

TITRATIONS

ACID-BASE CALCULATIONS

1. Write a balanced neutralization reaction, and calculate the unknown quantity for the complete neutralization of the following.

<u>ACID</u>		<u>BASE</u>	
<u>CONCENTRATION</u>	<u>VOLUME</u>	<u>CONCENTRATION</u>	<u>VOLUME</u>
a) 0.250 M HCl	30.0 cm ³	? NaOH	25.0 cm ³
<chem>HCl + NaOH -> NaCl + H2O</chem>		$C_b = \frac{C_a V_a R_b}{V_b R_a} = \frac{(0.250 M)(30.0 \text{ cm}^3)(1)}{(25.0 \text{ cm}^3)(1)}$	
$\frac{C_a V_a}{R_a} = \frac{C_b V_b}{R_b}$		$= 0.300 M$	
b) 0.500 M H ₂ SO ₄	?	0.750 M KOH	20.0 cm ³
<chem>H2SO4 + 2 KOH -> K2SO4 + 2 H2O</chem>		$V_a = \frac{C_b V_b R_a}{C_a R_b} = \frac{(0.750 M)(20.0 \text{ cm}^3)(1)}{(0.500 M)(2)} = 15.0 \text{ cm}^3$	
$V_a = \frac{C_b V_b R_a}{C_a R_b}$			
c) ? HNO ₃	15.0 cm ³	1.50 M NH ₄ OH	25.0 cm ³
<chem>HNO3 + NH4OH -> NH4NO3 + H2O</chem>		$C_a = \frac{C_b V_b R_a}{V_a R_b} = \frac{(1.50 M)(25.0 \text{ cm}^3)(1)}{(15.0 \text{ cm}^3)(1)} = 2.50 M$	
$C_a = \frac{C_b V_b R_a}{V_a R_b}$			
d) 0.400 M HNO ₃	30.0 cm ³	0.800 M NaOH	?
<chem>HNO3 + NaOH -> NaNO3 + H2O</chem>		$V_b = \frac{C_a V_a R_b}{C_b R_a} = \frac{(0.400 M)(30.0 \text{ cm}^3)(1)}{(0.800 M)(1)} = 15.0 \text{ cm}^3$	
$V_b = \frac{C_a V_a R_b}{C_b R_a}$			

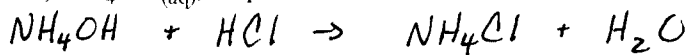
2. What is the molarity of an NaOH solution if 25.00 cm³ is required to completely neutralize 40.00 cm³ of a 1.50 M solution of H₂SO₄? 2 NaOH + H2SO4 -> Na2SO4 + 2 H2O

$$C_b = \frac{C_a V_a R_b}{V_b R_a} = \frac{(1.50 M)(40.00 \text{ cm}^3)(2)}{(25.00 \text{ cm}^3)(1)} = 4.80 M$$

3. Calculate the volume of a 0.600 M solution of HNO₃ necessary to neutralize 28.55 cm³ of a 0.450 M solution of KOH. KOH + HNO3 -> KNO3 + H2O

$$V_a = \frac{C_b V_b R_a}{C_a R_b} = \frac{(0.450 M)(28.55 \text{ cm}^3)(1)}{(0.600 M)(1)} = 21.4 \text{ cm}^3$$

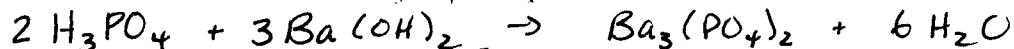
4. A titration of 15.00 cm³ of household ammonia, NH₄OH_(aq), required 38.57 cm³ of 0.780 M HCl. Calculate the molarity of the ammonia.



$$C_b = \frac{C_a V_a R_b}{V_b R_a} = \frac{(0.780 \text{ M})(38.57 \text{ cm}^3)(1)}{(15.00 \text{ cm}^3)(1)}$$

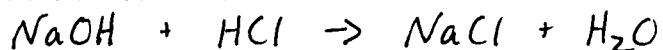
$$= 2.01 \text{ M}$$

5. What volume of 0.250 M H₃PO₄ is required to neutralize 30.00 cm³ of a 0.0500 M Ba(OH)₂ solution?



$$V_a = \frac{C_b V_b R_a}{C_a R_b} = \frac{(0.0500 \text{ M})(30.00 \text{ cm}^3)(2)}{(0.250 \text{ M})(3)} = 4.00 \text{ cm}^3$$

6. What is the concentration of NaOH if 25.00 cm³ are neutralized by 40.80 cm³ of 0.125 M HCl?



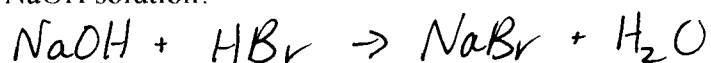
$$C_b = \frac{C_a V_a R_b}{V_b R_a} = \frac{(0.125 \text{ M})(40.80 \text{ cm}^3)(1)}{(25.00 \text{ cm}^3)(1)} = 0.204 \text{ M}$$

7. 17.5 g of NaOH is dissolved in enough water to make 500.0 cm³ of solution. What volume of 0.625 M HBr would be required to neutralize 50.0 cm³ of the NaOH solution?

$$\frac{17.5 \text{ g NaOH}}{39.997 \text{ g/mol}}$$

$$= 0.438 \text{ mol}$$

$$\frac{0.438 \text{ mol}}{0.5000 \text{ L}} = 0.875 \text{ M NaOH}$$



$$V_a = \frac{C_b V_b R_a}{C_a R_b}$$

$$V_a = \frac{(0.875 \text{ M})(50.0 \text{ cm}^3)(1)}{(0.625 \text{ M})(1)}$$

$$= 70.0 \text{ cm}^3$$

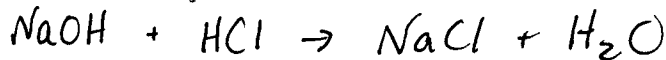
8. 31.6 cm³ of 0.125 M HNO₃ are required to neutralize a 25.0 cm³ sample of Mg(OH)₂. What is the concentration of the Mg(OH)₂?



$$C_b = \frac{C_a V_a R_b}{V_b R_a} = \frac{(0.125 \text{ M})(31.6 \text{ cm}^3)(1)}{(25.0 \text{ cm}^3)(2)}$$

$$= 0.0790 \text{ M}$$

9. A solution was prepared by dissolving 25.9 g of sodium hydroxide in enough water to make 500 cm³ of solution. 25.0 cm³ of this solution was titrated with 17.6 cm³ of hydrochloric acid. What is the concentration of the hydrochloric acid solution?



$$\frac{25.9 \text{ g NaOH}}{39.997 \text{ g/mol}}$$

$$= 0.6475 \text{ mol}$$

$$\frac{0.6475 \text{ mol}}{0.500 \text{ L}} = 1.30 \text{ M}$$

$$C_a = \frac{C_b V_b R_a}{V_a R_b}$$

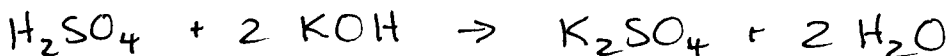
$$= \frac{(1.30 \text{ M})(25.0 \text{ cm}^3)(1)}{(17.6 \text{ cm}^3)(1)} = 1.84 \text{ M}$$

10. A solution was prepared by taking 8.60 cm³ of 18.0 M H₂SO₄ and diluting it to a volume of 750.0 cm³. 28.7 cm³ of this solution was required to completely neutralize 25.0 cm³ of a KOH solution. What is the molarity of the base?

Dilution $C_1 V_1 = C_2 V_2$

$$C_2 = \frac{(18.0 \text{ M})(8.60 \text{ cm}^3)}{(750.0 \text{ cm}^3)}$$

$$= 0.2064 \text{ M}$$



$$C_b = \frac{C_a V_a R_b}{V_b R_a} = \frac{(0.2064 \text{ M})(28.7 \text{ cm}^3)(2)}{(25.0)(1)}$$

$$= 0.474 \text{ M}$$

11. What mass of Ca(OH)₂ would be required to completely neutralize 50.0 cm³ of 0.125 M HCl?

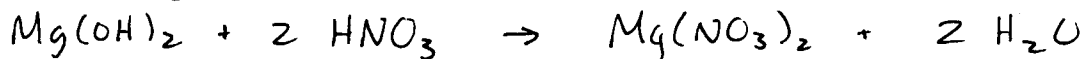


$$(0.0500 \text{ L})(0.125 \text{ M}) = 0.00625 \text{ mol HCl}$$

$$(0.00625 \text{ mol HCl}) \left(\frac{1 \text{ mol Ca(OH)}_2}{2 \text{ mol HCl}} \right) (74.09268 \frac{\text{g}}{\text{mol}})$$

$$= 0.231 \text{ g}$$

12. What mass of Mg(OH)₂ would be required to completely neutralize 70.0 cm³ of 0.175 M HNO₃?

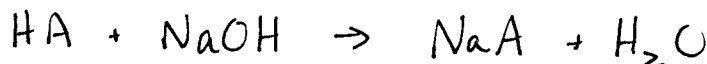


$$(0.0700 \text{ L})(0.175 \text{ M}) = 0.01225 \text{ mol HNO}_3$$

$$(0.01225 \text{ mol HNO}_3) \left(\frac{1 \text{ mol Mg(OH)}_2}{2 \text{ mol HNO}_3} \right) (58.31968 \frac{\text{g}}{\text{mol}})$$

$$= 0.357 \text{ g}$$

13. A 1.20 g sample of an unknown acid is dissolved in water and titrated with 0.150 M NaOH to the equivalence point. The volume of base is 69.0 cm³. Calculate the molar mass of the acid. The titration curve shows that the acid is monoprotic.



$$(0.150 \text{ M})(0.0690 \text{ L}) = 0.01035 \text{ mol NaOH}$$

$$\text{mol} = \frac{\text{mass}}{\text{mol mass}}$$

$$\cancel{0.01035} (0.01035 \text{ mol NaOH}) \left(\frac{1 \text{ mol HA}}{1 \text{ mol NaOH}} \right) = 0.01035 \text{ mol HA}$$

$$\text{mol mass} = \frac{\text{mass}}{\text{mol}}$$

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$$= \frac{1.20 \text{ g}}{0.01035 \text{ mol}} = 116 \text{ g/mol}$$