium atoms in a region of the solar corona where the temperature is* *?* |
| Solution | (a)  (b) |
| 42. | *The escape velocity of any object from Earth is 11.2 km/s. (a) Express this speed in m/s and km/h. (b) At what temperature would oxygen molecules (molecular mass is equal to 32.0 g/mol) have an average velocity  equal to Earth’s escape velocity of 11.1 km/s?* |
| Solution | (a)  (b) |
| 43. | *The escape velocity from the Moon is much smaller than from Earth and is only 2.38 km/s. At what temperature would hydrogen molecules (molecular mass is equal to 2.016 g/mol) have an average velocity  equal to the Moon’s escape velocity?* |
| Solution |  |
| 44. | *Nuclear fusion, the energy source of the Sun, hydrogen bombs, and fusion reactors, occurs much more readily when the average kinetic energy of the atoms is high—that is, at high temperatures. Suppose you want the atoms in your fusion experiment to have average kinetic energies of* *. What temperature is needed?* |
| Solution |  |
| 45. | *Suppose that the average velocity  of carbon dioxide molecules (molecular mass is equal to 44.0 g/mol) in a flame is found to be* *. What temperature does this represent?* |
| Solution |  |
| 46. | *Hydrogen molecules (molecular mass is equal to 2.016 g/mol) have an average velocity  equal to 193 m/s. What is the temperature?* |
| Solution |  |
| 47. | *Much of the gas near the Sun is atomic hydrogen. Its temperature would have to be*  *for the average velocity  to equal the escape velocity from the Sun. What is that velocity?* |
| Solution | Since the sun consists of atomic hydrogen, not hydrogen molecules: |
| 48. | *There are two important isotopes of uranium— and ; these isotopes are nearly identical chemically but have different atomic masses. Only  is very useful in nuclear reactors. One of the techniques for separating them (gas diffusion) is based on the different average velocities  of uranium hexafluoride gas, . (a) The molecular masses for   and   are 349.0 g/mol and 352.0 g/mol, respectively. What is the ratio of their average velocities? (b) At what temperature would their average velocities differ by 1.00 m/s? (c) Do your answers in this problem imply that this technique may be difficult?* |
| Solution | (a)  (b)  From this we see that the difference in their velocities is:  and we want this to equal 1.00 m/s.    Solving for :    (c) This temperature is equivalent to , which is hot but not impossible to achieve. Thus, this process is doable. At this temperature, however, there may be other considerations that make this process difficult. |
| 13.6 humidity, evaporation, and boiling | |
| 49. | *Dry air is 78.1% nitrogen. What is the partial pressure of nitrogen when the atmospheric pressure is* *?* |
| Solution |  |
| 50. | *(a) What is the vapor pressure of water at ? (b) What percentage of atmospheric pressure does this correspond to? (c) What percent of  air is water vapor if it has 100% relative humidity? (The density of dry air at  is .)* |
| Solution | (a) Vapor Pressure for  (b) Divide the vapor pressure by atmospheric pressure:  (c) The density of water in this air is equal to the saturation vapor density of water at this temperature, taken from Table 13.5. Dividing by the density of dry air, we can get the percentage of water in the air: |
| 51. | *Pressure cookers increase cooking speed by raising the boiling temperature of water above its value at atmospheric pressure. (a) What pressure is necessary to raise the boiling point to ? (b) What gauge pressure does this correspond to?* |
| Solution | (a) Using Table 13.5:  (b) |
| 52. | *(a) At what temperature does water boil at an altitude of 1500 m (about 5000 ft) on a day when atmospheric pressure is*  *(b) What about at an altitude of 3000 m (about 10,000 ft) when atmospheric pressure is* *?* |
| Solution | (a) From Table 13.5:  (b) From Table 13.5: |
| 53. | *What is the atmospheric pressure on top of Mt. Everest on a day when water boils there at a temperature of* |
| Solution | From Table 13.5: |
| 54. | *At a spot in the high Andes, water boils at , greatly reducing the cooking speed of potatoes, for example. What is atmospheric pressure at this location?* |
| Solution | From Table 13.5: |
| 55. | *What is the relative humidity on a  day when the air contains  of water vapor?* |
| Solution |  |
| 56. | *What is the density of water vapor in  on a hot dry day in the desert when the temperature is  and the relative humidity is 6.00%?* |
| Solution |  |
| 57. | *A deep-sea diver should breathe a gas mixture that has the same oxygen partial pressure as at sea level, where dry air contains 20.9% oxygen and has a total pressure of* *. (a) What is the partial pressure of oxygen at sea level? (b) If the diver breathes a gas mixture at a pressure of* *, what percent oxygen should it be to have the same oxygen partial pressure as at sea level?* |
| Solution | (a)  (b) |
| 58. | *The vapor pressure of water at  is* *. Using the ideal gas law, calculate the density of water vapor in  that creates a partial pressure equal to this vapor pressure. The result should be the same as the saturation vapor density at that temperature .* |
| Solution |  |
| 59. | *Air in human lungs has a temperature of  and a saturation vapor density of* *. (a) If 2.00 L of air is exhaled and very dry air inhaled, what is the maximum loss of water vapor by the person? (b) Calculate the partial pressure of water vapor having this density, and compare it with the vapor pressure of .* |
| Solution | (a) The maximum loss of water would occur if the exhaled air is completely saturated, and the inhaled air is devoid of water. The maximum water vapor loss is:  (b)  The two values are nearly identical. |
| 60. | *If the relative humidity is 90.0% on a muggy summer morning when the temperature is , what will it be later in the day when the temperature is , assuming the water vapor density remains constant?* |
| Solution | Let = percent relative humidity, = vapor density, and = saturation vapor density. |
| 61. | *Late on an autumn day, the relative humidity is 45.0% and the temperature is . What will the relative humidity be that evening when the temperature has dropped to , assuming constant water vapor density?* |
| Solution | Let = percent relative humidity, = vapor density, and = saturation vapor density. |
| 62. | *Atmospheric pressure atop Mt. Everest is* *. (a) What is the partial pressure of oxygen there if it is 20.9% of the air? (b) What percent oxygen should a mountain climber breathe so that its partial pressure is the same as at sea level, where atmospheric pressure is* *? (c) One of the most severe problems for those climbing very high mountains is the extreme drying of breathing passages. Why does this drying occur?* |
| Solution | (a)  (b)  Set that equal to the percent oxygen times the pressure at the top of Mt. Everest:    Thus,  (c) This drying process occurs because the partial pressure of water vapor at high altitudes is decreased substantially. The climbers breathe very dry air, which leads to a lot of moisture being lost due to evaporation. The breathing passages are therefore not getting the moisture they require from the air being breathed. |
| 63. | *What is the dew point (the temperature at which 100% relative humidity would occur) on a day when relative humidity is 39.0% at a temperature of ?* |
| Solution | Let = percent relative humidity, = vapor density, and = saturation vapor density.    Now, assuming the relationship between temperature at saturation vapor pressure is linear between  and , we can use the fact that the value of  is constant between  and our temperature and between our temperature and  to interpolate, which yields:   |  |  | | --- | --- | | *T*()  0  4.7\*  5 | svd()  4.84  6.708  6.80 |     Therefore, the Dew point |
| 64. | *On a certain day, the temperature is  and the relative humidity is 90.0%. How many grams of water must condense out of each cubic meter of air if the temperature falls to ? Such a drop in temperature can, thus, produce heavy dew or fog.* |
| Solution | Let = percent relative humidity, = vapor density, and = saturation vapor density.    Water density leaving air |
| 65. | ***Integrated Concepts*** *The boiling point of water increases with depth because pressure increases with depth. At what depth will fresh water have a boiling point of , if the surface of the water is at sea level?* |
| Solution | From Table 13.5: |
| 66. | ***Integrated Concepts*** *(a) At what depth in fresh water is the critical pressure of water reached, given that the surface is at sea level? (b) At what temperature will this water boil? (c) Is a significantly higher temperature needed to boil water at a greater depth?* |
| Solution | (a)  (b) At  from Table 13.5.  (c) No. Water at a greater depth should boil for any temperature above the critical temperature. |
| 67. | ***Integrated Concepts*** *To get an idea of the small effect that temperature has on Archimedes' principle, calculate the fraction of a copper block's weight that is supported by the buoyant force in  water and compare this fraction with the fraction supported in  water.* |
| Solution | In  water:  Let  = the buoyant force,  = the weight of water displaced,  = the weight of the copper block, and  = the volume of the copper block.    In  water:    . As we can see, the buoyant force supports nearly the exact same amount of force on the copper block in both circumstances. |
| 68. | ***Integrated Concepts*** *If you want to cook in water at , you need a pressure cooker that can withstand the necessary pressure. (a) What pressure is required for the boiling point of water to be this high? (b) If the lid of the pressure cooker is a disk 25.0 cm in diameter, what force must it be able to withstand at this pressure?* |
| Solution | (a) From Table 13.5, vapor pressure  (b)  Here, we need to use Newton’s laws to balance forces. Assuming that we are cooking at sea level, the forces on the lid will stem from the internal pressure, found in part (a), the ambient atmospheric pressure, and the forces holding the lid shut. Thus we have a “balance of pressures”: |
| 69. | *Unreasonable Results (a) How many moles per cubic meter of an ideal gas are there at a pressure of*  *and at ? (b) What is unreasonable about this result? (c) Which premise or assumption is responsible?* |
| Solution | (a)  (b) It is unreasonably large.  (c) At high pressures such as these, the ideal gas law can no longer be applied. As a result, unreasonable answers come up when it is used. |
| 70. | ***Unreasonable Results*** *(a) An automobile mechanic claims that an aluminum rod fits loosely into its hole on an aluminum engine block because the engine is hot and the rod is cold. If the hole is 10.0% bigger in diameter than the  rod, at what temperature will the rod be the same size as the hole? (b) What is unreasonable about this temperature? (c) Which premise is responsible?* |
| Solution | (a) Call the hole diameter  and the cold rod diameter . We have . The area of the hole is , and the cold rod area is . The area of the rod at temperature  will be . Since the area is proportional to the diameter squared, we have:    (b) This temperature is unreasonably high—higher than the boiling point of aluminum.  (c) The premise that the part can expand to 10% larger is unreasonable. This is much too great for almost any material. |
| 71. | *Unreasonable Results The temperature inside a supernova explosion is said to be* *. (a) What would the average velocity  of hydrogen atoms be? (b) What is unreasonable about this velocity? (c) Which premise or assumption is responsible?* |
| Solution | (a)  (b) The velocity is too high—it is greater than the speed of light.  (c) The assumption that hydrogen inside a supernova behaves as an ideal gas is unreasonable because of the great temperature and density in the core of a star. Furthermore, when a velocity close to the speed of light is obtained, classical physics must be replaced by relativity. |
| 72. | *Unreasonable Results Suppose the relative humidity is 80% on a day when the temperature is . (a) What will the relative humidity be if the air cools to  and the vapor density remains constant? (b) What is unreasonable about this result? (c) Which premise is responsible?* |
| Solution | (a) Let = percent relative humidity, = vapor density, and = saturation vapor density.    (b) The answer is unreasonable because the maximum possible relative humidity is 100%.  (c) The premise that the vapor density remains constant is unreasonable when the temperature drops below dew point, as evidenced by the 106% relative humidity. |

# Test Prep For AP® Courses

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| 1. | *A fixed amount of ideal gas is kept in a container of fixed volume. The absolute pressure P, in pascals, of the gas is plotted as a function of its temperature T, in degrees Celsius. Which of the following are properties of a best fit curve to the data? Select two answers.*  (A) Having a positive slope  (B) Passing through the origin  (C) Having zero pressure at a certain negative temperature  (D) Approaching zero pressure as temperature approaches infinity |
| Solution | (a), (c) |
| 2. | *The figure above shows a clear plastic container with a movable piston that contains a fixed amount of gas. A group of students is asked to determine whether the gas is ideal. The students design and conduct an experiment. They measure the three quantities recorded in the data table below.*  [Table 13\_03\_01]     1. *Select a set of data points from the table and plot those points on a graph to determine whether the gas exhibits properties of an ideal gas. Fill in blank columns in the table for any quantities you graph other than the given data. Label the axes and indicate the scale for each. Draw a best-fit line or curve through your data points.* 2. *Indicate whether the gas exhibits properties of an ideal gas, and explain what characteristic of your graph provides the evidence.* 3. *The students repeat their experiment with an identical container that contains half as much gas. They take data for the same values of volume and temperature as in the table. Would the new data result in a different conclusion about whether the gas is ideal? Justify your answer in terms of interactions between the molecules of the gas and the container walls.* |
| Solution | 1. Plot *P* as a function of 1­/*V* for a single value of *T*. Draw a best-fit line through the data. 2. Graph of *P* versus 1/­*V* for an ideal gas should be linear if *n* and *T* are held constant. In the graphed set of data, *n* and *T* are held constant and the graph is linear, so there is evidence that the gas is ideal. 3. No, the conclusion would be the same. Reducing the amount of gas by half would result in there being half the rate of collisions with the container walls and half as much pressure needed to compress the gas to the same volume at the same temperature. The graph of *P* as a function of 1­/*V* would still be linear, but with half the slope. |
| 3. | *Two samples of ideal gas in separate containers have the same number of molecules and the same temperature, but the molecular mass of gas X is greater than that of gas Y. Which of the following correctly compares the average speed of the molecules of the gases and the average force the gases exert on their respective containers?*  Average Speed of Molecules Average Force on Container  (A) Greater for gas X Greater for gas X  (B) Greater for gas X The forces cannot be compared without knowing the volumes of the gases.  (C) Greater for gas Y Greater for gas Y  (D) Greater for gas Y The forces cannot be compared without knowing  the volumes of the gases. |
| Solution | (d) |
| 4. | *How will the average kinetic energy of a gas molecule change if its temperature is increased from 20ºC to 313ºC?*   1. It will become sixteen times its original value. 2. It will become four times its original value 3. It will become double its original value 4. It will remain unchanged. |
| Solution | (c) |
| 5. | *The graph (in the figure above) shows the Maxwell-Boltzmann distribution of molecular speeds in an ideal gas for two temperatures, T1 and T2. Which of the following statements is false?*   1. *T*1 is lower than *T*2 2. The *rms* speed at *T*1 is higher than that at *T*2. 3. The peak of each graph shows the most probable speed at the corresponding temperature. 4. None of the above. |
| Solution | (b) |
| 6. | *Suppose you have gas in a cylinder with a movable piston which has an area of 0.40 m2. The pressure of the gas is 150 Pa when the height of the piston is 0.02 m. Find the force exerted by the gas on the piston. How does this force change if the piston is moved to a height of 0.03 m? Assume temperature remains constant.* |
| Solution | a) 60N b) decreases to 40N |
| 7. | *What is the average kinetic energy of a nitrogen molecule (N2) if its rms speed is 560 m/s? At what temperature is this rms speed achieved?* |
| Solution | a) 7.29 × 10-21 J b) 352K or 79ºC |
| 8. | *What will be the ratio of kinetic energies and rms speeds of a nitrogen molecule and a helium atom at the same temperature?* |
| Solution | a) 1:1 b) 0.378:1 or 378:1000 |

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