# Student Worksheet – part 1

## Getting to Know the Chemical Nature of Everyday Substances

### Topics

acids, bases, determining pH, indicators

### Objectives

According to the Slovenian Chemistry Curriculum for Primary School (Chemistry Curriculum for Primary School, 2011).

* Students should be able to distinguish between acidic, basic, and neutral substances from everyday life and determine the pH value.
* Students are encouraged to develop experimental-research skills.
* Students should understand the interdependence of the structure, properties, and uses of chemical compounds.
* Students should develop responsible attitudes towards use of chemical compounds and their consequences for health and the environment (chemical safety).
* Students are encouraged to observe systematically and use observations as a source of data.

### Introduction

We encounter acids and bases in everyday life. Our senses can immediately recognise lemon juice, vinegar, or apples as acidic. But not all substances we use in everyday life can be tested with our senses, e.g., for their acidity.

pH is a logarithmic scale that gives a quantitative measure of the acidity or alkalinity of an aqueous solution. The pH value is a measure of the concentration of hydrogen ions (H+) in a solution, and ranges between 0 and 14. The lower the pH value, the more acidic the solution; the higher the pH value, the more basic the solution.

There are various methods for determining the pH value, e.g., the use of pH meters, pH indicators and pH test papers. Each of these methods has its own advantages, so we must weigh up which of the methods is most suitable for our experiment.

A pH indicator is a substance that changes colour depending on the pH of the solution. This is a way to visually determine the pH. pH indicators are a good way to quickly and easily determine the approximate pH compared to a standard by colour. The indicator used in this experiment is obtained from a natural source, red cabbage, and has a certain colour depending on the pH of the solution.

While pH indicators are useful for qualitative purposes, a pH meter is used when an accurate quantitative value is needed. A laboratory pH meter usually has a special probe with a membrane that responds to H+ ion concentrations. The metre displays the exact pH value of the solution under investigation.

### Lab equipment

* 5 x 100 mL beakers
* graduated cylinder
* pH meter (optionally: various kinds of school equipment that enable pH measuring)
* 10 x test tubes
* 7 droppers
* permanent marker

### Chemicals

* universal indicator solution
* red cabbage solution
* lemon juice
* vinegar
* baking powder solution
* laundry washing powder solution
* bottled water

### Safety Information

Mandatory personal protective equipment: goggles, lab coat, and gloves. Before starting, it is necessary to carefully read the instructions for safe work. The waste must be handled properly / according to the description in the risk assessment or teacher instructions.



## Guided inquiry

### Generating Researchable Questions

In your inquiry focus onthe researchable questions listed below:

**1RQ:** From what everyday source can an indicator be made that would replace the universal indicator solution for use in the school laboratory?

**2RQ:** Can pH values of solutions from everyday life be determined using red cabbage solution?

### Planning

#### Formulating a hypothesis

#### Postulate the controlled, independent, and dependent variables

Controlled variables:

Independent variable:

Dependent variable:

#### Planning of the experimental procedure

#### Planning of collecting the data

### Carrying out the Plan

Carry out the experiment and collect data.

### Life Cycle Analysis

Use a life cycle analysis (LCA) – an evaluation of the environmental impact of a product over its entire lifecycle to assess the overall sustainability of a product to determine which method of measuring the pH of everyday substances – using universal indicator solution or red cabbage solution – is more favourable from a sustainable point of view.

|  |  |  |
| --- | --- | --- |
|  | Determining pH of everyday substances with universal indicator solution | Determining pH of everyday substances with red cabbage solution |
| **MATERIALS**What was used to make the product? (e.g., plastics, metals) |  |  |
| **PRODUCTION**How and where was it produced? (e.g., in your country or overseas) |  |  |
| **DISTRIBUTION**How was it transported at each stage of the lifecycle? (e.g., ship, lorry, train) |  |  |
| **USE**What impact do the products have during the use stage? (e.g., environmental impact, efficiency) |  |  |
| **DISPOSAL**How can it be disposed of? (e.g., recycled, landfill) |  |  |
| **OTHER NOTES/REMARKS** |  |  |

You might also be interested in examining the greenness of the determination of pH of everyday substances with universal indicator solution and red cabbage solution. For instructions see Student Worksheet – Part 2.

### Results and Discussion

In relation to research question, organize, interpret, and communicate your experimental results using tables, graphs and/or charts. Also consider the life cycle analysis. If you evaluated the experiment with green chemistry metrics (see Student Worksheet – Part 2) discuss the findings and implications.

### Conclusion

In this phase the students summarize and evaluate the results presented in the Results and Discussion phase.

# Student Worksheet – part 2

## Evaluation of experimental work with green chemistry metrics

Evaluate the experiment *Getting to know the chemical nature of everyday substances* using green chemistry metrics. In this activity you will

* determine the hazards of the substances used in the experiment, thereby you will learn how to obtain and use safety data sheets and develop a practical understanding of hazard (H) and precautionary (P) statements
* determine the value of perceived greenness of the experiment, thereby you will be introduced to the 12 principles of green chemistry
* construct the green star of the experiment, thereby you will present the data obtained using graphical means to get a better overview of greenness of the experiment.

 Follow the instructions below and use appendix 2–4 to help with the activity.

### 1. Determine the hazards of the substances used in experimental work

1. In table 1, insert the names of the chemical compounds included in the experiment in the first column.
2. For each chemical used, consult the safety data sheets you can obtain via the QR code in the risk assessment and write the hazard codes of each chemical in the second column.
3. Use "Criteria to classify the hazards of substances” (appendix 2) to obtain scores\* (1–3) attributed to health, environment, and physical hazards for each chemical used in the experiment. Insert the obtained scores in the appropriate (third/fourth/fifth) column. If no hazard code is assigned for a chemical, assign a score of 1.

Table 1: Hazards of the substances used in experimental work.

|  | Hazard code | Scores (S) attributed to hazards\* |
| --- | --- | --- |
| Health | Environment | Physical |
| **Determining pH of everyday substances with universal indicator solution**  |
|  |  |  |  |  |
| **Determining pH of everyday substances with red cabbage solution** |
|  |  | – | – | – |
| **Common substances used in experimental work** |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |

\* Scores (S) attributed to hazards on a scale from 1 (low hazard) to 3 (high hazard)

### 2. Determine the value of perceived greenness

1. To fill table 2, see the appendix 2 “Green chemistry principles and assessment criteria for the value of perceived greenness (V)”.
2. Decide the number of principles (e.g., 6 or 10 principles) that provides the most meaningful evaluation of perceived greenness of the experiment.
3. The value (V) of perceived greenness can be derived from appendix 2. V ranges from 1 (minimum) to 3 (maximum). Write NA when non applicable.

Table 2: Green chemistry principles and the value of perceived greenness to construct the green star of the experimental work.

| Green Chemistry Principle | Value of perceived greenness (V) with universal indicator solution | Value of perceived greenness (V) with red cabbage solution |
| --- | --- | --- |
| P1 – prevention |  |  |
| P2 – atom economy\* |  |  |
| P3 – less hazardous chemical synthesis\* |  |  |
| P4 – designing safer chemicals\*\* |  |  |
| P5 – safer solvents and auxiliary substances |  |  |
| P6 – increase energy efficiency |  |  |
| P7 – use renewable feedstocks |  |  |
| P8 – reduce derivatives\* |  |  |
| P9 – catalysts\* |  |  |
| P10 – design for degradation |  |  |
| P11 – real-time analysis for pollution prevention\*\* |  |  |
| P12 – safer chemistry for accident prevention |  |  |

\* Applicable when using 10 or 12 Principles. \*\* Applicable only when using all 12 Principles

### 3. Construction of the green star

Construct a green star for measuring the pH of everyday substances – using universal indicator solution and red cabbage solution.

1. If you are constructing the green star on paper, colour the radar chart shown in figure 1a and 1b. Colour the area corresponding to a specific principle (e.g., P1, P2, etc.) based on the determined value V in table 2.
2. If you have a computer, you can construct the green star in Excel and insert a copy of the green star in your worksheet.
	* Open appendix 1 (Excel file) and select “Green star (10 principles)”.
	* Use your results from table 2 to fill in the data in the green cells.
	* Copy the image of your green stars and replace the images below.

Figure 1a: Greenness assessment of determining pH with universal indicator solution.

Figure 1b: Greenness assessment determining pH with red cabbage solution.

### 4. reflect on the results of the evaluation of experimental protocols with green chemistry metrics

What are the advantages and disadvantages of using a particular method to determine the pH of a solution?

### References

Ribeiro, M. G. T., Costa, D. A., & Machado, A. A. (2010). “Green Star”: a holistic Green Chemistry metric for evaluation of teaching laboratory experiments. *Green Chemistry Letters and Reviews, 3*(2), 149-159. https://doi.org/10.1080/17518251003623376

Ribeiro, M. G. T., & Machado, A. A. (2014). Green star construction. <http://educa.fc.up.pt/documentosQV/EV/Construction%20of%20Green%20Star_6_points_GSAI.xlsx>