Chemistry Lecture #98: Acid-Base Titration Problems

If you have 10.0 L of 8.00 M HCl, how many moles of H^+ are in solution?

moles of $H^+ = M_A V_A$

where M_A = molarity of acid = 8.00 M or 8.00 moles/L
V_A = volume of acid = 10.0 L

moles $H^+ = M_A V_A$

$$\frac{8.00 \text{ moles}}{\text{L}} \times \frac{10.0 \text{ L}}{1}$$

= 80.0 moles

If you have 3.00 L of 4.00 M NaOH, how many moles of OH^- are in solution?

moles $OH^- = M_B V_B$

where M_B = molarity of base = 4.00 moles/L
V_B = volume of base = 3.00 L

moles $OH^- = M_B V_B$

$$= \frac{4.00 \text{ moles}}{\text{L}} \times \frac{3.00 \text{ L}}{1}$$

= 12.0 moles

When acids and bases neutralize each other,

moles of H^+ = moles OH^-

$M_AV_A = M_BV_B$

We can use the above formula to calculate molarity when an acid of unknown concentration is titrated with a base of known concentration.

It takes 20.0 mL of 4.00 M NaOH to neutralize 5.00 mL of HCl solution. What is the concentration of the HCl solution?

Answer

$HCl + NaOH \longrightarrow H_2O + NaCl$

$M_A = ?$ $M_B = 4.00\ M$

$V_A = 5.00\ mL$ $V_B = 20.0\ mL$

We can use any unit of volume we want as long as we use the same unit for both acid and base.

$M_AV_A = M_BV_B$

$M_A(5.00) = (4.00)(20.0)$

$$M_A = \frac{(4.00)(20.0)}{(5.00)}$$

$M_A = 16.0\ M$

What if H_2SO_4 was being neutralized?

$H_2SO_4 \longrightarrow$ 2 moles H^+.

There's a subscript "2" below the "H" in H_2SO_4. We need to modify our formula to account for the fact that 1 mole of H_2SO_4 produces 2 moles of H^+.

Let S_A = subscript of H in the acid.
moles $H^+ = M_AV_A \times 2$ or
$M_AV_A\ S_A$

We use the above formula for polyprotic acids that produce more than one mole of H^+.

What if $Ca(OH)_2$ was being neutralized?

$Ca(OH)_2 \longrightarrow$ 2 moles OH^-

One mole of base produces two moles of OH^-. Notice the subscript "2" below the "(OH)". Again, need to modify our formula to account for multiple hydroxides.

Let S_B = subscript of (OH) in the base.
moles $OH^- = M_BV_B \times 2$ or
$M_BV_B\ S_B$

The final titration formula is

$M_AV_A\ S_A = M_BV_B\ S_B$

Sample acids & bases

Acid	S_A	Base	S_B
HCl	1	NaOH	1
H_2SO_4	2	$Ca(OH)_2$	2
H_3PO_4	3		

If 60.0 mL of 0.400 M H_2SO_4 solution neutralize 15.0 mL of KOH solution, find the concentration of KOH solution.

Answer

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

$M_A = 0.400$ M $\qquad M_B = ?$

$V_A = 60.0$ mL $\qquad V_B = 15.0$ mL

$S_A = 2 \qquad S_B = 1$

$$M_A V_A S_A = M_B V_B S_B$$

$$(0.400)(60.0)(2) = M_B\,(15.0)(1)$$

$$M_B = \frac{(0.400)(60.0)(2)}{(15.0)(1)}$$

$$M_B = 3.20 \text{ M}$$

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

If 25.0 mL of 0.823 M H_3PO_4 require 95.5 mL of $Ba(OH)_2$ for complete neutralization, what is the concentration of the $Ba(OH)_2$ solution?

Answer

$M_A = 0.823$ M $\quad M_B = ?$

$V_A = 25.0$ mL $\quad V_B = 95.5$ mL

$S_A = 3 \quad S_B = 2$

$M_A V_A S_A = M_B V_B S_B$

$(0.823)(25.0)(3) = M_B(95.5)(2)$

$$M_B = \frac{(0.823)(25.0)(3)}{(95.5)(2)}$$

$M_B = 0.323$ M