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# Identifying Student's Misconceptions about SALT

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**Abstract**

In the study students' misconceptions about "salts" topic were tried to determine by benefiting from experiences of the researcher and teachers who are working in this field. A test was prepared which are consisted of open-ended and multiple choice questions to determine possible misconceptions about "salts" by benefiting from various chemistry books. It was determined that students have misconceptions about "salts" in basic level. Also suggestions were made to eliminate these misconceptions by determining the reasons of these.

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*Keywords:* Salt; misconceptions; chemistry education; teaching of salts; chemistry textbook.

## 1. Introduction

The recent studies in science ed ucation have focused on how scientific concepts are perceived by the students as well as what the learning difficulties and misconceptions of students regarding these topics are (Novak, 1993; Simpson, 1988; Novak, 1984; Ausubel, 1968; Strauss, 1981; Gilbert, 1977; Bahar, 1999; Griffiths, 1994; Gamelt, 1995; Novick and Nussbaum, 1978; Novick and Mannis, 1976; Wheeler and Kass, 1978; Hesse and Anderson, 1992; Kadayifci, et. all., 2000; Calik and Ayas, 2005; Ayas, and Costu, 2001; Ayas, and Demirbas, 1997; Zoller, 1990). Misconceptions are described in many studies as very difficult to overcome as they are resistant to many teaching methodologies applied in courses (Gilbert, 1977; Bahar, 1999; Johnstone, 1980).

Determination of the misconceptions is very important in terms of choosing correct teaching methodologies and tools as well as preparing an effective curriculum. According to learning psychologists, the most important factor in the conceptual learning of an individual is what s/he already knows. Therefore, misconceptions and determination of misconceptions are important for teaching (Kadayifci, et. all., 2000). The main reasons of misconceptions could be listed as the student, the teacher and course books (Chi, 1992). According to the Committee on Undergraduate Science Education (http://www.nap.edu/readingroom/books/str/4.html), misconceptions may also be categorized into these five groups. Preconceived notions are popular conceptions rooted in everyday experiences. Nonscientific beliefs include views learned by students from sources other than scientific education, such as religious or mythical teaching. Conceptual misunderstandings develop when students are taught scientific information in a way that does not challenge them to confront paradoxes and conflicts resulting from their own preconceived notions and

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nonscientific beliefs. Vernacular misconceptions arise from the use of words that mean one thing in everyday life and something else in scientific contexts. Factual misconceptions are falsities often learned at an early age that remain unchallenged into adulthood (http://www.nap.edu/readingroom/books/str/4.html).

This study has taken "salts" as an interdisciplinary topic, which is closely related to science especially to physics, chemistry and biology, and will discuss the misconceptions determined regarding this topic. The science education literature contains a number of studies about students' misconceptions in high school science courses. Many chemistry studies have dealt with students' comprehension of atom and atomic structure (Tsaparlis, 1997; Nakiboglu, 2003), the particulate nature of matter (Novick, 1978), bonding (Peterson, 1989; Taber, 1994; Nicoll, 2001), stochiometry (Huddle, 1996), chemical equilibrium (Hackling, 1985), and electrochemistry (Ozkaya, 2002). However, few studies have examined students' understanding and identified misconceptions of nuclear chemistry concepts (Nakiboglu, 2006). The literature research showed no existence of a direct study on salts, however, many studies were found on misconceptions related to 'acid-bases'', which would contribute to the approach to the topic (Cros and Maurin, 1986; Banerjee, 1991; Ross and Munby, 1991; Bradley and Mosimege, 1998). In another study on neutralization (Schmidt, 1991), when students were asked about the neutralization reaction, they responded that a salt solution appeared in neutralization and this was no-way-back reaction. There are a number of methods used for the determination of misconceptions. In many national and international studies regarding the topic (Helm, 1980; Osborne and Wittrock, 1983; Boeha, 1990; Trumper, 1996), it was observed that various assessment and evaluation tools were used in order to report and explain the misconceptions of the students "Salts" as a topic, the misconceptions regarding which are currently focused in the study, is one of the most important topics of chemistry. In fact, there is no theme or unit called "salts" in neither high school programs nor university chemistry course books. However, when explaining nonmetals, semimetals and metals on the periodical table, salts are indirectly talked about within the chemical reactions. The most detailed information regarding salts takes place within the topic of acids and bases. Therefore, students have difficulties in uniting and relating the knowledge they attain about salts in different places and times.

## 1. Subjects

A total of 121 students, who were aged between 18 and 23 and had studied the basic chemistry course at Universities in Turkey, participated in the study.

## 2. The Purpose of the Study

An effective chemistry lesson could be constructed on teaching of the stimulants that would aid students in establishing correct schemes in their minds. If students were not able to establish correct schemes in their minds, necessary precautions should be taken to determine and overcome these misconceptions. Many recent studies have focused on the valid and reliable assessment, sources of these false assumptions called misconceptions. Therefore, by examining how the topics involving salts were directly or indirectly presented in the chemistry course books, it was aimed to determine the misconceptions in students related to salts with the help of the problems occurred during the teaching of salts. Basic questions on salts were asked to students in order to determine the meaning they attached to the concept of salt and their knowledge regarding salts.

## 3. Instrument Development

The path traced in determining the questions to assess the misconceptions regarding salts is described in this section. When preparing the items aiming to determine the misconceptions regarding salts, the high school and university level chemistry course books, which were most favored by the instructors, were made use of. Kaya (2006); Polat and Arik (2006, a and b course books are in use in various high schools in Turkey and are recommended by the chemistry teachers. In Turkey, students have to succeed in a national exam called the 'university entrance test' in order to attend universities. The books mentioned above are widely made use of in chemistry during the preparation for this exam. In universities, for both basic chemistry and analytical chemistry classes in the chemistry departments of science, engineering and education faculties, the course books mentioned below are used. For the course book choice of this study, the books that presented the topic in various ways were preferred. The questions in the study were responded by the students, who were taught using these books. These books were reviewed in terms of topics, which were directly or indirectly related to salts (Skoog, 1996; Gunduz, 1990, Haris, 1982; Butler, 1963; Mortimer, 1986; Petrucci, 2002; Atkins, 1989; Polat and Arik, 2006 a, b, Kaya, 2006). The aim was to determine the points that caused the misconceptions or learning difficulties in students. Therefore, these course books were examined before the questions were prepared in order to determine the misconceptions of students regarding salts by analyzing how salts as a topic was presented in them. The findings are listed below.

- In Skoog, West, and Holler (1996) "Salt is formed as a result of the reaction of an acid and a base". Salts could be exemplified with NaCl, $Na_2SO_4$ and $CH_3COONa$. Moreover, $HClO_4$ / $ClO_4^-$; HCl / $Cl^-$; $H_3PO_4$ / $H_2PO_4^-$; $Al(H_2O)_3^+$ / $AlOH(H_2O)_2^+$; $HC_2H_3O_2$ / $C_2H_3O_2^-$; $H_2PO_4^-$ / $HPO_4^=$; $NH_4^+$ / $NH_3$ could be listed as the examples of some common acids and conjugate bases.
- In Petrucci (2002), it was avoided to make a definition of salt within the topic of acids and bases. However, the acid and base examples, which take place in classical books, were given as acid-base examples.
- In the book called "Chemistry, Molecules, Matter and Change" by Peter Atkins and Loretta Jones (1989), there was a section called 'Salt Solutions'. Salts were not defined directly in this course book; however, there were sections under the *acidic ions* title as *"the salts of conjugated acids of weak bases form acidic liquid solutions. The salts of metal cations with small diameters and large loadings also form acidic solutions*" and under the *basic ions* title as "*salts that involve the conjugated bases of weak acids provide basic solutions*" and "*the pH level is lower than 7 in liquid solutions of salts involving acidic cations, whereas the pH level in salt solutions involving basic anions is greater than 7*". The following examples were given for some cations with acid characteristics:

| *Characteristic* | *Examples* |
|---|---|
| **ACIDIC** | |
| The conjugated acids of weak bases | $C_6H_5NH_3^+$ ; $C_5H_5NH^+$ ; $NH_4^+$ ; $CH_3NH_3^+$ |
| Small sized large loaded metal cations | $Fe^{3+}$ (in water); $Cr^{3+}$ (in water); $Al^{3+}$ (in water); $Fe^{2+}$ (in water); $Cu^{2+}$ (in water); $Ni^{2+}$ (in water) |
| **NEUTRAL** | |
| Group 1 and Group 2 Cations and metal cations | $Li^+$; $Na^+$; $K^+$; $Mg^{2+}$; $Ca^{2+}$; $Ag^+$ |

There is also a table displaying the acidic and basic characteristics of common anions.

| *Characteristic* | *Examples* |
|---|---|
| **ACIDIC** | |
| Very little amount of | $HSO_4^-$ ; $H_2PO_4^-$ |
| **NEUTRAL** | |
| The conjugated bases of strong acids | $Cl^-$; $Br^-$, $I^-$, $NO_3^-$, $ClO_4^-$ |
| **BASIC** | |
| The conjugated bases of weak acids | $F^-$ ; $O^{2-}$ ; $OH^-$ ; $S^{2-}$ ; $HS^-$ ; $CN^-$ ; $CO_3^{2-}$ ; $PO_4^{3-}$ ; $NO_2^-$ ; $CH_3COO^-$, other carboxylate ions |

In the section it was also mentioned that "*ions with small ionic radiuses but large load density and large loadings applied stronger gravity force on shared electrodes and there were some cations acting as acids in this way"* and some examples were displayed ona related table. Additionally,

- "*Group 1 and 2 metal cations and cations in other groups with +1 loadings were very weak Lewis acids and therefore and did not act as acids in water solutions*",
- "*these metal cations were so large in size not to be able to cause an important polarization on hydrated water molecules that surrounded themselves",*
- *"Because of their small loadings water molecules could not release their protons easily*" were among the important information presented.

- "A salt is a compound that is formed as a result of the combination of one base and one acid. Salts involve the cation of the base and the anion of the acid" (Mortimer, 1986). HF, HCl, HBr, HI, $H_2S$, $HNO_3$, $HNO_2$,

$HClO_4$, $HClO_3$, $HClO_2$, $HC_2H_3O_2$, $H_2SO_4$, $H_2SO_3$, $H_3PO_4$, $H_2CO_3$, $H_3BO_3$ could be listed as commonly mentioned acids.
In the acid base definition of Mortimer Arhennius, it is expressed that "The oxides of many nonmetals react with water to form acids and are called acidic oxides or acid anhydrides".

Ex: $N_2O_5(s) + H_2O \longrightarrow 2\ H^+(aq) + 2\ NO_3^-(aq)$

Additionally, it is expressed that "Many oxides of metals dissolve in water to form hydroxides; such compounds are called basic oxides".

$Na_2O(s) + H_2O \longrightarrow 2\ Na^+(aq) + 2\ OH^-(aq)$

Moreover, most important of all it is indicated that "Acidic oxides and basic oxides react to produce salts in the absence of water". Among all the analytical basic chemistry course books examined, different approaches about salts, except for the ones mentioned by Mortimer (1986) and Atkins (1989), were not observed. The ones that existed were not observed to have a unity; instead there was information on salt formations in different sections. Looking at high school chemistry course books (Polat, 2006a, b; Kaya, 2006) the following information was observed to exist regarding salts within the topic of "chemical reactions".
<u>Topics listed under the title of "Chemical Reactions"</u>

a) <u>Combustion or burning reactions:</u> The definition of combustion or burning reactions is given; there is no information on the possible formation of salt during the process.
b) <u>Synthesis reactions:</u> The definition "synthesis is purposeful execution of chemical reactions in order to get a product, or several products." is given and these examples follow:

*Examples;*
$Na(s) + ½\ Cl_2(g) \longrightarrow NaCl(s)$ There is not a statement indicating the formation of salt.
$Ca(k) + Cl_2(g) \longrightarrow CaCl_2$ "
$Na_2CO_3 + CO_2 + H_2O \longrightarrow 2\ NaHCO_3$ "
$CaO(k) + CO_2(g) \longrightarrow CaCO_3$ "

c) <u>Analysis reactions:</u> The definition "analysis reactions means the distribution of a compound into simpler substances than itself" is given and this example follows:

*Example;*
$2\ NaHCO_3(s) \longrightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l)$ There is not a statement indicating the formation of salt.

d) <u>Substitution reactions:</u> The definition "it is the substitution of an element atom in a compound with another element atom." is given and various examples follow including the activities:

*Examples;*
$Ca\ (s) + ZnCl_2(aq) \longrightarrow CaCl_2(aq) + Zn(s)$ There is not a statement indicating the formation of salt.
$½\ Cl_2(g) + NaBr(aq) \longrightarrow NaCl(aq) + ½\ Br_2(l)$ "
$NaCl(aq) + AgNO_3(aq) \longrightarrow NaNO_3(aq) + AgCl(s)$ "

<u>e) Precipitation reactions:</u> The definition "Precipitation is the formation of a solid in a solution during a chemical reaction. When the reaction occurs, the solid formed is called the precipitate, and the liquid remaining above the solid is called the supernate" is given and the following examples take place:

*Examples;*
$NaCl(aq) + AgNO_3(aq) \longrightarrow NaNO_3(g) + AgCl(s)$ There is not a statement indicating the formation of salt.
$BaCl_2(aq) + Na_2SO_4(aq) \longrightarrow BaSO_4(s) + 2NaCl(aq)$ "

<u>f) Oxidation Reduction reactions:</u> The definitions are followed by these examples:
*Examples;*

$$Fe(s) + 2\,HCl(aq) \longrightarrow FeCl_2 + H_2(g)$$
$$Cu(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + SO_2(g) + 2\,H_2O$$

g) Neutralization reactions: "In chemistry, neutralization is a chemical reaction in which an acid and a base or alkali (soluble base) reacts to produce salt and water ($H_2O$)." For the first time, there is a definition involving the concept of **SALT** and these examples follow:

$$\text{Acid} + \text{Base} \longrightarrow \text{Salt} + \text{Water}$$
$$\text{H(root)} + \text{(Metal)OH} \longrightarrow \text{Metal root} + H_2O$$

As seen above, the concept of salt takes place in high school course books only within the definition of neutralization reactions. There is such an expression that the formation of salts occurs only as a result of the reaction of a Bronsted-Lowry acid and base. However, as the above examples have illustrated, there are a lot of chemical reactions that enable the formation of salt. However, among all these chemical reactions, only the topic of acids and bases involve the concept of salt, which is an important factor causing students' misconceptions.

Later on, the conceptual difficulties and the causes of misconceptions were examined through observations within discussions. There were 4 questions in the test, which was utilized for this study. The test consisted of open ended and multiple choice questions. The open ended questions were chosen in order to control the mental process the students followed while answering the questions and determine the conceptual difficulties as well as misconceptions.

The test consisting of 4 questions is given below:

1. What is a salt?
2. Among the listed substances, choose the ones that are salts!

Table 1. The second question of the test

| **$NaCl$** | **$NH_3$** | **$NaH_2PO_4$** | **$Al_2(SO_4)_3$** | **$FeCl_3$** | **$NH_4Cl$** | **$Na_3AsO_4$** | **$CH_3COONa$** |
|---|---|---|---|---|---|---|---|
| $TlOH$ | $Ba(NO_3)_2$ | $CrCl_3$ | $H_2CO_3$ | $NaHC_2O_4$ | $ZnCl_2$ | $C_6H_5NH_2$ | |

3. Which reactions result with the substances you chose as salts above?
4. What would you say about the bonds of the substances you chose as salts above?

## 4. Results and Discussion

The 1st question was an open ended question asking the students "what is a salt?". In the light of the book review made above, these questions were evaluated and the conclusions were come to. Looking at the students' responses to the first question, the following statements are observed: *(the italic prints are taken directly from students' responses without any changes)*

1. *It is the product that occurs as a result of the reaction of acids and bases* (This response was given by 63students).

* *It is the product of a strong acid and strong base reaction,*
* *It is the product of a weak acid and weak base reaction,*
* *It is the product of a weak acid and strong base reaction,*
* *It is the product of a strong acid and weak base reaction.*

2. *It is the substance, which could separate into its ions when there is hydrolysis in water, and the anions and cations of which are formed by acids and bases.* (This response was given by 18 students).
3. *The anions or cations of salts could come from any acids or bases. These could both be strong or weak; or one of them could be weak and the other could be strong. If there is a salt coming from a weak type, its ions are hydrolyzed in water, so its pH and pOH could be calculated.* (This response was given by 12 students)
4. *"Metal salts?" I didn't understand! Mustn't there be acids or bases?*(This response was given by 19 students)
5. *9 students could not answer this question at all.*

The interesting point here is the response "*metal salts, what are they?"*. When talking about metal salts in response to this question, students take the salts among the choices such as $Al_2(SO_4)_3$, $FeCl_3$, $CrCl_3$, $ZnCl_2$. The student knows for sure that NaCl is salt. However, s/he looks at its formation from a single perspective. According to the Bronsted-Lowry definition, acid is the proton giving substance (HCl), and base is the proton taking substance (NaOH). Since it is talked about a lot in daily life (as table salt), this salt is well-known by most students. They think that the formation of NaCl could only occur through this way because of the given certain definitions as:

*"acid + base $\longrightarrow$ salt +water"*

The strange aspect of this situation is that although sodium is a metal, too, students do not have any hesitation about it and choose the substance as salt. The main affecting reason for this is that there are many examples in course books related to this salt and they learnt very early that "salt" they use everyday is NaCl. Therefore, if variable examples are given or emphasis is made on the fact that the formation of salt could occur in different ways, than students could have the chance to think, comment and relate when they see similarities. Various examples could get places in their minds through this way. Under such conditions, it is inevitable for the students to have misconceptions about "salt"; because, in their course books, salt is expressed to be formed by Bronsted and Lowry acid-bases. This stems from the usual definitions of salt in course books, lack of classification or reminders of past knowledge when salt is talked about within the topic of acids and bases, and within the types of chemical reactions topic, the expression of salt taking place only under the title of neutralization reactions. When salt is taught within the topic of acids and bases, if there were reminders and examples about the past knowledge regarding the formation of salt, this would both enable the relation of the topic to the schemes in students' minds and lead to a multidimensional perspective towards the topic.

***2<sup>nd</sup> Question***: Among the listed substances, choose the ones that are salts!

Table 2. The frequencies of the answers given to second question

| | **NaCl** | **$NH_3$** | **$NaH_2PO_4$** | **$Al_2(SO_4)_3$** | **$FeCl_3$** | **$NH_4Cl$** | **$Na_3AsO_4$** | **$CH_3COONa$** |
|---|---|---|---|---|---|---|---|---|
| **Frequency** | 121 | - | 27 | 105 | 63 | 117 | 78 | 121 |
| | TlOH | $Ba(NO_3)_2$ | $CrCl_3$ | $H_2CO_3$ | $NaHC_2O_4$ | $ZnCl_2$ | $C_6H_5NH_2$ | |
| **Frequency** | 5 | 104 | 72 | - | 95 | 73 | 76 | |

Looking at the table above, it is observed that all of the students know that NaCl and $CH_3COONa$ are salts as well as $NH_3$ and $H_2CO_3$ are not salts. The consideration of TlOH and $C_6H_5NH_2$ as salts is also very interesting. Regarding TlOH, only 5 students noticed that this substance was salt. The reason for TlOH, which is one of the strong bases, was chosen as salt is the limitedness of the examples on course books, and chosen substances by the teachers during lessons and Students know that NaOH, KOH is a strong base quite well. They also know that the group 1A hydroxides have strong basic characteristics. In solving problems or giving examples about strong bases, TlOH is not a common type to be used. By giving examples related to sodium and potassium hydroxides in the group and and leaving the generalizations to the students, teacher might have aimed to develop their critical thinking abilities. This either created some amount of misconceptions in students who prefer to memorize in stead of meaningful learning and critical thinking or students did not know anything about this component and they answered by chance. Similarly, among the organic acids, $CH_3COOH$ and $H_2C_2O_4$, and among the bases $NH_3$, are so frequently used in the examples of the course books, $C_6H_5NH_2$ (aniline) did not seem familiar to the students. Considering the formation of salt as a product of Bronsted-Lowry acid bases, it is interesting to see what students wrote about Question 3, where students took aniline as salt. There are serious problems regarding the determination of others. In other words, if the salt is one of the salts that are formed by a Bronsted Lowry acid base, students do not have any problems for its determination. When they find a suitable acid and base, they can easily write the salt formed by them. However; if the formation of salt is through different ways, they either do not prefer to write it because it is difficult or they do not know it. If the variety of the substances used in the examples or during the lesson is limited, then the problem occurs.

**3rd Question:** Which reactions result with the substances you chose as salts above?

***Students' responses:***

**NaCl**

$NaOH + HCl \longrightarrow NaCl + H_2O$ (98% of the students who chose NaCl as salt suggested this reaction).

The 98% of the students wrote the above mentioned reaction for NaCl formation and did not consider that NaCl could be formed through another way. Among the students, 2% also suggested for the formation of NaCl.

$Na(s) + Cl_2(g) \longrightarrow NaCl\ (s)$

**$NaH_2PO_4$**

- $NaOH + H_3PO_4 \longrightarrow NaH_2PO_4 + H_2O$ (47% of the students who chose $NaH_2PO_4$as salt suggested this reaction).
- $Na^+ + H_2PO_4^- \longrightarrow NaH_2PO_4$ (14% of the students who chose $NaH_2PO_4$ as salt suggested this reaction).
- Among the students, 39% left the question unanswered.

**$Al_2(SO_4)_3$**

- $Al(OH)_3 + H_2SO_4 \longrightarrow Al_2(SO_4)_3 + H_2O$ (14% of the students who chose $(Al_2(SO_4)_3$ as salt suggested this reaction).
- $Al_2O_3 + 3H_2SO_4 \longrightarrow Al_2(SO_4)_3 + 3H_2O$ (69% of the students who chose $(Al_2(SO_4)_3$ as salt suggested this reaction).
- $Al^{3+} + 3\ SO_4^{2-} \longrightarrow Al_2(SO_4)_3$ (11% of the students who chose $(Al_2(SO_4)_3$ as salt suggested this reaction).
- Among the students, 6% left the question unanswered.

**$FeCl_3$**

- $Fe(OH)_3 + 3HCl \longrightarrow FeCl_3 + 3H_2O$ (74% of the students who chose $FeCl_3$ as salt suggested this reaction).
- $Fe^{3+} + Cl^- \longrightarrow FeCl_3$ (11% of the students who chose $FeCl_3$ as salt suggested this reaction).
- Among the students, 15% left the question unanswered.

**$NH_4Cl$**

- $NH_4^+ + Cl^- \longrightarrow NH_4Cl$ (38% of the students who chose $NH_4Cl$ as salt suggested this reaction).
- $NH_4OH + HCl \longrightarrow NH_4Cl + H_2O$ (62% of the students who chose $NH_4Cl$ as salt suggested this reaction).

**$Na_3AsO_4$**

- $3\ NaOH + H_3AsO_4 \longrightarrow Na_3AsO_4 + 3H_2O$ (28% of the students who chose $Na_3AsO_4$ as salt suggested this reaction).

- $Na^{+} + AsO_4^{3-} \longrightarrow Na_3AsO_4$ (21% of the students who chose $Na_3AsO_4$ as salt suggested this reaction).
- Among the students, 51% left the question unanswered.

**$CH_3COONa$**

- $CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$ (91% of the students who chose $CH_3COONa$ as salt suggested this reaction).
- $CH_3COO^{-} + Na^{+} \longrightarrow CH_3COONa$ (9% of the students who chose $CH_3COONa$ as salt suggested this reaction).

**TlOH**

- Very few students considered TlOH as a salt and there was not a reaction mechanism given for that.

**$Ba(NO_3)_2$**

- $Ba(OH)_2 + HNO_3 \longrightarrow BaNO_3 + H_2O$ (99% of the students who chose $BaNO_3$ as salt suggested this reaction)
- The percentage of students, who expressed that they had no idea about this question, is 1%.

**$CrCl_3$**

- $Cr(OH)_3 + 3HCl \longrightarrow CrCl_3 + 3H_2O$ (51% of the students who chose $CrCl_3$ as salt suggested this reaction)
- $Cr_2O_3 + 3HCl \longrightarrow CrCl_3 + 3H_2O$ (29% of the students who chose $CrCl_3$ as salt suggested this reaction)
- The percentage of students, who expressed that they had no idea about this question, is 20%.

**$NaHC_2O_4$**

- $NaOH + H_2C_2O_4 \longrightarrow NaHC_2O_4 + H_2O$ (81% of the students who chose $NaHC_2O_4$ as salt suggested this reaction)
- $Na^{+} + HC_2O_4^{-} \longrightarrow NaHC_2O_4$ (4% of the students who chose $NaHC_2O_4$ as salt suggested this reaction)
- The percentage of students, who expressed that they had no idea about this question, is 15%.

**$ZnCl_2$**

- $Zn^{2+} + Cl^{-} \longrightarrow ZnCl_2$ (43% of the students who chose $ZnCl_2$ as salt suggested this reaction)
- $Zn(OH)_2 + HCl \longrightarrow ZnCl_2 + H_2O$ (46% of the students who chose $ZnCl_2$ as salt suggested this reaction)
- Among the students, 11% left the question unanswered.

**$C_6H_5NH_2$**

The students that considered aniline as a salt, which were considerably high in number, suggested the following reaction. Among the students, 76 mentioned that aniline was a salt and 81% of these students suggested the following reaction:

- $C_6H_5OH + NH_3 \longrightarrow C_6H_5NH_2 + H_2O$

It must be notified that, just like in all the responses given, students tend to place an acid and a base into reaction in order to form the salt. Among the students, 19 % left the question unanswered.

**Question 4: What would you say about the bonds of the substances you chose as salts above?**

Students expressed that the salts were made of ionic bonds except for the $NH_4Cl$, $CH_3COONa$, $NaHC_2O_4$ salts and $C_6H_5NH_2$, which they considered as a salt. Their responses for the above-mentioned substances were that they were made of covalent bonds; or they were made of both covalent and ionic bonds. There were also some students, who mentioned that they were made of metallic bonds. However; the answer sought was for the question that which bond the salts were formed by? Students were expected to respond doubtlessly that they were made of ionic bonds. Since their responses regarding aniline was wrong from the beginning, the same mistake also continued.

**Ionic bonded: 59**

**Covalent bonded: 17**

**Both ionic and covalent bonded: 35**

**Metallic bonds: 10**

The responses of the students regarding salts displayed the fact that students had quite essential misconceptions. The determined misconceptions were;

1. They only use the statement "it is a substance that is formed as a result of the reaction of acids and bases". This definition is correct but not enough, because; salts are not formed only by acids and bases. As a result of such a definition, they always seek for the Bronste-Lowry acids and bases for the formation of salt. Although this was caused by definitions in the course books, it created misconceptions in students, which reveled that lessons were not organized to overcome or avoid these misconceptions.
2. In addition to their definition of salts as substances that are formed by acids and bases, they evaluate salts as substances that could only be formed by Brosted-Lowry acids and bases. There are many substances with acidic or basic characteristics that could form salts, which are not Bronsted-Lowry acids or bases. There are many substances with acidic or basic characteristics that could form salts, which are not Bronsted-Lowry acids or bases. For example;

$BF_3 + NH_3 \longrightarrow F_3B\text{-}NH_3$

$MgO \text{ (base)} + CO_2 \text{ (acid)} \longrightarrow MgCO_3$

$CaO \text{ (base)} + SiO_2 \text{ (acid)} \longrightarrow CaSiO_3$

For example; Potassium permanganate is the inorganic a water soluble salt. Potassium permanganate is manufactured on a large scale from manganese dioxide. The mineral pyrolusite is fused with potassium hydroxide and heated in air or with potassium nitrate.

$2MnO_2 + 2KOH + 3/2\ O_2 \longrightarrow 2\ KMnO_4 + H_2O$

3. If there is an organic compound in the anion or cation that forms the salt, students were observed to have misconceptions regarding the bond of the salt. They consider the bonds of the organic compound within the basic formation of the salt and this shows that they are having misconceptions about the bonds of the salts.

## 5. Recommendation for Instruction

Because of the reasons mentioned above, although salts are taught under the title of acids and bases, the following introduction would contribute to its learning.
Therefore, this study suggests the following introduction.

***Definition:* "***Salts are electrically neutral substances formed by cation and anion. Among these cation and anions, $H^+$ and $OH^-$ are exceptions,,. The bonds between these ions are ionic bonds. All compounds with this type of bonds are salts without any exception. Salts could 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 nonmetals or their oxides.*

*Organic salts, however, are compounds that are formed from at least one anion and one cation. Their anions are organic acid based ($H_2C_2O_4$, $CH_3COOH$ such as).*

*The formation reactions of salts could generally be given as follows (Salts are formed by a chemical reaction between):*

1) *Neutralization reactions:* "A base and an acid"

$$\text{Acid + Base} \longrightarrow \text{Salt + Water}$$

2) *Formation from its Elements Reactions (Synthesis):*

$$\text{Metal + Nonmetal} \longrightarrow \text{Salt}$$

3) *Reactions of Metals with Acids (Redox):*

$$\text{Metal(active) + Acid} \longrightarrow \text{Salt} + H_2\text{ (g)}$$

4) *Reactions of Metal Oxides (basic anhydride) with Acids:*

$$\text{Metal oxide (basic anhydride) + Acid} \longrightarrow \text{Salt + Water}$$

5) *Reactions of Nonmetal Oxides (acid anhydride) with base:*

$$\text{Nonmetal oxide (acid anhydride) + Base} \longrightarrow \text{Salt + Water}$$

6) *The reaction of one salt with another. Salts can also form if solutions of different salts are mixed, their ions recombine, and the new salt is insoluble and precipitates.*

$$\text{Salt solution (A) + Salt solution (B)} \longrightarrow \text{Salt solution (C) + Salt solution (D)}$$

7) *Some decomposition reactions form salt.*
8) *Substitution reactions (considering the activities)*

$$\text{Metal + Salt solution} \longrightarrow \text{Salt + Metal}$$

$$\text{Nonmetal + Salt solution} \longrightarrow \text{Salt + Nonmetal}$$

This type of presentation would enable the students to observe many ways of formation at single sight and not to fall into the misconceptions as in the second question. That is, they would notice that salts were not the types that could only be formed by the reactions of Bronsted Lowry acid bases as they imagined in their minds, but could also be formed through different ways. Although there was not a variety of examples, since the topic is unified, students would be able to evaluate and distinguish between the types of examples they could come across. The chosen examples, though, are taught indirectly to students in the chosen books under various topic titles. Since there was not a significant title for salts, students could assume that these substances could also be salts and have misconceptions.

- The definition of salts should not be given only within the topic of acids and bases. Salts should be saved from the implication that they are substances that are formed by only Brosted-Lowry acids and bases. The above-suggested introduction should be made.
- When giving examples for salts, substances other than commonly known salts such as NaCl, $NH_4Cl$, $CH_3COONa$ should be listed in order to provide the variety of examples. As in this study, talking about different types of salts would enable the students to think through a wider scope and in a detailed way despite it is within the topic of acids and bases.
- Students should be provided with the chance to identify the salts, which are formed as a result of various salt formation experiments through different ways in laboratories. For example, the formation of NaCl should be made in different ways and it should be proven together with the students that no matter what the used way is, the formation results with the same substance.

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