TITRATIONS

ACID-BASE CALCULATIONS

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

	ACID		BASE	
	CONCENTRATION	VOLUME	CONCENTRATION	VOLUME
a)	0.250 M HCl	30.0 cm^3	? NaOH	25.0 cm^3

$HCl + NaOH \rightarrow NaCl + H_2O$

$\frac{C_aV_a}{R_a} = \frac{C_bV_b}{R_b}$ $\quad C_b = \frac{C_aV_aR_b}{V_bR_a} = \frac{(0.250\,M)(30.0\,cm^3)(1)}{(25.0\,cm^3)(1)}$

$= 0.300\ M$

b)	0.500 M H_2SO_4	?	0.750 M KOH	20.0 cm^3

$H_2SO_4 + 2\,KOH \rightarrow K_2SO_4 + 2H_2O$

$V_a = \frac{C_bV_bR_a}{C_aR_b}$ $\quad V_a = \frac{(0.750\,M)(20.0\,cm^3)(1)}{(0.500\,M)(2)} = 15.0\,cm^3$

c)	? HNO_3	15.0 cm^3	1.50 M NH_4OH	25.0 cm^3

$HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$

$C_a = \frac{C_bV_bR_a}{V_aR_b} = \frac{(1.50\,M)(25.0\,cm^3)(1)}{(15.0\,cm^3)(1)} = 2.50\ M$

d)	0.400 M HNO_3	30.0 cm^3	0.800 M NaOH	?

$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$

$V_b = \frac{C_aV_aR_b}{C_bR_a} = \frac{(0.400\,M)(30.0\,cm^3)(1)}{(0.800\,M)(1)} = 15.0\,cm^3$

2. What is the molarity of an NaOH solution if 25.00 cm^3 is required to completely neutralize 40.00 cm^3 of a 1.50 M solution of H_2SO_4? $2\,NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\,H_2O$

$C_b = \frac{C_aV_aR_b}{V_bR_a} = \frac{(1.50\,M)(40.00\,cm^3)(2)}{(25.00\,cm^3)(1)} = 4.80\ M$

3. Calculate the volume of a 0.600 M solution of HNO_3 necessary to neutralize 28.55 cm^3 of a 0.450 M solution of KOH. $KOH + HNO_3 \rightarrow KNO_3 + H_2O$

$V_a = \frac{C_bV_bR_a}{C_aR_b} = \frac{(0.450\,M)(28.55\,cm^3)(1)}{(0.600\,M)(1)} = 21.4\,cm^3$

4. A titration of 15.00 cm^3 of household ammonia, $NH_4OH_{(aq)}$, required 38.57 cm^3 of 0.780 M HCl. Calculate the molarity of the ammonia. $NH_4OH + HCl \rightarrow NH_4Cl + H_2O$

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

$$= 2.01\ M$$

5. What volume of 0.250 M H_3PO_4 is required to neutralize 30.00 cm^3 of a 0.0500 M $Ba(OH)_2$ solution?

$2 H_3PO_4 + 3 Ba(OH)_2 \rightarrow Ba_3(PO_4)_2 + 6 H_2O$

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

6. What is the concentration of NaOH if 25.00 cm^3 are neutralized by 40.80 cm^3 of 0.125 M HCl?

$NaOH + HCl \rightarrow NaCl + H_2O$

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

7. 17.5 g of NaOH is dissolved in enough water to make 500.0 cm^3 of solution. What volume of 0.625 M HBr would be required to neutralize 50.0 cm^3 of the NaOH solution?

$$\frac{17.5\ g\ NaOH}{39.9971\ g/mol} = 0.438\ mol$$

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

$NaOH + HBr \rightarrow NaBr + H_2O$

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

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

$$= 70.0\ cm^3$$

8. 31.6 cm^3 of 0.125 M HNO_3 are required to neutralize a 25.0 cm^3 sample of $Mg(OH)_2$. What is the concentration of the $Mg(OH)_2$?

$2 HNO_3 + Mg(OH)_2 \rightarrow Mg(NO_3)_2 + 2 H_2O$

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

$$= 0.0790\ M$$

9. A solution was prepared by dissolving 25.9 g of sodium hydroxide in enough water to make 500 cm3 of solution. 25.0 cm^3 of this solution was titrated with 17.6 cm^3 of hydrochloric acid. What is the concentration of the hydrochloric acid solution?

$NaOH + HCl \rightarrow NaCl + H_2O$

$\frac{25.9\ g\ NaOH}{39.997\ g/mol} = 0.6475\ mol$

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

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

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

10. A solution was prepared by taking 8.60 cm^3 of 18.0 M H_2SO_4 and diluting it to a volume of 750.0 cm^3. 28.7 cm^3 of this solution was required to completely neutralize 25.0 cm^3 of a KOH solution. What is the molarity of the base?

$H_2SO_4 + 2\ KOH \rightarrow K_2SO_4 + 2\ H_2O$

Dilution $C_1V_1 = C_2V_2$

$C_2 = \frac{(18.0\ M)(8.60\ cm^3)}{(750.0\ cm^3)} = 0.2064\ M$

$C_b = \frac{C_a V_a R_b}{V_b R_a} = \frac{(0.2064\ M)(28.7\ cm^3)(2)}{(25.0)(1)} = 0.474\ M$

11. What mass of $Ca(OH)_2$ would be required to completely neutralize 50.0 cm^3 of 0.125 M HCl?

$Ca(OH)_2 + 2\ HCl \rightarrow CaCl_2 + 2\ H_2O$

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

$(0.00625\ mol\ HCl)\left(\frac{1\ mol\ Ca(OH)_2}{2\ mol\ HCl}\right)\left(74.0926 \frac{g}{mol}\right)$

$= 0.231\ g$

12. What mass of $Mg(OH)_2$ would be required to completely neutralize 70.0 cm^3 of 0.175 M HNO_3?

$Mg(OH)_2 + 2\ HNO_3 \rightarrow Mg(NO_3)_2 + 2\ H_2O$

$(0.0700\ L)(0.175\ M) = 0.01225\ mol\ HNO_3$

$(0.01225\ mol\ HNO_3)\left(\frac{1\ mol\ Mg(OH)_2}{2\ mol\ HNO_3}\right)\left(58.31968 \frac{g}{mol}\right)$

$= 0.357\ g$

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 cm^3. Calculate the molar mass of the acid. The titration curve shows that the acid is monoprotic.

$HA + NaOH \rightarrow NaA + H_2O$

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

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

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

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

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