

Problem Set #4
CHEM101A: General College Chemistry

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1 Topic C Problem R-1

A container holds 415 mL of air at a pressure of 1.88 atm. If you want to reduce the pressure to 1.55 atm without changing the temperature, to what volume must you expand the air?

1.1 Solution

$$\begin{aligned} \text{C.R-1} \quad V_1 &= 415 \text{ mL}; P_1 = 1.88 \text{ atm}; P_2 = 1.55 \text{ atm} \\ P_1 V_1 &= P_2 V_2 \\ V_2 &= \frac{P_1 V_1}{P_2} = \frac{1.88 \text{ atm} \times 415 \text{ mL}}{1.55 \text{ atm}} = 503 \text{ mL} \end{aligned}$$

2 Topic C Problem R-2

A balloon is filled with 3.85 L of oxygen at 31°C and a pressure of 734 torr. The balloon is then taken to the top of a mountain, where the pressure is 591 torr. The volume of the oxygen is found to be 4.13 L. What is the temperature of the oxygen? Give your answer in °C.

2.1 Solution

$$\begin{aligned} \text{CR-2] } V_1 &= 3.85 \text{ L}; T_1 = 31^\circ\text{C} [+273.15 \text{ K}] = 304.15 \text{ K} \\ P_1 &= 734 \text{ torr}; P_2 = 591 \text{ torr}; V_2 = 4.13 \text{ L} \\ \frac{P_1 V_1}{T_1} &= \frac{P_2 V_2}{T_2} \\ T_2 &= T_1 \frac{P_2 V_2}{P_1 V_1} = \frac{304.15 \text{ K} \times \frac{591 \text{ torr} \times 4.13 \text{ L}}{734 \text{ torr} \times 3.85 \text{ L}} - 262.78}{=} \\ &= 262.78 \text{ K} - 273.15^\circ\text{C} = -10.4^\circ\text{C} = \boxed{-10^\circ\text{C}} \end{aligned}$$

3 Topic C Problem R-3

A container is filled with gaseous O₂ at 21.4°C (70.5°F) and a pressure of 754 torr. If the volume of the container is one gallon (3785 mL), what is the mass of the O₂?

3.1 Solution

$$\boxed{\text{C.R-3} \quad T = 21.4^\circ\text{C} = 294.55\text{K}; P = 754 \text{ torr}; V = 3.785 \text{ L}}$$
$$PV = nRT$$
$$n = \frac{PV}{RT} = \frac{754 \text{ torr} \times 3.785 \text{ L}}{62.36 \frac{\text{torr} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 294.55\text{K}} = 0.15537276 \text{ mol}$$
$$MM(O_2) = 2 \times 16.00 \text{ g/mol} = 32.00 \text{ g/mol}$$
$$m = n(O_2) \times MM(O_2) = 0.15537 \text{ mol} \times 32.00 \text{ g/mol} = \boxed{4.97 \text{ g}}$$

4 Topic C Problem R-4

A container is filled with 25.3 g of gaseous CO₂ at 31°C. If the carbon dioxide exerts a pressure of 3.88 atm, what is the volume of the container?

4.1 Solution

$$\begin{aligned} \text{C.R-4] } \text{MM(CO}_2\text{)} &= 12.01 + 2 \times 16.00 = 44.01 \text{ g/mol} \\ m &= 25.3 \text{ g}; T = 31^\circ\text{C} + 273.15 \text{ K} = 304.15 \text{ K}; P = 3.88 \text{ atm} \\ n &= \frac{m}{\text{MM}} = \frac{25.3}{44.01 \text{ g/mol}} = 0.574869 \text{ mol}; PV = nRT \\ V &= \frac{nRT}{P} = \frac{0.574869 \text{ mol} \times 0.08206 \frac{\text{atm} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 304.15 \text{ K}}{3.88 \text{ atm}} \\ &= 3.6979126 \text{ L} = \boxed{3.70 \text{ L}} \end{aligned}$$

5 Topic C Problem R-5

What is the density of gaseous carbon dioxide at 51°C and a pressure of 855 torr?

5.1 Solution

$$\boxed{\begin{aligned} \text{C.R-5] } M\text{M}(CO_2) &= 44.01 \text{ g/mol}; T = 51^\circ\text{C} + 273.15\text{K} = 324.15\text{K} \\ P &= 855 \text{ torr}; R = 62.36 \text{ torr}\cdot\text{L/mol}\cdot\text{K}; PV = nRT \\ d &= \frac{m}{V} = \frac{MM \times n}{V} = \frac{MM \times P}{R \times T} \\ &= \frac{44.01 \times 855}{62.36 \times 324.15} = \underline{\underline{1.8615 \text{ g/L}}} = \boxed{1.86 \text{ g/L}} \end{aligned}}$$

6 Topic C Problem 1

A gaseous compound has the following composition: 85.63% carbon, 14.37% hydrogen. The density of this compound is 1.63 g/L at 33.2°C and a pressure of 739 torr. What is the molecular formula of the compound?

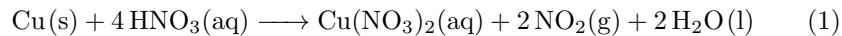
6.1 Solution

C.1 $T = 33.2^\circ\text{C} + 273.15\text{K} = 306.35\text{K}$; $d = 1.63$.
85.63% C, 14.37% H; $P = 739 \text{ torr}$

$$d = \frac{m}{V} = \frac{MM \times n}{R \times T}$$
$$MM = \frac{d \times R \times T}{P} = \frac{1.63 \text{ g/L} \times 62.36 \frac{\text{torr} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 306.35}{739 \text{ torr}}$$
$$= 42.137 \text{ g/mol}$$
$$MM(C_x) = 0.8563 \times MM_H = 0.8563 \times 42.137 = 36.08 \text{ g/mol}$$
$$MM(H_y) = 0.1437 \times MM_H = 0.1437 \times 42.137 = 6.055 \text{ g/mol}$$
$$x = MM(C_x)/MM(C) = 36.08/12.01 \approx 3 \quad \text{propene or}$$
$$y = MM(H_y)/MM(H) = 6.055/1.008 \approx 6 \quad \boxed{C_3H_6} \text{ cyclopropane}$$

7 Topic C Problem 2

Copper reacts with nitric acid as shown below:



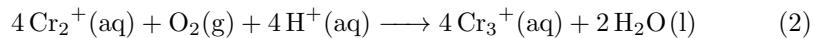
If 4.71 g of copper reacts with excess 3 M nitric acid, what volume of nitrogen dioxide will be formed at 31°C and 1.022 atm?

7.1 Solution

$$\boxed{\begin{aligned} & \text{C.2 } T = 31^\circ\text{C} + 273.15\text{K} = 304.15\text{K}, P = 1.022 \text{ atm}; R = 0.08206 \frac{\text{atm}\cdot\text{mol}}{\text{mol}\cdot\text{K}} \\ & n(\text{NO}_2) = \frac{4.71 \text{ g Cu}}{63.55 \text{ g/mol}} \times \frac{2 \text{ NO}_2}{1 \text{ Cu}} = 0.148 \text{ mol } \text{NO}_2 \\ & PV = nRT \rightarrow V = \frac{nRT}{P} = \frac{0.148 \text{ mol} \times 0.08206 \frac{\text{atm}\cdot\text{mol}}{\text{mol}\cdot\text{K}} \times 304.15\text{K}}{1.022 \text{ atm}} \\ & = 3.61996 \text{ L} = \boxed{3.62 \text{ L}} \end{aligned}}$$

8 Topic C Problem 3

Consider the following reaction:



A container that holds 562 mL of gaseous oxygen at 21°C is prepared. Then, 21.3 mL of a solution that contains 0.131 M Cr^{2+} ions is added to the container. After the reaction, the pressure of the oxygen in the container is found to be 119 torr and the temperature is still 21°C. What was the pressure of oxygen in the container before the Cr^{2+} solution was added? (You can assume that H^+ is present in excess.)

8.1 Solution

C.3 $T_f = T_i = 21^\circ\text{C} = 294.15\text{K}$; $V_i = 562\text{mL}$; $P_f = 119\text{torr}$

$$n(\text{Cr}^{2+}) = M \times V = 0.131 \text{M} \times 21.3 \text{mL} = 2.7903 \mu\text{mol Cr}^{2+}$$
$$-\Delta n(\text{O}_2) = \frac{4}{4} \times n(\text{Cr}^{2+}) = 2.7903 \text{ mol Cr}^{2+} \times \frac{2}{4} = 0.697575 \text{ mol O}_2$$

Suppose the only change in the volume of the O_2 is from the solution added.

$$V_f = V_i - 21.3\text{mL} = 562\text{mL} - 21.3\text{mL} = 540.7\text{mL}$$

From here, find the final mole count.

$$n_f = \frac{P_f V_f}{R T} = \frac{119 \text{ torr} \times 540.7 \text{ mL}}{62.36 \frac{\text{torr} \cdot \text{L}}{\text{mol} \cdot \text{K}} \times 294.15 \text{ K}} = 3.50775 \text{ mmol O}_2$$
$$n_f - n_i = \Delta n \rightarrow n_f = n_i + \Delta n = 3.50774 + 0.697575 \text{ mmol O}_2 = 4.20532 \text{ mmol O}_2$$
$$P_i = \frac{n_i R T}{V_i} = \frac{4.20532 \text{ mmol O}_2 \times 62.36 \frac{\text{torr} \cdot \text{L}}{\text{mol} \cdot \text{K}}}{562 \text{ mL}} \times 294.15 \text{ K}$$
$$= 137.2581 \text{ torr} = 137 \text{ torr}$$

9 Topic C Problem 4

A chemist puts 200.0 mL of water into a 2.50 L container, and adds enough gaseous H₂S to give a pressure of 180.2 torr at a temperature of 13.0°C. Some of the H₂S then dissolves in the water, causing the pressure in the container to drop to 155.9 torr. The temperature remains constant throughout this experiment. What is the molar concentration of H₂S in the water at the end of the experiment?

9.1 Solution

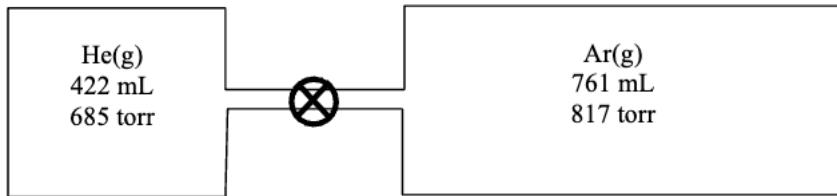
C.4] $T = 13.0^\circ\text{C} = 286.15\text{K}$; $P_1 = 180.2\text{torr}$; $P_2 = 155.9\text{torr}$
 $V = 2.50\text{L} - 0.20\text{L} = 2.30\text{L}$

Suppose the volume occupied by the hydrosulfuric acid is unchanged.
The change of moles of gas is the negative of the change of
moles of the H₂S in the water.

$$\Delta n = n_f - n_i = \frac{P_2 V_2 - P_1 V_1}{R T} = \frac{V(P_2 - P_1)}{62.36 \frac{\text{torr}\cdot\text{L}}{\text{mol}\cdot\text{K}} \times 286.15\text{K}} = -3.13209 \text{ mmol H}_2\text{S}$$
$$[\text{H}_2\text{S}] = \frac{-\Delta n}{V} = \frac{3.13209 \text{ mmol H}_2\text{S}}{200 \text{ mL}} = [0.016 \text{ M H}_2\text{S}]$$

10 Topic C Problem 5

Consider the apparatus pictured below, which consists of two containers separated by a valve.



Assuming that the two gases are the same temperature and that the temperature does not change, what will be the total final pressure in the system after the valve is opened and the gases mix completely?

10.1 Solution

$$\boxed{\text{C.5} \quad P_{\text{tot}} = P_{\text{Ar}} + P_{\text{He}}; \quad P_1 V_1 = P_2 V_2; \quad V_2 = 761 \text{ mL} + 422 \text{ mL} = 1183 \text{ mL}}$$
$$\text{Ar: } P_2 = P_1 \times \frac{V_1}{V_2} = 817 \text{ torr} \times \frac{761 \text{ mL}}{1183 \text{ mL}} = 525.559 \text{ torr} = P_{\text{Ar}}$$
$$\text{He: } P_2 = P_1 \times \frac{V_1}{V_2} = 685 \text{ torr} \times \frac{422 \text{ mL}}{1183 \text{ mL}} = 244.353 \text{ torr} = P_{\text{He}}$$
$$P_{\text{tot}} = P_{\text{Ar}} + P_{\text{He}} = 525.559 \text{ torr} + 244.353 \text{ torr} = 769.913 \text{ torr} = \boxed{770 \text{ torr}}$$

11 Topic C Problem 6

Complete the following ICE table. All of the reactants and products for this reaction are gases, and the temperature and volume are constant during the reaction.

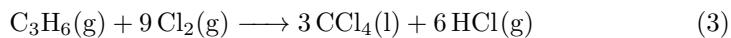
torr	$\text{C}_2\text{H}_6 + 7\text{F}_2 \rightarrow 2\text{CF}_4 + 6\text{HF}$			
Initial pressure (torr)	127.3	329.5	89.1	0
Change (torr)				
Ending pressure (torr)				

11.1 Solution

C.6	torr	$\text{C}_2\text{H}_6(g) + 7\text{F}_2(g) \rightarrow 2\text{CF}_4(g) + 6\text{HF}(g)$		
I	127.3	329.5	89.1	0
C	-47.07	-329.5	+94.14	+282.43
E	80.2	0	183.2	282.43
	$329.5/7 = 47.07$	$329.5 \times \frac{2}{7} = 94.14$		
	$329.5 \times \frac{6}{7} = 282.43$			
	$127.3 - 47.07 \approx 80.2$	$89.1 + 94.14 \approx 183.2$		

12 Topic C Problem 7

At 30°C, propylene (C_3H_6) reacts with chlorine as follows:



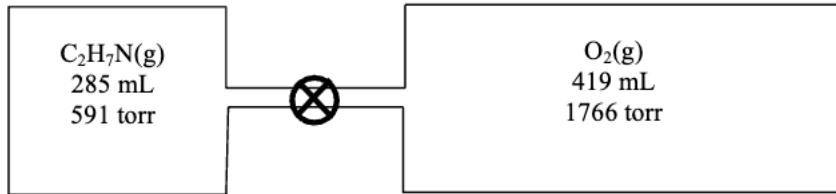
A mixture containing 15.5 torr of C_3H_6 and 174.5 torr of Cl_2 is allowed to react at 30°C. What will be the total gas pressure in the container when the reaction is complete? You may assume that the volume and temperature are constant.

12.1 Solution

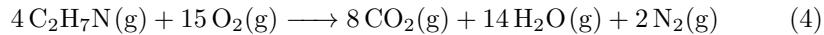
C.7) $C_3H_6(g) + 9 Cl_2(g) \rightarrow 3 CCl_4(l) + 6 HCl(g)$				
I	15.5	174.5	?	0
C	-15.5	-139.5	?	+93
E	0	35	?	93
$\frac{174.5 \text{ Cl}_2}{15.5 C_3H_6} \approx 11.26 > \frac{9 \text{ Cl}_2}{1 C_3H_6}$, so C_3H_6 is LR.				
$15.5 \times 6 = 93$; $15.5 \times 9 = 139.5$; $174.5 - 139.5 = 35$				
$P_{\text{tot}} = P_{Cl_2} + P_{HCl} = 35 + 93 = 128 \text{ torr}$				

13 Topic C Problem 8

Consider the apparatus pictured below, which consists of two containers separated by a valve.



The valve is opened and the gases react as follows (note that the temperature is high enough that the water is produced as a gas):



What will be the total pressure in the apparatus when the reaction has gone to completion? Assume that the temperature does not change.

13.1 Solution

C.8 ICE table. For initial values, use $P_1 V_1 = P_2 V_2$					
Torr	$4 \text{C}_2\text{H}_7\text{N}(\text{g}) + 15 \text{O}_2(\text{g}) \rightarrow 8 \text{CO}_2(\text{g}) + 14 \text{H}_2\text{O}(\text{g}) + 2 \text{N}_2(\text{g})$				
I	239.25	1051.07	0	0	0
C	-239.25	-897.20	478.51	837.39	219.63
E	0	153.87	478.51	837.39	219.63

$V_0 = 285 \text{ mL} + 419 \text{ mL} = 704 \text{ mL}$

$\text{C}_2\text{H}_7\text{N}: P_2 = P_1 \times \frac{V_1}{V_2} = 591 \times \frac{285 \text{ mL}}{704 \text{ mL}} = 239.25 \text{ torr}$

$\text{O}_2: P_2 = P_1 \times \frac{V_1}{V_2} = 1766 \times \frac{419 \text{ mL}}{704 \text{ mL}} = 1051.07 \text{ torr}$

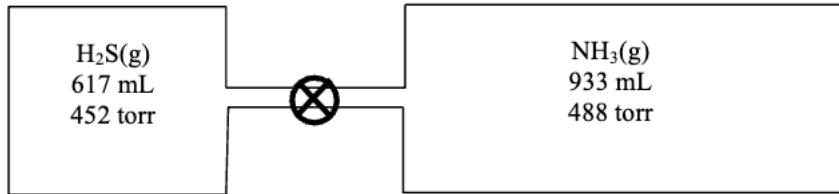
$239.25 \times \frac{15}{4} = 897.20; 1051.07 - 897.20 = 153.87$

$239.25 \times \frac{8}{4} = 478.51; 239.25 \times \frac{14}{4} = 837.39; 239.25 \times \frac{2}{4} = 219.63$

$P_{\text{total}} = \sum P_i = 153.87 + 478.51 + 837.39 + 219.63 = 1589.39 \text{ torr} \approx 1589 \text{ torr}$

14 Topic C Problem 9

Consider the apparatus pictured below, which consists of two containers separated by a valve.



The valve is opened and the gases react as follows:



What will be the total pressure in the apparatus when the reaction has gone to completion? Assume that the temperature does not change.

14.1 Solution

C.9] Find pressures after opening valve, before rxn ($P_1V_1 = P_2V_2$)			
$V_2 = 617 \text{ mL} + 933 \text{ mL} = 1550 \text{ mL}$			
$\text{H}_2\text{S: } P_2 = P_1 \times \frac{V_1}{V_2} = 452 \text{ torr} \times \frac{617 \text{ mL}}{1550 \text{ mL}} = 179.925 \text{ torr}$			
$\text{NH}_3: P_2 = P_1 \times \frac{V_1}{V_2} = 488 \text{ torr} \times \frac{933 \text{ mL}}{1550 \text{ mL}} = 293.745 \text{ torr}$			
Now use an ICE table. Only one gas will remain, then non-LR.			
torr	$\text{H}_2\text{S(g)} + 2 \text{NH}_3(\text{g}) \rightarrow (\text{NH}_4)_2\text{S(s)}$	293.745 $\text{NH}_3 < 2 \text{NH}_3$	
I	179.925	293.745	$\frac{452 \text{ torr}}{2 \text{H}_2\text{S}}$
C	-146.872	-293.745	$\text{H}_2\text{S is LR}$
E	33.053	0	$179.925 - \frac{146.872}{2 \text{NH}_3} \times 293.745 = 33.053 \text{ torr}$
$P_{\text{tot}} = P_{\text{H}_2\text{S}} + P_{\text{NH}_3} = 33.053 \text{ torr} + 0 \text{ torr} = 33.053 \text{ torr} = 33 \text{ Torr}$			

Contents

1 Topic C Problem R-1	2
1.1 Solution	2
2 Topic C Problem R-2	3
2.1 Solution	3
3 Topic C Problem R-3	4
3.1 Solution	4
4 Topic C Problem R-4	5
4.1 Solution	5
5 Topic C Problem R-5	6
5.1 Solution	6
6 Topic C Problem 1	7
6.1 Solution	7
7 Topic C Problem 2	8
7.1 Solution	8
8 Topic C Problem 3	9
8.1 Solution	9
9 Topic C Problem 4	10
9.1 Solution	10
10 Topic C Problem 5	11
10.1 Solution	11
11 Topic C Problem 6	12
11.1 Solution	12
12 Topic C Problem 7	13
12.1 Solution	13
13 Topic C Problem 8	14
13.1 Solution	14
14 Topic C Problem 9	15
14.1 Solution	15