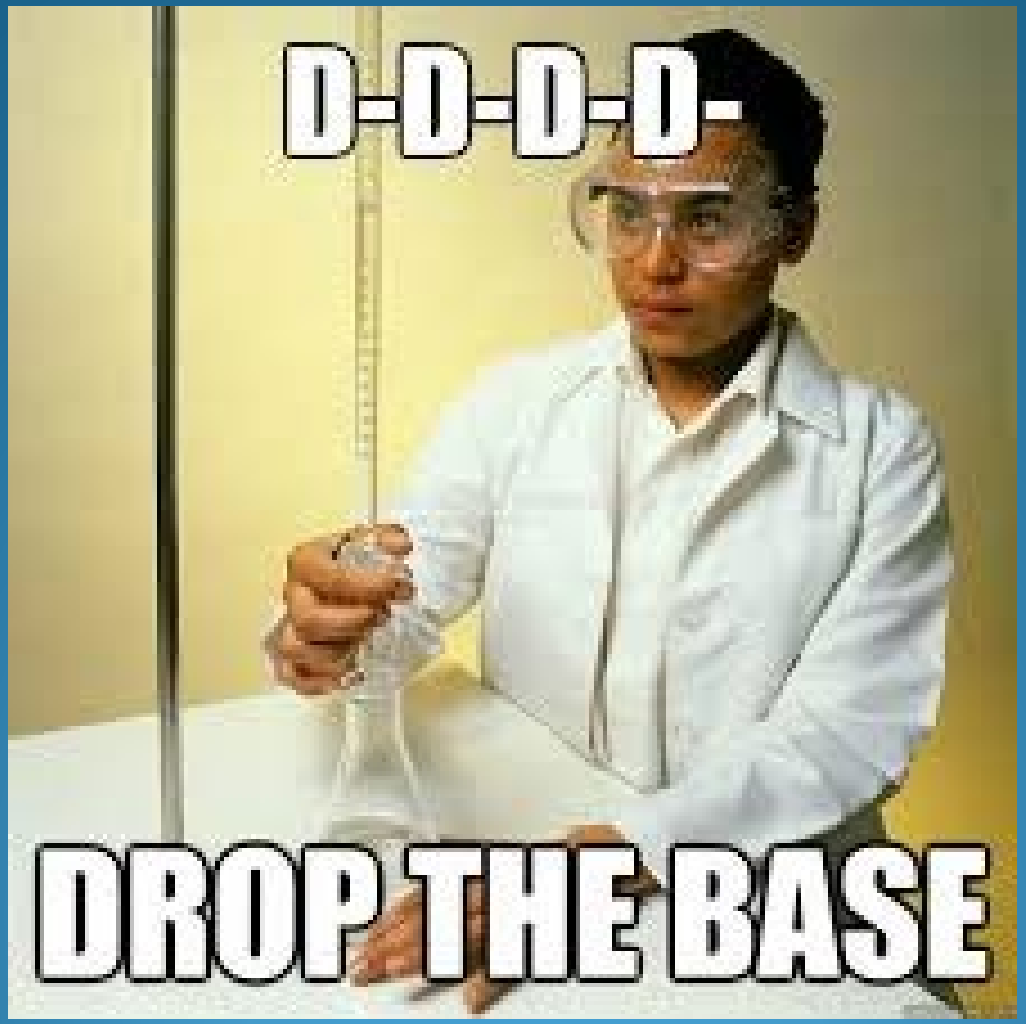
Acid Base Titration



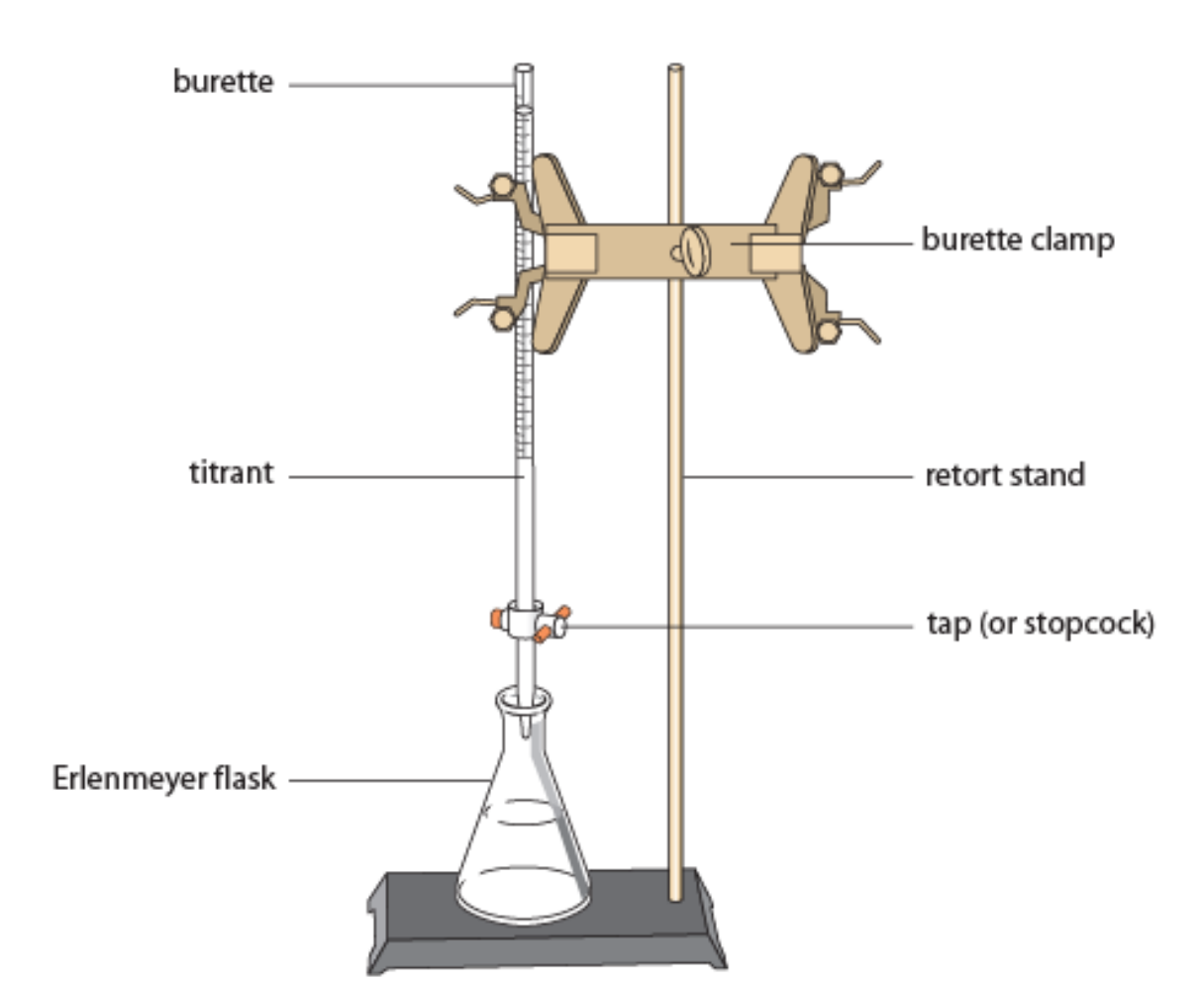
Curriculum

- perform a titration using a strong monoprotic acid and a strong monoprotic base
- use titration data to determine the concentration of a strong acid or a strong base
- use appropriate scientific conventions when communicating solutions to titration problems

Titration

- **Titration** is a technique that chemists use to find concentration
- Titrations always contain 1 solution of known concentration called **standard solution**
- The solution that is being added and its volume measured is called the **titrant**
- The titrant solution is the standard solution and added to the unknown solution

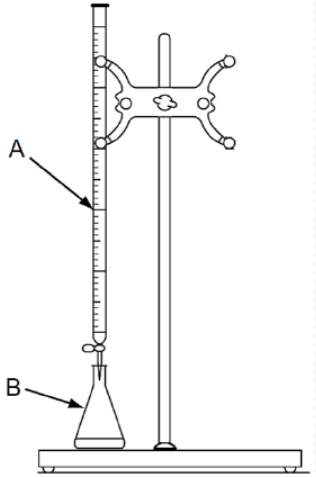
Titration Apparatus



Titration

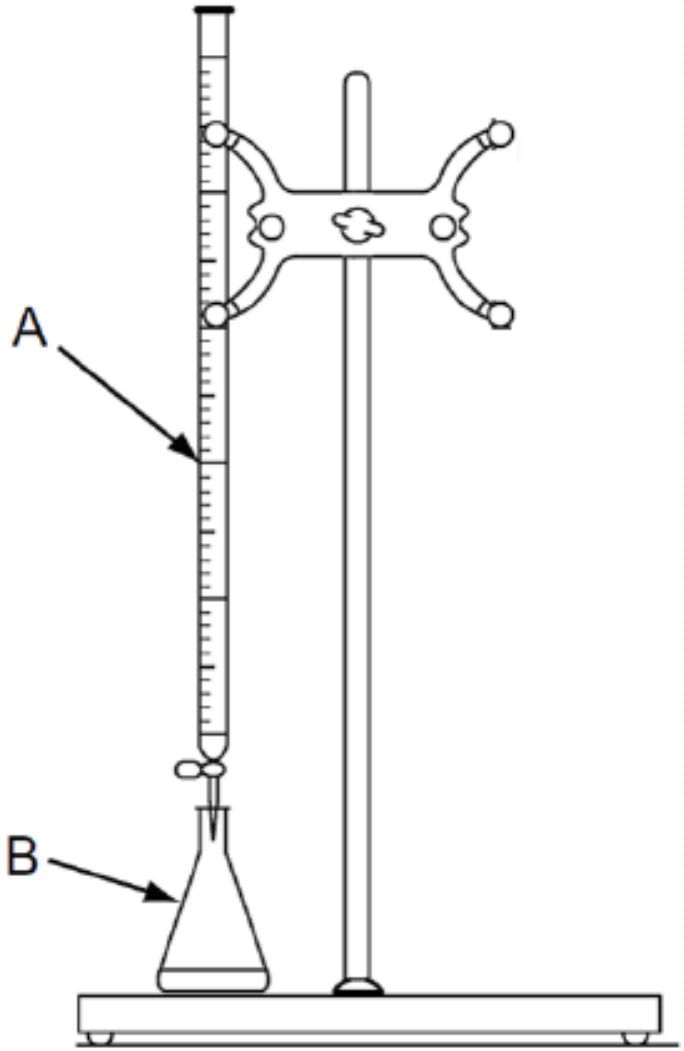
- The stage of the titration where the reaction is complete is called the **equivalence point**
- The equivalence point occurs when stoichiometrically equivalent amounts of the reactant have been used
- An indicator is used to determine when the reaction is over which is called the **endpoint (when we get the color change)**
- The endpoint is when a dramatic color change happens

How to do a titration

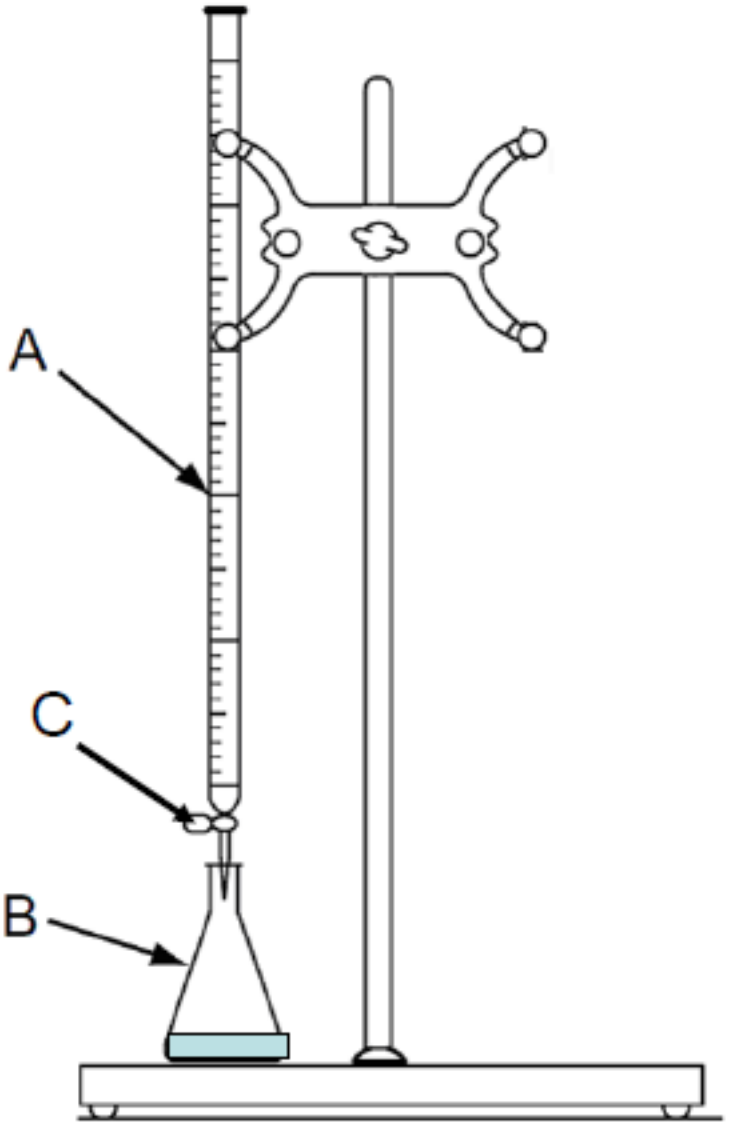


How to do a titration:

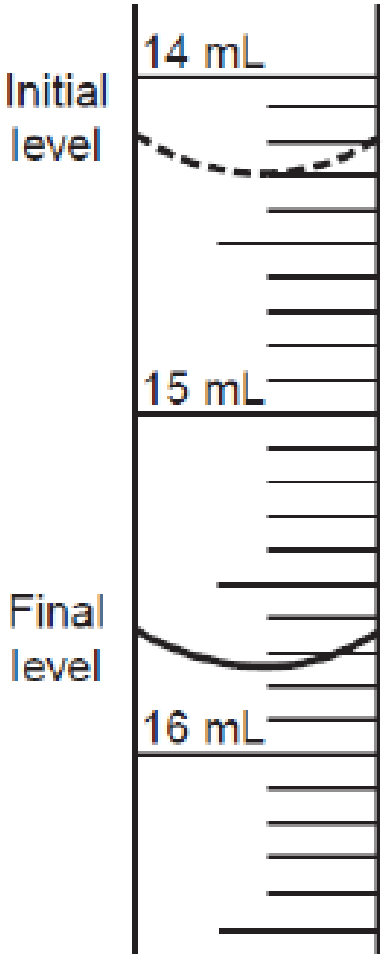
- Fill buret (A) with known concentration solution
- Place known volume of other solution in flask (B) (unknown concentration)
- Add a few drops of indicator to B



- Record initial amount of solution in A
- Open stopcock (C)
- Swirl flask
- Close (C) when indicator changes colour permanently (a very faint change)
- Record final amount in (A)



How to read a buret



- Read the bottom of the curved portion (meniscus)
- Initial level 14.30 mL
- Final level 15.75 mL
- Volume used = 1.45 mL

https://youtu.be/YDzzMcrdyB4

- Titration video

The Equivalence Point

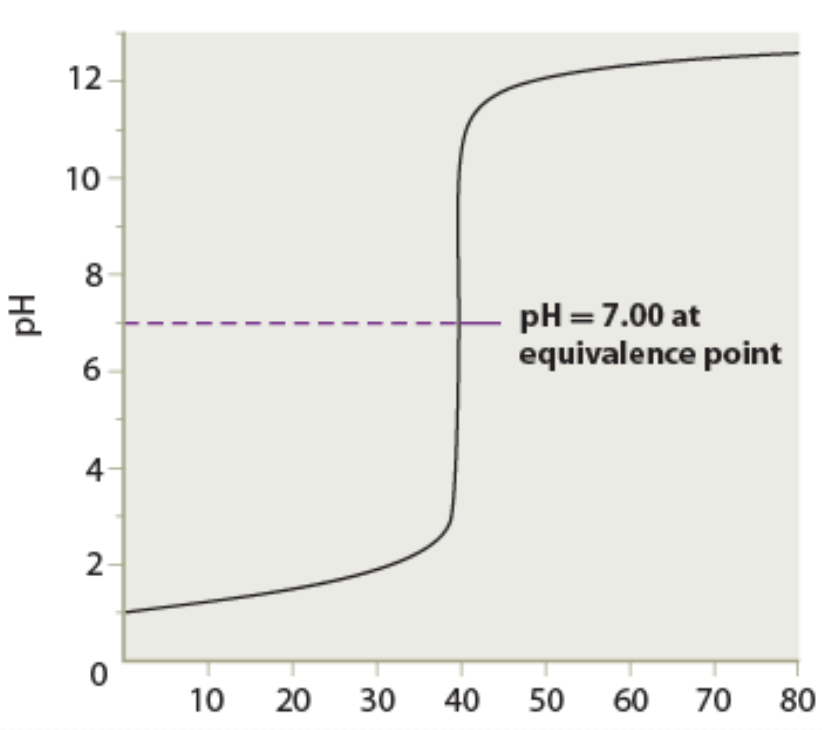
- In an acid-base titration of monoprotic acids and bases, the equivalence point is reached when the number of moles of acid and base is equal

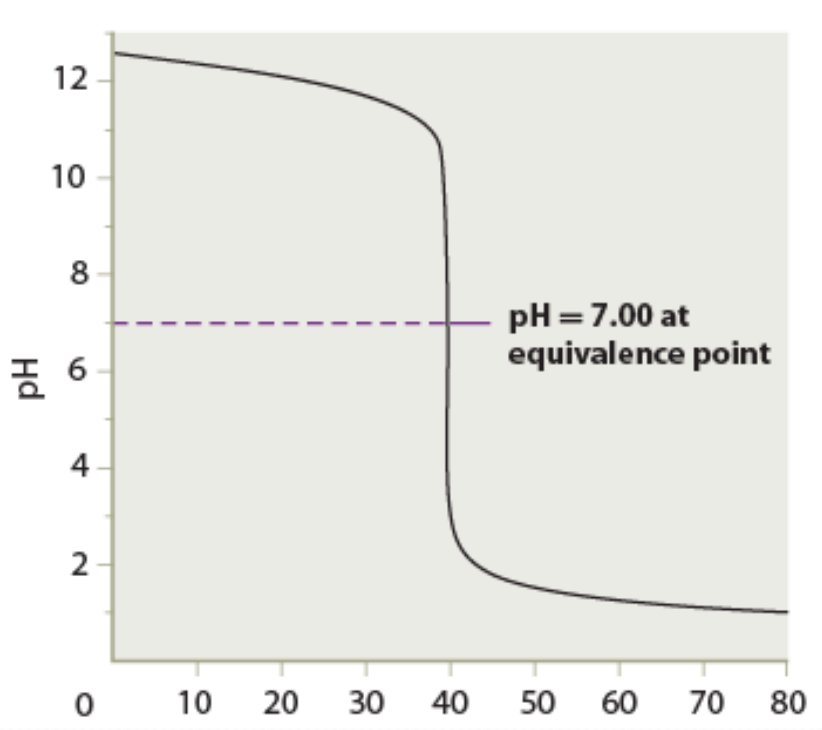
$$HCl(aq) + NaOH(aq) \rightarrow H_2O(\ell) + NaCl(aq)$$

- When the equivalence point is reached, the pH will be 7 which means all of the HCl is neutralized by the NaOH
- There are no extra hydronium or hydroxide ions

Acid-Base Titration Curves

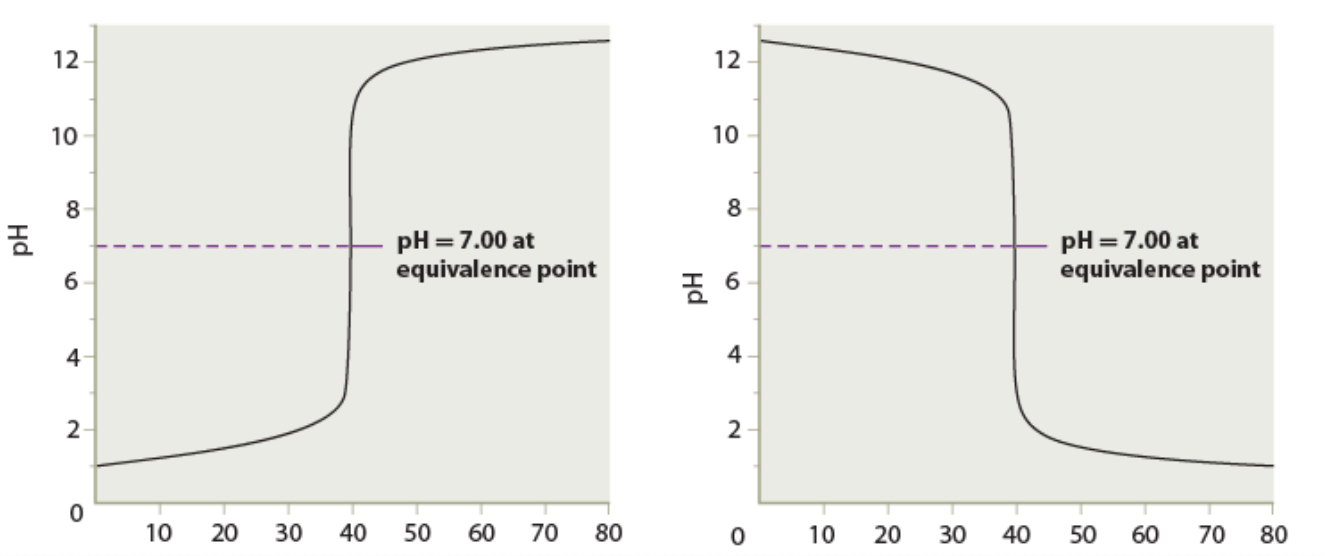
- A plot of the pH of the reaction mixture vs. volume is called a **pH titration curve**



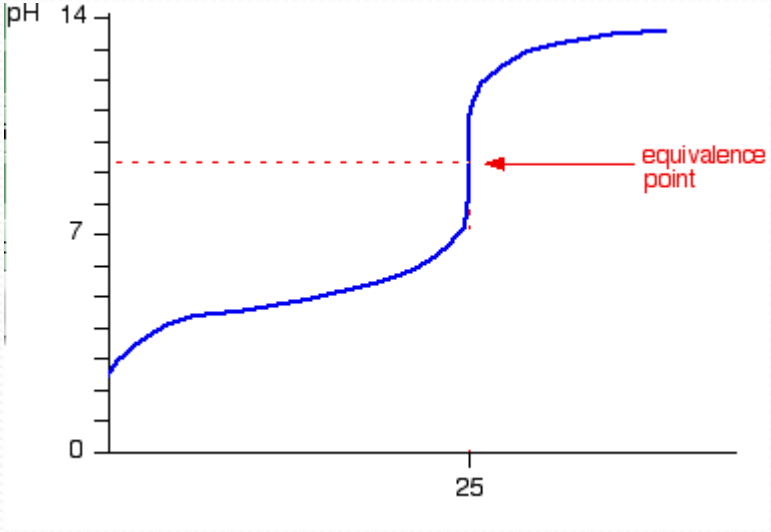


Acid-Base Titration Curves

- Next to the equivalence point the pH changes very rapidly
- If you add just an extra drop of acid or base you can change the pH significantly



Buffer Region



- Buffering region is where the pH does not change very much

$$CH_3COO^- + H_3O^+ \Leftrightarrow$$

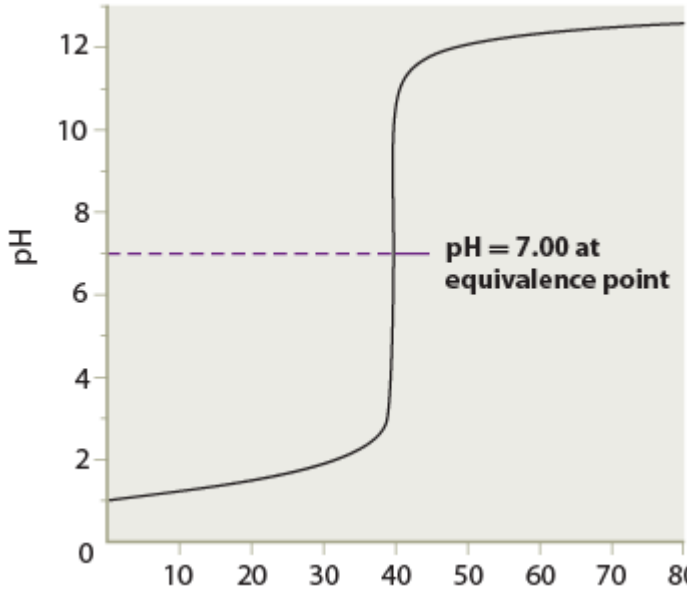
Buffer Capacity

- **Buffer capacity** refers to the amount of acid or base that you can add to a buffer before it is all consumed
- After the buffer capacity has been reached, there is a sharp incline in pH
- How would you increase the buffer capacity?

The goal of a buffer is to keep the pH of a solution within a narrow range.

Choosing an Indicator

- When choosing an indicator you want to choose one that is within the area of steepness



Acid–Base Indicators at 25°C

Indicator	Abbreviation (acid/conjugate base)	pH Range	Colour Change as pH Increases
methyl violet	$HMv(aq) / Mv^-(aq)$	0.0 – 1.6	yellow to blue
thymol blue	$H_2Tb(aq) / HTb^-(aq)$	1.2 – 2.8	red to yellow
thymol blue	$HTb^-(aq) / Tb^{2-}(aq)$	8.0 – 9.6	yellow to blue
orange IV	$HOr(aq) / Or^-(aq)$	1.4 – 2.8	red to yellow
methyl orange	$HMo(aq) / Mo^-(aq)$	3.2 – 4.4	red to yellow
bromocresol green	$HBg(aq) / Bg^-(aq)$	3.8 – 5.4	yellow to blue
litmus	$HLt(aq) / Lt^-(aq)$	4.5 – 8.3	red to blue
methyl red	$HMr(aq) / Mr^-(aq)$	4.8 – 6.0	red to yellow
chlorophenol red	$HCh(aq) / Ch^-(aq)$	5.2 – 6.8	yellow to red
bromothymol blue	$HBb(aq) / Bb^-(aq)$	6.0 – 7.6	yellow to blue
phenol red	$HPr(aq) / Pr^-(aq)$	6.6 – 8.0	yellow to red
phenolphthalein	$HPh(aq) / Ph^-(aq)$	8.2 – 10.0	colourless to pink
thymolphthalein	$HTh(aq) / Th^-(aq)$	9.4 – 10.6	colourless to blue
alizarin yellow R	$HAy(aq) / Ay^-(aq)$	10.1 – 12.0	yellow to red
indigo carmine	$HIc(aq) / Ic^-(aq)$	11.4 – 13.0	blue to yellow
1,3,5–trinitrobenzene	$HNb(aq) / Nb^-(aq)$	12.0 – 14.0	colourless to orange

Using a Burette

- You will record a chart in your observations like this:

Volumes of 0.06649 mol/L NaOH(aq) Added to 10.00 mL Samples of HCl(aq)

Trial #	1	2	3	4
Final burette volume (± 0.1 mL)				
Initial burette volume (± 0.1 mL)				
volume change				
Indicator colour at endpoint				

- Your initial volume does not have to be at zero
- You want to get 3 readings within 0.1 mL of each other

Steps for solving solution stoichiometry problems

1. Write a complete balanced equation
2. Write information given under each chemical substance
3. Rearrange $C_1V_1=C_2V_2$
4. Solve for unknown substance

Example

- What is the minimum volume of 0.250 mol/L $HNO_3(aq)$ needed to neutralize in a 60mL solution of 0.300 mol/L NaOH(aq)

$C_1V_1 = c_2v_2$

$0.250 \times V_1 = 0.300 \times 60$

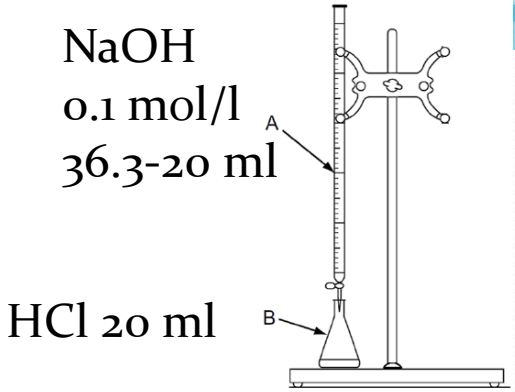
$= 72$ mL

Board Question

- What is the concentration of hydrochloric acid when 13.3 mL of acid is needed to neutralize 10.00 mL of a 0.100 mol/L potassium hydroxide solution?

- = 0.075 mol/L

Example



A student titrates 20.00 mL of a solution of hydrochloric acid, HCl(aq), with 0.1000 mol/L NaOH(aq). The initial reading of the burette is 0.20 mL. At the endpoint, the burette reads 36.30 mL. What is the concentration of the hydrochloric acid?

0.0815 mol/l

Sample Diploma Problem

Use the following information to answer numerical-response question 2.

In order to accurately determine the concentration of hydronium ions, $[H_3O^+(aq)]$, in a sample of lake water, an environmental scientist conducted a titration experiment in which the lake water was titrated with a known concentration of NaOH(aq). Bromothymol blue indicator was used.

Steps in a Titration

1 Take final reading of burette
2 Take initial reading of the burette
3 Titrate until the indicator changes colour
4 Pipette 10.00 mL of lake water into the Erlenmeyer flask

Numerical Response

4, 2, 3, 1 OR 2, 4, 3, 1

2. To properly complete the titration, the order of the steps numbered above is _____, _____, _____, and _____. (There is more than one correct answer.)

(Record all **four digits** of your answer in the response boxes at the bottom of the screen.)

Use the following information to answer question 6.

A solution of hydrochloric acid, HCl(aq), was titrated with a solution containing sodium hydroxide, NaOH(aq). Students recorded the following data.

	Trial 1	Trial 2	Trial 3
Volume of NaOH(aq) used in each trial (mL)	48.1	48.0	48.2
Average volume of NaOH(aq) used (mL)	48.1		
Concentration of NaOH(aq) in burette (mol/L)	0.100		
Volume of HCl(aq) in Erylenmeyer flask for each trial (mL)	25.0		

6. According to the data above, the concentration of the hydrochloric acid solution is

A. 5.20×10^{-2} mol/L
B. 1.92×10^{-1} mol/L
C. 5.77×10^{-1} mol/L
D. 1.20×10^{4} mol/L

$NaOH + HCl \rightarrow H_2O + NaCl$

$C_1 = 0.1$ $C_2 = ?$

$V_1 = 48.1$ $V_2 = 25$

0.1924

Sample Diploma Problem

$NaOH + HNO_3 \rightarrow H_2O + NANO_3$

$C_1 = 5.28 \times 10^{-2}$ $C = ?$

$V = 1.75$ $V_2 = 4.25$

Numerical Response

3. If 1.75 L of a sodium hydroxide solution with a molar concentration of 5.28×10^{-2} mol/L is required to neutralize 4.25 L of a nitric acid solution, then the concentration of hydronium ions, $[H_3O^+(aq)]$, in the acid solution is _____ $\times 10^{-2}$ mol/L.

(Record your **three-digit answer** in the response boxes at the bottom of the screen.)

2.17

Use the following information to answer question 9.

Students performed a titration experiment to determine the relative acidity of four brands of salt-and-vinegar-flavoured potato chips. They weighed out 10.0 g of each brand of potato chip and added the chips to 100 mL of distilled water to allow the vinegar (acetic acid) on the chips to dissolve in the water. They performed three titration trials, using 20.0 mL of the chip-vinegar solution per trial, and 0.01 mol/L of sodium hydroxide, NaOH(aq), as the titrant. The results of their experiment are shown below.

	Volume of 0.01 mol/L NaOH(aq) Titrant Used (mL)		
Chip Brand	**Trial I**	**Trial II**	**Trial III**
1	12.5	13.0	12.7
2	9.0	9.1	9.4
3	49.8	50.0	49.7
4	22.6	22.8	23.0

9. Which of the following rows identifies the manipulated variable and the responding variable in the titration experiment above?

Row	**Manipulated Variable**	**Responding Variable**
A.	Volume of titrant used	Acidity of solution
B.	Volume of titrant used	Mass of potato chips
C.	Brand of potato chip	Acidity of solution
D.	Brand of potato chip	Mass of potato chips