# CHEMISTRY 2 LAB EVALUATION (1 h 30)

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- *1 A4 double-sided page. All type of calculators authorized.*
- *Data are given on page 4.*
- *Your answers and your approach must be justified. Literal formulas must be clearly written prior to numerical calculations.*
- *The requested diagrams should be carefully drawn and contain all the information you consider relevant.*

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## Experimental determination of $pK_A$ of couple $CH_3COOH/CH_3COO^-$.

### I. Presentation

*Acetic acid (or ethanoic acid), with the formula $CH_3COOH$, is a weak monocarboxylic acid whose conjugate base is the acetate (or ethanoate) ion with the formula $CH_3COO^-$. Very common in nature, it is a reagent widely used in chemical industry, in photography, in manufacturing process of some plastics and synthesis of many organic molecules. It is also the main organic compound constitutive of vinegar.*

The value of $\boldsymbol{pK_A}$ relative to the couple $CH_3COOH\ /CH_3COO^-$ has to be determined through 2 methods noted M1 and M2. For this, 2 experiments noted A and B are implemented.

Method 1 requires the analysis of results of experiment A only.

Method 2 requires the analysis of results of experiment A and experiment B.

The aqueous acetic acid solution used in these experiments is a commercial vinegar solution at about 6 wt.% (mass %).

### II. Description of experiments and results

#### 1. Experiment A:

##### a. Material

- *1 graduated burette of 25 mL (graduation 0.05 mL)*
- *1 gauged pipette of 20 mL,*
- *1 beaker of 100 mL,*
- *1 calibrated pH electrode,*
- *1 magnetic stirrer + magnetic bar*
- *1 titrating soda solution (NaOH) #1*
- *1 sample: commercial vinegar solution*

### b. Protocol

**At room temperature (25°C)**, **20 mL** of sample was placed in a beaker previously rinsed with water, and about **20 mL** of permuted water was added.
The titration was performed with soda solution #1.
The pH was read after each addition of soda solution. The solution in the beaker was homogenized using a magnetic bar.

### c. Results

The set of pH values as a function of the added volume of soda is given on Figure 1 (page 5).

## 2. Experiment B :

### a. Material

- *2 gauged flasks of 100 mL,*
- *1 thermometer (graduation 0.1 °C),*
- *1 magnetic stirrer + magnetic bar,*
- *1 calorimeter of thermal capacity expressed as water value :* $\mu = (30 \pm 5)g$
- *1 soda solution (NaOH) #2,*
- *1 sample: commercial vinegar solution.*

### b. Protocol

We wish to determine the change in molar enthalpy $\Delta_r\overline{H_T^{\circ}}$ that accompanies the neutralization reaction of one mole of acetic acid with soda carried out at temperature T, and then find the value of $pK_A$.
To do this:
100 mL of soda solution #2 was placed in a calorimeter (containing a magnetic rod) placed on a magnetic stirrer. The temperature was read for 15 min before adding 100 mL of sample, taking care to proceed quickly enough to consider that the adiabatic conditions had been met. The temperature was then read for about 10 min.

### c. Results

The set of temperature versus time is given on Figure 2 page 6.

## III. *Exploitation of results*

**For each experiment, a neat scheme of the experimental setup is required.**

You must use the experimental data to determine the $pK_A$ of acetic acid.

To do so, (non-exhaustive list):

- Describe as accurately as possible the reactions taking place in each experiment.
- Check that the experiments were carried out under the right conditions (e.g., enough reagent, total reaction...).
- Explain how to use the experimental data to calculate the necessary quantities. If you calculate the concentration of a solution, you will present the associated uncertainty calculation.
- Complete the figures provided and return them with your copy.
- Comment on the results and conclude.

You will present your reasoning rigorously and will give all the information that seems relevant to you, taking care to be both as explicit and as synthetic as possible. If you have to make hypotheses, you will take care to specify them and to justify them (either a priori or a posteriori).

For experiment B in particular:

- Write the affine relation relating the equilibrium constant $K_T^\circ$ of the neutralization reaction, the change in standard molar enthalpy $\Delta_r\overline{H_T^\circ}$ and in standard molar entropy $\Delta_r\overline{S_T^\circ}$.
- Calculate $\Delta_r\overline{S_T^\circ}$. from the tabulated values.
- Deduce a relationship linking the acidity constant $K_A$, the water self-dissociation constant $K_e$, the change in standard molar enthalpy $\Delta_r\overline{H_T^\circ}$ and change in standard molar entropy $\Delta_r\overline{S_T^\circ}$.
- For the $\Delta_r\overline{H_T^\circ}$, you will frame its value considering as uncertainties only the one on the calorimeter water value µ and the one on the temperature measurement to obtain $\Delta_r\overline{H_T^\circ}_{\text{min}}$ and $\Delta_r\overline{H_T^\circ}_{\text{max}}$

## IV. Data :

Gases are supposed ideal.
For calculations: $R = 8.314\, J.K^{-1}.mol^{-1}$ ; $0°C = 273\, K$, $1\, M$ means $1\, mole.L^{-1}$

The concentration in acetic acid of the commercial vinegar (expressed in mass %) corresponds to the mass (g) of $CH_3COOH$ for 100 g of vinegar solution.

$3 < pK_A\ CH_3COOH/CH_3COO^- < 6$ Reminder : $pK_A = -\log(K_A)$

Water self-dissociation constant at 25 °C: $K_e = 10^{-14}$

Changes in molar enthalpy $\Delta_r\overline{H_T^\circ}$ and molar entropy $\Delta_r\overline{S_T^\circ}$ are supposed independent on temperature.

Thermal capacities of all aqueous solutions are supposed equal to the one of pure water: $Cp_{solution} = Cp_{water} = 4.18\, J.K^{-1}.g^{-1}$.

All aqueous solutions have a density: $\rho = 1.00\, g.cm^{-3}$

*Table 1 : Molar masses*

| **Elements** | $\boldsymbol{H}$ | $\boldsymbol{C}$ | $\boldsymbol{O}$ | $\boldsymbol{Na}$ |
|---|---|---|---|---|
| $\boldsymbol{g.mol^{-1}}$ | 1 | 12 | 16 | 23 |

*Table 2 : Standard molar entropy values $S^\circ_{298\,K}$*

| **Compounds** | $\boldsymbol{CH_3COOH_{aq}}$ | $\boldsymbol{CH_3COO^-{}_{aq}}$ | $\boldsymbol{HO^-{}_{aq}}$ | $\boldsymbol{H_3O^+{}_{aq}}$ | $\boldsymbol{H_2O_{liq}}$ |
|---|---|---|---|---|---|
| $\boldsymbol{S^\circ_{298\,K}}$ $(\boldsymbol{J.K^{-1}.mol^{-1}})$ | 178.7 | 86.6 | -10.8 | 0.0 | 69.9 |

**Soda solution #1 (experiment A) :** *sodium hydroxide : $Na^+, HO^-$ obtained by dissolution of $6.040\, g$ of solid $NaOH$ in demineralized water in a 100 mL gauged flask.*

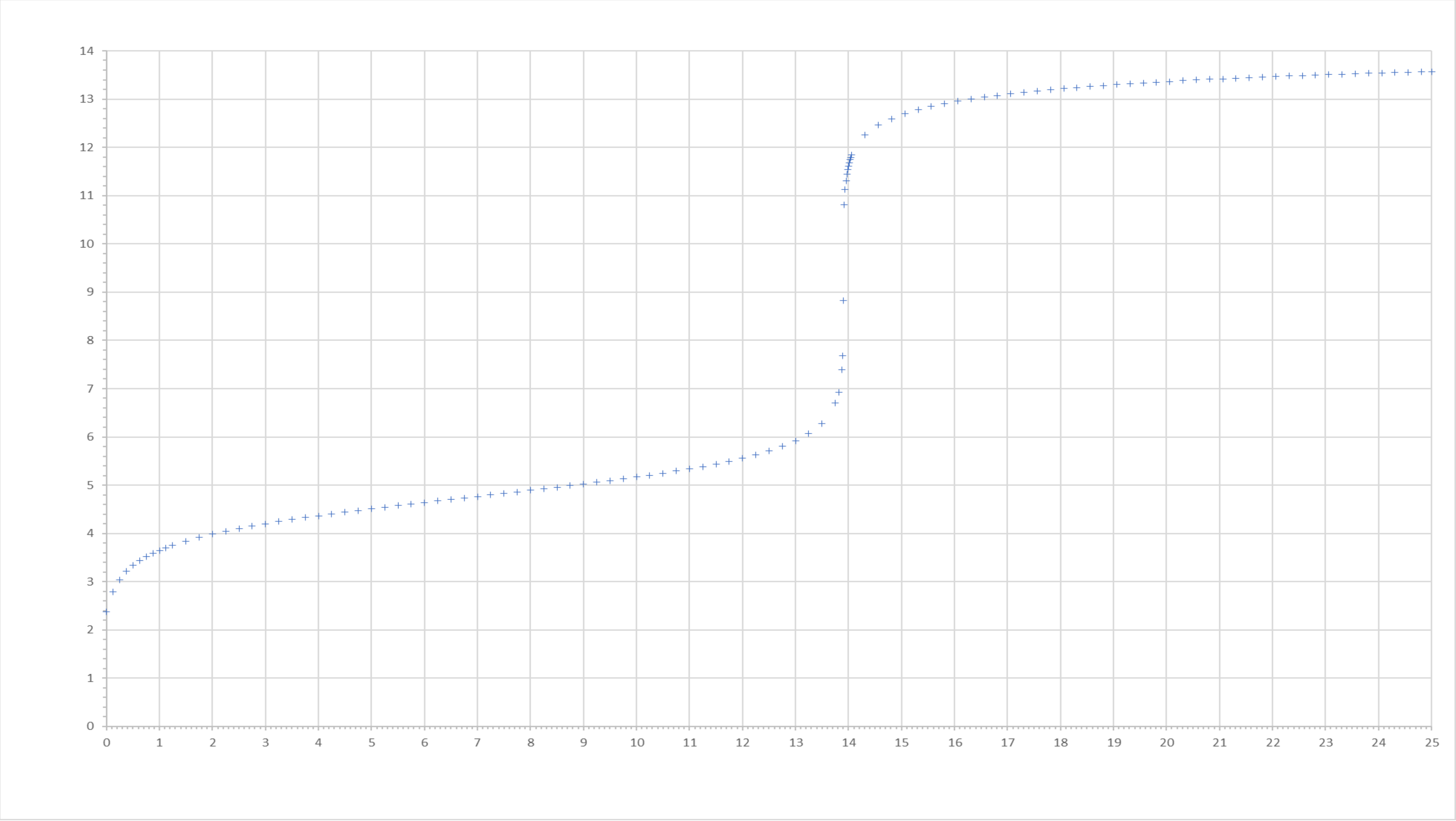
**Soda solution #°2 (experiment B) :** *sodium hydroxide : $Na^+, HO^-$ of concentration* $(1.100\ \pm 0.003)M$

**Uncertainties associated with the glassware used:**

- Gauged pipette: $\frac{\Delta V_{pipette}}{V_{pipette}} = \frac{1}{200}$
- Gauged flask: $\frac{\Delta V_{flask}}{V_{flask}} = \frac{1}{1000}$
- Graduated burette: $\frac{\Delta V_{burette}}{V_{burette}} = \frac{2\times\frac{1}{2}\, graduation}{V_{versé}}$
- Precision weighing scale: 0.001 g per reading

LAST NAME : FIRST NAME: Group # :

**Experiment A results. Complete this figure with as much information you can provide.**



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**Experiment B results. Complete this figure with as much information you can provide.**