WEEK 5 KEY

A certain partial pressure of A is added to a rigid vessel and allowed to react until it reaches equilibrium. At equilibrium the pressure of A_2 is found to be 8.0×10^{-3} bar. What was the initial partial pressure of A?

$$2A\,(g) \rightleftharpoons A_2\,(g) \qquad K_p = 6.9 \times 10^{-3}$$

	$2A$	A_2
I	y	0
C	$-2x$	$+x$
E	$y-2x$	$x = 8\times10^{-3}$

$$K_p = P_{A_2}/(P_A)^2$$

$$.0069 = .008/(y-.016)^2$$

$$.0069(y^2 - .032y + .000256) = .008$$

$$.0069y^2 - .000221y + 1.77\times10^{-6} = .008$$

$$.0069y^2 - .000221y - .008 = 0$$

$$x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$$

solve quadratic

$$y = P_{A,0} = 1.093 \text{ bar}$$

For the reaction below, 4.5 moles of each reactant is added to a 2.0 L aqueous solution and allowed to reach equilibrium. What is the concentration of B_2 at equilibrium?

$$2A + 4B \rightleftharpoons A_2B + 2B_2 \qquad K_c = 3.4 \times 10^{-7}$$

	$2A$	$4B$	A_2B	$2B_2$
I	2.25	2.25	0	0
C	$-2x$	$-4x$	$+x$	$+2x$
E	$2.25-2x$	$2.25-4x$	x	$2x$

$$K_c = \frac{[B_2]^2[A_2B]}{[A]^2[B]^4}$$

$$3.4\times10^{-7} = \frac{(2x)^2 x}{(2.25-2x)^2(2.25-4x)^4}$$

assume 2x and 4x are negligible

$$3.4\times10^{-7} = \frac{4x^3}{(2.25)^6}$$

$$x = .02246$$

$$[B_2] = 2x = 0.0449\,M$$

5% test - must use 4x!

$$\frac{4(.02246)}{2.25} \times 100 = 3.9\%$$

✓✓✓ passes

For the reaction below, 3.0 bar of every species is added to a rigid vessel and allowed to reach equilibrium. What is the pressure of A at equilibrium?

$$2A\,(g) \rightleftharpoons B\,(g) + C\,(g) \qquad K_p = 2.6 \times 10^{-2}$$

	2A	⇌ B	+ C
I	3.0	3.0	3.0
C	+2x	-x	-x
E	3+2x	3-x	3-x

$Q = \frac{P_B \times P_C}{(P_A)^2} = \frac{3 \times 3}{(3)^2}$

$Q = 1 > K$ ∴ rxn proceeds left

$2.6 \times 10^{-2} = (3-x)^2/(3+2x)^2$

— square root of both sides

$0.16 = 3-x/3+2x$

$0.48 + 0.32x = 3 - x$

$x = 1.909$

$P_A = 3 + 2x = 6.82$ bar

Baking soda (sodium bicarbonate) decomposes according to the following endothermic reaction (ΔH = 129.2 kJ mol^{-1}):

$$2NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

What effect would each of the following have on the reaction? (i.e. which way would the equilibrium shift?)

a. Increasing the volume of the reaction vessel

lowers pressure, shifts right

b. Increasing the external pressure (by adding an inert gas)

no shift, partial pressures constant

c. Increasing the temperature of the reaction vessel

shifts right

d. Opening the reaction vessel to the atmosphere

shifts right

e. Condensing the gaseous water and removing it from the system

shifts right

5. Why is the acetate ion, CH_3COO^-, a base according to the Bronsted-Lowry model?

because it is a proton acceptor

a. What is the conjugate acid of CH_3COO^-?

CH_3COOH - acetic acid

b. Write a balanced equation in which CH_3COO^- acts as a base.

$$CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$$

6. Complete the table below:

$[H_3O^+]$	$[OH^-]$	pH	pOH
1.00×10^{-7} M	1.0×10^{-7} M	7.0	7.0
3.12×10^{-3} M	3.21×10^{-12} M	2.51	11.49
4.37×10^{-10} M	2.29×10^{-5} M	9.36	4.64

7. Write the dissociation reaction and corresponding K_a equilibrium expression for each of the following acids in water.

a. HCN

$$HCN + H_2O \rightleftharpoons CN^- + H_3O^+ \qquad K_a = \frac{[CN^-][H_3O^+]}{[HCN]}$$

b. HOC_6H_5

$$HOC_6H_5 + H_2O \rightleftharpoons OC_6H_5^- + H_3O^+ \qquad K_a = \frac{[OC_6H_5^-][H_3O^+]}{[HOC_6H_5]}$$

c. $C_6H_5NH_3^+$

$$C_6H_5NH_3^+ + H_2O \rightleftharpoons C_6H_5NH_2 + H_3O^+$$

$$K_a = \frac{[C_6H_5NH_2][H_3O^+]}{[C_6H_5NH_3^+]}$$

8. For each of the following aqueous reactions, identify the acid, the base, the conjugate base, and the conjugate acid

a. $Al(H_2O)_6^{3+} + H_2O \rightleftharpoons H_3O^+ + Al(H_2O)_5(OH)^{2+}$

acid base conj acid conj. base

b. $H_2O + HONH_3^+ \rightleftharpoons HONH_2 + H_3O^+$

base acid conj base conj acid

c. $HOCl + C_6H_5NH_2 \rightleftharpoons OCl^- + C_6H_5NH_3^+$

acid base conj base conj. acid

9. Calculate [H+] in the following solutions at 25°C. Identify each solution as neutral, acidic, or basic.

a. $[OH^-] = 1.5$ M $K_w = [OH^-][H_3O^+]$

$[H_3O^+] = 6.67 \times 10^{-15}$ M $\Rightarrow$ BASIC

b. 10.5 g of potassium hydroxide in 250.0 mL aqueous solution

$[KOH] = [OH^-] = 0.7486$ M $\Rightarrow [H_3O^+] = 1.33 \times 10^{-14}$ M $\Rightarrow$ BASIC

c. $[OH^-] = 1.0 \times 10^{-7}$ M

$[H_3O^+] = 1.0 \times 10^{-7}$ M $\Rightarrow$ neutral

d. $[NaOH] = 7.3 \times 10^{-4}$ M

$[H_3O^+] = 1.4 \times 10^{-11}$ M $\Rightarrow$ BASIC

10. Consider the following exothermic reaction at equilibrium. Predict how the following changes affect the number of moles of each component (at equilibrium) by completing the table below (use the terms increase, decrease, or no change).

$$N_2 (g) + 3H_2 (g) \rightleftharpoons 2NH_3$$

	N_2	H_2	NH_3
Add N_2 * shift right	decrease	decrease	increase
Remove H_2 * shift left	increase	increase	decrease
Add HCl * shift right	decrease	decrease	increase
Add Ne (g) – At constant volume * no shift	no change	no change	no change
Increase the temperature * shift left	increase	increase	decrease
Decrease the volume * shift right	decrease	decrease	increase
Add a catalyst * no shift	no change	no change	no change

reacts with NH_3 $HCl + NH_3 \rightarrow NH_4^+ + Cl^-$