

## 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?

$$\text{moles of } H^+ = M_A V_A$$

where  $M_A$  = molarity of acid = 8.00 M or 8.00 moles/L

$V_A$  = volume of acid = 10.0 L

$$\text{moles } H^+ = M_A V_A$$

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

$$= 80.0 \text{ moles}$$

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

$$\text{moles } OH^- = M_B V_B$$

where  $M_B$  = molarity of base = 4.00 moles/L

$V_B$  = volume of base = 3.00 L

$$\text{moles } OH^- = M_B V_B$$

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

$$= 12.0 \text{ moles}$$

When acids and bases neutralize each other,

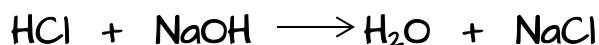
moles of  $H^+$  = moles  $OH^-$

$$M_A V_A = M_B V_B$$

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*



$$\begin{aligned} M_A &= ? & M_B &= 4.00 \text{ M} \\ V_A &= 5.00 \text{ mL} & V_B &= 20.0 \text{ mL} \end{aligned}$$

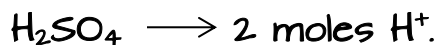
We can use any unit of volume we want as long as we use the same unit for both acid and base.

$$\begin{aligned} M_A V_A &= M_B V_B \\ M_A (5.00) &= (4.00)(20.0) \end{aligned}$$

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

$$M_A = 16.0 \text{ M}$$

What if  $\text{H}_2\text{SO}_4$  was being neutralized?



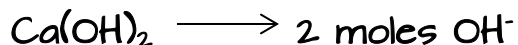
There's a subscript "2" below the "H" in  $\text{H}_2\text{SO}_4$ . We need to modify our formula to account for the fact that 1 mole of  $\text{H}_2\text{SO}_4$  produces 2 moles of  $\text{H}^+$ .

Let  $S_A$  = subscript of H in the acid.

$$\text{moles } \text{H}^+ = M_A V_A \times 2 \text{ or} \\ M_A V_A S_A$$

We use the above formula for polyprotic acids that produce more than one mole of  $\text{H}^+$ .

What if  $\text{Ca}(\text{OH})_2$  was being neutralized?



One mole of base produces two moles of  $\text{OH}^-$ . 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.

$$\text{moles } \text{OH}^- = M_B V_B \times 2 \text{ or} \\ M_B V_B S_B$$

The final titration formula is

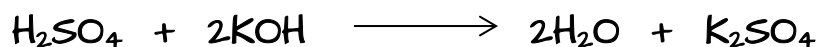
$$M_A V_A S_A = M_B V_B S_B$$

### 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



$$M_A = 0.400 \text{ M}$$

$$M_B = ?$$

$$V_A = 60.0 \text{ mL}$$

$$V_B = 15.0 \text{ mL}$$

$$S_A = 2$$

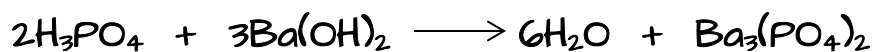
$$S_B = 1$$

$$M_A V_A S_A = M_B V_B S_B$$

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

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

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



If 25.0 mL of 0.823 M  $\text{H}_3\text{PO}_4$  require 95.5 mL of  $\text{Ba}(\text{OH})_2$  for complete neutralization, what is the concentration of the  $\text{Ba}(\text{OH})_2$  solution?

*Answer*

$$M_A = 0.823 \text{ M}$$

$$M_B = ?$$

$$V_A = 25.0 \text{ mL}$$

$$V_B = 95.5 \text{ mL}$$

$$S_A = 3$$

$$S_B = 2$$

$$M_A V_A S_A = M_B V_B S_B$$

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

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

$$M_B = 0.323 \text{ M}$$