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Unit 7 – Acids and Bases

Progress Tracker

Test Date:

Webassign Due *Score*

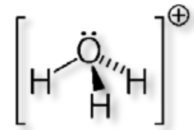
Packet Progress Checks

Test Readiness Checks:

- ☐ My webassign scores indicate I am ready for the test.
- ☐ I went to ASP for Webassign help when needed.
- ☐ I have completed the unit review AND checked my answers.
- ☐ I am aware that I cannot retake the test unless my webaassign and packet progress checks are all above 80%.

Learning Objectives

7.1 Acids, Bases, and pH
7.2 Acid Base Reactions
7.3 Acid Base Reaction Calculations



7.1 Acids, Bases, and pH

- Be able to identify an acid:
  - o by the presence of a dissociable proton in formula.
  - o by a representation as **hydronium ion (H_3O^+)**.
  - o by the **pH** of the solution or its effect on the pH of another solution when combined.
  - o by its reaction with metal.
  - o by its effect on **litmus** paper.
- Be able to identify a base:
  - o by the presence of a dissociable **hydroxide (OH^-)**. in formula.
  - o by the pH of the solution or its effect on the pH of another solution when combined.
  - o by its reaction with metal.
- Calculate the pH or pOH of a solution from concentrations.

$$pH = -\log[H_3O^+] \qquad pOH = -\log[OH^-]$$

- Calculate the pH or pOH of a solution after the solution is diluted.
- Estimate the pH of a solution without a calculator to demonstrate an understanding of the how logarithms alter concentration values.
- Be able to interconvert the 4 common ways of describing the acidity of a solution (pH, pOH, [OH-], [H+]).

$$K_w = [H_3O^+][OH^-] \qquad pK_w = pH + pOH$$

- Using the **autohydrolysis of water** and an understanding of aqueous solutions, explain the inverse relationship between the concentration of hydronium and hydroxide in a solution.
- Explain the relative strengths of two acids (or two bases) by:
  - o Drawing particulate representations and discussing dissociation.
  - o Comparing the pH of each solution.
  - o Comparing the **conductivity** of the solutions.

7.2 Acid-Base Reactions

- Predict the products of acid base reactions:
    - Double displacement style reactions

      ($HCl + NaOH \rightarrow NaCl + H_2O$)

    - Those involving ammonia. (No other amines required.)

      ($NH_3 + HCl \rightarrow NH_4Cl$)

- Be able to identify the salt that forms in an acid base reaction.
- Label the acid, base, conjugate acid, and conjugate base in a reaction.
- Predict the formula of a conjugate acid or base of a compound. (What is the conjugate base of HN_3?)
- Use Bronsted-Lowry thinking to identify the acid and base in a reaction based on loss or gain of protons:

  ($HCO_3^- + H_3PO_4 \rightarrow H_2CO_3 + H_2PO_4^{2-}$)

7.3 Acid-Base Reaction Calculations

- Using particulate diagrams, represent a beaker containing acid and a beaker containing base. Use the diagram to explain if the solution will be acidic or basic once mixed.
- Calculate the pH of a solution after mixing a solution of an acid with a solution of a base. (Given the concentration and volume of each prior to mixing.)
- Know key titration terminology and be familiar with titration equipment and techniques: **analyte, titrant, indicator, buret, equivalence point, end point**
- Design an experiment to determine the concentration of an acid in a solution of unknown concentration using a titration. Be able to find the answer with a high degree of accuracy.
- Be familiar with common titration language. (e.g. – label where the chemicals are likely to go in a titration setup given the statement: *Hydrofluoric acid is titrated with sodium hydroxide.)* Know which chemical is likely to be the analyte.
- Predict the shape of a titration curve given the two solutions involved in the titration. (Weak acid titrated with a strong base)
- Identify the equivalence point of the titration from the titration curve.

Intro to Acids and Bases

Acids and Bases are two very important classes of chemicals. They are opposites in many of their chemical properties.

Goal: From a group of compounds, you will figure out which ones are acids and which are bases. Our second goal is to notice how acids affect our tests differently than bases do.

You will have these chemicals to test to see if they are acids or bases. Before we start, you may have a feeling about some of them. Feel free to record whether they are acids or bases at anytime.

Chemical	*Na_2CO_3*	*NaOH*	*HCl*	*NH_3*	*NaCl*	*H_2SO_4*	*KOH*	*Vinegar (HCH_3OO)*	*$Ca(OH)_2$*
Acid or Base?									

What to do: There are three tests that you need to run on each chemical. It is a good idea to do one test on all of them before doing the next test.

Test 1:
- Put a little bit of each solution (a few drops) on the litmus paper. You can do many on one piece of paper but you must be doing it on a "fresh" area of the paper.
- Record if the color changes or not.

Chemical	*Na_2CO_3*	*NaOH*	*HCl*	*NH_3*	*NaCl*	*H_2SO_4*	*KOH*	*Vinegar (HCH_3OO)*	*$Ca(OH)_2$*
Litmus paper changed color? (Y or N)									

Test 2:
- Clean your reaction plate with water and a scrub brush.
- Put a small (as small as possible) piece of Zn in 9 wells of your reaction plate.
- Now add Na_2CO_3 to well one. Did a reaction happen? Record your answer below. Now add NaOH to well to and so on until your have tried them all.

Chemical	*Na_2CO_3*	*NaOH*	*HCl*	*NH_3*	*NaCl*	*H_2SO_4*	*KOH*	*Vinegar (HCH_3OO)*	*$Ca(OH)_2$*
Did a reaction happen? (Y or N)									

Test 3:

- pH paper also changes colors (like litmus paper) but it has more colors that it can become.
- Add one drop of each chemicals to pH paper. You can do many on one piece of paper but you must be doing it on a “fresh” area of the paper.
- Compare the color of your spot to the “key” on the side of the bottle. Record a pH (number) below.
-

Chemical	*Na_2CO_3*	*NaOH*	*HCl*	*NH_3*	*NaCl*	*H_2SO_4*	*KOH*	*Vinegar (HCH_3OO)*	*$Ca(OH)_2$*
pH									

Follow up Tasks:

1. Now you have three tables of information. Do you see a pattern? Are there two distinct groups? Go back up to the first table and fill in which are acids and which are bases.

2. Acids have what effect on red litmus paper? ______________________
3. Bases have what effect on red litmus paper? ______________________

4. How do acids behave in the presence of metals?
   ____
   ____

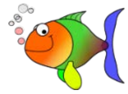
5. How do bases behave in the presence of metals?
   ____
   ____

6. Acids can have a range of pH values. What range did you find in your experiment? _________________.
7. Bases, also, can have a range of pH values. What range did you find in your experiment? __________________.

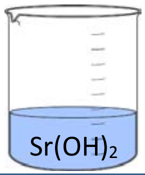
8. Look at the chemical formulas of each compound. What element do most acids have in the far left of their formula? ________

9. Look at the chemical formulas of each compound. What polyatomic ion do most bases have on the right of their formula? ________

Acid-Base Reactions



Acids and bases often react together. Let's first investigate the chemicals in the two beakers shown below. Label the chemical that represents the acid, and the chemical represents the base. Explain how you determined your answers.

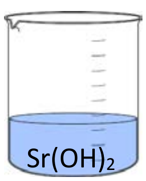


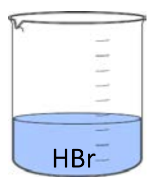
Answers:

Explanation: (How did you know?)

Note: This guy is totally proud of you for getting this question correct. Svante Arrhenius was the guy who taught us this way of recognizing acids and bases. (That actually is his proud and excited face.)

A chemist measured the pH of each of the beakers and determined that one of the beaker had a pH = 3 and the other had a pH = 9. Label each beaker below with the pH that you think belongs to it. Explain how you determined your answer.





pH:

Explanation: (How did you know?)

When acids and bases are mixed together, the reaction that occurs is a **neutralization** reaction. Fortunately, we already know how to predict the product of these reactions because they are simply double displacement reactions. Predict the products of the reaction that will occur between $Sr(OH)_2$ and HBr. (Remember to check charges!)

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These reactions are called neutralization reactions because both products that are made are neutral. That is, neither product is an acid or a base. Water is one of the products of the reaction that you drew on the previous page, the other product that was made is called a **salt**.

What is the formula of the **salt** that you made in the reaction on the previous page? [ ]

For each of the neutralization reactions below:

- Label each reactant as an acid or a base in the box below it.
- Predict the products of the reaction.
- Label the product that is the salt. (This will mean leaving one box blank.)
-

1. H_2S + KOH → ______________________ + ______________________

2. $NaOH$ + HNO_3 → ______________________ + ______________________

3. $Ca(OH)_2$ + HCl → ______________________ + ______________________

4. HI + $Mg(OH)_2$ → ______________________ + ______________________

5. H_2SO_4 + $CsOH$ → ______________________ + _______________________

6. $Be(OH)_2$ + H_3PO_4 → ______________________ + _______________________

Reflection on our progress:

- Which chemical in reaction 6 would react with metals? ____________
- Which chemical in reaction 5 would feel slippery? ____________
- Which chemical in reaction 4 could have a pH = 4? ______________
- Which chemical in reaction 3 could have a pH = 7? __________and ________
- Which chemical in reaction 2 could have a pH = 10? ______________

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An Alternative View of Acids and Bases

These guys took acids and bases very seriously! ☺

We have seen one way to identify acids and bases based on whether they contain an H^+ ion or an OH^- ion. Not all acids and bases can be recognized so easily however. Two scientist, Johannes Bronsted and Thomas Lowry propose a better way to recognize acids and bases – by watching how they behave in a reaction. Let's look at the **Bronsted-Lowry** way of identifying acids and bases.

Key Skill: Learning to Draw Tie Lines

Look at each example drawn below. Sets of partners (called **conjugates**) are matched with "tie lines".

$HNO_3 + OH^- \rightarrow NO_3^- + H_2O$

$CH_3NH_2 + H_2O \rightarrow CH_3NH_3^+ + OH^-$

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

Note that conjugates are the same compound that has either gained or lost an H^+. One of the reactants is always matched with one of the _____________ (reactants or products)

Draw tie lines for each of these reactions:

(a) $OH^- + HPO_4^{-2} \rightarrow PO_4^{-3} + H_2O$

(b) $NH_3 + HBr \rightarrow NH_4^+ + Br^-$

(c) $HC_2H_3O_2 + H_2O \rightarrow H_3O^+ + C_2H_3O_2^-$

Key Skill: Labeling the Acid and Base.

Tie lines allow us to figure out if the substance was an acid or a base. We can do this by determining if the reactant "*gained*" or "*lost*" an H^+. Look at these examples:

Gained H^+

$HNO_3 + OH^- \rightarrow NO_3^- + H_2O$

Lost H^+

- Since acids lose (or donate) H^+, then **HNO_3** is the <u>acid.</u>
- Since bases gain H^+, then **OH^-** is the <u>base</u>.

Lost H^+

$CH_3NH_2 + H_2O \rightarrow CH_3NH_3^+ + OH^-$

Gained H^+

- Since acids lose (or donate) H^+, then **H_2O** is the <u>acid.</u>
- Since bases gain H^+, then **CH_3NH_2** is the <u>base</u>.

2. Notice only the ______________ (reactants or products) get labeled as an acid or a base.

3. Draw tie lines and label the tie lines with (*Lost H^+ or Gained H^+*) as in the examples above. Then record the acid and base in the space provided.

(a) $H_2SO_4 + NH_3 \rightarrow HSO_4^- + NH_4^+$ ______(acid) ______ (base)

(b) $NH_3 + HBr \rightarrow NH_4^+ + Br^-$ ______(acid) ______ (base)

(c) $HC_2H_3O_2 + H_2O \rightarrow H_3O^+ + C_2H_3O_2^-$ ______(acid) ______ (base)

Key Skill: Labeling the Conjugate Acid and Conjugate Base.

We have labeled the reactants, but the products also have names too. They are called the conjugate acid and the conjugate base. Look at how they are labeled in these examples:

HNO_3 + OH^- → NO_3^- + H_2O

Acid *base* *conjugate Base* *conjugate acid*

CH_3NH_2 + H_2O → $CH_3NH_3^+$ + OH^-

Base *Acid* *conjugate Acid* *conjugate Base*

4. Look at one set of tie lines. A ***base*** is always connected to a ___________________ (*conjugate acid or conjugate base*). An ***acid*** is always connected to a ___________________ (*conjugate acid or conjugate base*).

5. For each of these reactions label the acid and base first. Then label the conjugate acid and conjugate base.

a) $HBr + OH^- \rightarrow H_2O + Br^-$

b) $NH_3 + HF \rightarrow NH_4^+ + F^-$

c) $H_2CO_3 + NO_2^- \rightarrow HNO_2 + HCO_3^-$

d) $F^- + H_3PO_4 \rightarrow HF + H_2PO_4^-$

e) $HC_2H_3O_2 + OH^- \rightarrow C_2H_3O_2^- + H_2O$

STOP ____ Instructor signature

Key Skill: Predicting the conjugate without an equation.

Example problem 1:

What is the *conjugate base* of H_2O?

Solution:

When we draw tie lines, the **conjugate base** is always attached to an **acid**. (Check page 3 to confirm this.) So if the problem wants us to find a conjugate base of H_2O, then water must be an acid.

H_2O → **?**

Acid — *conjugate Base*

Since acids donate (give away) H^+ (see page 2 to confirm this) then the conjugate base must have one less H than H_2O. **Answer: OH^-**

Example problem 2:

What is the *conjugate acid* of $H_2PO_4^-$?

Solution:

If the problem wants us to find a *conjugate acid* of $H_2PO_4^-$, then $H_2PO_4^-$ must be an base.

$H_2PO_4^-$ → **?**

Base — *conjugate Acid*

Since bases accept H^+ (see page 2 to confirm this) then the conjugate acid must have one more H than $H_2PO_4^-$. **Answer:** H_3PO_4

6. Try the same logic on this problem:

What is the *conjugate acid* of NH_2^-?

NH_2^- → **?**

_______ *conjugate acid*

Fill in the blank: is NH_2^- an *acid or base*?

The answer is a conjugate acid according to the problem.

Is NH_2^- going to gain or lose an H to become the conjugate acid? ___________

What is the formula of the conjugate acid? ______________

7. Try the same logic on this problem:

What is the *conjugate base* of HCO_3^-?

HCO_3^- → **?**

_______ *conjugate base*

Fill in the blank: is HCO_3^- an *acid or base*?

The answer is a conjugate base according to the problem.

Is HCO_3^- going to gain or lose an H to become the conjugate base? ___________

What is the formula of the conjugate base? ______________

Skill Practice:

1. What is the conjugate base of HSO_4^-?

(Before you start. If they are asking for the conjugate base of HSO_4^-, then HSO_4^- must be an _____________ (acid or base))

*HSO_4^- → **?***
conjugate base

2. What is the conjugate acid of $H_2PO_4^-$? (Draw the appropriate diagram like in #1, then answer the question.)

3. What is the conjugate base of HF? (Draw the appropriate diagram like in #1, then answer the question.)

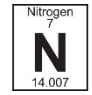
4. What is the conjugate acid of SO_4^{2-}? (Draw the appropriate diagram like in #1, then answer the question.)

5. What is the conjugate base of $HBrO_2$? (Draw the appropriate diagram like in #1, then answer the question.)

6. What is the conjugate acid of OH^-? (Draw the appropriate diagram like in #1, then answer the question.)

7. Why would it **not be possible** to ask you to find the conjugate base of CN^-? Explain in complete sentences.

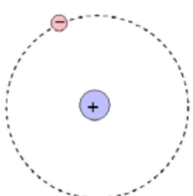
Continue on to the next page



8. A chemists would describe what happened in problem 2 like this: "*$H_2PO_4^-$ is a base, so it gained a **proton***". Based on what we have been doing in this exercise, the term proton must be the same as what?

9. Draw the reaction described in this sentence: "Ammonia gained a proton to become ammonium ion." (hint: Look up ammonia in the list of bases on your periodic table.)

10. This is an atomic structure of hydrogen (H). Label the protons, electrons, and neutrons in the model. Using the drawing, explain why chemists refer to H^+ as a proton. (What changes about the model when H becomes H^+?)



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Conjugate Acid-Base Practice

Identify the acid, base, conjugate acid and conjugate base for each of the following. You can use labels A, B, CA, CB but be sure to draw tie-lines and write "gained" or "lost" on the lines.

1. $HClO_4(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + ClO_4^-(aq)$

2. $H_2SO_3(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + HSO_3^-(aq)$

3. $HC_2H_3O_2(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + C_2H_3O_2^-(aq)$

4. $H_2S(g) + H_2O(l) \rightleftarrows H_3O^+(aq) + HS^-(aq)$

5. $HSO_3^-(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + SO_3^{2-}(aq)$

6. $NH_3(g) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$

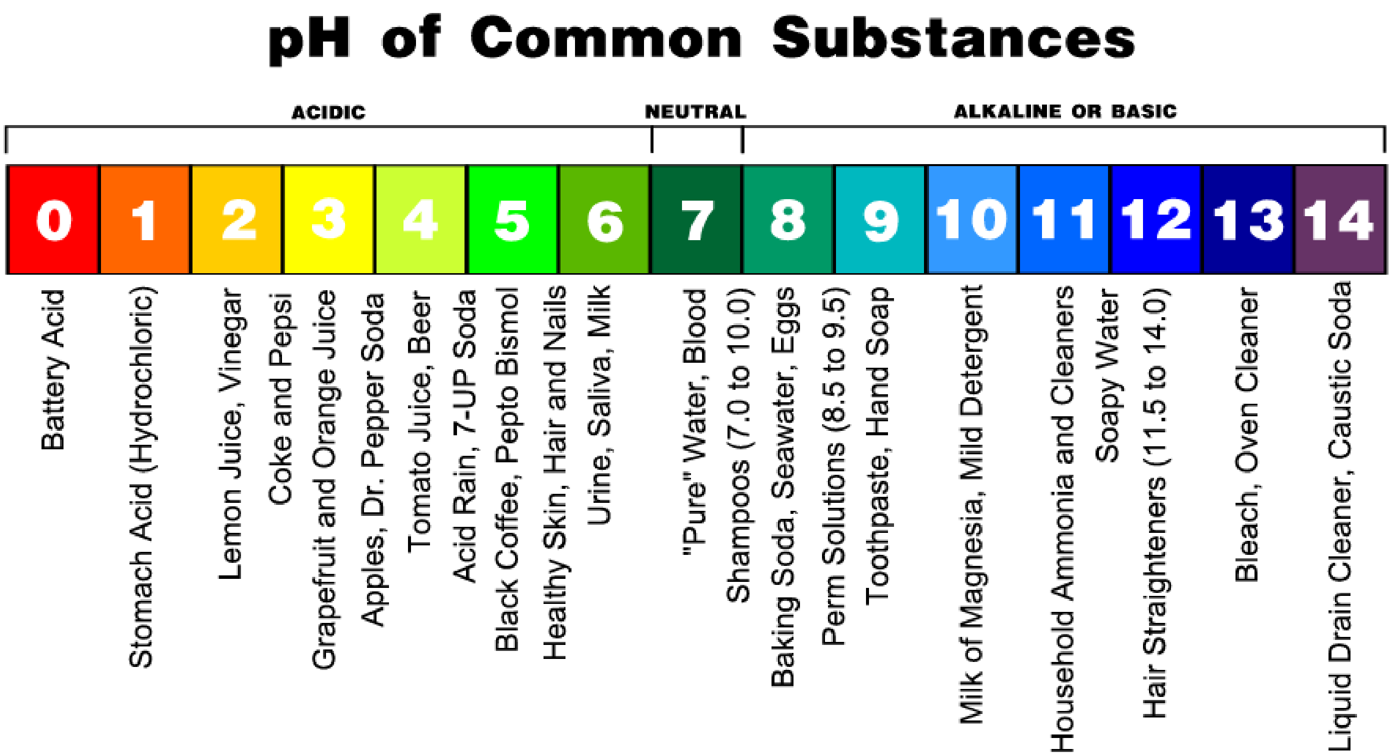
7. $HF(aq) + HSO_3^-(aq) \rightleftarrows F^-(aq) + H_2SO_3(aq)$

8. $HNO_2(aq) + HS^-(aq) \rightleftarrows NO_2^-(aq) + H_2S(aq)$

9. Most of these questions involved drawing tie-lines to see if protons were gained or lost. We were using "Bronsted-Lowry" thinking. All of the bases shown below can gain a proton and so they are all "Bronsted Lowry" bases. Arrhenius saw bases differently though. Circle the bases that Arrhenius would have recognized as bases. (Hint: there are only 3.)

   NH_3 $NaOH$ $C_2H_3O_2^-$ HSO_3^- $Ca(OH)_2$ ClO_4^- KOH H_2NNH_2

pH Scale Notes



What is hydronium? (And how is it created?)

What does the “p” in pH stand for?

What does the “H” in pH stand for?

Examples:

1. Is grapefruit juice or lemon juice more acidic? How many times more acidic?
2. Is ammonia or bleach more basic? How many times more basic?
3. Is toothpaste or milk more acidic? How many times acidic?

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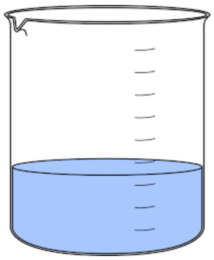
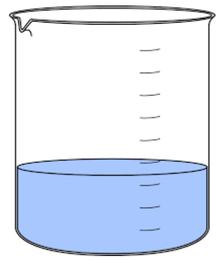
pH Calculation Notes

Goal: To understand how pH is measured and calculated.

Hydrochloric acid (HCl) is like all acids, it dissolve well in water. Using this beaker, draw HCl when it is dissolved in water.



4g of HCl



2g of HCl

Which solution is most acidic?

0.001 M HCl or 0.1 M HI or 0.01M HBr

How do we calculate pH?

Practice:

Solution	Estimate	Actual Calculation
0.02 M HCl	pH ___________________	pH ___________________
0.00034 M HNO_3	pH ___________________	pH ___________________
1.0×10^{-5} M HBr	pH ___________________	pH ___________________
2.2×10^{-6} M HI	pH ___________________	pH ___________________
9.0×10^{-12} M HI	pH ___________________	pH ___________________

Example: What is the pH of a solution when you add 18 g of HCl to 1000 mL of water?

Practice:

1. What is the pH of a solution when you add 0.50 g of HNO_3 to 100 mL of water?

2. What is the pH of a solution when you add 1.2 g of HI to 600 mL of water?

3. What is the pH of a solution when you add 1.2 g of HI and 0.50 g of HNO3 to 300 mL of water?

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Practice Calculating pH 

Find the pH of the following acidic solutions:

1) A 0.001 M solution of HCl (hydrochloric acid).

2) A 0.09 M solution of HBr (hydrobromic acid).

3) A 1.34×10^{-4} M solution of hydrochloric acid.

4) A 2.234×10^{-6} M solution of HI (hydroiodic acid).

5) A 7.98×10^{-2} M solution of HNO_3 (nitric acid).

6) 12 L of a solution containing 1 mole of hydrochloric acid.

7) 735 L of a solution containing 0.34 moles of nitric acid.

8) 1098 L of a solution containing 8.543 moles of hydrobromic acid.

9) 660 L of a solution containing .0074 moles of hydrochloric acid.

10) 120 mL of a solution containing 0.005 grams of hydrochloric acid.

11) 1.2 L of a solution containing 5.0×10^{-4} grams of hydrobromic acid.

12) 2.3 L of a solution containing 4.5 grams of nitric acid.

13) 792 mL of a solution containing 0.344 grams of hydrochloric acid.

14) 100 mL of a solution containing 1.00 grams of nitric acid.

15) 8.7 L of a solution containing 1.1 grams of nitric acid.

16) 1.5 L of a solution containing 5.6 grams of hydroiodic acid.

17) 10.7 L of a solution containing 0.01 grams of hydrochloric acid.

18) 8,000 L of a solution containing 6.7 grams of nitric acid and 4.5 grams of hydrochloric acid.

19) 150,000 L of a solution containing 45 grams of nitric acid and 998 grams of hydrobromic acid.

20) 50 L of a solution containing 0.09 grams of HCl, 0.9 grams of HBr, 9.0 grams of HI, and 90.0 grams of HNO_3.

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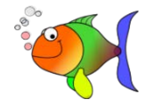
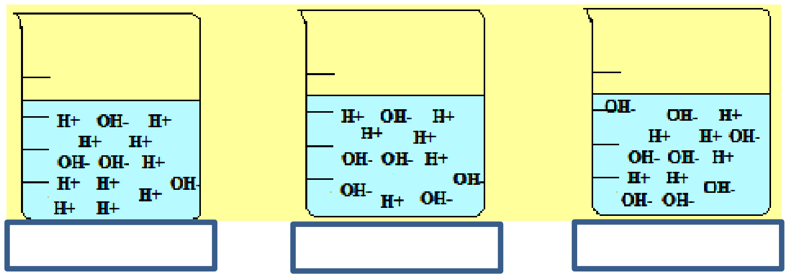
The Relationship Between H⁺ and OH⁻



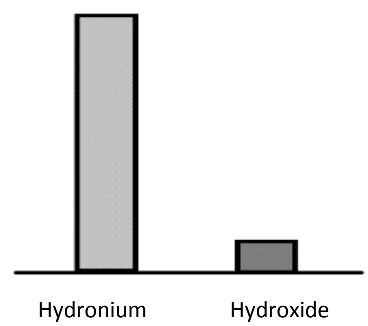
1. Label each solution as neutral, basic, or acidic



2. For the solution that you labeled as neutral, why did you decide that it was neutral?

3. Notice that all three solutions contain acid (H+) and base (OH-). Explain why the basic solution is basic, despite the fact that it contains acid.

4. This graph shows the relative concentration of hydronium and hydroxide in a solution. Determine if the solution is acidic or basic and explain how you determined your answer.

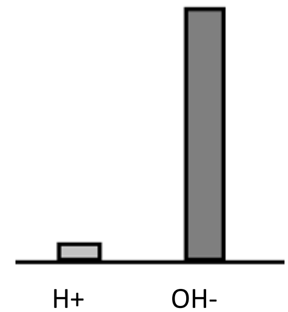


5. A solution is known to have a pH = 8. Which of these must be true? Explain.

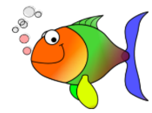
   A. $[H_3O^+] > [OH^-]$
   B. $[H_3O^+] = [OH^-]$
   C. $[H_3O^+] < [OH^-]$

6. When a chemist writes the symbol **$[OH^-]$**, the way they would say the symbol is "*the concentration of hydroxide*". Which *word* in the statement is represented by the brackets in the symbol?

7. The relative concentration of acid and base for a solution is shown below. Given the graph, which would be more likely to be the pH of the solution, pH = 4 or pH = 11? Explain how you know.



8. The graph above was not very accurate. If the graph were to scale, how many times taller would the OH^- bar need to be relative to the H^+ bar given the pH of the solution? (Hint: If the bars would be the same height at pH=7, how many times more basic is the solution than neutral water?)

Finding the pOH of a Solution 

KEY SKILL: Calculating pOH

pOH can be calculated if you know the $[OH^-]$. This is done in the same way that pH is calculated from $[H_3O^+]$ by using the log button on your calculator. This is because:

$$pH = -\log [H_3O^+]$$
$$pOH = -\log [OH^-]$$

Example: A solution of NaOH has a hydroxide concentration of 0.01 M. What is the pOH of the solution?

Answer: pOH = 2 (Try it in your calculator to make sure you agree before going on.)

Calculate the pOH for these solutions:

1. A solution of KOH has a hydroxide concentration of 0.07 M. What is the pOH of the solution?

2. A 60 mL solution contains 0.02 moles of CsOH. What is the pOH of the solution?

3. A 2000 mL solution contains 6 g of NaOH. What is the pOH of the solution?

KEY SKILL: Interconverting pH and pOH

It is <u>not possible</u> to calculate the pOH of the solution in the next question directly:

Example: A solution of HCl has a concentration of 0.01 M. What is the pOH of the solution?

What is different about this question that keeps us from calculating the pOH as we did in question 1? (Hint: What is different about the chemical involved?)

____

____

____

To solve question like the one in the example above, we need to know the following:

pH + pOH = 14

For example: If the pOH = 6.2, then the pH = 7.8 because 6.2 + 7.8 = 14

Fill in the blanks in this table:

SOLUTION	PH	POH	TOTAL
#4	4		= 14
#5		12.3	= 14
#6	9.4		= 14
#7		0.24	= 14

So to solve problems that you cannot calculate directly, it will take two steps:

Example: A solution of HCl has a concentration of 0.01 M. What is the pOH of the solution?

Answer: Use a calculator to convert 0.01 M to pH. pH = 2.00
Now convert to pOH: pH + pOH = 14
2.00 + pOH = 14 pOH = 12.00

8. A solution of **HNO_3** has concentration of 0.12 M. What is the **pOH** of the solution?

9. A solution of **RbOH** has concentration of 0.004 M. What is the **pH** of the solution?

10. A 0.72 L solution contains 0.02 moles of **NaOH**. What is the **pH** of the solution?

11. A 150 mL solution contains 0.3 g of **H_2SO_4**. What is the **pOH** of the solution?

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KEY SKILL: Converting pH back to [H_3O^+]

As you can imagine, if we know the pH of a solution we can find the concentration of that solution.

Example: What is the [H_3O^+] of a solution of HNO_3 that has a pH = 3?

Answer: This one we can figure out without a calculator! 1×10^{-3} M

To use your calculator in examples that have harder numbers, we use the "anti-log" button since we are going the other way this time. For most of you, it will be on the same button as the log button, but will be the "2nd" function of that key. We are looking for the "10x" key. Here is how to plug it in:

- Push the blue or yellow "2nd" button on the top left.
- Push the 10^x button
- Put a (-) sign before the number.
- Then type the number (3 in this case).
- Ask for help if you don't get 1×10^{-3} or .001as your answer.

Solve these questions using the same technique:

12. What is the [H_3O^+] of a solution of HBr that has a pH = 8.4?

13. What is the [H_3O^+] of a solution of sulfuric acid that has a pH = 5.62?

14. What is the [OH^-] of a solution of KOH that has a pOH = 7.4?

15. What is the [OH^-] of a solution of CsOH that has a pOH = 11.3

The next two are a little trickier. What do you need to do to the pH number before converting it to concentration in #16?

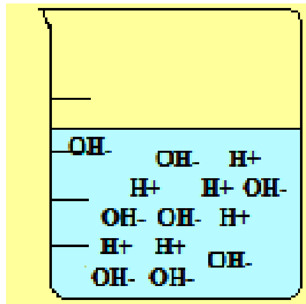
____

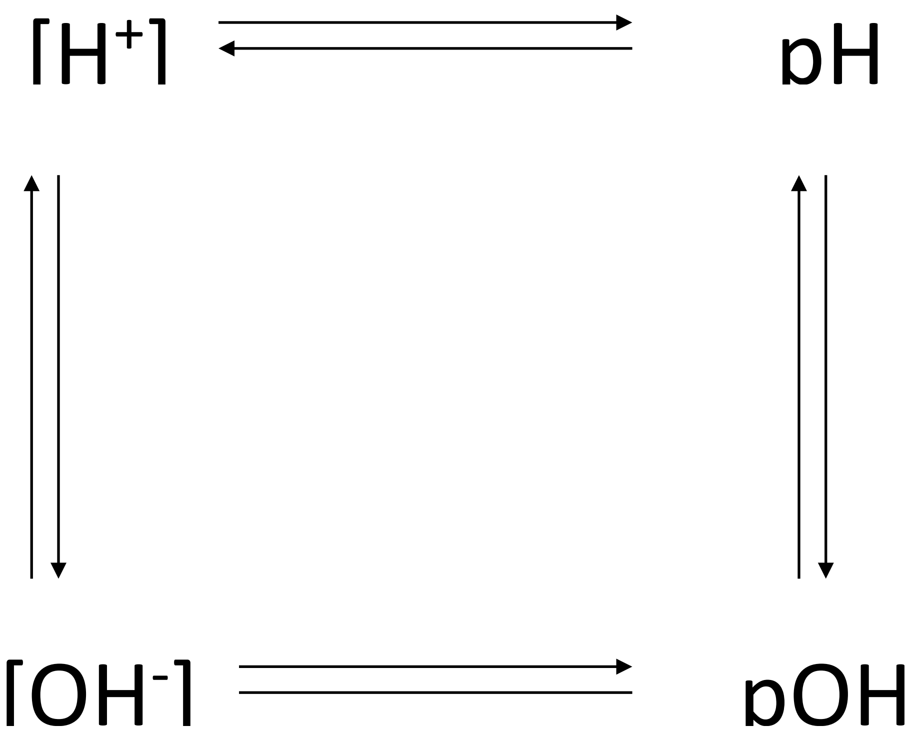
____

16. What is the **[OH^-]** of a solution of NaOH that has a **pH** = 8.15

17. What is the **[H_3O^+]** of a solution of HCl that has a **pOH** = 3.62

4 Ways to Represent a Single Solution





Practice Relating [H+], [OH-], pH, pOH

Show your work for each problem.

1. Determine the pOH of a 0.0034M HNO_3 solution.

2. Determine the pH of a 4.3 x 10^{-4}M NaOH soluton.

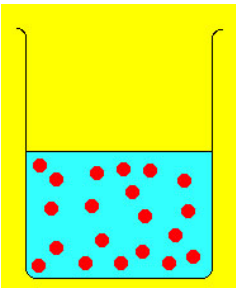
3. A solution has a pH = 4.
    a. Is this solution acidic or basic?
    b. Find the $[OH_-]$ and the $[H_3O^+]$.
    c. Which value was larger, $[OH_-]$ or $[H_3O^+]$? Did this agree with your answer to part (a)?

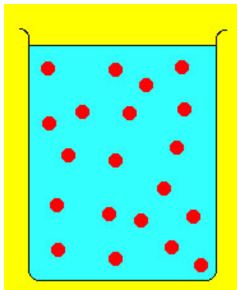
4. A solution has a pOH = 12
    a. Is this solution acidic or basic?
    b. Find the $[OH_-]$ and the $[H_3O^+]$.
    c. Which value was larger, $[OH_-]$ or $[H_3O^+]$? Did this agree with your answer to part (a)?

5. What is the pH and pOH of a solution with a volume of 5400 mL that contains 15 grams of hydrochloric acid and 25 grams of nitric acid?

Changes in pH When a Solution is Diluted

Assume the dots in the beaker represent the H^+ ions of an acidic solution.



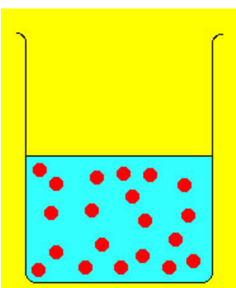


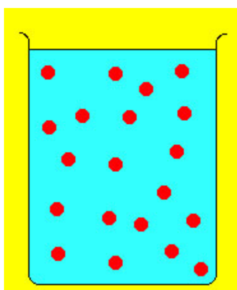
Make a prediction about how the pH will change when water is added to the beaker. Will the pH increase or decrease? Why?

pH = 4

pH=?

Now let's assume the dots in the beaker represent the OH^- ions of a basic solution.





Make a prediction about how the pH will change when water is added to the beaker. Will the pH increase or decrease? Why?

pH = 10

pH=?

When we dilute a solution, what will change during the dilution?

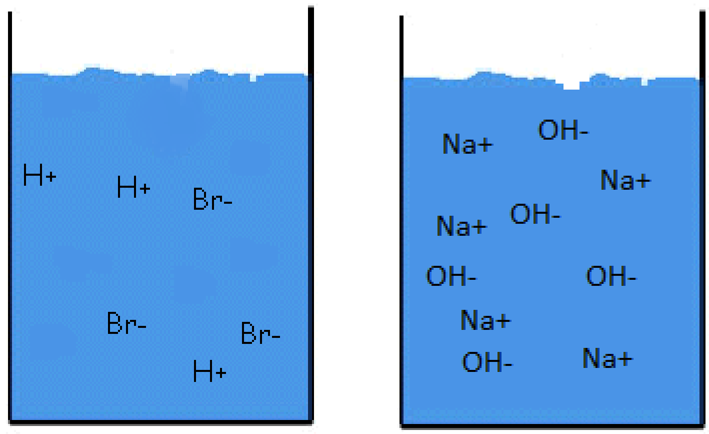
$$M = \frac{moles}{L}$$

Example: A solution with a [H+] = 1 x 10^{-4} M is diluted from 20 mL to 40 mL. What would be the final pH of the solution?

Practice: A solution has 0.500 grams of HCl dissolved in 50.0 mL of water. Find the pH of the solution before and after you dilute it to a final volume of 85.0 mL.

Mixing Acids and Bases

How can we find the pH of the solution after the beakers below are poured together?



3 moles 5 moles

Problem solving strategy when mixing acids and bases:

1. It's a reaction!. What tool should we use? ________________________
2. Figure out whether the acid or base is left over in the reaction!
3. Be cautious when calculating the pH. What do we need to watch out for? _________________________

Example 1: A beaker containing 100. mL of 0.500 M HCl is mixed with a beaker containing 200. mL of 0.200 M KOH. What would be the pOH of the solution?

Practice Mixing Acids and Bases

Hint: Remember to figure your concentration based on the total volume of liquid at the end.

1. **What is the [OH-] of a 10 mL solution that contains 2.6 moles of HCl and 2.8 moles of NaOH?**

2. **What is the pH of a 0.72L solution that contains 0.68 moles of HBr and 0.74 moles of LiOH?**

3. **What is the pH of a 0.20 L, 6.0 M HCl solution after 1.4 moles of solid NaOH have been added?**

4. **Calculate the pH of 50 mL of 0.10 M HCl after addition of 20 mL of 0.1 M NaOH.**

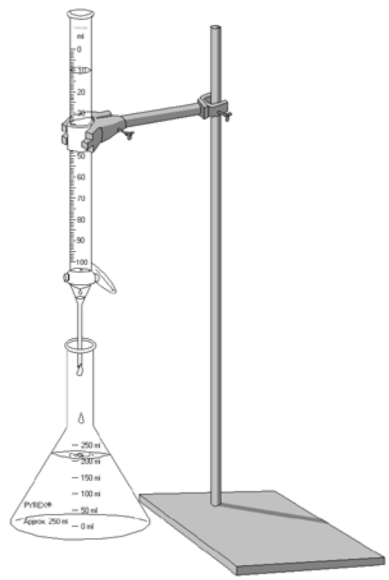
5. **What is the pH when 25.00 mL of 0.112 *M* NaOH has been added to 45.00 mL of 0.016 *M* HCl?**

6. **Calculate the pOH when 49.20 mL of 0.100 *M* NaOH solution have been added to 50.00 mL of 0.100 *M* HCl solution.**

Understanding Titrations 

Why do chemists do titrations?

Label the diagram below with the names of the equipment and other helpful information for when you do a titration.



Define:

- Analyte
- Titrant
- Buret
- Indicator
- End point
- Equivalence point

How should you "prepare" your buret?

1.
2.

Example: A student has 50.0 mL of an acid that is of unknown concentration. They titrate the solution with 0.020 M NaOH. It takes 15 mL of the NaOH to neutralize the acid. What was the concentration of the acid?

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Titration Lab

Goal: We are going to learn the technique of "titration" to determine the concentration of an unknown acid (HCl) solution.

Materials:

- 50 mL buret
- 250 mL Erlenmeyer flask
- HCl solution (unknown concentration)
- 3 drops of Phenolphthalein solution
- 0.05 M NaOH solution (100 mL)*

*Calculate the mass (in grams) of NaOH required to make the last solution in the list. Show your work here:

Background:

Titration allows us to figure out the concentration (M) of an unknown acid because at the equivalence point:

$M_{base}V_{base\ added} = M_{acid}V_{acid\ added}$

Read through the materials and procedure and figure out which of these numbers we already know before we start the titration. Put the numbers in the appropriate place.

$(M_{base}$_______) x $(V_{base\ added}$_______) = $(M_{acid}$_________) x $(V_{acid\ added}$_________)

Circle the part of the equation that we are trying to determine at the end of this titration.

Procedure:

Preparing your buret:

- Burets break easily at the neck or "stopcock" area. Be very careful when moving your buret around.
- Rinse the buret with ~10 mL of your NaOH solution. (*Use a funnel*). Be sure the solution contacts all of the glass in the buret. Why do you think we are doing this:
  ____
  ____
  ____

- *Close the stopcock*, place the buret in the ring stand and fill the buret with the rest of your NaOH solution. (*Use a funnel*). Let 1 mL of the solution out through the stopcock. Why do you think we are letting some flow through? (Watch the inside of the glass tip as you do it.) Explain:
  ____
  ____
  ____
  ____

Fill your 250 mL Erlynmeyer flask:

- Add 10 mL of the unknown HCl solution to the flask.
- Add 2 drops of phenolphthalein.
- Swirl the flask to mix everything.

Conducting your titration:

- Record the initial volume reading on your buret. ____________ (Don't forget to include the correct number of significant figure and units.)
- Note: OUR GOAL IS TO NOT OVER SHOOT THE EQUIVALENCE POINT!!!
- Add the base (the titrant) to the Erlenmeyer flask slowly with constant swirling of the flask. When the solution starts to turn pink, add the solution one drop at a time. Swirl the flask between each drop. Keep adding more as necessary until the solution stays pink while swirling for 1 minute.
- Record the end volume on your buret. _______________
- How do you figure out the volume of base use? Show your work:

- You now have everything that you need to finish your calculations! Go back up to the calculation and plug in the missing values and solve for the concentration of the unknown acid. When you know the concentration of the unknown acid, record it here and put units on the answer.
  ____

Waste disposal:

- All liquids can go down the drain with running water.

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Titration Calculation Practice

1) If it takes 54 mL of 0.1 M NaOH to neutralize 125 mL of an HCl solution, what is the concentration of the HCl?

2) If it takes 25 mL of 0.05 M HCl to neutralize 345 mL of NaOH solution, what is the concentration of the NaOH solution?

3) If it takes 50 mL of 0.5 M KOH solution to completely neutralize 125 mL of sulfuric acid solution (H_2SO_4), what is the concentration of the H_2SO_4 solution?

4) Can I titrate a solution of unknown concentration with another solution of unknown concentration and still get a meaningful answer? Explain your answer in a few sentences.

5) Explain the difference between an endpoint and equivalence point in a titration.

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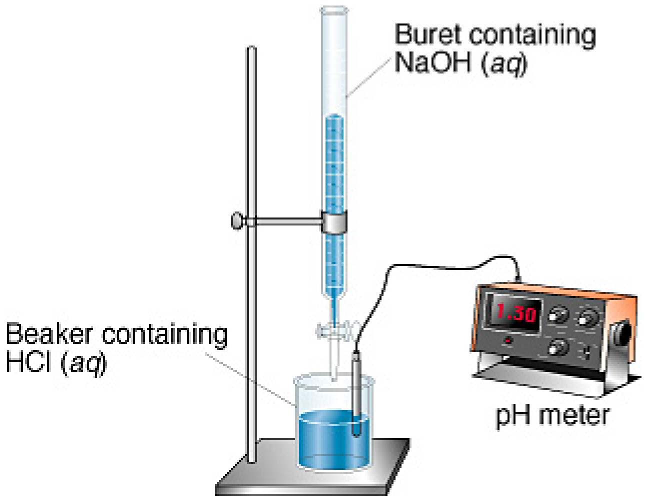
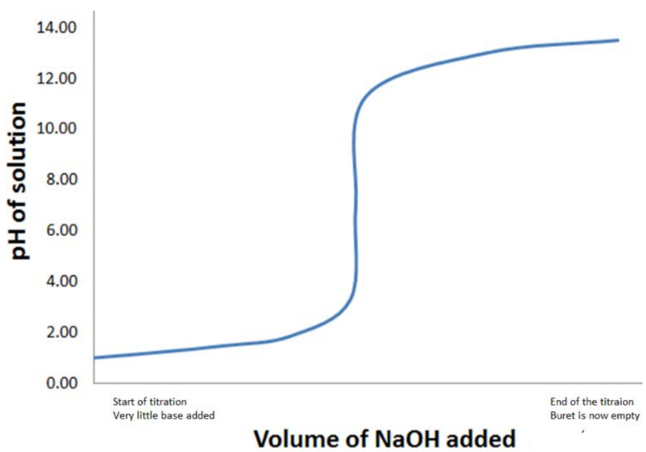
Titration Curves 

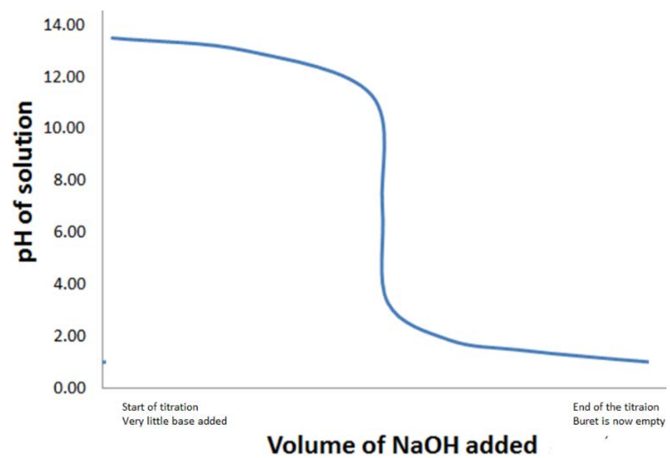
A student decides to monitor a titration by putting a pH meter in the beaker as shown below.



A pH meter or pH probe instantly shows the pH of the solution. As the pH changes, the meter will reflect those changes.

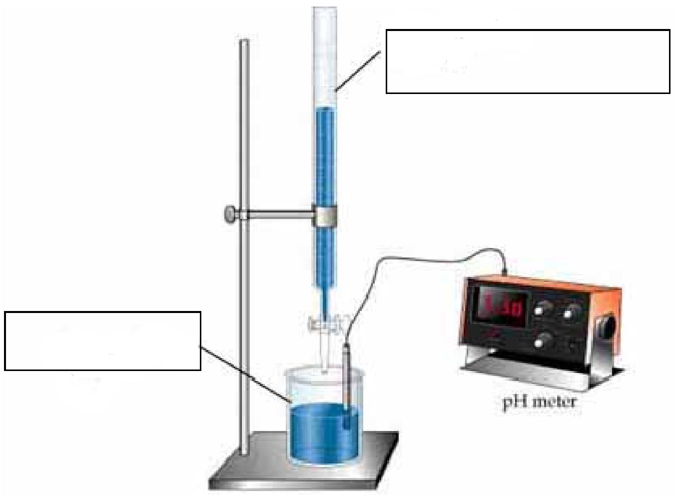
Which of the graphs below do you think is the one that the student actually saw as they plotted the pH changes over time? (Explain your thinking.)

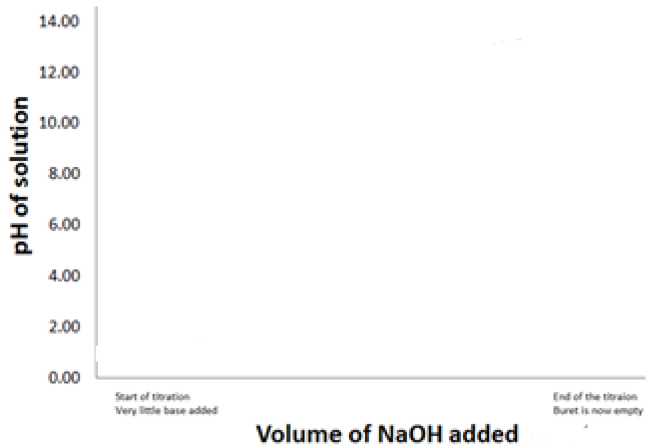




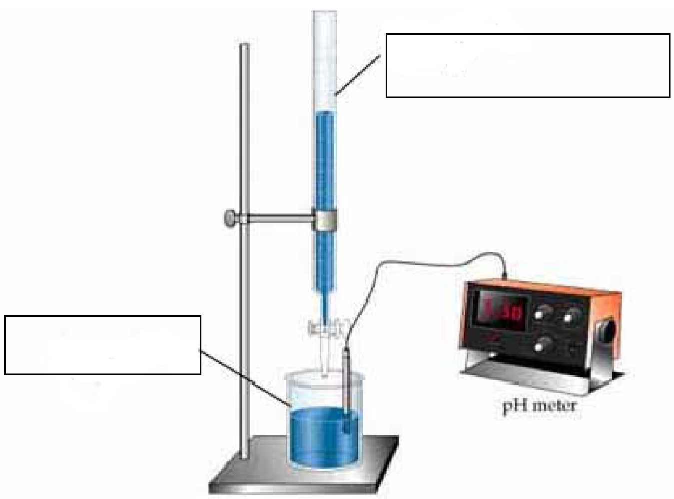
How do we find the equivalence point of the titration?

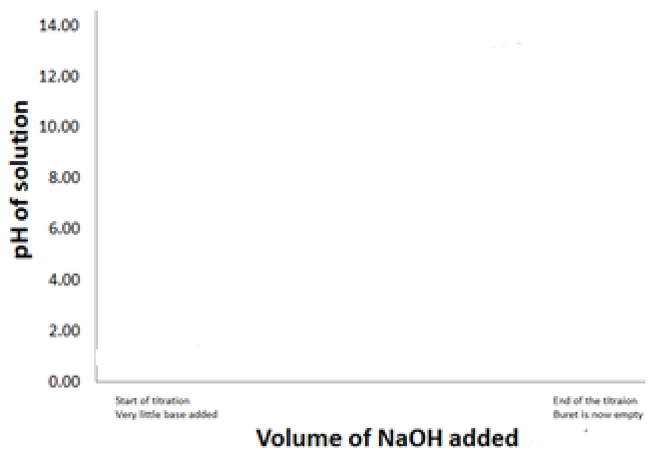
A student wants *to titrate a strong base (KOH) with a weak acid (HF)*. Label the titration apparatus below showing where the chemicals go. (Write KOH in one box and HF in another.) Then draw a rough sketch of the titration curve.





A student wants *to titrate a weak base (NH_3) with a strong acid (HNO_3)*. Label the titration apparatus below showing where the chemicals go. (Write KOH in one box and HF in another.) Then draw a rough sketch of the titration curve.

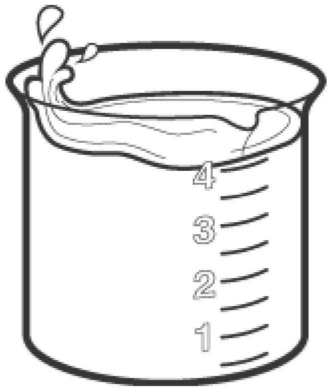




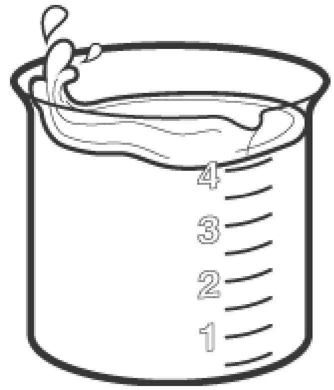
Other than a strong acid- strong base titration, what is the only other scenario that will produce an equivalence point with pH=7? Draw the titration curve to explain your answer.

Strong Versus Weak Acids

What makes an acid strong while another is weak?

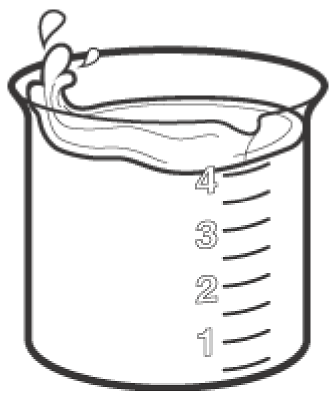


HCl

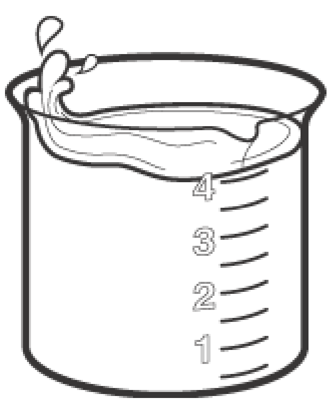


$HC_2H_3O_2$

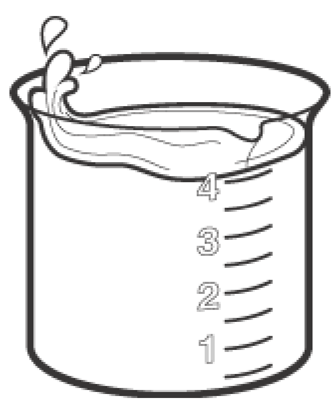
Look up HF on your acid base chart to see if it is strong or weak, then draw a good representation of it in this beaker.



NaOH is a strong base, whereas Mg(OH)2 is a weak base. How should we represent the ions for each solution?



NaOH



Mg(OH)2

Conductivity: A solution that conducts electricity is a considered an electrolyte.

What is required for a solution to conduct electricity?

Do strong acids or weak acids conduct electricity well?

Do strong bases or weak bases conduct electricity well?

Which of these would be a good **electrolyte**?

$HClO_3$ NH_3 KOH $Sr(OH)_2$ HI HF