

ACIDIC COLA

Determining phosphoric acid concentration in colas



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Languages available

English, Hungarian

Summary

Food grade phosphoric acid is used to acidify foods and beverages such as various colas, but not without controversy about its health effects. Phosphoric acid, used in many soft drinks (primarily cola), has been linked, in several studies, to lower bone density (osteoporosis) and severe tooth damage. Although the classic thrilling story that a tooth can be dissolved when left in cola overnight was proved false, research in 2006 showed that cola beverages destroy 10 times more tooth material than fruit juices in just the first three minutes of drinking. The harmful effect of these beverages was found to be due to the citric and/or phosphoric acid content.

Students are members of a team of scientists working in an approved food analysis laboratory and they are asked to determine the phosphoric acid content of different cola samples with different analytical methods.

Activity type **E**

Use of scientific knowledge and understanding to solve problems

Working in teams to solve problems

Communication

Time and workload management

Techniques

Ultraviolet and Visible (UV-VIS) Absorption Spectroscopy

Potentiometry

Field

Health

Food safety

Time

Practical lessons: 360 minutes

Theory lessons: ..70 minutes

Out of class time: 120 minutes

StandardBase procedures

Determination of phosphate in diet Coca Cola using visible spectrophotometry

Determination of phosphoric acid in diet Coca Cola using potentiometry

StandardBase techniques

Ultraviolet and Visible (UV-VIS) Absorption Spectroscopy

Potentiometry

Other resources

Technomatch, Emmen, the Netherlands; www.technomatch.nl

<http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1995/L/01995L0002-20060815-en.pdf>

Student's document

ACIDIC COLA: Determining phosphoric acid concentration in colas

Phosphorus is a key element in all known forms of life. Inorganic phosphorus in the form of the phosphate PO_4^{3-} plays a major role in biological molecules such as DNA and RNA where it forms part of their structural framework. Living cells also use phosphate to transport cellular energy via adenosine triphosphate (ATP). Nearly every cellular process that uses energy obtains it in the form of ATP. ATP is also important for phosphorylation, a key regulatory event in cells. Phospholipids are the main structural components of all cellular membranes. Calcium phosphate salts assist in stiffening bones. An unbalanced calcium to phosphate ratio, however, leads to the loss of calcium from the body as inorganic salts. These salts are either excreted through the digestive system or accumulated in organs as stones (e.g. kidney stones).

One source that can cause phosphate overdose is the phosphate in beverages such as colas, since phosphoric acid is a common additive, used primarily in colas, as a so-called "flavour enhancer". Studies have shown that severe tooth damage and osteoporosis are two symptoms directly linked to the effects of the phosphoric acid content of beverages. Its ability to remove calcium from bones and teeth poses major risks and therefore the legal amount in beverages is strictly regulated by food standards legislation in the European Union.



Your brief

To improve safety standards for health, the European Food Safety Board has issued a new regulation for beverages. This new legislation has set lower limits for a number of food additives like flavour enhancers and preservatives. In order to acquire official approval for production, each cola manufacturer has to provide samples for testing. To meet the new quality standards, the products are tested against many criteria, one of which is the phosphoric acid/phosphate content, a potential risk factor of bone loss and tooth decay. The manufacturers have sent their samples to the Food Safety Board (FSB), responsible for licensing new products.

The FSB has sent these samples to approved laboratories to conduct all the required tests. Your group works in one of these certified food analysis laboratories and is asked to conduct the tests in order to determine the phosphoric acid content of the samples provided. You have two independent methods of carrying out the tests.

To complete the assignment within the time limit, you have to plan how you and your group will manage the workload, prior to starting the analyses. Communication with other groups will be necessary, to gather all the data for statistical analysis of the results and to compare results from the two methods. Finally, you have to communicate your results to the public.

Your investigation

Work in a group of four. Your group will be provided with cola samples and the information sheets on:

- *Determination of phosphate in diet Coca Cola using visible spectrophotometry*
- *Determination of phosphoric acid in diet Coca Cola using potentiometry*

Each group should carry out the two tests for the samples provided. Compare your results – concentration of phosphoric acid – with the results of other groups. Evaluate your results from the regulators' point of view – do they meet the EU standards?



Planning

Do some research using the Internet to find out the legal limit of phosphoric acid in beverages

(see <http://eur-lex.europa.eu/LexUriServ/site/en/consleg/1995/L/01995L0002-20060815-en.pdf>)

Look up the StandardBase procedures and the procedure described in this document. Each member of the group should have a copy. Read the procedure carefully, study the theory and make sure that everyone knows what needs to be done. As a group, discuss and agree what each member will do (preparation of solutions, database research etc.).

Make a plan for all the activities, book the necessary instruments and chemicals and set up a timetable (use the **Student sheet**).

Practical activity

A risk assessment must be carried out before starting practical work.

Once you have decided what each member of the group will be doing, set up your work area and collect the equipment and materials you need.

Make sure you read the instructions and understand how to carry out the tests and interpret the results.

All groups:

Gather information about the techniques you will use. When the theory is not clear, ask your teacher.

Discuss the planning, analytical methods, instruments and chemicals with the members of your group, another group and your teacher. For effective planning, consider the time needed for sample preparation, instrumentation set up (e.g. a spectrophotometer should be switched on at least thirty minutes prior to use), completing one run of measurements, data collection and evaluation, and report writing.

Each group:

- Prepare all solutions needed for the analysis.
- Prepare the standard KH_2PO_4 solutions.
- Prepare the calibration curves.
- Prepare the samples.
- Measure the samples.
- Gather the results from other groups, selecting those suitable for inclusion in the statistical analysis (e.g. omit those with high deviation). Evaluate the results of the two methods with respect to the FSB regulations.
- Communicate the results to the FSB, to the manufacturer and to the public.

Your findings

To communicate the results to those concerned (manufacturers, FSB) and the public, write a report that includes your findings. It can be in the form of a poster or PowerPoint presentation. The report should contain:

- a description of the procedures
- a planning sheet with time and workload schedule
- an evaluation sheet for the samples using the average values from each group, for each method (indicating whether or not they meet the food standards).

Student self assessment

This activity was about using scientific knowledge and understanding to solve problems, working in teams to solve problems and communicating scientific results. For each case, write about 50-100 words explaining:

- what scientific skills and knowledge you used and how effectively you used them
- how you worked as a team, giving examples of how you supported others in your group or were supported by them
- how effectively you used the physical resources
- how efficiently you managed time and workload
- how effective you think your report might be, for example in a seminar, given that it would be heard by people who might not have a scientific background.

You may decide to use alternative forms of self assessment.

Student sheet: Time and workload schedule

Discuss the tasks with the members of your group and assign a student to each task. Plan the time schedule for these tasks.

Task	Student	Time planned complete during planning	Time needed complete after measurements
KH ₂ PO ₄ standard solutions			
Cola solutions			
Ammonium iron(II) sulfate hexahydrate solution			
Ammonium heptamolybdate tetrahydrate			
Reagent R			
Calibration curve			
Potentiometry			
Spectrophotometry			
Evaluation of results			

Student datasheet: Evaluation

Gather all results from your group and from other groups (three measurements per sample/method/group). Calculate the average of the results for the samples using the data from all groups. Determine standard deviations (SD) for each method and use the more reliable one (lower SD) when evaluating the samples against the EU standards (use the value given for phosphoric acid).

sample	UV-VIS (mg/L) mean	SD	Potentiometry (mg/L) mean	SD	mg/L by better method	Pass/ Not pass EU standard

Teacher's document

Overview

Students work in small groups as a team in a food analysis laboratory. The team has been asked to test for the phosphoric acid/phosphate content of cola samples by two methods. The results of all groups are gathered (three measurements per sample/method/group) and averaged. They have to determine the more reliable method by choosing the one with lower standard deviation and evaluate the results against food standards criteria. They have to write a report in order to communicate the results to the manufacturer, the 'Food Safety Board' and the public. The type of communication can be a poster or PowerPoint presentation.

Developing students' skills

Students can gain greater skill in teamwork as they progress through the exercise. At the outset, it may be necessary for the teacher to organise the groups, set clear tasks, targets and deadlines, and elicit team working strategies through appropriate questioning.

Observations of practical work and the completed recording sheets and report should provide evidence that can be assessed against qualification criteria.

Students:

- manage relationships to work effectively with others to solve problems
- use scientific knowledge and understanding to solve problems
- manage time and workload
- observe, measure, analyse and evaluate scientific data
- communicate precisely both verbally and in writing
- search data using databases

Guidance and help

The amount of help depends on the nature of the students and their prior experience. Groups with successful experience of working together can be left more to their own resources. Whether students are inexperienced or experienced, a sharp eye should be kept on the clock and it may be necessary to bring the whole class together at some point to facilitate progress.

The time provided for this task is only enough to complete all the tests successfully if the team works together. Communication between group members and other groups, as well as making and keeping a plan for time and workload management, is therefore necessary.

Organising and managing the class

Students work in groups of three or four. Smaller groups will struggle to complete the tests within the time given. Assuming a class of 20-25 this means five to eight groups.

Groups must work together, as effective and fast results can only be obtained by teamwork.

Useful ideas can be learned on formulating groups of students at www.presentingscience.com/aflchem/key/groupwork.htm

For the practical work, each group tests three different cola samples using:

- the potentiometric method
- the visible spectrophotometric method.

Each sample is tested three times by each method (three independent measurements per sample for each method per group), therefore the total data from all groups is sufficient for a statistical analysis.

Although some prior knowledge is presumed, students may be provided with a brief operational guide to the spectrophotometer as well as to the potentiometric set-up, especially if an automated burette is used.

There is a substantial amount of practical work. Students should be given as much help as necessary to do this effectively.

Students should look up the legal amount of phosphoric acid/phosphate in beverages set up by the European Legislation Office in order to evaluate the data. However, in the document accessible via the URL provided, only the amount of phosphoric acid is given. Students should also use this data for evaluating phosphate content.

The two techniques used for determining the phosphoric acid content of samples have different accuracy. Explain to students how to calculate the standard deviation (SD) of the parallel measurements. They should use the more reliable technique - that is with lower SD. The formula for calculating standard deviation (σ) is as follows:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2}$$

Where N is the number of data points measured, x_i is the i^{th} data point and $\bar{x}$ is the mean of the measured data.

Trouble shooting vigilance may be needed to help with:

- technical aspects, including manipulative skills and correct handling of chemicals and equipment
- health and safety issues
- working relationships with others.

Session plan for teachers

Exact timing depends on many factors, but the following is suggested:

- Introduction and checking prior knowledge (20 minutes)
- Students, arranged in groups, discuss and plan the work (50 minutes)
- Carry out the practical work and analyse the data (360 minutes)
- Completion of data sheets, evaluation of results and report writing (120 minutes)

Technical notes

Students follow the procedures and techniques

- *Determination of phosphate in diet Coca Cola using visible spectrophotometry*
- *Determination of phosphoric acid in diet Coca Cola using potentiometry*
- *Ultraviolet and Visible (UV-VIS) Absorption Spectroscopy*
- *Potentiometry*

available on www.standardbase.com

Preparation

The necessary equipment and reagents must be supplied. Students should follow the instructions provided with the methods.

Twenty minutes boiling is generally found to be enough to degas cola samples for potentiometric titration. Shaking and ultrasound is therefore not necessary.

Equipment and materials

Each team of students will need sufficient volumes of water, standards and equipment to prepare the standard solutions. It is optional whether the students are provided with standardised solutions and boiled cola samples. If preferred, reagent solutions may also be prepared by technicians.

TESTING PRIOR KNOWLEDGE

Choose the correct answer.

1. A cola sample must be boiled prior to testing...

- a. to remove CO_2
- b. to get rid of caffeine.
- c. to remove H_3PO_4
- d. to kill bacteria.

2. 300.0 mg KH_2PO_4 is dissolved in 500.0 mL water. 25.00 mL is transferred to a volumetric flask and diluted to 100.0 mL. The concentration of KH_2PO_4 is then...

- a. 15 mg/L
- b. 150 mg/L
- c. 75 mg/L
- d. 125 mg/L

3. If the absorbance of a sample is 0.500, the transmittance is...

- a. 3.16%
- b. 1.70%
- c. 31.6%
- d. 50.0%

4. 50.00 mL cola, which contains 40 mg H_3PO_4 needs mL of NaOH solution $c(\text{NaOH}) = 0.0420 \text{ mol/L}$ to reach the first equivalence point.

- a. 35.68
- b. 13.86
- c. 9.718
- d. 11.53

5. What colour is a solution that absorbs in the red region (e.g. around 750 nm) of the visible spectrum?

- a. green
- b. blue
- c. yellow
- d. black

6. How much potassium dihydrogen phosphate do you weigh for a 1000.0 mL standard solution, if diluting 5.00 mL of this standard solution to 100.0 mL has a concentration of 1.0 mg/L phosphorus?

- a. 87.8 mg
- b. 93.4 mg
- c. 6805 mg
- d. 878 mg

Note: answers are given in red. These need to be removed before the test is used.

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