



Entrance Exam 2005-2006

CHEMISTRY

Duration: 1 hour

Answer the following two exercises

First Exercise (10 points)
Strong Acid and Weak Acid

Consider the following two solutions:

- Aqueous saturated solution (S_1) of benzoic acid (C_6H_5COOH).
- Aqueous solution (S_2) of nitric acid (HNO_3) of molar concentration $C_2 = 8 \times 10^{-3} \text{ mol.L}^{-1}$.

The pH of each solution is 3.

Given:

- Solubility of benzoic acid in water: $s = 2.4 \text{ g.L}^{-1}$.
- Molar mass of benzoic acid: $M = 122 \text{ g.mol}^{-1}$.
- pH range of bromothymol blue : yellow 6 green 7.6 blue.
- The temperature of each of the considered aqueous solutions is 25°C .

- 1- Calculate the molar concentration C_1 of the saturated solution (S_1).
- 2- Show that benzoic acid is a weak acid and nitric acid is a strong one.
- 3- Write the equation of the reaction of each acid with water.
- 4- Calculate the ionization coefficient of benzoic acid in (S_1).
- 5- Show that the pK_a of the pair benzoic acid/benzoate ion ($C_6H_5COOH/C_6H_5COO^-$) is equal to 4,26
- 6- Calculate the volume V_2 of nitric acid solution (S_2) that should be added to a volume $V_3 = 50 \text{ mL}$ of sodium benzoate solution (C_6H_5COONa) of concentration $C_3 = 8 \times 10^{-3} \text{ mol.L}^{-1}$ in order to obtain a buffer solution of $pH = 4,26$
Sodium benzoate is completely soluble in water.

Second Exercise (10 points)
Identification of an organic compound

The molecular formula of an organic compound (A) of an open saturated carbon chain is C_4H_8O .

- 1- Write the condensed structural formulas of possible isomers of (A).
- 2- Describe a test that allows to identifying the functional group that characterizes these isomers.



- 3- The mild oxidation of compound (A) with potassium dichromate solution acidified by sulphuric acid solution, gives compound (B). A sample of (B) changes the color of bromothymol blue to yellow. Deduce the systematic name (s) of the isomer (s) that is (are) involved.
- 4- Compound (B) reacts with SOCl_2 to give an organic compound organic (C) of a branched carbon chain. Deduce the condensed structural formula of (A). Write the condensed structural formulas of (B) and (C) and give the systematic name of each.
- 5- The hydrogenation of (A) gives a compound (D). Write the condensed structural formula of (D) and give its systematic name.
- 6- Write the equation of the reaction between (C) and (D).



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Solution of Chemistry

Duration: 1 hour

First Exercise (10 points)
Strong Acid and Weak Acid

1-
$$n = \frac{n}{M} = \frac{2,4}{122} = 0,01967 \text{ mol}$$

$$C_1 = \frac{n_1}{V} = \frac{0,01967}{1} = 0,01967 \text{ mol.L}^{-1}$$

$$[C_6H_5COOH] = 0,01967 \text{ mol.L}^{-1}$$

2- Show that HNO_3 is a strong acid?

* $S_2 : C_2 = 10^{-3} \text{ mol L}^{-1}$, $pH = 3$

$$[H_3O^+] = 10^{-pH} = 10^{-3}, [H_3O^+] = [HNO_3] = 10^{-3} \text{ mol.L}^{-1}$$

Then the nitric acid is a strong acid.

*Is $[C_6H_5COOH]$ a weak acid? $pH = 3$

$$C_1 = 0,01967 \text{ mol.L}^{-1}, \text{ there should be } C_1 > [H_3O^+]$$

$$pH = 3 \text{ thus } [H_3O^+] = 10^{-pH} = 10^{-3} \text{ mol.L}^{-1} \text{ or } 0,001 \text{ mol.L}^{-1}$$

$$C_1 = [C_6H_5COOH] = 0,01967 \text{ mol.L}^{-1} > [H_3O^+]$$

Then benzoic acid is a weak acid.

3- Equation of the reaction of each one of the acid in water : $HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$

While that of C_6H_5COOH , which is a weak acid, is: $C_6H_5COOH + H_2O \rightleftharpoons H_3O^+ + C_6H_5COO^-$

4- Let's draw the following table :

	$[C_6H_5COOH]$	$[H_3O^+]$	$[C_6H_5COO^-]$
Initial state	$C_1 = 1,96 \cdot 10^{-2}$	0	0
Final state	$C_1 (1-\alpha)$	$C_1 \alpha$	$C_1 \alpha$

$$[H_3O^+] = C_1 \alpha \quad \text{and} \quad \alpha = \frac{[H_3O^+]}{C_1} = \frac{10^{-3}}{0,0196} \approx 0,05. \quad \alpha = 0,05$$



$$5- [C_6H_5COOH] = C_1 (1-\alpha) = 0,01967 (1 - 0,05) = 0,01867$$

$$[H_3O^+] = [C_6H_5COO^-] = 10^{-3}$$

$$K_a = \frac{[H_3O^+][C_6H_5COO^-]}{[C_6H_5COOH]} = \frac{10^{-3} \times 10^{-3}}{0,01867} = 5,356 \cdot 10^{-5}$$

$$\text{And } pK_a = -\log K_a = 4,26$$

$$6- \text{Buffer solution, } pH = pK_a = 4,26$$

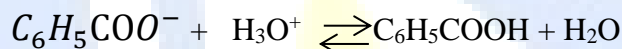
$$\text{At half- equivalence; } C_a V_a = \frac{C_b V_b}{2}$$

HNO₃ and C₆H₅COONa are totally soluble in water

$C_a V_a$ number of mole of HNO₃ or (H₃O⁺)

$C_b V_b$ number of mole of C₆H₅COONa or (C₆H₅COO⁻)

$C_b V_b$ should be more than $C_a V_a$ in order for C₆H₅COO⁻ to remain in the solution at the end of the reaction.



$$\text{Initial state } C_b V_b \quad C_a V_a \quad 0$$

$$\text{Final state } C_b V_b - C_a V_a \quad 0 \quad C_a V_a$$

The pH of the final solution is written as :

$$pH = pK_a + \log \frac{[C_6H_5COO^-]}{[C_6H_5COOH]} \quad \text{Or,} \quad pH = pK_a$$

$$\text{we know that } pH = pK_a : \text{ then we deduce that : } \log \frac{[C_6H_5COO^-]}{[C_6H_5COOH]} = 0$$



and $[C_6H_5COO^-] = [C_6H_5COOH]$

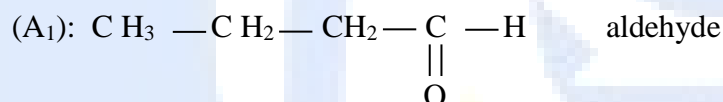
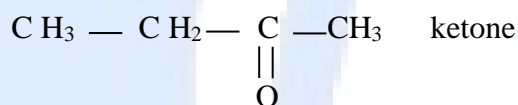
$$C_b V_b - C_a V_a = C_a V_a \text{ et } C_a V_a = \frac{C_b V_b}{2}$$

$$C_2 V_2 = \frac{1}{2} C_3 V_3 \text{ et } V_2 = \frac{C_3 V_3}{2 C_2} = \frac{8 \times 10^{-3} \times 50}{2 \times 10^{-3}} = 200 \text{ mL}$$

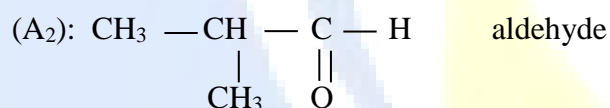
Second Exercise (10 points)
Identification of an organic compound

1- Condensed structural formulas of (A) C_4H_8O and of its isomers :

The carbon chain is saturated on the one hand and non-cyclic on the other hand



or



2- Identification :

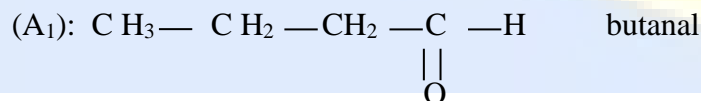
C_4H_8O + Schiff's reagent \rightarrow pink color: (A) is an aldehyde

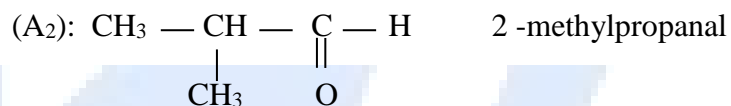
C_4H_8O + Schiff's reactant \rightarrow remains colorless: (A) is a ketone

3- (A) by mild oxidation \rightarrow (B)

(B) + Bromothymol blue \rightarrow yellow color

(B) is an acid and then (A) is an aldehyde

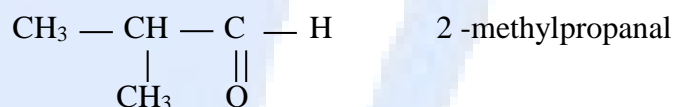




4- Formula of (A):

(B) acid + $\text{SOCl}_2 \rightarrow$ compound with a ramified chain (C)

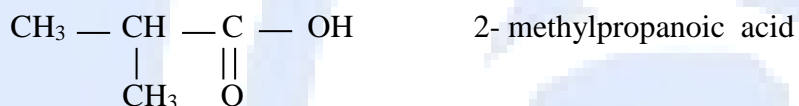
(B) derives from an aldehyde with a ramified chain



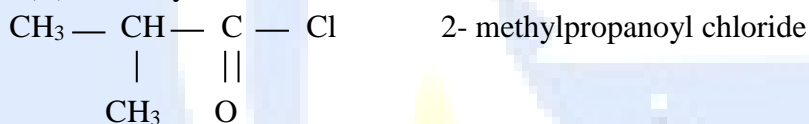
Condensed structural formulas

names

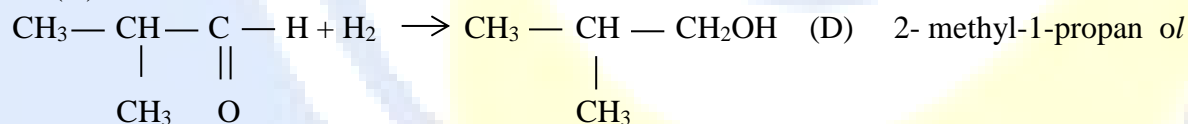
(B) is an acid with a ramified chain



(C) is an acyl chloride



5- (A) + $\text{H}_2 \rightarrow$ D



6- Equation of the reaction between (C) and (D) is

