This is a Class 1 exam

Lebanon Evangelical School
for Boys and Girls
Loucizeh - Baabda

Stage Exam 03
FEB2023

Do NOT write in this box. Your MARK will be placed here.

Subject :	Chemistry
Class :	12E and 12M
Teacher :	Mrs. Saydeh Nasrallah
Duration :	1 hour

Graph paper is needed

Your name :		*Time taken to complete exam*
Your Class :		
Exam Room :		
How many sheets, including cover sheet :		

- Do not open this paper until the teacher in charge instructs you to do so.
- The most important thing to remember in taking an exam is NEVER PANIC.
- If you are caught cheating in this exam, you will be awarded zero for ALL exams that are taken on this day.

First Exercise(3 points)
Sodium Bicarbonate

Sodium bicarbonate or sodium hydrogen carbonate, of formula $NaHCO_3$, is used in the production of beverages and carbonated water. Also it is used to reduce the excess stomach acid.

This exercise aims to study the behavior of hydrogen carbonate ions HCO_3^- in water.

Given:

- Ionic compounds $NaHCO_3$ and Na_2CO_3 are solids highly soluble in water.
- $\frac{[CO_3^{2-}]}{[HCO_3^-]} = \frac{\%(\text{by mol})CO_3^{2-}}{\%(\text{by mol})HCO_3^-}$.

Hydrogencarbonate ion, HCO_3^-, can react with water according to two chemical reactions of equations:

$HCO_3^- + H_2O \rightleftarrows CO_3^{2-} + H_3O^+$ (1) or $HCO_3^- + H_2O \rightleftarrows HO^- + CO_2, H_2O$ (2)

1- Show that hydrogencarbonate ion has an amphoteric character.

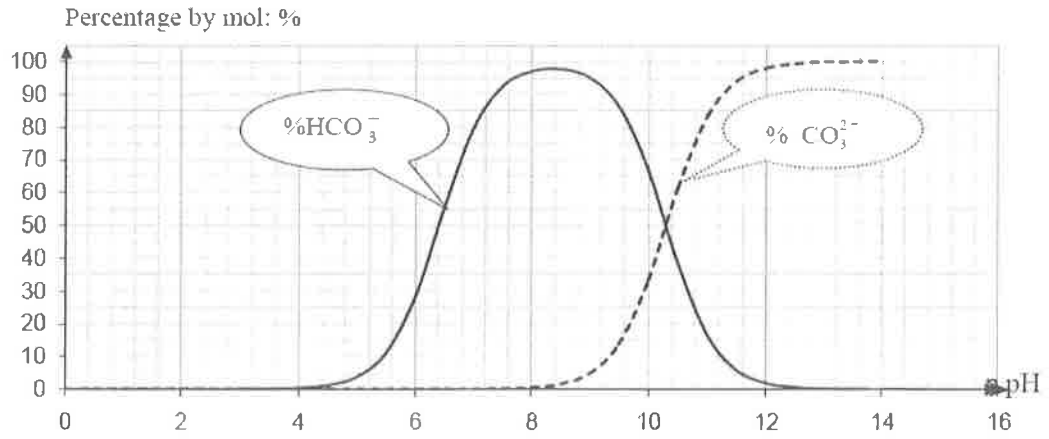
2- Using the data given the table below:

Conjugate acid/base pair	HCO_3^-/CO_3^{2-}	$(CO_2,H_2O)/HCO_3^-$	H_2O/HO^-	H_3O^+/H_2O
pK_a	10.3	6.4	14	0

2.1- Place the conjugate acid/base pairs, listed in the table, on an increasing pK_a scale.

2.2- Justify the fact that the "Bicarbonate of Soda" is recommended to reduce the excessive acidity in the stomach.

3- The following graph represents the change in the percentages by moles of the chemical species HCO_3^- and CO_3^{2-} in an aqueous solution (A) as a function of pH:



Calculate, based on the above graph, the ratio $\frac{[CO_3^{2-}]}{[HCO_3^-]}$ when the pH of solution (A) is equal to 10.

Second Exercise (7 points)
Titration of a Tablet of Vitamin C

The aim of this exercise is to verify the indication of a tablet of vitamin C (ascorbic acid of formula $C_6H_8O_6$) noted as HA.

Given:

- This study is performed at 25 °C.
- M (ascorbic acid: $C_6H_8O_6$) = $176\,g.mol^{-1}$
- M (sodium ascorbate: $C_6H_7O_6Na$) = $198\,g.mol^{-1}$

1- Titration and Preparation of Aqueous Solution of Sodium Hydroxide

A tablet of "VITAMIN C 500"is carefully grinded. The obtained powder is used to prepare 100 mL of a solution (S) of ascorbic acid, HA.

It is required to titrate the obtained solution (S) with a sodium hydroxide solution of molar concentration $C_b = 2.0\times10^{-2}mol.L^{-1}$.

For that, 10 mL of the solution (S) are introduced into a beaker and, distilled water is then added to immerse the electrode of the pH-meter.

The following materials are available:

- 50, 100 and 250 mL volumetric flasks;
- 100, 250 and 500 mL beakers;
- 5, 10 and 25 mL volumetric pipets;
- 25 mL buret;
- pH-meter and its electrode;
- Magnetic stirrer and its magnetic bar.

1.1- List the materials needed to perform this titration.

1.2- The sodium hydroxide solution of concentration $2.0\times10^{-2}mol.L^{-1}$ was prepared, just before its use, by diluting with precision a solution of concentration $1.0\times10^{-1}mol.L^{-1}$.
With justification, choose from the above list the materials used for this preparation.

2- pH-metric Follow-up

The change of the pH is followed when the sodium hydroxide solution of concentration $C_b = 2.0 \times 10^{-2} mol.L^{-1}$ is gradually added into the beaker containing the solution (S).

The results are given in the table below. (V_b is the volume of the sodium hydroxide solution added).

V_b (mL)	0	2.0	4.0	6.0	8.0	10.0	11.0	12.0
pH	3.1	3.5	3.8	4.1	4.3	4.6	4.8	5.1

V_b (mL)	13.0	13.5	14.0	14.5	15.0	16.0	18.0	20.0
pH	5.6	6.3	7.5	9.1	9.8	10.2	10.6	10.8

2.1- Write the equation of the titration reaction.
2.2- Plot, on a graph paper, the curve pH = f (V_b).
Take the following scale: 1 cm for 1 mL in abscissa and 1 cm for 1 unit of pH in ordinate.
2.3- Determine graphically the co-ordinates of the equivalence point.
2.4- Determine graphically the pK_a of the conjugate acid/base pair:
ascorbic acid/ascorbate ion, HA/A^-.
2.5- Determine the concentration of the solution (S).
Deduce the mass of ascorbic acid contained in a tablet. Is this result compatible with the indication (500) of the manufacturer "VITAMIN C 500"?

3- Buffered Vitamin C

On the label of a bottle of vitamin C we read for one tablet, among others, the following:

- Buffered Vitamin C.
- Ascorbic acid: 247 mg.
- Sodium ascorbate: 284 mg.

3.1- Based on the indications of the label, determine the number of moles of ascorbic acid and ascorbate ions present in the tablet.
Note: the number of moles of ascorbate ions is equal to that of sodium ascorbate.
3.2- A tablet of buffered vitamin C is dissolved in distilled water.
Determine the pH of the obtained solution.
3.3- Knowing that the pH inside the stomach is close to 1.
3.3.1- Indicate the one, of the two species of the conjugate acid/base pair (HA/A^-), that predominates in the stomach.
3.3.2- Deduce, by calculation, the indication "total ascorbic acid: 500 mg "carried also by the label.

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First Exercise.

1- In reaction (1), the HCO_3^- ions released protons and thus behaving as an acid. ✓
The acid/base conjugate pair is HCO_3^- / CO_3^{2-}. (1/2) ✓
In reaction (2), the HCO_3^- ions accepted protons and thus behaving as a base. ✓
The acid/base conjugate pair is (CO_2, H_2O) / HCO_3^- (1/2) ✓

As a result, the HCO_3^- ions have an amphoteric character. ✓

2.1-

	pka	
OH^-	14	H_2O
CO_3^{2-}	10.3	HCO_3^-
HCO_3^-	6.4	(CO_2, H_2O)
H_2O	0	H_3O^+

(1/2) ✓

2.2- The reaction between HCO_3^- and the acid in the stomach can be represented as:

$$HCO_3^- + H_3O^+ \rightleftharpoons H_2O + (CO_2, H_2O)$$ (1/4) ✓

$K_r = 10^{\Delta pka} = 10^{6.4-0} = 10^{6.4} > 10^4$ ⇒ reaction is complete (1/2) ✓ ✓

Therefore bicarbonate reduces the excessive acidity in the stomach. (1/4) ✓

3- $\frac{[CO_3^{2-}]}{[HCO_3^-]} = \frac{35}{65} = 0.54$ (1/2) ✓ ✓

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Second Exercise

1.1 - The materials needed for this titration are :
- 25 ml buret, 100 ml beaker, (1/2)
- 10 ml volumetric pipet.
- pH - meter and its electrode.
- magnetic stirrer and its magnetic bar.

1.2 - Dilution factor = $\frac{\text{Initial concentration}}{\text{final concentration}} = \frac{10^{-1}}{2\times10^{-2}} = 5$

Then final volume = 5 x volume of sample (1/4)

Therefore the materials needed for this preparation are:
100 ml beaker, 10 ml volumetric pipet and 50 ml volumetric flask (1/4)

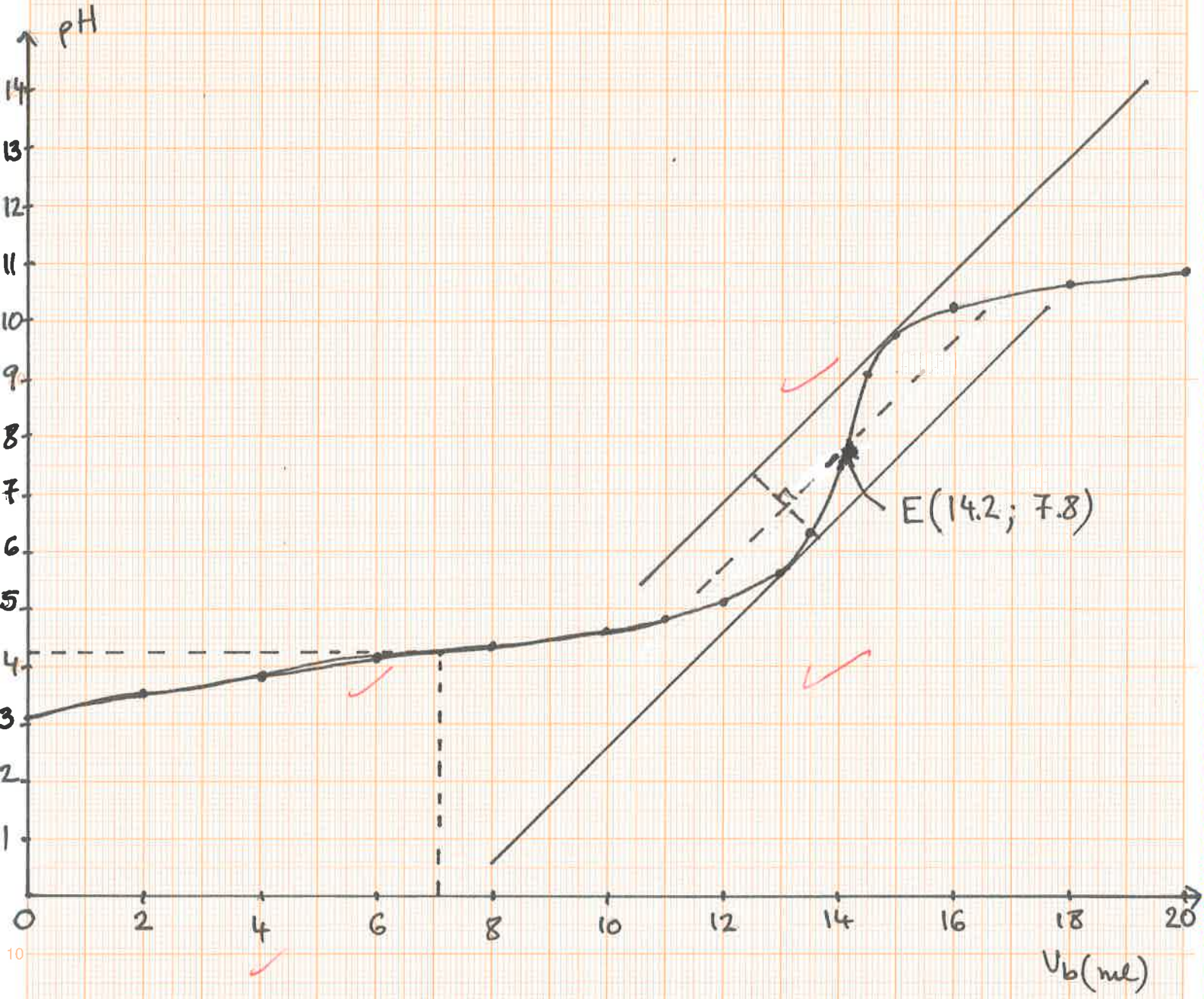
2.1 - $HA + OH^- \longrightarrow A^- + H_2O$ (1/2)

2.2 - On graph paper

2.3 - As shown on the graph, and using the parallel tangents method (1/2), the coordinates of the equivalence point E are (14.2 ; 7.8)

2.4 - $pK_a = pH$ if $[HA] = [A^-]$, which is obtained at half-equivalence point where $V_b = \frac{V_{bE}}{2} = 7.1ml$ (1/4)
Graphically $pH = pK_{a(HA/A^-)} = 4.2$ (1/4)

The curve $pH = f(V_b)$



(1)

$(\frac{1}{4})$: for correctly plotted points

$(\frac{1}{4})$: tangent lines

$(\frac{1}{2})$: smooth curve

2.5- at equivalence point :

$n_{HA} = n_{OH^-}$ (1/4)

$\Rightarrow C_{(HA)} \cdot V_{(HA)} = C_b \cdot V_b$

$\Rightarrow C_{(HA)} = \frac{2\times10^{-2} \times 14.2}{10} = 2.84 \times 10^{-2}$ mol.L^{-1} (1/4)

but $C_{(HA)} = \frac{m_{(HA)}}{V \times M_{(HA)}}$

$\Rightarrow m_{(HA)}$ in the tablet $= 2.84\times10^{-2} \times 100\times10^{-3} \times 176$

$= 499.84 \times 10^{-3}$ g (1/2)

or 499.84 mg $\simeq$ 500 mg

Thus, it is compatible with the indication 500. (1/4)

3.1- $n_{(HA)} = \frac{247 \times 10^{-3}}{176} = 1.40 \times 10^{-3}$ mol (1/4)

$n_{(A^-)} = \frac{284 \times 10^{-3}}{198} = 1.43 \times 10^{-3}$ mol (1/4)

3.2- $pH = pK_a + \log \frac{[A^-]}{[HA]}$

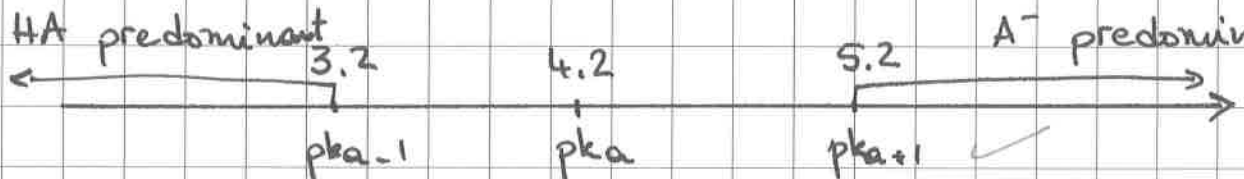
$\Rightarrow pH = pK_a + \log \frac{\frac{n_{A^-}}{V}}{\frac{n_{HA}}{V}}$

$\Rightarrow pH = pK_a + \log \frac{n_{A^-}}{n_{HA}}$

$\Rightarrow pH = 4.2 + \log \frac{1.43\times10^{-3}}{1.40\times10^{-3}} = 4.21$ (1/2)

3.3 - In the stomach, pH ≃ 1

3.3.1 - pH-scale of predominant species for the couple ascorbic acid / ascorbate (HA/A^-) according to pk_a value



(1/2)

According to the scale above, for medium of pH ≃ 1, HA is predominant.

3.3.2 - In strong acidic medium, such as the stomach, the following reaction takes place:

$$A^- + H_3O^+ \longrightarrow HA + H_2O$$ (1/4)

$$\Rightarrow n_{HA\,(Total)} = n_{HA\,(initial)} + n_{A^-\,(initial)}$$ (1/4)

$$= 1.40\times10^{-3} + 1.43\times10^{-3} = 2.83\times10^{-3}\ mol$$

$\Rightarrow$ total mass of ascorbic acid in tablet:

$$2.83\times10^{-3} \times 176 = 498\ mg \simeq 500\ mg$$ (1/4)

Thus verifying the indication: "total ascorbic acid: 500 mg."