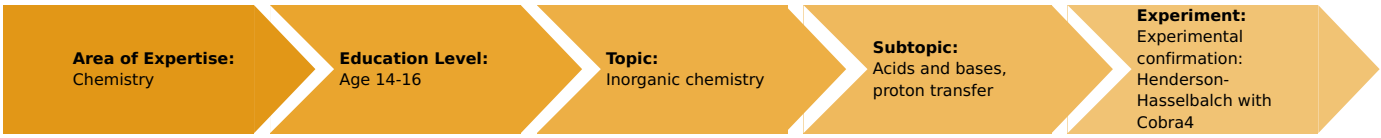
Experimental confirmation: Henderson-Hasselbalch with Cobra SMARTsense (Item No.: P7511769)

Curricular Relevance



Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	10 Minutes	20 Minutes	2 Students

Additional Requirements:

Experiment Variations:

Keywords:

pH-value, buffer, neutralisation, amount of substance, concentration

Information for teachers

Introduction

Application
Buffer solutions usually consist of a weak acid and its conjugate base. Acids neutralise hydroxide-ions, bases on the other hand oxonium-ions. A buffer solution is produced by adding an equimolar mixture of a weak acid and its salt (e.g. acetic acid and sodium acetate) or a weak base and its salt (e.g. ammonium chloride and ammonia).

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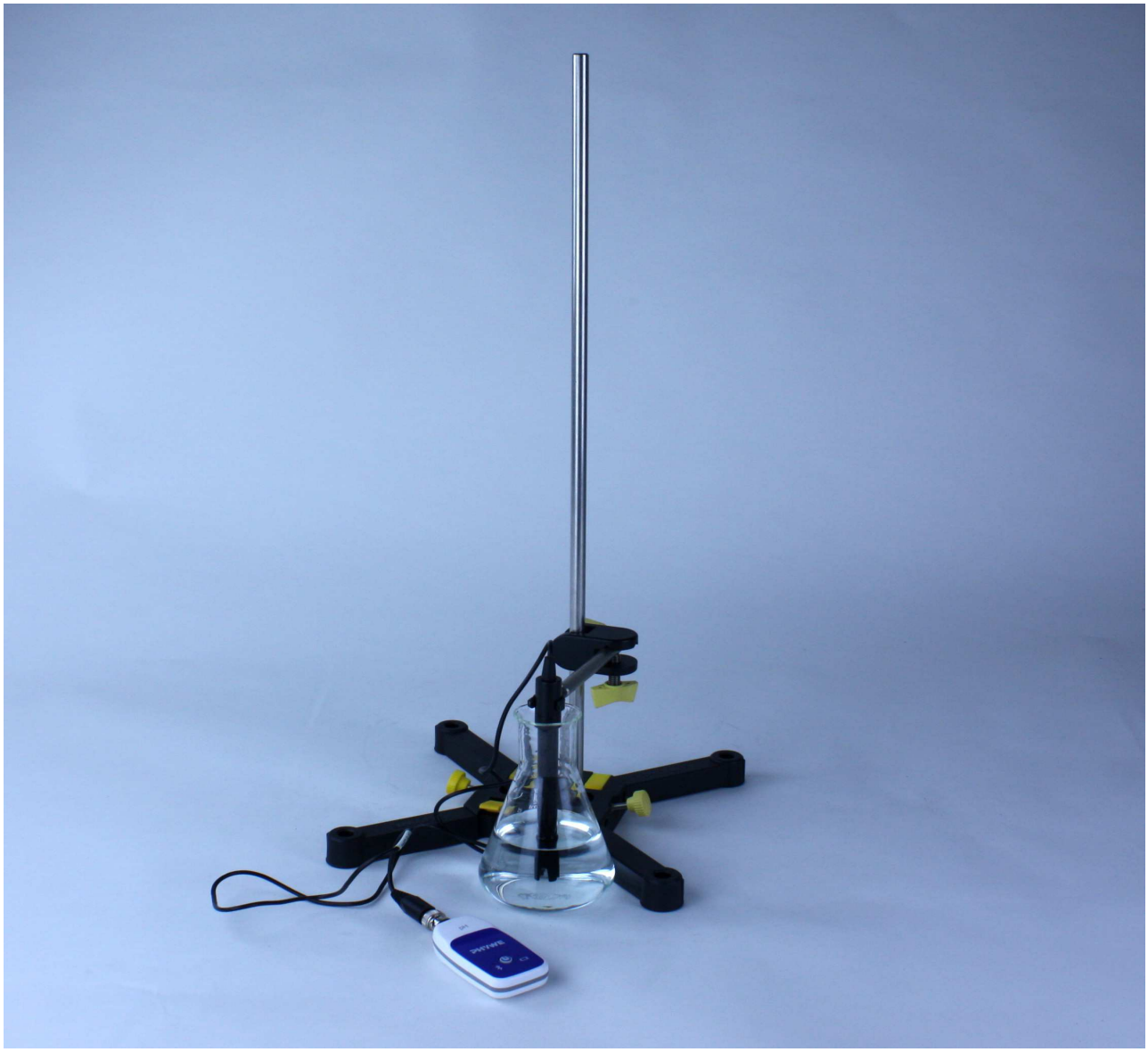

Experiment set-up

Educational objectives
The students will gain a deeper understanding of buffers and how they work, furthermore they will familiarise with the Henderson-Hasselbalch equation.

Task
The students will examine the basic characteristics of a buffer solution by adding a strong base to a buffer solution (here: acetate buffer).

Prior knowledge
The students should have already gained experimental experience concerning the handling of acids and bases.
They should be familiar with the mode of operation of volumetric measuring instruments (graduated pipette, pipettor bulb).
A basic superficial knowledge of buffer solutions is recommended.

Principle
The Henderson-Hasselbalch equation describes the relationship between a pH-value and the state of equilibrium of an acid-base reaction, it is derived from the protolysis equilibrium of weak electrolytes. The Henderson-Hasselbalch is especially useful to estimate the pH of a buffer solution. To produce a buffer solution of a certain pH-value, one can calculate the needed amount of the conjugate base (or acid) with the help of the equation.

$$\mathrm{pH} = \mathrm{p}K_\mathrm{S} + \log_{10}\frac{c(\mathrm{A}^-)}{c(\mathrm{HA})}$$

Henderson-Hasselbalch equation

Vorbereitung:

Prepare a 0.1 M acetic acid solution (add 250 ml distilled water to a suitable volumetric flask, pipette 2.8 ml concentrated acetic acid and fill up to 500 ml with distilled water).

The students need to calculate the required amount of sodium acetate trihydrate.
Exemplary result: $\mathrm{m(NaCH_3COO \cdot 3H_2O) = 0.23648\ g}$

Disposal
After use, the solutions can be collected in the collecting tank for waste acids and bases for disposal.

Equipment

Position No.	Material	Order No.	Quantity
1	Cobra SMARTsense - pH, 0 ... 14	12921-00	1
2	Support rod, stainless steel, l = 370 mm, d = 10 mm	02059-00	1
3	Erlenmeyer wide neck, boro., 100 ml	46151-00	1
4	Graduated pipette, 5 ml	36599-00	1
5	Laboratory pencil	38711-00	1
6	Wash bottle, plastic	33930-00	1
7	Protecting glasses, clear glass	39316-00	1
8	Beaker, 50 ml, low form	36080-00	2
9	Pipettor, bulb, 3 valves, 100 ml max.	47127-02	1
10	Boss head	02043-00	1
11	Spring balance holder	03065-20	1
12	Electrode support, rotable arm	18461-88	1
13	Support base, variable	02001-00	1
	Spatula, double blade, 150 mm	33460-00	1
	Portable balance, OHAUS YA102	49212-00	1
	Sodium acetate trihydrate	30149-25	
	Water, distilled, 5 l	31246-81	
	Acetic acid, 99-100%, 500 ml	31301-50	
	Buffer solution tablets, pH 4.00, 100 pcs	30281-10	
	Buffer solution tablets, pH 10.00, 100 pcs	30283-10	

Safety information

Hazard and precautionary statements

Acetic acid (0.1 M)	
H226:	Flammable liquid and vapour.
H314:	Causes severe skin burns and eye damage.
P280:	Wear protective gloves/protective clothing/eye protection/face protection.
P301 + P330 + P331:	IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P307 + P310:	IF exposed: Immediately call a POISON CENTER or doctor/physician.
P305 + P351 + P338:	IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.

Hazards

- Acids and bases have a strong irritating effect!
- Wear protective glasses!

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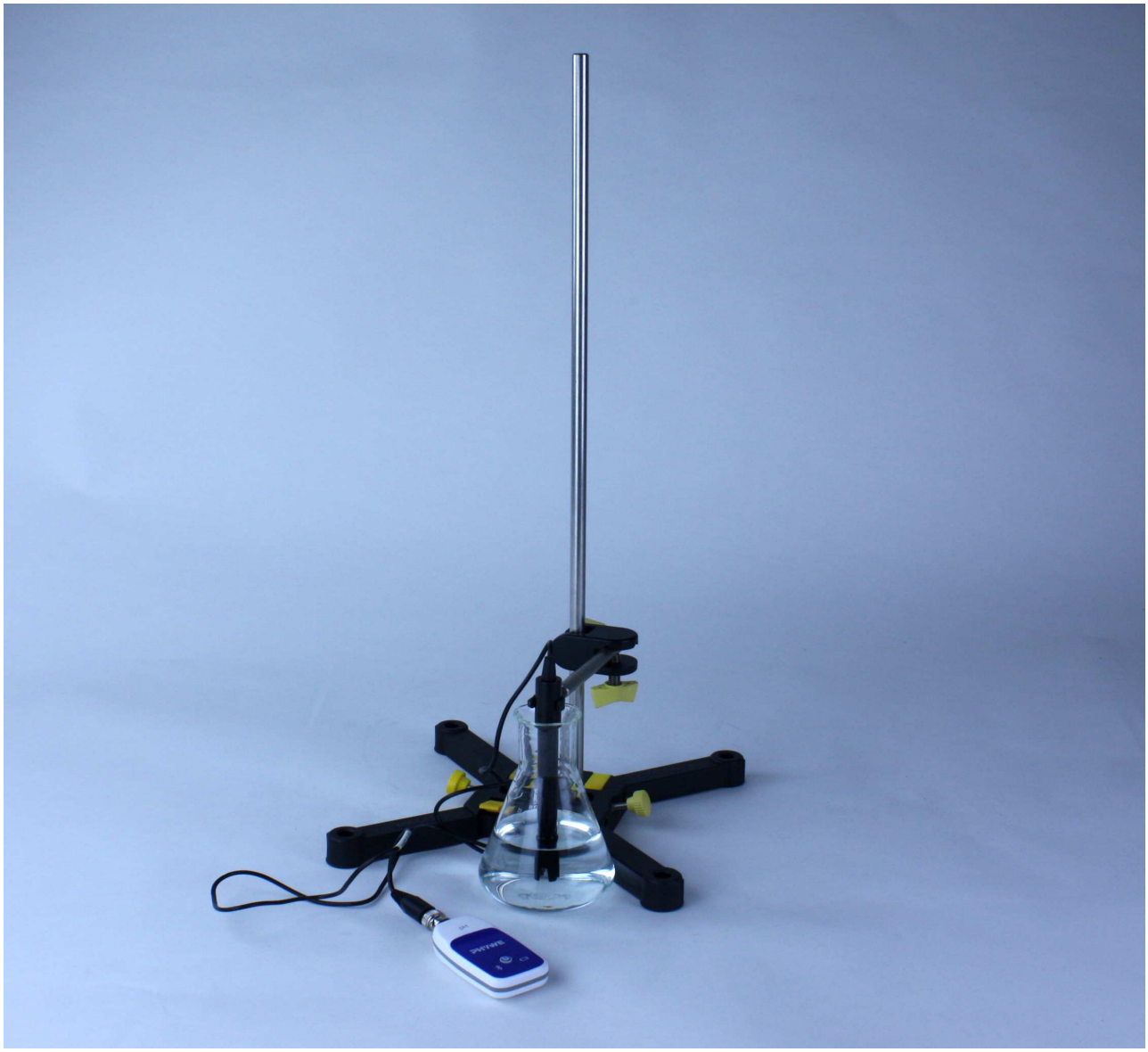
Introduction

Application and task

How does a buffer solution work?

Application
Buffer solutions are used in chemistry laboratories to conduct experiments with a constant pH-value. However, buffer systems also play an important role in our body. The physiological and required pH-value in many organism such as the human body is 7.4. Many reactions only work with a pH-value close to this value (e.g. enzymes). However, the pH-value in the human body varies all the time due to acidic or alkaline metabolic products. Buffer systems are therefore needed to keep the physiological pH constant, which is crucial to our survival.



Experiment set-up

Task
Produce an acetate buffer with a pH of 5. Calculate the required amount of sodium acetate trihydrate beforehand, use the Henderson-Hasselbalch equation.

Equipment

Position No.	Material	Order No.	Quantity
1	Cobra SMARTsense - pH, 0 ... 14	12921-00	1
2	Support rod, stainless steel, l = 370 mm, d = 10 mm	02059-00	1
3	Erlenmeyer wide neck, boro., 100 ml	46151-00	1
4	Graduated pipette, 5 ml	36599-00	1
5	Laboratory pencil	38711-00	1
6	Wash bottle, plastic	33930-00	1
7	Protecting glasses, clear glass	39316-00	1
8	Beaker, 50 ml, low form	36080-00	2
9	Pipettor, bulb, 3 valves, 100 ml max.	47127-02	1
10	Boss head	02043-00	1
11	Spring balance holder	03065-20	1
12	Electrode support, rotable arm	18461-88	1
13	Support base, variable	02001-00	1
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	Water, distilled, 5 l	31246-81	
	Acetic acid, 99-100%, 500 ml	31301-50	
	Buffer solution tablets, pH 4.00, 100 pcs	30281-10	
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Set-up and procedure

Set-up

Hazards

- Acids and bases have a strong irritating effect!
- Wear protective glasses!

Set-up

- Connect the pH electrode to the corresponding port of the Cobra SMARTsense 'pH'.
- Switch on the Cobra SMARTsense 'pH' by pressing the power button.
- Ensure Bluetooth is activated on your device. Open the PHYWE measure App and select the sensor "pH" (Fig. 2) and the measurement channel 'pH' (Fig. 3).

Fig. 2: Select the sensor "pH"

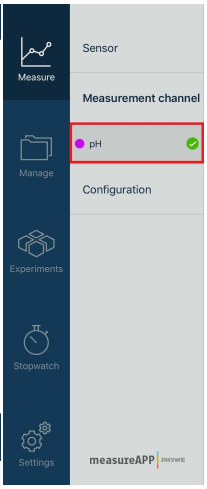

Fig. 3

Combine the two halves of the support base (Fig. 4). Fasten the support rod in the support base (Fig. 5).

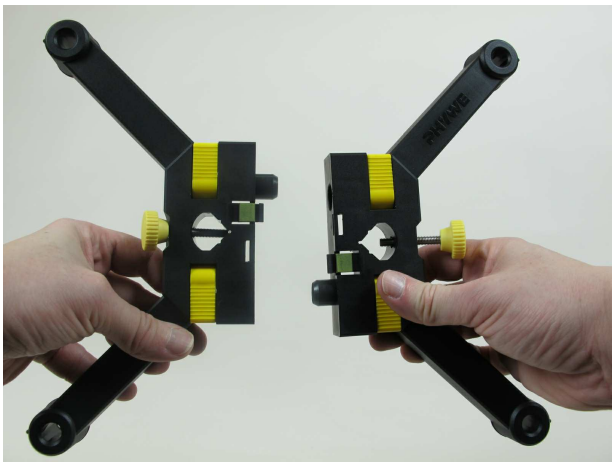

Fig. 4

Fig. 5

Join together the electrode holder from the support rod with hole and the spring balance holder (Fig. 6).

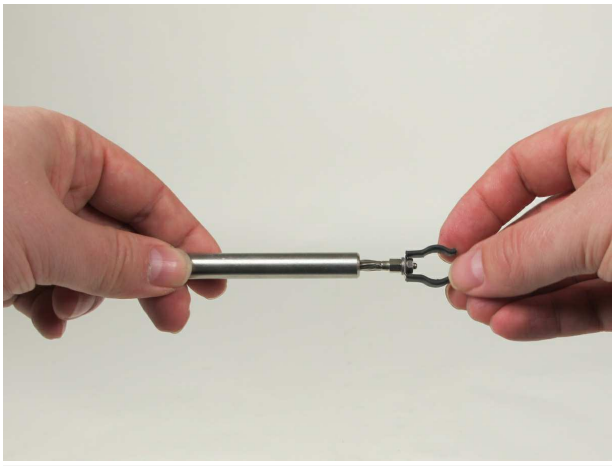

Fig. 6

Attach the electrode holder to the support rod by using the bosshead (Fig. 7 + 8) and fasten the pH electrode to the electrode holder.

Fig. 7

Fig. 8

Attach the pipettor bulb to the graduated pipette (Fig. 9). Compress valve "A" with your thumb and index finger. Use the other

fingers to press the air out of the pipettor bulb (Fig. 10).

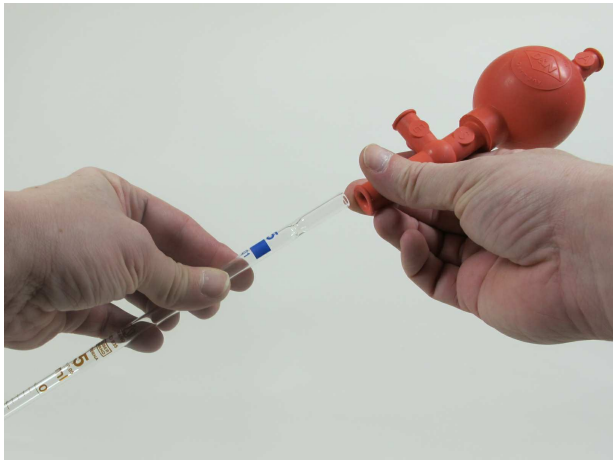

Fig. 9

Fig. 10

Hold the graduated pipette in a vertical position and plunge its tip into the acetic acid solution. Carefully compress valve "S" so that the pipette is slowly filled with the base. Do not fill the pipette too quickly. Ensure that there are no air bubbles in the liquid.
Caution: Ensure that no liquid penetrates the pipettor bulb!
Fill the pipette approximately up to the six-millilitre-mark (Fig. 11).

Compress valve "E" and let some of the ammonia solution flow out of the graduated pipette until it is precisely filled with 5 ml of the liquid (Fig. 12). Read the filling level as described below.

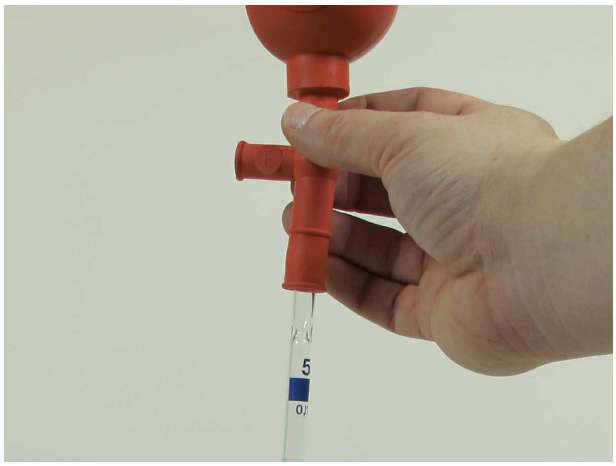

Fig. 11

Fig. 12

A concave curve, the so-called meniscus (from Greek "meniskos" = crescent), forms on the surface of the liquid column in the burette. In order to identify precisely when the liquid column reaches the upper calibration mark, the lowest point of this curve must be used for orientation. Your eyes should be precisely on the same level as the calibration mark (Fig. 13).

Fig. 13

Remove the graduated pipette carefully from the acetic acid solution and insert it into the Erlenmeyer flask. Compress valve "E" in order to transfer its content completely into the flask (Fig. 5). During this process, a small drop will remain in the tip of the graduated pipette. This has been taken into consideration during the calibration of the pipette so that it does not need to be removed from the pipette. In total, you have to pipette 10 ml of the 0.1 M acetic acid solution into the Erlenmeyer flask.

Calibration of the pH electrode

- **Calibrate the pH electrode:**
  To do so, fill the two buffer solutions into two 50 ml beakers and proceed in the app as follows:

  - go to "Configuration" (Fig. 14)
  - then go to "Calibration" (Fig. 14)
  - Click on the value (Fig. 15)

  If the electrode has already been calibrated recently, a new calibration is not necessary.

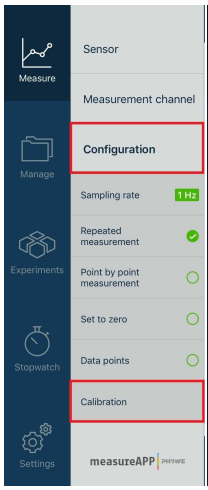

Fig. 14

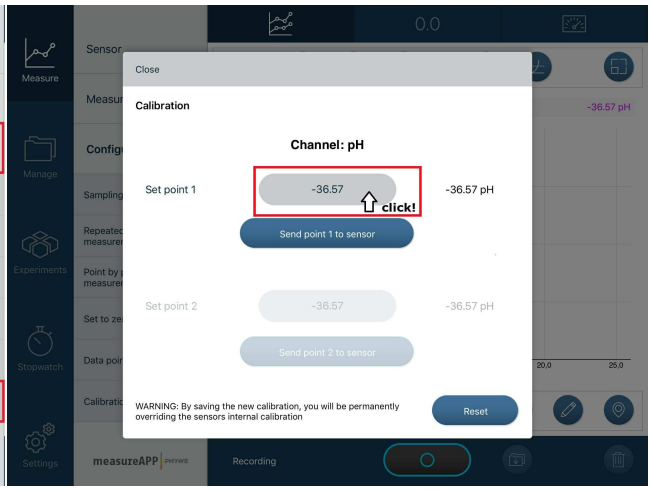

Fig. 15

- Repeat the procedure for the second value (set point 2).

Procedure

Calculation

To produce an acetate buffer with a pH-value of 5, you have to use the Henderson-Hasselbalch equation.

Henderson-Hasselbalch equation

$$\mathrm{pH} = \mathrm{pK_a} + \log_{10} \cdot \frac{\mathrm{c(A^-)}}{\mathrm{c(HA)}}$$

Use the values below to calculate the required amound of sodium acetate trihydrate.

$\mathrm{pK_a(acetic\ acid)}$: 4.76
$\mathrm{c(acetic\ acid)}$: 0.1 M
$\mathrm{V(acetic\ acid)}$: 10 ml

For any further informations needed, use a formulary.

Note your calculated value in the report.

Procedure

Add the calculated amount of sodium acetate trihydrate to the prepared Erlenmeyer flask and fill it up to 20 ml with distilled water, mix well. Determine the pH. Note down the pH value in the report.

Disposal
After use, the solutions can be collected in the collecting tank for waste acids and bases for disposal.

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