Chemistry

Name: Date:

§ 14/15 Test Acids & Bases - REVIEW

1. Compare the Arrhenius and Brønsted-Lowy definitions for acids and bases.

Definition	Acid	Base
Arrhenius	donates H^+ e.g., $HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$	loses OH^- e.g., $NaOH(aq) \rightarrow Na^+(aq) + OHl^-(aq)$
Brønsted-Lowry	(same as Arrhenius)	accepts H^+ e.g., $NH_3(aq)+H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$
Lewis	accepts lone electron pair e.g., $H^+ + :B \rightarrow H : B^+$	donates lone electron pair

2. What are the properties of acids? of bases?

Acids	Bases
• taste sour • change indicators (e.g., litmus = red) • react with certain metals to produce H_2 gas • react with carbonates (CO_3^{2-}) and hydrogen carbonates (HCO_3^-) to produce CO_2 gas • electrolytes • pH < 7	• taste bitter • change indicators (e.g., litmus = blue) • feel slippery • electrolytes • pH > 7

3. Define amphoteric.

A substance that can act as an acid AND a base.

Is water amphoteric?

Yes: e.g., base: $HCl + H_2O \rightarrow H_3O^+ + Cl^-$

acid: $NH_3 + H_2O \rightarrow NH_4^+ + OH^-$

Give an example of another amphoteric compound.

a) $H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$ (HSO_4^- acts as a base)

$HSO_4^- + H_2O \rightarrow H_3O^+ + SO_4^{2-}$ (HSO_4^- acts as an acid)

4. What are, and give an example, of each: binary acid, polyprotic acid, diprotic acid, and triprotic acid. (The H's below can be donated. $HC_2H_3O_2$ is a monoprotic acid)

binary acid: contains two different elements e.g., HCl, H_2S

polyprotic acid: contains two or more H's: e.g., H_2SO_4, H_3PO_4

diprotic acid: contains two H's: e.g., H_2SO_4

triprotic acid: contains three H's: e.g., H_3PO_4

5. Define a strong acid/base. Define a weak acid/base.
   Strong acids and bases completely ionize

   e.g., $HCl + H_2O \rightarrow H_3O^+ + Cl^-$ has no HCl remaining after the reaction

   Weak acids and bases DO NOT completely ionize

   e.g., $HF + H_2O \rightleftarrows H_3O^+ + F^-$ has HF remaining after the reaction

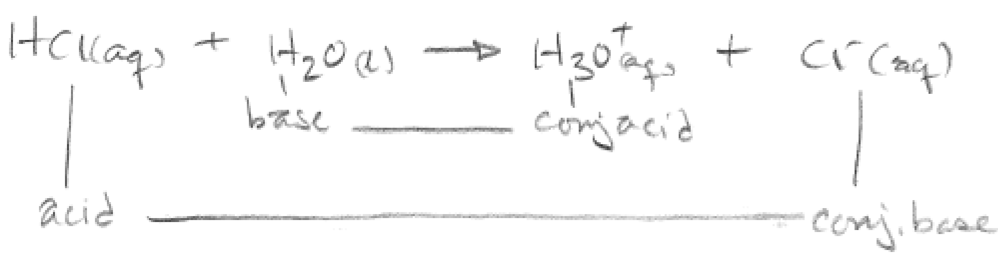
6. List six strong acids and six strong bases.

Strong Acids		Strong Bases	
H + halogen (except HF):	HCl HBr HI	alkali metal + OH:	LiOH NaOH KOH
Other	$HClO_4$ HNO_3 H_2SO_4	heavy alkaline-earth + OH:	$Ca(OH)_2$ $Sr(OH)_2$ $Ba(OH)_2$

7. What acid is in each of the following:
   A) car batteries: sulfuric acid (H_2SO_4)
   B) Pepsi & Coke: phosphoric acid (H_3PO_4)
   C) blood and seltzer: carbonic acid (H_2SO_4)
   D) stomach acid: hydrochloric acid (HCl)
   E) vinegar: acetic acid ($HC_2H_3O_2$)

8. Is ammonia (NH_3) a strong acid, a weak acid, a strong base, or weak base? Explain.
   a. It is a BASE: turns litmus blue, pH > 7, doesn't react with metals to produce H_2 gas (It is the classic example of overcoming the limits of the Arrhenius definition.)
   b. It is weak: ionization isn't complete; NH_3 is a weak base and, therefore, NH_4^+ is a strong acid.

9. Identify the Brønsted-Lowry conjugate acid-base pairs in each of the following reactions:
   a. hydrochloric acid + water



b. carbonic acid + water

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_3^-$$

H_2CO_3: acid — HCO_3^-: conjugate base

H_2O: base — H_3O^+: conj. acid

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$$

HCO_3^-: acid — CO_3^{2-}: conj. base

H_2O: base — H_3O^+: conj. acid

c. sulfuric acid + water (both reactions)

$$H_2SO_4(aq) + H_2O(l) \longrightarrow H_3O^+(aq) + HSO_4^-(aq)$$

H_2SO_4: acid — HSO_4^-: conj. base

H_2O: base — H_3O^+: conj. acid

$$HSO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + SO_4^{2-}(aq)$$

HSO_4^-: acid — SO_4^{2-}: conj. base

H_2O: base — H_3O^+: conj. acid

d. phosphoric acid + water (all reactions)

$$H_3PO_{4(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)}$$

acid, base, conj. acid, conj. base

$$H_2PO_4^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

acid, base, conj. acid, conj. base

$$HPO_4^{2-}{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + PO_4^{3-}{}_{(aq)}$$

acid, base, conj. acid, conj. base

10. Lemon juice has a pH of about 2. Distilled water has a pH of 7. How many times greater is the H_3O^+ concentration in lemon juice than it is in water?

(A) Lemon juice: pH ~ 2 ⇒ $[H_3O^+] \approx 1.0 \times 10^{-2}$ M

Water : pH ~ 7 ⇒ $[H_3O^+] \sim 1.0 \times 10^{-7}$ M

(B) $\frac{\text{lemon juice}}{\text{water}} \sim \frac{1\times10^{-2}}{1\times10^{-7}} = \frac{0.01}{0.0000001} =$ 100,000 x's (1×10^{5})

11. What are the pH, pOH, $[H_3O+]$, and $[OH^-]$ for the following solutions?

N.B.
(A) pH values do NOT have units! (e.g., pH = 12.09)
(B) pH values are given with no more than two decimal places (e.g., 12.09)
(C) The H^+'s on polyprotic acids are donated one at a time, as shown below for H_2SO_4. HOWEVER, the donation of the second (or third) H^+ is very small compared with the first H+. Thus, in actually, loss of only the first H+ would determine the pH, pOH, etc. (This is not the case for bases, e.g., see below $Ca(OH)_2$ and $Mg(OH)_2$.

a. 2.3 x 10^{-4} M calcium hydroxide

STEPS 2.3×10^{-4} $Ca(OH)_2$ ⇒ $\underline{1}Ca(OH)_2 \rightarrow \underline{1}Ca^{2+} + \underline{2}OH^-$

① $[OH^-]$ (b/c $Ca(OH)_2$ is a base)

2.3×10^{-4} M $Ca(OH)_2$ ⇒ 4.6×10^{-4} M OH^-

② pOH : $pOH = -\log[OH^-] = -\log(4.6 \times 10^{-4})$

$pOH = 3.34$

③ pH : $14 = pH + pOH$ ⇒ $pH = 14 - pOH$

$pH = 10.66$

④ $[H_3O^+]$: 10^{-pH} ⇒ $[H_3O^+] = 10^{-10.66}$

$[H_3O^+] = 2.17 \times 10^{-11}$ M

(2.2 c̄ sig. figures)

this order b/c you start c̄ a base.
An acid would give you $[H_3O^+]$ instead of $[OH^-]$

$pH = 10.66$
$pOH = 3.34$
$[H_3O^+] = 2.2 \times 10^{-11}$ M
$[OH^-] = 4.6 \times 10^{-4}$ M

b. 9.4×10^{-3} M sulfuric acid

$9.4 \times 10^{-3}\ M\ H_2SO_4 \Rightarrow \underline{1} H_2SO_4 + H_2O \rightarrow \underline{2} H^+ + \underline{1} SO_4^{2-}$

$2(9.4 \times 10^{-3}) = 1.9 \times 10^{-2}\ M = [H_3O^+]$

① $[H_3O^+] = \underline{1.9 \times 10^{-2}\ M}$

② $pH = -\log[H_3O^+] = \underline{1.7}$

③ $pOH = 14 - pH = \underline{12.3}$

④ $[OH^-] = 10^{-12.3} = 5.32 \times 10^{-13}\ \underline{M}$

N.B., See question 11 above for an explanation of what is really happening in the the reaction:
CORRECT ANSWER:

$9.4 \times 10^{-3}\ \underline{M}\ H_2SO_4 \Rightarrow \underline{1} H_2SO_{4(aq)} + \underline{1} H_2O_{(aq)} \rightarrow \underline{1} HSO_{4(aq)}^- + H_2O_{(l)}$

① $9.4 \times 10^{-3}\ M$; $1(9.4 \times 10^{-3}\ M)$; $[OH^-] = \underline{9.4 \times 10^{-3}\ M}$

② $pOH = -\log[OH^-] = -\log(9.4 \times 10^{-3}\ M) \Rightarrow \underline{pOH = 2.03}$

③ $pH = 14 - pOH$; $\underline{pH = 11.97}$

④ $[H_3O^+] = 10^{-pH}$; $\underline{[H_3O^+] = 1.1 \times 10^{-12}\ M}$

Σ

$pH = 11.97$
$pOH = 2.03$
$[H_3O^+] = 1.1 \times 10^{-12}\ M$
$[OH^-] = 9.4 \times 10^{-3}\ M$

} CHECK: $pH + pOH = 14 \Rightarrow 11.97 + 2.03 = 14.00$

} CHECK: $[H_3O^+][OH^-] = 1 \times 10^{-14} \Rightarrow 1.0 \times 10^{-14}$

c. A solution made by dissolving 3.00 grams of sodium hydroxide in distilled water and brought up to 250. mL of solution.

(c) 3.00 g NaOH / 250 mL ⇒ pH, pOH, $[H_3O^+]$, $[OH^-]$

① Molarity – all of these (pH, pOH, etc.) require concentration (M)

$$\frac{3.00\,g\,NaOH}{0.250\,L} \times \frac{1\,mol\,NaOH}{39.98\,g\,NaOH} \times \frac{1\,mol\,OH^-}{1\,mol\,NaOH} = 0.300\,M\,OH^- \quad (3.00\times10^{-1})$$

② $pOH = -\log[OH^-] = -\log(0.300) = 0.52\ pOH$

③ $pH = 14 - 0.52 = 13.48\ pH$

④ $[H_3O^+] =$ (another way to calculate :)

$$[H_3O^+][OH^-] = 1\times10^{-14}$$

$$[H_3O^+] = \frac{1\times10^{-14}}{3.00\times10^{-1}}$$

$$[H_3O^+] = 3.33\times10^{-14}\,M$$

N.B.
WE USE SIG. FIGS
SO WE DON'T USE
REPEATING
DECIMALS
(OR ≈ approx)

③ $pH = 13.48$
② $pOH = 0.52$
④ $[H_3O^+] = 3.33\times10^{-14}\,M$
① $[OH^-] = 3.00\times10^{-1}\,M$

d. A solution is made by dissolving 20.0 grams of magnesium hydroxide in distilled water and brought up to 1.5 L of solution.

(d)

$\frac{20.0g\ Mg(OH)_2}{1.5L} \Rightarrow \ 1\ Mg(OH)_{2(aq)} \rightarrow 1\ Mg^{2+}_{(aq)} + 2\ OH^-_{(aq)}$

① Molarity (OH-): $\frac{20.0g\ Mg(OH)_2}{1.5L} \times \frac{1mol\ Mg(OH)_2}{58.32g\ Mg(OH)_2} \times \frac{2mol\ OH^-}{1mol\ Mg(OH)_2}$

$[OH^-] = 4.57\times10^{-1}\ M$

② $pOH = -\log[OH^-] = -\log 4.57\times10^{-1}\ M \Rightarrow pOH = 0.34\ pOH$

③ $pH = 14 - pOH$ $\qquad pH = 13.66\ pH$

④ $[H_3O^+] = 10^{-[H_3O^+]} = 10^{-13.66} \Rightarrow [H_3O^+] = 2.19\times10^{-14}\ M$

Σ!
$pH = 0.34$
$pOH = 13.66$
$[H_3O^+] = 2.19\times10^{-14}\ M$
$[OH^-] = 4.57\times10^{-1}\ M$

12. A 10.0-mL solution hydrochloric acid of unknown concentration is neutralized by 40.0-mL of a 5.00 x 10^{-2} M solution of sodium hydroxide. What is the molarity of the hydrochloric acid?

(10.0 mL HCl) + (40.0 mL of 5.00 x 10^{-2} M NaOH)

¿M HCl?

$$M_1V_1 = M_2V_2 \Rightarrow \frac{(40.0)(5.00\times10^{-2})}{(10.0)} = 2.00\times10^{-1}\ M$$