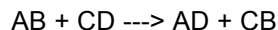


Objective 6. Double replacement reactions 2: balancing acid-base and gas forming reactions, identifying strong and weak acids, write net ionic equations to predict whether a reaction occurs, perform C-V-mole and mole ratio calculations (volumetric)

Quiz Practice problems:

Key ideas: In a double replacement reaction, Compound AB reacts with Compound CD to form Compound AD and Compound CB.



Another type of double replacement reaction is an acid-base reaction. An acid donates H^+ and a base accepts H^+ so a transfer of H^+ occurs in an acid-base reaction.

A gas forming reaction is a type of acid-base reaction. If H_2CO_3 is produced as a product, replace the H_2CO_3 with H_2O and CO_2 gas.

Acids are classified by strength (strong or weak).

A net ionic equation is used to predict whether a reaction occurs.

Skills: Given reactants of a double replacement reaction, predict the products (write chemical formulas) of the reaction.

Balance an acid-base reaction.

Identify an acid as strong or weak.

Write a net ionic equation. Identify spectator ions.

Predict whether a reaction occurs from a net ionic equation.

Perform chemical calculations involving an acid-base reaction.

For solutions, use concentration in Molarity = moles/volume. Use algebra to solve for one of these variables.

1. a. Life consists of give and take. Does an acid give or take H^+ ? Does a base give or take H^+ ?

b. (i) Name an experiment that you can do to identify an acid.

(ii) Name an experiment that you can do to identify a base.

c. Fill in the blanks in the table: (brackets [] mean concentration in M)

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

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

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

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

$$pH + pOH = 14$$

Substance	pH	pOH	$[H^+]$, M	$[OH^-]$, M
Lemon juice	2.4			
Stomach acid = HCl	2.5			
Milk		7.5		
blood				2.51×10^{-7}
Household ammonia			3.16×10^{-12}	
0.15 M NaOH				

Answers:

a. An acid gives H^+ . A base takes H^+ .

b. (i) acid experiment: blue litmus turns red, phenolphthalein is colorless, $pH < 7$

(ii) base experiment: red litmus turns blue, phenolphthalein is pink, $pH > 7$

c.

Substance	pH	pOH	$[H^+]$, M	$[OH^-]$, M
Lemon juice	2.4	11.6	$10^{-2.4} = 4.0 \times 10^{-3}$	$10^{-11.6} = 2.5 \times 10^{-12}$
Stomach acid = HCl	2.5	11.5	$10^{-2.5} = 3.2 \times 10^{-3}$	$10^{-11.5} = 3.2 \times 10^{-12}$
Milk	6.5	7.5	$10^{-6.5} = 3.2 \times 10^{-7}$	$10^{-7.5} = 3.2 \times 10^{-8}$
blood	7.4	6.6	4.0×10^{-8}	2.51×10^{-7}
Household ammonia	11.5	2.5	3.16×10^{-12}	3.2×10^{-3}
0.15 M NaOH	13.18	0.82	6.6×10^{-14}	0.15

2. What ions are in the following acids and bases?

a. muriatic acid = HCl

b. lye = NaOH

c. acetic acid = $HC_2H_3O_2$

d. washing soda = sodium carbonate

Answers:

a. acid

b. base

- c. acid
- d. base

You can predict whether an acid-base reaction occurs if you can write a net ionic equation.

3. For each reaction,

Predict the products. If H_2CO_3 is produced as a product, replace the H_2CO_3 with H_2O and CO_2 gas.

Balance the equation.

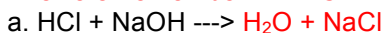
Write a net ionic equation. Strong acids dissociate into ions, e.g., HCl breaks up into H^+ and Cl^- .

Weak acids do not dissociate (actually, only one in a few thousand or million weak acid molecules break up), e.g., $\text{HC}_2\text{H}_3\text{O}_2$ stays as $\text{HC}_2\text{H}_3\text{O}_2$ in an ionic equation.

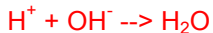
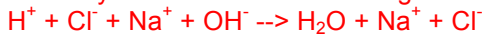
ID the spectator ions.

- a. $\text{HCl} + \text{NaOH} \rightarrow$
- b. baking soda + $\text{HC}_2\text{H}_3\text{O}_2 \rightarrow$
(This is a gas forming reaction.)
- c. $\text{KOH} + \text{HC}_2\text{H}_3\text{O}_2 \rightarrow$
- d. $\text{H}_2\text{SO}_4 + \text{Na}_2\text{CO}_3 \rightarrow$

Answers: remember $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}$

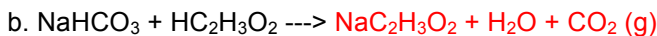


HCl = hydrochloric acid is a strong acid.



Spectator ions: $\text{Na}^+ + \text{Cl}^-$

Note: the basic part of NaOH is OH^- .

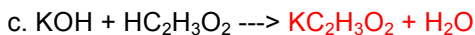


$\text{HC}_2\text{H}_3\text{O}_2$ is a weak acid.

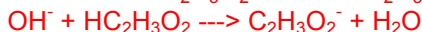


Spectator ion: Na^+

Note: the basic part of NaHCO_3 is HCO_3^- .



$\text{HC}_2\text{H}_3\text{O}_2$ is a weak acid.



Spectator ion: K^+

Note: the basic part of KOH is OH^- .



H_2SO_4 = sulfuric acid is a strong acid.



Spectator ions: $\text{SO}_4^{2-} + \text{Na}^+$

Note: the basic part of Na_2CO_3 is CO_3^{2-} .

4. Our stomach contains acid, which helps digest food.

a. What happens to this pH when a person gets heartburn? You calculated the pOH , $[\text{H}^+]$, and $[\text{OH}^-]$ of stomach acid in Question 1.

b. Milk of Magnesia (magnesium hydroxide ($\text{Mg}(\text{OH})_2$)) is used in antacids. Describe how an antacid works. Write a balanced molecular equation and net ionic equation that shows how this antacid works. How many moles of antacid reacts with 1 mole of stomach acid?

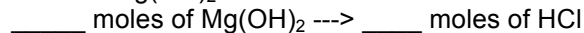
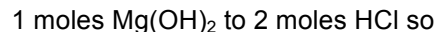
c. Calculate the mass of HCl that reacts with 500 mg of Milk of Magnesia.

Step 1: write a balanced chemical equation

Step 2: Given the mass of one substance, calculate moles:



Step 3: Use coefficients to determine mole ratio:

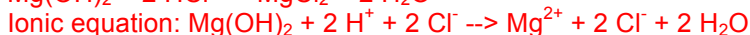


Step 4: What conversion to do next?

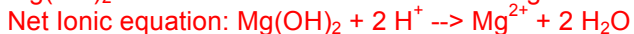
Answers: remember $\text{AB} + \text{CD} \rightarrow \text{AD} + \text{CB}$

a. pH drops due to excess stomach acid.

b. An antacid is a base that reacts with and neutralizes the excess stomach acid.



Mg(OH)₂ is insoluble in water. HCl is a strong acid. MgCl₂ is soluble in water.



H⁺ is the acid part of HCl.

1 mole of stomach acid (HCl) reacts with 0.5 moles of Mg(OH)₂. 1 mole HCl (1 mole Mg(OH)₂/2 moles HCl) = 0.5 moles Mg(OH)₂.

c. 500 mg Mg(OH)₂ (1 g/1000 mg)(1 mole Mg(OH)₂/58.3 g Mg(OH)₂)(2 moles HCl/1 mole Mg(OH)₂)(36.5 g HCl/1 mole HCl) = 0.626 g HCl

Round to 1 significant figure based on 500 mg Mg(OH)₂, which has 1 significant figure ==> 0.6 g HCl.

5. a. Alka-Selzer (Baking soda, NaHCO₃) and Tums (calcium carbonate (CaCO₃)) are used in antacids. For each antacid, write a balanced molecular equation and net ionic equation that shows how each antacid works. For each antacid, how many moles of antacid reacts with 1 mole of stomach acid?

(Answer: CaCO₃ + 2 HCl → CaCl₂ + H₂O + CO₂ for Tums)

b. Antacid commercial: "How many times its weight in excess stomach acid does (antacid) neutralize?"

(i) Calculate the moles of HCl that reacts with 0.50 moles of baking soda.

(ii) Calculate the mass of HCl that reacts with 500 mg of baking soda.

(iii) How many g of HCl reacts with 500 mg of CaCO₃?

(iv) Based on your answers from parts (ii) and (iii), which antacid is more effective? Give reasons.

c. Which antacid, Milk of Magnesia or Alka-Selzer or Tums, will make you burp?

d. 550 mg of CaCO₃ is added to 100 ml of pH 1.5 HCl.

(i) How many moles of HCl are present?

a. 0.15 b. 0.032 c. 0.0032

(ii) The limiting reactant is:

a. CaCO₃ b. HCl c. H₂O

(iii) How many g of CO₂ are produced?

a. 0.070 b. 1.4 c. 0.48

Answers: remember AB + CD ---> AD + CB

a. for Tums: CaCO₃ + 2 HCl → CaCl₂ + H₂O + CO₂ (g)



CaCO₃ is insoluble in water. HCl is a strong acid. CaCl₂ is soluble in water.



For Alka-Selzer: NaHCO₃ + HCl → NaCl + H₂O + CO₂ (g)



NaHCO₃ is soluble in water. HCl is a strong acid. NaCl is soluble in water.



HCO₃⁻ is the basic part of Alka-Selzer/baking soda.

b. Antacid commercial: "How many times its weight in excess stomach acid does (antacid) neutralize?"

(i) Calculate the moles of HCl that reacts with 0.50 moles of baking soda.



0.50 moles NaHCO₃ (1 mole HCl/1 mole NaHCO₃) = 0.50 moles HCl

(ii) Calculate the mass of HCl that reacts with 500 mg of baking soda.

500 mg NaHCO₃ (1 g/1000 mg)(1 mole NaHCO₃ /84 g NaHCO₃)(1 mole HCl/1 mole NaHCO₃)(36.5 g HCl/1 mole HCl) = 0.217 g HCl

Round to 1 significant figure based on 500 mg NaHCO₃, which has 1 significant figure ==> 0.2 g HCl.

(iii) How many g of HCl reacts with 500 mg of CaCO₃?



500 mg CaCO₃ (1 g/1000 mg)(1 mole CaCO₃ /100 g CaCO₃)(2 moles HCl/1 mole CaCO₃)(36.5 g HCl/1 mole HCl) = 0.365 g HCl

Round to 1 significant figure based on 500 mg CaCO₃, which has 1 significant figure ==> 0.4 g HCl.

(iv) Based on your answers from parts (ii) and (iii), which antacid is more effective? Give reasons.

CaCO₃ is more effective than NaHCO₃ because it neutralizes more HCl (0.4 g HCl per 500 mg compared to 0.2 g HCl per 500 mg).

c. Which antacid, Milk of Magnesia or Alka-Selzer or Tums, will make you burp?

Alka-Selzer and Tums will make you burp. Both antacids produce CO₂ gas.

d. 550 mg of CaCO₃ is added to 100 ml of pH 1.5 HCl.

Convert pH 1.5 to [H⁺]. [H⁺] = 10^{-pH} = 10^{-1.5} = 0.032 M

(i) How many moles of HCl are present?

- a. 0.15 b. 0.032 c. 0.0032

Molarity = moles/Volume.

Rearrange and solve for moles = Molarity x Volume = 0.032 M x 0.100 l = 0.0032 moles

(ii) The limiting reactant is:

- a. CaCO₃ b. HCl c. H₂O



500 mg CaCO₃ (1 g/1000 mg)(1 mole CaCO₃ /100 g CaCO₃)(1 mole CO₂ /1 mole CaCO₃) = 0.005 moles CO₂.

0.032 M HCl x 0.100 l x (1 mole CO₂ /2 mole HCl) = 0.0016 moles CO₂.

So HCl is the limiting reactant.

OR



Initial moles	0.005	0.0032
Moles that react	0.0016	0.0032
Moles leftover	0.0034	0
	Excess	limiting

(iii) How many g of CO₂ are produced?

- a. 0.070 b. 1.4 c. 0.48

Use limiting reactant to calculate amount of CO₂ produced.

0.032 M HCl x 0.100 l x (1 mole CO₂ /2 moles HCl) (44 g CO₂/1 mole CO₂)= 0.070 g CO₂.

A titration is performed to accurately determine the concentration of an acid or base. Usually, the base is in the buret and is added (titrated) to an acid.

6. You prepare a solution of NaOH from NaOH solid. You transfer this solution to a buret. You will titrate a known volume and concentration of HCl to determine the concentration of NaOH.

You pipet 10.00 ml of 0.923 M HCl into a flask. You add one drop of phenolphthalein. 12.76 ml of NaOH is needed to turn this solution pink for 15 to 30 seconds.

a. Write a chemical equation that represents the HCl-NaOH reaction.

b. for solutions: Molar concentration = moles/volume in liters.

Calculate the moles of HCl in 10.00 ml of 0.923 M HCl. (What is the conversion factor?)

c. Calculate the moles of NaOH that reacts with HCl. (What is the conversion factor?)

d. Calculate the concentration of the NaOH solution. (Answer: between 0.7 and 0.75 M)

Answers: remember AB + CD ----> AD + CB

a. HCl + NaOH ----> H₂O + NaCl

b. Molarity = moles/Volume.

Rearrange and solve for moles = Molarity x Volume = 0.923 M x 0.01000 l = 0.00923 moles HCl

c. 0.00923 moles HCl (1 mole NaOH /1 mole HCl) = 0.00923 moles NaOH

d. Molarity = moles/Volume.

Molarity of NaOH = moles NaOH /Volume NaOH = 0.00923 moles NaOH/0.01276 l = 0.723 M NaOH

Limiting and excess reactants:

7. You pipet 10.00 ml of 0.923 M HCl into a flask. You add one drop of phenolphthalein. You titrate this solution with 0.73 M NaOH (the NaOH is in a buret).

a. You add 1.00 ml of the 0.73 M NaOH. (The solution is not going to be pink.) The NaOH is the limiting reactant.

Calculate the volume of 0.923 M HCl that is leftover.

(i) Calculate the moles of NaOH. (What equation do you want to use?)

(ii) Calculate the moles of HCl that reacts with the NaOH. (What is the conversion factor?)

(iii) Calculate the moles of HCl in 10.00 ml of 0.923 M HCl. This is the original amount of HCl in the flask. (What equation do you want to use?)

(iv) Subtract the moles of HCl that reacts from the original moles of HCl.

(v) Convert moles of HCl to volume of HCl. (What is the conversion factor?)

b. You add 11.00 ml of the 0.73 M NaOH. The NaOH is the limiting reactant. Calculate the volume of 0.923 M HCl that is leftover. What color is the solution?

c. You add 15.00 ml of the 0.73 M NaOH. The NaOH is the excess reactant. Calculate the volume of 0.73 M NaOH that is leftover. What color is the solution?

Answers: remember AB + CD ----> AD + CB

a. HCl + NaOH ----> H₂O + NaCl

Initial moles (iii) 0.00923 (i) 0.73 M x 0.00100 l = 0.00073

Moles that react (ii) 0.00073 0.00073 (1:1 mole ratio of HCl to NaOH)

Moles leftover (iv) 0.0085 0

Excess limiting

(v) Molarity = moles/Volume.

Rearrange and solve for Volume = moles/Molarity = 0.0085 moles HCl/0.923 M = 0.0092 l = 9.2 ml of 0.923 M HCl.

b.	HCl	+	NaOH	--->	H ₂ O + NaCl
Initial moles	0.00923		0.73 M x 0.01100 l = 0.00803		
Moles that react	0.00803		0.00803 (1:1 mole ratio of HCl to NaOH)		
Moles leftover	0.00120		0		
	Excess		limiting		

Volume = moles/Molarity = 0.0012 moles HCl/0.923 M = 0.0013 l = 1.3 ml of 0.923 M HCl.

Solution is colorless. Phenolphthalein is colorless in acid solution.

c.	HCl	+	NaOH	--->	H ₂ O + NaCl
Initial moles	0.00923		0.73 M x 0.01500 l = 0.01095		
Moles that react	0.00923		0.00923 (1:1 mole ratio of HCl to NaOH)		
Moles leftover	0		0.00172		
	Limiting		Excess		

Volume = moles/Molarity = 0.00172 moles NaOH/0.73 M = 0.00236 l = 2.36 ml of 0.73 M NaOH.

Solution is pink. Phenolphthalein is pink in basic solution.

8. You titrate 15.00 ml of HCl solution with 19.32 ml of 0.157 M KOH. Calculate the concentration of the HCl.

Answers: remember AB + CD ---> AD + CB

	HCl	+	KOH	--->	H ₂ O + KCl
Initial moles	15 ml, ? M		0.157 M x 0.01932 l = 0.00303 moles KOH		
Moles that react	0.00303		0.00303 (1:1 mole ratio of HCl to KOH)		
Moles leftover	0		0		

In a titration, all of the acid is neutralized by the base.

Molarity = moles/Volume.

Molarity HCl = moles HCl /Volume HCl = 0.00303/0.01500 l = 0.202 M HCl

OR

All in 1 step: 0.157 M KOH x 0.01932 l KOH x (1 mole HCl /1 mole KOH) (1/0.015 l HCl) = 0.202 M HCl

9. You want to determine the concentration of battery acid. 2.00 ml of battery acid is titrated with 31.74 ml of 2.241 M NaOH. What is the concentration of battery acid?

Answers: remember AB + CD ---> AD + CB

Battery acid is sulfuric acid (H₂SO₄).



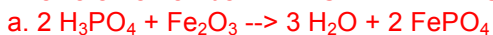
All in 1 step: 2.241 M NaOH x 0.03174 l NaOH x (1 mole H₂SO₄ /2 moles NaOH) (1/0.00200 l H₂SO₄) = 17.8 M H₂SO₄

10. a. Phosphoric acid (H₃PO₄), which is an acid is soda, removes rust (Fe₂O₃). This means you can use soda to remove rust from a rusty part. Write a balanced chemical equation and net ionic equation.

b. You add 1 can (355 ml) of soda (assume 0.05 M H₃PO₄) to 1.0 g of rust (from a rusty nail). Is this enough soda to remove the rust? In other words, the limiting reactant is _____. Calculate the amount of excess reactant leftover.

c. The reaction of rust with sulfuric acid is faster than the reaction of rust with acetic acid. Write balanced chemical equations and net ionic equations to explain why one reaction is faster than the other.

Answers: remember AB + CD ---> AD + CB



H₃PO₄ is a weak acid. Fe₂O₃ is insoluble in water. FePO₄ is insoluble in water.

Ionic and net ionic equation: 2 H₃PO₄ + Fe₂O₃ --> 3 H₂O + 2 FePO₄

b.	2 H ₃ PO ₄	+	Fe ₂ O ₃	-->	3 H ₂ O + 2 FePO ₄
Initial moles	0.05 M x 0.355 l = 0.01775 moles		1.0 g (1 mole Fe ₂ O ₃ /160 g Fe ₂ O ₃) = 0.00625 moles Fe ₂ O ₃		
Moles that react	0.0125		0.00625 (2:1 mole ratio of H ₃ PO ₄ to Fe ₂ O ₃)		
Moles leftover	0.00525		0		
	Excess		limiting		

1 can of soda will remove 1.0 g of rust.



Sulfuric acid is a strong acid. Fe₂(SO₄)₃ is soluble in water.

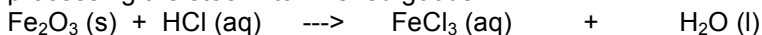
Ionic equation: 6 H⁺ + 3 SO₄²⁻ + Fe₂O₃ --> 3 H₂O + 2 Fe³⁺ + 3 SO₄²⁻

Net ionic equation: 6 H⁺ + Fe₂O₃ --> 3 H₂O + 2 Fe³⁺

H⁺ is the acid part of Sulfuric acid.

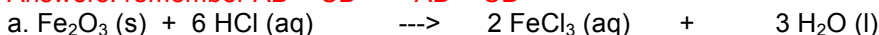
Sulfuric acid is a strong acid (high [H⁺]) and will react with rust faster than H₃PO₄, which is a weak acid (low [H⁺]).

11. You can buy hydrochloric acid at a hardware store as muriatic acid. Hydrochloric acid is used commercially in the "pickling" of steel. Pickling consists of dipping steel into an acid bath to remove rust (Fe_2O_3) from its surface before processing the steel into finished goods.

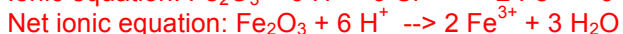


- Balance the chemical equation. Write a net ionic equation.
- If 0.5 moles of rust are present, calculate the moles of acid that reacts.
- You have 10.0 g of rust. Calculate the mass of acid that reacts with all of the rust and the mass of each product (theoretical yield) that is produced when 10.0 g of rust reacts.
- The % yield of FeCl_3 is 75%. Calculate the actual yield of FeCl_3 .

Answers: remember AB + CD \rightarrow AD + CB



HCl is a strong acid. FeCl_3 is soluble in water.



b. 0.5 moles Fe_2O_3 (6 moles HCl / 1 mole Fe_2O_3) = 3 moles HCl

c. 10.0 g Fe_2O_3 (1 mole Fe_2O_3 / 160 g Fe_2O_3)(6 moles HCl / 1 mole Fe_2O_3) (36.5 g HCl / 1 mole HCl) = 13.7 g HCl

d. 10.0 g Fe_2O_3 (1 mole Fe_2O_3 / 160 g Fe_2O_3)(2 moles FeCl_3 / 1 mole Fe_2O_3) (162.5 g FeCl_3 / 1 mole FeCl_3) = 20.3 g FeCl_3 .

This mass is the theoretical yield of FeCl_3 .

% yield = (actual yield / theoretical yield) x 100

Rearrange and solve for actual yield = % yield x theoretical yield / 100 = 75% x 20.3 g / 100 = 15.2 g FeCl_3 .