5) let HLac : $HC_3H_5O_3$

$HLac \rightleftharpoons H^+ + Lac^-$ $K_a = 10^{-3.86} = 1.4\times10^{-4}$

	HLac	H^+	Lac^-
I	0.100	0	0
C	−x	+x	+x
E	0.100 − x	x	x

$K_a = \frac{[H^+][Lac^-]}{[HLac]} = \frac{x^2}{0.100-x}$

$x = [H^+] = 3.7\times10^{-3}$

$pH = -\log(3.7\times10^{-3}) = 2.43$

$\%_0 = \frac{3.7\times10^{-3}}{0.100}\times100 = 3.7\%$ ✓

mmol HLac = (0.100M)(25.0mL) = 2.50 mmol

mmol OH^- = (0.100M)(4.0mL) = 0.40 mmol

$HLac + OH^- \rightarrow H_2O + Lac^-$

	HLac	OH^-	Lac^-
I	2.50	0.40	0
C	−0.40	−0.40	+0.40
E	2.10	0	0.40

$pH = pK_a + \log\frac{B}{A} = 3.86 + \log\frac{0.40}{2.10} = 3.14$

* buffer region up to 24.9mL

volume of titrant	pH
5.0mL	3.53
12.5	3.86
20.0	4.46
24.0	5.24
24.5	5.60
24.9	6.30

@ 25.0 mL = stoichiometric equivalence pt

mmol OH^- = (0.100 M)(25.0 mL) = 2.50 mmol

mmol OH^- = mmol Lac^-

$[Lac^-] = \frac{2.50 \text{ mmol}}{25.0 + 25.0 \text{ mL}} = 0.0500 \text{ M}$

	Lac^- + H_2O	⇌	HLac	+	OH^-
I	0.0500		0		0
C	−x		+x		+x
E	0.0500 − x		x		x

$K_b = \frac{1\times10^{-14}}{1.4\times10^{-4}} = 7.1\times10^{-11} = \frac{x^2}{0.0500 - x}$

$x = [OH^-] = 1.9\times10^{-6}$ M

$pOH = -\log(1.9\times10^{-6}) = 5.72$

$pH = 14 - 5.72 = 8.28$

5% $\frac{1.9\times10^{-6}}{0.0500} \times 100$ ✓

past equivalence → OH^- is in excess

mmol OH^- = (0.100 M)(25.1 mL) = 2.51 mmol

excess OH^- = 2.51 − 2.50 = 0.01 mmol OH^-

$[OH^-] = \frac{0.010 \text{ mmol}}{25.0 + 25.1 \text{ mL}} = 2\times10^{-4}$ M

pOH = 3.7

pH = 10.3

titrant added	pH
26.0	11.30
28.0	11.75
30.0	11.96

57)

	NH_3	+ H_2O	⇌	NH_4^+	+ OH^-
I	0.100			0	0
C	−x			+x	+x
E	0.100 − x			x	x

$K_b = 1.8\times10^{-5} = \frac{x^2}{(0.100-x)}$ $x = [OH^-] = 1.3\times10^{-3}\,M$

$pOH = -\log(1.3\times10^{-3}) = 2.89$

$pH = 14 - 2.89 = 11.11$

$\% = \frac{1.3\times10^{-3}}{0.100}\times100 = 1.3\%$ ✓

buffer region (4.0–24.9 ml added)

initial mmol NH_3 = (0.100 M)(25.0 ml) = 2.50 mmol

initial mmol H^+ = (0.100 M)(4.0 ml) = 0.40 mmol

	H^+	+ NH_3	→ NH_4^+
I	0.40	2.50	0
C	−0.40	−0.40	+0.40
E	0	2.10	0.40

$pH = pKa + \log\frac{B}{A} = 9.25 + \log\frac{0.40}{2.10} = 9.97$

titrant added	pH
8.0 ml	9.58
12.5 ml	9.25
20.0 ml	8.65
24.0	7.87
24.5	7.60
24.9	6.90

25.0 ml H^+ added = equivalence pt

mmol H^+ = mmol NH_4^+

mmol H^+ = (0.100 M)(25.0 ml) = 2.50 mmol

$[NH_4^+] = \frac{2.50\text{ mmol}}{25.0 + 25.0\text{ ml}} = 0.0500\,M$

	NH_4^+	⇌	H^+	+ NH_3
I	0.0500		0	0
C	−x		+x	+x
E	0.0500 − x		x	x

$K_a = 5.6\times10^{-10} = \frac{x^2}{0.0500-x}$

$x = [H^+] = 5.3\times10^{-6}\,M$

$pH = 5.28$

post equivalence pt → H^+ is in excess

H^+ added = (0.100 M)(25.1 mL) = 2.51 mmol

H^+ in excess = 2.51 - 2.50 = 0.010 mmol

$$[H^+]\text{ excess} = \frac{0.010\text{ mmol}}{25.0 + 25.1\text{ mL}} = 2.0\times10^{-4}\text{ M}$$

$pH = -\log(2.0\times10^{-4}) = 3.71$

titrant added	pH
26.0 mL	2.71
28.0 mL	2.24
30.0 mL	2.04

5a) weak acid - strong base titration

½ equivalence pt pH = pKa

$pH = -\log(6.4\times10^{-5}) = 4.19$

* @ equivalence pt mmol $HC_7H_5O_2$ = mmol OH^-

mmol $HC_7H_5O_2$ = (0.10 M)(100.0 mL) = 10.0 mmol

	OH^-	+	$HC_7H_5O_2$	→	H_2O	+	$C_7H_5O_2^-$
I	10.0		10.0				0
C	-10.0		-10.0				+10.0
E	0		0				10.0

$$\text{volume of base added} = \frac{10.0\text{ mmol}}{0.10\text{ M}} = 100.0\text{ mL}$$

$$[C_7H_5O_2^-] = \frac{10.0\text{ mmol}}{100.0 + 100.0\text{ mL}} = 0.050\text{ M}$$

	$C_7H_5O_2^-$	+	H_2O	⇌	$HC_7H_5O_2$	+	OH^-
I	0.050				0		0
C	-x				+x		+x
E	0.050-x				x		x

$$K_b = \frac{1.0\times10^{-14}}{6.4\times10^{-5}} = 1.6\times10^{-10} = \frac{x^2}{0.05 - x} \qquad x = 2.83\times10^{-6}$$

$pOH = -\log(2.83\times10^{-6}) = 5.54$ $pH = 8.45$

b) $\frac{1}{2}$ equivalence   pH = pKa

$K_a = \frac{1 \times 10^{-14}}{5.6 \times 10^{-4}} = 1.8 \times 10^{-11}$

pH = $-\log(1.8 \times 10^{-11}) = 10.74$

* equivalence pt   mmol $C_2H_5NH_2$ = mmol H+

mmol $C_2H_5NH_2$ = (0.10M)(100.0ml) = 10.0mmol

volume of H+ = $\frac{10.0 mmol}{0.20M}$ = 50.0ml

$[C_2H_5NH_3^+] = \frac{10.0 mmol}{100.0 + 50.0 ml} = 0.067 M$

	$C_2H_5NH_3^+$	⇌	H^+	+	$C_2H_5NH_2$
I	0.067		0		0
C	−x		+x		+x
E	0.067 − x		x		x

$K_a = 1.8 \times 10^{-11} = \frac{x^2}{0.067 - x}$

$x = [H^+] = 1.1 \times 10^{-6} M$

pH = $-\log(1.1 \times 10^{-6})$

pH = 5.96

5% ✓

c) $\frac{1}{2}$ equivalence

mmol H+ = (0.50M)(100.0ml) = 50.0mmol H+

$\frac{1}{2}$ equivalence → 25.0mmole H+ remain

volume OH- used = $\frac{25.0 mmol}{0.25M}$ = 100.0ml

$[H^+] = \frac{25.0 mmol}{100.0 + 100.0 ml} = 0.125 M$

pH = $-\log(0.125) = 0.903$

b.) $OH^- + HA \longrightarrow H_2O + A^-$

mmol HA = (0.10 M)(75.0 ml) = 7.5 mmol HA

mmol OH^- = (0.10 M)(30.0 ml) = 3.0 mmol OH^-

	OH^-	+	HA	$\longrightarrow$	H_2O	+	A^-
I	3.0		7.5				0
C	-3.0		-3.0				+3.0
E	0		4.5				3.0

$pH = pKa + \log \frac{B}{A}$

$5.50 = pKa + \log \frac{3.0}{4.5}$

$pKa = 5.67$

$Ka = 10^{-5.67} = 2.14 \times 10^{-6}$