AP® CHEMISTRY
2008 SCORING GUIDELINES (Form B)

Question 1

Answer the following questions regarding the decomposition of arsenic pentafluoride, $AsF_5(g)$.

(a) A 55.8 g sample of $AsF_5(g)$ is introduced into an evacuated 10.5 L container at 105°C.

(i) What is the initial molar concentration of $AsF_5(g)$ in the container?

$\text{mol } AsF_5 = 55.8 \text{ g } AsF_5 \times \frac{1 \text{ mol } AsF_5}{169.9 \text{ g } AsF_5} = 0.328 \text{ mol}$ $[AsF_5]_i = \frac{0.328 \text{ mol } AsF_5}{10.5 \text{ L}} = 0.0313\ M$	One point is earned for the correct molar mass. One point is earned for the correct concentration.

(ii) What is the initial pressure, in atmospheres, of the $AsF_5(g)$ in the container?

$PV = nRT$ $P = \frac{0.328 \text{ mol} \times 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1} \times 378 \text{ K}}{10.5 \text{ L}} = 0.969 \text{ atm}$	One point is earned for the correct substitution. One point is earned for the correct pressure.

At 105°C, $AsF_5(g)$ decomposes into $AsF_3(g)$ and $F_2(g)$ according to the following chemical equation.

$$AsF_5(g) \rightleftarrows AsF_3(g) + F_2(g)$$

(b) In terms of molar concentrations, write the equilibrium-constant expression for the decomposition of $AsF_5(g)$.

$K = \frac{[AsF_3]\,[F_2]}{[AsF_5]}$	One point is earned for the correct equation.

(c) When equilibrium is established, 27.7 percent of the original number of moles of $AsF_5(g)$ has decomposed.

(i) Calculate the molar concentration of $AsF_5(g)$ at equilibrium.

$100.0\% - 27.7\% = 72.3\%$ $[AsF_5] = 0.723 \times 0.0313\ M = 0.0226\ M$	One point is earned for the correct concentration.

Question 1 (continued)

(ii) Using molar concentrations, calculate the value of the equilibrium constant, K_{eq}, at 105°C.

$[AsF_3] = [F_2] = 0.277 \times [AsF_5]_i$ $= 0.277 \times 0.0313\ M = 0.00867\ M$ $K_{eq} = \frac{[AsF_3]\,[F_2]}{[AsF_5]} = \frac{[0.00867]\,[0.00867]}{[0.0226]} = 0.00333$	One point is earned for setting $[AsF_3] = [F_2]$. Note: the point is not earned if the student indicates that $[AsF_3] = [F_2] = [AsF_5]$. One point is earned for the correct calculation of $[AsF_3]$ and $[F_2]$. One point is earned for the correct calculation of K_{eq}.

(d) Calculate the mole fraction of $F_2(g)$ in the container at equilibrium.

mol $AsF_5 = 0.0226\ M \times 10.5$ L $= 0.237$ mol mol F_2 = mol $AsF_3 = 0.00867\ M \times 10.5$ L $= 0.0910$ mol mol fraction $F_2 = \frac{\text{mol } F_2}{\text{mol } F_2 + \text{mol } AsF_3 + \text{mol } AsF_5}$ $= \frac{0.0910}{0.0910 + 0.0910 + 0.237} = 0.217$ OR mol fraction $F_2 = \frac{0.00864}{0.00864 + 0.00864 + 0.0226} = 0.217$	One point is earned for the correct calculation of the mole fraction of $F_2(g)$.

1 A 1

CHEMISTRY
Section II
(Total time—95 minutes)

Part A
Time—55 minutes
YOU MAY USE YOUR CALCULATOR FOR PART A.

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

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Answer Questions 1, 2, and 3. The Section II score weighting for each question is 20 percent.

1. Answer the following questions regarding the decomposition of arsenic pentafluoride, $AsF_5(g)$.

   (a) A 55.8 g sample of $AsF_5(g)$ is introduced into an evacuated 10.5 L container at 105°C.

      (i) What is the initial molar concentration of $AsF_5(g)$ in the container?

      (ii) What is the initial pressure, in atmospheres, of the $AsF_5(g)$ in the container?

   At 105°C, $AsF_5(g)$ decomposes into $AsF_3(g)$ and $F_2(g)$ according to the following chemical equation.

   $$AsF_5(g) \rightleftarrows AsF_3(g) + F_2(g)$$

   (b) In terms of molar concentrations, write the equilibrium-constant expression for the decomposition of $AsF_5(g)$.

   (c) When equilibrium is established, 27.7 percent of the original number of moles of $AsF_5(g)$ has decomposed.

      (i) Calculate the molar concentration of $AsF_5(g)$ at equilibrium.

      (ii) Using molar concentrations, calculate the value of the equilibrium constant, K_{eq}, at 105°C.

   (d) Calculate the mole fraction of $F_2(g)$ in the container at equilibrium.

1. a)

(i) $[AsF_5] = \frac{\text{number of moles of } AsF_5}{\text{volume of solution (L)}}$

volume of solution = 10.5 L

GO ON TO THE NEXT PAGE.

number of moles of AsF_5 = mass of AsF_5 / Molar mass of AsF_5

mass of AsF_5 = 55.8 g

Molar mass of AsF_5 = $74.929\ g/mol + (19.9\ g/mol \times 5) = 169.9\ g/mol$

number of moles of AsF_5 = $\frac{55.8\ g}{169.9\ g/mol} = 0.328\ mol$

$[AsF_5] = \frac{0.328\ mol}{10.5\ L} = 0.312\ mol \cdot L^{-1}$

(ii) $PV = nRk$

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

$n = 0.328\ mol$

$R = 0.08206\ atm \cdot L/mol \cdot K^\circ$

$V = 10.5\ L$

$k = 105 + 273 = 378\ k^\circ$

$P = \frac{(0.328\ mol)(0.08206\ atm \cdot L/mol \cdot K^\circ)(378\ K^\circ)}{10.5\ K}$

$P = 0.969\ atm$

b)

$k_{eq} = \frac{[AsF_3][F_2]}{[AsF_5]}$

c) The number of moles of AsF_5 has decomposed is:

$\frac{n}{0.328} = .277$

$n_1 = 0.328 \times .277 = 0.0909$ mol

(i) number of moles of AsF_5 has remained at equilibrium is

$n_2 = 0.328\text{mol} - 0.0909\text{ mol} = 0.237$ mol

So,

$[AsF_5]$ at equilibrium $= \frac{0.237\text{mol}}{10.5\text{ L}} = 0.0226\ \text{mol}\cdot\text{L}^{-1}$

(ii)

	$AsF_{5(g)}$	$\rightleftharpoons$	$AsF_{3(g)}$	+	$F_{2(g)}$
I	.0328 mol		0		0
C	-0.0909		$+0.0909$		$+0.0909$
E	0.237 mol		0.0909 mol		0.0909 mol

$[F_2] = [AsF_3] = \frac{0.0909\text{ mol}}{10.5\text{ L}} = 0.00866\ \text{mol}\cdot\text{L}^{-1}$

$K_{eq} = \frac{[0.00866][0.00866]}{[0.0226]} = 3.32 \times 10^{-3}$

d)

$X_{F_2} = \frac{n_{F_2}}{n_t} = \frac{n_{F_2}}{n_{F_2} + n_{AsF_3} + n_{AsF_5}}$

$= \frac{0.0909\text{ mol}}{(0.0909 + 0.0909 + 0.237)\text{ mol}} = 0.217$

CHEMISTRY
Section II
(Total time—95 minutes)

1 B 1

Part A
Time—55 minutes
YOU MAY USE YOUR CALCULATOR FOR PART A.

CLEARLY SHOW THE METHOD USED AND THE STEPS INVOLVED IN ARRIVING AT YOUR ANSWERS. It is to your advantage to do this, since you may obtain partial credit if you do and you will receive little or no credit if you do not. Attention should be paid to significant figures.

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   (a) A 55.8 g sample of $AsF_5(g)$ is introduced into an evacuated 10.5 L container at 105°C.

   (i) What is the initial molar concentration of $AsF_5(g)$ in the container?

   (ii) What is the initial pressure, in atmospheres, of the $AsF_5(g)$ in the container?

   At 105°C, $AsF_5(g)$ decomposes into $AsF_3(g)$ and $F_2(g)$ according to the following chemical equation.

$$AsF_5(g) \rightleftarrows AsF_3(g) + F_2(g)$$

   (b) In terms of molar concentrations, write the equilibrium-constant expression for the decomposition of $AsF_5(g)$.

   (c) When equilibrium is established, 27.7 percent of the original number of moles of $AsF_5(g)$ has decomposed.

   (i) Calculate the molar concentration of $AsF_5(g)$ at equilibrium.

   (ii) Using molar concentrations, calculate the value of the equilibrium constant, K_{eq}, at 105°C.

   (d) Calculate the mole fraction of $F_2(g)$ in the container at equilibrium.

1. (a) (i) mole of $AsF_5 = \frac{55.8}{169} = 0.330$ mol

molarity $= \frac{0.330\ mol}{10.5\ L} = 0.031\ mol/L$

(ii) $PV = nRT$ $\quad P = \frac{nRT}{V} = \frac{0.031\ mol/L \times 0.0821 \times 378K}{10.5\ L} = 0.091$

$\therefore 0.091$

1 B2

(b) $K_{eq} = \dfrac{[AsF_3][F_2]}{[AsF_5]}$

(c) (i) $0.330 \text{ mol} \times \dfrac{100 - 27.7}{100} = 0.239$

(ii)

$$AsF_5(g) \rightleftharpoons AsF_3(g) + F_2(g)$$

	AsF_5	AsF_3	F_2
①	0.330 mol	0 mol	0 mol
②	− 0.091	+ 0.091 mol	+ 0.091 mol
③	0.239 mol	0.091 mol	0.091 mol

$$K_{eq} = \frac{\left(\frac{0.091 \text{ mol}}{10.5 \text{ L}}\right) \times \left(\frac{0.091 \text{ mol}}{10.5 \text{ L}}\right)}{\left(\frac{0.239 \text{ mol}}{10.5 \text{ L}}\right)} = 0.035$$

(d) mole fraction of F_2.

$$= \frac{\text{mole } F_2}{\text{mole } AsF_5 + \text{mole } F_2 + \text{mole } AsF_3} = \frac{0.091}{0.239 + 0.091 + 0.091}$$

$$= 0.216$$

1C1

CHEMISTRY
Section II
(Total time—95 minutes)

Part A
Time—55 minutes
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      (i) What is the initial molar concentration of $AsF_5(g)$ in the container?

      (ii) What is the initial pressure, in atmospheres, of the $AsF_5(g)$ in the container?

   At 105°C, $AsF_5(g)$ decomposes into $AsF_3(g)$ and $F_2(g)$ according to the following chemical equation.

   $$AsF_5(g) \rightleftarrows AsF_3(g) + F_2(g)$$

   (b) In terms of molar concentrations, write the equilibrium-constant expression for the decomposition of $AsF_5(g)$.

   (c) When equilibrium is established, 27.7 percent of the original number of moles of $AsF_5(g)$ has decomposed.

      (i) Calculate the molar concentration of $AsF_5(g)$ at equilibrium.

      (ii) Using molar concentrations, calculate the value of the equilibrium constant, K_{eq}, at 105°C.

   (d) Calculate the mole fraction of $F_2(g)$ in the container at equilibrium.

1 Decomposition of arsenic pentafluoride, $AsF_5(g)$

(a) 55.8g sample of $AsF_5(g)$ in an evacuated 10.5L container at 105°C

i) Initial molecular concentration of $AsF_5(g)$ in the container

1 mol of AsF_5's mass equals $74.90 + 19.00 \times 5 = 74.90 + 95.00 = 169.90$

In the container there are $\frac{55.8}{169.90} \approx 0.32839 \approx 0.3$ mol of $AsF_5(g)$

ii) Since $PV = nRT$ $P = \frac{nRT}{V}$

GO ON TO THE NEXT PAGE.

1C2

$V=10.5L \quad R=0.0821 \text{ L atm mol}^{-1}\text{K}^{-1} \quad T=(105+273)K \quad n=0.3 \text{ mol}$

$P=\frac{(0.0821 \text{ L atm mol}^{-1}\text{K}^{-1})(378K)(0.3 \text{ mol})}{10.5L} \approx 0.88668 \text{ atm} \approx 0.887 \text{ atm}$

At 105°C $AsF_5(g)$ decompose into $AsF_3(g)$ and $F_2(g)$

$$AsF_5(g) \rightleftharpoons AsF_3(g) + F_2(g)$$

(b) $K_c=\frac{[AsF_3][F_2]}{[AsF_5]}$

(c) At equilibrium 27.7 percent of original moles of $AsF_5(g)$ has decomposed

1) Calculate concentration of AsF_5 at equilibrium

$$AsF_5(g) \rightleftharpoons AsF_3(g) + F_2(g)$$

I	x	0	0
C	$-\frac{277}{1000}x$	$\frac{277}{1000}x$	$\frac{277}{1000}x$
E	$\frac{723}{1000}x$	$\frac{277}{1000}x$	$\frac{277}{1000}x$

Since this is at equilibrium $Q=K$

$Q=\left(\frac{277}{1000}\right)^2 x \quad K=\frac{277^2}{723}x$

(d) K_{eq} at 105°C = 106x

(e) Since there are $\frac{723}{1000}x$ moles of product and $\frac{277}{1000}x$ is for F_2, the mole fraction of $F_2(g)$ is $\frac{277}{554}=\frac{1}{3}$

AP® CHEMISTRY
2008 SCORING COMMENTARY (Form B)

Question 1

Sample: 1A
Score: 10

This response earned all 10 points: 2 for part (a)(i), 2 for part (a)(ii), 1 for part (b), 1 for part (c)(i), 3 for part (c)(ii), and 1 for part (d).

Sample: 1B
Score: 7

Two points were earned in part (a)(i). Only 1 of the 2 points was earned in part (a)(ii); molarity is substituted for *n* instead of number of moles, so the substitution point was not earned. The point was earned in part (b). The point was not earned in part (c)(i); number of moles is used in the calculation instead of molarity. In part (c)(ii) 1 point was earned for setting $[AsF_3] = [F_2]$, and 1 point was earned for correct calculation of their concentrations, but no point was earned for the calculation because of a math error. The point was earned in part (d).

Sample: 1C
Score: 4

In part (a)(i) 1 point was earned for the correct molar mass, but the second point was not earned because the initial molar concentration is not calculated. In part (a)(ii) 1 point was earned for the correct substitution into $PV = nRT$. However, the second point was not earned because the incorrect number of significant figures in 0.3 mol results in an incorrect pressure. The point was earned for the correct equation in part (b). The point was not earned in part (c)(i). In part (c)(ii) 1 point was earned for setting $[AsF_3] = [F_2]$, but the other 2 points were not earned. The point was not earned in part (d).