XIV) Titrations

January 17, 2018 11:11 PM

[Titration introduction | Chemistry | Khan Academy](https://www.khanacademy.org/science/chemistry/acid-base-equilibrium/titrations/v/titration-introduction)

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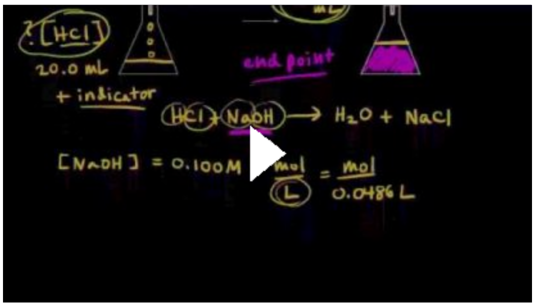

[How to do titrations | Chemistry for All | FuseSchool]

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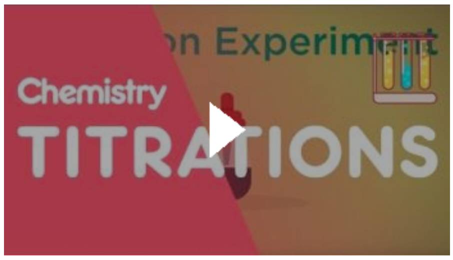

XIV) Titrations

A **titration** is a laboratory technique that is most often used to find the concentration (molarity) of a solution. Acid/base titrations are a common type of titration in which a base is used to find an unknown acid (or base) concentration, or *visa versa*.

Suppose you are cleaning up the lab and you find a large container labeled 'hydrochloric acid', but the concentration is not given. A Titration can be done to find the unknown concentration.

Titration is a process (laboratory procedure and calculations) for determining the concentration of a substance accurately and precisely using a measurable volume of a standardized solution. A standardized solution is simply a reactant of known concentration. (the one that we create / prepare)

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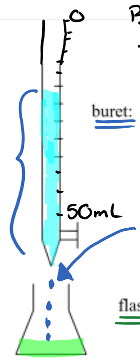
[Acid-Base Titration]

The standardized solution (or **titrant**) used to find the concentration of hydrochloric acid would be a strong base, such as NaOH solution. The volume of NaOH added to the acid solution would be measured using a skinny tube called a **buret**.

Burette incraments increase Top → bottom ∴ must be read from top down. Volume used is the difference between V_i and V_f.



0.10M NaOH

buret: • standardized solution (known concentration) • keep an accurate record of volume used.

Added slowly, drop by drop.

10.00mL unknown [conc.] HCl

flask: • contain the unknown [conc.] solution • known volume
∗ also contain an indicator

The flask contains a measured volume of the solution of unknown concentration, in this case 10.00mL of $HCl_{(aq)}$, and the buret contains a standardized base, in this case 0.10M $NaOH_{(aq)}$.

The flask contains a measured volume of the solution of unknown concentration, in this case 10.00mL of $HCl_{(aq)}$, and the buret contains a standardized base, in this case 0.10M $NaOH_{(aq)}$.

The standardized base is added from the buret to the flask. The OH^- from the buret reacts with the H_3O^+ from the flask to produce water. This continues until the equivalence point is reached, the point at which moles of H_3O^+ = moles of OH^-.

indicator is use to help visualize this point.

At this point, what is in the flask? neutral solution : water + salt

$HCl + NaOH \rightarrow H_2O + NaCl$

For a strong acid/strong base titration, such as the example we are investigating, the pH at the equivalence point is 7.

*How do you know when the equivalence point has been reached in an acid/base titration?

An indicator is used to help visually determine when the

eg. phenolpthalein, bromothymol blue, methyl orange, etc....

equivalence point has been reached in an acid/base titration. The indicator changes colour at or very near the equivalence point, signaling an end to the titration. When an indicator changes colour, it's called the endpoint, or transition point, and this is what signals that the (pH) **equivalence point** (neutralized) has been reached.

(The chemistry of indicators will be studied in the Acid/Base II unit.) ...coming soon!

Since at the equivalence point, moles of OH^- = moles of H_3O^+, if we can calculate the moles of OH^- that vacated the buret, it will be equal to the moles of H_3O^+ that were originally in the flask (since H_3O^+ and OH^- react one to one). The [NaOH] = 0.10M, and we kept track of the volume of NaOH that vacated the buret (using the scale on the buret), therefore we can find the moles of OH^- that went into the flask. If we stop the titration at the equivalence point, the moles of OH^- that went into the flask will be equal to the moles of H_3O^+ in the flask. Since we know the original volume of H_3O^+ in the **flask**, we can calculate the unknown [HCl] on the next page:

volume used (burette)

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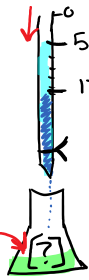

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5.24mL (start volume)

17.87mL (end)

HCl

Volume of NaOH used?

17.87mL − 5.24mL = 12.63mL NaOH used

$NaOH \rightarrow Na^+ + OH^-$

0.10M 0.10M

How may moles of OH^- were used? $c = \frac{n}{v}$

mol OH^- = (0.10M)(0.01263L) = 1.263×10^{-3} mol

*@ equivalence point = neutralized = mol OH^- = mol H_3O^+

∴ must have been 1.263×10^{-3} mol H_3O^+ originally in the flask.

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$ (same) 1.263×10^{-3} mol

$[HCl] = \frac{1.263 \times 10^{-3} mol}{(0.01000L)} = \boxed{0.13M}$

original volume of unknown [?] acid.

Now, the HCl solution is standardized, as we know the concentration.

Practice Questions:

unknown base.

1. A 10.00mL sample of an unknown concentration of $LiOH_{(aq)}$ is titrated using 23.62mL of 0.150M HNO_3. Determine [LiOH].

in burette.

$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$

0.150M ∴ 0.150M

mols of H_3O^+ used = (0.150M)(0.02362L)

*at equivalence point mol OH^- = mol H_3O^+

∴ mol OH^- = 0.003543

$LiOH \rightarrow Li^+ + OH^-$

∴ 0.003543

$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$
0.150M ∴ 0.150M

mols of H_3O^+ used $= (0.150M)(0.02362L)$
$= 0.003543$ mol

∴ mol $OH^- = 0.003543$
$LiOH \rightarrow Li^+ + OH^-$
∴ 0.003543

$$\boxed{[LiOH] = \frac{0.003543\text{ mol}}{0.01000L} = 0.354M}$$

Base

2. 37.86mL of 0.250M NaOH was required to neutralize a 20.0mL sample of HF. Calculate the [HF]. *Even though HF is a weak acid and in water it will only dissociate under 5%, in the presence of a strong base such as NaOH, it will react 100%.

→ titrating to the equivalence point*

mol OH^- = mol H_3O^+
neutralized

$NaOH \rightarrow Na^+ + OH^-$
0.250M ∴ 0.250M

mol of OH^- used $= (0.250M)(0.03786L)$
$= 9.465\times10^{-3}$ mol

neutralized.

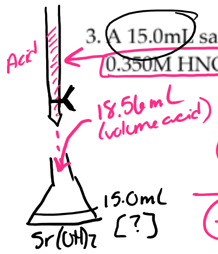
@ equivalence point mol OH^- = mol H_3O^+

∴ mol of H_3O^+ originally in flask $= 9.465\times10^{-3}$ mol

$HF + H_2O \rightarrow H_3O^+ + F^-$
equal
mol

$$[HF] = \frac{9.465\times10^{-3}\text{ mol}}{0.0200L} \rightarrow 0.473M\ HF$$

volume of acid



3. A 15.0mL sample of unknown $[Sr(OH)_2]$ was titrated using 18.56mL of 0.350M HNO_3. Find $[Sr(OH)_2]$.

$HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$
0.350M ∴ 0.350M

⇒ mol $H_3O^+ = (0.350M)(0.01856L)$
$= 0.006496$ mol H_3O^+

×

÷

@ equivalence point mol OH^- = mol H_3O^+

∴ 0.006496 mol of OH^-

$Sr(OH)_2 \rightarrow Sr^{2+} + 2OH^-$
0.003248 ÷2 0.006496 mol

$$\boxed{[Sr(OH)_2] = \frac{0.003248\text{ mol}}{0.0150L} = 0.217\ M}$$

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*Don't forget to write dissoc. equat. + Balance!! :)

* Any stoichiometry before equivalence point (x) multiply
after " " (÷) divide

4. 50.78mL of 0.020M $Ba(OH)_2$ was required to neutralize a 30.0mL sample of H_2SO_4. Find $[H_2SO_4]$. ? = M

$Ba(OH)_2 \rightarrow Ba^{2+} + 2OH^-$
0.020M ×2 0.040M

∴ mol OH^- = (0.040M)(0.05078L)
= 0.00203

∴ $[H_2SO_4]$ = $\frac{0.001016 \text{mol}}{0.03000L}$ = 0.034M

@ equivalence point
mol OH^- = mol H_3O^+
∴ mol H_3O^+ = 0.00203

$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$
0.001016 ÷2 0.00203

$H_2SO_4 \rightarrow H^+ + HSO_4^-$
$HSO_4^- \rightarrow H^+ + SO_4^-$
*reacts fully. can be no acid remaining (HSO_4^-) if solution is neutralized by OH^-

Assignment 12: Titration Exercises

1. Find the concentration of an HCl solution if 25.00mL is titrated with 28.46mL of a 0.105M standardized solution of NaOH.
2. You titrated a 30.0mL solution of HNO_3 with 23.75mL of a 0.25M standardized solution of KOH. What is the $[HNO_3]$?
3. A 35.00mL unknown solution of LiOH is titrated with 17.67mL of 0.200M HI. What is the [LiOH]?
4. A 24.00mL sample of H_2SO_4 is titrated with 32.43mL of 0.150M NaOH solution. Find $[H_2SO_4]$.
5. A 40.00mL sample of $Ca(OH)_2$ is titrated with 16.55mL of 0.100M HCl. Find $[Ca(OH)_2]$.
6. A 20.00mL sample of H_3PO_4 is titrated with 25.76 mL of a 0.100M $Ba(OH)_2$ solution. Find $[H_3PO_4]$.

Making Standardized Solutions

How could you make 1.0L of a 0.50M solution of NaOH in the lab? NaOH originates as solid white pellets.