Acid-Base Reactions

Terms to remember

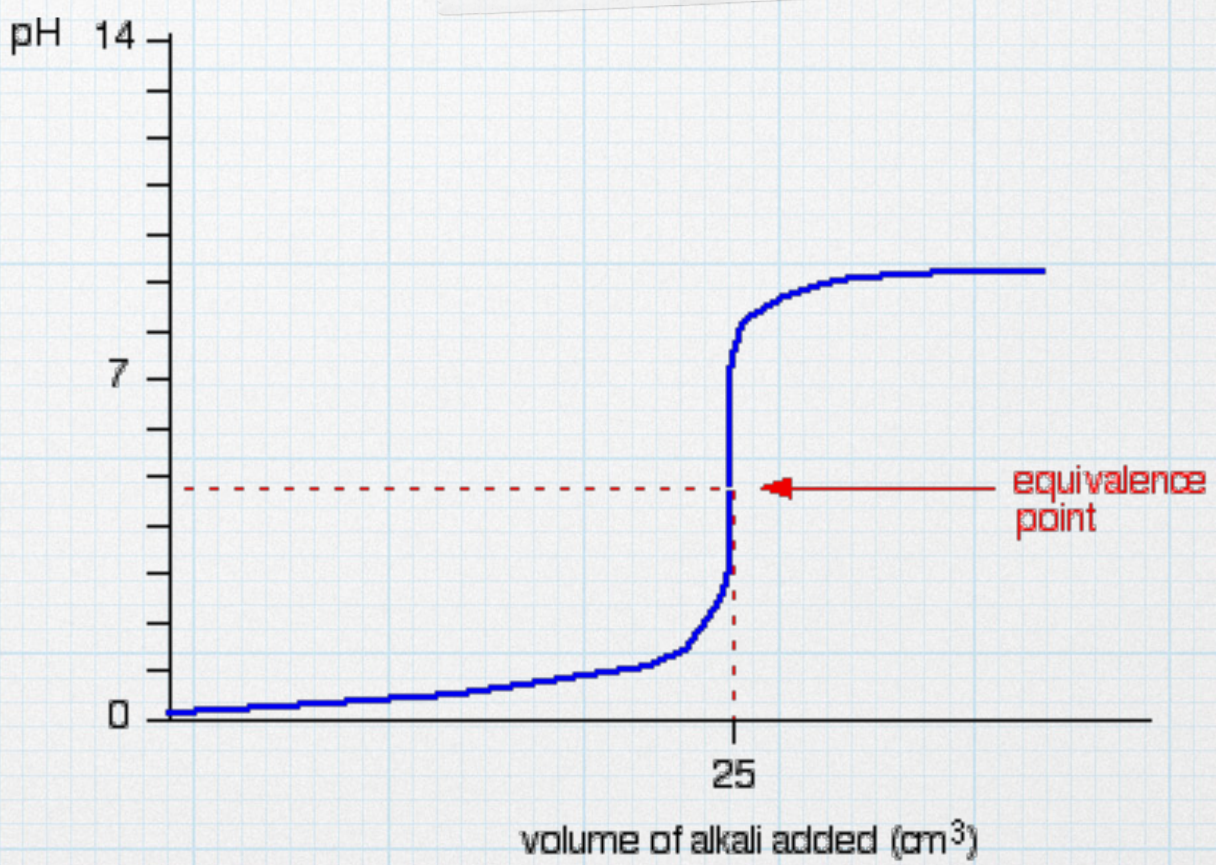
* **Neutralization:** Acid + base → salt + water, a double displacement reaction

* **Titration:** An lab technique to determine the concentration, adding an acid to a base

* **Equivalence point:** the point at which the reaction is complete (Same moles of each)

Titration Curve

* Titration curve: a graph of the pH of an acid (or base) against the volume of an added base (or acid)
* Equivalence point is equal to the midpoint on the titration curve.



Steps to Solve Strong Acid/Base

* Determine moles of each and which substance will remain.
* Calculate the concentration of [H+]
* Calculate pH

Example

* A 40.00 mL solution of 0.100 mol/L hydrochloric acid, HCl is titrated with 20 mL of 0.100 mol/L NaOH.
* $NaOH + HCl \rightarrow NaCl + H_2O$
* Calculate the pH of the solution of the solution before the equivalence point.

Solution

* Calculate moles of each

$n_{HCl} = C \times V$

$n_{NaOH} = C \times V$

Solution

* Calculate moles of each

$n_{HCl} = C \times V$
C= 0.100 M
V=0.04 L

$n_{NaOH} = C \times V$
C = 0.100 M
V=0.02 L

Solution

* Calculate moles of each

n_{HCl}= C x V
C= (0.100) (0.04)
V=0.004 M

n_{NaOH} = C x V
C = (0.100)(0.02)
V=0.002 M

Solution

* Calculate moles of each

n_{HCl}= C x V
C= (0.100) (0.04)
V=0.004 mol

n_{NaOH} = C x V
C = (0.100)(0.02)
V=0.002 mol

Which one will you use up? How much of the other substance will remain?

Solution

* $NaOH$ will be used up

Solution

* NaOH will be used up
* This means 0.002 mol of HCl will be left over

Solution

* Calculate concentration of H_3O^+
* $C = n/V$
  * $n = 0.002$ mol
  * $V = V_{total}$

Solution

* Calculate concentration of H_3O^+
* $C = n/V$
  * n= 0.002 mol
  * $V = V_{HCl} + V_{NaOH}$

Solution

* Calculate concentration of H_3O^+
* C = n/V
  * n= 0.002 mol
  * V = 0.04 L + 0.02L
    * V= 0.06L

Solution

- Calculate concentration of H_3O^+
- C = n/V
  - n= 0.002 mol
  - V = 0.04 L + 0.02L
    - V= 0.06L

Solution

* Calculate concentration of H_3O^+
* $C = n/V$
    * $C = 0.002\ mol / 0.06\ L$
    * $C = 0.033\ M$

Solution

* Use $[H_3O^+]$ to calculate pH
  * pH = - log [H3O+]
  * pH= - log (0.033)
  * pH= 1.48

Equivalence point of a strong acid/weak base reaction

* Calculate the pH at the equivalence point when 40 mL of 0.100 M ammonia is titrated with 40 mL of 0.100 M HCl.
  * $HCl + NH_3 \rightarrow NH_4Cl$
  * *When combined with water NH_4Cl, which can be represented in the following reaction:
  * $H_2O_{(l)} + NH_4^+{}_{(aq)} \rightleftharpoons NH_{3\,(aq)} + H_3O^+{}_{(aq)}$

Steps to Solve Weak Acid/Base

1) Determine number of moles (Stoichiometry)

2) Determine equilibrium concentrations (Using and ICE table)

3) Determine new pH using $[H^+]$ ions

Solution

* Determine the number of moles added

Given
C_{NH3} = 0.01M
V= 40 mL = 0.04 L

n_{NH3} = (C)(V)

Given
C_{HCl} = 0.01M
V= 40 mL = 0.04 L

n_{HCl} = (C)(V)

Solution

* Determine the number of moles added

Given
C_{NH_3} = 0.01M
V= 40 mL = 0.04 L

n_{NH_3} = (C)(V)
n_{NH_3}= (0.100 M)(0.04 L)
n_{NH_3} = 0.004 mol

Given
C_{HCl} = 0.01M
V= 40 mL = 0.04 L

n_{HCl} = (C)(V)
n_{HCl}= (0.100 M)(0.04 L)
n_{HCl} = 0.004 mol

Solution

* $HCl + NH_3 \rightarrow NH_4Cl$
    * Remember that at equivalence point the number of moles is equal.
    * That means that 0.004 mol of NH_3 will react with 0.004 mol of HCl.

Solution

* We now want to determine the amount of NH_4Cl created after the titration. We can achieve this two ways:
  * Stoichiometry
  * ICE Table

Solution

* Using Stoichiometry

$HCl + NH_3 \longrightarrow NH_4Cl$

	NH_3	NH_4Cl
	n= 0.004 mol	n= ?

Solution

* Using Stoichiometry

$HCl + NH_3 \rightarrow NH_4Cl$

NH_3: n= 0.004 mol

NH_4Cl: n= ?

↔ Molar Ratio

Solution

* Using Stoichiometry

$HCl + NH_3 \rightarrow NH_4Cl$

NH_3	NH_4Cl
n= 0.004 mol	n= ?

$$\frac{1}{1} = \frac{0.004\ mol}{n_{NH4Cl}}$$

Solution

* Using Stoichiometry

$HCl + NH_3 \rightarrow NH_4Cl$

NH_3: n= 0.004 mol

NH_4Cl: n= 0.004 mol

$$\frac{1}{1} = \frac{0.004\ \text{mol}}{n_{NH4Cl}}$$

Solution

* Using an ICE chart

* $HCl + NH_3 \rightarrow NH_4Cl$

	HCl	NH_3	NH_4Cl
I	0.004	0.004	0
C	- x	-x	+ x
E			

Solution

* Complete an ICE chart

* $HCl + NH_3 \rightarrow NH_4Cl$

	HCl	NH_3	NH_4Cl
I	0.004	0.004	0
C	-x	-x	+x
E	0	0	

Solution

* Complete an ICE chart

* $HCl + NH_3 \rightarrow NH_4Cl$

	HCl	NH3	NH4Cl
I	0.004	0.004	0
C	-0.004	-0.004	+ 0.004
E	0	0	0.004

Steps to Solve

1) Determine number of moles (Stoichiometry)

2) Determine equilibrium concentrations (Using and ICE table)

3) Determine new pH using $[H^+]$ ions

Solution

* Determine the number concentration of NH_4Cl at the equivalence point

Given

n= 0.004 mol

V = total volume present

Solution

* Determine the number concentration of NH_4Cl at the equivalence point

  Given

  n= 0.004 mol

  V = total volume present

  = 40 mL + 40 mL = 80 mL

  = 0.08 L

Solution

* Determine the number concentration of NH_4Cl at the equivalence point

C= n/v
C= 0.004 mol/ 0.08 L
C= 0.050 M

Solution

* Now use an ICE chart to determine $[H_3O^+]$

$H_2O_{(l)} + NH_4^+{}_{(aq)} \rightarrow NH_{3\,(aq)} + H_3O^+{}_{(aq)}$

I	0.050 M	0	0
C			
E			

Solution

* Now use an ICE chart to determine [H_3O^+]

$H_2O_{(l)}$ + $NH_4^+{}_{(aq)}$ → $NH_{3\,(aq)}$ + $H_3O^+{}_{(aq)}$

I	0.050 M	0	0
C	-x	+x	+ x
E			

Solution

* Now use an ICE chart to determine [H_3O^+]

$$H_2O_{(l)} + NH_4^+{}_{(aq)} \rightarrow NH_{3\,(aq)} + H_3O^+{}_{(aq)}$$

I	0.050 M	0	0
C	-x	+x	+ x
E	0.050 - x	+x	+x

Solution

- Solve for x

$$H_2O_{(l)} + NH_4^+{}_{(aq)} \longrightarrow NH_{3\,(aq)} + H_3O^+{}_{(aq)}$$

$$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$

Solution

* Solve for x

$H_2O_{(l)}$ + NH_4^+ (aq) → NH_3 (aq) + H_3O^+(aq)

$$K_a = \frac{[NH_3][H_3O^+]}{[NH_4^+]}$$

From appendix: $K_a = 5.6 \times 10^{-10}$

Solution

- Solve for x

$H_2O_{(l)} + NH_4^+{}_{(aq)} \rightarrow NH_{3\,(aq)} + H_3O^+{}_{(aq)}$

$K_a = \dfrac{[NH_3][H_3O^+]}{[NH_4^+]}$

From appendix: $K_a = 5.6 \times 10^{-10}$

$5.6 \times 10^{-10} = \dfrac{(x)^2}{(0.05 - x)}$

Solution

* Solve for x

$H_2O_{(l)} + NH_4^+{}_{(aq)} \longrightarrow NH_{3\,(aq)} + H_3O^+{}_{(aq)}$

$K_a = \dfrac{[NH_3][H_3O^+]}{[NH_4^+]}$

From appendix: $K_a = 5.6 \times 10^{-10}$

$5.6 \times 10^{-10} = \dfrac{(x)^2}{(0.05 - x)}$

Small Ka, can use Hundred's Rule

Solution

* Solve for x

$$5.6 \times 10^{-10} = \frac{(x)^2}{(0.05)}$$

Small Ka, can use Hundred's Rule

Solution

* Solve for x

$$5.6 \times 10^{-10} = \frac{(x)^2}{(0.05)}$$

$$(5.6 \times 10^{-10})(0.05) = x^2$$

Small Ka, can use Hundred's Rule

Solution

* Solve for x

$$5.6 \times 10^{-10} = \frac{(x)^2}{(0.05)}$$

$$(5.6 \times 10^{-10})(0.05) = x^2$$

$$x = \sqrt{(5.6 \times 10^{-10})(0.05)}$$

$$x = 5.29 \times 10^{-6}$$

Small Ka, can use Hundred's Rule

Solution

* From the ICE table, the $[H_3O^+]$ was equal to x
  * Therefore $[H_3O^+] = 5.29 \times 10^{-6}$ M

Steps to Solve

1) Determine number of moles (Stoichiometry)

2) Determine equilibrium concentrations (Using and ICE table)

3) Determine new pH using [H^+] ions

Solution

* Now Solve for pH

$pH = -\log [H_3O^+]$

Solution

- Now Solve for pH

$pH = -\log [H_3O^+]$

$pH = -\log (5.29 \times 10^{-6})$

$pH = 5.27$

Homework

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