AP Chemistry

Key

1980

1. Heat + $NH_4Cl_{(s)} \rightleftarrows NH_{3(g)} + HCl_{(g)}$ $\Delta H = +42.1$ kilocalories

Suppose the substances in the reaction above are at equilibrium at 600K in volume V and at pressure P. State whether the partial pressure of $NH_{3(g)}$ will have increased, decreased, or remained the same when equilibrium is reestablished after each of the following disturbances of the original system. Some solid NH_4Cl remains in the flask at all times. Justify each answer with a one-or-two sentence explanation.

a. A small quantity of NH_4Cl is added. No effect — $NH_4Cl(s)$ has constant [ ]

No

b. The temperature of the system is increased. P_{NH_3} ↑ since Endo T↑ K↑ for forward rxn ↓ shifts Rt → container bigger so overall pressure the same!

c. The volume of the system is increased. No change — Even though more molecules of NH_3 . . .

d. A quantity of gaseous HCl is added. P_{NH_3} ↓ HCl reacts the NH_3 !

e. A quantity of gaseous NH_3 is added. - Some of the NH_3 is used up

P_{NH_3} No change As V ↑ some solid NH_4Cl decomposes to form new NH_3 so NH_3 remains constant

But as V ↑ P_{NH_3} remains constant

However if a Large amount of NH_3 is added the overall P_{NH_3} would go up!!!

1981 A

Ammonium hydrogen sulfide is a crystalline solid that decomposes as follows:

$$NH_4HS_{(s)} \rightarrow NH_{3(g)} + H_2S_{(g)}$$

a. Some solid NH_4HS is placed in an evacuated vessel at 25°C. After equilibrium is attained, the total pressure inside the vessel is found to be 0.659 atmosphere. Some solid NH_4HS remains in the vessel at equilibrium. For this decomposition, write the expression for K_p and calculate its numerical value at 25°C.

b. Some extra NH_3 gas is injected into the vessel containing the sample described in part (a). When equilibrium is reestablished at 25°C, the partial pressure of NH_3 in the vessel is twice the partial pressure of H_2S. Calculate the numerical value of the partial pressure of NH_3 and the partial pressure of H_2S in the vessel after the NH_3 has ben added and the equilibrium has been reestablished.

c. In a different experiment, NH_3 gas and H_2S gas are introduced into an empty 1.00 liter vessel at 25°C. The initial partial pressure of each gas is 0.500 atmospheres. Calculate the number of moles of solid NH_4HS that is present when equilibrium is established.

1981A — Equilibrium (Ch. 15) Free Response

(X)

$NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$

$K_p = [NH_3][H_2S]$; $P_{NH_3} = P_{H_2S} = .659\ atm \left|\frac{1\ mol}{2\ moles}\right| = .330\ atm$

$K_p = (.330)^2 = .109$

(b.)

	$NH_4HS(s)$	$\rightleftharpoons$	$NH_3(g)$	+	$H_2S(g)$
(I)	–				
[C]	–		$2x$		x
[E]	–		$2x$		x

$P_{NH_3} = 2\,P_{H_2S}$

$K_p = .109 = (2x)(x) = 2x^2$

$x = .233\ atm = P_{H_2S}$

$\therefore P_{NH_3} = .466\ atm$

(c.)

	$NH_4HS(s)$	$\rightleftharpoons$	$NH_3(g)$	+	$H_2S(g)$
I	–		$.500\ atm$		$.500\ atm$
P_C	–		$-x$		$-x$
P_E			$.500 - x$		$.500 - x$

$PV = nRT$; $n = \frac{PV}{RT} = \frac{(.170\ atm)(1.00L)}{\left(.0821\ \frac{L\,atm}{mol\,K}\right)(298K)} = 6.95 \times 10^{-3}\ mol$

$K_p = .109 = (.500 - x)^2$

$\sqrt{.109} = \sqrt{(.500 - x)^2}$; $\sqrt{.109} = .500 - x$;

$x = .500 - \sqrt{.109} = .170\ atm$

Equilibrium

1995A $CO_2(g) + H_2(g) \rightleftharpoons H_2O(g) + CO(g)$

(a) mole fraction of $CO(g)$ (χ)

$$\frac{.55 \text{ moles}}{2(.55) + .20 + .30} = \frac{.55}{1.6} = \boxed{.34}$$

(b) $$K_c = \frac{[H_2O][CO]}{[CO_2][H_2]} = \frac{(.55M)^2}{(.30M)(.20M)} = \boxed{5.04}$$

K_p also.

(c) $K_p = K_c(RT)^{\Delta n}$; $\Delta n = 0$

$K_p = K_c = 5.04$

(d)

	$CO_2(g)$	+ $H_2(g)$	$\rightleftharpoons H_2O(g)$	+ $CO(g)$
[I]	.30M	.20M	.55M	.55M
[Δ]	+.165	+.165	−.165	−.165
[Eq]	.47	.37	.39	.39

$.55 \times 30\% = .165$

$$K = \frac{(.39)^2}{(.37)(.47)} = .87$$

(e)

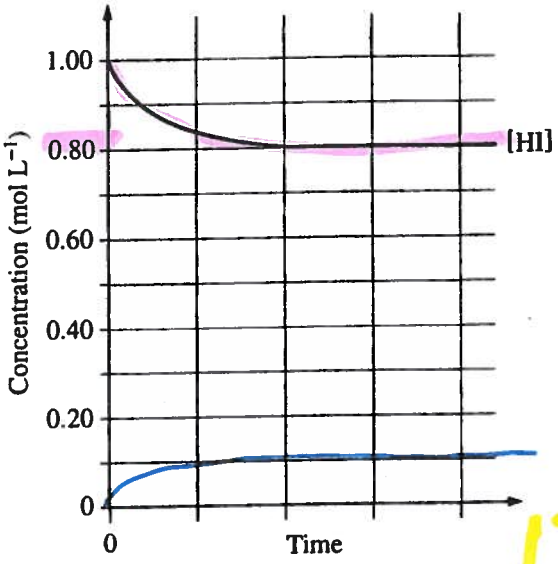
	$CO_2(g)$	+ $H_2(g)$ (.17)	$\rightleftharpoons H_2O(g)$	+ $CO(g)$
[I]	.17M	.167M	—	—
[Δ]	$-x$	$-x$	x	x
[Eq]	$.17-x$	$.17-x$	x	x

$$K_c = \sqrt{5.04} = \sqrt{\frac{x^2}{(.17-x)^2}} \quad ; \quad \frac{x}{.17-x} = 2.25$$

$x = .38 - 2.25x$; $3.25x = .38$; $\boxed{x = .12M = [CO]}$

$$2\,HI(g) \rightleftarrows H_2(g) + I_2(g)$$

1. After a 1.0 mole sample of $HI(g)$ is placed into an evacuated 1.0 L container at 700. K, the reaction represented above occurs. The concentration of $HI(g)$ as a function of time is shown below.



(a) Write the expression for the equilibrium constant, K_c, for the reaction.

$$K_c = \frac{[H_2][I_2]}{[HI]^2}$$

(b) What is [HI] at equilibrium?

.80M

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

I	1.00M		
C	−.20M	.10M	.10M
E	.80M	.10M	.10M

(c) Determine the equilibrium concentrations of $H_2(g)$ and $I_2(g)$.

(d) On the graph above, make a sketch that shows how the concentration of $H_2(g)$ changes as a function of time.

(e) Calculate the value of the following equilibrium constants at 700. K.

(i) K_c

(ii) K_p = K_c since $\Delta n = 0$

$$K_c = \frac{(.10M)(.10M)}{(.80)^2} = .016$$

(f) At 1,000 K, the value of K_c for the reaction is 2.6×10^{-2}. In an experiment, 0.75 mole of $HI(g)$, 0.10 mole of $H_2(g)$, and 0.50 mole of $I_2(g)$ are placed in a 1.0 L container and allowed to reach equilibrium at 1,000 K. Determine whether the equilibrium concentration of $HI(g)$ will be greater than, equal to, or less than the initial concentration of $HI(g)$. Justify your answer.

$$Q = \frac{[H_2][I_2]}{[HI]^2} = \frac{(.10M)(.50M)}{(.75M)^2} = 8.9 \times 10^{-2} = Q$$

$K < Q$

So shift ~~Right~~ left

$$N_2(g) + 3\,H_2(g) \rightleftarrows 2\,NH_3(g)$$

1. For the reaction represented above, the value of the equilibrium constant, K_p, is 3.1×10^{-4} at 700. K.

(a) Write the expression for the equilibrium constant, K_p, for the reaction.

$K_p = \dfrac{(P_{NH_3})^2}{(P_{N_2})(P_{H_2})^3}$

(b) Assume that the initial partial pressures of the gases are as follows:

$p_{N_2} = 0.411$ atm, $p_{H_2} = 0.903$ atm, and $p_{NH_3} = 0.224$ atm.

(i) Calculate the value of the reaction quotient, Q, at these initial conditions.

(ii) Predict the direction in which the reaction will proceed at 700. K if the initial partial pressures are those given above. Justify your answer.

(c) Calculate the value of the equilibrium constant, K_c, given that the value of K_p for the reaction at 700. K is 3.1×10^{-4}.

(d) The value of K_p for the reaction represented below is 8.3×10^{-3} at 700. K.

$$NH_3(g) + H_2S(g) \rightleftarrows NH_4HS(g)$$

Calculate the value of K_p at 700. K for each of the reactions represented below.

(i) $NH_4HS(g) \rightleftarrows NH_3(g) + H_2S(g)$

(ii) $2\,H_2S(g) + N_2(g) + 3\,H_2(g) \rightleftarrows 2\,NH_4HS(g)$

(b) (i) $Q = \dfrac{(.224)^2}{(.411)(.903)^3} = 0.166$

ii $K < Q$ so too much product ∴ shift left to attain Equilib

(c) $K_p = K_c(RT)^{\Delta n}$ $\quad 3.1\times10^{-4} = K_c\left(.0821 \frac{L\,atm}{mol\,K}\right)^{-2}$

$K_c = 1.0$

(d) (i) $K_p = \dfrac{1}{8.3\times10^{-3}} =$

1.2×10^2

$K_p = (8.3\times10^{-3})$

$2H_2S(g) + N_2(g) + 3H_2(g) \rightleftarrows 2NH_4HS(g)$

$2\,[NH_3(g) + H_2S(g) \rightleftarrows NH_4HS(g)]$

$N_2(g) + 3H_2(g) \rightleftarrows 2NH_3(g)$ $\quad K_p = 3.1\times10^{-4}$

$K_p = (8.3\times10^{-3})^2(3.1\times10^{-4}) = 2.1\times10^{-2}$

① 2008 B

a. (i) $\frac{55.8\ g\ AsF_5 \mid mol}{10.5\ L \mid 74.92 + 5(19)\ (169.92)} = .0313\ M$

(ii) $P = \frac{nRT}{V} = (.0313M)(.0821)(378K) = .971\ atm$

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

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

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c.

	$AsF_5(g)$	$\rightleftharpoons$	$AsF_3(g)$	+	$F_2(g)$
[I]	.0313				
[C]	−.00867		+.00867		+.00867
[E]	.0226		.00867		.00867

(i) $\left(\frac{27.7\%}{100}\right)(.0313) = .00867$ $\quad [AsF_5]_E = .0313 - .00867 = .0226M$

(ii) $K_{eq} = \frac{(.00867)^2}{.0226} = .06333$

(d) $\chi_{F_2} = \frac{.00867}{.0226 + 2(.00867)} = .217$