

Chemistry BC2001x: General Chemistry I



Lecture 15: Thursday, November 5, 2009

Topics: Titrations: monoprotic acids and bases

How does pH vary with added acid or base?

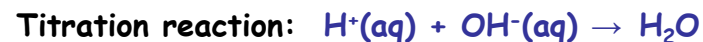
Hand in problem set 7.

Pick up

- 1) Problem set 8
- 2) Titrations
- 3) Indicators
- 4) Graded Exam 2
answers, results, and advice on WWW.

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Titration of a strong acid with a strong base



Example: 100 mL of 0.040 M HCl(aq) in conical flask and 0.100 M NaOH(aq) in buret

We start with (100 mL)(0.040 mmole/mL)
= 4.0 mmole of H^+ present initially

What is V_e , volume NaOH needed to reach equivalence?
at V_e : (mmoles OH^- added) = (mmoles H^+ initially)
but (mmoles OH^- added) = (molarity NaOH)(V_e mL)
so $V_e = (4.0 \text{ mmole}) / (0.100 \text{ mmole/mL}) = 40 \text{ mL}$

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Titration of a strong acid with a strong base

Titration of 100.0 mL of 0.0400 M HCl with 0.1000 M NaOH

STRONG ACID titrated with a STRONG BASE

Initial acid: 4.0 mmoles

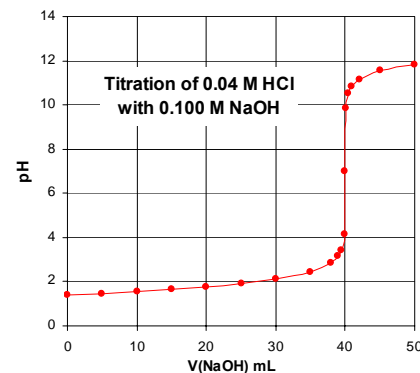
Volume of base at equivalence: 40 mL

V_{NaOH} (mL)	V_{tot} (mL)	mmol OH^- added	mmol H^+ remaining	mmol OH^- remaining	$[H^+]$	pH
0.00	100.0	0.00	4.00	0.00	0.0400	1.40
10.00	110.0					
20.00	120.0					
30.00						
39.00						
39.90						
40.00						
40.10						
41.00						
50.00						

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Titration of a strong acid with a strong base

$V(NaOH)$ mL	$V(tot)$ mL	mmol OH^- added	mmol H^+ left	mmol OH^- left	$[H^+]$	pH
0	100	0	4		0.04	1.398
5	105	0.5	3.5		0.033333	1.477
10	110	1	3		0.027273	1.564
15	115	1.5	2.5		0.021739	1.663
20	120	2	2		0.016667	1.778
25	125	2.5	1.5		0.012	1.921
30	130	3	1		0.007692	2.114
35	135	3.5	0.5		0.003704	2.431
38	138	3.8	0.2		0.001449	2.839
39	139	3.9	0.1		0.000719	3.143
39.5	139.5	3.95	0.05		0.000358	3.446
39.9	139.9	3.99	0.01		7.15E-05	4.146
40	140	4	0	0	1.00E-07	7.000
40.1	140.1	4.01		0.01	1.40E-10	9.854
40.5	140.5	4.05		0.05	2.81E-11	10.551
41	141	4.1		0.1	1.41E-11	10.851
42	142	4.2		0.2	7.10E-12	11.149
45	145	4.5		0.5	2.90E-12	11.538
50	150	5		1	1.50E-12	11.824



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Titration of a weak acid with a strong base

titration reaction (~100%): $\text{HCOOH} + \text{OH}^- \rightarrow \text{HCOO}^- + \text{H}_2\text{O}$

acidity reaction (proceeds a little): $\text{HCOOH} \rightleftharpoons \text{H}^+ + \text{HCOO}^-$ K_a

Titration of 100.0 mL of 0.0400 M HCOOH with 0.1000 M NaOH

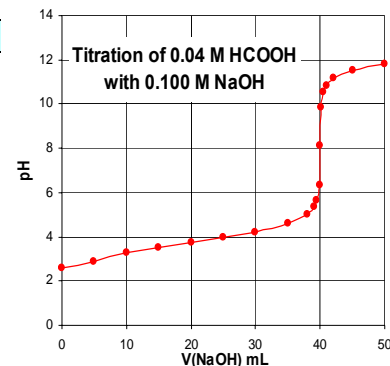
WEAK ACID ($\text{p}K_a = 3.74$) titrated with a STRONG BASE

Initial acid: _____ mmoles Volume of base at equivalence: _____ mL

V_{NaOH} (mL)	mmol OH ⁻ added	mmol OH ⁻ remaining	Approximate mmol HCOOH	Approximate mmol HCOO ⁻	pH	Approach
0.00	0.00			~0		weak acid
10.00						buffer
20.00						buffer
30.00						buffer
39.00						~ buffer
40.00						weak base
41.00						excess OH ⁻
50.00						excess OH ⁻

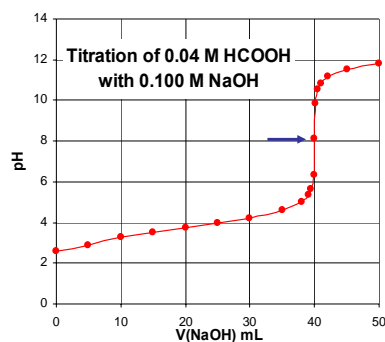
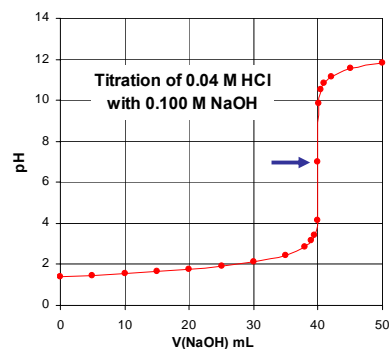
Titration of a weak acid with a strong base

$V(\text{NaOH})$ mL	$V(\text{tot})$ mL	mmol OH ⁻ added	~mmol HCOOH	~mmol HCOO ⁻	mmol OH ⁻ left	[H ⁺]	pH
0	100	0	4	0		0.002698	2.57
5	105	0.5	3.5	0.5		0.001274	2.89
10	110	1	3	1		0.000546	3.26
15	115	1.5	2.5	1.5		0.000303	3.52
20	120	2	2	2		0.000182	3.74
25	125	2.5	1.5	2.5		0.000109	3.96
30	130	3	1	3		6.07E-05	4.22
35	135	3.5	0.5	3.5		2.60E-05	4.59
38	138	3.8	0.2	3.8		9.58E-06	5.02
39	139	3.9	0.1	3.9		4.67E-06	5.33
39.5	139.5	3.95	0.05	3.95		2.30E-06	5.64
39.9	139.9	3.99	0.01	3.99		4.56E-07	6.34
40	140	4	0	4	0	7.98E-09	8.10
40.1	140.1	4.01			0.01	1.40E-10	9.85
40.5	140.5	4.05			0.05	2.81E-11	10.55
41	141	4.1			0.1	1.41E-11	10.85
42	142	4.2			0.2	7.10E-12	11.15
45	145	4.5			0.5	2.90E-12	11.54
50	150	5			1	1.50E-12	11.82



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Comparison of strong/weak titration curves



Both have **very steep** jump at V_e . pH at V_e differs (> 7 for weak).

Identical after V_e .

Before V_e : weak acid has larger pH throughout, somewhat steeper rise in buffer region. Sometimes a brief steeper climb at the beginning.

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