1. *The dissociation constant for butanoic acid is 1.5×10^{-5} mol l^{-1}.*

   Calculate the pH of a 0.010 mol l^{-1} butanoic acid solution.

2. *The pH of a 0.0010 mol l^{-1} solution of the base, BOH, is 10.*
   (a) *Calculate the dissociation constant, K_b, for the base.*
   (b) *State the relationship between K_b and pK_b.*
   (c) *Calculate pK_b for the base.*

3.

Acid	Dissociation in water	Dissociation constant
hydrogen sulphide	$H_2S \rightleftharpoons H^+ + HS^-$	8.9×10^{-8}
ethanoic	$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$	1.7×10^{-5}
chloroethanoic	$CH_2ClCOOH \rightleftharpoons H^+ + CH_2ClCOO^-$	1.3×10^{-3}
hypochlorous	$HClO \rightleftharpoons H^+ + ClO^-$	3.7×10^{-8}
chromic	$H_2CrO_4 \rightleftharpoons H^+ + HCrO_4^-$	1.0×10^{1}
propanoic	$CH_3CH_2COOH \rightleftharpoons H^+ + CH_3CH_2COO^-$	1.3×10^{-5}

(a) *Which of the above acids is*
  (i) *the weakest*
  (ii) *the strongest?*

(b) *Calculate the pK_a value for hypochlorous acid.*

(c) *Name the **two** acids from the above table which can undergo a second stage of dissociation.*
*For **each** of these acids, write the equation for the second stage of dissociation.*

4. *The reaction between sodium sulphite and hydrochloric acid takes place in two stages:*

   1st stage: $SO_3^{2-} + H^+ \rightleftharpoons HSO_3^-$ $\quad K = 1.6 \times 10^{7}$

   2nd stage: $HSO_3^- + H^+ \rightleftharpoons H_2SO_3$ $\quad K = 8.3 \times 10^{1}$

(a) *Calculate the dissociation constant, K_a, and the corresponding pK_a value for each of the two acids, HSO_3^- and H_2SO_3, given that they dissociate in the following way:*

$$HSO_3^- \rightleftharpoons H^+ + SO_3^{2-}$$

and

$$H_2SO_3 \rightleftharpoons H^+ + HSO_3^-$$

(b) *Which is the weaker acid, HSO_3^- or H_2SO_3?*

(c) *Which of the species, SO_3^{2-} or HSO_3^- or H_2SO_3, would predominate in a solution of* (i) pH = 0
  (ii) pH = 14?

5. *0.12 mol l^{-1} methanoic acid solution has a pH of 2.3.*

(a) *Calculate the dissociation constant of methanoic acid.*

(b) *If solid sodium methanoate is added to this solution of methanoic acid, explain what will happen to*
  (i) *the dissociation constant of methanoic acid*
  (ii) *the pH of the solution.*

1. pK_a (butanoic acid) $= -\log K_a = -\log 1.5\times10^{-5}$

$= 4.82$

$pH = \frac{1}{2} pK_a - \frac{1}{2}\log C$

$= \frac{1}{2}\times(4.82) - \frac{1}{2}\log(0.01)$

$= 2.41 - (\frac{-2}{2})$

$= \underline{3.41}$

2.

$$[H^+] = \text{antilog}(-pH)$$

$$= \text{antilog}(-10)$$

$$= 1 \times 10^{-10}$$

$$[OH^-] = \frac{1 \times 10^{-14}}{1 \times 10^{-10}} = 1 \times 10^{-4} \text{ mol/l}$$

$$K(b) = \frac{[OH]^2}{C} = \frac{(1 \times 10^{-4})^2}{0.001}$$

$$= \frac{1 \times 10^{-8}}{0.001}$$

$$= \underline{1 \times 10^{-5}}$$

3. (a)

(i) hypochlorus (lowest Ka)

(ii) chromic (Highest Ka)

(b)

$$pKa_{(\text{hypochlorus})} = -\log Ka = -\log(3.7 \times 10^{-8}) = \underline{7.43}$$

(c) Chromic and ~~H~~ Hydrogen Sulphide

$$HS^- \rightleftharpoons H^+ + S^{2-}$$

and

$$HCrO_4^- \rightleftharpoons H^+ + CrO_4^{2-}$$

4.

$$Ka_{(\text{1st stage})} = \frac{[SO_3^{2-}][H^+]}{[HSO_3^-]} = \frac{1}{\frac{[HSO_3^-]}{[SO_3^{2-}][H^+]}} = \frac{1}{1.6 \times 10^7} = \underline{\underline{6.25 \times 10^{-8}}}$$

$$Ka_{(\text{2nd stage})} = \frac{[HSO_3^-][H^+]}{[H_2SO_3]} = \frac{1}{\frac{[H_2SO_3]}{[HSO_3^-][H^+]}} = \frac{1}{8.3 \times 10^1} = \underline{\underline{0.012}}$$

$$pKa_{(\text{1st stage})} = -\log Ka = -\log(6.25 \times 10^{-8}) = \underline{\underline{7.2}}$$

$$pKa_{\text{2nd stage}} = -\log Ka = -\log(0.012) = \underline{1.92}$$

5. (a) $[H^+] = \text{antilog}(-pH)$

$= \text{antilog}(-2.3) = 5.01 \times 10^{-3}$ mol/l

$$K_a = \frac{[H^+]^2}{C} = \frac{(5.01 \times 10^{-3})^2}{0.12} = \frac{2.51 \times 10^{-5}}{0.12}$$

$$= \underline{2.09 \times 10^{-4}}$$

(b) (i) no effect, Ka is independent of changes in concentration

(ii) pH would increase, $[H^+]$ would decrease due to the weak acid equilibrium shifting to reduce the concentration of methanoate ions

ie

$$CH_3COO^-_{(aq)} + H^+_{(aq)} \longrightarrow CH_3COOH_{(l)}$$

H^+ removed by joining to methanoate ions which form methanoic acid molecules.