



Neutralization Practice – Supplemental Worksheet KEY

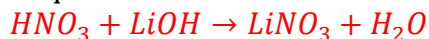
1. A salt is produced in the reaction between an **acid** and a **base**. A salt is a(n) **ionic** compound in which the anion is neither O^{2-} nor OH^- .
2. Identify the salts among the following compounds:

CaO, HClO₄, **Na₂SO₄**, NH₃, CH₄, CH₃NH₂, Ba(OH)₂, H₂C₂O₄, H₂O₂, K₂O,
NH₄Cl, Fe(OH)₃, C₆H₆, **HOCN**, **Li₃PO₃**.

3. Write down the products of the following neutralization reactions, balance the equations and name the salts:

- a. $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ sodium sulfate
- b. $2H_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6H_2O$ calcium phosphate
- c. $2HClO_4 + Sr(OH)_2 \rightarrow Sr(ClO_4)_2 + 2H_2O$ strontium perchlorate
- d. $2HNO_3 + Ba(OH)_2 \rightarrow Ba(NO_3)_2 + 2H_2O$ barium nitrate
- e. $CH_3COOH + NaOH \rightarrow NaCH_3COO + H_2O$ sodium acetate
- f. $HF + LiOH \rightarrow LiF + H_2O$ lithium fluoride
- g. $H_2SO_3 + Ba(OH)_2 \rightarrow BaSO_3 + 2H_2O$ barium sulfite
- h. $HCN + KOH \rightarrow KCN + H_2O$ potassium cyanide
- i. $H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$ sodium carbonate
- j. $2HIO + Ca(OH)_2 \rightarrow Ca(IO)_2 + 2H_2O$ calcium hypoiodite

4. What volume of a 0.025 M lithium hydroxide solution, LiOH, is needed to react completely with 75 mL of a 0.50 M nitric acid solution, HNO₃? Do not forget to write a balanced chemical equation!



$$\left| \frac{75 \text{ mL } HNO_3 \text{ sol'n}}{1000 \text{ mL } HNO_3 \text{ sol'n}} \right| \left| \frac{1 \text{ L } HNO_3 \text{ sol'n}}{1 \text{ L } HNO_3 \text{ sol'n}} \right| \left| \frac{0.50 \text{ mol } HNO_3}{1 \text{ mol } HNO_3} \right| \left| \frac{1 \text{ mol } LiOH}{1 \text{ mol } HNO_3} \right| \left| \frac{1 \text{ L } LiOH \text{ sol'n}}{0.025 \text{ mol } LiOH} \right|$$
$$= 1.5 \text{ L } LiOH \text{ sol'n}$$

Strategy used: Since the molarity of the LiOH solution is known, calculating the number of moles of LiOH in the solution allows the determination of the volume. The problem gives the molarity and volume of the HNO₃ solution which allows



the calculation of the number of moles of nitric acid. The stoichiometric ratio is then used to determine the number of moles of LiOH.

Stepwise Explanation:

First, calculate the number of moles of nitric acid that reacted (Note: Do not forget to convert the volume of the acid to liters!)

$$\left| \frac{75 \text{ mL HNO}_3 \text{ soln}}{1000 \text{ mL HNO}_3 \text{ sol'n}} \right| \left| \frac{1 \text{ L HNO}_3 \text{ sol'n}}{1 \text{ L HNO}_3 \text{ sol'n}} \right| \left| \frac{0.50 \text{ mol HNO}_3}{1 \text{ L HNO}_3 \text{ sol'n}} \right| = 0.0375 \text{ mol HNO}_3$$

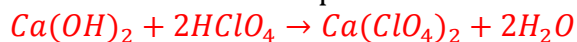
Second, use the stoichiometric ratio from the chemical equation to figure out the corresponding number of moles of LiOH:

$$\frac{0.0375 \text{ mol HNO}_3}{1 \text{ mol HNO}_3} \left| \frac{1 \text{ mol LiOH}}{1 \text{ mol HNO}_3} \right| = 0.0375 \text{ moles of LiOH}$$

Finally, use the molarity of the LiOH solution and the calculated number of moles of LiOH to calculate the volume used.

$$\frac{0.0375 \text{ mol LiOH}}{0.025 \text{ mol LiOH}} \left| \frac{1 \text{ L LiOH sol'n}}{0.025 \text{ mol LiOH}} \right| = 1.5 \text{ L of LiOH solution}$$

5. What volume of a 0.025 M calcium hydroxide, Ca(OH)₂, solution is needed to completely neutralize 75 mL of a 0.50 M perchloric acid solution, HClO₄?



$$\left| \frac{75 \text{ mL HClO}_4 \text{ soln}}{1000 \text{ mL HClO}_4 \text{ sol'n}} \right| \left| \frac{1 \text{ L HClO}_4 \text{ sol'n}}{1 \text{ L HClO}_4 \text{ sol'n}} \right| \left| \frac{0.50 \text{ mol HClO}_4}{1 \text{ L HClO}_4 \text{ sol'n}} \right| \left| \frac{1 \text{ mol Ca(OH)}_2}{2 \text{ mol HClO}_4} \right| \left| \frac{1 \text{ L Ca(OH)}_2 \text{ sol'n}}{0.025 \text{ mol Ca(OH)}_2} \right| = 0.75 \text{ L Ca(OH)}_2 \text{ sol'n}$$

Strategy used: Same strategy as the previous problem. Since the molarity of the Ca(OH)₂ solution is known, calculating the number of moles of Ca(OH)₂ in the solution allows the determination of the volume. The problem gives the molarity and volume of the HClO₄ solution which allows the calculation of the number of moles of perchloric acid. The stoichiometric ratio is then used to determine the number of moles of Ca(OH)₂.

Stepwise Explanation:

First, calculate the number of moles of perchloric acid that reacted (Note: Do not forget to convert the volume of the acid to liters!)

$$\left| \frac{75 \text{ mL HClO}_4 \text{ soln}}{1000 \text{ mL HClO}_4 \text{ sol'n}} \right| \left| \frac{1 \text{ L HClO}_4 \text{ sol'n}}{1 \text{ L HClO}_4 \text{ sol'n}} \right| \left| \frac{0.50 \text{ mol HClO}_4}{1 \text{ L HClO}_4 \text{ sol'n}} \right| = 0.0375 \text{ mol HClO}_4$$

Second, use the stoichiometric ratio from the chemical equation to figure out the corresponding number of moles of Ca(OH)₂:



$$\frac{0.0375 \text{ mol HClO}_4}{1} \left| \frac{1 \text{ mol Ca(OH)}_2}{2 \text{ mol HClO}_4} \right| = 0.01875 \text{ moles of Ca(OH)}_2$$

Finally, use the molarity of the LiOH solution and the calculated number of moles of LiOH to calculate the volume used.

$$\frac{0.01875 \text{ mol Ca(OH)}_2}{1} \left| \frac{1 \text{ L Ca(OH)}_2 \text{ sol'n}}{0.025 \text{ mol Ca(OH)}_2} \right| = 0.75 \text{ L of Ca(OH)}_2 \text{ solution}$$

6. A 10.0 mL sample of 0.20 M chloric acid solution is required to neutralize 20.0 mL of sodium hydroxide solution, NaOH.

a. What is the molarity of the sodium hydroxide solution?

$$\begin{aligned} & \text{HClO}_3 + \text{NaOH} \rightarrow \text{NaClO}_3 + \text{H}_2\text{O} \\ & \left| \frac{10.0 \text{ mL HClO}_3 \text{ sol'n}}{1} \right| \left| \frac{1 \text{ L HClO}_3 \text{ sol'n}}{1000 \text{ mL HClO}_3 \text{ sol'n}} \right| \left| \frac{0.20 \text{ mol HClO}_3}{1 \text{ L HClO}_3 \text{ sol'n}} \right| \left| \frac{1 \text{ mol NaOH}}{1 \text{ mol HClO}_3} \right| \\ & = 2.0 \times 10^{-3} \text{ mol NaOH} \end{aligned}$$

$$\text{Molarity} = \frac{2.0 \times 10^{-3} \text{ mols NaOH}}{0.020 \text{ L NaOH sol'n}} = 0.10 \text{ M NaOH sol'n}$$

Strategy used: One needs to calculate the number of moles of NaOH and use the given volume of the NaOH sol'n to determine the molarity. So, use the given molarity and volume of HClO3 sol'n to calculate the number of moles of the acid and use the stoichiometric ratio to calculate the corresponding number of moles of NaOH. The given volume of the NaOH sol'n is then used to determine the molarity.

b. What is the molarity of the salt that forms?

$$\begin{aligned} & \left| \frac{10.0 \text{ mL HClO}_3 \text{ sol'n}}{1} \right| \left| \frac{1 \text{ L HClO}_3 \text{ sol'n}}{1000 \text{ mL HClO}_3 \text{ sol'n}} \right| \left| \frac{0.20 \text{ mol HClO}_4}{1 \text{ L HClO}_4 \text{ sol'n}} \right| \left| \frac{1 \text{ mol NaClO}_3}{1 \text{ mol HClO}_3} \right| \\ & = 2.0 \times 10^{-3} \text{ mol NaClO}_3 \end{aligned}$$

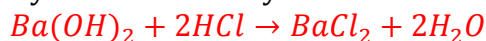
Note that the volume of the final solution is: 20.0 mL (NaOH sol'n) + 10.0 mL (HClO₃ sol'n) = 30 mL or 0.030 L

$$\text{Molarity} = \frac{2.0 \times 10^{-3} \text{ mols NaClO}_3}{0.030 \text{ L sol'n}} = 0.067 \text{ M NaClO}_3$$

Strategy Used: One needs to calculate the number of moles of NaClO₃ and use the TOTAL volume of the sol'n to determine the molarity of the salt.

7. A 10. mL sample of 0.20 M hydrochloric acid solution is required to neutralize 20. mL of barium hydroxide, Ba(OH)₂.

a. What is the molarity of the barium hydroxide solution?





$$\left| \frac{10.0 \text{ mL HCl soln}}{1000 \text{ mL HCl sol'n}} \right| \left| \frac{1 \text{ L HCl sol'n}}{1 \text{ L HCl sol'n}} \right| \left| \frac{0.20 \text{ mol HCl}}{1 \text{ L HCl sol'n}} \right| \left| \frac{1 \text{ mol Ba(OH)}_2}{2 \text{ mol HCl}} \right|$$

$$= 1.0 \times 10^{-3} \text{ mol Ba(OH)}_2$$

$$\text{Molarity} = \frac{1.0 \times 10^{-3} \text{ mols NaOH}}{0.020 \text{ L NaOH soln}} = 0.05 \text{ M Ba(OH)}_2 \text{ sol'n}$$

b. What is the molarity of the salt that forms?

$$\left| \frac{10.0 \text{ mL HCl soln}}{1000 \text{ mL HCl sol'n}} \right| \left| \frac{1 \text{ L HCl sol'n}}{1 \text{ L HCl sol'n}} \right| \left| \frac{0.20 \text{ mol HCl}}{1 \text{ L HCl sol'n}} \right| \left| \frac{1 \text{ mol BaCl}_2}{2 \text{ mol HCl}} \right|$$

$$= 1.0 \times 10^{-3} \text{ mol BaCl}_2$$

Note that the volume of the final solution is: 20.0 mL (Ba(OH)₂ sol'n) + 10.0 mL (HCl sol'n) = 30 mL or 0.030 L

$$\text{Molarity} = \frac{1.0 \times 10^{-3} \text{ mols BaCl}_2}{0.030 \text{ L soln}} = 0.033 \text{ M BaCl}_2$$

Strategy Used: Same as number 3.

8. We use 625.0 mL of a sodium hydroxide, NaOH, solution to completely neutralize 4.50 grams of phosphoric acid.

a. What is the molarity of the NaOH solution?

$$3\text{NaOH} + \text{H}_3\text{PO}_4 \rightarrow \text{Na}_3\text{PO}_4 + 3\text{H}_2\text{O}$$

$$\left| \frac{4.50 \text{ g H}_3\text{PO}_4}{98.0 \text{ g H}_3\text{PO}_4} \right| \left| \frac{1 \text{ mol H}_3\text{PO}_4}{1 \text{ mol H}_3\text{PO}_4} \right| \left| \frac{3.0 \text{ mol NaOH}}{1 \text{ mol H}_3\text{PO}_4} \right| = 0.138 \text{ mols NaOH}$$

Molarity of the NaOH solution:

$$\text{Molarity} = \frac{0.138 \text{ moles NaOH}}{0.625 \text{ L soln}} = 0.221 \text{ M solution}$$

b. What are the name and the mass of the salt that forms?

Name of the salt: sodium phosphate

Mass of the salt:

$$\left| \frac{4.50 \text{ g H}_3\text{PO}_4}{98.0 \text{ g H}_3\text{PO}_4} \right| \left| \frac{1 \text{ mol H}_3\text{PO}_4}{1 \text{ mol H}_3\text{PO}_4} \right| \left| \frac{1 \text{ mol Na}_3\text{PO}_4}{1 \text{ mol H}_3\text{PO}_4} \right| \left| \frac{164 \text{ g Na}_3\text{PO}_4}{1 \text{ mol Na}_3\text{PO}_4} \right| = 7.53 \text{ g Na}_3\text{PO}_4$$

Strategy used: Use the number of moles of phosphoric acid and the stoichiometric ratio to determine the number of moles of the salt. Then, use the molar mass of the salt, 164 g/mol to determine its mass.

9. What volume of 0.405 M KOH solution is needed to react completely with 2.15 g of copper (II) sulfate, CuSO₄? The products of the chemical reaction are copper (II) hydroxide and potassium sulfate.

$$2\text{KOH} + \text{CuSO}_4 \rightarrow \text{Cu(OH)}_2 + \text{K}_2\text{SO}_4$$

$$\left| \frac{2.15 \text{ g CuSO}_4}{159.6 \text{ g CuSO}_4} \right| \left| \frac{1 \text{ mol CuSO}_4}{1 \text{ mol CuSO}_4} \right| \left| \frac{2 \text{ mol KOH}}{1 \text{ mol CuSO}_4} \right| \left| \frac{1 \text{ L KOH sol'n}}{0.405 \text{ mol KOH}} \right| = 0.0665 \text{ L KOH sol'n}$$