AP® Chemistry
2003 Sample Student Responses

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2A,

Answer EITHER Question 2 below OR Question 3 printed on page 14. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 20 percent.

2. A rigid 5.00 L cylinder contains 24.5 g of $N_2(g)$ and 28.0 g of $O_2(g)$.

(a) Calculate the total pressure, in atm, of the gas mixture in the cylinder at 298 K.

(b) The temperature of the gas mixture in the cylinder is decreased to 280 K. Calculate each of the following.

(i) The mole fraction of $N_2(g)$ in the cylinder

(ii) The partial pressure, in atm, of $N_2(g)$ in the cylinder

(c) If the cylinder develops a pinhole-sized leak and some of the gaseous mixture escapes, would the ratio $\frac{\text{moles of } N_2(g)}{\text{moles of } O_2(g)}$ in the cylinder increase, decrease, or remain the same? Justify your answer.

A different rigid 5.00 L cylinder contains 0.176 mol of $NO(g)$ at 298 K. A 0.176 mol sample of $O_2(g)$ is added to the cylinder, where a reaction occurs to produce $NO_2(g)$.

(d) Write the balanced equation for the reaction.

(e) Calculate the total pressure, in atm, in the cylinder at 298 K after the reaction is complete.

(a) $24.5\text{g } N_2 \times \frac{1\text{ mol } N_2}{28.0\text{g } N_2} = .875\text{ mol } N_2$

$28.0\text{g } O_2 \times \frac{1\text{ mol } O_2}{32\text{g } O_2} = .875\text{ mol } O_2$ +

$1.75\text{ mol gas total}$ ← $PV=nRT$

$P(5.00\text{L}) = 1.75\text{mol}(.0821)298\text{K}$

$P = 8.56\text{ atm}$

(b) (i) $\chi_{N_2} = \frac{.875\text{mol } N_2}{1.75\text{ mol total}} = .500$

(ii) $\frac{8.56\text{ atm}}{298\text{K}} = \frac{x\text{ atm}}{280\text{K}}$ $\quad \frac{P}{T} = \frac{P}{T}$

$x = 8.04\text{ atm}$

$P_{N_2} = 8.04\text{atm}(.500)$ $\quad P_A = P_{total}(\chi_A)$

$P_{N_2} = 4.02\text{atm}$

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(c) $\frac{\text{rate } N_2}{\text{rate } O_2} = \sqrt{\frac{32.0\,g}{28.0\,g}} = 1.07$ $\qquad \frac{r_1}{r_2} = \sqrt{\frac{MM_2}{MM_1}}$

The rate of N_2 escaping in comparison to O_2 is 1.07, greater than one, which meant that more N_2 will escape per time than O_2. The ratio $\left(\frac{\text{mol } N_2}{\text{mol } O_2}\right)$ will decrease.

(d) $2NO_{(g)} + O_{2(g)} \Longrightarrow 2NO_{2(g)}$

(e) NO is the limiting reactant - it can only use ½ the O_2 available (.0880 moles)

$$.176 \text{ mol NO} \cdot \frac{1 \text{ mol } NO_2}{1 \text{ mol NO}} = .176 \text{ mol } NO_2$$

$.176 \text{ mol } NO_2 + .0880 \text{ mol } O_2 = .264 \text{ mol gas total}$

$P(5.00\,L) = .264\,(.0821)(298\,K)$ $\qquad PV = nRT$

$P = 1.28 \text{ atm}$

.176
.0880
.2640

.264

.0	0/0	0/0	0/0
8	1/6	4/8	3/2
2	0/4	1/2	0/8
1	0/2	0/6	0/4

.0216 4 4

.0217

2	0/0	0/4	1/2	1/4
9	0/0	1/8	0/9	6/3
8	0/0	1/6	0/8	5/6

6.4066

1.28
5 | 6.4066
-5 |
1 4
-1 0
40

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2B,

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(a) Calculate the total pressure, in atm, of the gas mixture in the cylinder at 298 K.

(b) The temperature of the gas mixture in the cylinder is decreased to 280 K. Calculate each of the following.

(i) The mole fraction of $N_2(g)$ in the cylinder

(ii) The partial pressure, in atm, of $N_2(g)$ in the cylinder

(c) If the cylinder develops a pinhole-sized leak and some of the gaseous mixture escapes, would the ratio $\frac{\text{moles of } N_2(g)}{\text{moles of } O_2(g)}$ in the cylinder increase, decrease, or remain the same? Justify your answer.

A different rigid 5.00 L cylinder contains 0.176 mol of $NO(g)$ at 298 K. A 0.176 mol sample of $O_2(g)$ is added to the cylinder, where a reaction occurs to produce $NO_2(g)$.

(d) Write the balanced equation for the reaction.

(e) Calculate the total pressure, in atm, in the cylinder at 298 K after the reaction is complete.

a) $PV = nRT$

$P = \frac{nRT}{V}$ $V = 5\,L$ $R = .0821\ L\cdot atm/mol\,K$ $T = 298\,K$

n = total moles $= (24.5\,g\,N_2 / 28\,g/mol + 28.0\,g\,O_2/32\,g/mol)$

$= .875 + .78\ mol = 1.65\,mol$

$P = \frac{(1.65\,mol)(.0821\ L\cdot atm/mol\,K)(298\,K)}{5\,L} = 8.09\ atm$

$P = 8.09\ atm$

b) i) mol fraction $= \frac{\text{mol } N_2}{\text{total mol}}$ total mol $= 1.65$

$24.5\,g\,N_2 / 28\,g/mol = 0.875\,mol$

$\frac{0.875\,mol}{1.65\,mol} = 0.529 = \text{mol fraction } N_2$

ii) $P = \frac{nRT}{V}$, $n = .875\,mol$, $R = .0821\ L\cdot atm/mol\,K$

$T = 280\,K$, $V = 5\,L$

$P_{N_2} = \frac{(.875\,mol)(.0821\ L\cdot atm/mol\cdot K)(280\,K)}{5\,L} = 4.02\ atm = P_{N_2}$

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c) The ratio of mols of $N_2(g)/O_2(g)$ would decrease since the rate of effusion is determined by $\frac{r_1}{r_2} = \frac{\sqrt{m_2}}{\sqrt{m_1}}$, meaning the smaller the molar mass, the faster the molecules will effuse, thus the N_2 w/ a MM of 28 g/mol will effuse faster than O_2 w/ a MM of 36 g/mol, resulting in a decrease in the mol $N_2(g)/O_2(g)$ ratio.

d) $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

e) .176 mol $NO(g)$, .176 mol $O_2(g)$

mol ratio of $NO : O_2 = 2:1$, ratio of $NO : NO_2 = 1:1$

.176 mol NO + $\frac{.176}{2}$ mol $O_2 \rightarrow$ .176 mol NO_2

.176/2 mol O_2 reacts, leaving .176/2 or .088 mol O_2

$PV = nRT$

n = total mols = .088 mol O_2 + .176 mol NO_2

= 0.264 mol

R = .0821 L·atm/mol K, T = 298K, V = 5L

$P = \frac{nRT}{V} = \frac{(0.264\text{ mol})(.0821\text{ L·atm/(mol K)})(298\text{ K})}{5\text{ L}}$

= 1.29 atm

P = 1.29 atm

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2C1

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(a) Calculate the total pressure, in atm, of the gas mixture in the cylinder at 298 K.

(b) The temperature of the gas mixture in the cylinder is decreased to 280 K. Calculate each of the following.

(i) The mole fraction of $N_2(g)$ in the cylinder

(ii) The partial pressure, in atm, of $N_2(g)$ in the cylinder

(c) If the cylinder develops a pinhole-sized leak and some of the gaseous mixture escapes, would the ratio $\frac{\text{moles of } N_2(g)}{\text{moles of } O_2(g)}$ in the cylinder increase, decrease, or remain the same? Justify your answer.

A different rigid 5.00 L cylinder contains 0.176 mol of $NO(g)$ at 298 K. A 0.176 mol sample of $O_2(g)$ is added to the cylinder, where a reaction occurs to produce $NO_2(g)$.

(d) Write the balanced equation for the reaction.

(e) Calculate the total pressure, in atm, in the cylinder at 298 K after the reaction is complete.

a) $24.5\text{ g } N_2 \times \frac{1\text{ mol}}{28.0\text{ g}} = .875\text{ mol } N_2$

$28.0\text{ g } O_2 \times \frac{1\text{ mol}}{32.0\text{ g}} = .875\text{ mol } O_2$

$PV = nRT$

$P = \frac{nRT}{V}$

$= \frac{(2 \times .875\text{ mol})\left(.0821 \frac{\text{L atm}}{\text{mol K}}\right)(298\text{ K})}{5.00\text{ L}}$

$= 8.56\text{ atm pressure in the cylinder}$

b) i. mole fraction $= \frac{\text{mol } N_2}{\text{total mol}}$

$= \frac{.875\text{ mol } N_2}{1.75\text{ mol total}}$

$= \frac{1}{2}$ ~~mol fraction of N_2~~

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2.

ii.

$P_{N_2} = P_{total} \times \text{mole fraction}$

$= (8.56 \text{ atm})\left(\frac{1}{2}\right)$

$= \boxed{4.28 \text{ atm}}$ ← part. pressure of N_2 in Cylinder

c) No, the ratio $\frac{\text{mol } N_2}{\text{mol } O_2}$ would NOT remain the same. N_2 has a smaller molecular weight than O_2, therefore slightly more Nitrogen will escape from the hole compared to the O_2. This changes the ratio of $\frac{\text{mol } N_2}{\text{mol } O_2}$.

d) $2NO_{(g)} + O_{2(g)} \longrightarrow 2NO_{2(g)}$

e) $PV = nRT$

$P = \frac{nRT}{V}$

$= \frac{(.176 \times 2 \text{ mol})\left(.0821 \frac{L\,atm}{mol\,K}\right)(298 \text{ K})}{(5.00 \text{ L})}$

$= \boxed{1.72 \text{ atm in the cylinder}}$