

TITLE: Colour & Chemistry: Exploring pH

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A red cabbage juice solution is prepared and used as a natural indicator, to test the pH of various household substances.

KEYWORDS: Chemistry, pH, indicator, colour change

BRIEF DESCRIPTION: The chemistry of colour is explored in this exercise. Visible colour change of a substance often signals a chemical change at the invisible molecular level. By noticing and documenting these changes, students gain experiential insight and then further explore the more complex underlying physical concepts by writing a short essay on pH & Colour. Students perform a hands-on 'kitchen science' experiment, where they prepare a natural pH indicator of red cabbage juice. They then test the acidities of various household substances, and document any colour change in the indicator that they notice. They write their results up using the scientific method, and further delve into the topic by writing a short essay on the fundamental principles of acids, bases, pH and indicators, which they can link back to their experiential kitchen science experiment.

LEVEL: The pH Experiment is applicable to many levels – if a teacher prepares the cabbage juice solution, the experiment can be performed by elementary school students. The cabbage juice solution may be prepared by grade 5 students and higher. The experimental description is suitable for high school students. The essay portion would be suitable for upper level high school and first year university students.

GENERAL INFORMATION:

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|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|-------------------------|---------|-------|
| Exercise Title | <i>Colour & Chemistry: Exploring pH</i> | | | | |
| Course Title & Level | <i>Understanding Colour</i> 1st year undergraduate u(non-specialist science course) | | | | |
| Ideal environment | Home: X | Classroom: X (if solution prepared in advance) | Laboratory: X | Online: | (any) |
| Duration | 2 hours for pH experiment, few days for research essay | | | | |
| Learning Outcomes | 1. To notice colour changes of a natural indicator, as it is placed in substances with varying acidities | | | | |
| | 2. To document and describe the experimental process | | | | |
| | 3. To recognize that colour change can indicate an underlying chemical change at the molecular level; colour is the visible manifestation of an invisible process | | | | |
| | 4. To connect scientific principles with elements of our everyday lives | | | | |

STEP BY STEP INSTRUCTIONS:

| Step | Description | Resources (Materials) | Duration |
|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-----------------|
| 1. | Coarsely chop $\frac{1}{2}$ head of red cabbage, place in a large pot and cover with water, with 1-2 inches of water above the level of cabbage. | Red cabbage, pot | 5min |
| 2. | Boil the pot of cabbage for approximately 20 minutes, until the cabbage is soft, and the water has turned a reddish-purple colour. | | 20min |
| 3. | Let cool and remove the cabbage. The reddish-purple water is now a natural indicator (it contains anthocyanin), and now can be used to test the acidity of various substances. | | |
| 4. | In several clear glasses or plastic cups, pour approximately $\frac{1}{4}$ cup of various household substances in each cup, and add 1-2 tablespoons of the cabbage juice indicator and note the colour change. (You may need to add more or less of the indicator; you will have to experiment with what works best.) When you document the observed colour in your | Clear glasses or plastic cups, various household substances for testing pH values. | 30-45min |

| | | | |
|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--------|
| | experimental write-up, you could include digital photos to show the colour change (recommended), or include swatches of sample colours (e.g. could use coffee filters, soak them in the indicator solution, and dip them in the various substances). | | |
| 5. | Try to estimate the pH of the substance using Table 1 below. After you complete your experiment, you can look up the actual pH for your substances, and give your reference. | | 15min |
| 6. | Write up your experiment using the Scientific Method: 1. Purpose: State the purpose of your experiment. 2. Method: Describe how you went about your experimental process (~1/2 page) 3. Observations: best to collect data in a table. Possible format shown in Table 2 below. 4. Results & Conclusions: Discuss your overall results. Generally summarize your findings in a few sentences. You will discuss the chemical process in greater detail in your essay. | | 1 hour |
| 7. | Write a 4-5 page (12-point, double spaced) research paper on the chemistry behind pH, and what drives colour change in indicators. Discuss at a molecular level the differences between acidic and alkaline solutions. Discuss the chemical change that an indicator undergoes when it is an acidic vs. neutral vs. alkaline solution and how this chemical change drives the colour change of the solution. Find a representation (molecular diagram) for anthocyanin (the indicator in red cabbage), and how its molecular structure changes in an acidic vs. alkaline environment. Describe how your experimental results and your research on the physical mechanism support each other. Include all references used, in a recognized format (e.g. APA, MLA- your choice), and make sure you correctly cite any directly sourced material/facts with the corresponding in-text citation style. | | 1 week |

Suggested substances for testing pH:

7-up or other clear pop/soda (hard to see any colour change of indicator with Coke), vinegar, lemon juice, Windex, toothpaste, baking soda, milk (can choose others)

Table 1: pH scale for red cabbage juice

| pH | 0-1 | 2-3 | 4-5 | 6-7 | 8 | 9-10 | 11-12 | 13-14 |
|--------|-------------|------|-----------|-------------|----------|-------------|-------|-----------------|
| Colour | dark red | pink | Violet | Blue-violet | Blue-ish | Blue- green | Green | Greenish yellow |
| | | | | | | | | |
| | strong acid | | weak acid | Neutral | Neutral | weak base | | strong base |

Table 2: Experimental Observations (suggested format)

| Expt. | Substance | Colour | Colour after indicator added | Estimated pH | Actual pH | Reference |
|-------|-------------|--------|------------------------------|--------------|-----------|-----------|
| 1 | 7-Up | | | | | |
| 2 | lemon juice | | | | | |
| 3 | Windex | | | | | |
| | ... | | | | | |
| | ... | | | | | |

EVALUATION GUIDELINES:

| Suggested Evaluation Guidelines | Criteria |
|----------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|
| Students followed the directions as specified (e.g. did not put multiple substances in cups, etc.) | Well organized Experimental Observations Table |
| Students were able to describe what they saw | Students made insightful comments for Results and Conclusions section |
| Students were able to describe the chemistry of acids, bases and why indicators change colour at the molecular level | Clear description written in essay with all relevant details included |
| Students were able to link their research on the chemistry of colour with their experimental results | Clear statement linking research with experimental experiences |

FURTHER SUGGESTIONS & REMARKS:

| Suggestions for the teacher | Suggestions for students |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"> • Make sure students describe what they actually see, not what they think they should be seeing • If they record colours on filter paper – the colour can degrade quickly • If they use bleach, bleach is alkaline, so the cabbage juice will turn greenish/yellowish initially. The bleach will then dissociate the anthocyanin molecule, and the colour solution will turn clear, or yellowish – more complex chemistry can be observed • Can be some variations in the indicator colour – depends on the cabbage itself, type of pot, pH of water used. Also, various brands of substances may have slight pH variations (e.g. Windex vs. a generic brand), etc. • Essay with descriptions of chemical process may be omitted; experiment itself is a fun exercise for all ages | <ul style="list-style-type: none"> • Make sure to use red cabbage • Cabbage juice can stain, so be careful with surfaces, clothes, etc. |

ADDITIONAL REFERENCES:

MAKING AN INDICATOR FROM RED CABBAGE

The compounds that give red cabbage its colour can be extracted and used as a pH indicator solution. Here we look at the method and the colours!

MAKING THE INDICATOR

- 1
ROUGHLY CHOP THE CABBAGE
- 2
BOIL FOR A FEW MINUTES
- 3
STRAIN AND LET COOL
- 4
USE AS AN INDICATOR!

The red cabbage extract can be used to determine whether substances are acidic or alkaline. The structures of the anthocyanin pigments which give the red cabbage its colour are subtly changed at varying pH. These different structures give a range of colours.

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(Note – your colours may be darker or slightly different than those shown above)
 Above figure from: <https://www.compoundchem.com/2017/05/18/red-cabbage/>