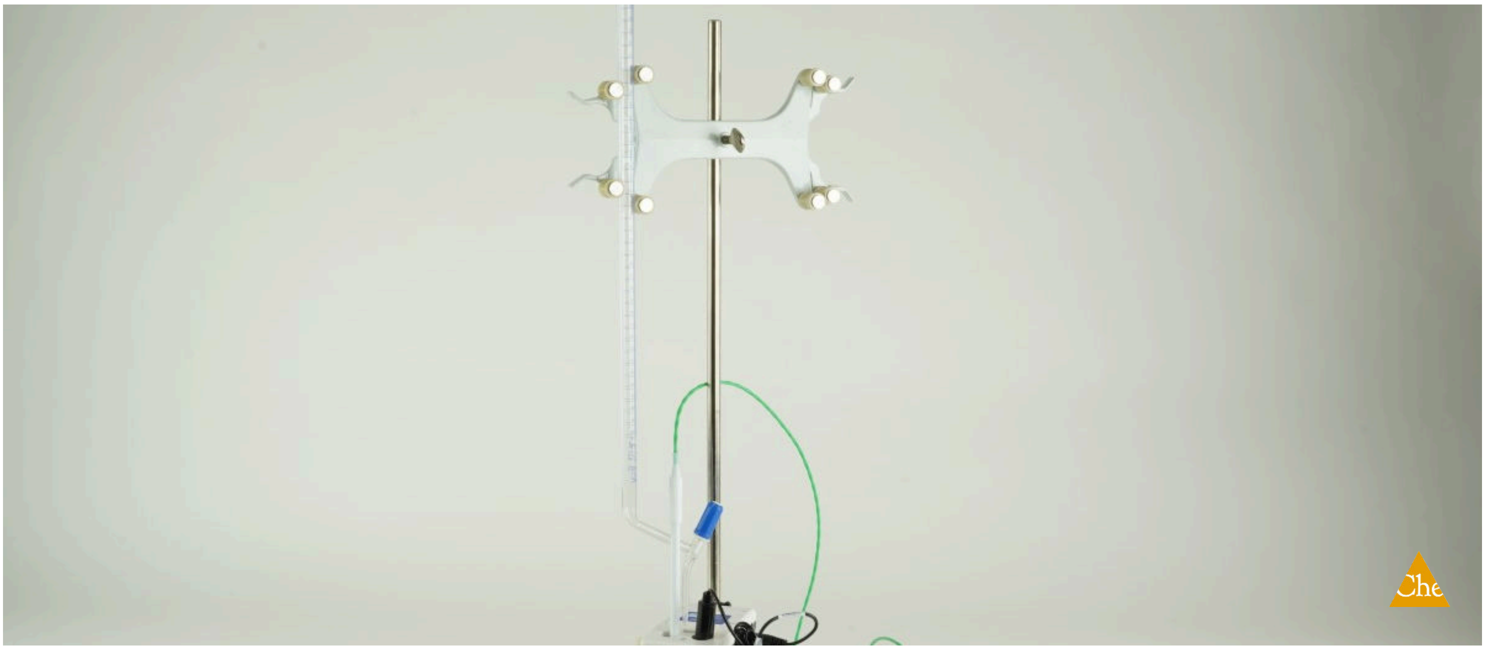
Potentiometric pH titration (phosphoric acid in soft drinks) with CobraSMARTsense



The cell voltage and the Galvani voltage of the electrodes of a galvanic cell are dependent upon the concentration of the ions involved in the potential forming process. Thus, conclusions can be made about the concentration of the ions to be investigated from the measured cell voltage at a constant potential of a suitable reference electrode (potentiometric titration).

Chemistry > Physical chemistry > Electrochemistry > pH & potential measurement

Difficulty level	Group size	Preparation time	Execution time
medium	2	10 minutes	20 minutes

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General information

Application

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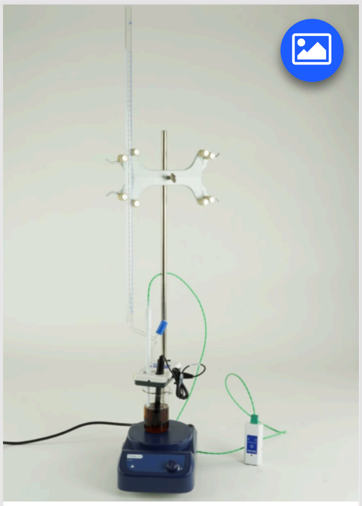

The experimental setup

We often encounter solutions containing unknown concentrations of acids and bases. One example is cola. Here it is stated that phosphoric acid is present in the beverage but not how much.

This concentration can be determined with the use of potentiometric pH titration.

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Robert-Bosch-Breite 10
37079 Göttingen

Tel.: 0551 604 - 0
Fax: 0551 604 - 107

info@phywe.de
www.phywe.de

Other information (1/2)

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Prior knowledge

The students should be familiar with the Nernst equation, meaning of the pH value and the method of titration. Furthermore, students should be familiar working autonomously with chemical agents and be familiar with good laboratory practice.

Scientific principle

The cell voltage and the Galvani voltage of the electrodes of a galvanic cell are dependent upon the concentration of the ions involved in the potential forming process. Thus, conclusions can be made about the concentration of the ions to be investigated from the measured cell voltage at a constant potential of a suitable reference electrode (potentiometric titration).

Other information (2/2)

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Learning objective

The students learn to determine the amount of acid inside a solution using potentiometric pH titration.

Tasks

Measure the change in pH of:

- diluted phosphoric acid with 0.1 molar sodium hydroxide solution.
- sample of a carbonated beverage (Cola) containing phosphoric acid (E 338) with 0.1 M sodium hydroxide solution and calculate the beverage's phosphoric acid content from the consumption of the standard solution.

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Safety instructions

For this experiment the general instructions for safe experimentation in science lessons apply.

When handling chemicals, you should wear suitable protective gloves, safety goggles, and suitable clothing.

For H- and P-phrases please consult the safety data sheet of the respective chemical.

Disposal

The diluted and neutralised solutions of the used acid and base can be disposed by rinsing into the drain.

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37079 Göttingen
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Fax: 0551 604 - 107
info@phywe.de
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Equipment

Position	Material	Item No.	Quantity
1	Cobra SMARTsense - Dropcounter, 0 ... ∞ (Bluetooth + USB)	12923-00	1
2	Cobra SMARTsense - Thermocouple, -200 ... +1200 °C (Bluetooth + USB)	12938-01	1
3	USB charger for Cobra SMARTsense and Cobra4	07938-99	1
4	pH-electrode, plastic body, gel, BNC	46265-15	1
5	Immersion probe NiCr-Ni, teflon, 300 °C	13615-05	1
6	Magnetic stirrer with heater MR Hei-Standard	35751-93	1
7	Magnetic stirring bar 15 mm, cylindrical	46299-01	1
8	Right angle boss-head clamp	37697-00	3
9	Retort stand, h = 750 mm	37694-00	1
10	Burette clamp, roller mount., 2 pl.	37720-00	1
11	Burette, lateral stopcock, Schellbach, 50 ml	MAU-24022024	1
12	Funnel, diameter = 40 mm, plastic (PP)	36888-00	1
13	Beaker, Borosilicate, tall form, 50 ml	46025-00	2
14	Beaker, Borosilicate, tall form, 150 ml	46032-00	1
15	Beaker, 150ml, low-form	46060-00	1
16	Beaker, Borosilicate, low form, 250 ml	46054-00	1
17	Volumetric pipette, 50 ml	36581-00	1
18	Pipettor	36592-00	1
19	Wash bottle, plastic, 500 ml	33931-00	1
20	Caustic soda sol.,0.1M 1000 ml	48328-70	1
21	Buffer solution, pH 4.62 1000 ml	30280-70	1
22	Buffer solution, pH 9 1000 ml	30289-70	1
23	Water, distilled 5 l	31246-81	1
24	measureLAB, multi-user license	14580-61	1
25	Holder for Cobra SMARTsense	12960-00	1
26	Ortho-phosphoric acid 85% 250 ml	30190-25	1

Additional equipment

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Additional Equipment	
Soft drink (e.g. Cola)	200 ml

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Setup and procedure

Setup

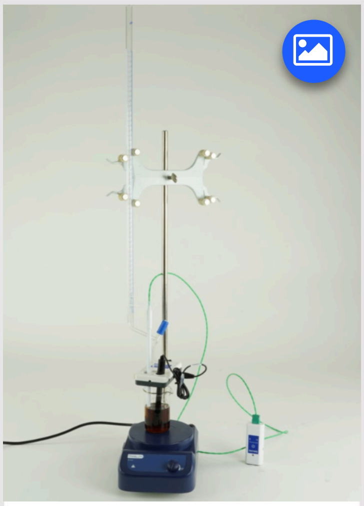

Fig. 1

1. Attach the Cobra SMARTSense DropCounter and burette to the stand. Choose the height so that the pH sensor can be fully immersed into the soft drink.

2. Attach the temperature probe to the Cobra SMARTsense Thermocouple, switch the sensor on and dip the probe into the soft drink.

3. Start measureLab and load up the experiment "Potentiometric pH titration (phosphoric acid in soft drinks) with Cobra SMARTSense".

Procedure (1/2)

1. Pour approximately 150 ml of the soft drink into a 250 ml beaker. Place the beaker on the magnetic stirrer and heat it carefully to remove dissolved carbon dioxide. Allow to cool to room temperature.

2. Pipette 50 ml of the soft drink in the 150 ml beaker and slip a magnetic stirring rod in. Fill the burette up to the 50 ml mark with 0.1 molar sodium hydroxide solution. Position the magnetic heating stirrer under the stand.

3. Position the beaker containing the soft drink on the magnetic stirrer so that the pH measuring electrode dips into the solution (Note: The pH electrode must dip at least so deep in the solution that the diaphragm is completely immersed in the solution. Add more water if necessary).

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37079 Göttingen
Tel.: 0551 604 - 0
Fax: 0551 604 - 107
info@phywe.de
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Procedure (2/2)

4. Position the tap of the burette so that sodium hydroxide solution can drop into the beaker. Also ensure that individual drops will be recorded by the drop counter. Adjust the stirrer to a medium stirring speed (Note: Do not allow the magnetic stirring bar to hit against the measuring electrode.)

5. Start the measurement by clicking the corresponding icon. Add sodium hydroxide solution drop-wise to the soft drink solution from the burette. (Note: Take care that the addition of the drops is not so rapid that the light barrier cannot register individual drops.)

6. When about 30 ml of sodium hydroxide has been so added, close the tap of the burette and click on the icon to terminate the measurement.

Evaluation (1/7)

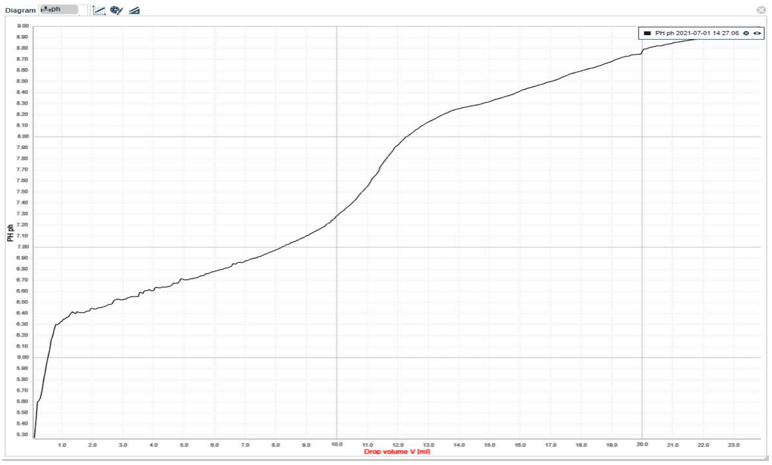

Fig. 2: Examplary measurement

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Evaluation (2/7)

The titration curve recorded shows pH as a function of the volume of sodium hydroxide solution added. The pH measurement is a potentiometric measurement. It can only be carried out, when the potential of the indicator electrode is measured against that of a reference electrode.

Both electrodes are contained in single-rod pH measuring systems. A glass electrode is used as the indicator electrode. When this is immersed in an aqueous solution, a swelling layer (gel) is formed at the pH sensitive glass membrane.

Evaluation (3/7)

This also occurs at the inner side of the membrane, which is in contact with a defined buffer solution, commonly of pH 7. According to the pH of the test solution, hydronium ions diffuse either out of, or into, the outer swelling layer, whereby the potential of this layer changes.

The pH, and so also the potential, of the inner side of the glass membrane remains constant while this occurs. With regard to the pick-up electrode, the same system is chosen as for the reference electrode (AgCl), so that the potential difference between the two electrodes is equal to zero.

The voltage measured with the single-rod measuring system therefore results from the potential difference between the inside and outside swelling layers of the glass electrode.

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Fax: 0551 604 - 107
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Evaluation (4/7)

When the system is dipped into a test solution of pH 7, then a potential of 0 mV should be given, as the inner potential is equal to the outer potential. Theoretically, when the pH changes by a single unit, the voltage should change by 59.16 mV. This can be calculated using the Nernst equation, which is as follows for hydrogen:

$$E = E_0 + 2.3 \cdot RT/F \cdot \log a(H) \text{ , where}$$

$E^0 = 0$

$\log a(\mathrm{H}^+) \cong \log c(H) = -\mathrm{pH}$

$2.3 \cdot RT/F = 59.16\ \mathrm{mV}$

$T =$ Absolute Temperature

$R =$ Universal gas constant

$F =$ Faraday constant

From this it follows that: $E = -59.16\ \mathrm{mV} \cdot \mathrm{pH}$

Evaluation (5/7)

This rise in the pH-characteristic line is called the slope of the single-rod pH measuring system. The slope of real pH measuring deviates like the zero point from the theoretical value given by the Nernst equation.

The two equivalence points coreesdpont to the following dissociation equilibria:

$$\mathrm{H_3PO_4} + \mathrm{Na^+} + \mathrm{OH^-} \rightarrow \mathrm{H_2PO_4}^- + \mathrm{Na^+} + \mathrm{H_2O}$$

$$\mathrm{H_3PO_4} + \mathrm{Na^+} + \mathrm{OH^-} \rightarrow \mathrm{H_2PO_4}^- + \mathrm{Na^+} + \mathrm{H_2O}$$

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Evaluation (6/7)

The second equivalence point is only weakly shown in the titration curve for the soft drink. This is because, in addition to phosphoric acid, further acids like citric acid are present here which also take part in the titration with sodium hydroxide solution and exert a buffering effect in the region of the second equivalence point.

A knowledge of the first equivalence point suffices for the calculation of the quantity of phosphoric acid contained in the soft drink.
The concentration c_2 , and so the content m_2 of acid-forming substance in the sample of volume V_2 , can be calculated from the corresponding consumption V_1 of standard solution of known concentration c_1 .

$$c_1 V_1 = c_2 V_2 = m_2 / M_2$$

, where

M Molar Mass of phosphoric acid (= 98 g/mol)

Evaluation (7/7)

Data and results

The first point of inflection of the titration curve gives $V_1 = 5.37 \text{ ml NaOH}$, from which a phosphoric acid concentration $c_2 = 1.07 \cdot 10^{-2} \text{ mol/l}$ can be calculated, and from this a content of $m = 52.63 \text{ mg } H_3PO_4$ in the volume of the sample tested ($V_2 = 50 \text{ ml}$).

A 1.5 l bottle of the soft drink tested therefore contains 1578.8 mg of phosphoric acid.

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Fax: 0551 604 - 107
info@phywe.de
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