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PreMedia Global, Inc Photo Research: Heather Jackson Art Director: Julia Hall Cover Designer: Quinn Banting Cover Image: GGS Higher Education Resources, a Division of PreMedia Global, Inc Photo Research: Heather Jackson Art Director: Julia Hall Cover Designer: Miguel Acevedo Interior Designer: Quinn Banting Cover Image: GGS Higher Education Resources, a Division of PreMedia Global, Inc Photo Research: Heather Jackson Art Director: Julia Hall Cover Designer: Miguel Acevedo Interior Designer: Quinn Banting Cover Image: GGS Higher Inc For permission to reproduce copyright dates of America WARNING: Many of the compounds and chemical reactions described or pictured in this book are hazardous Do not attempt any experiment pictured or implied in the text except with permission in an authorized laboratory setting and under adequate supervision Brief Table of Contents 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 Matter: Its Properties and Measurement Atoms and the Atomic Theory 34 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Some Basic Physical Concepts A11 SI Units A15 Data Tables A17 Concept Maps A37 Glossary A39 Answers to Concept Assessment Questions A55 iii Contents About the Authors Preface xv xiv Matter: Its Properties and Measurement 1-1 1-2 1-3 1-4 1-5 1-6 1-7 The Scientific Method Properties of Matter Classification of Matter Classification of Matter: SI (Metric) Units Density and Percent Composition: Their Use in Problem Solving 13 Uncertainties in Scientific Measurements 18 Significant Figures 19 Summary 23 Integrative Example 24 Exercises 26 Integrative and Advanced Exercises 29 Feature Problems 31 Self-Assessment Exercises 32 Atoms and the Atomic Theory 2-1 2-2 2-3 2-4 2-5 2-6 2-7 2-8 Early Chemical Discoveries in Atomic Physics 38 The Nuclear Atom 42 Chemical Elements 44 Atomic Mass 48 Introduction to the Periodic Table 51 The Concept of the Mole and the Avogadro Constant 54 Using the Mole Concept in Calculations 56 Summary 59 Integrative Example 59 Exercises 64 Feature Problems 65 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Representing the Orbitals of the Hydrogen Atom 327 Electron Atoms 336 8-9 8-10 Contents 8-11 8-12 Electron Configurations 339 Electron Configurations and the Periodic Table 344 Summary 348 Integrative Example 349 Exercises 351 Integrative and Advanced Exercises 357 Feature Problems 358 Self-Assessment Exercises 359 The Periodic Table and Some Atomic Properties 360 9-1 Classifying the Elements: The Periodic Law and the Periodic Table 361 Metals and Nonmetals and Their Ions 364 Sizes of Atoms and lons 367 Ionization Energy 374 Electron Affinity 378 Magnetic Properties 379 Periodic Properties of the Elements 381 Summary 386 Integrative and Advanced Exercises 391 Feature Problems 392 Self-Assessment Exercises 393 9-2 9-3 9-4 9-5 9-6 9-7 10 Chemical Bonding I: Basic Concepts 395 10-1 10-2 10-3 10-4 10-5 10-6 10-7 10-8 10-9 Lewis Theory: An Overview 396 Covalent Bonding: An Introduction 399 Polar Covalent Bonds and Electrostatic Potential Maps 402 Writing Lewis Structures 408 Resonance 416 Exceptions to the Octet Rule 418 Shapes of Molecules 421 Bond Order and Bond Lengths 433 Bond Energies 434 Summary 438 Integrative Example 439 Exercises 446 Feature Problems 447 Self-Assessment Exercises 446 Feature Problems 447 Self-Assessment Exercises 446 Integrative Example 439 Exercises 446 Integrative and Advanced Exercises 446 Feature Problems 447 Self-Assessment Exercises 446 Integrative Example 439 Exercises 448 11 Chemical Bonding II: Additional Aspects 11-1 11-2 11-3 11-4 11-5 11-6 11-7 11-8 What a Bonding Theory Should Do 450 Introduction to the Valence-Bond Method 451 Hvbridization of Atomic Orbitals 453 Multiple Covalent Bonds 461 Molecular Orbital Theory 465 Delocalized Electrons: Bonding in Metals 480 Some Unresolved Issues: Can Electron Charge-Density Plots Help? 484 Summary 489 Integrative Example 489 Exercises 491 Integrative and Advanced Exercises 494 Feature Problems 495 Self-Assessment Exercises 497 12 Intermolecular Forces: Liquids and Solids 498 12-1 12-2 12-3 12-4 12-5 Intermolecular Forces 499 Some Properties of Liquids 508 Some Properties of Solids 520 Phase Diagrams 522 Network Covalent Solids and Ionic Solids 526 449 vii viii Contents 12-6 12-7 Crystal Structures 530 Energy Changes in the Formation of Ionic Crystals 542 Summary 545 Integrative Example 546 Exercises 552 Feature Problems 554 Self-Assessment Exercises 556 13 Solutions and Their Physical Properties 557 Types of Solutions: Some Terminology 558 Solution Concentration 558 Intermolecular Forces and the Solutions 573 Osmotic Pressure 577 Freezing-Point Depression and Boiling-Point Depre Mixtures 587 Summary 590 Integrative Example 591 Exercises 592 Integrative and Advanced Exercises 597 Feature Problems 599 Self-Assessment Exercises 600 13-1 13-2 13-3 13-4 13-5 13-6 13-7 13-8 14 Chemical Kinetics 602 The Rate of a Chemical Reaction 603 Measuring Reaction Rates 605 Effect of Concentration on Reaction Rates: The Rate Law 608 14-4 Zero-Order Reactions 611 14-5 First-Order Reactions 612 14-6 Second-Order Reactions 619 14-7 Reaction Kinetics: A Summary 620 14-8 Theoretical Models for Chemical Kinetics 622 14-9 The Effect of Temperature on Reaction Rates 626 14-10 Reactions 612 14-6 Second-Order Reactions 619 14-7 642 Integrative Example 643 Exercises 645 Integrative and Advanced Exercises 650 Feature Problems 652 Self-Assessment Exercises 654 14-1 14-2 14-3 15 Principles of Chemical Equilibrium 15-1 15-2 15-3 15-4 15-5 Dynamic Equilibrium 656 The Equilibrium Constant Expression 656 Relationships Involving Equilibrium Constants 663 The Magnitude of an Equilibrium Constant 669 The Reaction Quotient, Q: Predicting the Direction of Net Change 670 Altering Equilibrium Calculations: Some Illustrative Examples 679 Summary 686 Integrative Example 686 Exercises 688 Integrative and Advanced Excercises 693 Feature Problems 694 Self-Assessment Exercises 695 15-6 15-7 665 226 Chapter Gases When high-pressure UF61g2 is forced through a barrier having millions of submicroscopic holes per square centimeter, molecules containing the isotope 235 U pass through the barrier slightly faster than those containing 238U, just as expected from expression (6.25), and therefore UF61g2 contains a slightly higher ratio of 235U to 238U than it did previously The gas has become enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying this process through several thousand passes yields a product highly enriched in 235U carrying the process through several thousand passes yields a product highly enriched in 235U carrying the process through several thousand passes yields a product highly enriched the process through several thousand passes yields a product highly enriched the process through several thousand passes yields a product highly enriched the process through several thousand pa provide us with clear evidence that real gas are not ideal. We should comment briefly on the conditions under which a real gas is ideal or nearly so and what to when the conditions lead to nonideal behavior A useful measure of how much a gas deviates from ideal gas behavior is found in its compressibility factor. factor of a gas is the ratio PV>nRT From the ideal gas equation we see that for an ideal gas, PV>nRT = For a real gas, the compressibility factor can have values of the compressibility factor are given in Table 6.5 for a variety of gases at 300 K and 10 bar The data in Table 6.5 show that the deviations from ideal gas behavior can be small or large, depending on the gas At 300 K and 10 bar, He, H 2, CO, N2, and O2 behave almost ideally 1PV>nRT L 0.882 In Figure 6-20, the compressibility factor is plotted as a function of pressure for three different gases The principal conclusion from this plot is that all gases behave ideally at sufficiently low pressures, say, below atm, but that deviations set in at increased pressures at very high pressures, the compressibility factor is always greater than one Nonideal gas behavior can be described as follows: Boyle s law predicts that at very high pressures, a gas volume becomes extremely small and 1.5 1.0 H2 TABLE 6.5 van der Waals Constants and Compressibility Factors (at 10 bar and 300 K) for Various Gases O2 Ideal gas Gas 0.5 CO2 200 400 600 800 1000 Pressure, atm FIGURE 6-20 The behavior of real gases compressibility factor as a function of pressure at *C Values of the compressibility factor less than one signify that intermolecular forces of attraction are largely responsible for deviations from ideal gas behavior Values greater than one are found when the volume of the gas molecules themselves is a significant fraction of the total gas volume H2 He Ideal gas N2 CO O2 CH NF3 CO2 N2O C2H NH SF6 C3H SO2 van der Waals Constants a, bar L2 mol-2 b, L mol-1 0.2452 0.0346 1.370 1.472 1.382 2.303 3.58 3.658 3.852 5.580 4.225 5.580 4.225 5.580 9.39 7.857 0.0265 0.0238 0.0395 0.0319 0.0431 0.0545 0.0429 0.0444 0.0651 0.0371 0.0651 0.0905 0.0879 Compressibility Factor 1.006 1.005 0.998 0.997 0.994 0.983 0.965 0.950 0.945 0.922 0.887 0.880 a a Source: van der Waals constants are from the CRC Handbook of Chemistry and Physics, 83rd ed., David R Lide (ed.)., Boca Raton, FL: Taylor & Francis Group, 2002 Compressibility factors are calculated by using data from the National Institute of Standards and Technology (NIST) Chemistry WebBook, available online at aAt 10 bar and 300 K, C H and SO are liquids 6-9 (a) Nonideal (Real) Gases 227 (b) FIGURE 6-21 The effect of finite molecular size In (a), a significant fraction of the container is empty space and the gas can still be compressed to a smaller volume In (b), the molecules occupy most of the available space The volume of the system is only slightly greater than the total volume of the molecules approaches zero This cannot be, however, because the molecules themselves occupy space and are practically incompressible, as suggested in Figure 6-21 Because of the finite size of the molecules, the PV product at high pressures is larger than predicted for an ideal gas, and the compressibility factor is greater than one Another consideration is that intermolecular forces exist in gases Figure 6-22 shows that because of attractive forces between the molecules, the force of the collisions of gas molecules with the container walls is less than expected for an ideal gas Intermolecular forces of attraction account for compressibility factors of less than one These forces become increasingly important at low temperatures, where translational molecular motion slows down To summarize: Gases tend to behave ideally at high temperatures and low pressures Gases tend to behave ideally at high temperatures and low pressur Equation A number of equations can be used for real gases, equations that apply over a wider range of temperatures and pressures than the ideal gas equation They contain terms that have specific, but different, values for different gases. volume associated with the molecules themselves and for intermolecular forces of attraction Of all the equation, equation (6.26), is the simplest to use and interpret aP + an2 V2 b 1V - nb2 = nRT (6.26). The equation incorporates two molecular parameters, a and b, whose values vary from molecule to molecule, as shown in Table 6.5 The van der Waals equation both have the form pressure factor, P + an2>V2, in place of P and a modified volume factor, V - nb, in place of V In the modified volume factor, the term nb accounts for the volume of the molecules themselves The parameter b is called the excluded volume per mole, and, to a rough approximation, it is the volume that one mole of gas occupies when it condenses to a liquid Because the FIGURE 6-22 Intermolecular forces of attraction Attractive forces of the red molecules for the green molecule cause the green molecule to exert less force when it collides with the wall than if these attractions did not exist The van der Waals equation reproduces the observed behavior of gases with moderate accuracy It is most accurate for gases comprising approximately spherical molecules that have small dipole moments We will discuss molecular shapes and dipole moments in Chapter 10 228 Chapter Gases molecular motion is V - nb As suggested in Figure 6-21(b), the volume available for molecular motion is quite small at high pressures To explain the significance of the term an2>V2 in the modified pressure factor, it is helpful to solve equation (6.26) for P: P = * In Chapter 12, we will examine intermolecular forces of attraction in greater detail and establish why the strength of the attractive intermolecular forces as the sizes of the molecules increase EXAMPLE 6-17 nRT an2 - V - nb V Provided V is not too small, the first term in the equation above is approximately equal to the pressure exerted by a real gas will be less than that of an ideal gas: Figure 6-22 illustrates why Because of attractive forces, molecules near the container walls are attracted toward the molecules behind them; as a result, the gas exerts less force on the container walls The term an2>V2 takes into account the decrease in pressure caused by intermolecular attractions In 1873, the Dutch physicist Johannes van der Waals reasoned that the decrease in pressure caused by intermolecular attractions should be proportional to the square of the concentration, and so the decrease in pressure is represented in the form an2>V2 The proportionality constant, a, provides a measure of how strongly the molecules attract each other A close examination of Table 6.5 shows that the values of both a and b increase as the sizes of the molecules increase The smaller the values of a and b increase In Example 6-17 we calculate the pressure of a real gas by using the van der Waals equation Solving the equation for either n or V is more difficult, however (see Exercise 121) Using the van der Waals Equation to Calculate the Pressure of a Gas Use the van der Waals equation to Calculate the Pressure of a Gas Use the van der Waals equation for either n or V is more difficult, however (see Exercise 121) Using the van der Waals equation for either n or V is more difficult. volume of 2.00 L at 273 K The value of a = 6.49 L2 atm mol -2, and that of b = 0.0562 L mol -1 Analyze This is a straightforward application of equation (6.26) It is important to include units to make sure the units cancel out properly Solve Solve equation (6.26) for P P = nRT n 2a - V - nb V Then substitute the following values into the equation n = 1.00 mol; V = 2.00 L; T = 273 K; R = 0.08206 atm L mol -1 K -1 L2 atm = 6.49 L2 atm n2a = 11.0022 mol2 * 6.49 mol2 nb = 1.00 mol * 0.08206 atm L mol -1 K -1 * 273 K P = 12.00 - 0.05622L 12.0022 L2 P = 11.5 atm - 1.62 atm = 9.9 atm Summary 229 Assess The pressure calculated with the ideal gas equation is 11.2 atm By including only the b term in the van der Waals equation, we get a value of 11.5 atm Under the conditions of this problem, intermolecular forces of attraction are the main cause of the departure from ideal behavior Although the deviation from ideality here is rather large, in problem-solving situations, you can generally assume that the ideal gas equation will give satisfactory results Substitute CO21g2 for Cl21g2 in Example 6-17, given the values a = 3.66 L2 bar mol -2 and b = 0.0427 L mol Which gas, CO2 or Cl2, shows the greater departure from ideal gas behavior? [Hint: For which gas you find the greater difference in calculated pressures, first using the ideal gas equation and then the van der Waals equation?] PRACTICE EXAMPLE A: -1 Substitute CO1g2 for Cl21g2 in Example 6-17, given the values a = 1.47 L2 bar mol -2 and b = 0.0395 L mol -1 Including CO2 from Practice Example 6-17A, which of the three gases Cl2, CO 2, or CO shows the greatest departure from ideal gas behavior? PRACTICE EXAMPLE B: 6-10 CONCEPT ASSESSMENT Following are the measured densities at 20.0 °C and atm pressure of three gases: O2, 1.331 g>L; OF2, 2.26 g>L; NO, 1.249 g>L Arrange them in the order of increasing adherence to the ideal gas equation [Hint: What property can you calculate and compare with a known value?] www.masteringchemistry.com The blanket of gases surrounding Earth forms our atmosphere It not only protects us from harmful radiation but also plays an essential role in moving water. essential to life. from the oceans to the land For a discussion of the regions and composition of Earth's atmosphere, go to the Focus On feature for Chapter on the MasteringChemistry site Summary 6-1 Properties of Gases: Gas Pressure A gas is described in terms of its pressure, temperature, volume, and amount Gas pressure is most readily measured by comparing it with the pressure exerted by a liquid column, usually mercury (equation 6.2) The pressure exerted by a column of mercury in a barometer and called the barometer (Fig 6-4) Other gas pressure scan be measured with a manometer (Fig 6-5) Pressure can be expressed in a variety of units (Table 6.1), including the SI units pascal (Pa) and kilopascal (kPa) Also commonly used are bar; millimeter of mercury (mmHg); torr (Torr), where atm = 760 mmHg = 760 Torr 6-2 The Simple Gas Laws The most common sim- ple gas laws are Boyle s law relating gas pressure and volume (equation 6.5, Fig 6-6); Charles s law relating gas volume and temperature (equation 6.8, Fig 6-7); and Avogadro s law, relating volume and temperature (equation 6.6), the standard conditions of temperature and pressure (STP), and the molar volume of a gas at STP 22.7 L>mol (expression 6.10) 6-3 Combining the Gas Laws: The Ideal Gas Equation and the General Gas Equation and the General Gas Equation The simple gas laws can be combined into the ideal gas equation, PV = nRT (equation 6.11), where R is called the gas constant A gas whose behavior can be predicted with this equation is known as an ideal, or perfect, gas The ideal gas equation can be solved for any one of the variables are held. constant and others are allowed to change 6-4 Applications of the Ideal Gas Equation An important application of the ideal gas equation 6.13) and gas densities (equation 6.14) 6-5 Gases in Chemical Reactions Because it relates the volume of a gas at a given temperature and pressure to the amount of gas, the ideal gas equation often enters into stoichiometric calculations for reactants and/or products measured at the same temperature and pressure, the law of combining volumes is generally applicable 230 Chapter Gases 6-6 Mixtures of Gases The ideal gas equation kinetic energy and Kelvin temperature (equation 6.21) An important aspect of the kinetic-molecular speeds (Figs 6-15 and 6-16) applies to mixtures of ideal gases as well as to pure gases The enabling principle. known as Dalton s law of partial pressures, is that each gas expands to fill the container, exerting the same pressure as if it were alone in the container (Fig 6-12) The total pressure is that of mole fraction, the fraction, the fraction of the molecules in a mixture contributed by each component (equation 6.17) In the common procedure of collecting a gas over water (Fig 6-13), the particular gas being isolated is mixed with water vapor 6-8 Gas Properties Relating to the KineticMolecular Theory The diffusion and effusion of gases (Fig 6-19) can be described by the kinetic-molecular theory Using an approximation known as Graham s law, molar masses can be determined by measuring rates of effusion (equation 6.23) 6-9 Nonideal (Real) Gases The ular size and intermolecular forces of attraction (Figs 6-21 and 6-22), real gases generally behave ideally only at high temperatures and low pressures Other equations of state, such as the van der Waals equation (equation 6.26), take into account the factors causing nonideal behavior and often work when the ideal gas equation fails kinetic-molecular theory of gases yields a basic expression (equation 6.18) from which other relationships can be established between the root-mean-square speed 1urms2 of molecules, temperature, and molar mass of a gas (equation 6.20), and the average molecular translational Integrative Example Combustion of 1.110 g of a gaseous hydrocarbon yields 3.613 g CO and 1.109 g H2O, and no other products A 0.288 g sample of the hydrocarbon occupies a volume of 131 mL at 24.8 °C and 753 mmHg Write a plausible structural formula for a hydrocarbon corresponding to these data Analyze Use the combustion data for the 1.110 g sample of hydrocarbon and the method of Example 3-6 on page 83 to determine the empirical formula Use the P - V - T data in equation (6.13) for the 0.288 g sample to determine the molar mass and molecular mass of the hydrocarbon By comparing the empirical formula mass and the molecular formula consistent with the molecular formula Solve Calculate the number of moles of C and H in the 1.110 g sample of hydrocarbon based on the masses of CO2 and H2O obtained in its combustion mol CO2 mol C * = 0.08209 mol C * = 0.08209 mol C 44.01 g CO2 mol H ? mol H = 1.109 g H2O * * = 0.1231 mol H 18.02 g H2O mol H ? mol H = 0.1231 mol H 18.02 g H2O mol H ? mol H = 0.1231 mol H = 0.1231 mol H = 0.1231 mol H = 0.08209 mol C * = 0.08209 mo two to obtain the empirical formula C0.08209 H CH1.500 = C2H3 To determine the molar mass, use a modified form of equation (6.13) M = The empirical formula, 27.0 g mol -1, is almost exactly onehalf the observed molar mass of 54.3 g mol -1 The molecular formula of the hydrocarbon is The four-carbon alkane is butane, C4H10 Removal of H atoms to obtain the formula C4H6 is achieved by inserting two C-to-C double bonds? mol C = 3.613 g CO2 * $0.08209 \ 0.1231 \ 0.08209 \ 0.123$ 12.0 u 1.01 u b + a3 H atoms * b = 27.0 u C atom H atom C2 * 2H2 * = C4H6 H 2C CH ¬ CH CH or H 2C C CH ¬ CH CH or H 2C C CH ¬ CH3 or H3C ¬ C C ¬ CH3 or H3C ¬ C H 2 C C ¬ CH3 or H3C ¬ C C ¬ C C ¬ CH3 or H3C ¬ C C certainty However, because of isomerism the exact structural formula cannot be pinpointed All that we can say is that the hydrocarbon might have any one of the four structures shown, but it might be still another structure, for example, based on a ring of C atoms rather than a straight chain PRACTICE EXAMPLE A: When a 0.5120 g sample of a gaseous hydrocarbon was burned in excess oxygen, 1.687 g CO2 and 0.4605 g H2O were obtained The density of the compound, in its vapor form, is 1.637 g/L at 25 °C and 101.3 kPa Determine the molecular formula of the hydrocarbon, and draw a plausible structural formula for the molecule PRACTICE EXAMPLE B: An organic compound contains only C, H, N, and O When the compound is burned in oxygen, with appropriate catalysts, nitrogen gas 1N22, carbon dioxide 1CO22, and water vapor 1H2O2 are produced A 0.1023 g sample of the compound yielded 151.2 mg CO2, 69.62 mg H2O, and 9.62 mL of N21g2 at 0.00 °C and 1.00 atm The density of the compound, in its vapor form, was found to be 3.57 g L-1 at 127 °C and 748 mmHg What is the molecular formula of the compound? You II find a link to additional self study area on www.masteringchemistry.com Exercises Pressure and Its Measurement Convert each pressure to an equivalent pressure in atmospheres (a) 736 mmHg; (b) 0.776 bar; (c) 892 Torr; (d) 225 kPa Calculate the height of a mercury column required to produce a pressure (a) of 0.984 atm; (b) of 928 Torr; (c) equal to that of a column of water 142 ft high Calculate the height of a column of liquid benzene 1d = 0.879 g>cm32, in meters, required to exert a pressure of 0.970 atm Calculate the height of a column of liquid glycerol 1d = 1.26 g>cm32, in meters, required to exert the same pressure (in mmHg) of the gas inside the apparatus below if Pbar = 740 mmHg, h1 = 30 mm and h2 = 50 mm? What is the pressure (in mmHg) of the gas inside the apparatus below if Pbar = 740 mmHg, h1 = 30 mm and h2 = 40 mm? Pbar h1 Gas h2 Pbar Mercury (Hg) h1 Gas h2 Mercury (Hg) At times, a pressure is stated in units of mass per unit area rather than force per unit area Express P = atm in the unit kg>cm2 [Hint: How is a mass in kilograms related to a force?] Express P = atm in pounds per square inch (psi) [Hint: Refer to Exercise 7.] 232 Chapter Gases The Simple Gas Laws A sample of O21g2 has a volume of 26.7 L at 762 Torr What is the new volume if, with the temperature and amount of gas held constant, the pressure is (a) lowered to 385 Torr; (b) increased to 3.68 atm? 10 An 886 mL sample of Ne(g) is at 752 mmHg and 26 °C What will be the new volume if, with the pressure and amount of gas held constant, the temperature is (a) increased to 98 °C; (b) lowered to - 20 °C? 11 If 3.0 L of oxygen gas at 177 °C is cooled at constant pressure until the volume becomes 1.50 L, then what is the final temperature? 12 We want to change the volume of a fixed amount of gas from 725 mL to 2.25 L while holding the temperature constant To what value must we change the pressure is 105 kPa? 13 A 35.8 L cylinder of Ar(g) is connected to an evacuated 1875 L tank If the temperature is held constant and the final pressure is 721 mmHg, what must have been the original gas pressure in the cylinder, in atmospheres? 14 A sample of N21g2 occupies a volume of 42.0 mL under the existing barometric pressure by 85 mmHg reduces the volume to 37.7 mL What is the prevailing barometric pressure, in millimeters of mercury? 15 A weather balloon filled with He gas has a volume of 2.00 * 103 m3 at ground level, where the atmospheric pressure is 1.000 atm and the temperature 27 °C After the balloon rises high above Earth to a point where the atmospheric pressure is 0.340 atm, its volume increases to 5.00 * 103 m3 What is the temperature of the atmospheric pressure is 1.000 atm and the temperature 27 °C After the balloon rises high above Earth to a point where the atmospheric pressure is 0.340 atm, its volume increases to 5.00 * 103 m3 What is the temperature of the atmospheric pressure is 0.340 atm. the contraction of an argon-filled balloon when it is cooled from a room temperature of about - 22 °C? 17 What is the mass of argon gas in a 75.0 mL volume at STP? 18 What volume of gaseous chlorine at STP would you need to obtain a 250.0 g sample of pA 31g2 (used in the manufacture of flame-retardant chemicals) is obtained at STP (a) What is the mass of this gas, in milligrams? (b) How many molecules of PH are present? 20 A 5.0 * 1017 atom sample of radon gas is obtained (a) What is the mass of this sample, in micrograms? (b) What is the volume of this sample at STP, in microliters? 21 You purchase a bag of potato chips at an ocean beach to take on a picnic in the mountains At the picnic, you notice that the bag has become inflated, almost to the point of bursting Use your knowledge of gas behavior to explain this phenomenon 22 Scuba divers know that they must not ascend guickly from deep underwater because of a condition known as the bends, discussed in Chapter 13 Another concern is that they must constantly exhale during their ascent to prevent damage to the lungs and blood vessels Describe what would happen to the lungs of a diver who inhaled compressed air at a depth of 30 m and held her breath while rising to the surface General Gas Equation 23 A sample of gas has a volume of 4.25 L at 25.6 °C and 748 mmHg What will be the volume of this gas at 26.8 °C and 742 mmHg? 24 A 10.0 g sample of a gas has a volume of 5.25 L at 25 °C and 762 mmHg If 2.5 g of the same gas is added to this constant 5.25 L volume and the temperature raised to 62 °C, what is the new gas pressure? 25 A constant-volume vessel contains 12.5 g of a gas at 21 °C If the pressure of the gas is to remain constant as the temperature is raised to 210 °C, how many grams of gas must be released? 26 A 34.0 L cylinder contains 305 g O21g2 at 22 °C How many grams of O 21g2 must be released to reduce the pressure in the cylinder to 1.15 atm if the temperature remains constant? Ideal Gas Equation 27 What is the volume, in milliliters, occupied by 89.2 g CO 21g2 at 37 °C and 737 mmHg? 28 A 12.8 L cylinder contains 35.8 g O2 at 46 °C What is the pressure of this gas, in atmospheres? 29 Kr(g) in a 18.5 L cylinder exerts a pressure of 11.2 atm at 28.2 °C How many grams of gas are present? 30 A 72.8 L constant-volume cylinder containing 7.41 g He is heated until the pressure reaches 3.50 atm What is the final temperature in degrees Celsius? 31 A laboratory high vacuum system is capable of evacuating a vessel to the point that the amount of gas remaining is 5.0 * 109 molecules per cubic meter What is the residual pressure, in pascals, exerted by 1242 g CO1g2 when confined at - 25 °C to a cylindrical tank 25.0 cm in diameter and 1.75 m high? Exercises 33 What is the molai volume of an ideal gas at (a) 25 °C and 1.00 atm; (b) 100 °C and 748 Torr? 233 34 At what temperature is the molar volume of an ideal gas equal to 22.4 L, if the pressure of the gas is 2.5 atm? Determining Molar Mass 35 A 0.418 g sample of gas has a volume of 115 mL at 66.3 °C and 743 mmHg What is the molar mass of this gas? 36 What is the molar mass of a gas found to have a density of 0.841 g>L at 415 K and 725 Torr? 37 What is the molecular formula of a gaseous fluoride of sulfur containing 70.4% F and having a density of approximately 4.5 g>L at 20 °C and atm? 38 A 2.650 g sample of a gaseous compound occupies 428 mL at 24.3 °C and 742 mmHg The compound consists of 15.5% C, 23.0% Cl, and 61.5% F, by mass What is its molecular formula? 39 A gaseous hydrocarbon weighing 0.231 g occupies a volume of 102 mL at 23 °C and 749 mmHg What is the molar mass of this compound? What conclusion can you draw about its molecular formula? 40 A 132.10 mL glass vessel weighs 56.1035 g when evacuated and 56.2445 g when filled with the gaseous hydrocarbon acetylene at 749.3 mmHg and 20.02 °C What is the molar mass of acetylene? What conclusion can you draw about its molecular formula? Gas Densities 41 A particular application calls for N21g2 with a density of 1.80 g>L at 32 °C What must be the pressure of the N21g2 in millimeters of mercury? What is the molar volume under these conditions? 42 Monochloroethylene is used to make polyvinylchloride (PVC) It has a density of 2.56 g>L at 22.8 °C and 756 mmHg What is the molar mass of monochloroethylene? What is the molar volume under these conditions? 43 In order for a gas-filled balloon to rise in air, the density of the gas in the balloon must be less than that of air (a) Consider air to have a molar mass of 28.96 g>mol; determine the density of air at 25 °C and atm, in g>L Gases in Chemical Reactions 47 What volume of O21g2 is consumed in the combustion of 75.6 L C3H 81g2 if both gases are measured at STP? 48 How many liters of H 21g2 at STP are produced per gram of Al(s) consumed in the following reaction? Al1s2 + HCl1ag2 ; AlCl31ag2 + H 21g2 49 A particular coal sample contains 3.28% S by mass When the coal is burned, the sulfur is converted to SO21g2, measured at 23 °C and 738 mmHg, is produced by burning 1.2 * 106 kg of this coal? 50 One method of removing CO21g2 from a spacecraft is to allow the CO to react with LiOH How many liters of CO21g2 at 25.9 °C and 751 Torr can be removed per kilogram of LiOH1s2 + CO21g2 i Li 2CO31s2 + H 2O1l2 51 A 3.57 g sample of a KCI KCIO3 mixture is decomposed by heating and produces 119 mL O21g2, measured at 22.4 °C and 738 mmHg What is the mass percent of KCIO3 in the mixture? KCIO 31s2 ; KCI1s2 + O21g2 (b) Show by calculation that a balloon filled with carbon dioxide at 25 °C and atm could not be expected to rise in air at 25 °C 44 Refer to Exercise 43, and imum temperature to which the balloon described in part (b) would have to be heated before it could begin to rise in air (Ignore the mass of the balloon itself.) 45 The density of phosphorus vapor is 2.64 g>L at 310 °C and 775 mmHg What is the molecular formula of the phosphorus under these conditions? 46 A particular gaseous hydrocarbon that is 82.7% C and 17.3% H by mass has a density of 2.33 g>L at 23 °C and 746 mmHg What is the molecular formula of this hydrocarbon? 52 Hydrogen peroxide, H 2O2, is used to disinfect contact lenses How many milliliters of O21g2 at 22 °C and 752 mmHg can be liberated from 10.0 mL of an aqueous solution containing 3.00% H 2O2 by mass? The density of the aqueous solution of H 2O2 is 1.01 g>mL H 2O21ag2 ; H 2O112 + O21g2 53 Calculate the volume of H 21g2; measured at 26 °C and 751 Torr, required to react with 28.5 L CO1g2, measured at °C and 760 Torr, in this reaction CO1g2 + H 21g2; C3H 81g2 + H 2O112 54 The Haber process is the principal method for fixing nitrogen (converting N2 to nitrogen compounds) N21g2 + H 21g2 i NH 31g2 and that the gases behave ideally (a) What volume of NH 31g2 can be produced from 152 L N21g2 and 313 L of H 21g2 if the gases are measured at 315 °C and 5.25 atm? (b) What volume of NH 31g2, measured at 25 °C and 727 mmHg, can be produced from 152 L N21g2 and 313 L H 21g2, measured at 315°C and 5.25 atm? 234 Chapter Gases Mixtures of Gases 55 What is the volume, in liters, occupied by a mixture of 15.2 g Ne1g2 and 34.8 g Ar1g2 at 7.15 atm? pressure and 26.7 °C? 56 A balloon filled with H 21g2 at 0.0 °C and 1.00 atm has a volume of 2.24 L What is the final gas volume if 0.10 mol He1g2 is added to the balloon and the temperature is then raised to 100 °C while the pressure and amount of gas are held constant? 57 A gas cylinder of 53.7 L volume contains N21g2 at a pressure of 28.2 atm and 26 °C How many grams of Ne1g2 at 762 mmHg and 24 °C is connected to a 3.17 L container of He1g2 at 728 mmHg and 24 °C After mixing, what is the total gas pressure, in millimeters of mercury, with the temperature remaining at 24 °C? 59 Which actions would you take to establish a pressure of 2.00 atm in a 2.24 L cylinder containing 1.60 g O2; (c) add 2.00 g He; (d) add 0.60 g He 60 A mixture of 4.0 g H 21g2 and 10.0 g He1g2 in a 4.3 L flask is maintained at °C (a) What is the total pressure in the container? (b) What is the partial pressure of each gas? 61 A 2.00 L container is filled with Ar(g) at 752 mmHg and 35 °C A 0.728 g sample of C6H vapor is then added (a) What is the total pressure in the container? (b) What is the partial pressure of Ar and of C6H 6? 62 The chemical composition of air that is exhaled (expired) is different from ordinary air A typical analysis of expired air at 37 °C and 1.00 atm, expressed as percent by volume, is 74.2% N2, 15.2% O2, 3.8% CO2, 5.9% H 2O, and 0.9% Ar The composition of ordinary air is given in Practice Example 6-12B (a) What is the ratio of the partial pressure of CO 21g2 in expired air to that in ordinary air? (b) Would you expect the density of expired air to be greater or less than that of ordinary air at the same temperature and pressure? Explain (c) Confirm your expectation by calculating the densities of ordinary air and expired air at 37 °C and 1.00 atm Collecting Gases over Liquids 67 A 1.65 g sample of AI reacts with excess HCl, and the liberated H is collected over water at 25 °C at a barometric pressure of 744 mmHg What volume of gaseous mixture, in liters, is collected over water at 21.3 °C at a barometric pressure of 756 mmHg (vapor pressure of water at 21.3 °C = 19 mmHg) (a) What is the partial pressure of O21g2 in the sample collected, in millimeters of mercury? (b) What is the volume percent O2 in the drawing below, 1.00 g H 21g2 is maintained at atm pressure in a cylinder closed off by a freely moving piston Which sketch, (a), (b), or (c), best represents the mixture obtained when 1.00 g He1g2 is added? Explain 1.00 g H2 (a) (b) (c) 64 In the drawing above, 1.00 g H2 (a) (b), or (c), best represents the mixture obtained when 0.50 g H 21g2 is added and the temperature is reduced to 275 K? Explain your answer 65 A 4.0 L sample of O2 gas has a pressure of 1.0 atm A 2.0 L vessel, what is the final pressure of the mixture? Assume that the temperature remains unchanged 66 The following figure shows the contents and pressures of three vessels of gas that are joined by a connecting tube He 0.75 atm 1.0 L Valve Xe 0.45 atm 2.5 L Ar 1.20 atm 1.0 L After the valves on the vessels are opened, the final pressure is measured and found to be 0.675 atm What is the total volume of the connecting tube? Assume that the temperature remains constant 69 A sample of O21g2 is collected over water at 24 °C The volume of gas is 1.16 L In a subsequent experiment, it is determined that the mass of O2 present is 1.46 g What must have been the barometric pressure at the time the gas was collected? (Vapor pressure of water = 22.4) Torr.) 70 A 1.072 g sample of He1g2 is found to occupy a volume of 8.446 L when collected over hexane at 25.0 °C and 738.6 mmHg barometric pressure of hexane at 25 °C 71 At elevated temperatures, solid sodium chlorate 1NaClO32 decomposes to produce sodium chloride, NaCl, and O2 gas A 0.8765 g sample of impure Exercises sodium chlorate was heated until the production of oxygen ceased The oxygen gas was collected over water and occupied a volume of 57.2 mL at 23.0 °C and 734 Torr Calculate the mass percentage of NaClO3 in the original sample Assume that none of the impurities produce oxygen on heating The vapor pressure of water is 21.07 Torr at 23 °C 72 When solid KClO3 is heated strongly, it decomposes to form solid potassium chloride, KCl, and O2 gas a produced by the decomposition is collected over water When the wet O2 gas is cooled back to 26 °C, the total volume is 229 mL and the total pressure is 323 Torr What is the mass percentage of KClO3 in the original sample? Assume that none of the impurities produce oxygen on heating The vapor pressure of water is 25.22 Torr at 26 °C Kinetic-Molecular Theory 73 Calculate urms, in meters per second, for Cl21g2 molecules at 30 °C 74 The urms of H molecules at 273 K is 1.84 * 103 m>s At what temperature is urms for H twice this value? 75 Refer to Example 6-14 What must be the molecular mass of a gas if its mole exist as atoms, not molecules (they are monatomic) Cite one noble gas whose urms at 25 °C is higher than the speed of the rifle bullet and one whose urms for He at 300 K? 78 Determine um, u, and urms for a group of ten automobiles clocked by radar at speeds of 38, 44, 45, 48, 50, 55, 57, 58, and 60 mi>h, respectively 79 Calculate the average kinetic energy, ek, for O21g2 at 25 °C and 1.00 atm [Hint: First calculate the average kinetic energy, ek,] Diffusion and Effusion of Gases 81 If 0.00484 mol N2O1g2 effuses through an orifice in a certain period of time, how much NO21g2 would effuse in the same time under the same conditions? 82 A sample of N21g2 effuses through a tiny hole in 38 s What must be the molar mass of a gas that requires 64 s to effuse under identical conditions? 83 What are the ratios of the diffusion rates for the pairs of gases (a) N2 and O2; (b) H 2O and D2O (D = deuterium, i.e., 21H); (c) 14CO2 and 12CO2; (d) 235UF6 and 238UF6? 84 Which of the following visualizations best represents the distribution of O2 and SO molecules near an orifice some time after effusion occurs in the direction indicated by the arrows? The initial condition was one of equal numbers of O2 molecules () and SO2 molecules () on the left side of the orifice Explain (a) (b) (c) (d) 85 It takes 22 hours for a neon-filled with helium, then how long would it have taken for the balloon to shrink to half its original volume at STP If the same balloon had been filled with helium, then how long would it have taken for the balloon to shrink to half its original volume at STP? 86 The molar mass of radon gas was first estimated by comparing its diffusion rate with that of mercury vapor, Hg1g2 What is the molar mass of radon gas? Assume that Graham s law holds for diffusion Nonideal Gases 87 Refer to Example 6-17 Recalculate the pressure of Cl21g2 by using both the ideal gas equation and the van der Waals equation at the temperatures (a) 100 °C; (b) 200 °C; (c) 400 °C From the results. confirm the statement that a gas tends to be more ideal at high temperatures than at low temperatures 88 Use both the ideal gas equation and the van der Waals equation to calculate the pressure exerted by 1.50 mol of SO21g2 when it is confined at 298 K to a volume of (a) 100.0 L, (b) 50.0 L, (c) 20.0 L, (d) 10.0 L Under which of these conditions is the pressure calculated with the ideal gas equation within a few percent of that calculated with the van der Waals equation? Use values of a and b from Table 6.5 89 Use the value of the van der Waals constant b for He1g2, given in Table 6.5, to estimate the radius, r, of a single helium atom Give your answer in picometers [Hint: The volume of the van der Waals constant b for CH 41g2, given in Table 6.5, to estimate the radius of the CH molecule (See Exercise 89.) How does your estimate of the radius compare with the value r = 228 pm, obtained experimentally from an analysis of the structure of solid methane? (b) The density of CH 41q2 is 66.02 g mL-1 at 100 bar and 325 K What is the value of compressibility factor at this temperature and pressure? 236 Chapter Gases Integrative and Advanced Exercises 91 Explain why it is necessary to include the density of Hg1l2 and the value of the acceleration due to gravity, g, in a precise definition of a millimeter of mercury (page 194) 92 Assume the following initial conditions for the graphs labeled A, B, and C in Figure 6-7 (A) 10.0 mL at 400 K; (B) 20.0 mL at 400 K; (C) 40.0 mL at 400 K Use Charles s law to calculate the volume of each gas at 0. - 200. - 250. and - 273 K and 1.00 atm With as much detail as possible, illustrate the final condition after each of the following changed to 250 mmHg while standard temperature is changed to 140 K while standard pressure is changed to 250 mmHg while the temperature is changed to 250 mmHg while standard temperature is changed to 140 K while standard temperature is changed to 250 mmHg while standard pressure is changed to 250 mmHg while standard temperature is changed to 250 mmHg w 550 K (d) An additional 0.5 mol of gas is introduced into the cylinder, the temperature is changed to 135 °C, and the pressure is changed to 2.25 atm What is the total gas pressure, in atmospheres, in the flask at 250 °C when the NH 4NO3 has completely decomposed? NH 4NO31s2 i N2O1g2 + H 2O1g2 98 Ammonium nitrite, NH 4NO2, decomposes according to the chemical equation below NH 4NO 21s2; N21g2 + H 2O1g2 99 100 101 102 Initial Final 94 Two evacuated bulbs is placed in a constant-temperature bath at 225 K and the other bulb is placed in a constant-temperature bath at 350 K Exactly mol of an ideal gas is injected into the system Calculate the final number of moles of gas in each bulb 95 A compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon by mass The rest is hydrogen When 10.0 g of the compound is 85.6% carbon 0.7178 g sample of a hydrocarbon occupies a volume of 390.7 mL at 65.0 °C and 99.2 kPa When the sample is burned in excess oxygen, 2.4267 g CO2 and 0.4967 g H2O are obtained What is the molecular formula of the hydrocarbon? Write a plausible structural formula for the molecule 97 A 3.05 g sample of NH 4NO 31s2 is introduced into an evacuated 2.18 L flask and then heated to 250 °C 103 104 105 106 What is the total volume of products obtained when 128 g NH 4NO decomposes at 819 °C and 101 kPa? A mixture of 1.00 g H and 8.60 g O2 is introduced into a 1.500 L flask at 25 °C When the mixture is ignited, an explosive reaction occurs in which water is the only product What is the total gas pressure when the flask is returned to 25 °C? (The vapor pressure of water at 25 °C is 23.8 mmHg.) In the reaction of CO21g2 and solid sodium peroxide 1Na 2O22, solid sodium carbonate 1Na 2CO 32 and oxygen gas are formed This reaction is used in submarines and space vehicles to remove expired CO21g2 and to generate some of the O21g2 required for breathing Assume that the volume, and the gases are at 25 °C and 735 mmHg If the CO21g2 and O21g2 in the above reaction are measured at the same temperature and pressure, (a) how many milliliters of O21g2 are produced per minute and (b) at what rate is the Na 2O21s2 consumed, in grams per hour? What is the partial pressure of Cl21g2, in millimeters of mercury, at 0.00 °C and 1.00 atm in a gaseous mixture that consists of 46.5% N2, 12.7% Ne, and 40.8% Cl2, by mass? A gaseous mixture of He and O2 has a density of 0.518 g>L at 25 °C and 721 mmHg What is the mass percent He in the mixture? When working with a mixture of gases, it is sometimes convenient to use an apparent molar mass (a weighted average molar mass) Think in terms of replacing the mixture with a hypothetical single gas What is

the apparent molar mass of air, given that air is 78.08% N2, 20.95% O2, 0.93% Ar, and 0.036% CO 2, by volume? A mixture, the partial pressures of N2O and O2 are 612 Torr and 154 Torr, respectively Calculate (a) the mass percentage of N2O in this mixture, the partial pressures of N2O and O2 are 612 Torr and 154 Torr, respectively Calculate (a) the mass percentage of N2O in this mixture, the partial pressures of N2O and O2 are 612 Torr and 154 Torr, respectively Calculate (a) the mass percentage of N2O in this mixture, the partial pressures of N2O and O2 are 612 Torr and 154 Torr, respectively Calculate (a) the mass percentage of N2O in this mixture, the partial pressures of N2O and O2 are 612 Torr and 154 and (b) the apparent molar mass of this anesthetic [Hint: For part (b), refer to Exercise 103.] Gas cylinder A has a volume, contains He(g) at 9.50 atm and 25 °C When the two cylinders are connected and the gases mixed, the pressure in each cylinder becomes 8.71 atm What is the volume of cylinder B? The accompanying sketch is that of a closed-end manometer Describe how the gas pressure is measurement of Pbar not necessary when using this manometer? Explain why the closed- Integrative and Advanced Exercises end manometer is more suitable for measuring low pressures and the open-end manometer more suitable for measuring pressures nearer atmospheric pressure 237 density as that of air at 25 °C and 1.00 atm? See Exercise 103 for the composition of air 113 Chlorine dioxide, CIO2, is sometimes used as a chlorinating agent for water treatment It can be prepared from the reaction below: Cl21g2 + NaClO1ag2 ; NaClO passing the mixture through a solution of excess potassium iodide, KI Ozone reacts with the iodide ion as follows: Gas 107 Producer gas is a type of fuel gas made by passing air or steam through a bed of hot coal or coke A typical producer gas is a type of fuel gas made by passing air or steam through a bed of hot coal or coke A typical producer gas has the following composition in percent by volume: 8.0% CO2, 23.2% CO, 17.7% H 2, 1.1% CH 4, and 50.0% N2 (a) What is the density of this gas at 23 °C and 763 mmHg, in grams per liter? (b) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure of CO in this mixture at 0.00 °C and atm? (c) What is the partial pressure at 0.00 °C and atm? (c) What is the partial pressure at 0.00 °C and atm? (c) What is the partial pressure at 0.00 ° 741 Torr? [Hint: Which three of the constituent gases are combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate comes from the biochemical combustible?] 108 The heat required to sustain animals while they hibernate combustible?] 108 The heat required to sustain animals while they hibernate combustible?] 108 The heat required to sustain animals while they hibernate combustib approximately 78.1% N2 and 20.9% O2, by volume Other gases make up the remaining 1.0% 109 A mixture of H 21g2 and O21g2 is prepared by electrolyzing 1.32 g water, and the mixture of gases is collected over water at 30 °C and 748 mmHg The volume of wet gas obtained is 2.90 L What must be the vapor pressure of water at 30 °C °C? electrolysis "H 1g2 + O 1g2 H O1l2 2 110 Aluminum (AI) and iron (Fe) each react with hydrochloric acid solution (HCI) to produce a chloride salt and hydrogen gas, H 21g2 A 0.1924 g sample of a mixture of AI and Fe is treated with excess HCI solution A volume of 159 mL of H gas is collected over water at 19.0 °C and 841 Torr What is the percent (by mass) of Fe in the mixture? The vapor pressure of water at 19.0 °C is 16.5 Torr 111 A 0.168 L sample of O21g2 is collected, what is the percent water vapor (a) by volume; (b) by number of molecules; (c) by mass? (Vapor pressure of water at 26 °C = 25.2 mmHg.) 112 A breathing mixture is prepared in which He is substituted for N2 The gas is 79% He and 21% O2, by volume (a) What is the density of this mixture in grams per liter at 25 °C and 1.00 atm? (b) At what pressure would the He O2 mixture have the same O31g2 + 31 - 1aq2 + H 2O1l2 i O21g2 + 1 - 1aq2 + 20H -1ag2 The amount of I 3- produced is determined by titrating with thiosulfate ion, S 2O 2-: I -1ag2 + S 4O - 1ag2 + S 4O + 1ag2 + 1ag2 + S 4O + 1ag2 + 1ag2 + 1ag2 + 1ag2 + 1ag2 + 1ag2 + 1ag2 + 1 solution requires 26.2 mL of 0.1359 M Na 2S 2O3 to titrate to the end point Calculate the mole fraction of ozone in the original mixture 115 A 0.1052 g sample of H 2O1I2 in an 8.050 L sample water: 20 °C, 17.54 mmHg; 19 °C, 16.48 mmHg; 18 °C, 15.48 mmHg; 17 °C, 14.53 mmHg; 16 °C, 13.63 mmHg; 15 °C, 12.79 mmHg [Hint: Go to Focus On feature for Chapter on the MasteringChemistry site, www.masteringchemistry.com, for a discussion of relative humidity.] 116 An alternative to Figure 6-6 is to plot P against 1>V The resulting graph is a straight line passing through the origin Use Boyle s data from Feature Problem 125 to draw such a straight-line graph What factors would affect the slope of this straight line? Explain 117 We have noted that atmospheric pressure depends on altitude can be calculated with an equation known as the barometric formula: P = P0 * 10-Mgh>2.303RT In this equation, P and P0 can be in any pressure units, for example, Torr P0 is the pressure at sea level, generally taken to be 1.00 atm or its equivalent The units in the exponential term must be SI units, however Use the barometric formula to (a) estimate the barometric pressure at the top of Mt Whitney in California (altitude: 14,494 ft; assume a temperature of 10 °C) (b) show that barometric pressure decreases by onethirtieth in value for every 900-ft increase in altitude 118 Consider a sample of O 21g2 at 298 K and 1.0 atm Calculate (a) urms and (b) the fraction of molecules that have speed equal to urms 238 Chapter Gases 119 A nitrogen molecule 1N22 having the average kinetic energy at 300 K is released from Earth s surface to travel upward lf the molecules, then how high would it go before coming to rest? Give your answer in kilometers [Hint: When the molecule comes to rest, the potential energy of the molecule will be mgh, where m is the molecular mass in kilograms, g = 9.81 m s -2 is the acceleration due to gravity, and h is the height, in meters, above Earth s surface.] 120 For H 21g2 at °C and atm, calculate the percentage of molecules that have speed (a) m s -1; (b) 500 m s -1; (c) 1000 m s -1; (d) 1500 m s -1; (e) 2000 m s -1; (e) 2000 m s -1; (f) 2500 m s -1; (g) 3500 m s -1; (g volume, in liters, occupied by 185 g CO21g2 at a pressure of 12.5 atm and 286 K? For CO21g2, a = 3.61 L2 atm mol -2 and b = 0.0429 L mol -1 [Hint: Use the ideal gas equation to obtain an estimate of the volume Then refine your estimate, either by trial and error, or using the method of successive approximations See Appendix A, pages A5 A6, for a description of the method of successive approximations.] 122 According to the CRC Handbook of Chemistry and Physics (83rd ed.), the molar volume of O21g2 is 0.2168 L mol -1 at 280 K and 10 MPa (Note: MPa = * 106 Pa.) (a) Use the van der Waals equation to calculate the pressure of one mole of O21g2 at 280 K if the volume is 0.2168 L What is the % error in the calculated pressure? The van der Waals constants are a = 1.382 L2 bar mol -2 and b = 0.0319 L mol -1 (b) Use the ideal gas equation to calculate the volume of one mole of O21g2 at 280 K and 10 MPa What is the % error in the calculated volume? 123 A particular equation of state for O21g2 has the form PV = RT a1 + C B b + V V2 where V is the molar volume, B = - 21.89 cm3>mol and C = 1230 cm6>mol (a) Use the equation to calculate the pressure exerted by mol O21g2 confined to a volume of 500 cm3 at 273 K (b) Is the result calculated in part (a) consistent with that suggested for O21g2 by Figure 6-20? Explain 124 A 0.156 g sample of a magnesium aluminum alloy dissolves completely in an excess of HCI(aq) The liberated H 21g2 is collected, the water and gas gradually warm to the prevailing room temperature of 23 °C The pressure of the collected gas is again equalized against the barometric pressure of 752 Torr, and its volume is found to be 202 mL What is the percent composition of the magnesium aluminum alloy? (Vapor pressure of vater: 6.54 mmHg at 23 °C) Feature Problems 125 Shown to the right is a diagram of Boyle s original apparatus At the start of the experiment, the length of the air column (A) on the left was 30.5 cm and the heights of mercury in the arms of the tube (smaller volume) (b) was produced, and the entrapped air on the left was compressed into a shorter length of the tube (smaller volume) as shown in the illustration for A = 27.9 cm and B = 7.1 cm Boyle s values of A and B, in centimeters, are listed as follows: A: B: 30.5 0.0 27.9 7.1 25.4 12.7 105.6 10.2 147.6 7.6 224.6 Barometric pressure at the time of the experiment was 739.8 mmHg Assuming that the length of the air column (A) is proportional to the volume of air, show that these data conform reasonably well to Boyle s law Pbar * 739.8 mmHg A * 27.9 cm B * 7.1 cm 126 In 1860, Stanislao Cannizzaro showed how Avogadro s hypothesis could be used to establish the atomic masses of elements in gaseous compounds Cannizzaro took the atomic mass of hydrogen to be exactly one and assumed that hydrogen exists as H molecules (molecular mass = 2) Next, he determined the volume is 22.4 L Then he assumed that 22.4 L of any other gas would have the same number of molecules as in 22.4 L of H 21g2 (Here is where Avogadro s hypothesis Feature Problems entered in.) Finally, he reasoned that the ratio of their molecular masses The sketch below illustrates Cannizzaro s reasoning in establishing the atomic weight of oxygen as 16 The gases in the table all contain the element X Their molecular masses were determined by Cannizzaro s method Use the percent composition data to deduce the atomic mass of X, the number of atoms of X in each of the gas molecules, and the identity of X Relative mass * H Compound Molecular Mass, u Mass Percent X, % Nitryl fluoride Nitrosyl fluoride Thionyl fluoride 5.01 49.01 86.07 102.07 49.4 32.7 18.6 31.4 Number of molecules equal to the Avogadro constant, NA: NA * 6.02 + 1023 mol,1 H H Relative mass * 22.4 L at °C and atm 22.4 L at ° densities, John Rayleigh, a physicist, found that the density of O21g2 had the same value whether the gas was obtained from air or derived from ai value if the N21g2 was extracted from air In 1894, Rayleigh enlisted the aid of William Ramsay, a chemist, to solve this apparent mystery; in the course of their work they discovered the noble gases (a) Why you suppose that the N21g2 extracted from liquid air did not have the same density as N21g2 obtained from its compounds? (b) Which gas you suppose had the greater density: N21g2 extracted from air or N21g2 prepared from nitrogen compounds? Explain (c) The way in which Ramsay proved that nitrogen gas extracted from air was itself a mixture of gases involved allowing this nitrogen to react with magnesium metal to form magnesium nitride Explain the significance of this experiment (d) Calculate the percent difference in the densities at 0.00 °C and 1.00 atm of Rayleigh s N21g2 extracted from air and N21g2 derived from air and N21 M>RT, which can be derived from equation (6.14), suggests that the ratio of the density (d) to pressure (P) of a gas at constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a constant temperature should be a (a) Calculate values of d>P, and with a graph or by other means determine the ideal value of the term d>P for O21g2 at 273.15 K [Hint: The ideal value of d>P from part (a) to calculate a precise value for the atomic mass of oxygen, and compare this value with that listed on the inside front cover P, mmHg: d, g/L: 760.00 1.428962 570.00 1.071485 380.00 0.714154 190.00 0.356985 129 A sounding balloon is a rubber bag filled with H 21g2 and carrying a set of instruments (the payload) Because this combination of bag, gas, and payload has a smaller mass than a corresponding volume of air, the balloon rises As the balloon rises, it expands From the table below, estimate the maximum height to which a spherical balloon, 120 ft at 0.00 °C and 1.00 atm; diameter of balloon at maximum height, 25 ft Air pressure and temperature as functions of altitude are: Altitude, km 10 20 30 40 50 60 Pressure, mb 1.0 5.4 2.7 5.5 1.2 2.9 8.1 2.3 * * * * * * 10 102 102 101 101 100 10-1 Temperature, K 288 256 223 217 230 250 256 240 Chapter Gases Self-Assessment Exercises 130 In your own words, define or explain each term or symbol (a) atm; (b) STP; (c) R; (d) partial pressure; (e) urms 131 Briefly describe each concept or process: (a) absolute zero of temperature; (b) collection of a gas over water; (c) effusion of a gas equation; (d) ideal gas and real gas 133 Which exerts the greatest pressure, (a) a 75.0 cm column of Hg1l2 1d = 13.6 g>mL2; (b) a column of CCl41l2 1d = 1.59 g>mL2; (d) 10.0 g H 21g2 at STP? 134 For a fixed amount of gas at a fixed pressure, changing the temperature from 100.0 °C to 200 K causes the gas volume to (a) double; (b) increase, but not to twice its original value; (c) decrease; (d) stay the same 135 A fragile glass vessel will break if the internal pressure equals or exceeds 2.0 bar If the vessel is sealed at °C and 1.0 bar, then at what temperature will the vessel break? Assume that the vessel does not expand when heated 136 Which of the following choices represents the molar volume of an ideal gas at 25 °C and 1.5 atm? (a) 1298 * 1.5>2732 * 22.4 L; (b) 22.4 L; (c) 1273 * 1.5>2982 * 22.4 L; (d) 3298>1273 * 1.5>2982 * 22.4 L; (e) 3273>1298 * 1.5>2982 * 1.5>2982 * 22.4 L; (e) 3273>1298 * 1.5>2982 * 22.4 L; (e) 3273>12 temperature of a sample of ideal gas doubles (e.g., from 200 K to 400 K), what happens to the root-mean-square speed, urms? (a) urms increases by a factor of 2; (b) urms increases by a factor of 12; (c) urms decreases by a factor of 2; (c) urms increases by a factor of to (e) below Assume that H 21g2 and O21g2 behave ideally State whether each of the following statements is true or false For each false statement (a) Under the same conditions of temperature and pressure, the average kinetic energy of O2 molecules is less than that of H molecules (b) Under the same conditions of temperature and pressure, H molecules move faster, on average, than O2 molecules (c) The volume of 2.0 g H 21g2 is equal to the volume of 32.0 g O21g2, at the same temperature and pressure (e) In a mixture of H and O2 gases, with partial pressures PH2 and PO2, respectively, the total pressure of 751 Torr The vapor pressure of 021g2 is collected over water at 23 °C and a barometric pressure of 751 Torr; (c) 0.96 atm; (d) 1.02 atm 141 At °C and 0.500 atm, 4.48 L of gaseous NH (a) contains 6.02 * 1022 molecules; (b) has a mass of 3.40 g 142 To establish a pressure of 2.00 atm in a 2.24 L cylinder containing 1.60 g O21g2 at °C, (a) add 1.60 g O2; (b) add 0.60 g He1g2; (c) add 2.00 g He1g2; (d) release 0.80 g O21g2 143 Carbon monoxide, CO, and hydrogen react according to the equation below CO1g2 + H 201g2 143 145 146 147 148 149 150 What volume of which reactant gas remains if 12.0 L CO1g2 and 25.0 L H 21g2 are allowed to react? Assume that the volumes of both gases are measured at the same temperature and pressure A mixture of and 5.0 * 10-5 mol H 21g2 -5 5.0 * 10 mol SO 21g2; (b) is equal to that of the SO21g2; (c) exceeds that of the SO21g2; (d) is the same as in the original mixture Under which conditions is Cl2 most likely to behave like an ideal gas? Explain (a) 100 °C and 0.50 atm; (d) 400 °C and 10.0 atm; (d) 400 °C and 10.0 atm Without referring to Table 6.5, state which species in each of the following pairs has the greater value for the van der Waals constant a, and which one has the greater value for the van der Waals constant b (a) He or Ne; (b) CH or C3H 8; (c) H or Cl2 Explain why the height of the mercury column in a barometer is independent of the diameter of the barometer tube A gaseous hydrocarbon that is 82.7% C and 17.3% H by mass has a density of 2.35 g>L at 25 °C and 752 Torr What is the molecular formula of this hydrocarbon? Draw a box to represented as circles) in their correct proportions How many squares and circles would you need to draw to also represent the CO21g2 in air through a single mark? What else should you add to the box for this more complete representation of air? [Hint: See Exercise 103.] Appendix E describes a useful study aid known as concept mapping Using the method presented in Appendix E. relationships among all the gas laws described in this chapter ... Self-Assessment Exercises 448 11 Chemical Bonding II: Additional Aspects 11 -1 11 -2 11 -3 11 -4 11 -5 11 -6 11 -7 11 -8 What a Bonding Theory Should Do 450 Introduction to the Valence-Bond Method 4 51 Hybridization... 812 Integrative and Advanced Exercises 815 Feature Problems 816 Self-Assessment Exercises 817 18 -4 18 -5 18 -6 18 -7 18 -8 18 -9 745 19 Spontaneous Change: Entropy and Gibbs Energy 819 19 -1 19-2 19 -3... and Advanced Exercises 912 Feature Problems 914 Self-Assessment Exercises 915 21 Chemistry of the Main-Group Elements I: Groups 1, 2, 13 , and 14 917 21-1 21- 2 21- 3 21- 4 21- 5 Periodic Trends and - Xem thêm: Ebook General chemistry principles and modern applications (10th edition) Part 1, Ebook General chemistry principles and modern applications (10th edition) Part 1

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