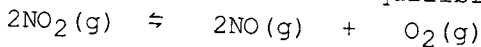


1. What is the equilibrium expression,  $K_c$ , for the following reaction?  
 $\text{Ca}_3(\text{PO}_4)_2(\text{s}) \rightleftharpoons 3\text{Ca}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq})$

- a)  $K_c = [\text{Ca}_3(\text{PO}_4)_2] / [\text{Ca}^{2+}][\text{PO}_4^{3-}]^2$
- b)  $K_c = [\text{Ca}^{2+}][\text{PO}_4^{3-}]$
- c)  $K_c = [\text{Ca}^{2+}]^3[\text{PO}_4^{3-}]^2 / [\text{Ca}_3(\text{PO}_4)_2]$
- d)  $K_c = [\text{Ca}^{2+}]^3[\text{PO}_4^{3-}]^2$**
- e)  $K_c = [3\text{Ca}^{2+}]^3[2\text{PO}_4^{3-}]^2 / [\text{Ca}_3(\text{PO}_4)_2]$

$$K_{sp} = [\text{Ca}^{2+}]^3 [\text{PO}_4^{3-}]^2$$

2. A 1.00 liter flask contained 0.24 mol  $\text{NO}_2$  at 700 K. which decomposed according to the following equation. When equilibrium was achieved, 0.14 mol  $\text{NO}$  was present. Calculate  $K_c$ .



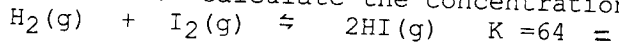
- a) 0.098
- b) 0.14**
- c)  $1.1 \times 10^{-2}$
- d)  $5.7 \times 10^3$
- e)  $9.6 \times 10^{-3}$

$$K_c = \frac{[\text{NO}]^2 [\text{O}_2]}{[\text{NO}_2]^2}$$

I	0.24	0	0	$K_c = \frac{(0.14)^2 [0.07]}{(0.24 - 0.14)^2}$
C	-	+2x	+x	$K_c = 0.137$
E	0.24 - 2x	2x	x	

$2x = 0.14 \quad x = 0.07$

3. A mixture of 0.40 moles of  $\text{H}_2$  and 0.40 moles of  $\text{I}_2$  is placed in a 1.00 liter container at  $650^\circ\text{C}$  and allowed to reach equilibrium according to the following equation. The equilibrium constant is 64. Calculate the concentrations of all species present at equilibrium.



- a)  $[\text{H}_2] = 0.13 \quad [\text{I}_2] = 0.13 \quad [\text{HI}] = 0.53$
- b)  $[\text{H}_2] = 0.040 \quad [\text{I}_2] = 0.040 \quad [\text{HI}] = 0.32$
- c)  $[\text{H}_2] = 0.080 \quad [\text{I}_2] = 0.080 \quad [\text{HI}] = 0.64$**
- d)  $[\text{H}_2] = 0.32 \quad [\text{I}_2] = 0.32 \quad [\text{HI}] = 0.24$
- e)  $[\text{H}_2] = 0.015 \quad [\text{I}_2] = 0.015 \quad [\text{HI}] = 0.12$

$$K = \frac{[\text{HI}]^2}{[\text{H}_2][\text{I}_2]}$$

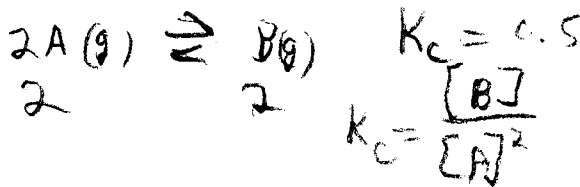
I	0.40	0.40	0
C	-x	-x	+2x
E	0.40 - x	0.40 - x	2x

$64 = \frac{(2x)^2}{(0.40-x)^2}$  "perfect square"

$8 = \frac{2x}{0.40-x} \Rightarrow 3.2 = 2x \Rightarrow 3.2 = 10x \Rightarrow x = 0.32$

4. Consider the reaction  $2\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g})$  where  $K_c = 0.5$  at the temperature of the reaction. If 2.0 moles of A and 2.0 moles of B are introduced into a 1.00 liter flask, what change in concentrations (if any) would occur in time?

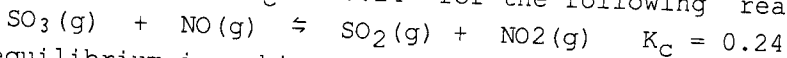
- a) [A] increases and [B] increases
- b) [A] increases and [B] decreases
- c) [A] decreases and [B] increases
- d) [A] decreases and [B] decreases
- e) [A] and [B] remain the same**



$$Q = \frac{[2]}{[2]^2} = 0.5$$

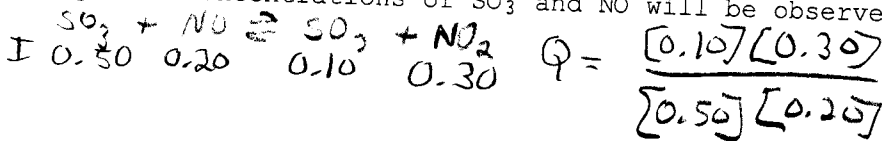
$$Q = K_c$$

5. Exactly 0.50 mole of sulfur trioxide, 0.10 mole of sulfur dioxide, 0.20 mole of nitrogen monoxide and 0.30 mole nitrogen dioxide are sealed in a 1.0-L flask at 1500°C. The equilibrium constant  $K_c$  is 0.24 for the following reaction.



When equilibrium is achieved, what changes in concentrations of  $\text{SO}_3$  and  $\text{NO}$  will be observed?

- a)  $[\text{SO}_3]$  increases;  $[\text{NO}]$  increases  
 b)  $[\text{SO}_3]$  increases;  $[\text{NO}]$  decreases  
 c)  $[\text{SO}_3]$  decreases;  $[\text{NO}]$  decreases  
 d)  $[\text{SO}_3]$  decreases;  $[\text{NO}]$  increases  
 e) all concentrations remain the same



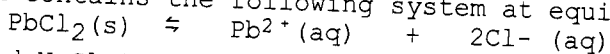
$$Q > K_c \quad Q = 0.3 \quad \leftarrow \text{shift}$$

6. In which of the following reactions does a decrease in the volume of the container increase the concentration of the products? Assume constant temperature.

- a)  $\text{SO}_2\text{Cl}_2(\text{g}) \rightleftharpoons \text{SO}_2(\text{g}) + \text{Cl}_2(\text{g})$   
 b)  $\text{C}(\text{s}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{H}_2(\text{g})$   
 c)  $2\text{SO}_3(\text{g}) \rightleftharpoons 2\text{SO}_2(\text{g}) + \text{O}_2(\text{g})$   
 d)  $\text{I}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{ICl}(\text{g})$   
 e)  $2\text{NO} + \text{Br}_2(\text{g}) \rightleftharpoons 2\text{NOBr}(\text{g})$



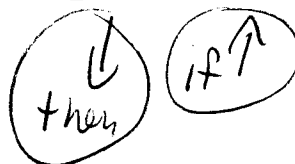
7. A flask contains the following system at equilibrium:



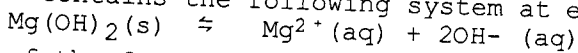
If solid  $\text{NaCl}$  is added to the system, what change (if any) will be observed?

- a) more  $\text{PbCl}_2$  will dissolve  
 b) more  $\text{PbCl}_2$  will precipitate  
 c) more  $\text{Pb}^{2+}$  will be in solution  
 d) fewer  $\text{Cl}^{-}$  will be in solution  
 e) no change will be observed

$$K_{sp} = [\text{Pb}^{2+}][\text{Cl}^{-}]^2$$

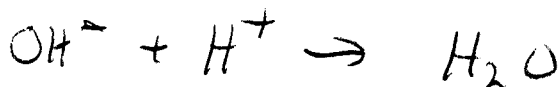


8. A flask contains the following system at equilibrium:



Which of the following reagents could be added to increase the solubility of  $\text{Mg}(\text{OH})_2$ ?

- a)  $\text{NaCl}$   
 b)  $\text{NaOH}$   
 c)  $\text{HCl}$   
 d)  $\text{H}_2\text{O}$   
 e)  $\text{MgCl}_2$



$$K_{sp} = [\text{Mg}^{2+}][\text{OH}^{-}]^2$$

↑      ↓

9. Which of the following statements concerning equilibrium is true?

- a) Catalysts are an effective means of changing the position of an equilibrium.  
 b) The concentration of the products equals the concentration of reactions for a reaction at equilibrium.  
 c) The equilibrium constant may be expressed in pressure terms or concentration terms for any reaction.  
 d) When two opposing processes are proceeding at the same rate, the system is at equilibrium.  
 e) A system at equilibrium cannot be disturbed.

Acid                      Base      C.B                      C.A

10. In the equation,  $\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$

- a)  $\text{NH}_4^+$  is an acid and  $\text{NH}_3$  is its conjugate base.
- b)  $\text{H}_2\text{O}$  is an acid and  $\text{H}_3\text{O}^+$  is its conjugate base.
- c)  $\text{NH}_3$  is an acid and  $\text{H}_3\text{O}^+$  is its conjugate base.
- d)  $\text{H}_2\text{O}$  is an acid and  $\text{NH}_4^+$  is its conjugate base.
- e)  $\text{NH}_3$  is an acid and  $\text{NH}_4^+$  is its conjugate base.

11. The conjugate base of  $\text{HCO}_3^-$  is

- a)  $\text{CO}_3^{2-}$
- b)  $\text{H}_2\text{CO}_3$
- c)  $\text{H}_3\text{O}^+$
- d)  $\text{OH}^-$
- e)  $\text{H}_2\text{O}$

Acid -  $\text{H}^+$  = C.B.

12. At  $50^\circ\text{C}$  the water ionization constant,  $K_w$ , is  $5.48 \times 10^{-14}$ . What is the  $[\text{H}_3\text{O}^+]$  in neutral water at  $50^\circ\text{C}$ ?

- a)  $5.48 \times 10^{-7}$
- b)  $2.34 \times 10^{-7}$
- c)  $1.00 \times 10^{-7}$
- d)  $5.48 \times 10^{-14}$
- e)  $4.27 \times 10^{-13}$

$[\text{H}^+][\text{OH}^-] = K_w$  and  $[\text{H}^+] = [\text{OH}^-]$   
 $[\text{H}^+] = [\text{OH}^-] = \sqrt{K_w} = \sqrt{5.48 \times 10^{-14}}$

13. What is the pH of a 0.0813 M  $\text{HNO}_3$  solution at  $25^\circ\text{C}$ ?

- a) 0.813
- b) 0.910
- c) 1.090
- d) 1.813
- e) 1.870

↑  
Strong Acid  $[\text{H}^+] = \text{conc of acid}$   
 $\text{pH} = -\text{Log}(0.0813) =$

14. What is the pH of a 1.86 M  $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$  solution at  $25^\circ\text{C}$ ?  $K_a = 1.3 \times 10^{-5}$

- a) 4.92
- b) 4.88
- c) 2.42
- d) 2.31
- e) 2.08

WEAK ACID

$\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$	$\rightleftharpoons$	$\text{H}^+$	+	$\text{CH}_3\text{CH}_2\text{CO}_2^-$	$K_a =$	$\frac{[\text{H}^+][\text{CH}_3\text{CH}_2\text{CO}_2^-]}{[\text{CH}_3\text{CH}_2\text{CO}_2\text{H}]}$
I 1.86		0		0		
C -x		+x		+x		
E 1.86-x		x		x		$1.3 \times 10^{-5} = \frac{x^2}{1.86-x}$

15. What is the pH of a 0.0144 M  $\text{Ca}(\text{OH})_2$  solution at  $25^\circ\text{C}$ ?

- a) 1.54
- b) 1.84
- c) 10.84
- d) 12.16
- e) 12.45

Strong Base

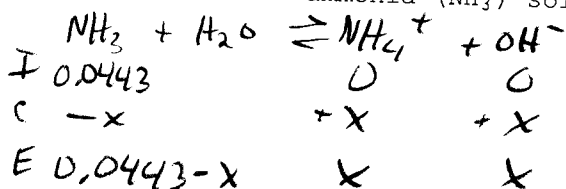
$\text{Ca}(\text{OH})_2 \rightarrow \text{Ca}^{2+} + 2\text{OH}^-$

$X = 0.004917 = [\text{H}^+]$   
 $\text{pH} = -\text{Log}([\text{H}^+])$

$[\text{OH}^-] = 2(0.0144) = 0.0288$   
 $\text{pOH} = 1.54$   
 $\text{pH} = 12.45$

16. What is the pH of a 0.0443 M ammonia ( $\text{NH}_3$ ) solution at  $25^\circ\text{C}$ ?  $K_b = 1.8 \times 10^{-5}$

- a) 3.05  
b) 6.10  
c) 9.25  
 d) 10.95  
e) 12.64



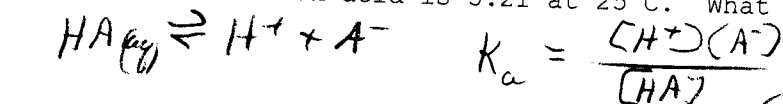
$$K_b = 1.8 \times 10^{-5} = \frac{x^2}{0.0443 - x}$$

$$x = 8.91 \times 10^{-4} = [\text{OH}^-]$$

$$\text{pOH} = 3.049 \quad \text{pH} = 10.95$$

17. The pH of a 2.28 M solution of a weak acid is 5.21 at  $25^\circ\text{C}$ . What is  $K_a$  for the weak acid?

- a)  $2.1 \times 10^{-5}$   
b)  $6.2 \times 10^{-6}$   
c)  $8.8 \times 10^{-9}$   
d)  $4.8 \times 10^{-10}$   
 e)  $1.7 \times 10^{-11}$



$$[\text{H}^+] = 10^{-5.21} = 6.16 \times 10^{-6}$$

$$K_a = \frac{(6.16 \times 10^{-6})^2}{(2.28 - 6.16 \times 10^{-6})}$$

$$K_a = 1.7 \times 10^{-11}$$

18. Three weak acids have the formulas and  $K_a$  values listed.

Formic acid  $\text{CHO}_2\text{H}$   $1.8 \times 10^{-4}$

Cyanic Acid  $\text{HOCN}$   $3.5 \times 10^{-4}$

Chloroacetic Acid  $\text{C}_2\text{H}_2\text{ClO}_2\text{H}$   $1.4 \times 10^{-3}$

weakest Acid

Which of the following is the strongest base?

- a)  $\text{C}_2\text{H}_2\text{ClO}_2^-$   
b)  $\text{OCN}^-$   
 c)  $\text{HCO}_2^-$   
d)  $\text{H}_2\text{O}$   
e)  $\text{H}_3\text{O}^+$

weakest acid gives strongest conj BASE.

19. Of the salts,  $\overset{s}{\text{K}}\overset{w}{\text{CH}_3\text{CO}_2}$ ,  $\overset{w}{\text{NH}_4}\overset{s}{\text{Cl}}$ ,  $\text{KBr}$ , and  $\overset{w}{\text{NH}_4}\overset{s}{\text{NO}_3}$ , how many would form an acidic aqueous solution?

- a) four  
b) three  
 c) two  
d) one  
e) zero (none form basic solutions)



20. If you mix equal molar quantities of  $\overset{s}{\text{KOH}}$  and  $\overset{s}{\text{HNO}_3}$ , the resulting solution will be

- a) acidic because a small amount of  $\text{KNO}_3$  is present.  
b) acidic because a small amount of  $\text{H}_3\text{O}^+$  is present.  
c) basic because a small amount of  $\text{OH}^-$  is present.  
d) basic because a small amount of  $\text{KNO}_3$  is present.  
 e) neutral.