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Titration Practice Problems

Chemists perform titrations to determine the concentration of an unknown acid or base solution. In the Virtual Lab that we did in class, the mole ratio was always 1:1. However, in the real world, that is not always so. Therefore, it is important to account for the different mole ratios, when performing titration calculations.

The formula for titration calculations is $\mathbf{M_A C_B V_A = M_B C_A V_B}$. Where M represents the molarity, C represents the mole coefficient from the balanced chemical equation, and V represents the volume used. As expected, A stands for acid, and B stands for base.

Sample Problem:

A student titrates 20.00 ml of 0.25 M H_2SO_4 solution to neutralize an unknown concentration of NaOH. The equivalence point is reached when 25.00 ml of base are added. What is the concentration of the base?

$$M_A\, C_B\, V_A = M_B\, C_A\, V_B$$

Note that since we are solving for the concentration of the base, we are trying to solve for M_B. Therefore, the equation above can be rearranged as shown below:

$$\frac{M_A\, C_B\, V_A}{C_A\, V_B} = \frac{M_B\, C_A\, V_B}{C_A\, V_B}$$

$$\frac{M_A\, C_B\, V_A}{C_A\, V_B} = M_B$$

Now write the balanced chemical equation to determine the mole coefficients. The equation shows that there are two moles of base for every one mole of acid.

$$\mathbf{1\ H_2SO_4 + 2\ NaOH \rightarrow 1\ Na_2SO_4 + 2\ H2O}$$

Now substitute the values into the appropriate places in the titration equation to determine the concentration of the base.

$$\frac{M_A\, C_B\, V_A}{C_A\, V_B} = \frac{(0.25\ M)\ (2)\ (20.00\ ml)}{(1)\ (25.00\ ml)} = M_B = 0.40\ M\ NaOH$$

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Practice Problems:

1. The concentration of NaOH is 0.50 M, if 30.0 ml of the base is needed to titrate 35.0 mL of HCl acid, what is the concentration of the acid?

$$1\ NaOH + 1\ HCl \rightarrow NaCl + H_2O$$

$$\frac{M_B\ C_A\ V_B}{C_B\ V_A} = \frac{(0.50\ M)\ (1)\ (30.00\ ml)}{(1)\ (35.00\ ml)} = M_A = 0.43\ M\ HCl$$

2. A 15.00 mL sample of acetic acid is titrated with 23.12 mL of 0.9940M Sodium Hydroxide. What is the concentration of the acetic acid?

$$1\ HC_2H_3O_2 + 1\ NaOH \rightarrow Na\ C_2H_3O_2 + H_2O$$

$$\frac{M_B\ C_A\ V_B}{C_B\ V_A} = \frac{(0.9940\ M)\ (1)\ (23.12\ ml)}{(1)\ (15.00\ ml)} = M_A = 1.53\ M\ HC_2H_3O_2$$

3. A student titrates 28.3 ml of 0.10 M H_3PO_4 solution to neutralize an unknown concentration of NaOH. The equivalence point is reached when 35.00 ml of base are added. What is the concentration of the base?

$$1\ H_3PO_4 + 3\ NaOH \rightarrow Na_3PO_4 + 3\ H_2O$$

$$\frac{M_A\ C_B\ V_A}{C_A\ V_B} = \frac{(0.10\ M)\ (3)\ (28.3\ ml)}{(1)\ (35.00\ ml)} = M_B = 0.24\ M\ NaOH$$

4. What volume of a 0.87 M solution of sulfuric acid would be needed to titrate 12.00 mL of a 0.225 M solution of calicum hydroxide?

$$1\ H_2SO_4 + 1\ Ca(OH)_2 \rightarrow CaSO_4 + 2\ H_2O$$

$$V_A = \frac{M_B\ C_A\ V_B}{M_A\ C_B} = \frac{(.225\ M)\ (1)\ (12.00\ ml)}{(0.87\ M)(1)} = 3.10\ ml\ H_2SO_4$$

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Bonus Question:

A tractor trailer truck containing 20,000 L of a 6.0M HCl has been in an accident and is in danger of spilling its cargo. What volume of 12.0 M calcium hydroxide should be sent to the scene in order to neutralize all of the acid in case the tank bursts?

$$\mathbf{2\ HCl\ +\ 1\ Ca(OH)_2 \rightarrow\ CaCl_2\ +\ 2\ H_2O}$$

$$V_B = \frac{M_A\, C_B\, V_A}{M_B\, C_A} = \frac{(6.0\ M)\ (1)\ (20{,}000\ L)}{(12.0\ M)(1)} = 10{,}000\ L\ Ca(OH)_2$$