• Учебни опити и демонстрации •

• Teaching Chemical Experiment •

BEHAVIOUR OF PHENOLPHTHALEIN IN STRONGLY BASIC MEDIA

Vladimir M. PETRUŠEVSKI*,
Keti RISTESKA,
Sts. Cyril and Methodius University,
Skopje, MACEDONIA

Abstract. Phenolphthalein as an acid-base indicator and its colour change (from colourless to raspberry-purple) is widely known to virtually every student of chemistry. It turns to be far from a well-known fact that the colour may disappear in very strongly basic solutions. A simple demonstration (type of an "experiment of surprise") is offered to point to this fact.

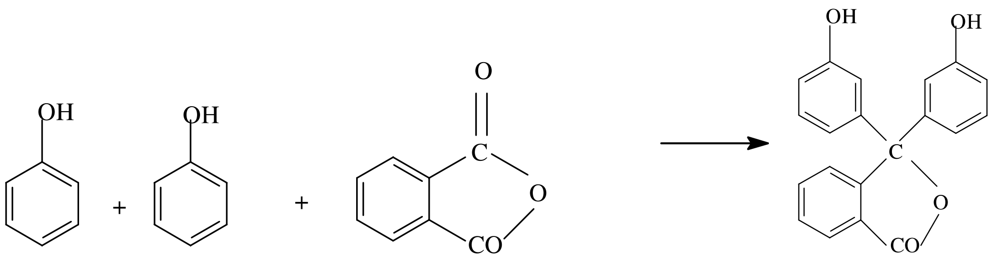
Keywords: acid-base indicators; phenolphthalein; strongly basic media; experiments of surprise.

Introduction

The instructor might start the class with a simple question: "What is the colour of phenolphtalein in a basic solution?"

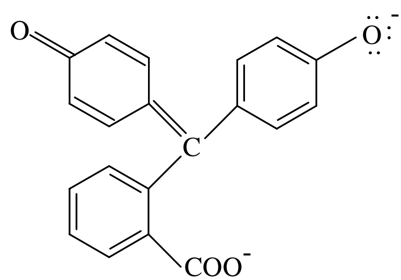
The question seems so trivial, that any experienced student will hardly take it seriously. You will probably get 100 % answers like "reddish-violet", "purple" or similar. However, in chemistry things (even the "well-known ones") may often turn to be not as trivial as they seem in the beginning.

Phenolphthalein[1-5)] is a well-known member in the family of acid-base indicators [1]. It could be synthesized by a condensation reaction [2] from phenol and phtalic anhydride:

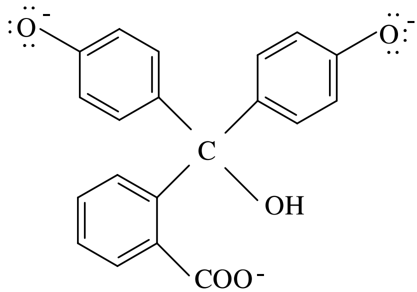


phenol phtalic anhydride phenolphthalein

As an acid-base indicator, it has been used very often. In aqueous solutions where the pH value is below 8.3, it is colourless. At pH ≈ 10 its colour is intensive raspberry-purple. Below 8.3 it is present entirely as phenol lacton (the rightmost structure in the above scheme). The coloured form (that corresponds to a salt) adopts the following structure (one resonant structure of the anion is shown):



However, in a very strongly basic medium (pH ≥ 14) the indicator is again colourless (!), this being a consequence of its transformation into carbinol.



It appears that although the above is a simple fact for any organic chemist, it is practically not known to either students or instructors dealing in the fields of general, inorganic or analytical chemistry. The reason seems to be a simple one: the use of phenolphthalein as an indicator is as a rule limited to solutions of base with a concentration of ≤ 0.1 mol/L. Under these circumstances (pH < 13) the formation of carbinol is not possible. Things change gradually when th e concentration of hydroxide ions is increased by 1–2 orders of magnitude, as will be demonstrated soon.

Reagents and Equipment

Solid NaOH, distilled (deionized) water, solution of phenolphthalein in ethanol, 4 large test-tubes with suitable test-tube rack, a dropper, weighing glass, a 100 mL beaker, 4 rubber stoppers (to match the test-tubes used), technical balance.

Experimental

The first step is to prepare concentrated solution (~ 4 mol/L) of NaOH. Consult the heading on safety hazards before proceeding.

About 8 g of NaOH are dissolved in ~ 50 mL of deionized water. 20 mL of this solution (roughly of concentration 4 mol/L) are put in a large test-tube. In another test-tube 10 mL of the solution are diluted with 10 mL of deionized water. In a third test-tube, 5 mL of the solution are diluted with 15 mL of deionized water. One may experiment with other ratios, in order to find the best concentrations. The three test tubes containing the original and two diluted solutions are placed in a test-tube rack and are to be used in the first demo.

The remaining 15 mL of the original NaOH solution are diluted with equal volume of water, transferred into a new test-tube, and will be used in the second demo.

Demonstrations

Demo 1. The test-tube rack with the three test-tubes containing aqueous solutions of NaOH (left to right ~ 4, 2 and 1 mol/L) is placed on the demonstration table. Equal volumes (say 5–10 drops) of phenolphthalein solution in ethanol are added to all three test-tubes, the tubes are corked and are vigorously shaken. The results are presented in Fig. 1:

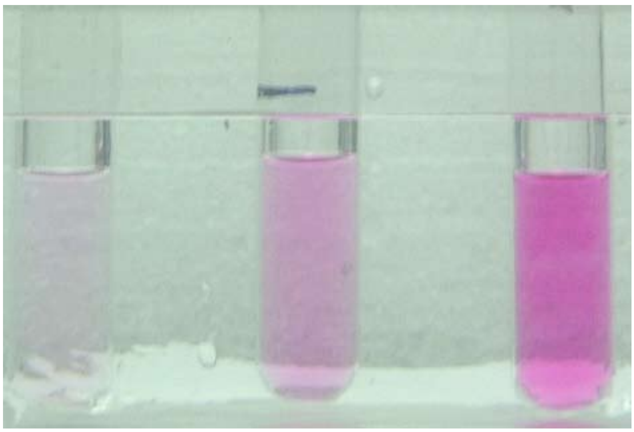


Figure 1: The colour of phenolphthalein in 4 mol/L (left), 2 mol/L (middle) and 1 mol/L (right) solutions of NaOH, immediately after the indicator was added

In the solution of highest concentration, the purple colour quickly disappears, in the medium one it takes some time (1–2 minutes) and in the most diluted solution the colour persists for a long period of time.

Demo 2. The fourth test-tube is placed in the rack, 10 drops of phenolphthalein solution are added, the tube is stoppered and shaken and is phtographed at 30 s. The results are shown in Fig. 2:

Figure 2: Fading of the phenolphthalein colour with time in a strongly alkaline solution

The results of both of the above demonstrations are in sharp disagreement with the expectations. For things to be even worse, the expectations and the corresponding conclusions are not made *a priory* (literally everybody has seen the purple colour of phenolphthalein in basic solution). The trick is in the fact that we did not specify the concentration of the alkaline solution. And this turns to be of crucial importance!

Such experiments, the results of which are in a sharp disagreement with the expectations are often called “experiments of surprise” [3]. Similar behaviour exhibit other indicators as well (thymolphthalein, p-xylenolphthalein etc.).

Let us mention in the end that all colour changes are reversible (meaning that, by careful addition of acid to the strongly alkaline solution, the purple colour reappears).

Safety Hazards and Disposal

Sodium hydroxide is highly corrosive compound! Avoid eye and skin contact. Wear face shield and protective gloves during preparation of the solutions and at all times during performing the demonstration. In case of accident, wash off with plenty of water (diluted vinegar might be used in case of skin burns), and call for physician immediately. When NaOH is dissolved in water, the process is very exothermic (the temperature may rise to above 70 ºC).

The excess of solution is disposed under the drain, with plenty of water.

NOTES:

1. http://chemistry.about.com/library/weekly/aa112201a.htm (accessed January 14th 2007).
2. http://chemistry.about.com/library/weekly/aa112201a.htm (accessed January 14th 2007).
3. http://www.carlton.srsd119.ca/chemical/equilibrium/abindicators.htm (accessed January 14th 2007).
4. http://antoine.frostburg.edu/chem/senese/101/acidbase/indicators.shtml (accessed January 14th 2007).
5. http://www.csudh.edu/oliver/chemdata/indicators.htm (accessed January 14th 2007).

References

1. Kolthoff, I.M., E. R. Sandell. *Textbook of Quantitative Inorganic Analysis*, 3rd Ed. Naučna knjiga, Beograd, 1963, pp, 409–414 (Serbo-Croatian translation).
2. Noller, C.R. *Chemistry of Organic Compounds*, Tehnička knjiga, Zagreb, 1968, p. 700 (Croatian translation).
3. Dragić, R. *Metodika nastave hemije*, Svjetlost, Sarajevo, 1973, pp. 62–85.

ФЕНОЛФТАЛЕИН В СИЛНО АЛКАЛНА СРЕДА

Резюме. Фенолфталеинът като киселинно-основен индикатор с неговата промяна на цвета от безцветен до червен е познат на всеки студент по химия. Изглежда по-малко известно обезцветяването на фенолфталеина в силно алкална среда. Предложена е демонстрация от типа „изненадващи опити”, която илюстрира този факт.

✉ **Prof. Dr. Vladimir M. Petruševski**,
Institute of Chemistry,
Faculty of Natural Sciences and Mathematics,
Sts. Cyril and Methodius University,
Arhimedova 5, PO Box 162,
1001 Skopje, Republic of Macedonia
E-Mail: vladop@iunona.pmf.ukim.edu.mk