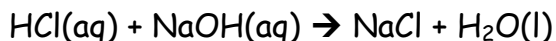


Plot a pH curve for the titration of 20.0 mL of 0.300 mol/L hydrochloric acid with 0.200 mol/L sodium hydroxide.



First, calculate the volume of sodium hydroxide required to reach the endpoint of the titration.

$$\text{endpoint } \frac{C_a V_a}{R_a} = \frac{C_b V_b}{R_b} \quad \therefore V_b = \frac{C_a V_a R_b}{C_b R_a}$$
$$V_b = \frac{(0.300 \text{ M})(0.0200 \text{ L})(1)}{(0.200 \text{ M})(1)} = 0.0300 \text{ L or } 30.0 \text{ mL}$$

The pH at the endpoint of a titration of a strong acid with a strong base will equal seven.

Next, select volumes of sodium hydroxide for the data table. Initially, the volume of NaOH should increase in large increments, but as you approach the endpoint, the increments should become smaller and smaller.

Volume of NaOH added (mL)	pH
0	
10.0	
20.0	
25.0	
27.0	
28.0	
29.0	
29.5	
29.9	
30.0 (endpoint)	7
30.1	
30.5	
31.0	
32.0	
35.0	
40.0	
50.0	
60.0	

Next, calculate the pH for each of the volumes selected for the data table.

0 mL of base added

At this point, only acid is present. HCl is a strong acid: $\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$

$$[\text{H}^+] = 0.300 \text{ M} \therefore \text{pH} = -\log(0.300) = \mathbf{0.523}$$

10 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0100 \text{ L}) = \underline{0.00200 \text{ mol OH}^-}$$

$$\text{excess} = 0.00400 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00400 \text{ mol} \div 0.0300 \text{ L} = 0.133 \text{ M}$$

$$\therefore \text{pH} = -\log(0.133) = \mathbf{0.875}$$

20 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0200 \text{ L}) = \underline{0.00400 \text{ mol OH}^-}$$

$$\text{excess} = 0.00200 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00200 \text{ mol} \div 0.0400 \text{ L} = 0.0500 \text{ M}$$

$$\therefore \text{pH} = -\log(0.0500) = \mathbf{1.30}$$

25 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0250 \text{ L}) = \underline{0.00500 \text{ mol OH}^-}$$

$$\text{excess} = 0.00100 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00100 \text{ mol} \div 0.0450 \text{ L} = 0.0222 \text{ M}$$

$$\therefore \text{pH} = -\log(0.0222) = \mathbf{1.65}$$

27 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0270 \text{ L}) = \underline{0.00540 \text{ mol OH}^-}$$

$$\text{excess} = 0.00060 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00060 \text{ mol} \div 0.0470 \text{ L} = 0.0128 \text{ M}$$

$$\therefore \text{pH} = -\log(0.0128) = \mathbf{1.89}$$

28 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0280 \text{ L}) = \underline{0.00560 \text{ mol OH}^-}$$

$$\text{excess} = 0.00040 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00040 \text{ mol} \div 0.0480 \text{ L} = 0.00833 \text{ M}$$

$$\therefore \text{pH} = -\log(0.00833) = \mathbf{2.08}$$

29 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0290 \text{ L}) = \underline{0.00580 \text{ mol OH}^-}$$

$$\text{excess} = 0.00020 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00020 \text{ mol} \div 0.0490 \text{ L} = 0.00408 \text{ M}$$

$$\therefore \text{pH} = -\log(0.00408) = \mathbf{2.39}$$

29.5 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0295 \text{ L}) = \underline{0.00590 \text{ mol OH}^-}$$

$$\text{excess} = 0.00010 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00010 \text{ mol} \div 0.0495 \text{ L} = 0.00202 \text{ M}$$

$$\therefore \text{pH} = -\log(0.00202) = \mathbf{2.69}$$

29.9 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0299 \text{ L}) = \underline{0.00598 \text{ mol OH}^-}$$

$$\text{excess} = 0.00002 \text{ mol H}^+$$

$$[\text{H}^+] = (n \div V) = 0.00002 \text{ mol} \div 0.0499 \text{ L} = 0.000401 \text{ M}$$

$$\therefore \text{pH} = -\log(0.000401) = \mathbf{3.40}$$

30.1 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0301 \text{ L}) = \underline{0.00602 \text{ mol OH}^-}$$

$$\text{excess} = 0.00002 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00002 \text{ mol} \div 0.0501 \text{ L} = 0.000399 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.000399) = 3.40, \quad \therefore \text{pH} = \mathbf{10.6}$$

30.5 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0305 \text{ L}) = \underline{0.00610 \text{ mol OH}^-}$$

$$\text{excess} = 0.00010 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00010 \text{ mol} \div 0.0505 \text{ L} = 0.00198 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.00198) = 2.70, \quad \therefore \text{pH} = \mathbf{11.3}$$

31.0 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0310 \text{ L}) = \underline{0.00620 \text{ mol OH}^-}$$

$$\text{excess} = 0.00020 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00020 \text{ mol} \div 0.0510 \text{ L} = 0.00392 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.00392) = 2.41, \quad \therefore \text{pH} = \mathbf{11.6}$$

32.0 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0320 \text{ L}) = \underline{0.00640 \text{ mol OH}^-}$$

$$\text{excess} = 0.00040 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00040 \text{ mol} \div 0.0520 \text{ L} = 0.00769 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.00769) = 2.11, \quad \therefore \text{pH} = \mathbf{11.9}$$

35.0 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0350 \text{ L}) = \underline{0.00700 \text{ mol OH}^-}$$

$$\text{excess} = 0.00100 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00100 \text{ mol} \div 0.0550 \text{ L} = 0.0182 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.0182) = 1.74, \quad \therefore \text{pH} = \mathbf{12.3}$$

40.0 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0400 \text{ L}) = \underline{0.00800 \text{ mol OH}^-}$$

$$\text{excess} = 0.00200 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00200 \text{ mol} \div 0.0600 \text{ L} = 0.0333 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.0333) = 1.48, \quad \therefore \text{pH} = \mathbf{12.5}$$

50.0 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0500 \text{ L}) = \underline{0.0100 \text{ mol OH}^-}$$

$$\text{excess} = 0.00400 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00400 \text{ mol} \div 0.0700 \text{ L} = 0.0571 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.0571) = 1.24, \quad \therefore \text{pH} = \mathbf{12.8}$$

60.0 mL of base added

$$\text{mol H}^+ = (0.300 \text{ M})(0.0200 \text{ L}) = 0.00600 \text{ mol H}^+$$

$$\text{mol OH}^- = (0.200 \text{ M})(0.0600 \text{ L}) = \underline{0.0120 \text{ mol OH}^-}$$

$$\text{excess} = 0.00600 \text{ mol OH}^-$$

$$[\text{OH}^-] = (n \div V) = 0.00600 \text{ mol} \div 0.0800 \text{ L} = 0.0750 \text{ M}$$

$$\therefore \text{pOH} = -\log(0.0750) = 1.12, \quad \therefore \text{pH} = \mathbf{12.9}$$

Volume of NaOH added (mL)	pH
0	0.523
10.0	0.875
20.0	1.30
25.0	1.65
27.0	1.89
28.0	2.08
29.0	2.39
29.5	2.69
29.9	3.40
30.0	7
30.1	10.6
30.5	11.3
31.0	11.6
32.0	11.9
35.0	12.3
40.0	12.5
50.0	12.8
60.0	12.9

pH versus volume of NaOH added

