USING STARCH TO DISPENSE INDICATORS AND REAGENTS

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Abstract

The new experimental method described above can help in teaching and learning acid-base concepts. It is suitable for experimental work performed by pupils and can be used also for teacher's demonstrations. In this method, a soft medium based on flour is used as a reaction medium to carry out chemical reactions that can normally run in water solution. No laboratory glassware is necessary for the experiments, and there is no risk of spillage. The experiments can be done anywhere, safely and individually also in a larger group of pupils. Micro or semi-micro quantities of chemicals are employed, and the soft medium, which has been used, can be safely disposed afterwards.

Introduction

The results in teaching can be further improved if the learning of concepts is associated with exploring [1], or with fun. Changes in colour of indicators in the acid-base reactions can be quite fascinating, and such experiments are performed to amuse audiences in so called "chemistry magic shows" [2], or are used as introductory experiments in teaching concepts associated with acids and bases [3-5].

In order to teach and to learn chemical concepts associated with acids and bases at all levels of education, different reactions in water solution can be studied. Many experiments have been developed for use as teacher's demonstrations [4-7] or as activities for students [8,9]. In addition to using water solutions, these concepts can also be demonstrated in a two phase liquid system in which water and a non polar solvent are involved [10], or on chromatographic paper where one of the reagents is adsorbed on paper while the water solution of the other is sprayed on the surface of the paper [11]. Solid polysaccharide beads named "chameleon balls" are prepared by dropping a mixture of a plant extract and a solution of sodium alginate into a calcium chloride solution [12].

These beads can be repeatedly used as an indicator. In addition to the commonly used paper, solid supports - such as ion-exchange resins [13], silica gel beads [14], or super absorbent polymer [15] - were used to more or less permanently fix the indicators and reagents in order to make them reusable and also to make the changes in small scale experiments in water solutions better visible. In addition to the experiments, methods based on analogy and models were also used in teaching more complex concepts associated with acids and bases, e.g. titrations [16].

We report here that a soft material based on flour can be easily prepared and used as a medium for various chemical experiments. The experiments can be performed in the classroom or elsewhere because they are safe and clean and do not require any laboratory equipment or containers for liquids.

Experimental

The soft medium described here is a soft, non-sticky, easily kneadable material prepared from fine flour. Various chemical reactions that take place in a water solution can be carried out in it. This material serves at the same time as a solvent and as a solid support. The experiments in the soft medium can be used to introduce chemical concepts and to assist teaching and learning. To bring about a chemical reaction it is necessary to knead with the fingers two or more pieces of the soft medium, which contains different reagents. The chemical changes can be observed easily when a colour or smell change occurs as the reaction proceeds. In addition to qualitative features, the quantitative aspects of the experiment can be discussed as well if, for example, a small spoon or a similar object is used as a tool to measure a unit mass or a unit volume. The quantities of chemicals used in the experiments can be at micro or semi-micro levels. The soft medium based on flour itself is safely disposable. The soft medium based on flour and the reagents in this medium can be prepared following the procedure described below [17].

Soft medium

Into a 2.5 L beaker with 1200 mL of boiling water 250 g white flour is added *in one portion*, and with *no stirring*, in such a way that a ball is formed (very important). The flour ball is cooked for 25 minutes *without stirring*.

The water is then decanted and the dough ball well-warmed, but not too hot to cause possible burns is well mixed while adding 20 mL of oil. Any type of non-poisonous and colourless oil can be used. The product can be mixed kneading it by hand or using a food processor. At the end of this step a soft kneadable ball is obtained (the small pieces obtained when using a food processor should be well pressed together, and mixing should be repeated to assure homogeneity). Then, 50 g of finely powdered sodium chloride is admixed and the procedure of kneading is repeated once again. If too much water is lost during the preparation of the product it may be crumbly. This can be adjusted by adding a few mL of water while kneading, but the change should be done with care and preferably while the dough is still warm otherwise the product can become sticky. The 400 g of product thus obtained is well pressed into a homogeneous, easily kneadable, non-sticky material and stored so that loss of water is prevented (a closed plastic container, waxy paper or plastic foil can be used). The soft medium based on flour can be used for a few weeks and will not deteriorate. If longer storage is necessary, an additional preservant such as benzoic acid, sodium benzoate or other perservants used in the food industry must be introduced to prevent the development of moulds.

Reagents in the soft medium

In most cases, up to 0.1 mol of the reagent per 1 kg of the medium described can be used without altering the properties such as kneadability, softness and non-stickiness. In the case of indicators, a concentration up to 0.02% of indicator in the soft medium is usually enough to obtain good results. Liquid reagents are directly introduced into the soft medium, while solid reagents are admixed in the form of a very fine powder or as a very concentrated solution (water or other non-poisonous solvents or mixtures can be used). The weight of the liquids admixed to prepare the dispersion of a reagent in the soft medium should not exceed 3% of the weight of the medium used, otherwise the product may become sticky. The homogenisation of the reagents in the soft medium is very

important for obtaining good results. The reagents in the soft medium should be pressed together and stored as described above if not in use, in order to prevent drying out.

Results and discussion

Many different reagents can be prepared in the soft medium following the above procedure. The use of these reagents offers an attractive approach for discussing the concepts associated with acids and bases, such as neutralisation, acid and base strength, dissociation, reversibility, etc. While the properly chosen reagents in the soft medium are being kneaded together during the experiment, one can also observe the importance of the process of bringing the reactants into contact to allow the reaction to occur. The reagents described here can be listed according to their main property, as:

a) acids

b) bases and

c) indicators

Acids and bases

When an acid, a base or a salt is dispersed in the soft medium the obtained reagent can be used for the experiments (Tables 1, 2 and 3). The results presented in Tables 1 and 2 were obtained by kneading a piece of a soft medium dispersion of acid (or base) with a piece of the same size of a soft medium dispersion of the indicator (concentrated red cabbage extract, RC, see below).

The changes observed by kneading together two or more small pearls of different dispersions of appropriate compounds in soft medium can be used to discuss concepts associated with acids and bases:

- a neutralisation reaction can be followed by kneading a pearl of a soft medium dispersion of acid with a pearl of a soft medium dispersion of base, followed by kneading the obtained product with a pearl of a soft medium dispersion of an indicator;

- the differences in equilibrium constants of the acid-base equilibrium reaction of ammonium chloride with basic salts in which ammonia is formed can be demonstrated by using pearls of dispersions of reagents in the soft medium, thus obtaining similar results as these described by M.Anderson and A.Buckley [18]. When a pearl of

dispersion of ammonium chloride in the soft medium is kneaded with a pearl of dispersion of a base in soft medium (Table 2) the intensity of the ammonia odour depends on the K_b of the base dispersed in the soft medium. However, the odour will be less strong compared with the experiments in which water solutions are used.

Table 1. Colour of the product obtained by mixing the soft medium acid dispersion with the soft medium indicator dispersion RC[a]

Acid compound[b]	K_a	Colour observed
malonic acid	1.4×10^{-3} 2.2×10^{-6}	reddish-violet
citric acid	7.1×10^{-4} 1.7×10^{-5} 4.1×10^{-7}	violet-reddish
acetic acid	1.6×10^{-5}	violet
ammonium chloride	5.6×10^{-10}	lavender-grey

[a]For determining the colour, equal volumes of the dispersion of acid in soft medium and dispersion on indicator RC in the soft medium were used (RC= concentrated red cabbage extract)

[b]The amounts of all acid compounds incorporated in the soft medium correspond to a concentration of 0.1 mol of reagent per kg of the prepared reagent.

Table 2. Colour of the product obtained by mixing the soft medium base dispersion with the soft medium indicator dispersion RC[a]

Basic compound[b]	K_b	Colour observed
sodium carbonate	5.6×10^{-4}	green
sodium hydrogen carbonate	2.4×10^{-8}	greyish-blue
sodium acetate	5.6×10^{-10}	greyish-lavender
sodium sulphate	8.3×10^{-13}	lavender

[a]For determining the colour equal volumes of the dispersion of base in soft medium and dispersion of indicator RC in the soft medium were used (RC= concentrated red cabbage extract).

[b]The amounts of all basic compounds incorporated in the soft medium correspond to a concentration 0.1 mol of reagent per kg of the prepared reagent.

Table 3. Concentration dependence of the colour of the product obtained by mixing the soft medium base dispersion of different NaOH concentrations with the soft medium indicator dispersion RC[a]

NaOH (mol/kg)	0.10	0.05	0.02	0.01	0.00
Colour observed	yellowish-green	green	bluish-green	greyish-lavender	lavender

[a] Finely powdered NaOH the was used to prepare dispersions of the base in the soft medium with a concentration of NaOH of 0.1 mol/kg; to prepare lower concentrations, one volume unit of the dispersion of the base in the soft medium was mixed with an appropriate number of unit volumes of the pure soft medium. For determining the colour, equal volumes of the dispersion of base in soft medium and dispersion of indicator RC in the soft medium were used (RC = concentrated red cabbage extract).

Acid-base indicators

Different indicators can be used to prepare dispersions in the soft medium, e.g. synthetic substances, as well as plant pigments, which are obtained from different plants by extraction [3, 12, 19-21]. As a rule, the plant extract must be concentrated to a smaller volume in order to be mixed with the soft medium, because the liquids admixed to prepare the dispersions should not exceed 3% of the weight of the medium used. To prepare 100 g of RC indicator in the soft medium, 100 mL of red cabbage extract in water [19] evaporated to max. 3 mL must be admixed.

The experiments with indicators in the soft medium can be used to become familiar with the concept of indicators in general, or as an aid to learning more about a specific indicator. They can also be used to better understand the concepts of equilibrium and reversibility.

A slow colour change can be observed by kneading a pearl of dispersion of an indicator in a soft medium with a pearl of a proper reagent in the soft medium. A change of colour in the medium can be observed due to the diffusion process if the dispersions are left for some time in contact even without kneading. If an approx. 1 mm thick layer of a soft medium indicator dispersion (rolled out with a small roller) is placed on a piece of a dispersion of acid (or base) in a soft medium a change of colour can be observed in the indicator layer. The change can be observed after one day, but the time is very much dependent also on the thickness of the indicator layer. The object to be observed should be kept in a closed (preferably transparent) container to prevent it from drying. An attractive colourful transformation can be achieved when a sequence of pearls of different dispersions of acids and/or bases in soft medium is prepared and then wrapped into an approx. 1 mm thick layer of the dispersion of indicator prepared with red cabbage extract or some other universal indicator. In Table 4, a presentation is given of the colour dispersions of some indicators in the soft medium and the colour changes observed when

each was mixed with an equal amount of a dispersion of sodium carbonate in the soft medium or a dispersion of citric acid in the soft medium.

Table 4. Colour change of dispersions of indicators in soft medium[a]

Indicator	pH range	Colour change of the soft medium
red cabbage extract	1-14	lavender to dark green[b] lavender to reddish-violet[c]
bromthymol blue	6.0-7.7	pale yellowish to green[b]
litmus blue	4.5-8.3	blue to red[c]
cresol red	7.2-8.8	yellow to red[b]

[a]A concentration of synthetic indicators of 0.01-0.02% is sufficient to achieve intensive colours: 1-2 mL of water or ethanol solution (if not water soluble) of 10-20 mg of indicator is mixed with 2-3 g of the pure soft medium and the paste obtained is mixed with 95-97 g of the pure soft medium.

[b]Colour change obtained by mixing one pearl of the indicator dispersion with one pearl of the sodium carbonate dispersion in the soft medium (conc. corresponds to 0.1 mol/kg).

[c]Colour change obtained by mixing one pearl of indicator dispersion with one pearl of citric acid dispersion in the soft medium (conc. corresponds to 0.1 mol/kg).

Experiments with the dispersion of indicators (plant extracts or synthetic) in the soft medium can also be applied as motivation experiments. Due to the mouldability of the soft medium based on flour, the dispersions of indicators in it can be used to make wonderful coloured objects, which can be left at room temperature to dry out and to harden. They can be kept for a very long time and will not deteriorate.

Safety measures

The experiments in the soft medium reported here can be performed anywhere and are safe from spilling. If corrosive compounds are used, safety measures are necessary (wearing of plastic gloves). Plastic gloves should be worn also when preparing any dispersion in the soft medium with the hands, in order to prevent contact with pure compounds.

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Povzetek

V članku je opisana nova eksperimentalna metoda, ki jo lahko uporabimo pri razvijanju pojmov s področja kislin in baz pri pouku kemije. Pri tej metodi uporabimo namesto vodnih raztopin, ki jih običajno uporabljamo pri eksperimentiranju s kislinami in bazami, mehki medij na osnovi moke, ki ima hkrati vlogo topila in vlogo trdnega nosilca. V članku so opisani primeri priprave reagentov, disperzij različnih spojin v mehkem mediju, in primeri reakcij s pripravljenimi reagenti. Reakcije z reagenti v mehkem mediju izvajamo brez topil in za izvedbo eksperimentov ne potrebujemo posode. Učenci lahko te eksperimente izvajajo samostojno in varno. Uporaba semimikro oziroma mikro množin kemikalij pri tej eksperimentalni metodi omogoča, da preostanke reagentov lahko odstranimo skupaj s komunalnimi odpadki.