ASSESSMENT OF STUDENTS' UNDERSTANDING OF THE SALT HYDROLYSIS: MISCONCEPTIONS AND CLARIFICATIONS

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Salt hydrolysis is an important concept in acid-base chemistry. Students are often given a qualitative idea at the secondary level and quantitative information at the college level in the curriculum. In literature, this concept is reported to be vague for students at all stages of education. Hence, the present study is undertaken to integrate both theoretical and practical aspects of this complex phenomenon. The microscale chemistry technique is used in place of a traditional chemistry laboratory to reach a large number of students as it is SEAT friendly, i.e., S (Student), E (Environment), A (Administrator), and T (Teacher). The investigation is conducted in three parts, a pre–laboratory interactive session followed by experimentation and a post–laboratory discussion. The outcome of the study is very encouraging, as revealed by students' feedback. Participants could understand the phenomenon of salt hydrolysis, obtain hands-on-experience, and could predict hydrolysis behaviour of salts of various types (strong acid–strong base; strong acid–weak base; weak acid–strong base; weak acid–weak base It is felt that in dealing with the concepts of chemistry, wherever feasible, teachers can adopt an integrated approach involving experimentation rather than restricting themselves only to descriptive chemistry.

Keywords: Salt hydrolysis, acids, bases, neutralization, constructivist approach, microscale chemistry technique, microscale chemistry laboratory kit, integrated approach, pH value, universal indicator solution

Introduction

Hydrolysis is a chemical reaction in which water breaks the bond between the compounds and makes bond between the compounds and changes its makeup. Both organic and inorganic compounds undergo hydrolysis. In most instances of organic hydrolysis, water combines with neutral molecules; while in inorganic hydrolysis, water combines with ionic molecules such as acids, bases, and salts. In the science curriculum, hydrolysis is an important concept in chemistry and biology. This phenomenon is taught in the chemistry curriculum from secondary to college level. Hydrolysis, being an interdisciplinary topic, finds significance in daily life also, as evidenced by mention in ATP hydrolysis (Biology), digestion process (Biochemistry), Saponification, conversion of ester into acid and alcohol (Chemistry). Hydrolysis is not taught as a separate unit/theme in the curriculum despite its biological and industrial importance. Only qualitative aspects are dealt with in undergraduate courses, and quantitative descriptions and related mathematical relations are discussed at the college level. The concept of 'Salt' introduced in Bronsted-Lowry acids and bases, is erroneously understood and limited to reverse of neutralization. Salt hydrolysis is a reaction when a salt completely dissociates in an aqueous medium, and its anion/cation reacts with water to produce hydroxide ions or hydronium ions that affect the pH of a solution. A hydration reaction is a chemical reaction in which a substance is surrounded by water molecules. Often the terms 'hydration' & hydrolysis' apparently cause misconceptions among students.

Aqueous phase reactions constitute an essential chemistry component at the secondary, senior secondary, and college or upper senior secondary stages of the science curriculum. Unfortunately, few studies have examined students' understanding and have identified misconceptions or alternate ideas in some concepts, especially those that are multidisciplinary. For example, acids and bases (Cooper 2016, Pan and Henriques 2015, Boz 2009, Kousathana, et al., 2005), Chemical equilibrium (Hackling 1985), Electrochemistry (Anita and Lee 2016), Chemical bonding (Vrabec and Proksa 2016), Atomic structure (Papageorgiou et al., 2016), Nuclear Chemistry (Usta and Ayas, 2010) are a few which are of interest to investigators.

Salt hydrolysis is an essential concept in acid-base chemistry. Incidentally, this is recorded as one of the topics well known to cause many misconceptions among students. (Demircioglu 2009, Secken 2010, Putri 2014). These studies are based on testing students' knowledge using a questionnaire/test consisting of open-ended and multiple-choice items, correlating textbook information with students' responses, by the tasks assigned to write chemical equations/products obtained after salt hydrolysis, stating acidic/basic nature of salt solutions, etc. Orwat et al. (2017) suggested that laboratory exercises can help understand the phenomenon of salt hydrolysis. However, no concerted efforts are reported in this direction.

Experimentation is an important means of combining knowledge, creativity, and skills to examine hypotheses. In addition, this approach provides hands-on experience about all steps of a scientific process. The crucial role of practical work and experimentation in science is universally appreciated. This is more so in chemistry, an experimental science. Most of the concepts in this area are developed by laboratory exercises. Considering the merits of the laboratory method, the present work is undertaken with the following objectives:

1. To find out and enrich student's knowledge about salt hydrolysis through an interactive pre-laboratory session.
2. To study hydrolysis behaviour of selected salts of various types (Strong acid – Strong base; Strong acid–Weak base; Weak acid- Strong base; Weak acid-Weak base) to account for the acidic/basic nature of products obtained after hydrolysis.

To facilitate laboratory experience, Microscale Chemistry Laboratory developed by NCERT is used. In addition, conventional experiments are restructured to suit the study. This follows the National Curriculum Framework (NCF – 2005) recommendations designed by NCERT.

Selection of Sample

The research was conducted during the odd semester of the 2017-2018 academic year. The research sample consisted of 100 students segregated into 50 batches of two students each. They have completed their Senior Secondary course at various schools of Southern States (Karnataka, Kerala, Andhra Pradesh, Telangana, Tamil Nadu, Pondicherry, and Lakshadweep). Some (about 8%) have studied in their respective mother tongue like Kannada, Telugu, Tamil, Malayalam, and Hindi. The majority of learners have studied the CBSE syllabus, while a few have opted for respective senior secondary state syllabus prescribed by the Board of Pre-University Education. Qualitative aspects of salt hydrolysis were dealt with in the chemistry syllabus at the secondary and senior secondary stages. Detailed qualitative and quantitative information about salt hydrolysis forms a part of course work for Semester IV (second year) of M.Sc.Ed. and B.Sc.Ed. courses offered by the Regional Institute of Education (NCERT) Mysuru, Karnataka state.

Methodology

The study is undertaken in three parts. The first component consisted of a pre-laboratory session followed by experimentation.

In the first session, some relevant questions on salt hydrolysis were raised.

Focus questions follow the below-mentioned sequence:

1. What is salt?
2. Write formulae of salts considered in the present study.
3. Indicate names of parent acid and parent base constituting these salts.
4. Can these salts be classified into different categories?
5. What is salt hydrolysis?
6. Which type of salts undergo hydrolysis?
7. Whether hydrolysis products are acidic, basic, or neutral?
8. How to identify products? What are the available, feasible, easy, and quick methods?

Participants were categorised into 20 groups; each group consisted of 5 learners. In this session, a student-centred or constructivist approach is followed. Students worked in groups, from their previous knowledge of textbook information, classroom teaching, laboratory experience, peer group discussion, responded for questions posed, and presented their answers/responses. The investigator enlisted plausible answers on the blackboard; necessary corrections were made and supplemented. Wherever necessary, the constructivist approach is used. Students were imparted/enriched with basic information about salt hydrolysis with this exercise. This step is believed to provide a guideline for other parts of the investigation.

The first question raised was to define the term 'salt.' Varied statements and ideas obtained from different groups were noted systematically. The definition suggested by Secken (2010) is quoted in this context: "Salts are electrically neutral substances formed by cation and anion". Among these cations and anions, H^+ and OH^- are exceptions. The bonds formed between those entities are ionic. All compounds with this type of bond are salts without any exception. Salts should be listed under two groups: (a) Inorganic salts (b) Organic salts. In inorganic salts, the cation is generally made of metals, and the anion is generally made of non-metals or their oxides. In the present study, only inorganic salts were selected (Annexure-I).

In writing formulae of the selected ionic compounds (Salts), Cris-Cross method or Cross-over method was used. This is based on the Zero-sum rule, which states that— For neutral chemical formulae containing ions, the sum of the positive and negative ions must be equal and their sum is equal to zero.

The following steps were followed in finding formulae of ionic compounds.

Step 1: Assign charge to each element.
Step 2: Cris-Cross the charges to find subscript; charges must add to zero.

Example: To write the formula for Sodium Sulphate (Na_2SO_4),

Assign charge to each element / ion: Charge for Sodium ion is +1, charge for Sulphate ion is -2

The sum of positive and negative ions will become zero when two sodium ions and one sulphate ion is considered, i.e., 2 Na^+ and 1 $(SO_4)^{-2}$

Na^{+1} $(SO_4)^{-2}$

2 1

Cris-Crossing, the formula assigned is Na_2SO_4. This method is based on the valency of atoms and ions. Therefore, the same procedure can be adapted for any given ion, enabling writing the salt formula. In addition, the steps followed above also familiarise learners about the nomenclature of ionic compounds.

In the same example, Na_2SO_4, writing names of the ions,

Na^{+1} SO_4^{2-}
Sodium-ion Sulphate-ion

Sodium Sulphate

The next task assigned was to write the names of parent acids and parent bases constituting salts. Salts can be the products of different kinds of acids and bases, both weak and strong. The strategy followed in writing parent acid and parent base is mentioned below:

Starting with an electrolyte formula, first, identify positive and negative ions formed when an electrolyte dissociates in water. If the positive ion is H^+, the compound is an acid. If the negative ion is OH^-, the compound is a base. Generalization is that anion and cation of salt can come from any acid or base (strong and/or weak). Following relationship was also suggested to participants for consideration whenever required:

Example: Potassium Carbonate, K_2CO_3

Parent acid = H^+ and anion of the compound

Parent acid: $H^+ + CO_3^{2-} \longrightarrow H_2CO_3$
Anion is CO_3^{2-} , Carbonate-ion

Acid is H_2CO_3, Carbonic acid

Parent base = OH^- and cation of the compound

Parent base: $OH^- + K^+ \longrightarrow KOH$
Cation is K^+, Potassium ion

Base is KOH, Potassium hydroxide.

Participants were asked to define and explain the term 'Salt hydrolysis.' This question forms the focus question for the present study. Students were expected to express their understanding in a statement /short answer. They were instructed to use previous knowledge, interact with their peer, and refer to text/reference books or any other source of information. At this stage, an inductive process, concept attainment, is utilized, allowing learners to construct concepts by searching for common characteristics.

Illustration: Students can compare ' yes ' examples of salt hydrolysis with' No ' examples of salt hydrolysis.

Students were presented with six testers to either classify as being ' yes ' or ' no ' examples of salt hydrolysis. This enabled them to differentiate between hydrolysis and other chemical reactions. The main idea was to bring about characteristics of salt hydrolysis.

(a) Hydrolysis of Amides

(b) Mixing dilute solutions of Sodium Hydroxide and Nitric acid

(c) Hydrolysis of triglyceride with Sodium Hydroxide to Glycerol.

(d) Conversion of Cellulose to Glucose

(e) Dissolution of Ammonium Carbonate in water

(f) Production of ADP from ATP

'Yes' examples	'No' examples Testers
Dissolution of Ammonium chloride	**Mixing solutions of KOH and H Cl**
Dissolution of Sodium acetate in water	$CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$
Conversion of starch into glucose	$NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$
$NH_3^+ H_2O \rightleftharpoons NH_4^+ +OH^-$	$H_2O + H_2O \rightleftharpoons OH^- +H_3O^+$

The question is now focused on identifying salts exhibiting hydrolysis behaviour. At this stage, the investigator displayed names of strong acids and strong bases as enlisted in the textbook (Table 1)

Learners were asked to identify ions that react with water and those which act as spectator ions when ionic salts are put into water. An illustration is given in Table 2.

In writing product/products of salt hydrolysis, participants were unambiguous that products are acids and bases only, maybe by nature, weak or strong. However, when they wished to name parent acids and bases, it hinted that these are the only hydrolysis product. To identify resulting acids and bases produced on hydrolysis, quick, simple methods were tried as it was required to handle several samples simultaneously. In the present study, phenolphthalein, litmus solution, pH paper strips (both wide range and narrow range) and universal indicator solution were chosen as indicators. Well Plate employed by each group enabled a comprehensive, simultaneous observation of 96 samples.

The focus of the second component of the investigation was experimentation. In this part, chemicals/apparatus mentioned below were used.

Table 1
Names of strong acids and strong bases

Acids	Bases
Hydrochloric acid (HCl)	Lithium hydroxide (LiOH)
Hydrobromic acid (HBr)	Sodium hydroxide (NaOH)
Hydroiodic acid (HI)	Potassium hydroxide (KOH)
Nitric acid (HNO_3)	Rubidium hydroxide (RbOH)
Sulphuric acid (H_2SO_4)	Cesium hydroxide (CsOH)
Chloric acid ($HClO_3$)	Magnesium hydroxide [Mg $(OH)_2$]
Perchloric acid ($HClO_4$)	Calcium hydroxide [$Ca(OH)_2$]
	Strontium hydroxide [$Sr(OH)_2$]
	Barium hydroxide [$Ba(OH)_2$]

Table 2
Summary of Acid-Base properties of salts

Salt Solution (example)	P^H	Nature of ions	Ion that reacts with water
Neutral (NaCl, KBr)	=7.0	Cation of strong base (group IA, group.2A but not Be^{2+}) Anion of strong acid (Cl^-, Br^-, I^-,NO^{3-}, ClO_4^-)	None
Acidic NH_4Cl, NH_4NO_3	<7.0	Cation of weak base(NH_4^+, Al^{3+}, Fe^{3+}) Anion of strong acid (Cl^-, Br^-,I^-,NO_3^-, ClO_4^-)	Cation
$AlCl_3$, $FeBr_3$	<7.0	Small highly charged cation The anion of strong acid	Cation
Basic CH_3COONa	>7.0	Cation of a strong base The anion of a weak acid (F^-, NO_2^-, CN^-, CH_3COO^-)	Anion

Chemicals: Ammonium Sulphate, Zinc Sulphate, Aluminium Sulphate, Ammonium Carbonate, Sodium acetate, Ammonium acetate, Sodium chloride, Potassium nitrate, Ammonium fluoride, Sodium bicarbonate, Potassium nitrate, Sodium carbonate.

All chemicals were of A.R. grade purchased from Sd. Fine Chem. Limited., Mumbai, Maharashtra, India. 0.1 M solution of salts was prepared using de-ionized water, stored in stopper bottles.

Indicators:Phenolphthalein (0.5% solution (w/v) in ethanol (1:1), blue litmus solution, red litmus solution, universal indicator solution. These indicators were procured from Nice Chemicals Private Ltd., Edapally, Kochi - 682024, Kerala State, India.

Microscale chemistry Laboratory Kit

Microscale chemistry laboratory kit developed by Workshop Department of NCERT, New Delhi was used. The kit consisted of a wooden box to accommodate about 45 items (glass/ plastic ware, apparatus) required to perform basic chemistry experiments. In the present work, Well Plate (Acrylic tissue culture plate, TARSON), plastic graduated droppers to dispense test solutions/indicators), screw-capped plastic vials (to store solid substances), plastic dropper bottles (to hold liquid reagents) were used.

Well Plate: This consisted of 96 wells or reaction vessels. Each well is labelled, can hold 0.3 ml volume per well. Salt solutions/ indicators were added using graduated droppers; mixing was done using small, thin plastic colourless sticks. Three drops of test solution are mixed with a drop of the indicator.

Application of salt solution: Salt solutions were added to wells in the order mentioned below (Table 3).

Table 3

Mode of application of salt solutions

Sl. No.	Name of Salt	Formulae	Well number
1	Sodium chloride	Na Cl	A_1, C_1, E_1, G_1
2	Sodium acetate	CH_3COONa	A_2, C_2, E_2, G_2
3	Potassium nitrate	KNO_3	A_3, C_3, E_3, G_3
4	Sodium carbonate	Na_2CO_3	A_4, C_4, E_4, G_4
5	Sodium bicarbonate	$NaHCO_3$	A_5, C_5, E_5, G_5
6	Ammonium chloride	NH_4Cl	A_6, C_6, E_6, G_6
7	Aluminium sulphate	$Al_2(SO_4)_3$	A_7, C_7, E_7, G_7
8	Ammonium acetate	CH_3COONH_4	A_8, C_8, E_8, G_8
9	Ammonium sulphate	$(NH_4)_2SO_4$	A_9, C_9, E_9, G_9
10	Ammonium fluoride	NH_4F	A_{10}, C_{10}, E_{10}, G_{10}
11	Ammonium carbonate	$(NH_4)_2CO_3$	A_{11}, C_{11}, E_{11}, G11
12	Zinc sulphate	$ZnSO_4$	A_{12}, C_{12}, E_{12}, G_{12}

The addition of indicators in rows of Well Plate follows the pattern presented in Table 4.

Table 4

The pattern of addition of indicator solutions

Sl. No.	Indicator	Row
1	Phenolphthalein	A
2	Blue litmus	C
3	Red litmus	E
4	Universal indicator	G

To facilitate laboratory work for all groups, 20 well plates were used. Participants worked in a group of 5 and collected the data.

The final part consisted of compiling the data, analysing the observations on the response of salt solutions towards different indicators, drawing inferences based on observations, and correlating laboratory data with textbook information. In addition, the focus was also to get feedback about the adoption of the microscale chemistry technique and its relevance as an alternative to the traditional laboratory.

Results

In the pre-laboratory session, some relevant primary data about salt hydrolysis was sought, and enrichment was done accordingly.

Initially, when students were probed to define 'Salt,' various responses emerged.

Some relevant statements are mentioned below:

(i) When an acid reacts with a base, a compound formed is called Salt.

(ii) It is a naturally occurring substance.

(iii) Salt is something soluble in water.

(iv) Salt is made up of an anion and a cation.

(v) When strong acid and strong base solutions are mixed, salt is produced.

(vi) It is a substance that could separate into ions when kept in water.

(vii) Salt is formed when the neutralisation reaction takes place.

(viii) Salt is a product of the reaction of an acid and any base in an aqueous solution.

(ix) Salt is a neutral compound.

(x) When an acid and a base react, salt is produced. It is in equilibrium with the reactants.

In writing chemical formulae of salts, about 80% of them were comfortable writing formulae of those salts as exemplified by NaCl, KNO_3, CH_3COONa, CH_3COONH_4. However, the majority of the participants (about 90%) faced difficulties in writing formulae like $(NH_4)_2CO_3$, $Al_2(SO_4)_3$. When both anion and cation were univalent, the mistakes committed were lesser. However, when anion, cation, or both possess more than one valency, the probability of writing incorrect formulae was more.

In identifying parent acid and parent base constituting salts, all of them were comfortable with salts made up of strong acid and strong base. For example, for NaCl, students were unanimous in identifying that HCl is parent acid and NaOH its parent base.

Students were asked to evolve a classification scheme of salts belonging to Strong Acid - Strong Base; Strong Acid-Weak Base; Weak Acid-Strong Base; Weak Acid-Weak Base. In arriving at this design, participants were contingent on either textbook/reference book or the investigator. A compiled data was also presented to them. Many were astonished as there can be many salts in contrast to their belief that salt is constituted invariably by strong acid and strong base.

In defining 'Salt hydrolysis,' the general idea was to consider it a reverse of a neutralisation reaction. Some students were trying to apply literature interpretation of the term. Accordingly, in Greek, 'hydro' means 'water' and ' lysis ' means ' loosening 'or 'disengagement. ' With this, about 25% of them assumed that hydrolysis is a dissociation reaction with their previous knowledge. The general opinion was that it is a chemical transformation involving water.

Given several salts and finding whether it will undergo hydrolysis or not (from the nature of parent acid and parent base) was the next task assigned to them. At this stage, hardly any predictions were made by participants. Taking individual names of salt, the investigator had to provide the required information. This unexpected poor response may be because salt hydrolysis is treated briefly and qualitatively as a part of acid-base chemistry. Compiled data of Part-1 is presented in Table 5.

Table 5:
Composition of some selected salts

Sl.No.	Salt	Parent acid	Parent base	Type of acid	Type of base	Hydrolysis yes / no
1	Sodium chloride	Hydrochloric acid	Sodium hydroxide	Strong	Strong	no
2	Sodium acetate	Acetic acid	Sodium hydroxide	Weak	Strong	yes
3	Potassium nitrate	Nitric acid	Potassium hydroxide	Strong	Strong	no
4	Sodium carbonate	Carbonic acid	Sodium hydroxide	Weak	Strong	yes
5	Sodium bicarbonate	Carbonic acid	Sodium hydroxide	Weak	Strong	yes
6	Ammonium chloride	Hydrochloric acid	Ammonium hydroxide	Strong	Weak	yes
7	Aluminium sulphate	Sulphuric acid	Aluminium hydroxide	Strong	Weak	yes
8	Ammonium acetate	Acetic acid	Ammonium hydroxide	Weak	Weak	yes
9	Ammonium sulphate	Sulphuric acid	Ammonium hydroxide	Strong	Weak	yes
10	Ammonium fluoride	Hydrofluoric acid	Ammonium hydroxide	Strong	Weak	yes
11	Ammonium carbonate	Carbonic acid	Ammonium hydroxide	Weak	Weak	yes
12	Zinc sulphate	Sulphuric acid	Zinc hydroxide	Strong	Weak	yes

Based on the above observations, a classification scheme for salts was arrived at. (Table 6)

In part-2, participants worked in groups of 5, performed the experiment, recorded diverse colors developed by salt solutions

Table 6
Classification of salts

Sl. No.	Type of Salt	Name of salts	Other examples
1	Strong acid, Strong base	NaCl, KNO_3	$Ba(NO_3)_2$, KBr, K_2SO_4
2	Strong acid, Weak base	NH_4Cl, $Al_2(SO_4)_3$, $(NH_4)_2SO_4$, NH_4F, $ZnSO_4$	NH_4Br, $FeCl_3$,$CuSO_4$
3	Weak acid, Strong base	CH_3COONa, Na_2CO_3, $NaHCO_3$	KNO2, NaNO2, Na F
4	Weak acid, Weak base	CH_3COONH_4, $(NH_4)_2CO_3$	$HCOONH_4$, NH_4HCO_3 NH_4F

Provision was also made to write other examples of salts belonging to four types mentioned in Table 6. Discussion with a peer, reference books, and previous knowledge, textbook data helped them elaborate the list and insert some more examples like Barium nitrate Ba $(NO_3)_2$ and Potassium bromide (KBr) in the first category.

with selected indicators. Data is presented in Table 7.

Abbr: H Ph: Phenolphthalein; BL: Blue litmus; RL: Red litmus; UI: Universal indicator; NC: No color

GN green; PE purple; BE blue; GY green-yellow; PK pink; PH peach; YG yellow-green

Table 7
Response of Salt solutions to different indicators

Indicator	Row ---→	1	2	3	4	5	6	7	8	9	10	11	12
H Ph	A	NC	NC	NC	pink	pink	NC	NC	NC	NC	NC	pink	NC
BL	B	blue	blue	blue	blue	blue	blue	red	blue	blue	blue	blue	blue
RL	C	red	red	red	blue	blue	red	red	red	red	blue	blue	red
UI	D	GN	GN	GN	PE	PE	GY	PK	GN	PH	GN	BE	YG

Note: Rows 1 to 12 indicate names of the salts as in Table 4

pH values of salt solutions were found using pH paper strips (both wide and narrow range), Universal indicator solution, and pH meter. Observations are compiled in Table 8.

When phenolphthalein is used, Sodium carbonate, Sodium bicarbonate, and

Table 8

pH values of salt solutions using different indicators

Sl. No.	Salt	pH paper*	Universal indicator	pH meter
1	Sodium chloride	7.2	7	7.49
2	Sodium acetate	7.4	8	7.18
3	Potassium nitrate	7.2	7	7.58
4	Sodium carbonate	10.2	10	11.38
5	Sodium bicarbonate	9.6	10	9.97
6	Ammonium chloride	5.6	5	5.20
7	Aluminium sulphate	3.2	3	2.80
8	Ammonium acetate	7.2	7	7.55
9	Ammonium sulphate	4.6	5	4.92
10	Ammonium fluoride	6.4	6	6.88
11	Ammonium carbonate	9.2	9	9.06
12	Zinc sulphate	6.2	6	6.40

*both wide range and narrow range

Ammonium carbonate exhibit pink colour with different intensities while other salt solutions remain colourless. The blue colour of the litmus solution lasts unchanged with all salt solutions except Aluminium sulphate. Upon adding a drop of blue litmus, an instant red colour appeared. Response of salt solutions towards red litmus was unlike. Solutions of Sodium carbonate, Sodium bicarbonate, Ammonium fluoride, and Ammonium carbonate turned blue instantaneously. Universal indicator solution could display an intermixture of colors with salt solutions as its working range is capacious. The colour paragon observed was diverse (pink, green, yellow, blue, violet) depending on the archetype of salt (Table 7). The nature of the hydrolysis of salts, their pH ranges, and eventuate colour developed are represented in Table 9.

Table 9

Nature of products obtained from salt hydrolysis

pH range	Description	Colour
Less than 3	Strong acid	Red
3 to 6	Weak acid	Orange or Yellow
7	Neutral	Green
8 to 11	Weak base	Blue
More than 11	Strong base	Violet or Indigo

Discussion

The research confirms that students are hindered in understanding aqueous-phase chemical reactions in general and the phenomenon of salt hydrolysis in particular. In defining the term 'salt' itself, assorted statements were made by participants. For most of them, salt is meant solely as a product when an acid reacts with a base. This response may be for reasons that, in the curriculum, 'Salt,' the entitle finds its significance either while dealing with nature and properties of metals/non-metals or in acid-base chemistry. Another reason for misconception is that while teaching neutralization reaction, usually, examples are chosen from the strong acid-strong base category. Other possibilities that salt can also be a product when Weak Acid-Weak Base/ Weak Acid-Strong Base/Strong Acid-Weak Base interact chemically is not emphasised in the curriculum.

Chemical formulae is a descriptive and heuristic tool in the field of science, especially in chemistry. In writing formulae of salts, most participants (about 80 %) were comfortable with those familiar with daily life situations and /or mentioned in the textbook. When a clue about applying knowledge of valency to facilitate the task is given, they could present correct formulae for ionic compounds. However, when the investigator used the word' metal salt' in one context, many got bewildered. After careful examination of formulae, they realised that the cation of salt could be metal like Sodium, Potassium, or Zinc in many cases.

In writing names of parent acids and parent bases constituting various salts, again, participants could offer correct names to only those compounds learnt by them. For unfamiliar/less familiar salts, the investigator had to interact with groups to elucidate the correct names of acids and bases. Difficulties in correctly identifying products of hydrolysis are observed by K. Orwat et al. (2017). In a study conducted for upper secondary students, pupil imbibed with alternative conceptions of salt hydrolysis, could not predict the products obtained when some salts (Sodium Carbonate, Zinc Chloride, Magnesium Chloride, and Chromium Sulphite) were put into water and made to react with it. The error was also made in writing chemical equations, showing the direction of arrows, whether it is a reversible/ irreversible change. This situation may probably be overcome if exemplar salts of different prototypes (Strong acid-Strong base, Strong acid-Weak base, Weak acid-Strong base, Weak acid-Weak Base) are dealt with in a classroom. In another study, Naah (2012) observed that representation of subscripts in writing chemical formulae can influence students understanding of solubility of ionic compounds in water. Such observations were more conspicuous when ionic compounds had monoatomic subscripts ($MgCl_2$, $Al_2(SO_4)_3$) or polyatomic subscripts (KNO_3, K_2SO_4). The Cross-Overrule may be of relevance in such contexts.

Pinarbasi (2007) observed that, when students have posed a question, 'what is salt hydrolysis? 73% of them replied that hydrolysis is the separation of matter into ions by water thus bewildering the concept of hydrolysis for the dissociation process. In the present research, statements given by novice point out that they possessed alternate conceptions. Incorrect responses may stem from the fact that the pupil may not recognise and consider all the factors holistically due to limited discussion in the chemistry curriculum on various facets of salt hydrolysis. Probably, taking suitable measures like exposing students with multiple and a variety of reactions of salts with water, recalling and reinforcing the concept of acids and bases with a focus on Bronsted – Lowry definition, strengths of acids and bases, quoting a variety of other exemplar reactions leading to the formation of salts, recalling conditions of chemical equilibrium, narrating different types of chemical reactions may help to overcome misconceptions.

In addressing the question regarding the nature of products of hydrolysis (acidic, basic, or neutral), participants opined that products are neutral. The justification was that when an acid interacts with a base, the reaction occurs as stoichiometry, leaving products neutral. This prediction may stem from the fact that in textbooks illustration is done with a strong acid and strong base. As salt hydrolysis appears only as a component of acid-base chemistry, teachers usually take a few examples and a brief discussion. The complexity of the phenomenon is ignored. In addition, laboratory testing of products of hydrolysis is done very rarely. Reasons like non-availability of laboratory, handling a large number of students at a time, cost, time may contribute to shying away of students from the experiments. Microscale technique in finding the response of salt solutions with indicators gave unambiguous results. Students were thrilled to observe that all salts do not undergo hydrolysis, and resulting products need not be neutral. This was evident by a spectrum of colours produced by indicators; these observations were further confirmed by measuring the pH of test solutions using a pH meter.

In the post-laboratory session, the investigator administered an opinion as to find out students' enriched knowledge about salt hydrolysis and microscale technique. Because of background knowledge (provided in Part–I), they were unimpeded about the objectives of the experiment. This created more interest and confidence. Participants expressed that microscale experiments served as an excellent supplement to discussion and effectively unveiled various facets of salt hydrolysis. The microchemistry kit helped them save time, space, chemicals, and being eco-friendly; it also enabled easy disposal of waste.

Above all, group activity was done in the classroom itself; traditional laboratory requirement was not an issue. This new exercise placed them in place of a researcher, offered hands-on experience, and helped conceptualise the theme 'Salt hydrolysis' satisfactorily. The application of the micro-scale technique in performing laboratory experiments successfully is also reported by Kelkar and Dhavale (2001), Kalogirou and Nicas (2010), and Pareek, et al. (2014).

Suggestions

1. In explaining salt hydrolysis, exemplar compounds belonging to a different category of salts can be chosen, and cases of specific salts may be analysed.
2. Students can be encouraged to include relevant chemical formulae while writing the name of salts. This exercise will boost

their confidence in remembering symbols of elements and enable them to express the formula of any given compound.

3. Different salts can be chosen for illustration in teaching acid-base chemistry, especially neutralisation (salt formation) reactions/salt hydrolysis. This can imply that the nature and pH of a salt solution depend on parent acid and parent base.
4. In dealing with salt hydrolysis, different kinds of chemical reactions lead to the formation of salt like precipitation, decomposition may be discussed with relevant examples. This will offer a broad perspective to students; provide scope to explore other possible modes of obtaining salts.
5. Experiments can be an integral part of an investigation dealing with science concepts. This will induct /enhance laboratory skills, offer hands-on– experience, enable me to appreciate chemistry and experimental science.
6. Application of microscale chemistry techniques maximizes opportunities for careful observation and interpretation. In addition, it offers the chance to conduct several trials with less expenditure and limited time.

Conclusion

In sum, the research confirms that the concept of salt hydrolysis is difficult for learners. In the present study, an integrated approach is followed, including discussion and experimental components. Pre–laboratory session could offer a sound theoretical background while the experimental part offered hands-on-experience in understanding' salt hydrolysis', examining the properties of the resulting solution (acidic/basic/neutral), and recording pH values. Students received both sessions well, served complimentary to each other, and gave a detailed insight into the phenomenon. In addition, the use of the constructivist approach enabled us to get a good idea about the theme with illustrative examples and non–examples. Application of microscale chemistry technique was of immense value to learn all crucial steps of learning science concepts. Participants experienced that, indeed, chemistry is an experimental science. They could save time, cost, space in the task despite conducting repeated trials. Even waste disposal was easy. This aspect was evident in the post–laboratory discussion. It is suggested that such integrated efforts can be used effectively in dealing with chemistry concepts.

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Annexure-I

Salt Hydrolysis

The concept of 'Salt' is introduced in secondary school textbooks only within the definition of neutralization. 'Salt ' is treated as a product formed when Bronsted-Lowry acids and Bronsted-Lowry bases react with each other.

Salt is an ionic compound containing positive ions other than H+ and negative ions other than OH-. Most salts dissociate to some degree when placed in water. In many cases, ions from salt react with water molecules to produce hydronium ions (H_3O^+) or hydroxide ions (OH). Any chemical reaction in which water is one of the reactants or interaction between an ion or ions of Salt with water resulting in the formation of a weak acid or a weak base or both (weak acid and weak base) is called hydrolysis.

There are four distinct groups of hydrolytic behaviour of salts. They are:

(a) Salts of strong acids and strong bases

(b) Salts of strong acids and weak bases

(c) Salts of weak acids and strong bases

(d) Salts of weak acids and weak bases

(a) Salts of strong acids and strong bases

Salt of strong acid and the strong base does not undergo hydrolysis. Solution of such Salt is neutral, and pH value will be around seven at 298 K. e.g.,: Na Cl dissociates in water to give an anion Cl^-. H Cl and Cl^- constitute an acid-base conjugate pair:

$$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

conjugate base. Since H Cl is a strong acid, Cl^- is a very weak base and unable to accept a proton (H+) from an acid, particularly water. Hence, Cl- does not hydrolyse. As a result, it cannot generate OH- ions as represented below:

$$Cl^- + H_2O \longrightarrow HCl + OH^-$$

The pH of the sodium chloride solution remains unaffected.

(b) Salts of strong acids and weak bases

Hydrolysis of Salt of strong acid and a weak base is due to hydrolysis of cation of a weak base. This can be represented as

$$BOH \rightleftharpoons B^+ + OH^-$$

B+ is the conjugate acid of the weak base, BOH. Therefore, it is a relatively strong acid. It accepts OH^- ion from water (H_2O) and forms unionized BOH and H^+ ions.

$$B^+ + H_2O \rightleftharpoons BOH + H^+$$

Accumulation of H^+ ions in solution imparts acidic nature.

(c) Salts of weak acids and strong bases

When Salt of a weak acid and strong base ionizes in an aqueous solution to form anion A^-,

$$HA \rightleftharpoons H^+ + A^-$$

A^- is the conjugate base of weak acid HA and is relatively strong. Thus, A^- accepts H^+ ion from water (H_2O) and undergoes hydrolysis.

$$A^- + H_2O \rightleftharpoons HA + OH^-$$

The resulting solution is slightly basic due to excess OH^- ions.

(d) Salts of weak acids and weak bases

When Salt of a weak acid and weak base is added to water, both B+ (conjugate acid) and A- (conjugate acid) ions participate in hydrolysis as they are relatively strong, accept H+ and OH- ions, respectively.

$A^- + H_2O \rightleftharpoons HA + OH$-----(i)

$B^+ + H_2O \rightleftharpoons BOH + H^+$----(ii)

Overall, hydrolysis may be represented as

$A^- + B^+ + H_2O \rightleftharpoons BOH + HA$

pH of the resulting solution will depend on the relative extent of anion hydrolysis (i) and cationic hydrolysis (ii). If both ions react to the same extent, $[OH^-] = [H^+]$, solution is neutral. If cation reacts to a greater extent, the solution is slightly acidic. If anion is a little more reactive, the solution will be basic.