21. a) $HCl \rightarrow H^+ + Cl^-$

$[HCl]_0 = [H^+] = 0.020M$

* $[H^+]$ from $HC_3H_5O_2$ is negligible

$pH = -\log(0.020) = 1.70$

b) H_2O

~~Na~~

$C_3H_5O_2^-$

H^+

~~Cl~~

	H^+	$+ \; C_3H_5O_2^-$	$\rightarrow HC_3H_5O_2$
I	0.020	0.100	0
C	−0.020	−0.020	+0.020
E	0	0.080	0.020

* what's left is a buffer solution

	$HC_3H_5O_2$	$\rightarrow C_3H_5O_2^-$	$+ \; H^+$
I	0.020	0.080	0
C	−x	+x	+x
E	0.020 − x	0.080 + x	x

$$K_a = \frac{[C_3H_5O_2^-][H^+]}{[HC_3H_5O_2]}$$

$$1.3\times10^{-5} = \frac{(0.080 + x)(x)}{0.020 - x}$$

$x = 3.25\times10^{-6}M = [H^+]$

$pH = -\log(3.25\times10^{-6}) = 5.49$

c) $[H^+] = 0.020\ M$ $\quad pH = -\log(0.020) = 1.70$

d) H_2O
$HC_3H_5O_2$
~~Na^+~~
$C_3H_5O_2^-$
$\rightarrow H^+$
~~Cl^-~~

	H^+	$+\ C_3H_5O_2^-$	$\longrightarrow HC_3H_5O_2$
I	0.020	0.100	0.100
C	−0.020	−0.020	+0.020
E	0	0.080	0.120

the buffer consumed all the acid and excess buffer remains

H_2O
$HC_3H_5O_2$
$C_3H_5O_2^-$

	$HC_3H_5O_2$	$\longrightarrow H^+$	$+\ C_3H_5O_2^-$
I	0.120	0	0.080
C	$-x$	$+x$	$+x$
E	$0.120-x$	x	$0.080+x$

$$K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = 1.3\times10^{-5} = \frac{(x)(0.080+x)}{0.120-x}$$

$x = 1.95\times10^{-5}\ M = [H^+]$

$pH = -\log(1.95\times10^{-5}) = 4.70$

5% $\quad \dfrac{1.95\times10^{-5}}{0.120}\times100 = 0.016\%$

✓

23) H_2O

$HC_3H_5O_2$

~~Na+~~

+ OH^-

	OH^-	+	$HC_3H_5O_2$	$\longrightarrow$	$C_3H_5O_2^-$	+	H_2O
I	0.020		0.100		0		
C	−0.020		−0.020		+0.020		
E	0		0.080		0.020		

what remains is a buffer

H_2O

$HC_3H_5O_2$

$C_3H_5O_2^-$

	$HC_3H_5O_2$	$\longrightarrow$	H^+	+	$C_3H_5O_2^-$
I	0.080		0		0.020
C	−x		+x		+x
E	0.080 − x		x		0.020 + x

$$K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = 1.3\times10^{-5} = \frac{(x)(0.020 + x)}{0.080 - x}$$

$x = 5.2\times10^{-5}\ M = [H^+]$

$pH = -\log(5.2\times10^{-5}) = 4.28$

$5\% \quad \frac{5.2\times10^{-5}}{0.080}\times100 = 0.065\%$ ✓

b) H_2O

~~Na^+~~

$C_3H_5O_2^-$

OH^-

the amount of the OH^- from weak base is negligible relative to the OH^- from the strong base

$[NaOH]_0 = [OH^-] = 0.020\ M$

$pOH = -\log(0.020) = 1.70$

$pH = 14 - 1.70 = 12.30$

c) H_2O

~~Na^+~~

OH^-

$[NaOH]_0 = [OH^-] = 0.020\ M$

$pOH = -\log(0.020) = 1.70$

$pH = 14 - 1.70 = 12.30$

a) H_2O
$HC_3H_5O_2$
Na^+
$C_3H_5O_2^-$
* OH^-

	OH^-	+ $HC_3H_5O_2$	$\rightarrow$ H_2O	+ $C_3H_5O_2^-$
I	0.020	0.100		0.100
C	-0.020	-0.020		+0.020
E	0	0.080		0.120

what's left is a buffer solution

H_2O
$HC_3H_5O_2$
$C_3H_5O_2^-$

	$HC_3H_5O_2$	$\rightleftharpoons$ H^+	+ $C_3H_5O_2^-$
I	0.080	0	0.120
C	$-x$	$+x$	$+x$
E	$0.080-x$	x	$0.120+x$

$$K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = 1.3\times10^{-5} = \frac{(x)(0.120+x)}{(0.080-x)}$$

$x = 8.67\times10^{-6}\,M = [H^+]$

$pH = -\log(8.67\times10^{-6}) = 5.06$

5% $\frac{8.67\times10^{-6}}{0.080}\times100 = 0.011\%$ ✓

25)

Solution	initial pH	after added H^+	after added OH^-
a	2.96	1.70	4.29
b	8.94	5.49	12.30
c	7.00	1.70	12.30
d	4.89	4.71	5.07

27) H_2O

HNO_2

Na^+

NO_2^-

	HNO_2	$\rightleftharpoons$	H^+	+	NO_2^-
I	1.00		0		1.00
C	$-x$		$+x$		$+x$
E	$1.00-x$		x		$1.00+x$

$$K_a = \frac{[H^+][NO_2^-]}{[HNO_2]} = 4.0\times10^{-4} = \frac{(x)(1.00+x)}{1.00-x}$$

$$x = 4.0\times10^{-4}\,M = [H^+]$$

$$\% = \frac{4.0\times10^{-4}}{1.00}\times 100 = 4.0\times10^{-2}\,\% \checkmark$$

$$pH = -\log(4.0\times10^{-4}) = 3.40$$

29) H_2O

HNO_2

Na^+

NO_2^-

OH^-

	OH^-	+ HNO_2	$\rightarrow$ H_2O	+ NO_2^-
I	0.10	1.00		1.00
C	−0.10	−0.10		+0.10
E	0	0.90		1.10

what's left is a buffer solution

H_2O

HNO_2

NO_2^-

	HNO_2	$\rightleftharpoons$ H^+	+ NO_2^-
I	0.90	0	1.10
C	−x	+x	+x
E	0.90−x	x	1.10+x

$$K_a = \frac{[H^+][NO_2^-]}{[HNO_2]} = 4.0\times10^{-4} = \frac{(x)(1.10+x)}{0.90-x}$$

$x = 3.3\times10^{-4}$ M $= [H^+]$

5% $\frac{3.3\times10^{-4}}{0.90}\times100 = 0.036\%$ ✓

$pH = -\log(3.3\times10^{-4}) = 3.48$

H_2O
HNO_2
Na^+
NO_2^-
* H^+
Cl^-

	H^+	+ NO_2^-	$\rightarrow$	HNO_2
I	0.20	1.00		1.00
C	-0.20	-0.20		+0.20
E	0	0.80		1.20

what's left is a buffer solution

NO_2^-
HNO_2
H_2O

	HNO_2	$\rightleftharpoons$	H^+	+ NO_2^-
I	1.20		0	0.80
C	$-x$		$+x$	$+x$
E	$1.20-x$		x	$0.80+x$

$$K_a = \frac{[H^+][NO_2^-]}{[HNO_2]} = 4.0\times10^{-4} = \frac{(x)(0.80+x)}{1.20-x}$$

$x = 6.0 \times 10^{-4}\,M = [H^+]$

$\%\ \frac{6.0\times10^{-4}}{1.20}\times 100 = 0.05\%$ ✓

$pH = -\log(6.0\times10^{-4}) = 3.22$