

MULTIPLE CHOICE

1. Given that the K_a for gallic acid, $(HC_7H_5O_5)$ is 4.57×10^{-3} , what is the K_b for the gallate ion $(NaC_7H_5O_5)$? $T = 25^\circ C$

- a) 4.57×10^{-3}
- b) 2.19×10^{-12}
- c) 5.43×10^{-5}
- d) 7.81×10^{-6}
- e) 2.19×10^2

$K_a K_b = 10^{-14}$

2. The pH of a 0.10 M solution of a weak base is 9.82. What is the K_b for this base?

- a) 2.1×10^{-4}
- b) 4.3×10^{-8}
- c) 8.8×10^{-8}
- d) 6.6×10^{-4}
- e) 2.0×10^{-5}

-pOH = 4.18

$$B + H_2O \rightleftharpoons HB^+ + OH^-$$

0.10	0	0
-x	+x	+x
0.10 - x	x	x

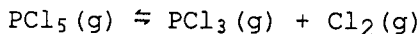
$x = 10^{-4.18}$

$$K_b = \frac{x^2}{0.10 - x}$$

$$K_b = \frac{(6.61 \times 10^{-5})^2}{0.10 - 6.61 \times 10^{-5}}$$

$$K_b = 4.3 \times 10^{-8}$$

3. Consider the following reaction:



Initially, 0.84 mol of $PCl_5(g)$ was placed in a 1.0 L flask. At equilibrium, 0.72 mol of $PCl_5(g)$ was present. The value of K_c for this reaction at this temperature is _____.

- a) 0.62
- b) 2.0×10^{-2}
- c) 0.72
- d) 0.12
- e) 0.60

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

I	0.84	0	0
C	-x	+x	+x
E	0.84 - x	x	x

$0.84 - x = 0.72 \quad x = 0.12$

$$K_c = \frac{(0.12)^2}{0.72}$$

$$K_c = 0.02$$

4. What is the pH of a 2.5 M solution of phosphoric acid? ($K_{a1} = 7.5 \times 10^{-3}$, $K_{a2} = 6.2 \times 10^{-8}$, $K_{a3} = 4.2 \times 10^{-13}$)

- a) 1.8
- b) 0.40
- c) 2.5
- d) 0.88
- e) 0.13

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO_4^{2-} \leftarrow \text{Controls pH}$$

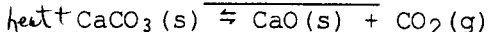
I	2.5	0	0
C	-x	+x	+x
E	2.5 - x	x	x

$$K_{a1} = \frac{[x]^2}{2.5 - x}$$

$$7.5 \times 10^{-3} = \frac{x^2}{2.5}$$

$$x = 0.136$$

5. For the endothermic reaction



- only _____ would favor shifting the equilibrium position to form more CO_2 gas.
- a) increasing the system temperature heat is a "reactant"
 - b) decreasing the system temperature
 - c) increasing the system pressure
 - d) increasing both the system temperature and the system pressure
 - e) both decreasing the system temperature and increasing the system pressure

Key

6. At equilibrium, _____.
- all chemical processes have ceased.
 - the rate of the forward reaction equals that of the reverse.
 - the rate constant for the forward reaction equals that of the reverse.
 - both the rate of the forward reaction equals that of the reverse and the rate constant for the forward reaction equals that of the reverse.
 - none of the above

7.

Acid	K_a
HOAc	1.8×10^{-5}
HCHO ₂	1.8×10^{-4}
HClO ₂	3.0×10^{-8}
HF	6.8×10^{-4}

weakest acid has strongest Conj. Base

$K_a K_b = 10^{-14}$

Which one of the following is the strongest base?

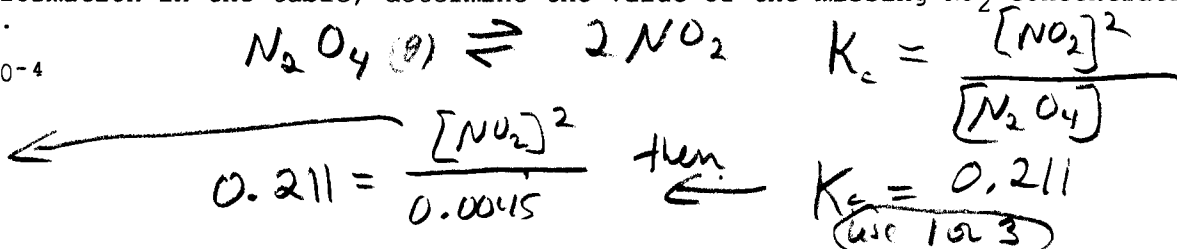
- OAc⁻
- CHO₂⁻
- ClO₂⁻
- F⁻
- OAc⁻ and CHO₂⁻

8. Consider the following incomplete table of data for the equilibrium between dinitrogen tetroxide and nitrogen dioxide.

Exp #	Equilibrium N ₂ O ₄ Concentration	Equilibrium NO ₂ Concentration
1	0.00140 M	0.0172 M
2	0.00452	?
3	0.00280	0.0243

From the information in the table, determine the value of the missing NO₂ concentration at equilibrium.

- 0.0486
- 9.54×10^{-4}
- 0.0814
- 0.115
- 0.0309



9. What is the concentration (in M) of hydronium ions in a solution at 25°C with a hydroxide ion concentration of 2.31×10^{-4} M?

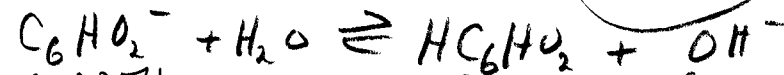
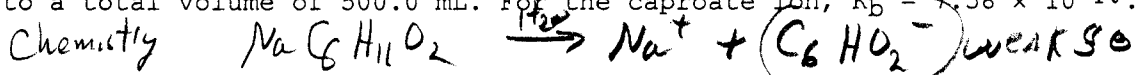
- 4.33×10^{-11}
- 2.31×10^{10}
- 9.72×10^{-4}
- 1.01×10^{-5}
- 2.31×10^{-18}

$[H_3O^+][OH^-] = 10^{-14}$

$[H_3O^+] = 10^{-14} / 2.31 \times 10^{-4} = 4.33 \times 10^{-11}$

10. Calculate the pH of a solution made by dissolving 1.87 g of sodium caproate, (NaC₆H₁₁O₂) in water and diluting to a total volume of 500.0 mL. For the caproate ion, $K_b = 7.58 \times 10^{-10}$.

- 5.344
- 8.656
- 5.494
- 8.505
- 4.53×10^{-6}



I	0.0271	0	0
C	-x	x	x
E	0.0271 - x	x	x

$K_b = \frac{x^2}{0.0271 - x}$ (Try to drop)

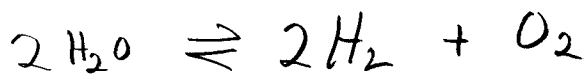
$x = 4.530 \times 10^{-6}$

pOH = 5.344

pH = 8.656

11. The equilibrium expression

$$K_c = \frac{[H_2]^2 [O_2]}{[H_2O]^2}$$



is the equilibrium constant expression for the reaction _____.

- a) $2H_2(g) + O_2(g) \rightleftharpoons 2H_2O(g)$
- b) $H_2O(g) \rightleftharpoons H_2(g) + 1/2O_2(g)$
- c) $H_2O(g) \rightleftharpoons 2H(g) + O(g)$
- d) $2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g)$
- e) $H_2 + O_2 \rightleftharpoons H_2O$

12. $4CuO(s) + CH_4(g) \rightleftharpoons CO_2(g) + 4Cu(s) + 2H_2O(g)$

$$\Delta n = 2$$

(gases)

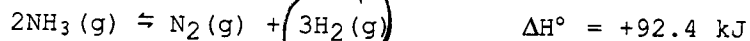
The value of K_c for this reaction is 1.10 at 25.0°C. What is the value of K_p for this reaction? (R = 0.0821 L-atm/K-mol)

- a) 658
- b) 37.2
- c) 26.9
- d) 4.63
- e) 1.52×10^{-3}

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

$$K_p = (1.10) (0.0821 \cdot 298)^2 = 658$$

13. Consider the following reaction at equilibrium:



Adding $N_2(g)$ to the system at equilibrium will _____.

- a) decrease the concentration of $NH_3(g)$ at equilibrium
- b) decrease the concentration of $H_2(g)$ at equilibrium
- c) increase the value of the equilibrium constant
- d) cause the reaction to shift to the right
- e) remove all of the $H_2(g)$

14. What is the conjugate acid of NH_3 ?

- a) NH_3
- b) NH_2^+
- c) NH_3^+
- d) NH_4^+
- e) NH_4OH

Add an H^+

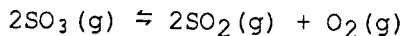
15. For which one of the following does $K_c = K_p$ at 25°C?

- a) $H_2(g) + F_2(g) \rightleftharpoons 2HF(g)$
- b) $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$
- c) $Al_2(SO_4)_3(s) + 6HCl(g) \rightleftharpoons 2AlCl_3(s) + 3H_2O(l) + 3SO_2(g)$
- d) $NH_4Br(s) + KOH(s) \rightleftharpoons NH_3(g) + KBr(s) + H_2O(l)$
- e) $2HF(g) \rightleftharpoons H_2(g) + F_2(g)$

Both since $\Delta n = 0$
(either)

Key

16. A 3.25 L tank was found to contain 0.343 mol O₂, 0.0212 mol SO₃, and 0.00419 mol SO₂, when equilibrium was attained. The equilibrium constant for the reaction below is _____.



E 0.0212 0.00419 0.343 mol

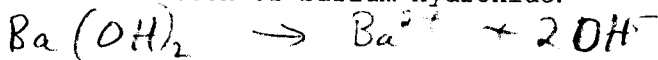
- a) 6.78×10^{-2}
- b) 1.34×10^{-2}
- c) 4.12×10^{-3}
- d) 4.35×10^{-2}
- e) 8.78

$$K_c = \frac{[\text{SO}_2]^2 [\text{O}_2]}{[\text{SO}_3]^3}$$

$$K_c = \frac{\left(\frac{0.00419}{3.25}\right)^2 \left(\frac{0.343}{3.25}\right)}{\left(\frac{0.0212}{3.25}\right)^3} = 0.00412$$

17. What is the pH of a 0.015 M solution of barium hydroxide?

- a) 12.48
- b) 12.18
- c) 1.82
- d) 10.35
- e) 1.52



$$[\text{OH}^-] = 0.030$$

$$\text{pOH} = -\log 0.030 = 1.52$$

18. The effect of a catalyst on an equilibrium is to _____.

- a) increase the rate of the forward reaction only
- b) increase the equilibrium constant so that products are favored
- c) slow the reverse reaction only
- d) increase the rate at which equilibrium is achieved without changing the composition of the equilibrium mixture
- e) shift the equilibrium to the right

19. Which one of the following is the weakest acid?

- a) HF ($K_a = 6.8 \times 10^{-4}$)
- b) HClO ($K_a = 3.0 \times 10^{-8}$)
- c) HNO₂ ($K_a = 4.5 \times 10^{-4}$)
- d) HCN ($K_a = 4.9 \times 10^{-10}$)
- e) Acetic acid ($K_a = 1.8 \times 10^{-5}$)

20. The [H⁺] and pH of a 0.021 M HNO₃ solution at 25°C are _____ M and _____, respectively

- a) 4.8×10^{-13} , 12.32
- b) 4.8×10^{-13} , -12.32
- c) 0.021, +1.68
- d) 0.021, -1.68
- e) 4.8×10^{-6} , +5.32

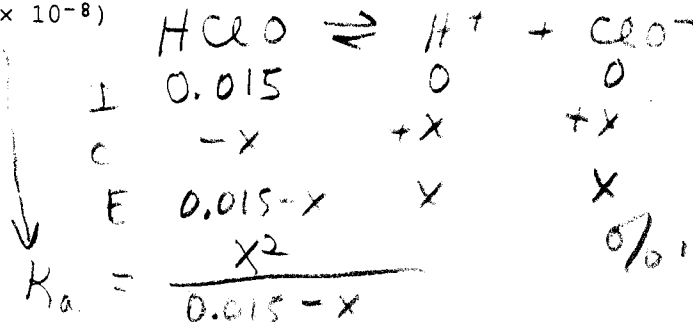
Strong acid

$$\text{pH} = -\log [0.021]$$

$$[\text{H}^+] = [\text{HNO}_3]$$

21. What is the % ionization of hypochlorous acid (HClO) in a 0.015 M aqueous solution of HClO at 25°C? ($K_a = 3.0 \times 10^{-8}$)

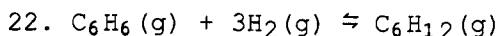
- a) 4.5×10^{-8}
- b) 14
- c) 2.1×10^{-5}
- d) 0.14
- e) 1.4×10^{-3}



$$\% \text{ ion.} = \frac{2.12 \times 10^{-5}}{0.015} \times 100$$

$$\% \text{ ion.} = 0.14 \%$$

$$x = 2.12 \times 10^{-5}$$



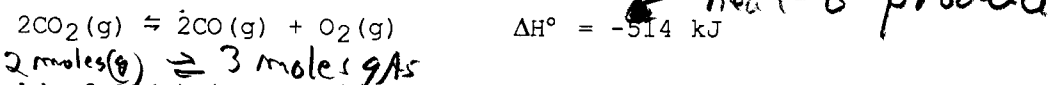
When 1.00 mol C_6H_6 and 3.00 mol H_2 were placed in a 200.0 L container and allowed to reach equilibrium over a catalyst at an elevated temperature, the resulting mixture contained 0.137 mol C_6H_{12} . The equilibrium amount (mol) of H_2 is _____. The initial amount of C_6H_{12} was zero.

$$C_6H_6 + 3H_2 \rightleftharpoons C_6H_{12}$$

I.	1.00 mol	3.00 mol	0	H_2	$3.00 - 3(0.137) = 2.59 \text{ mol}$
C.	$-x$	$-3x$	$+x$		
E.	$1.00 - x$	$3.00 - 3x$	x		

$E \quad 1.00 - 0.137 \quad 3 - 3(0.137) \quad x = 0.137 \text{ mol}$

23. Consider the following reaction at equilibrium:



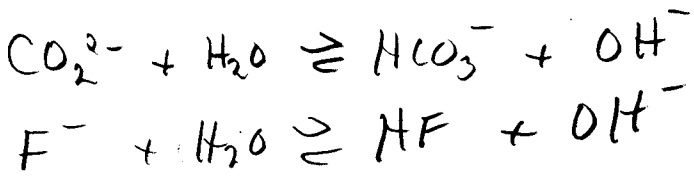
The yield of $CO(g)$ in reaction can be maximized by carrying out the reaction _____.

- a) at high temperature and high pressure
- b) at high temperature and low pressure
- c) at low temperature and low pressure
- d) at low temperature and high pressure
- e) in the presence of solid carbon

24. Of the following substances, an aqueous solution of _____ will form basic solutions.

<u>Acidic</u> NH_4Cl	<u>Acidic</u> $Cu(NO_3)_2$	<u>basic</u> K_2CO_3	<u>basic</u> NaF
---------------------------	-------------------------------	---------------------------	-----------------------

- a) $NH_4Cl, Cu(NO_3)_2$
- b) K_2CO_3, NH_4Cl
- c) NaF only
- d) NaF, K_2CO_3
- e) NH_4Cl only



25. The $[OH^-]$ and pH of a 0.0012 M $Ba(OH)_2$ ^{strong base} solution at 25°C are _____ M and _____, respectively.

- a) 0.00060, -2.62
- b) 0.0012, +2.92
- c) 0.0024, +11.38
- d) 0.0024, +2.62
- e) 0.0012, -2.92

$[OH^-] = 2 \times 0.0012 = 0.0024$
 $pOH = -\log 0.0024 = 2.62$
 $pH = 11.38$

26. At a certain temperature, a flask at equilibrium contains 0.0114 M HCl , 0.0931 M Cl_2 , and 0.0154 M H_2 . What is the value of K_c for the equilibrium: $2HCl(g) \rightarrow Cl_2(g) + H_2(g)$?

- a) 0.0909
- b) 11.0
- c) 1.63×10^{-5}
- d) 6.25×10^4
- e) 0.126

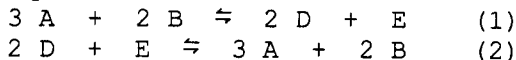
$2HCl(g) \rightarrow Cl_2(g) + H_2(g)$

E.	0.0114	0.0931	0.0154
----	--------	--------	--------

$$K_c = \frac{[0.0931][0.0154]}{[0.0114]^2} = 11.0$$

Key

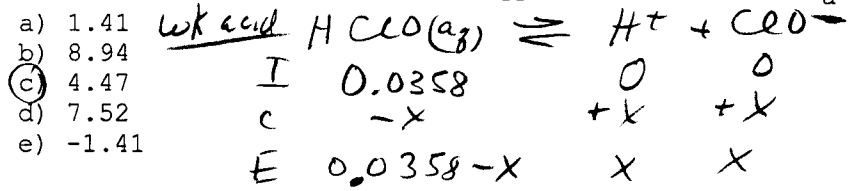
27. The equilibrium constant for reaction (1) below is 4.22×10^{-3} . The value of the equilibrium constant for reaction (2) is _____.



$$\frac{1}{4.22 \times 10^{-3}}$$

- a) 5.78×10^{-2}
- b) 4.22×10^{-3}
- c) 1.78×10^{-5}
- d) 237
- e) The value of K_2 cannot be determined from the data given.

28. Calculate the pH of 0.0385 M hypochlorous acid. ($K_a = 3.0 \times 10^{-8}$)



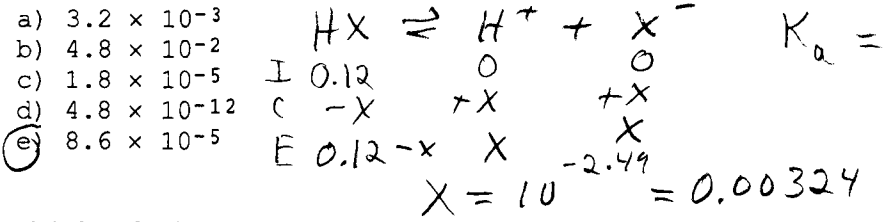
$$3.0 \times 10^{-8} = \frac{x^2}{0.0385 - x}$$

$$x = [H^+] = 3.38 \times 10^{-5}$$

$$pH = -\log = 4.48$$

- a) 1.41
- b) 8.94
- c) 4.47
- d) 7.52
- e) -1.41

29. A 0.12 M solution of a particular weak acid has pH = 2.49. What is the K_a of this acid?



$$K_a = \frac{x^2}{0.12 - x}$$

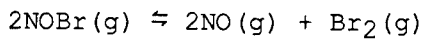
$$K_a = \frac{(0.00324)^2}{0.12 - 0.00324} = 8.7 \times 10^{-5}$$

- a) 3.2×10^{-3}
- b) 4.8×10^{-2}
- c) 1.8×10^{-5}
- d) 4.8×10^{-12}
- e) 8.6×10^{-5}

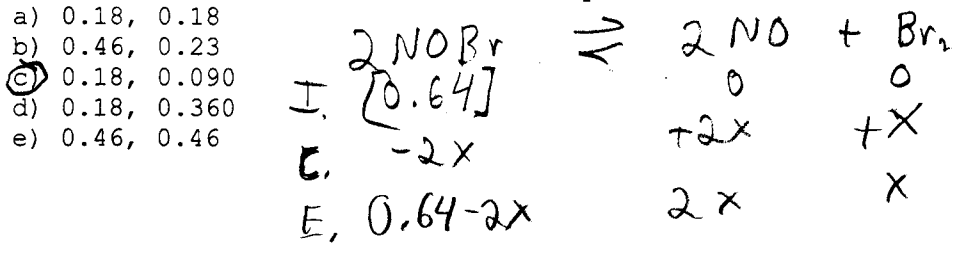
30. Which of the following acids is not a strong acid?

- a) H_2CO_3
- b) H_2SO_4
- c) HNO_3
- d) $HClO_4$
- e) HCl

31. Nitrosyl bromide decomposes according to the following equation:



A sample of NOBr (0.64 mol) was placed in a 1.00 L flask containing no NO or Br_2 . At equilibrium the flask contained 0.46 mol of NOBr. How many moles of NO and Br_2 , respectively, are in the flask at equilibrium?

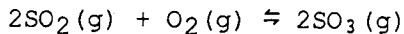


$$0.64 - 2x = 0.46$$

$$X = 0.09 \quad 2x = 0.18 \quad X = 0.09$$

- a) 0.18, 0.18
- b) 0.46, 0.23
- c) 0.18, 0.090
- d) 0.18, 0.360
- e) 0.46, 0.46

32. Consider the following equilibrium:



From which of the following starting conditions would it be impossible for this equilibrium to be achieved?

- a) 1.0 mol $\text{SO}_3(\text{g})$ in a 1.0-L container.
- b) 0.25 mol $\text{SO}_2(\text{g})$, 0.50 mol $\text{O}_2(\text{g})$, and 0.10 mol $\text{SO}_3(\text{g})$ in a 1.0-L container
- c) 0.25 mol $\text{SO}_2(\text{g})$ and 0.25 mol $\text{O}_2(\text{g})$ in a 1.0-L container
- d) 0.50 mol $\text{O}_2(\text{g})$ and 0.50 mol $\text{SO}_3(\text{g})$ in a 1.0-L container
- e) Equilibrium can be achieved from any of these starting conditions.

33. What is the concentration (in M) of hydroxide ions in a solution at 25°C with $\text{pH} = 4.282$?

- a) 4.282
- b) 9.718
- c) 1.91×10^{-10}
- d) 5.22×10^{-5}
- e) 1.66×10^4

$$\begin{aligned} \text{pOH} &= 14 - \text{pH} = 9.718 \\ [\text{OH}^-] &= 10^{-9.718} = \end{aligned}$$