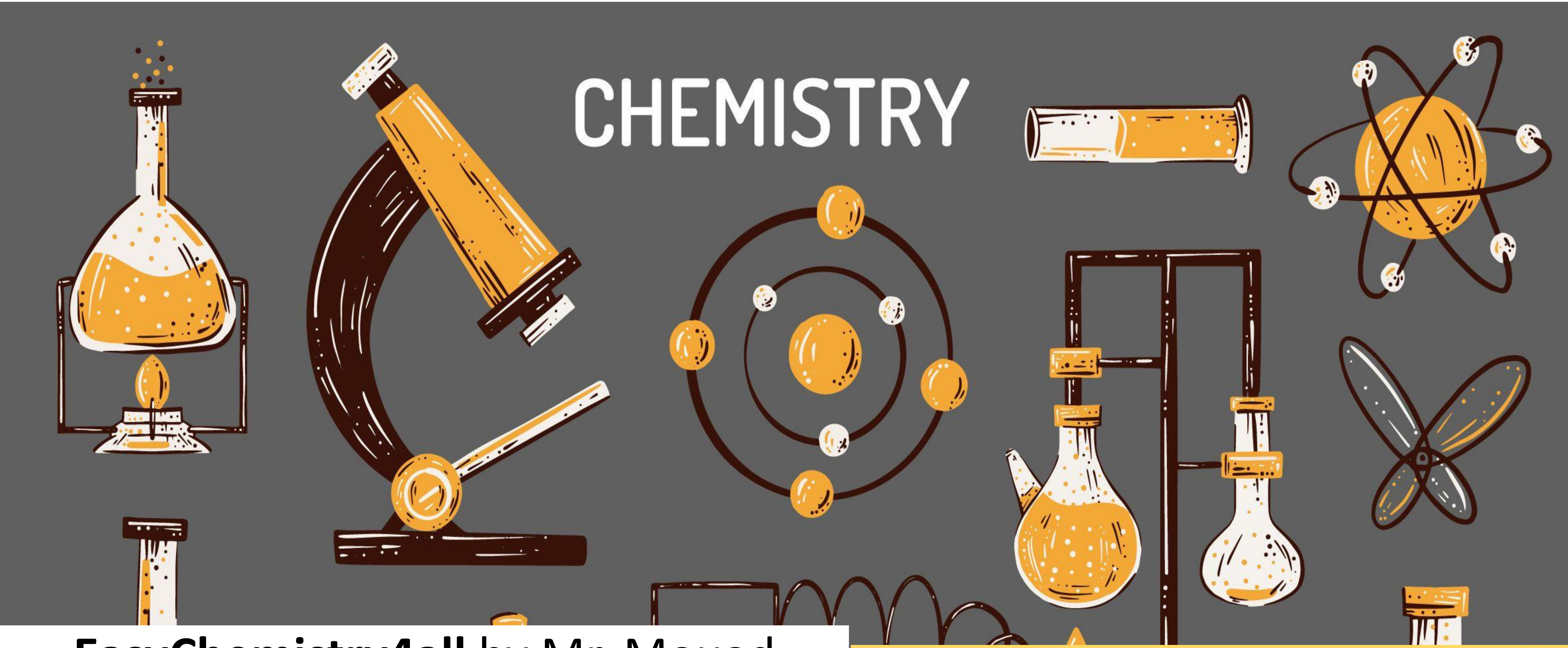

EasyChemistry4all by Mr. Mouad

مناهج دولة الإمارات

عام، متقدم ونخبة 12،11،10،9

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Inspire Chemistry
Module 17
"Acids & Bases"

التعادل

Lesson 4: "Neutralization"

Acid + Base → water

Learning Outcomes:

- **Write** chemical equations for neutralization reactions.
- **Explain** how neutralization reactions are used in acid-base titrations.

Focus Question

What happens when an acid and base react?

MAINIDEA **In a neutralization reaction, an acid reacts with a base to produce a salt and water.**

ionic compound

H_2O

New Vocabulary

neutralization reaction	acid-base indicator
salt	end point
titration	salt hydrolysis
titrant	buffer
equivalence point	buffer capacity

Review Vocabulary

stoichiometry: the study of quantitative relationships between the amounts of reactants used and products formed by a chemical reaction; is based on the law of conservation of mass

What You should intake when you experience heartburn(حموضة)?

- Take one of the antacids to relieve your discomfort

Figure 19 A dose of any of these antacids can relieve the symptoms of acid indigestion by reacting with the acidic solution in the stomach and neutralizing it.

- When $Mg(OH)_2$ and HCl react, a neutralization reaction occurs. (aq)
- Neutralization reaction: is a reaction in which an acid and a base in an aqueous solution react to produce a salt and water

HCl

base مضاد حموضة

$Mg(OH)_2$ (Antacids)

Reactions Between Acids and Bases

- A **neutralization reaction** is a reaction in which an acid and a base in an aqueous solution react to produce a salt and water.

- A **salt** is an ionic compound made up of a **cation(+ ion)** from a base and an **anion (- ion)** from an acid.

Reactions Between Acids and Bases

- Neutralization is a double-replacement reaction.

$$Mg(OH)_2(aq) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

$$\text{Base} + \text{Acid} \rightarrow \text{Salt} + \text{Water}$$

Mg^{2+} Cl

- The cation from the base (Mg^{2+}) is combined with the anion from the acid (Cl^-) in the salt ($MgCl_2$).

Grade 10 Adv Revision
Double-replacement reactions

Double-replacement reactions The final type of replacement reaction, which involves an exchange of ions between two compounds, is called a **double-replacement reaction.**

Positive
Negative
Replacement

$$AX + BY \longrightarrow AY + BX$$

Base

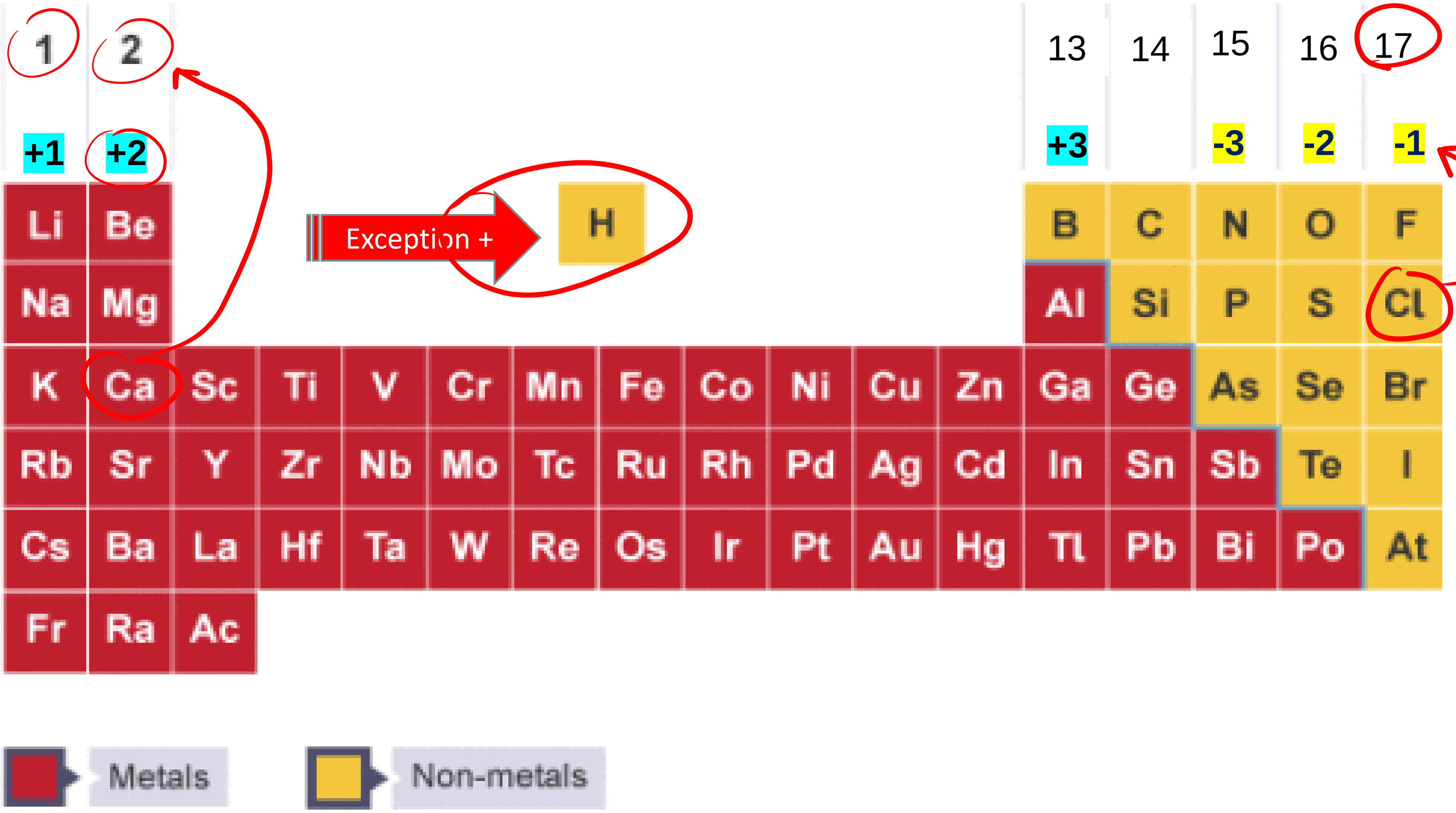
Acid

$$Ca(OH)_2(aq) + 2HCl(aq) \longrightarrow CaCl_2(aq) + 2H_2O(l)$$

Ca^{2+} OH^- H^+ Cl^-

Neutralization reaction

“Review the charges of ions”



+ sign

- sign

!Recall!

Common Polyatomic Ions			
Ion	Name	Ion	Name
NH_4^+	Ammonium	CO_3^{2-}	Carbonate
NO_2^-	Nitrite	HCO_3^-	Hydrogen carbonate Or Bicarbonate
NO_3^-	Nitrate	ClO^-	Hypochlorite
SO_3^{2-}	Sulfite	ClO_2^-	Chlorite
SO_4^{2-}	Sulfate	ClO_3^-	Chlorate
HSO_4^-	Hydrogen sulfate Or Bisulfate	ClO_4^-	Perchlorate
OH^-	Hydroxide	$C_2H_3O_2^-$	Acetate
CN^-	Cyanide	MnO_4^-	Permanganate
PO_4^{3-}	Phosphate	$Cr_2O_7^{2-}$	Dichromate

Grade 10 Adv Revision
Double-replacement reactions

Table 3 Guidelines for Writing Double-Replacement Reactions

Step	Example
1. Write the components of the reactants in a skeleton equation.	$Al(NO_3)_3 + H_2SO_4$
2. Identify the cations and the anions in each compound.	$Al(NO_3)_3$ has Al^{3+} and NO_3^- H_2SO_4 has H^+ and SO_4^{2-}
3. Pair up each cation with the anion from the other compound.	Al^{3+} pairs with SO_4^{2-} H^+ pairs with NO_3^-
4. Write the formulas for the products using the pairs from Step 3.	$Al_2(SO_4)_3$ HNO_3
5. Write the complete equation for the double-replacement reaction.	$Al(NO_3)_3 + H_2SO_4 \rightarrow Al_2(SO_4)_3 + HNO_3$
6. Balance the equation.	$2Al(NO_3)_3 + 3H_2SO_4 \rightarrow$ $Al_2(SO_4)_3 + 6HNO_3$

Reactions that take place in aqueous solutions and produce water "H_2O"

"**Neutralization reaction**" or "**Acid-Base Reaction**"

Acid + base ⟶ salt(ionic compound) + water

https://www.youtube.com/watch?v=RmnT9jwX4gQ

$HCl + NaOH \longrightarrow NaCl + H_2O$

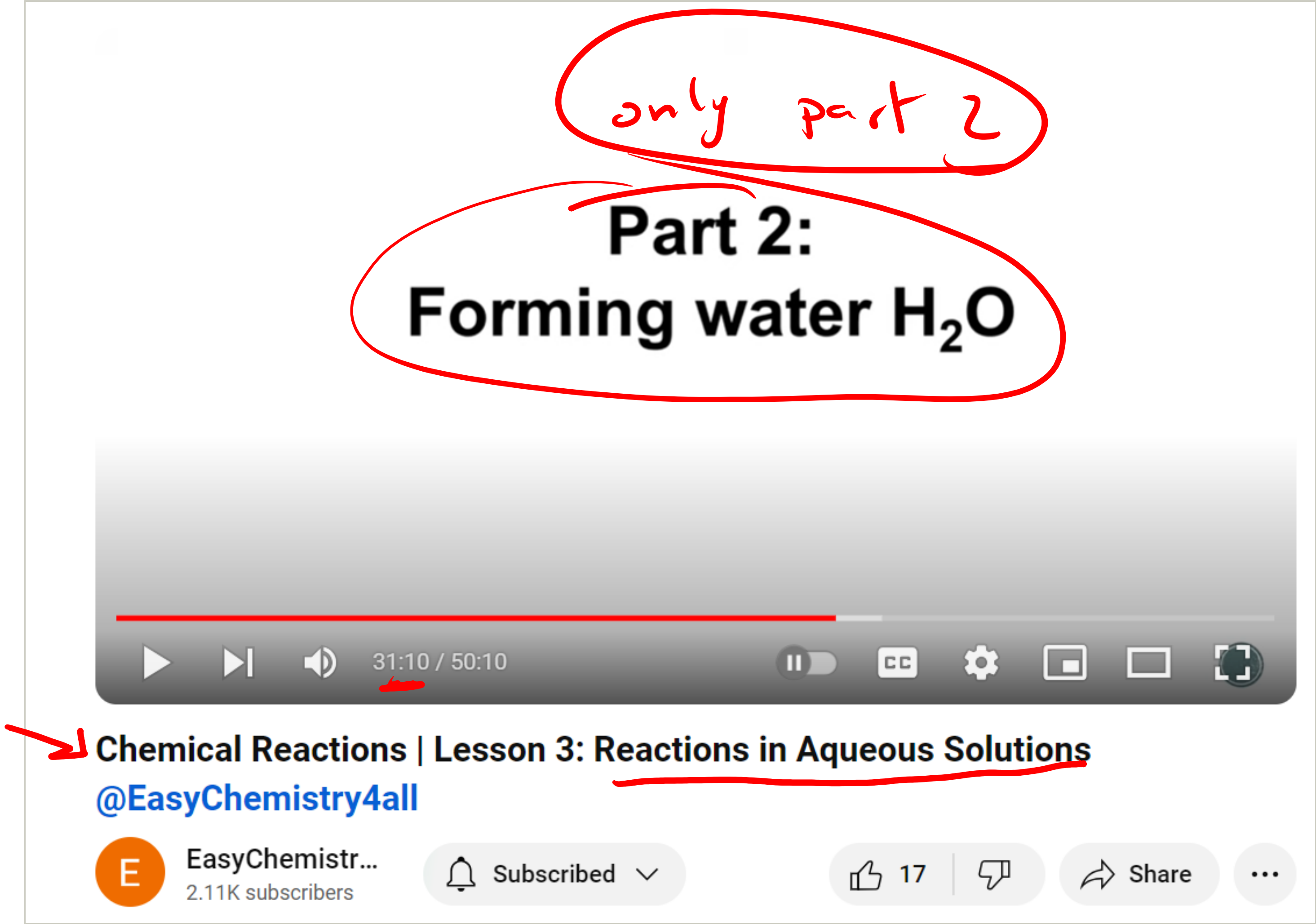
$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$

$H_2SO_4 + Ca(OH)_2 \longrightarrow CaSO_4 + H_2O$

Aqueous Solutions & Their reactions

"Formation of H_2O"

16



Describe the reactions that take place in aqueous solutions and produces water.

Reactions Between Acids and Bases
Complete Ionic & Net Ionic equations

- Neutralization is a double-replacement reaction.

$$Mg(OH)_2(aq) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

$$\text{Base} \quad + \quad \text{Acid} \quad \rightarrow \quad \text{Salt} \quad + \quad \text{Water}$$

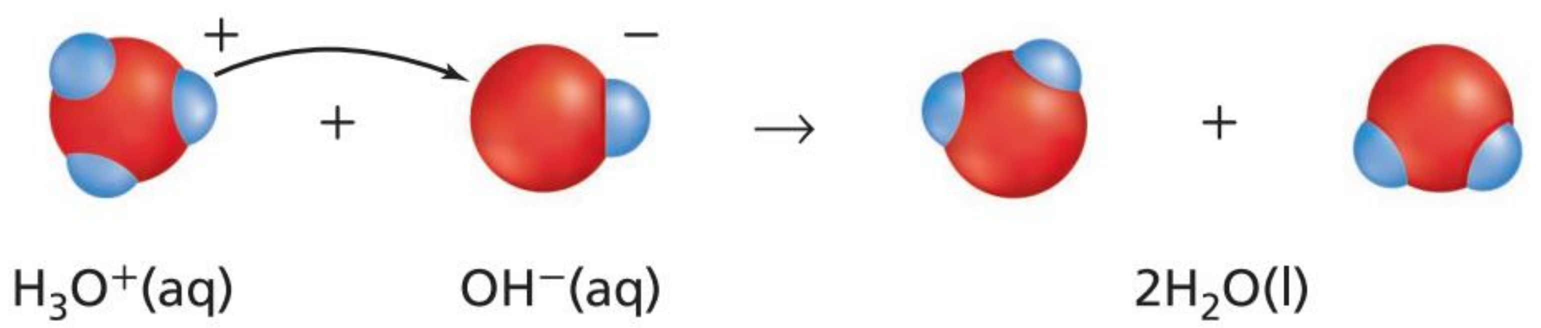
Reactions Between Acids and Bases
Complete Ionic & Net Ionic equations

Recall that in an aqueous solution, a H^+ ion exists as a H_3O^+ ion, so the net ionic equation for an acid-base neutralization reaction is

$$H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l).$$

$$H^+ + OH^- \rightarrow H_2O$$

■ **Figure 20** A hydronium ion transfers a hydrogen ion to a hydroxide ion. The loss of the hydrogen ion by H_3O^+ results in a water molecule. The gain of a hydrogen ion by OH^- also results in a water molecule.



Quiz

1. What are the products of a neutralization reaction?

~~Rectant~~

Reactants :- Acid & Base

A. an acid and a base

B. an acid and a salt

C. a base and a salt

D. a salt and water

CORRECT

Now try to write net ionic equation for KOH and HNO_3

$KOH_{(aq)} + HNO_{3\ (aq)} \longrightarrow$

Now try to write net ionic equation for KOH and HNO_3

double Replacement Reaction

base Acid salt

$$KOH_{(aq)} + HNO_{3\,(aq)} \longrightarrow KNO_{3(aq)} + H_2O_{(l)}$$ (Double replacement reaction)

KNO_3 (aq) H_2O (l)

K^+ OH^- H^+ NO_3^-

$$\cancel{K^+_{(aq)}} + OH^-_{(aq)} + H^+_{(aq)} + \cancel{NO_3^-{}_{(aq)}} \longrightarrow \cancel{K^+_{(aq)}} + \cancel{NO_3^-{}_{(aq)}} + H_2O_{(l)}$$

complete ionic equation

$$\cancel{K^+} + OH^- + H^+ + \cancel{NO_3^-} \longrightarrow \cancel{K^+} + \cancel{NO_3^-} + H_2O_{(l)}$$

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

Net ionic equation

$$H^+ + OH^- \longrightarrow H_2O$$

$$H_3O^+ + OH^- \longrightarrow 2H_2O$$

Now try to write net ionic equation for KOH and HNO_3

$$KOH_{(aq)} + HNO_{3\,(aq)} \longrightarrow KNO_{3(aq)} + H_2O_{(l)}$$

(Double replacement reaction)

complete ionic equation

$$\cancel{K^+}_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + \cancel{NO_3^-}_{(aq)} \longrightarrow \cancel{K^+}_{(aq)} + \cancel{NO_3^-}_{(aq)} + H_2O_{(l)}$$

Net ionic equation

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

If you have an acid or a base with a **known volume** and Unknown concentration (Molarity).

How can you find its concentration?

المعايرة

Acid-Base *Titration*

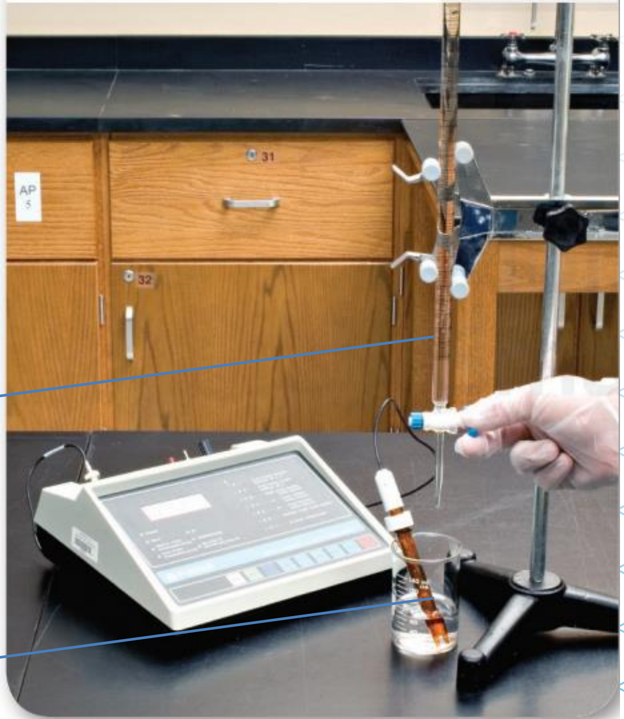
Neutralization Reaction

Acid-Base Titration

- **Titration** is a method for determining the concentration of a solution by reacting a known volume of that solution with a solution of known concentration.

Using solution of known concentration to determine the concentration of another solution

■ **Figure 21** In the titration of an acid by a base, the pH meter measures the pH of the acid solution in the beaker as a solution of a base with a known concentration is added from the buret.



$[A] = ?$

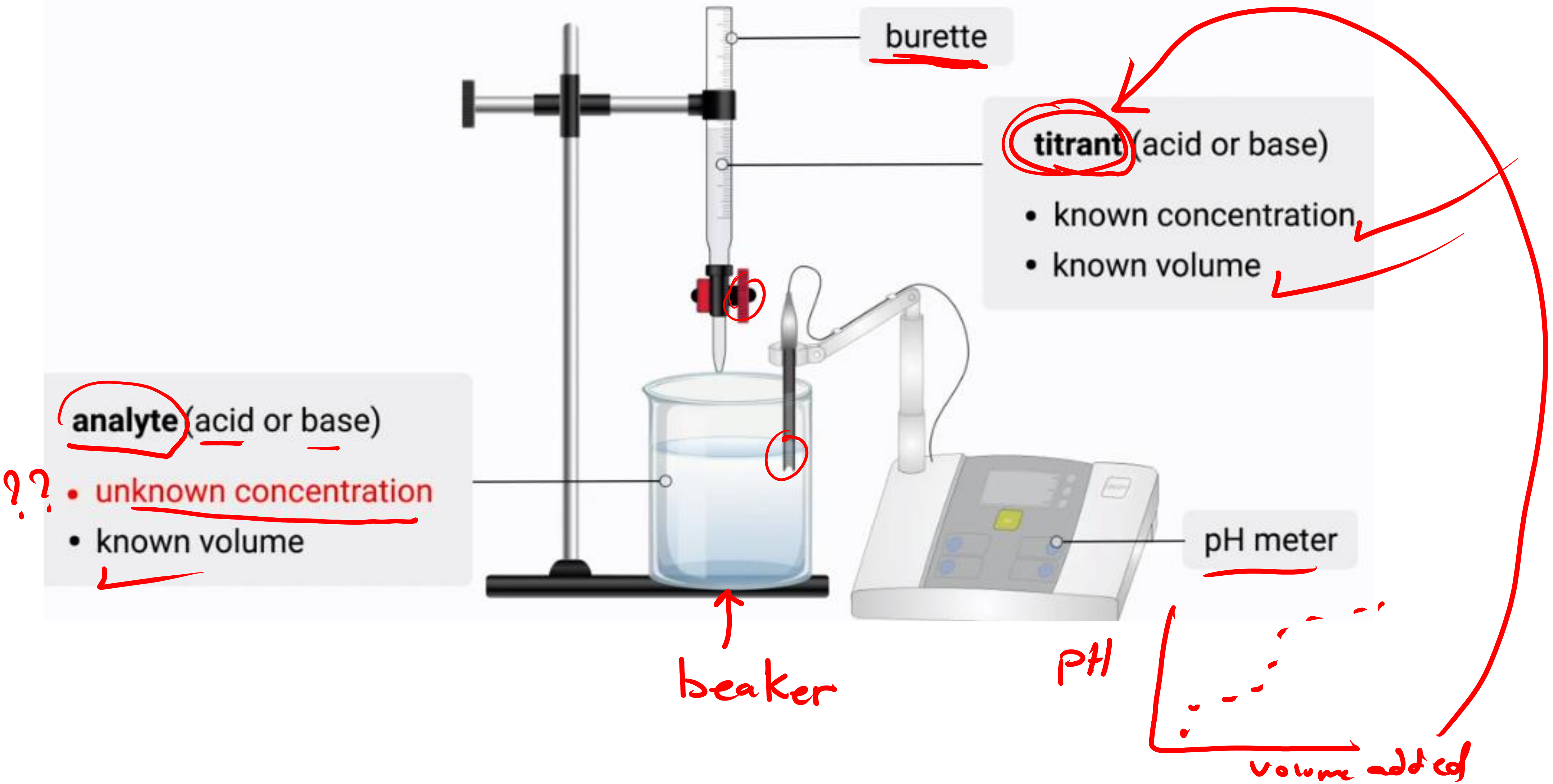
but $[B] =$ ✓

- Known concentration

$A + B \rightarrow$ Reaction

- Unknown concentration

Acid-Base Titrations



Acid-Base Titration

- **Titration** is the process in which an acid-base neutralization reaction is used to **determine the concentration of a solution of unknown concentration.**

Titration Procedure

How is an acid-base titration performed?

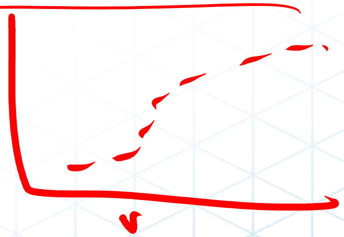
1. A measured volume of an acidic or basic solution of unknown concentration **(called analyte)** is placed in a beaker. The initial pH of the solution is read with a pH meter.
2. A buret is filled with the titrating solution of known concentration. This is the standard solution, or **titrant.**

titrant

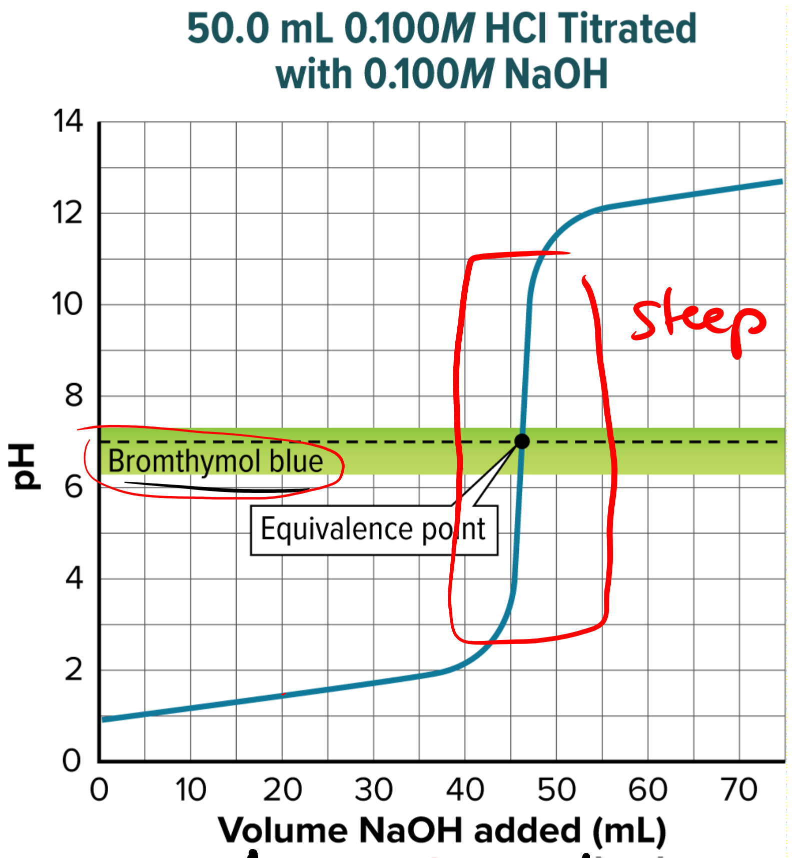
3. Measured volumes of the standard solution are added slowly to the beaker. The pH is read after each addition. This process continues until the reaction reaches the **equivalence point,** the point at which moles of H^+ ions from the acid equal moles of OH^- ions from the base.

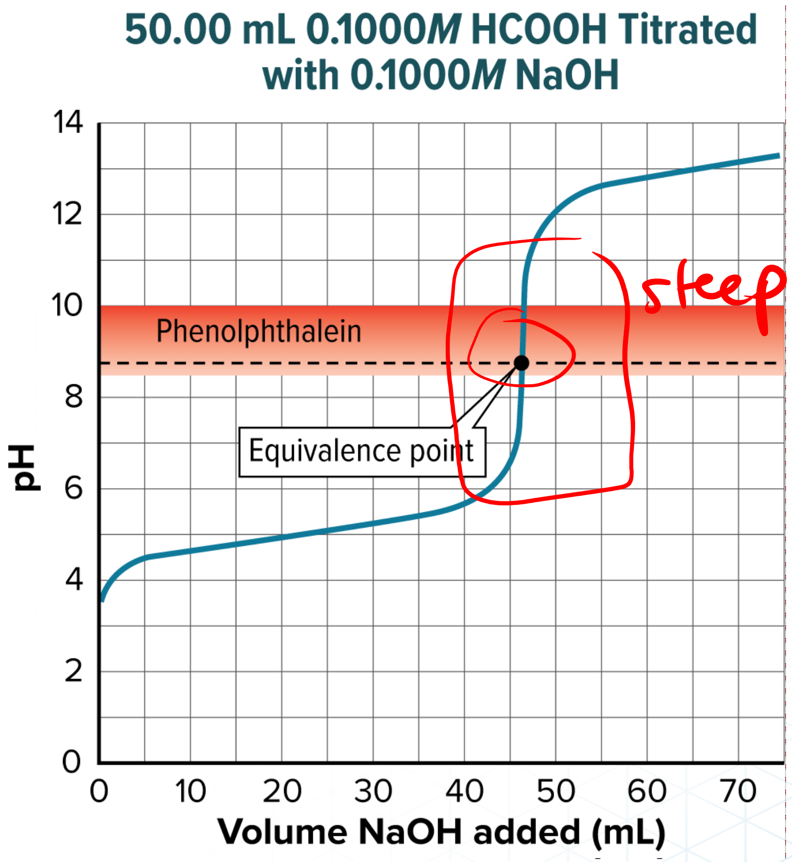
The color changes

pH

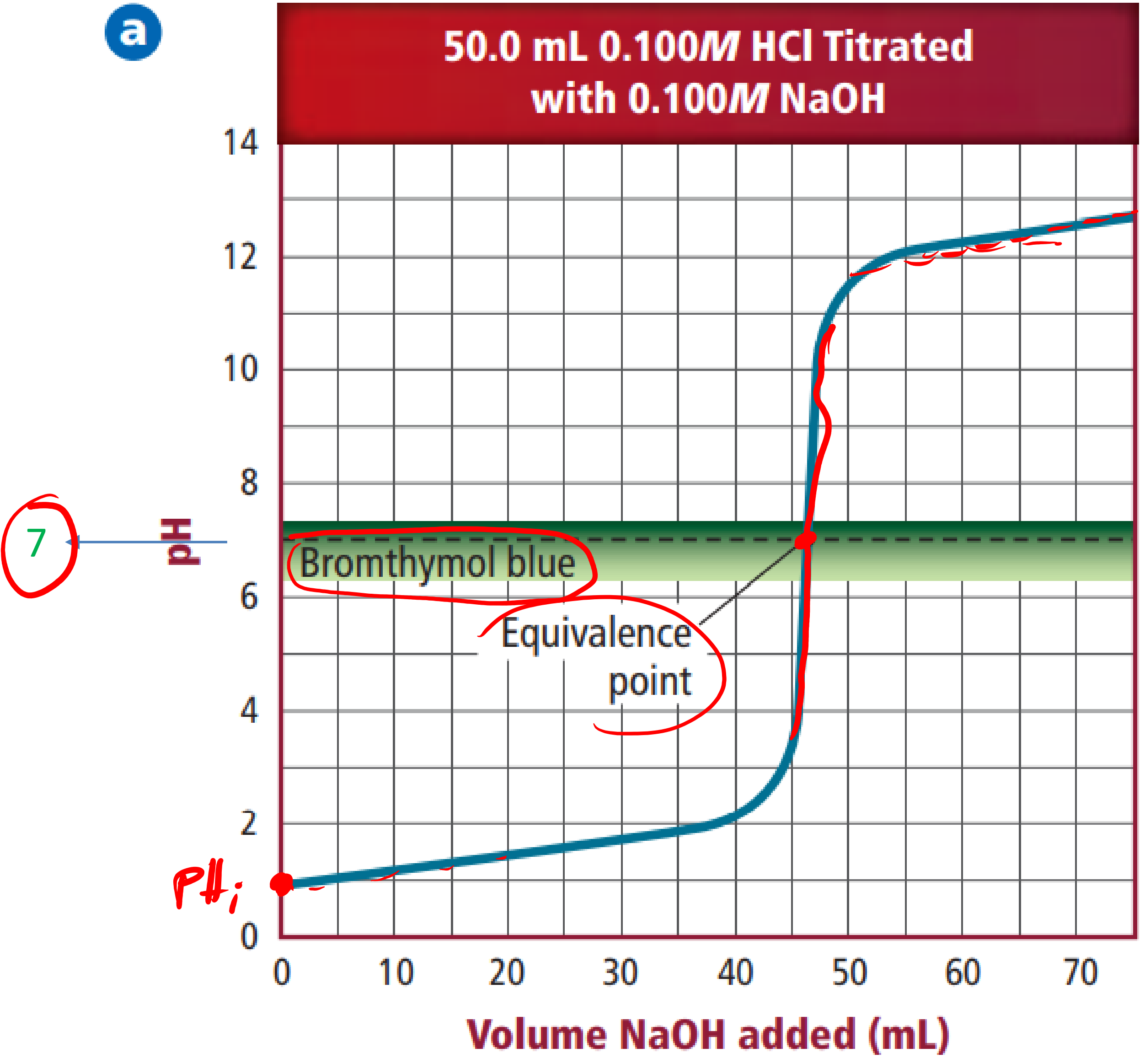


Acid-Base Titration

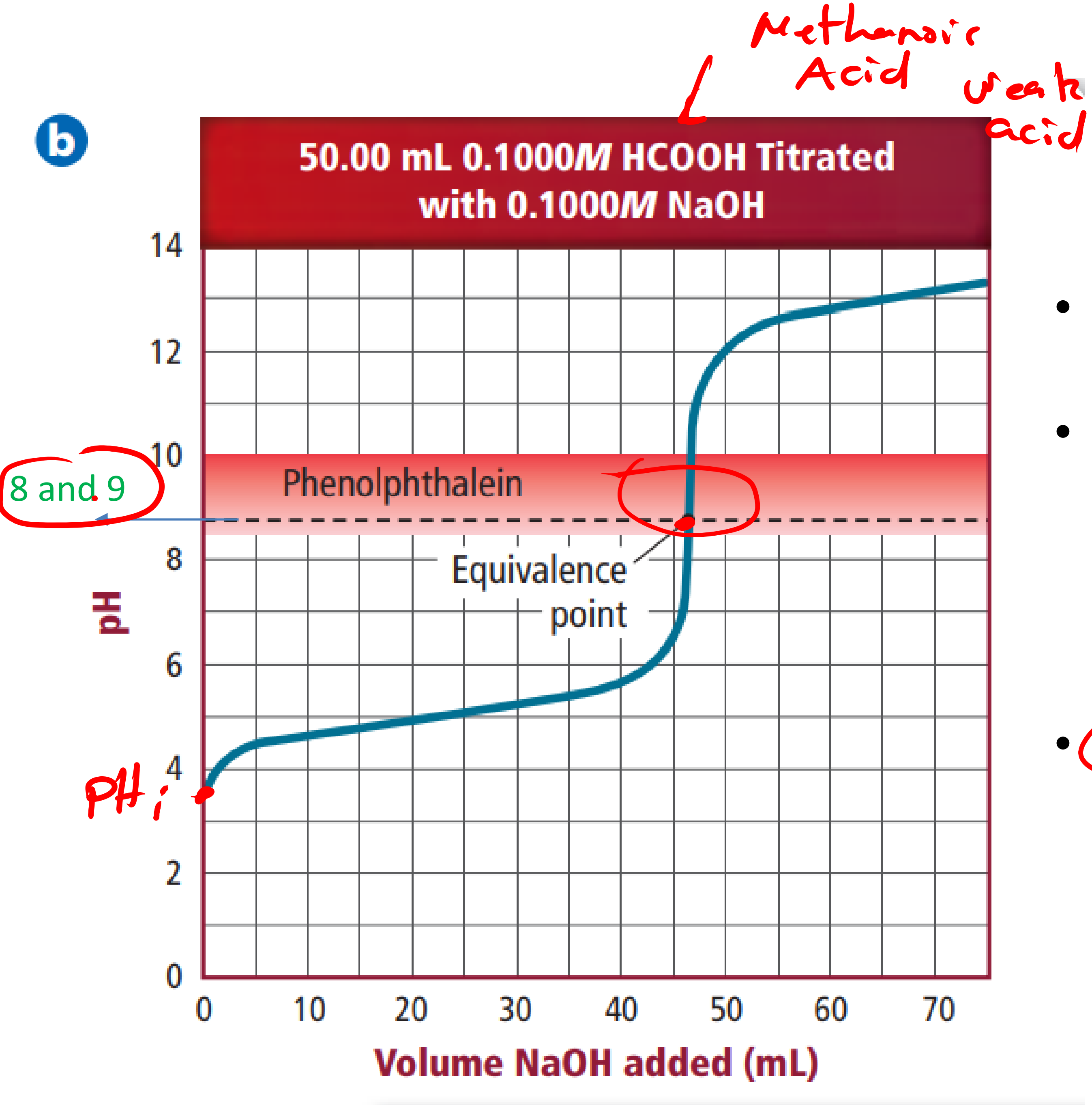




In each titration curve, a steep rise in the pH of the solution indicates that all of the H^+ ions from the acid have been neutralized by the OH^- ions of the base.



- Titration of 50.0 mL of 0.100M HCl, a strong acid, with 0.100M NaOH, a strong base.
- The initial pH of the 0.100M HCl is 1.00
- As NaOH is added, the acid is neutralized, and the solution's pH increases gradually.
- But, when nearly all the H^+ ions from the acid have been used up, the pH increases dramatically with the addition of an exceedingly small volume of NaOH. Abrupt increase in pH occurs at the equivalence point of the titration.
- Beyond the equivalence point, the addition of more NaOH again results in a gradual increase in PH
- Bromthymol blue is a good choice for a titration of a strong acid with a strong base



- Titration of weak acid (PH 3.5) with Strong base
- The equivalence point for the titration of Methanoic acid (a weak acid) with sodium hydroxide (a strong base) lies between pH 8 and pH 9
- Phenolphthalein changes color at the equivalence point of a titration of a weak acid with a strong base

Quiz

2. What term refers to the point in a titration when the concentration of H^+ ions from the acid equals the concentration of OH^- ions from the base?

- ~~A~~ the buffer capacity
- ~~B~~ the titration point
- C the equivalence point CORRECT
- ~~D~~ the turning point

Conclusion

$[OH^-] = [H^+]$ Neutral

equivalance pH = 7

- You might think that all titrations must have an equivalence point at pH 7 because that is the point at which concentrations of hydrogen ions and hydroxide ions are equal and the solution is neutral.

Acid + Base → salt + water

- This is not the case, however. Some titrations have equivalence points at pH values less than 7, and some have equivalence points at pH values greater than 7.

- These differences occur because of reactions between the newly formed salts and water (Later).

- **Equivalence point**: which is the point at which moles of H^+ ion from the acid equal moles of OH^- ion from the base.

helps us find the equivalence point

- **End point:** The point at which the indicator used in a titration changes color.

الصبغات

Acid-Base Indicators

- Chemists often $\boxed{\text{use a chemical dye}}$ to detect the equivalence point of an acid-base titration.

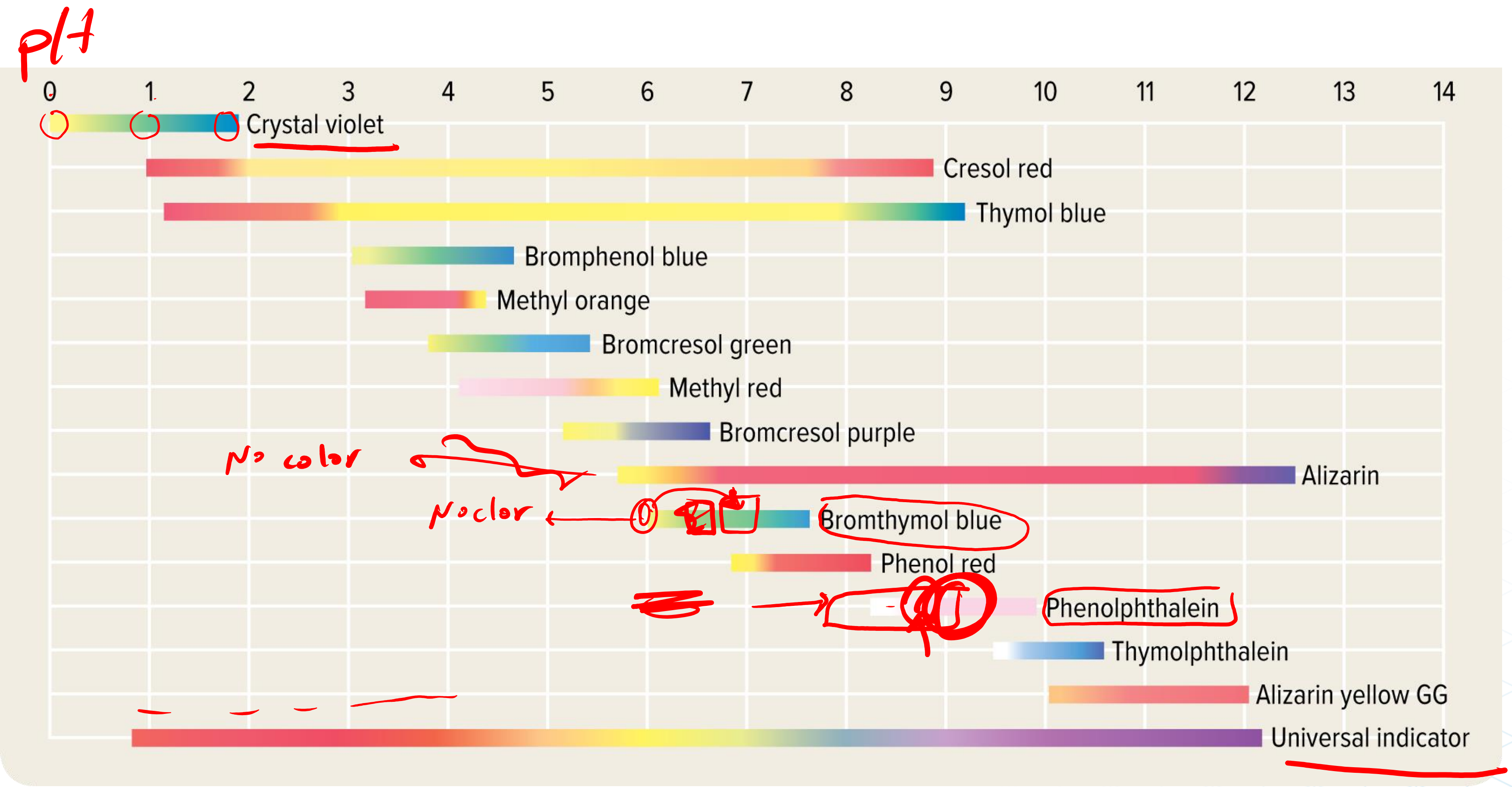
PH

- Chemical dyes whose colors are affected by acidic and basic solutions are called **acid-base indicators.**

- The point at which the indicator used in a titration changes color is called the **end point** of the titration.

- It is important to choose an indicator that will change color at the equivalence point of the titration.

Acid-Base Indicators



MOLARITY FROM TITRATION DATA

IN-CLASS EXAMPLE

Use with Example Problem 6.

titrant

Problem

A volume of 18.28 mL of a standard solution of 0.1000*M* NaOH was required to neutralize 25.00 mL of a solution of methanoic acid (HCOOH). What is the molarity of the methanoic acid solution?

How to find the concentration of an acid/base

$HCOOH + NaOH \rightarrow NaHCOO + H_2O$

$[NaOH] = 0.1M$

$M_{NaOH} = 0.1\ M \rightarrow \frac{mol}{L}$

$V_{NaOH} = 18.28\ mL \xrightarrow{\div 1000} L$

$V_{HCOOH} = 25\ mL$

$[HCOOH] = ??$

Titrant
Standard solution

step ① Find NaOH Moles

Moles = $M \times$ Volume (L) $= 0.1 \frac{mol}{L} \times \frac{18.28}{1000} L$

$= 1.828 \times 10^{-3}$ mol NaOH

step ② find Moles of HCOOH from Moles of NaOH

Balanced

$1\ HCOOH + 1\ NaOH \rightarrow NaHCOO + H_2O$

Moles HCOOH $= 1.828 \times 10^{-3}\ \cancel{mol\ NaOH} \times \frac{1\ mol\ HCOOH}{1\ \cancel{mol\ NaOH}} = 1.828 \times 10^{-3}$ mol HCOOH

MOLARITY FROM TITRATION DATA

IN-CLASS EXAMPLE

Use with Example Problem 6.

Problem

A volume of 18.28 mL of a standard solution of 0.1000*M* NaOH was required to neutralize 25.00 mL of a solution of methanoic acid (HCOOH). What is the molarity of the methanoic acid solution?

Moles of HCOOH $= 1.828 \times 10^{-3}$ mol

step 3

$$\text{Molarity} = \frac{\text{Moles}}{\text{volume (L)}}$$

$$V_{HCOOH} = 25 \text{ mL} \xrightarrow{\div 1000} \boxed{0.025 \text{ L}}$$

$$\text{Molarity} = [HCOOH] = \frac{1.828 \times 10^{-3}}{0.025} = 0.07312$$

M or $\frac{mol}{L}$

MOLARITY FROM TITRATION DATA

IN-CLASS EXAMPLE

Use with Example Problem 6.

Problem

A volume of 18.28 mL of a standard solution of 0.1000*M* NaOH was required to neutralize 25.00 mL of a solution of methanoic acid (HCOOH). What is the molarity of the methanoic acid solution?

Response

ANALYZE THE PROBLEM

You are given the molarity and volume of the NaOH solution and the volume of the methanoic acid (HCOOH) solution. The volume of base used is about four-fifths of the volume of the acid, so the molarity of the acid solution should be less than 0.1*M*.

KNOWN

V_A = 25.00 mL HCOOH

V_B = 18.28 mL NaOH

M_B = 0.1000*M*

UNKNOWN

M_A = ? mol/L

SOLVE FOR THE UNKNOWN

Write the balanced formula equation for the neutralization reaction.

$$HCOOH(aq) + NaOH(aq) \rightarrow HCOONa(aq) + H_2O(l)$$

- Write the acid to base mole relationship.

1 mol NaOH neutralizes 1 mol HCOOH.

- Convert volume of base from mL to L.

$$V_B = 18.28\ \cancel{mL} \times \frac{1\ L}{1000\ \cancel{mL}} = 0.01828\ L$$

MOLARITY FROM TITRATION DATA

IN-CLASS EXAMPLE

SOLVE FOR THE UNKNOWN ***(continued)***

Calculate moles of NaOH.

- Apply the relationship between moles, molarity, and volume of base.

$$\text{Mol NaOH} = (M_B)(V_B)$$

- Substitute $M_B = 0.1000M$ & $V_B = 0.01828$ L.

$$\text{Mol NaOH} = (0.1000\ \text{mol}/\cancel{\text{L}})(0.01828\ \cancel{\text{L}})$$

$$= 1.828 \times 10^{-3}\ \text{mol NaOH}$$

Calculate moles of HCOOH.

- Apply the stoichiometric relationship

$$1.828 \times 10^{-3}\ \text{mol NaOH} \times \frac{1\ \text{mol HCOOH}}{1\ \text{mol NaOH}}$$

$$= 1.828 \times 10^{-3}\ \text{mol HCOOH}$$

Calculate the molarity of HCOOH.

- Apply the relationship between moles of acids, molarity of acid, and volume of acid.

$$1.828 \times 10^{-3}\ \text{mol HCOOH} = (\boldsymbol{M_A})(V_A)$$

- Solve for M_A.

$$\boldsymbol{M_A} = \frac{1.828 \times 10{-}3\ \text{mol HCOOH}}{V_A}$$

- Convert volume of acid from mL to L.

$$V_A = 25.00\ \cancel{\text{mL}} \times \frac{1\ \text{L}}{1000\ \cancel{\text{mL}}} = 0.02500\ \text{L HCOOH}$$

- Substitute $V_A = 0.02500$ L.

$$\boldsymbol{M_A} = \frac{1.828 \times 10{-}3\ \text{mol HCOOH}}{0.02500\ \text{L HCOOH}} = \mathbf{7.312 \times 10^{-2}\ mol/L}$$

EVALUATE THE ANSWER

The answer agrees with the prediction that the molarity of HCOOH is less than 0.1M, and is correctly recorded with four significant figures and the appropriate units.

44. What is the molarity of a nitric acid solution if 43.33 mL of 0.1000*M* KOH solution is needed to neutralize 20.00 mL of the acid solution?

44. What is the molarity of a nitric acid solution if 43.33 mL of 0.1000*M* KOH solution is needed to neutralize 20.00 mL of the acid solution?

Section 4

Neutralization
Salt Hydrolysis (Page 147)

Learning Outcomes

- Define salt and salt hydrolysis.
- Identify the type of salt (acidic, basic or neutral) and its constituent acid and base with their strengths.

Salt Hydrolysis (Page 147)

Are Salt solutions acidic, basic or neutral?

Salts:

KF
NH_4Cl
$NaNO_3$

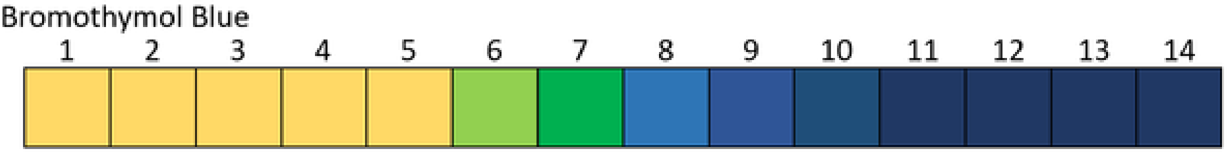


Figure 26 The indicator bromthymol blue provides surprising results when added to three solutions of ionic salts. An NH_4Cl solution is acidic, a $NaNO_3$ solution is neutral, and a KF solution is basic. The explanation has to do with the strengths of the acid and base from which each salt was formed.

Salt Hydrolysis (Page 147)

+ −

- Many salts react with water in a process known as salt hydrolysis.
- In **salt hydrolysis,** the anions of the dissociated salt accept hydrogen ions from water **or** the **cations** of the dissociated salt **donate hydrogen ions to water.**
- Salt hydrolysis can produce basic, acidic, or neutral solutions.

$KOH + HF \longrightarrow KF + H_2O$

Salts that produce basic solutions Potassium fluoride is the salt of a strong base (KOH) and a weak acid (HF). It dissociates into potassium ions and fluoride ions.

$$KF(s) \rightarrow K^+(aq) + F^-(aq)$$

The K^+ ions do not react with water, but the F^- ion is a weak Brønsted-Lowry base. Some fluoride ions establish this equilibrium with water.

$$F^-(aq) + H_2O(l) \rightleftharpoons HF(aq) + OH^-(aq)$$

basic

pH > 7

Salts that produce acidic solutions NH_4Cl is the salt of a weak base (NH_3) and a strong acid (HCl). When dissolved in water, the salt dissociates into ammonium ions and chloride ions.

NH_3 (aq)+ HCl (aq) → NH_4Cl

$$NH_4Cl(s) \rightarrow NH_4^+(aq) + Cl^-(aq)$$

The Cl^- ions do not react with water, but the NH_4^+ ion is a weak Brønsted-Lowry acid. Ammonium ions react with water molecules to establish this equilibrium.

$$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + \boxed{H_3O^+(aq)}$$

More H_3O^+ = **More acidic** solution

pH < 7

Salts that produce neutral solutions Sodium nitrate ($NaNO_3$) is the salt of a strong acid (HNO_3) and a strong base (NaOH). Little or no salt hydrolysis occurs because neither Na^+ nor NO_3^- react with water. Therefore, a solution of sodium nitrate is neutral.

$$NaOH + HNO_3 \longrightarrow \underline{NaNO_3} + H_2O$$

Page 148

APPLICATIONS

H_2O

47. Write equations for the salt hydrolysis reactions occurring when the following salts dissolve in water. Classify each as acidic, basic, or neutral.

a. ammonium nitrate **c.** rubidium acetate
b. potassium sulfate **d.** calcium carbonate

K^+ Cl^- NO_3^- Na^+

a. ammonium nitrate NH_4NO_3

$NH_4^+(aq) + H_2O(l) \leftrightarrow NH_3(aq) + H_3O^+(aq)$

The solution is acidic.

b. potassium sulfate K_2SO_4

$SO_4^{2-}(aq) + H_2O(l) \leftrightarrow HSO_4^-(aq) + OH^-(aq)$

The solution is neutral.

$HSO_4^- \leftrightarrow H^+ + SO_4^{2-}$

c. rubidium acetate $RbCH_3COO$

$CH_3COO^-(aq) + H_2O(l) \leftrightarrow CH_3COOH(aq) + OH^-(aq)$

The solution is basic.

d. calcium carbonate $CaCO_3$

$CO_3^{2-}(aq) + H_2O(l) \leftrightarrow HCO_3^-(aq) + OH^-(aq)$

The solution is basic.

Page 148

48. Challenge Write the equation for the reaction that occurs in a titration of ammonium hydroxide (NH_4OH) with hydrogen bromide (HBr). Will the pH at the equivalence point be greater or less than 7?

$$NH_4OH(aq) + HBr(aq) \rightarrow NH_4Br(aq) + H_2O(l)$$

$$NH_4^+(aq) + H_2O(aq) \leftrightarrow H_3O^+(aq) + NH_3$$

Hydronium ions are formed so the pH will be less than 7.

Quiz

3. In what process do anions of a dissociated salt accept hydrogen ions from water or cations of the salt donate hydrogen ions to water?

- neutralization
- titration
- C salt hydrolysis **CORRECT**
- buffering