Chapter 14 Practice Problems

In problems that require the atomic masses (atomic weights) of atomic hydrogen, oxygen, nitrogen, and carbon, we will use the rounded values, 1, 16, 14, and 12, respectively. The atomic masses of molecular hydrogen (H_2), oxygen (O_2), and nitrogen (N_2) are 2, 32, and 28, respectively.

SKIP PROBLEMS 1-4, 7-8

1. (a) How many atoms are there in one mole of hydrogen gas (H_2)? (b) Nitrogen gas (N_2)?

2. (a) How many hydrogen atoms are there one mole of methane, CH_4? (b) What is the mass (in grams) of one molecule of methane?

3. A cylindrical glass of water (H_2O) has a radius of 4.50 cm and a height of 12.0 cm. The density of water is 1.0 g/cm^3. (a) How many moles of water are in the glass? (a) How many molecules?

4. It takes 0.16 grams of helium (He, atomic mass 4)) to fill a balloon. How many grams of *nitrogen* gas would be required to fill the balloon to the same pressure, volume, and temperature?

5. An empty oven with a volume of 0.150 m^3 and a temperature of 300 K is vented so that the air pressure inside is always the same as atmospheric pressure.

Initially, the air pressure is 1000 millibars, but after the oven has warmed up to a final temperature of 460 K, the atmospheric air pressure has decreased by 50 millibars. How many moles of air leave the oven while it is heating up?

6. An ideal gas at 15.5 C and a pressure of 1.72 x 10^5 Pa occupies a volume of 2.81 m^3. (a) How many moles of gas are present? (b) If the volume is raised to 4.16 m^3 and the temperature raised to 28.2 C, what will be the pressure of the gas?

7. Oxygen (O_2) at 288 K is pressurized in a 0.20 m^3 tank at 65.0 P_o is allowed to expand for delivery to hospital patients at 1.0 P_o. Suppose the oxygen arrives at the lungs of the patients at 297 K.

How many cubic meters of oxygen would have been received by the patients once the tank is emptied?

8. A clown at a birthday party has brought along a helium cylinder, with which he intends to fill balloons. When full, each balloon contains 0.034 m^3 of helium at an absolute pressure of 1.2 x 10^5 Pa. The cylinder contains helium at an absolute pressure of 1.6 x 10^7 Pa and has a volume of 0.0031 m^3. The temperature of the helium in the cylinder and in the balloons is the same and remains constant. What is the maximum number of balloons that can be filled?

9. In a diesel engine, the piston compresses air at 305 C to a volume that is one-sixteenth of the original volume and a pressure that is 48.5 times the original pressure. What is the temperature of the air after the compression?

10. A 0.030-m^3 container is initially evacuated. Then, 4.0 grams of water is placed in the container, and after some time, all the water evaporates. If the temperature of the water vapor is 388 K, what is its pressure?

11. A cylinder contains oxygen gas at a temperature of 20 C and a pressure of 15 atm in a volume of 100 liters. A fitted piston is lowered into the cylinder, decreasing the volume occupied by the gas to 80 liters and raising the temperature to 25 C. What then is the gas pressure? (Note: one atm = P_o.)

12. An air bubble of 20 cm^3 volume is at the bottom of a lake 40 m deep where the temperature is 4 C. The bubble rises to the surface which is at a temperature 20 C. Find the bubble's volume just before it reaches the surface, assuming the number of moles of air inside the bubble doesn't change.

13. An automobile tire has a volume of 1000 in^3 and contains air at 0 C at a gauge pressure of 24 PSI. when the temperature of the air inside the tire is 0 C. What will be the gauge pressure of the air in the tires when its temperature rises to 27 C and its volume increases to 1020 in^3?

14. Compute the number of atoms of in a gas of atoms contained in a volume of 1.0 cm^3 at a pressure of 0.001 atm and a temperature of 200 K.

15. (a) What is the internal energy of 90 grams of argon (atomic mass = 39.9) gas at 50 C?
(b) What is the average kinetic energy per atom?
(c) What is the average speed?

16. (a) How many calories of heat energy must flow into a gas containing two moles of argon atoms at 293 C to raise its temperature to 333 C? (b) Calculate the specific heat capacity of argon gas.

Chapter 14 Problem Solutions

SKIP PROBLEMS 1-4, 7-8

1. H_2 and N_2 have two atoms per molecule. (a) $2\,(6.02 \times 10^{23}) = 1.204 \times 10^{24}$ (b) 1.204×10^{24}	2 (a) $4\,(6.02 \times 10^{23})$ (b) Molecular mass of CH_4: $12 + 4(1) = 16$ $m = 16/6.02 \times 10^{23}$ $= 2.66 \times 10^{-23}$ g
3. Molecular mass of water = 18 Density of water = 1.0 g/cm^3 Volume of a Cylinder = 9 $m = \rho V$ $= (1.0)\,\pi\,(4.50)^2\,12.0$ $= 763$ g (a) $n = 763/18$ $= 42.4$ moles (b) $N = (42.4)\,N_A$ $= 42.4\,(6.02 \times 10^{23})$ $= 2.55 \times 10^{25}$	4. $n = PV/RT$ PV/RT is the same number for both gases, so the number of moles n is also the same for both gases: <u>Helium</u>: $n = 0.16/4$ $= 0.04$ moles of helium <u>Nitrogen</u>: $n = 0.04$ moles of nitrogen Atomic weight of N_2 = 28 $0.04\,(28) = 1.12$ g

5. Note: One millibar = 100 Pa P_1 = 100,000 Pa P_2 = 95,000 Pa $V_1 = 0.150\ m^3$ $V_2 = 0.150\ m^3$ T_1 = 300 K T_2 = 460 K $n = PV/RT$ $\Delta n = n_2 - n_1$ $= P_2V_2/RT_2 - P_1V_1/RT_1$ = - 2.29 moles	6. T_1 = 273.0 + 15.5 = 288.5 K $P_1 = 1.72 \times 10^5$ Pa $V_1 = 2.81\ m^3$ (a) $n_1 = P_1V_1 / RT_1$ = 201.6 moles (b) $V_2 = 4.16\ m^3$ Gas neither enters nor escapes, so the number of moles of gas remains the same: $n_2 = n_1$ = 201.6 moles T_2 = 273 + 28.2 = 301.2 K $P_2 = n_2 RT_2 / V_2$ = (201.6) (8.31) (301.2)/4.16 = 121,298 Pa

7. $P_1 = 65\ P_o$ $V_1 = 0.20\ m^3$ $T_1 = 288\ K$ $P_2 = P_o$ $T_2 = 297\ K$ $(P_2/P_1)\ (V_2/V_1) = (T_2/T_1)$ $(P_o /65\ P_o)(V_2/0.20) = (297/288)$ $V_2 = 13.4\ m^3$	8. $P_1 = 1.6 \times 10^7$ Pa $V_1 = 0.0031\ m^3$ $P_2 = 1.2 \times 10^5$ Pa PV = nRT If T is a constant, then PV = constant: $P_2V_2 = P_1V_1$ $(1.2 \times 10^5)V_2 = (1.6 \times 10^7)\ (0.0031)$ $V_2 = 0.413\ m^3$ Number of Balloons: 0.413/0.034 = 12
9. $T_1 = 305 + 273$ $= 578\ K$ Recall Ratio Equation: $(T_2/T_1) = (P_2/P_1)\ (V_2/V_1)$ $T_2/578 = (48.5)\ (1/16)$ $T_2 = 1752\ K$	10. Molecular mass of H_2O: 18 g $n = 4.0/18.0$ $= 0.22$ mole $T = 388\ K$ $V = 0.03\ m^3$ $P = nRT/V$ $= 0.22\ (8.31)(388)/0.03$ $= 2.36 \times 10^4$ Pa

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<td>11.
$T_1 = 293$ K
$T_2 = 298$ K

$V_1 = 100$ L
$V_2 = 80$ L

$P_1 = 15$ atm

Use the Ratio Equation:

$(T_2/T_1) = (P_2/P_1)\ (V_2/V_1)$
$(298/293) = (P_2/15)\ (80/100)$

$P_2 = 19.07$ atm</td>
<td>12.

$T_1 = 277$ K
$T_2 = 293$ K

Add water pressure ρgh to atmospheric pressure to get total pressure:

$P_1 = 101{,}000 + 1000\ (9.8)(40)$
$= 493{,}000$ Pa
$P_2 = 101{,}000$ Pa

$V_1 = 20\ cm^3$
$V_2 = ?$

Use the Ratio Equation:

$(T_2/T_1) = (P_2/P_1)\ (V_2/V_1)$
$(293/277) = (101/493)\ (V_2/20)$
$V_2 = 103\ cm^3$</td>
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<td>13.

$T_1 = 273$ K
$T_2 = 300$ K

$V_1 = 1000\ in^3$
$V_2 = 1020\ in^3$

$P_1 = 24.0 + 14.7$
$= 38.7$ psi

Use Ratio Equation:

$(T_2/T_1) = (P_2/P_1)\ (V_2/V_1)$
$(300/273) = (P_2/38.7)(1020/1000)$
$P_2 = 41.7$ psi

Gauge Pressure $= 41.7 - 14.7$
$= 27.0$ psi</td>
<td>14.

$P = 0.001$ atm
$= 101$ Pa

$V = (1.0 \times 10^{-2}\ m)^3$
$= 1.0 \times 10^{-6}\ m^3$

$T = 200\ ^oK$

$PV = NkT$
$N = PV/kT$
$= 3.7 \times 10^{16}$</td>
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15.

$T = 323$ K

$n = 90/39.9$
$= 2.26$ moles

(a) $E = (3/2)\, nRT$
$= (3/2)(2.26)(8.31)(323)$
$= 9099$ J

(b) $K = (3/2)\,(1.38 \times 10^{-23})\,(323)$
$= 6.7 \times 10^{-21}$ J

(c) $m = 39.9/N_A$
$= 6.63 \times 10^{-24}$ g
$= 6.63 \times 10^{-27}$ kg

$\frac{1}{2}\,(6.63 \times 10^{-27})\, v^2 = 6.7 \times 10^{-21}$ J
$v = 1422$ m/s

16.

(a) Recall: 1.0 cal = 4.19 J (Chapter 12)

$E = 3/2\, nRT$
$Q = \Delta E$
$= 3/2\, nR\Delta T$
$= (3/2)\,(2)(8.31)(303\text{-}263)$
$= 997$ J
$= 997$ J/(4.19 J/cal)
$= 238$ cal

(b) Atomic mass of argon (Ar) = 39.9 g
$n = 2$ moles
$m = 2\,(39.9)$
$= 79.8$ g

$\Delta T = 40$ K
$= 40$ C
$Q = mc\Delta T$ (Chapter 12)
$c = Q/(m\Delta T)$
$= 238/(79.8 \times 40)$
$= 0.075$ cal/g-C