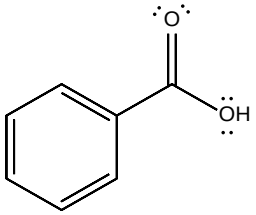
Practice Test Questions 12
Organic Acids and Bases

1. Benzoic acid is shown below. It has a pK_a value of 4.20.

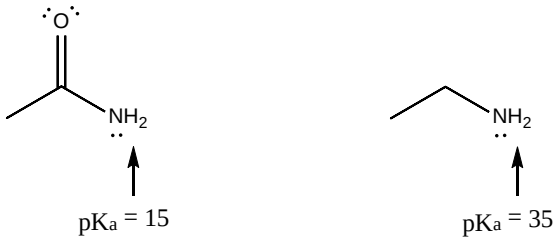


(a) Draw the conjugate base of benzoic acid. *Include all non-zero formal charges.*

(b) Calculate the K_a value for benzoic acid.

(c) Is benzoic acid a strong acid or a weak acid? How do you know? What does this tell you about its behavior in water?

2. The pK_a of ethanamide is approximately 15. The pK_a of ethanamine is approximately 35. Explain why there is such a large difference between these two pK_a values.



3. In concentrated sulfuric acid, the carbonyl group within a carboxylic acid is protonated.

(a) This tells us something about the relative strengths of two acids. What are the two acids in question, and which is the stronger of the two?

(b) The protonated carboxylic acid described above is resonance-stabilized. Draw all valid resonance structures for this cation.

4.

(a) Which of the following bases can exist in aqueous solution?

$CH_3CO_2^-$ HO^- HS^- H_2N^- H_3C^-

(b) Which of the following acids can exist in aqueous solution?

CH_3CO_2H NH_4^+ HF HBr

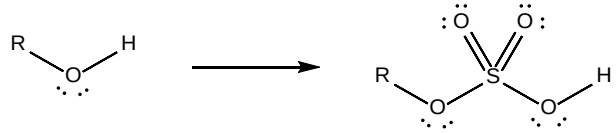
5. All of the hydrogen halides are strong acids except for HF. Explain why HF is a weaker acid than HCl, HBr and HI.

6. Phosphoric acid (orthophosphoric acid, H_3PO_4) is a relatively weak triprotic acid which can dissociate when dissolved in water.

$pK_{a1} = 2.15$
$pK_{a2} = 7.20$
$pK_{a3} = 12.32$

Use the information provided to sketch the distribution curve for orthophosphoric acid. Label both axes, along with the major species within each pH range.

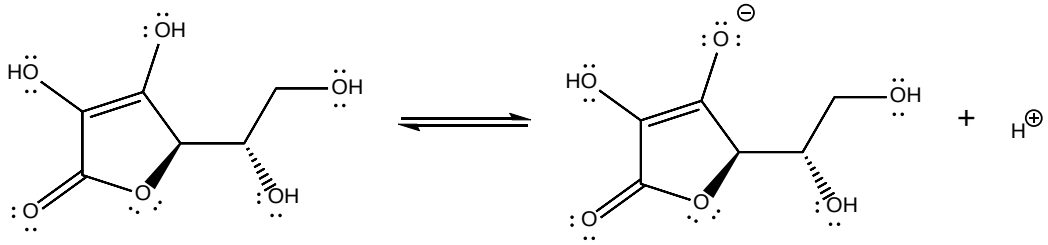
7. In order for a pharmaceutical to reach its target site, it is often necessary for it to be (at least temporarily) water soluble. One strategy that can be used to improve the water solubility of a drug is to convert an alcohol group to a sulfate ester:



This reaction is reversible, but the product is ideally stable enough to reach the target site.

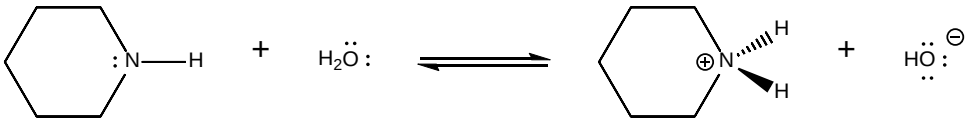
The pK_a of a typical sulfate ester is approximately -3 while the pK_a of a typical alcohol is approximately 15-19. Why does converting an alcohol group to a sulfate ester increase the water solubility of a drug in a biological system (pH ~7)?

8. What is the pH of a solution that is made up to be 0.25 M in ascorbic acid ($pK_a = 4.17$)?



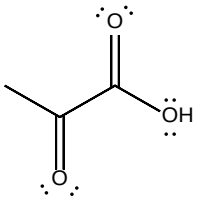
You may abbreviate "ascorbic acid" as HA.

9. What is the pH of a 0.047 M aqueous solution of piperidine ($pK_b = 2.89$) at 25 ℃ ?



You may abbreviate "piperidine" as *B*.

10. Pyruvic acid ($pK_a = 2.50\ at\ 25$ °C) has the following line-bond structure:



(a) Give the molecular formula for pyruvic acid.

(b) What functional group(s) does this molecule contain?

(c) Using an argument based on a distribution curve, explain why pyruvic acid would be almost completely dissociated in an extremely dilute solution (e.g. a solution with a concentration of pyruvic acid below 10^{-6} M).

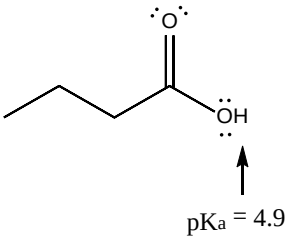
(d) In an extremely dilute aqueous solution of pyruvic acid, what equilibrium would govern the pH?

(e) Calculate the pH of an 8.0×10^{-7} M aqueous solution of pyruvic acid at 25 °C.

(f) What is the pK_a of pyruvic acid at 37 °C?

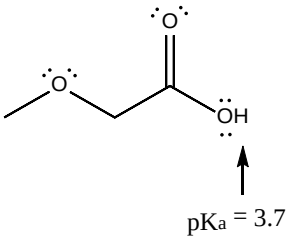
(g) Pyruvic acid is an important metabolic intermediate. In a cell at 37 °C and pH 7, would we mostly find pyruvic acid or its conjugate base, the pyruvate ion?

11. The structures and pK_a values for butanoic acid and methoxyethanoic acid are shown below:



pKa = 4.9

butanoic acid



pKa = 3.7

methoxyethanoic acid

(a) Is the reaction between butanoic acid and the methoxyethanoate anion ($CH_3OCH_2CO_2^-$) reactant-favoured or product-favoured at 25 °C? Justify your answer *(without doing any calculations).*

(b) Calculate the standard free energy of formation of the aqueous butanoate anion (the conjugate base of butanoic acid).

12. What volume of 0.025 M HCl would you have to add to 500.0 mL of 0.016 M $NH_{3(aq)}$ in order to produce a solution with a pH of 9.26 at 25 °C?

The pK_b of NH_3 is 4.74.

13. When sodium hydroxide is added to hydrogen peroxide (H_2O_2), the following reaction occurs:

$$H_2O_{2(aq)} + HO^-_{(aq)} \rightarrow H_2O_{(l)} + HO^-_{2(aq)}$$

(a) Rewrite this equation using Lewis structures and show the movement of electrons using curly arrows.

(b) Which is a stronger acid, water or hydrogen peroxide? Suggest one reason why this might be so.

(c) If the equilibrium constant for the reaction above is 200 at 25 ℃, calculate the K_a and pK_a values for H_2O_2.

Hint: If you add two reactions (1 and 2), the overall equilibrium constant will be $K_1 \times K_2$.

(d) Calculate the K_b and pK_b of HO_2^- (at 25°C).

14. The hydride ion (H^-) is a very strong base. It reacts readily with water:

$$NaH_{(s)} + H_2O_{(l)} \rightarrow H_{2(g)} + Na^+_{(aq)} + OH^-_{(aq)}$$

Give two good reasons why this reaction is favoured in the forward direction.