IB chemistry
acids and bases

$pH + pOH = 14$ $[H^+] = 10^{-pH}$ $pH = -\log [H^+]$

$[H+][OH-] = 10^{-14}$ $[OH^-] = 10^{-pOH}$ $pOH = -\log [OH^-]$

pH: 7 = neutral, <7 = acid, >7 = base

$c_1v_1 = c_2v_2$ c = concentration, v = volume

$HA(aq) + H_2O\ (l) \leftrightharpoons H_3O^+(aq) + A^-(aq)$ $B(aq) + H_2O\ (l) \leftrightharpoons BH^+(aq) + OH^-(aq)$

$$k_a = \frac{[H_3O^+][A^-]}{[HA]}$$

$$k_b = \frac{[BH^+][OH^-]}{[B]}$$

$K_a \times K_b = K_w = 10^{-14}$

pH sig figs = # of decimal places: 7.2 = 1, 7.22 = 2, 7.222 = 3

how the acid base unit is divided

part one: acids and bases:

- Arrhenius definition
- Bronsted-Lowry definition
- Conjugate pairs
- Properties of each
- Acid reactions
- Base reactions
- comparing net ionic reactions and full reactions: H+ vs. H_3O^+
- indicators
- endpoint vs. equivalence point
- pH
    - what it means
    - and pOH and [H+] and [OH-]
    - strong and weak acids and bases
    - some common examples
    - K_a and pK_a and K^b and pK_b and K_w
- are weak acids and bases rare?
- Lewis theory: omit until buffers
- nucleophiles and electrophiles: omit til buffers
- temperature effects….what is the pH of hot water??

part two: buffers and additional topics

- Buffers (pages 378-392)
- Amphiprotic substances (349)
- Reactions of acids with metals (351)
- Reactions of acids with carbonates (352)
- Indicators and litmus colors (data booklet)
- Lewis acids and bases, nucleophiles and electrophiles (364-366)
- Environmental aspects of acids and bases 😊 (393-399)

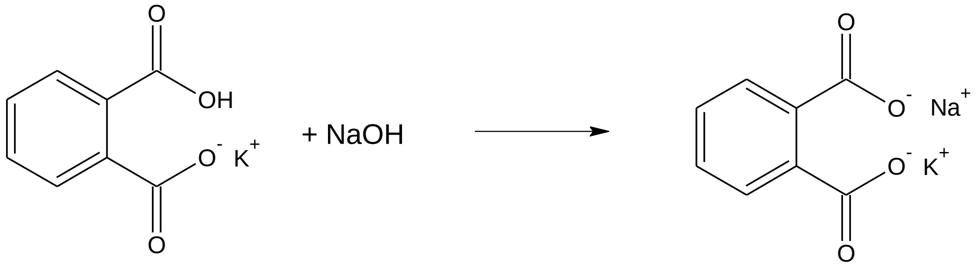
Names____

Standardization of a Sodium Hydroxide Solution

Objective: To standardize a sodium hydroxide solution.

Background: It is often necessary to precisely determine the concentration of a solution. This process, known as standardization, is usually done by titration, where it is quantitatively reacted with another solution of known concentration.

In this experiment we will determine the molarity of a sodium hydroxide solution by reacting it with a precisely massed amount of the acid potassium hydrogen phthalate, or KHP:



The NaOH solution will be dripped into the KHP solution that contains an indicator with a buret. At the *equivalence point* equal moles of KHP and NaOH have been combined, and the indicator will turn a persistent pale pink color.

Once the sodium hydroxide solution is standardized we will label it and store it, so that it can be used to determine the molarity of any acid solution.

Prelab Questions

1. A 50.00 mL solution of hydrochloric acid is titrated with a 0.100M solution of sodium hydroxide. The phenolphthalein end point was found at 37.50 mL of NaOH. What is the concentration of the NaOH solution?

2. We will mass out the KHP but it is not critical to measure how much water we add to it….why?

3. Define using your own words:
Titration
Equivalence point
standardization

Procedure:

You are to complete at least three trials in this experiment. The three determinations should be within +/-3%, if they are not you must do another determination.

1. Accurately weigh out 0.7-0.9 g of KHP (molar mass = 204.2 g/mol) in a labeled 125 mL Erlenmeyer flask. Add 50 ml of deionized water and 2 drop of phenolphthalein indicator. Swirl gently until fully dissolved; note that rapid swirling introduces carbon dioxide into the water making the water slightly acidic.
2. Get approximately 80 mL of the unknown NaOH in a labeled 150-200 mL beaker.
3. Pretreat the buret by rinsing with a small amount of the NaOH solution, then fill it. Measure the initial volume, being sure to estimate one digit between graduations.
4. Place a piece of white paper under the KHP flask which should now be under the NaOH filled buret.
5. Slowly add the NaOH solution to the KHP, swirling the flask after each addition.
6. Titrate to a pale pink endpoint, noting the amount of NaOH solution needed. If the titration requires too much base, repeat with a reduced amount of KHP.
7. Repeat the titration with two additional KHP solutions. Record your results below

	1	2	3
Initial Buret Reading, mL			
Final Buret Reading, mL			
Volume NaOH Dispensed			
Grams of KHP			
Moles of KHP			
Moles of Base			
Molarity of Base			
Average Molarity of Base			

Results and questions

In one paragraph summarize your experiment and comment on the precision of your results.

Postlab questions (include your calculations)

1. A mass of 0.497 g of the monoprotic acid sulfamic acid, NH_2SO_3H, dissolved in 50.0 mL of water is neutralized by 28.4 mL of NaOH at the phenolphthalein endpoint. What is the molarity of the NaOH solution? The formula weight of NH_2SO_3H is 97.1 g/mol:

$$NH_2SO_3H + NaOH \rightarrow NH_2SO_3^-Na^+ + H_2O$$

2. If the endpoint in the titration is surpassed (too pink) what effect does this have on the calculated molarity of the NaOH solution? Explain.

3. Why does the phenolphthalein color change fade with continual stirring?

4. A 25.00 mL sample of HBr is titrated with a 0.150 M standardized sodium hydroxide solution. The endpoint was reached when 18.80 mL of titrant had been added. Calculate the molar concentration of the HBr.

5. A 20.00 mL sample of sulfuric acid (H_2SO_4) is titrated with a 0.100 M solution of sodium hydroxide. The endpoint was reached when 45.65 mL of titrant was added. Calculate the molar concentration of sulfuric acid.

6. A 1.00 gram sample of an unknown acid HA is dissolved in 50.0 mL of water and titrated with 0.150 M sodium hydroxide. The endpoint was observed after 24.50 mL of titrant had been added. Calculate the molecular weight of the acid HA.

Name_______________________________________

IB Chemistry Acid-Base Titration Lab

INTRODUCTION

In this lab you will be titrating both a strong acid (HCl) and then a weak acid (HC2H3O2) with a strong base NaOH while recording the pH. From the collected data a titration curve will be plotted for each acids and differences in the curves noted.

Most substances that are acidic in water are actually weak acids. Because weak acids dissociate only partially in aqueous solution, equilibrium is formed between the acid and its ions. The ionization equilibrium is given by:

$$HX(aq)_{+} \Leftrightarrow_{-} H+ (aq) + X-(aq)$$

Where X is the conjugate base.
The equilibrium constant is then:

$$Ka= [H\ ][X\ ] / [HX]$$

The smaller the value for Ka, the weaker the acid. Weaker acids ionize less ([H] is smaller compared to [HX]) and therefore have a less drastic effect on pH.

Strong acids such as HCl ionizes almost completely in water.

For each of the titrations plot the graph of pH versus volume of base added. In each titration curve locate the equivalence point and the half-way point. The equivalence point assumed to correspond to the mid-point of the vertical portion of the curve, where pH is increasing rapidly. The half-way point is assumed to correspond to the mid-point of the horizontal portion of the curve, where pH is changing very little. From the graph read the volume of base need to the reach the end point and half-way point..

There are a number of differences between the titration curves for a strong acid versus the weak acid.

Weak Acid Titration

The weak-acid solution has a higher initial pH.
The pH rises more rapidly at the start, but less rapidly near the end point.
The pH at the equivalence point does not equal 7.00 (pH > 7.00) for the weak acid titration.

Purpose- To construct 2 titration curves. One of a strong acid with a strong bases and the other, a weak acid with a strong base. Also to determine the Ka of the weak acid using the constructed titration curve.

Procedure-

Strong Acid Strong Base Titration-

1. Attach the buret clamp to the ring stand.
2. Obtain a clean, dry 100-mL beaker and label it RXN.
3. Using a 25.00mL volumetric pipet, pipet 25.00mL of 0.1M HCl solution to your 100-mL RXN beaker.
4. In another 100-mL beaker (Label it B), obtain 75-mL of the 0.1M NaOH solution.
5. Rinse the buret with your standard solution two times. (With the stopcock closed add approximately 2-ml of the 0.1M NaOH, using the buret funnel. Swirl the NaOH around the buret and discard into the sink. Repeat.)
6. Using the buret funnel, carefully add the 0.1M NaOH to the buret. Make sure the stopcock is closed. Go about an inch past the top line on the buret, being careful not to let it overflow.
7. With Beaker B under the buret, slowly bring the meniscus to the zero mL line or below
8. Turn on the pH meter and place it into the RXN beaker. Record the pH.
9. Add 2.0-mL of NaOH to the RXN beaker. Swirl the solution and record the new pH.
10. Repeat step 11 until you reach a volume of 20. ml of NaOH.
11. From 20. mL to 30. mL of NaOH measure the pH in 1.0 mL increments.
12. From 30. mL to 50. mL add the NaOH in 2.0 mL increments.
13. Stop the experiment at 50. mL and wash out the RXN beaker. Refill the buret with NaOH for the next titration.

Weak Acid Strong base Titration

1. Using a 25.00mL volumetric pipet, pipet 25.00mL of 0.1M $HC_2H_3O_2$ solution to your 100-mL a new RXN beaker.
2. Refill the buret with the 0.1M NaOH
3. Repeat the previous experiment with the weak acid.

Data and Calculation

Strong Acid Titration (0.1M HCl)

Vol. 0.1M NaOH (ml)	pH
0	
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
32	
34	
36	
38	
40	
42	
44	
46	
48	
50	

Weak Acid Titration (0.1M $HC_2H_3O_2$)

Vol. 0.1M NaOH (ml)	pH
0	
2	
4	
6	
8	
10	
12	
14	
16	
18	
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
32	
34	
36	
38	
40	
42	
44	
46	
48	
50	

Strong Acid Titration (0.1M HCl)

Weak Acid Titration (0.1M HC2H3O2)

Data Analysis-

Strong Acid Titration

What is the pH of the end point (label the graph)?

How many mL of NaOH were used?

Weak Acid Titration

What is the pH of the end point (label the graph)??

How many mL of NaOH were used?

What is the pH of the half-way point (label the graph)??

How many mL of NaOH were used?

Using the pH of the half-way point, calculate the experimental value of the ionization constant for your weak acid.

Additional Questions-

1. What indicator is could replace the pH meter in determining the equivalence point of the strong acid?

   Why?

2. What indicator is could replace the pH meter in determining the equivalence point of the weak acid?

   Why?

Conclusion-

introduction to acids and bases

some you may not know

$NaCl$ (aq)

NH_3 (aq)

KI (aq)

$BeCl_2$ (aq)

NaF (aq)

CH_3CO_2Na (Aq)

NH_4F(aq)

NH_4NO_3 (aq)

MgO

CaCl2

$FeCl_3$

what is water?

H_2O

Is it H–O–H, or is it H^+OH^-?

covalent ↗ Both! ↖ ionic

$$\text{H–O–H (l)} \rightleftharpoons \text{H}^+\text{(aq)} + \text{OH}^-\text{(aq)}$$

(for a more detailed understanding review the autoionization of water)

$$K_{eq} = \underset{\text{Arrhenius acid}}{[H^+]}\underset{\text{Arrhenius base}}{[OH^-]}$$

Pure water: $[H^+] = [OH^-] =$ 10^{-7}M ← pH = 7

at room temp.

pH < 7 = acidic pH > 7 = basic

Predict the change in [H+], pH, and acidity of pure water as it is heated above room temperature

exponent math and water

$[10^{-7}]\,[10^{-7}]$	
$[10^{3}]\,[10^{-7}]$	
$[10^{3}]\,[10^{7}]$	
$[10^{-3}]\,[10^{-11}]$	
$\frac{10^{5}}{10^{3}}$	

[H+]	[OH⁻]
$[10^{-7}]$ pH:	 pOH:
$[10^{-3}]$ pH:	 pOH:
$[10^{-5}]$ pH:	 pOH:
$[10^{-13}]$ pH:	 pOH:

find the hydroxide ion concentration of a 3.0×10^{-2} M HCl solution.

logarithms and pH

10^2 =

10^{-2} =

conclusion: logarithms are

2 is the

of 100; -2 is the log of

If [H+] = 10^{-2} then pH =

So.

similarly:

[H+]	pH
10^{-4}	
0.1	
0.84	
4	

pH	$[H^+]$
7	
3	
3.4	
12.62	

acids and bases: equations

$pH + pOH = 14$ $[H^+] = 10^{-pH}$ $pH = -\log [H^+]$

$[H+][OH-] = 10^{-14}$ $[OH^-] = 10^{-pOH}$ $pOH = -\log [OH^-]$

pH: 7 = neutral, <7 = acid, >7 = base

$c_1v_1 = c_2v_2$ c = concentration, v = volume

pH	[H+]	pOH	[OH-]	acid or base?
3.78				

V_1 V_2 C_2

20.00 mL HNO_3 is neutralized with 43.33 mL of 0.1000M KOH. What is the concentration of HNO_3?

neutralization

HCl + $NaOH$ → $NaCl$ + H_2O

Acid	base		Salt	water
		→		
HBr	$NaOH$	→		
$2\ HBr$	$Mg(OH)_2$	→		
HNO_3	KOH	→		

others to know

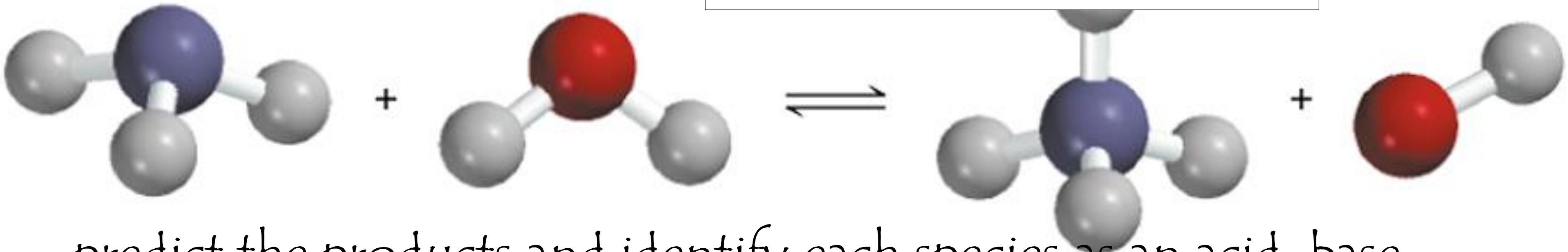
Acids and bases: definitions and their conjugates

An Arrhenius acid:

An Arrhenius Base:

A Brønsted acid is:

A Brønsted base is:



predict the products and identify each species as an acid, base, conjugate acid, or conjugate base

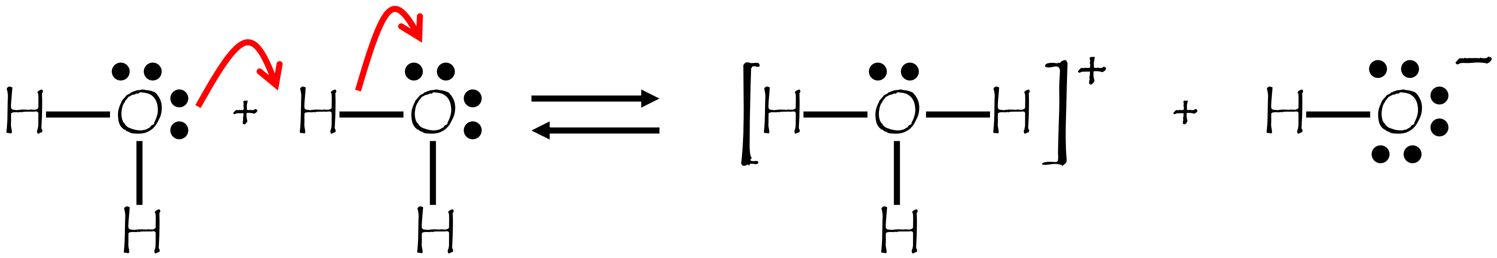
$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

Identify the conjugate acid-base pairs in the reaction between ammonia and hydrofluoric acid in aqueous solution

$$NH_3(aq) + HF(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)$$

how to identify each:

identify the conjugate acid base pairs in the autoionization of water, and write the reaction:



Interaction of electrolytes with water

Write the aqueous dissociation reaction with water

NaCl (s)

HCl (aq)

HF (aq)

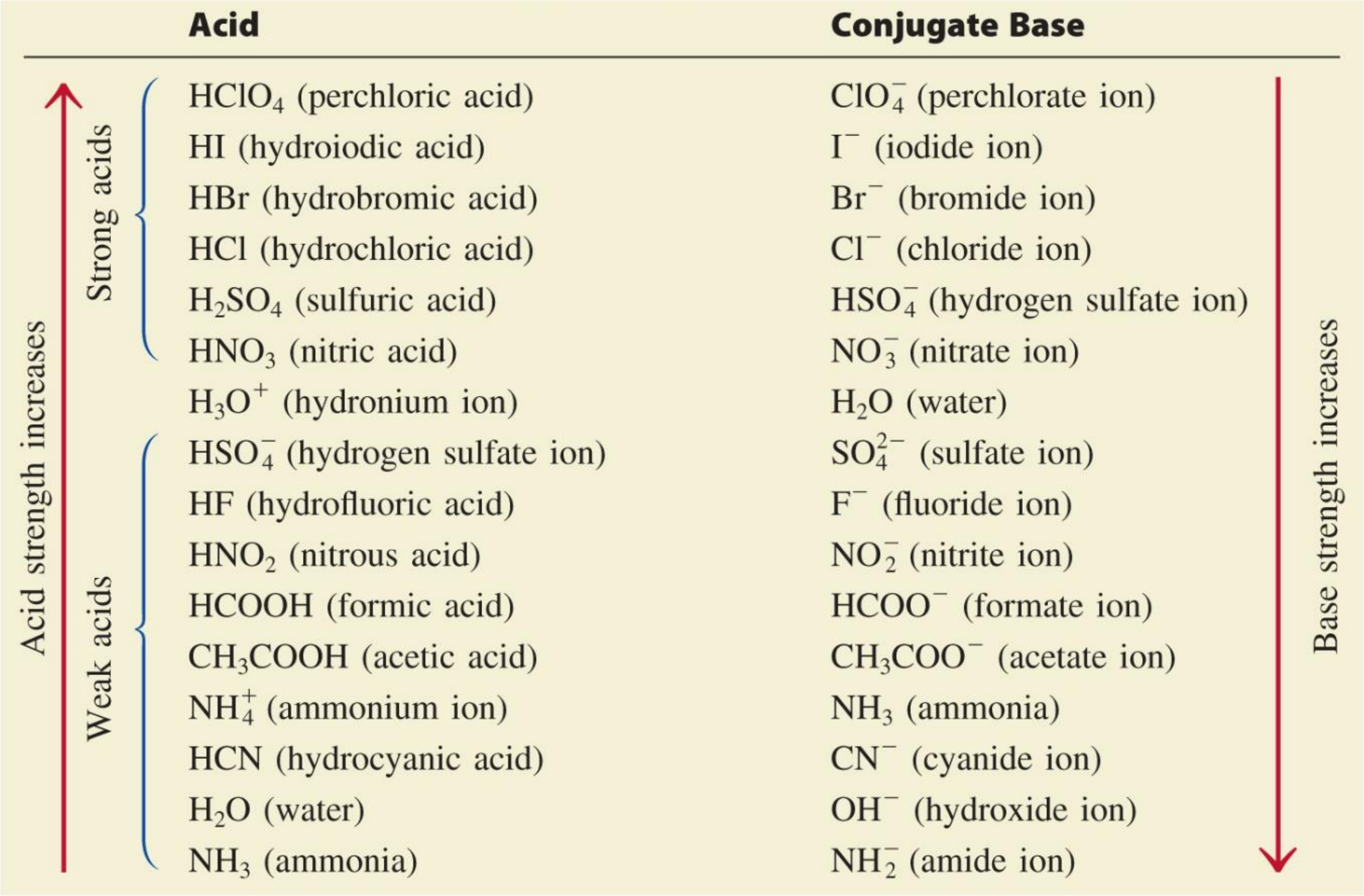
NaOH (s)

$HClO_4$ (aq)

HSO_4^-

F^- (aq)

acids and conjugate base strength



	Acid	**Conjugate Base**
Strong acids	$HClO_4$ (perchloric acid)	ClO_4^- (perchlorate ion)
	HI (hydroiodic acid)	I^- (iodide ion)
	HBr (hydrobromic acid)	Br^- (bromide ion)
	HCl (hydrochloric acid)	Cl^- (chloride ion)
	H_2SO_4 (sulfuric acid)	HSO_4^- (hydrogen sulfate ion)
	HNO_3 (nitric acid)	NO_3^- (nitrate ion)
	H_3O^+ (hydronium ion)	H_2O (water)
Weak acids	HSO_4^- (hydrogen sulfate ion)	SO_4^{2-} (sulfate ion)
	HF (hydrofluoric acid)	F^- (fluoride ion)
	HNO_2 (nitrous acid)	NO_2^- (nitrite ion)
	HCOOH (formic acid)	$HCOO^-$ (formate ion)
	CH_3COOH (acetic acid)	CH_3COO^- (acetate ion)
	NH_4^+ (ammonium ion)	NH_3 (ammonia)
	HCN (hydrocyanic acid)	CN^- (cyanide ion)
	H_2O (water)	OH^- (hydroxide ion)
	NH_3 (ammonia)	NH_2^- (amide ion)

Acid strength increases

Base strength increases

Should I memorize this?

calculating the pH of weak acids and bases.

First, note that pH of strong electrolytes is straightforward.

Calculate the pH of a

(a) 1.0 x 10^{-3} M HCl solution

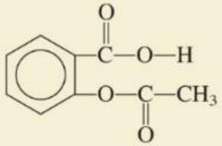
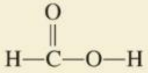
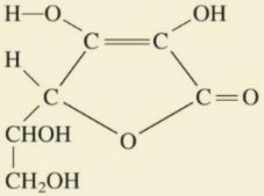
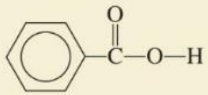
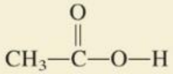
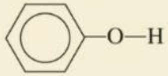
(b) 0.020 M $Ba(OH)_2$ solution

However weak acids and bases only dissociate a little so we need to know exactly to what extent they dissociate.

The number most frequently used is:

Weak Acids (HA) and Acid Ionization Constants

K_a is **acid ionization constant**

Name of Acid	Formula	Structure	K_a	Conjugate Base	K_b
Hydrofluoric acid	HF	H—F	7.1×10^{-4}	F^-	1.4×10^{-11}
Nitrous acid	HNO_2	O═N—O—H	4.5×10^{-4}	NO_2^-	2.2×10^{-11}
Acetylsalicylic acid (aspirin)	$C_9H_8O_4$		3.0×10^{-4}	$C_9H_7O_4^-$	3.3×10^{-11}
Formic acid	$HCOOH$	 $H{-}\overset{\overset{O}{\Vert}}{C}{-}O{-}H$	1.7×10^{-4}	$HCOO^-$	5.9×10^{-11}
Ascorbic acid*	$C_6H_8O_6$		8.0×10^{-5}	$C_6H_7O_6^-$	1.3×10^{-10}
Benzoic acid	C_6H_5COOH		6.5×10^{-5}	$C_6H_5COO^-$	1.5×10^{-10}
Acetic acid	CH_3COOH	 $CH_3{-}\overset{\overset{O}{\Vert}}{C}{-}O{-}H$	1.8×10^{-5}	CH_3COO^-	5.6×10^{-10}
Hydrocyanic acid	HCN	H—C≡N	4.9×10^{-10}	CN^-	2.0×10^{-5}
Phenol	C_6H_5OH		1.3×10^{-10}	$C_6H_5O^-$	7.7×10^{-5}

Calculate the pH of a 0.36 *M* nitrous acid (HNO_2) solution, given that it has a K_a of 4.5×10^{-4}.

fast method:

ice table method:

The pH of a 0.10 *M* solution of formic acid (HCOOH) is 2.39. What is the K_a of the acid?

warning: this problem is significantly harder.

A sample of 40.0 mL of 0.100 molar $HC_2H_3O_2$ solution is titrated with a 0.150 molar NaOH solution. K_a $HC_2H_3O_2 = 1.8 \times 10^{-5}$

a) What volume of NaOH is used in the titration in order to reach the equivalence point?

b) What is the molar concentration of $C_2H_3O_2^-$ at the equivalence point?

c) What is the pH of the solution at the equivalence point?

Question 2

A 0.682 gram sample of an unknown weak monoprotic organic acid, HA was dissolved in sufficient water to make 50 milliliters of solution and was titrated with a 0.135 molar NaOH solution. After the addition of 10.6 milliliters of base, a pH of 5.65 was recorded. The equivalence point (end point) was reached after the addition of 27.4 milliliters of the 0.135 molar NaOH.

(a) Calculate the number of moles of acid in the original sample.

warning- this problem is harder still.

(b) Calculate the molecular weight of the acid HA.

(c) Calculate the number of moles of unreacted HA remaining in solution when the pH was 5.65.

(d) Calculate the $[H_3O^+]$ at pH = 5.65

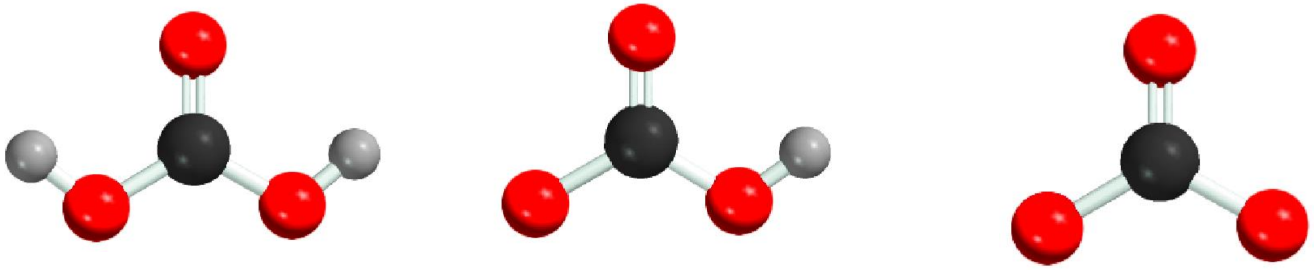
(e) Calculate the value of the ionization constant, K_a, of the acid HA.

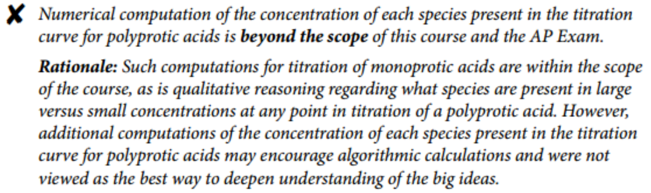
Diprotic and Triprotic Acids

- May yield more than one hydrogen ion per molecule.
- Ionize in a stepwise manner; that is, they lose one proton at a time.
- An ionization constant expression can be written for each ionization stage.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq) \qquad K_{a_1} = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

$$HCO_3^-(aq) \rightleftharpoons H^+(aq) + CO_3^{2-}(aq) \qquad K_{a_2} = \frac{[H^+][CO_3^{2-}]}{[HCO_3^-]}$$





✘ *Numerical computation of the concentration of each species present in the titration curve for polyprotic acids is **beyond the scope** of this course and the AP Exam.*

Rationale: *Such computations for titration of monoprotic acids are within the scope of the course, as is qualitative reasoning regarding what species are present in large versus small concentrations at any point in titration of a polyprotic acid. However, additional computations of the concentration of each species present in the titration curve for polyprotic acids may encourage algorithmic calculations and were not viewed as the best way to deepen understanding of the big ideas.*

Weak Bases and Base Ionization Constants

$$NH_3\ (aq) + H_2O\ (l) \rightleftharpoons NH_4^+\ (aq) + OH^-\ (aq)$$

K_b =

K_b is the base ionization constant

K_b ↑

weak base strength ↑

Solve weak base problems like weak acids except solve for [OH-] instead of [H^+].

What is the pH of an aqueous 0.40 *M* ammonia solution, given that $k_b = 1.8 \times 10^{-5}$?

what equilibrium reaction should be written??

$pH + pOH = 14$

$[H^+] = 10^{-pH}$

$pH = -\log [H^+]$

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

$[OH^-] = 10^{-pOH}$

$pOH = -\log [OH^-]$

fast:

ice table:

Molecular Structure and Acid Halide Strength

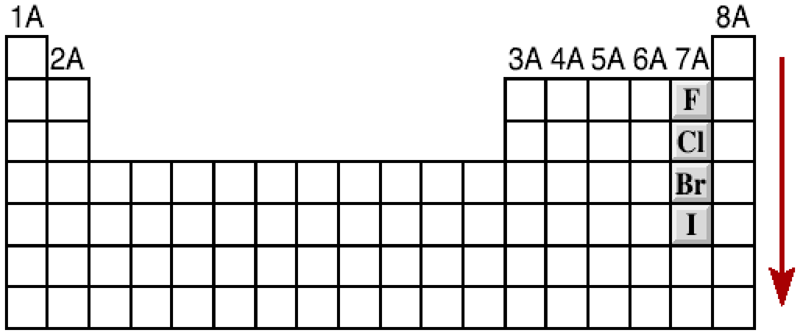
$$H\text{-}X \leftrightarrows H^{+} + X^{-}$$

$$\uparrow$$

The stronger the bond

The weaker the acid

$HF \ll HCl < HBr < HI$



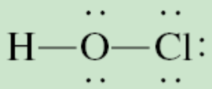
acidity increases

Bond	Bond Enthalpy (kJ/mol)	Acid Strength
H—F	568.2	weak ⇆
H—Cl	431.9	strong →
H—Br	366.1	strong →
H—I	298.3	strong →

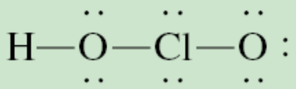
Molecular Structure and Acid Strength

2. Oxoacids having the same central atom (Z) but different numbers of attached groups.

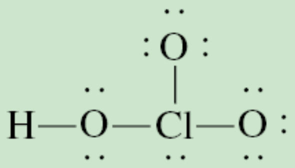
Acid strength increases as the oxidation number of Z increases.



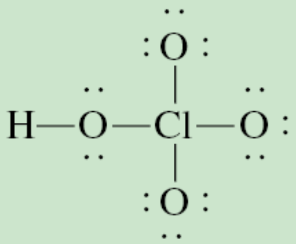
Hypochlorous acid (+1)



Chlorous acid (+3)



Chloric acid (+5)



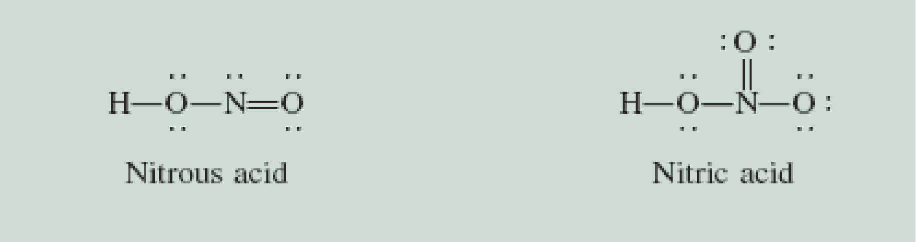
Perchloric acid (+7)

$HClO_4 > HClO_3 > HClO_2 > HClO$

Predict the relative strengths of the oxoacids in each of the following groups:

(a) HClO, HBrO, and HIO

(b) HNO_3 and HNO_2



Nitrous acid

Nitric acid

Acid-Base Properties of Salts

Neutral Solutions:

Salts containing an alkali metal or alkaline earth metal ion (except Be^{2+}) and the conjugate base of a strong acid (e.g. Cl^-, Br^-, and NO_3^-).

$$NaCl\ (s) \xrightarrow{H_2O} Na^+\ (aq) + Cl^-\ (aq)$$

Basic Solutions:

Salts derived from a strong base and a weak acid.

$$CH_3COONa\ (s) \xrightarrow{H_2O} Na^+\ (aq) + CH_3COO^-\ (aq)$$

$$CH_3COO^-\ (aq) + H_2O\ (l) \rightleftharpoons CH_3COOH\ (aq) + \boxed{OH^-}\ (aq)$$

Acid-Base Properties of Salts

Acid Solutions:

Salts derived from a strong acid and a weak base.

$$NH_4Cl\ (s) \xrightarrow{H_2O} NH_4^+\ (aq) + Cl^-\ (aq)$$

$$NH_4^+\ (aq) \rightleftharpoons NH_3\ (aq) + \boxed{H^+}\ (aq)$$

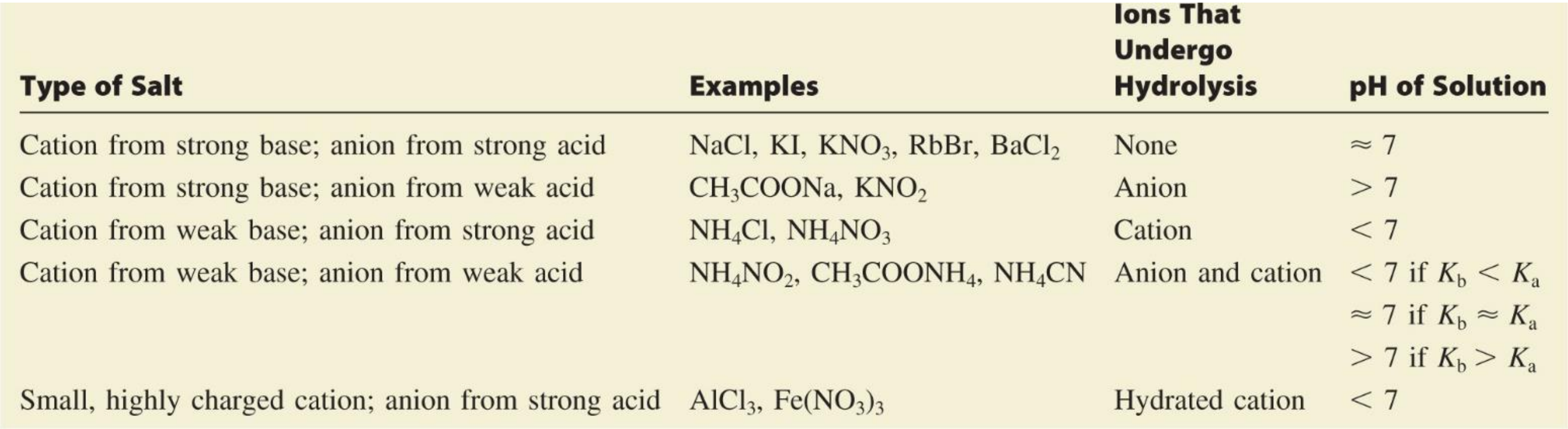
Salts with small, highly charged metal cations (e.g. Al^{3+}, Cr^{3+}, and Be^{2+}) and the conjugate base of a strong acid.

$$Al(H_2O)_6^{3+}(aq) \rightleftharpoons Al(OH)(H_2O)_5^{2+}(aq) + H^+\ (aq)$$

Acid-Base Properties of Salts

Solutions in which both the cation and the anion hydrolyze:

- K_b for the anion > K_a for the cation, solution will be basic
- K_b for the anion < K_a for the cation, solution will be acidic
- K_b for the anion ≈ K_a for the cation, solution will be neutral



Type of Salt	Examples	Ions That Undergo Hydrolysis	pH of Solution
Cation from strong base; anion from strong acid	NaCl, KI, KNO_3, RbBr, $BaCl_2$	None	≈ 7
Cation from strong base; anion from weak acid	CH_3COONa, KNO_2	Anion	> 7
Cation from weak base; anion from strong acid	NH_4Cl, NH_4NO_3	Cation	< 7
Cation from weak base; anion from weak acid	NH_4NO_2, CH_3COONH_4, NH_4CN	Anion and cation	< 7 if $K_b < K_a$ ≈ 7 if $K_b \approx K_a$ > 7 if $K_b > K_a$
Small, highly charged cation; anion from strong acid	$AlCl_3$, $Fe(NO_3)_3$	Hydrated cation	< 7

Predict whether the following solutions will be acidic, basic, or nearly neutral:

(a) NH_4I

(b) $NaNO_2$

(c) $FeCl_3$

to

s

(d) NH_4F

l

A fresh perspective on acids and bases: ChemTeam

Acid Base Problems & Videos

Return to ChemTeam Main Menu
Return to Acid Base Menu

Problem Sets

K_a related

1. Solving K_a Problems: Part One
2. Solving K_a Problems: Part Two
3. Solving K_a Problems: Part Three
4. Given pH and molarity, calculate K_a
5. Given pH and other concentration data, calculate K_a
6. Given osmotic pressure data, calculate K_a and percent ionization (omit for ap)
7. Given thermodynamic data, calculate K_a (omit until thermo unit is complete)

K_b related

1. Solving K_b Problems: Part One
2. Solving K_b Problems: Part Two
3. Solving K_b Problems: Part Three
4. Given pH and molarity, Calculate K_b

Percent Dissociation related

1. Given pH and K_a, Calculate the Percent Dissociation
2. Given Concentration and Percent Dissociation, Calculate K_a
3. Given Concentration and K_a, Calculate the Percent Dissociation
4. Given Percent Dissociation, Calculate the Concentration

Solutions of Salts

1. Calculations Involving Salts of Weak Acids
2. Calculations Involving Salts of Weak Bases
3. Given the K_a of an Acid, Calculate the pH of a Solution of the Salt of that Acid
4. Given the K_b of a Base, Calculate the pH of a Solution of the Salt of that Base
5. Given the pK of a Salt, Calculate the K of an Acid or a Base

Miscellaneous Problems

1. Titration problems (strong acids and bases)
2. Titration problems (weak acids and bases)
3. Miscellaneous problems

Videos

K_a related

1. Calculate the pH of a weak acid I
2. Calculate the pH of a weak acid II
3. Calculate the pH of a weak acid III
4. Calculate the pH of a weak acid IV
5. Calculate the pH of a weak acid V

K_b related

1. Calculate the pH of a weak base I
2. Calculate the pH of a weak base II
3. Calculate the pH of a weak base III

Salt related

1. Calculate the pH of salt of a weak acid

pH and pOH related

1. pH and pOH Calculations I
2. pH and pOH Calculations II
3. pH and pOH Calculations III
4. pH and pOH Calculations IV
5. pH and pOH Calculations V

Neutralization

1. Calculate the pH after neutralization I
2. Calculate the pH after neutralization II
3. Calculate the pH after neutralization III
4. Calculate the volume required for neutralization I
5. Calculate the volume required for neutralization II

Miscellaneous

1. Calculate the pH of a solution
2. Calculate the pH of two solutions after mixing
3. Calculate the hydroxide ion concentration
4. A trick pH calculation question

"I am a strong believer in luck and I find the harder I
work the more I have of it." --- Benjamin Franklin

Acids and bases Tutorials and Problem Sets and Tutorials

1. Observable Properties of Acids and Bases
2. Early Acid Base Theories: Lavoisier and Davy
3. Svante Arrhenius' Theory of Acids and Bases
4. Johannes Brønsted and Thomas Lowry: Broadening the Concept of Acids and Bases
5. Sören Sörenson and the pH scale
6. A warning about pH (and pOH) and sigificant figures (this is really good)
7. A warning about putting numbers into the calculator
8. Strong and Weak Acids: Definitions and Descriptions
9. K_w: The Behavior of Water and The Relationship Between pH and pOH
10. The pH of a Strong Acid or Base
11. Intro to K_a: The Acid Ionization Constant
12. Intro to K_b: The Base Ionization Constant
13. The Five Percent Rule
14. A Trick pH Question
15. $K_a K_b = K_w$
16. What are Salts?
17. The Hydrolysis of Salts in Water
18. A Brief Introduction to Hydrolysis Calculations
19. Introduction to Buffers (this is the next chapter)
20. Buffers: The Henderson-Hasselbalch Equation (this is the next chapter)
21. The Lewis Definition of Acids and Bases (omit)
    - Examples of Lewis Acids
    - Examples of Lewis Bases
22. Titration to the equivalence point
    - Calculating volumes (15)
    - Calculating masses (10) (10)
    - Calculating pH (strong/strong)
    - Calculating pH (strong/weak)
    - Titration curves and acid-base indicators

Problem Sets

See separate problem list.

Other Resources

Videos

See separate video list.

Links

1. A link to a site with a short explanation about using logarithms

Miscellaneous

1. Classroom Practice in Solving Weak Acid and Weak Base Problems
2. Additional worksheets and lecture notes for interested students

> "Learning is not attained by chance, it must be sought for with ardor and attended to with diligence."
>
> --- Abigail Adams

acids and bases problem set

Chemistry: pH and pOH calculations II

$$H_2O\ (l) \leftrightarrows H^+\ (aq) + OH^-(aq)$$

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

$[H^+] = 10^{-pH}$

$pH + pOH = 14$

$[OH^-] = 10^{-pOH}$

$pH = -\log [H^+]$

$pOH = -\log [OH^-]$

use the formulas above to complete the table below. Use the suggested formulas at the top of each column for assistance. The first column is done for you

	pH ($pH = 14 – pOH$) $pH = -\log [H^+]$	$[H^+]$ $[H^+] = 10^{-pH}$	pOH ($pOH = 14 – pH$) $pOH = -\log [OH^-]$	$[OH^-]$ $[OH^-] = 10^{-pOH}$	ACID or BASE? (<7 acid, >7 base)
1.	3.78	1.7 x 10^{-4} M	10.22	6.0 x 10^{-11} M	acid
2.		3.89 x 10^{-4} M			
3.			5.19		
4.				4.88 x 10^{-6} M	
5.	8.46				
6.		8.45 x 10^{-13} M			
7.			2.14		
8.				2.31 x 10^{-11} M	
9.	10.91				
10.		7.49 x 10^{-6} M			
11.			9.94		
12.				2.57 x 10^{-8} M	

1. Write the formula and give the name of the conjugate base of the acids below.

a NH_4^+
b. HCO_3^-
c. HBr
d. HCO_3^-

2. Write the formula and give the name of the conjugate acid of the bases below.

a NH_3
b. HCO_3^-
c. Br^-
d. CO_3^{-2}

3. What are the products of each of the following acid-base reactions? Identify each as an acid, base, conjugate acid, and conjugate base

a. $HClO_4 + H_2O \rightarrow$

b. $NH_4^+ + H_2O \rightarrow$

c. $HCO_3^- + OH^-$

4. An aqueous solution has a pH of 3.75. What is the hydronium ion concentration of the solution. Is it acidic or basic?

5. What is the pH of a 1.2×10^{-4} solution of KOH? What is the hydronium ion concentration of the solution?

6. The pH of a solution of $Ba(OH)_2$ is 10.66 at 26°C. What is the hydroxide ion concentration of the solution at that temperature? If the solution volume is 125 mL, what mass of $Ba(OH)_2$ was dissolved?

7. Several acids are listed with their respective equilibrium constants:

$C_6H_5OH(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + C_6H_5O^-(aq)$
$K_a = 1.3 \times 10^{-10}$
$HCO_2H(aq) + H_2O(l) \leftrightarrows H_3O^+ + HCO_2^{2-}$
$K_a = 1.8 \times 10^{-4}$
$HC_2O_4^-(aq) + H_2O(l) \leftrightarrows H_3O^+ + C_2O_4^{2-}(aq)$
$K_a = 6.4 \times 10\text{-}5$

a. Which is the strongest acid? Which is the weakest acid?

b. Which acid has the weakest conjugate base?

c. Which acid has the strongest conjugate base?

8. If each of the salts listed here were dissolved in water to give a 0.10M solution, which solution would have the highest pH? Which would have the lowest pH? Hint: You may have to look up the acidity or basicity of each ion.

a. Na_2S
b. Na_3PO_4
c. NaH_2PO_4
d. NaF
e. $NaCH_3CO_2$
f. $AlCl_3$

9. An organic acid has a pK_a of 8.9. What is its K_a value?

10. Chloroacetic acid ($ClCH_2CO_2H$) has a K_a of 1.41×10^{-3}. What is the value of K_b for the chloroacetate ion, $ClCH_2CO_2^-$?

11. A weak base has a K_b of 1.5×10^{-9}. What is the value of K_a for the conjugate acid?

12. Acetic acid and sodium hydrogen carbonate ($NaHCO_3$) are mixed in water. Write a balanced equation for the acid-base reaction that would occur. Noting that the K_a values are 1.8×10^{-5} for acetic acid and 4.2×10^{-7} for H_2CO_3, indicate whether the equilibrium lies predominantly to the right or the left.

13. Equal molar quantities of acetic acid and sodium hydrogen phosphate (Na_2HPO_4) are mixed.

a. Write a balanced net ionic equation for the acid base reaction that will occur.

b. Does the equilibrium lie to the right or the left? (You may need to look up some equilibrium constants. Explain.

14. A 0.015M solution of hydrogen cyanate (HOCN) has a pH value of 2.67.

a. What is the hydronium ion concentration of the solution?

b. Using an ICE table, determine the ionization constant (K_a) for the acid.

15. A 0.10M solution of chloroacetic acid (ClCH2CO2H) has a pH of 1.95. Calculate the K_a of this acid.

16. Phenol (C_6H_5OH) is a weak organic acid with a K_a of 1.3×10^{-10}. A 125 mL aqueous solution containing 0.195 g of phenol is prepared. What is the K_a and pH of this solution?

17. Calculate the pH of a 0.12 M aqueous solution of the base aniline ($C_6H_5NH_2$), which has a K_b of 4.0×10^{-10}

18. Calculate the hydronium ion concentration and pH of a 0.20M solution of ammonium chloride (NH_4Cl), given that the k_a of NH_4^+ is 5.6 x 10^{-10}.

19. Calculate the concentration of H_3O^+, OH^-, and pH of a 5.00 x 10^{-2} M HCN solution at 25°C, given that the K_a of HCN is 4.0 x 10^{-10}.

20. The sodium salt of propanoic acid ($CH_3CH_2CO_2Na$, also know as sodium propanoate) is used as an antifungal agent by veterinarians. Calculate the equilibrium concentrations of H_3O^+, OH^-, and the pH of a 0.10M solution of sodium propanoate, given that the K_a of propanoic acid is 1.3 x 10^{-5}.

21, 22. Calculate the hydronium ion concentration and the pH when 50 mL of 0.40M NH_3 is mixed with 50 mL of 0.40M HCl, given that the K_a of the ammonium cation NH_4^+ is 5.6×10^{-10}.

23. For each of the following cases, decide if the pH is less than 7, 7, or greater than 7.

a. Equal volumes of acetic acid and potassium hydroxide are mixed.

b. 25 mL of 0.015M NH_3 is mixed with 25 mL of 0.015M HCl.

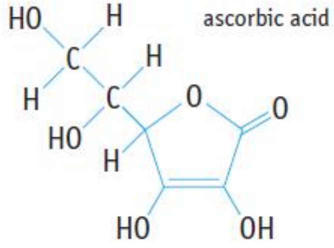
c. 150 mL of 0.20M HNO_3 is mixed with 75 mL of 0.40M NaOH

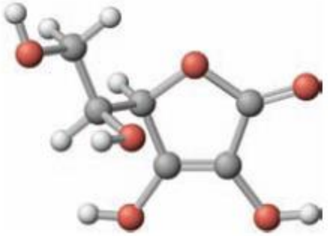
d. 25 mL of 0.45M H_2SO_4 is mixed with 25 mL of 0.90M NaOH

e. 15 mL of 0.050M formic acid (HCO_2H) is mixed with 25 mL of 0.30M NaOH.

f. 25 mL of 0.15M oxalic acid (HO_2CCO2H)is mixed with 25 mL of 0.50M NaOH. Note that NaOH removes both H^+ ions in oxalic acid.

24.Ascorbic acid (Vitamin C, molar mass 176.12 g/mol) is a diprotic acid with Ka1 of 6.8×10^{-5} and Ka2 of 2.7×10^{-12}. What is the pH of a 1.0 milliliter solution that contains 5.0 mg of ascorbic acid? Hint: ignore the second ionization.





25. For each of the follwing salts, predict whether a 0.10M solution has a pH less than, equal to, or greater than 7. Also determine the solution with the highest and lowest pH

a. $NaHSO_4$
b. NH_4Br
c. $LiClO_4$
d. Na_2CO_3
e. $(NH_4)_2S$
f. $NaNO_3$
g. Na_2HPO_4
h. LiBr
i. $FeCl_3$

26. Nicotine (C_{10}H14N_2) has two basic nitrogen atoms, both of with water. Given that K_{b1} is 7.0×10^{-7} and K_{b2} is 1.1×10^{-10}, calculate the approximate pH of a 0.20M aqueous nicotine solution. Ignore the second K_b.

27. Aspirin ($HC_9H_7O_4$) has a K_a of 3.27×10^{-4}. If you take two tablets of aspirin, each containing 325 mg of aspirin, and dissolve them in a glass of water creating 225 mL of solution, what is the pH of the solution?

The student will use the Bronsted-Lowry and Lewis theories of acids and bases

28. what is a bronsted acid?

29. what is a bronsted base?

30. show how HNO_3 can act as a Bronsted acid in water

31. show how water can act as a Bronsted acid and base in water

32. show how NH_4^+ can act as a Bronsted acid in water

33. show how a hydriated metal cation like $[Fe(H_2O)_6]^{3+}$ can act as a bronsted acid in water

34. show how $H_2PO_4^-$ can act as a Bronsted acid in water

33. show how NH_3 can act as a Bronsted base in water

36. show how CO_3^{2-} can act as a Bronsted base in water

37. show how $Fe(H_2O)_5((OH)]^{2+}$ can act as a Bronsted base in water

The student will use the Bronsted-Lowry and Lewis theories of acids and bases

recognize common mono and polyprotic acids and bases and write balanced equations for their ionization in water, and appreciate when a substance can be amphiprotic

38. show how sulfuric acid is a polyprotic acid

show how the carbonate ion is a polyprotic base

39. show how the hydrogen phosphate anion is amphiprotic

40. show how water can act as a Bronsted baseand when reacting with hydrochloric acid

41. show how water can act as a bronsted acid when reacting with ammonia

recognize the bronsted acid and base in a reaction and identify its conjugate pair

42. a substance that has gained H^+ is a

43. a substance that has lost H^+ is a

44.. show how the hydrogen carbonate anion can act as a bronsted acid with water and identify the conjugate pairs

The student will use the Bronsted-Lowry and Lewis theories of acids and bases and use the pH concept

45. does pure water conduct electricity? Explain

46. show the degree of autoionization of water by expressing Kw

47. how does Kw change with temperature?

48. Does the pH of pure water change as temperature increases?

calculating pH and pK

49. how does pH relate to [H_3O+]?

50. how does pH relate to pOH

51. how does pOH relate to [OH-]?

52. What is the pH, pOH, [H+], and [OH-] of pure water?

53. if pH = -log[H+], then what is pK?

54. if $K_w = 10^{-14}$, what is the pk_w of water?

55. What is the pH, of a weak acid or base

The student will use the Bronsted-Lowry and Lewis theories of acids and bases

identify common strong acids and bases, and weak acids and bases

56. list the big six strong acids

57. list three strong bases

58. list seven weak acids

59. list a weak base

60. classify NH_4^+, HCO_3^-, HPO_4^-, $H_2PO_4^-$, $[Fe(H_2O)_6]^{3+}$, and $[Fe(H_2O)_5(OH^-]^{2+}$

The student will apply the principles of chemical equilibrium to acids and bases in aqueous solutions

-write the equilibrium constants for weak acids and bases

61. write the equilibrium expression for the aqueous acetic acid

-calculate pK_a from K_a or the reverse, and understand how pK_a is correlated with acid strength

62. discuss K_a, K_b, pK_a, and pK_b for water

IB chemistry acids and bases: sample problems for each topic

part one: acids and bases:
- Arrhenius definition
  - what is an arrhenus acid?
  - List the six common strong acids
  - 50
- Bronsted-Lowry definition
- Conjugate pairs
- Properties of each
- amphiprotic substances: omit til buffers
- Acid reactions (will cover in more detail in buffers)
- Base reactions
- comparing net ionic reactions and full reactions: H^+ vs. H_3O^+
- indicators
- endpoint vs. equivalence point
- pH
  - what it means
  - and pOH and [H^+] and [OH^-]
  - strong and weak acids and bases
  - some common examples
  - Ka and pKa and Kb and pKb and Kw
- are weak acids and bases rare?
- Lewis theory: omit until buffers
- nucleophiles and electrophiles: omit til buffers
- temperature effects….what is the pH of hot water??
- Buffers: omit til buffers unit
- environmental aspects: omit til next unit