Answers to Exercise 12.2
K_a, pK_a, K_b and pK_a

1.

(a) Start with the initial equation:

$$K_a \cdot K_b = K_w$$

Take the logarithm of both sides and multiply both sides by -1:

$$-log(K_a \cdot K_b) = -log(K_w)$$

Recognize that the log$(a \times b) = log(a) + log(b)$:

$$-[log(K_a) + log(K_b)] = -log(K_w)$$

Break open the brackets on the left side of the equation:

$$-log(K_a) + [-log(K_b)] = -log(K_w)$$

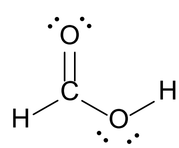
Use $pAnything = -log(Anything)$ to convert each term into $pSomething$:

$$pK_a + pK_b = pK_w$$

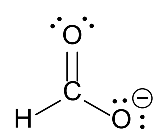
Finally, $pK_w = -log(K_w)$ and $K_w = 10^{-14}$ at 25°C.
So, $pK_w = -log(10^{-14}) = -(-14) = 14$ at 25°C.
Therefore, $pK_a + pK_b = 14$ at 25°C.

(b) $pK_a = -log(K_a)$ therefore $K_a = 10^{-pK_a}$
For formic acid, $K_a = 10^{-3.74} = 1.8 \times 10^{-4}$

(c)



formic acid
$K_a = 1.8 \times 10^{-4}$
$pK_a = 3.74$



formate
$K_b = 5.5 \times 10^{-11}$
$pK_b = 10.26$

(d) *The simplest approach is to calculate* pK_b *first then use it to calculate* K_b.
At 25°C, $pK_a(conj.acid) + pK_b(conj.base) = 14$.
Therefore, $pK_b(conj.base) = 14 - pK_a(conj.acid)$
Therefore, $pK_b(formate) = 14 - pK_a(formic\ acid) = 14 - 3.74 = 10.26$

$pK_b = -log(K_b)$ therefore $K_b = 10^{-pK_b}$
For formic acid, $K_a = 10^{-10.26} = 5.5 \times 10^{-11}$

2.

Relative Strength	pK_a	K_a	**Acid**
Strong	7	1×10^7 (10,000,000)	HCl
Border between strong and weak	0	1	H_3O^+
Weak	2.1	$10^{-2.1} = 0.008$	H_3PO_4
Very weak	14	1×10^{-14} (0.00000000000001)	H_2O
So weak we don't call it an acid	48	1×10^{-48}	CH_4

3.

(a) Look up the pK_a values for both CH_3CH_2SH and CH_3CH_2OH. Whichever species has a lower pK_a value is the stronger acid.

<u>or</u>

Look up the K_a values for both CH_3CH_2SH and CH_3CH_2OH. Whichever species has a higher K_a value is the stronger acid.

(b) Look up the pK_a values for both $CH_3CH_2SH_2^+$ and $CH_3CH_2OH_2^+$. Whichever species has a higher pK_a value is the weaker acid and therefore has the stronger conjugate base.

<u>or</u>

Look up the K_a values for both $CH_3CH_2SH_2^+$ and $CH_3CH_2OH_2^+$. Whichever species has a lower K_a value is the weaker acid and therefore has the stronger conjugate base.

It is important to note that it is the K_a (or pK_a) value for a base's conjugate acid that is relevant for part (b) ***<u>NOT</u>*** *the K_a (or pK_a) value for the base itself!*

If you want to compare properties of the bases themselves, compare K_b (or pK_b) values. A stronger base has a larger K_b or a smaller pK_b.