49. Hydrogen chloride HCl

Hydrogen chloride, like hydrochloric acid, is an important chemical in chemi industry, or in science.

A volume of hydrogen chloride equivalent to 10^{-2} mol is dissolved in one liter o water at 25°C.

Measurement of the pH of the solution (S) obtained using a pH meter gives a value of 2.

1. Write the equation of the ionization reaction of hydrogen chloride in water.
2. Deduce the concentrations of the chemical species present in the solution (S).
3. Show that the reaction between hydrogen chloride and water is quasi-complet Conclude.

50. A scale product : sulfamic acid

A scale product for a commercially available coffee-pot is in the form of a whit powder mainly contains sulfamic acid.

A scale product essentially contains sulfamic acid $(H_2)N\text{-}(SO_3)H$. It is considered to be the only acid contained in the scale product, and behaves like a strong acid. A sodium hydroxide solution is prepared by dissolving a little more than one gram of sodium hydroxide in 500 mL of distilled water : a solution S_1 is obtained. The concentration of should be calculated by titrating 20 mL of S_1 with 0.05 $mol.L^{-1}$ hydrochloric acid solution. The equivalence is obtained for 22.5 mL of added hydrochloric acid solution.

1. Determine the concentration of S_1.
2. Dissolution of 500 mg of the scale product in 100 mL of distilled water leads to solution S_2. 20 mL of S_2 are titrated with the solution S_1. The equivalence is obtained when 17.2 mL of S_1 have been poured.
   - **2.1.** Write the equation of the titration reaction.
   - **2.2.** Deduce the concentration of S_2.
3. Show that the percentage by mass of sulfamic acid in the scale product studied is 93 %.

Given : Molar masses in $g.mol^{-1}$: S = 32 ; O = 16 ; H = 1 ; N = 14.

51. pH - concentration - dilution - strong acid

1. State the definition of the pH of an aqueous solution.
2. The concentration of H_3O^+ ions in solution A is $[H_3O^+] = 2.0 \times 10^{-3}$ $mol.L^{-1}$. Calculate its pH.
3. An aqueous solution B has a pH of 3.5. Calculate the concentration of H_3O^+ ions in solution B.
4. Calculate the number of moles of H_3O^+ ions contained in a volume V = 20 mL of solution B.

5. A solution C is prepared by mixing a volume V = 20 mL of solution B with a volume V' = 80 mL of pure water. Calculate the concentration of the solution C by neglecting H_3O^+ ions obtained from the auto ionization of water.
6. Deduce the pH of solution C. Conclude.

52. Acid in the swimming pool

Hydrochloric acid is a dangerous acid. It is not recommended to use it in your swimming pool, even if it can lower the pH of water. This could harm the health of swimmers, causing significant water imbalances.

A swimming pool of length L = 25 m, width l = 6 m is filled with water at a height H = 2.5 m. The pH of the water is measured pH = 5.5.

250 mL of hydrochloric acid with a concentration of 12 $mol.L^{-1}$ are poured. Determine the final pH by considering that the hydronium ions brought by the acid are added to those supplied by the water.

53. Titration of a caustic product

Household caustic product poisoning is relatively common.

Two grade-12 students have a commercial solution of a caustic product, a sodium hydroxide solution showing the following indications : Density d = 1.03 ; Percentage by mass of sodium hydroxide 15 %.

They propose to titrate this solution by carrying out a pH-metric titration of the reaction between the strong acid (nitric acid HNO_3) and this solution. They are responsible for the development of the experimental protocol.

C_0 is the concentration of the commercial solution of a caustic product.

1. Write the equation of the titration reaction they want to make.
2. Show that the molar concentration $C_o = 4\ mol.L^{-1}$.
(Molar masses : H = 1 ; O = 16 ; Na = 23 $g.mol^{-1}$)

One of the two students said "it would be better to dilute this solution before titration"

3.1. "Why is it necessary to dilute?" They choose to dilute 50 times, they got a new solution called S_b. State the precautions to be taken during this dilution.

3.2. Determine the concentration C_b.

Students decide to titrate a volume $V_b = 10$ mL of S_b.

They have a solution S_a of nitric acid with a concentration $C_1 = 0.8\ mol.L^{-1}$, a graduated burette of 25 mL, a beaker of 100 mL, a magnetic stirrer and a magnetic bar, iron stand, clamps, and a pH-meter.

1. Make a labeled schematic diagram of the setup.
2. One student states that "by using such a nitric acid solution, it will not be possible to accurately determine the equivalence point by pH-metric titration." Justify by calculating the volume V_1 of acidic solution added to reach equivalence.

5. They then decided to dilute S_a. To do this they have to withdraw a portion from solution S_a by using a 15 mL volumetric pipette and to prepare the diluted solution by using either a 200 mL volumetric flask or another of 500 mL capacity. They are only allowed to use the graduated burette once.
Determine for the two possible dilutions the new concentrations C_a and C_a'.

6. Predict for each of the diluted acidic solutions the volume of acid at equivalence as well as the pH at equivalence. Deduce that one of the two dilutions is to be rejected.

7. One of the students at the beginning of the manipulations made the following reflection : "I cannot use the magnetic stirrer, there is not enough liquid, the rotating magnetic bar will destroy the pH-meter electrode."
The other student says : "then add enough water"
The first one says "You do not think that, it will distort the titration"
The second : but not the volume at equivalence,it will not be modified"
Who is right and why?

54. Hydrobromic acid - Strong acid

Hydrobromic acid is a strong acid formed by the dissolution of hydrogen bromide in water and can therefore be used to prepare bromine salts : bromides.

Given : Glassware and equipment available :
- 10 and 20 mL volumetric pipettes
- 25 mL graduated burette
- Volumetric flasks of 50, 100, 200, 500 and 1000 mL
- Beakers of 25, 50 and 100 m
- Magnetic stirrer and magnetic bar.
- Universal stand, clamps and distilled water bottle.

Document 1

During a session of practical chemistry, the professor proposes to his students to titrate a commercial solution S_0 of hydrobromic acid. This solution results from the dissolution of hydrogen bromide (HBr) in water. Hydrobromic acid is an acid which gives rise to a complete reaction with water.

The label of solution S_0 indicates :
Percent by mass 46 %
Density = 1.46
$M_{HBr} = 81\ g.mol^{-1}$

Document 2

1. **Study of commercial solution**

1.1. Write the equation for the reaction of hydrogen bromide with water.

1.2. According to **document 2**. Show that the molar concentration of solution S_o is $C_o = 8.29\ mol.L^{-1}$.

1.3. To check this concentration, the acid solution is titrated with a solution of sodium hydroxide NaOH with a concentration $C_b = 0.10\ mol.L^{-1}$.
The teacher proposes to students to predict the volume of the basic solution to be poured to achieve equivalence for a volume of 20 mL of the commercial acid solution S_o.

1.3.1. Write the equation of the titration reaction.

1.3.2. Determine the volume V_{bE} of the sodium hydroxide solution needed to achieve this equivalence.

1.3.3. Comment on the result by comparing with the available materials in **document 1**.

2. **Dilution of the commercial solution**

The teacher asks the students to dilute 100 times the commercial solution S_o in order to prepare a diluted solution S of volume 1 L with the available glassware.

2.1. Calculate the volume V_o to be taken, to carry out this dilution.

2.2. Describe the procedure by specifying the glassware used **(Document 1).**

3. **Verification of label indication by titration**

The pupils who have prepared this solution S, of molar concentration C, will make their titration. They take a volume $V'_a = 20.0$ mL of their solution S which they titrate with the same solution of sodium hydroxide in the presence of a colored indicator.

3.1. Specify the appropriate color indicator, among those proposed in the following table (**Document 3**):

α-naphtalphnoline	Red	3.7	orange	5.6	Yellow
Bromothymol Blue	Yellow	6.0	vert	7.6	Blue
Phenolphthalein	Colorless	8.0	rose	10	Purplish pink

Document 3

3.2. The students measured a volume of 16.7 mL V_{bE1} of sodium hydroxide solution.

3.2.1. Determine the molar concentration of S.

3.2.2. Deduce that of S_o.

3.2.3. Verify if the result is in agreement with that of question 1.2.

It is considered that the result is verified if the difference does not exceed 5 %.

3.3. If this titration is carried out by a pH-meter. Draw the shape of the curve $pH = f(V_b)$ while specifying 3 remarkable points.

Take for scales : 1 cm → 2 mL ; 1 cm → 1 unit of pH.

55. Study of a drain opener

Unclogging your drain with soda bicarbonate is easy, efficient and natural. So why buy expensive and toxic chemicals?

A drain opener consists essentially of a base marked B and shows on its label the following indications **(Document 1)** :

« ... corrosive product... percentage by mass 29 % ; d = 1.23 ; M_B = 40 g.mol^{-1} ... »

$K_e = 1.0 \times 10^{-14}$ at 25 °C

Document 1

The objective of our study, which is carried out at 25 °C, is to determine the nature of this base, if it is strong or weak, and verify the indication of the label by carrying out the necessary experimental work.

1. **Nature of Base B**

1.1. Show that the molar concentration of this commercial solution noted (S_o) is $C_o = 8.9$ mol.L^{-1}.

1.2. A solution (S) of the drain opener is prepared by diluting 100 times the solution (S_o).

1.2.1. Among the proposed glassware sets **(Document 2)**, choose, by justification, which one should be used to achieve the most accurate dilution of the solution (S_o).

Set - a	Set - b	Set - c
5 mLvolumetric pipette	10 mLvolumetric pipette	10 mLGraduated pipette of
100 mLbeaker	1000 mLvolumetricflask.	1000 mLvolumetricflask.

Document 2

1.2.2. The pH of the solution (S) is measured and a value of 12.95 is obtained. Show that B is a strong base.

2. **Determination of the base B contained in the drain opener**

To ensure the indication of the label, titrate 10 mL of the solution (S) thus prepared by using a solution of hydrochloric acid of concentration $C_a = 0.05$ mol.L^{-1}, in the presence of a suitable color indicator. The equivalence is reached for a volume of the added acid $V_{aE} = 16.6$ mL.

2.1. Select from **document 3** the material needed to perform this titration :

100 mL Beaker
20 mL graduated cylinder
25 mL graduated Burette
Magnetic stirrer, magnetic bar
pH-meter
10 mL graduated pipette
Universal stand and clamps

Document 3

2.2. Write the equation of the titration reaction.

2.3. Choose, by justifying, the colored indicators given in **document 4**, which is suitable to mark the end of the titration.

Methyl orange	Red	3.2	orange	4.4	Yellow
Bromothymol Blue	Yellow	6.0	green	7.6	Blue
Phenolphthalein	Colorless	8.0	pink	10	Purplish pink

Document 4

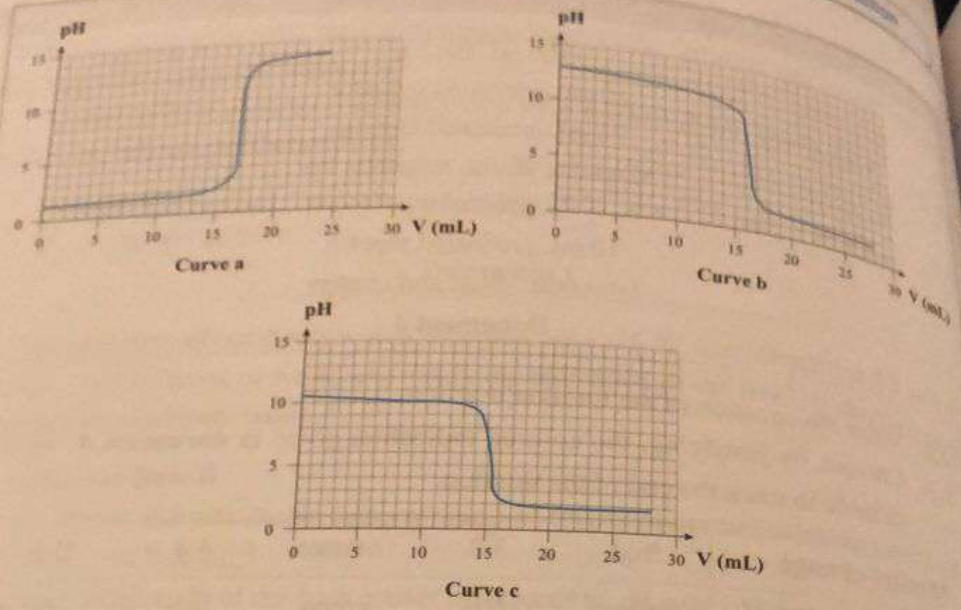
2.4. Determine the concentration of solution (S) in base (B).

2.5. Deduce the concentration of the base (B) in the commercial solution (S_0).

2.6. Determine the percentage of base B in the drain opener.
Specify if the indication is verified, given that in this titration it is considered that the indication is verified if the difference does not exceed 5 %.

3. pH-metric titration

This titration is carried out by using pH-meter and the pH = f (V) curve is plotted. Choose by justifying from the 3 curves given in **document 5**, that corresponds to this titration.



Document 5

56. Study of a scale product «sulfamic acid»

A scale product for a commercially available coffee-pot is in the form of a white powder, essentially sulfamic acid NH_2 - SO_3H. The solutions of this acid destroy the calcareous deposits formed by the passage of water.

The scale product for coffee-pot contains sulfamic acid, monoacid which can be noted as HA **(Document 1)**.

Given : $M_{(HA)} = 97.1\ g.mol^{-1}$.

Document 1

It is proposed to determine the degree of purity of sulfamic acid in the scale product. For this purpose, a solution S is prepared by dissolving a mass ***m*** of this product in 100 mL of an aqueous solution. A sample of this solution is then titrated by using pH-meter.

. Preliminary study

The solution S of volume 100 mL, thus prepared by dissolving the mass ***m*** of the scale product in distilled water, has a mass concentration $C_m = 2.6\ g.L^{-1}$.

1.1. Calculate ***m***.

1.2. Describe the procedure of this preparation, choosing from **document 2** the necessary material.

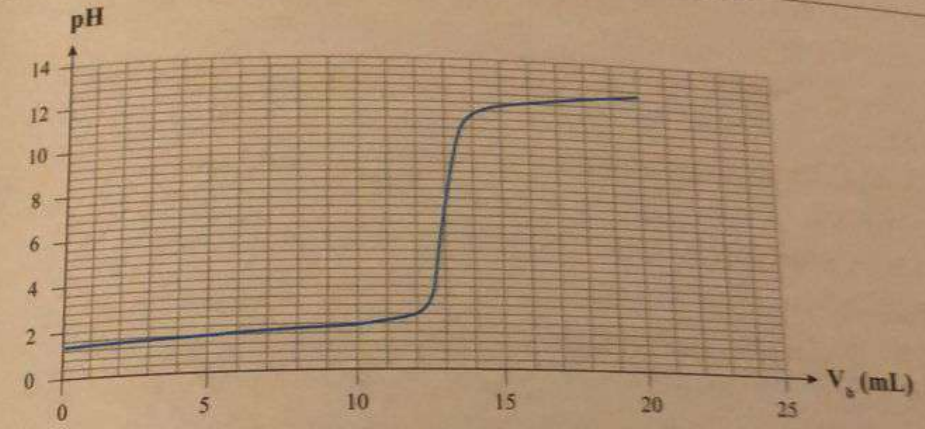
Graduated cylinders : 10, 50 and 100 mL
Precise balance
Watch glass
Spatula
Volumetric flasks : 50, 100 and 500 mL
Funnel

Document 2

1.3. The dilution ten times of sulfamic acid HA increases the pH of the solution by a single unit. Select,from the following propositions,the characteristic of this Acid :
a. Weak **b.** Strong **c.** Indifferent.

2. **Make use of Results**

A volume $V_a = 10$ mL of the solution S is taken and titrated with a solution of sodium hydroxide NaOH with a concentration $C_b = 0.02$ mol.L^{-1}.
The results obtained give the curve of **document 3**, V_b being the volume of the added base.



Document 3

2.1. Write the equation of the titration reaction.
2.2. Define the acid-base equivalence of the reaction.
2.3. Determine, from the curve, the coordinates of the equivalence point.
2.4. Deduce from the shape of the curve the characteristic of the sulfamic acid HA. Is this result consistent with that of question **1.3**.
2.5. In order to immerse the combined electrode of the pH meter, a certain volume of distilled water is added to the titration beaker. Verify if this affects the titration.
2.6. Calculate the molar concentration of sulfamic acid in the sample taken.
2.7. Deduce the mass of sulfamic acid contained in the solution and the degree of purity of sulfamic acid in the scale product studied.