

Name key (print) $K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$ $pK_w = pH + pOH = 14$
 show work for partial credit & full credit on the Short Answer Questions. $p(\text{anything}) = -\log(\text{anything})$

MULTIPLE CHOICE. Choose the one best alternative. (1 pt per MC question, 5 pts total)

- 1) The decomposition of nitrosyl bromide is exothermic: $2 \text{NOBr}(g) = 2 \text{NO}(g) + \text{Br}_2(g)$. Which of the following changes in reaction condition will shift the reaction to the left? 1) A, C
- Typo*
 A) add NO \leftarrow RXN
 B) decrease the pressure \rightarrow
 C) increase the temperature *add heat* \leftarrow RXN
 D) None of these \rightarrow
heat is product $\Delta H = -$
- 2) What are the conjugate acid-base pairs for $\text{NH}_3(aq) + \text{H}_2\text{O}(l) = \text{NH}_4^+(aq) + \text{OH}^-(aq)$ 2) D
- A) $\text{NH}_3, \text{H}_2\text{O}$ and $\text{NH}_4^+, \text{OH}^-$
 B) NH_3, OH^- and $\text{H}_2\text{O}, \text{NH}_4^+$
 C) NH_3 and NH_4^+
 D) $\text{NH}_3, \text{NH}_4^+$ and $\text{H}_2\text{O}, \text{OH}^-$
2 mol \rightarrow 3 mol
A conj A conj B
- 3) Which of the following statements about a catalyst is true? 3) C
- A) A catalyst increases the pressure of a reaction.
 B) A catalyst decreases the position of the equilibrium in a reaction.
 C) A catalyst provides a lower energy pathway for a reaction.
 D) A catalyst is consumed in a chemical reaction.
- 4) What is the equilibrium constant expression (K_a) for $\text{HCN}(aq) + \text{H}_2\text{O}(l) = \text{H}_3\text{O}^+(aq) + \text{CN}^-(aq)$. 4) A
- A) $K_a = ([\text{H}_3\text{O}^+][\text{CN}^-])/([\text{HCN}])$
 B) $K_a = ([\text{HCN}])/([\text{H}_3\text{O}^+][\text{CN}^-])$
 C) $K_a = ([\text{H}_3\text{O}^+][\text{CN}^-])/([\text{HCN}][\text{H}_2\text{O}])$
 D) $K_a = ([\text{HCN}][\text{H}_2\text{O}])/([\text{H}_3\text{O}^+][\text{CN}^-])$
- 5) What is the hydronium ion concentration with a pH of 3.15? 5) A
- A) $7.08 \times 10^{-4} \text{ M}$
 B) $1.41 \times 10^{-11} \text{ M}$
 C) 10.85 M
 D) 3.15 M
 $[H^+] = \text{antilog}(-3.15)$
 $[H^+] = 10^{-3.15} = 7.08 \times 10^{-4}$

Short Answer. Show work. $p(\text{Anything}) = -\log(\text{Anything})$, $[H^+] = \text{antilog}(-pH)$

- 6) What is the hydronium ion concentration of a 0.300 M acetic acid solution with $K_a = 1.8 \times 10^{-5}$? The equation for the dissociation of acetic acid is: (8 pts) $\text{CH}_3\text{CO}_2\text{H}(aq) + \text{H}_2\text{O}(l) = \text{H}_3\text{O}^+(aq) + \text{CH}_3\text{CO}_2^-(aq)$.

$\text{CH}_3\text{CO}_2\text{H}$	H_3O^+	CH_3CO_2^-
0.300 M	0	0
-x	+x	+x
0.300-x	x	x

$K_a = \frac{(x)^2}{(0.300-x)}$
 ② K_a small assume $x = \text{small}$
 ③ $(1.8 \times 10^{-5}) = \frac{x^2}{(0.300)}$
 ④ $(1.8 \times 10^{-5})(0.300) = x^2$
 ⑤ $x = \sqrt{(1.8 \times 10^{-5})(0.300)}$
 ⑥ $x = 2.32 \times 10^{-3} = [\text{H}_3\text{O}^+]$
 ⑦ $[HCl] = [H^+] = 1.7 \times 10^{-4}$ (7 pts)
 $pH = -\log(1.7 \times 10^{-4}) = 3.77$

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 show work for partial credit & full credit on the Short Answer Questions. $p(\text{anything}) = -\log(\text{anything})$

MULTIPLE CHOICE. Choose the one best alternative. (1 pt per MC question, 5 pts total)

- 1) What are the conjugate acid-base pairs for $NH_3(aq) + H_2O(l) = NH_4^+(aq) + OH^-(aq)$ 1) C
 A) NH_3 and NH_4^+ B) NH_3 , OH^- and H_2O , NH_4^+
 C) NH_3 , NH_4^+ and H_2O , OH^- D) NH_3 , H_2O and NH_4^+ , OH^-
- 2) What is the equilibrium constant expression (K_a) for $HCN(aq) + H_2O(l) = H_3O^+(aq) + CN^-(aq)$. 2) D
 A) $K_a = ([H_3O^+][CN^-])/([HCN][H_2O])$ B) $K_a = ([HCN][H_2O])/([H_3O^+][CN^-])$
 C) $K_a = ([HCN])/([H_3O^+][CN^-])$ D) $K_a = ([H_3O^+][CN^-])/([HCN])$
- 3) Which of the following statements about a catalyst is true? 3) B
 A) A catalyst decreases the position of the equilibrium in a reaction.
 B) A catalyst provides a lower energy pathway for a reaction.
 C) A catalyst is consumed in a chemical reaction.
 D) A catalyst increases the pressure of a reaction.

- 4) What is the hydronium ion concentration of an acid rain sample that has a pH of 3.25? 4) C
 A) 3.25 M B) 1.78×10^{-11} M C) 5.62×10^{-4} M D) 10.75 M

$pH = 3.25$
 $[H_3O^+] = \text{antilog}(-3.25)$
 $= 5.62 \times 10^{-4}$

- 5) The decomposition of nitrosyl bromide is exothermic: $2 NOBr(g) = 2 NO(g) + Br_2(g)$. Which of the following changes in reaction condition will shift the reaction to the left? 5) _____
 A) increase the temperature (add heat) B) decrease the pressure
 C) add NO D) None of these

$+ \text{heat}$
 $2 \text{ mol} \rightleftharpoons 3 \text{ mol}$

Short Answer. Show work even on questions which do not specify.

- 6) Determine the acid dissociation constant for a 0.010 M nitrous acid solution that has a pH of 2.70. Nitrous acid is a weak monoprotic acid. (8 pts) $HNO_2(aq) + H_2O(l) = H_3O^+(aq) + NO_2^-(aq)$. $[H^+] = 10^{-pH}$

HNO_2	H_3O^+	NO_2^-
0.010 M	0	0
2.0×10^{-3}	2.00×10^{-3}	2.00×10^{-3}
$0.010 - 2.00 \times 10^{-3}$	2.00×10^{-3}	2.00×10^{-3}

① $pH = 2.70$
 $[H_3O^+] = 10^{-2.70} = 2.00 \times 10^{-3}$
 ② $K_a = \frac{[H_3O^+][NO_2^-]}{[HNO_2]}$
 $K_a = \frac{(2.00 \times 10^{-3})^2}{(0.010 - 2.00 \times 10^{-3})} = 5.0 \times 10^{-4}$
 $14 - 3.99 = 10.23$

④ $K_a = \frac{(2.00 \times 10^{-3})^2}{(0.010 - 2.00 \times 10^{-3})} = 5.0 \times 10^{-4}$

- 7) What is the pH of a solution of $[NaOH] = 1.7 \times 10^{-4}$ (7 pts)

$[OH^-] = 1.7 \times 10^{-4}$ $pOH = -\log(1.7 \times 10^{-4})$
 $pOH = +3.77$ $pH = 10.23$
 $[H^+] = \frac{1 \times 10^{-14}}{1.7 \times 10^{-4}} = 5.88 \times 10^{-11} \rightarrow pH = 10.23$