Revista ARACÊ
ISSN: 2358-2472

ACIDS, BASES AND STRONG ACID-BASE NEUTRALIZATION REACTIONS: ANALYSIS OF TEACHING, HISTORY AND CONCEPTS

https://doi.org/10.56238/arev6n4-291

Submitted on: 11/18/2024 **Publication date:** 12/18/2024

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ABSTRACT

This article addressed aspects of teaching, research, history and concepts of acid-base theories and strong acid-base neutralization reactions with the objective of synthesizing and comparing such topics in two historical scenarios: before and after the twentieth century. Thus, the importance of the successive collaboration of the various authors for the strengthening of these concepts was evidenced and how they influenced the investigation, understanding and teacher explanation of various phenomena in the areas of chemistry and biology. Neutralization reactions in an unconventional approach, based on kinetic aspects, were also highlighted, highlighting the understanding of the important balance of autoprotolysis of water in the study of this phenomenon.

Keywords: Acid. Base. Neutralization Reactions.

INTRODUCTION

The acid-base phenomenon was identified a long time ago. Since then, scientists have developed theoretical concepts that seek to clarify this behavior. These theories attempt to define what constitutes an acid and a base, as well as explain how they interact, as well as address other secondary aspects. The intriguing thing is that, according to some current theories, most of the known substances exhibit this behavior, making this topic both interesting and essential for the study of chemistry (CHAGAS, 1998).

A notable example of the antiquity of these concepts is the Egyptian civilization, which mastered the techniques of alcoholic and acetic fermentation, resulting in the production of alcohol and vinegar. However, our original understanding of the concept of acid was conceived by the Greeks, relating it to taste. The word "acid" finds its root in the Greek word "oxein", which later influenced the Latin verb "acere", denoting the quality "sour" and thus originated the term "acetic acid". As for the expression "alkaline", it has its origin in the Arabic word "al qaly", which referred to the "ashes of plants". This term gained relevance in the Middle Ages, when potassium was obtained from ash, although there were also other natural sources for obtaining alkalis. Nowadays, it is understood that the designations "alkaline" and "basic" for a substance are considered synonymous. The concept of "base" was formalized in the eighteenth century with the introduction of the use of indicators in titling procedures (MAAR, 1999).

From remote times to the present day, concepts have taken on various forms, the result of the most diverse scientific observations and technological evolutions experienced by dozens of scholars. Many of these concepts have been forgotten, others have been coalesced into single definitions, and a few have gained eternity and are applied.

Acidic and basic compounds form the reactants of an important class of reactions for chemistry and biology: neutralization reactions. This type of reaction usually involves the formation of salt and water, with a tendency to neutralize the reactive medium. That is why they receive this name (HARRIS, 2008).

Neutralization reactions are often exothermic, releasing heat as a result of the formation of water. They are widely used in various applications, from acidic water treatment to the production of medicines and food. In addition, they are crucial for regulating pH in biological systems, such as the human body, maintaining ideal conditions for chemical reactions and metabolic processes (WRIGHT, 2007).

Although the terms acid and base are widely known, many students and professionals in the field do not understand their actual definition and how they react to each other, as chemistry education is often perceived as a collection of abstract theories, encouraging memorization of knowledge rather than highlighting the fundamental reason for learning.

In view of the above, this article addressed historical and conceptual aspects of the main contributions throughout history, with the aim of enriching the academic debate and making a synthesis of these approaches. For this, the acid-base theories were discussed in two scenarios: prior to the twentieth century and from the twentieth century onwards, also addressing the strong acid-strong base neutralization reaction, highlighting the kinetic aspects involved and, finally, a comparison between the approaches of the two scenarios.

METHOD

For the elaboration of this work, a literature review of the Narrative type was carried out. According to Ribeiro (2014), the narrative or traditional revision makes it possible to compile information from various sources and present it to the reader in a comprehensive way, without the obligation to explain in detail the criteria by which the works were selected and evaluated.

According to the instructions of Souza et al. (2018), it is possible to associate the narrative review with six distinct stages: 1) the delimitation of the theme; 2) research in the literature; 3) selection of sources; 4) comprehensive reading; 5) elaboration of the text; and 6) compilation of references.

For the narrative review, a selection of articles was made from the websites of the following journals in the field of chemistry or related: Royal Society of Chemistry (Discussions of the Faraday Society and Quarterly Reviews, Chemical Society); Semantic Scholar; Elsevier; SciELO Mexico; ResearchGate National Library of Medicine; Revistes Catalanes amb Accés Obert; Wiley Online Library.

The criteria for selecting the articles were: dissertation on acid and base in historical contexts; to discuss comparisons of acid-base theories; dissertation on strong acid-base neutralization reactions and dissertation on the teaching of these topics. A first screening of fifteen articles was carried out and only the most comprehensive were chosen and cited in the study.

In addition to the articles, renowned books widely used in the academic field in the field of chemistry that address acid-base theories and neutralization reactions were selected.

DEVELOPMENT

ACID-BASE THEORIES PRIOR TO THE TWENTIETH CENTURY

Throughout the Middle Ages, numerous alchemists were involved in the manipulation of corrosive substances known as "aguas acudas," as defined in the terminology of the time, as well as alkaline substances such as alkalis. In the twelfth century, two notable Arab alchemists stood out. The first of these was Abu Bakr Muhammad ibn Zakariyya Razi, who devoted himself to the handling of the "sharp waters," although these were not necessarily of acid origin. Razi possibly came close to obtaining hydrochloric acid in his recipe called "On the Sublimation of Ammonia Salt" (MAAR, 1999).

The second prominent alchemist is Abu Musa Jabir ibn Hayyan, although there is controversy regarding his existence due to the large number of works attributed to him, known as the "Jabirian corpus." However, regardless of the uncertainties, his contributions to the understanding of Arabic alchemy are invaluable.

Within the works of Jabir ibn Hayyan, there are methods of treating metals using these "acute waters," which probably resulted from the distillation of various substances, including the production of acetic acid from vinegar. There is even a supposed recipe for the production of nitric acid in his work "The Ark of Knowledge." However, it is more plausible that his theories served as a source of inspiration for Geber, his Latinized namesake, who, already in medieval Europe, developed mineral acids based on his concepts (MAAR, 1999).

Alchemists played a crucial role in the evolution of techniques that would later become fundamental to modern chemistry. While the Arab alchemists possessed knowledge about the production of milder acids and corrosive salt solutions, the European alchemists took a major step forward in creating higher potency acids. Among these innovations, the invention of substances such as "aqua fortis" or "nitro spirit" (nitric acid), "salt spirit" (hydrochloric acid), "vitriol spirit" (sulfuric acid) and its highly concentrated form, "vitriol oil" deserve to be highlighted. In addition, these alchemists developed a substance known as "aqua regia," a combination of hydrochloric and nitric acids, which has been shown to be extremely reactive and corrosive (BAENSAUDE, 1992).

In agreement with Porto (1997), in the seventeenth century, during the era of Iatrochemistry, the physician and chemist Van Helmont introduced an innovative theory known as the acid-alkaline theory. This theory postulated an equivalence between the processes of digestion and fermentation, suggesting that the secretions produced by the body could be classified as the products of these processes, dividing them into acidic and alkaline categories. According to this approach, Van Helmont argued that all materials should contain both acidic and alkaline elements. His main objective in developing this theory was the search for a closer integration between the fields of chemistry and physiology.

In the seventeenth century, the English chemist Robert Boyle played a crucial role in challenging the generalization of the acid-alkaline theory. Through a series of experiments and chemical and physical analyses, Boyle sought to improve the classification of substances as acidic or alkaline. During this process, he identified several substances that did not fit the established characteristics for acids and bases. Boyle named these substances as "neutral." The discovery of neutral substances profoundly questioned the validity of the previous theory that categorized all substances as acidic or alkaline. Despite this, the acid-alkaline theory continued to evolve with adaptations over the next century. Eventually, the classification methods developed by Boyle and his tests to identify acidic, basic and neutral substances became widely accepted and were adopted as the standard in most chemistry textbooks (PORTO, 1997).

Boyle, in 1664, also conducted a series of trials involving various plant extracts, including brazilwood, which was famous for its use in the coloring of tissues and for its ability to alter its coloration over time or in the presence of certain substances. Boyle recognized the usefulness of redwood extract as an indicator for identifying acidic and alkaline substances. In addition, he used litmus and violet extract as indicators in his investigations. Boyle's research had a notable impact on the introduction of the practice of employing plant extracts as indicators in chemical experiments. This method was widely disseminated in eighteenth-century chemistry, particularly in titration procedures (MAAR, 1999).

Later, Nicolas Lémery, within the framework of a mechanistic model, offered a microscopic interpretation of the neutralization process. He proposed that acidic particles were sharp (as they caused "stings" on the skin) and that alkaline particles were permeable. As a result, neutralization was conceived as the union of the two forms of particles, leading to the formation of substances with neutral properties (GAGLIARDI, 1986).

In 1699, Hobemberg undertook the first forays to determine the relative ratios between acids and bases. However, it was not until 1729 that Geoffroy conducted the pioneering acid-base titration. Lewis, still during the eighteenth century, stood out as the precursor when he used an indicator for the first time in a titling process (CHAGAS, 2006).

Chagas (2006) also contributes that in the eighteenth century, during this time, the studies of the French chemist Antonie Lavoisier stood out. In this context, oxygen had already been identified by chemists such as Scheele (1742–1786) and Priestley (1733–1804). Lavoisier conducted a series of experiments aimed at better understanding this gas. Based on the results of his investigations, he began to believe in the existence of an acidifying principle or an oxygen principle. Thus, in a text presented to the Academy on September 5, 1777, Lavoisier proposed that all acids were formed by combining oxygen with other elements, an idea that is no longer accepted today.

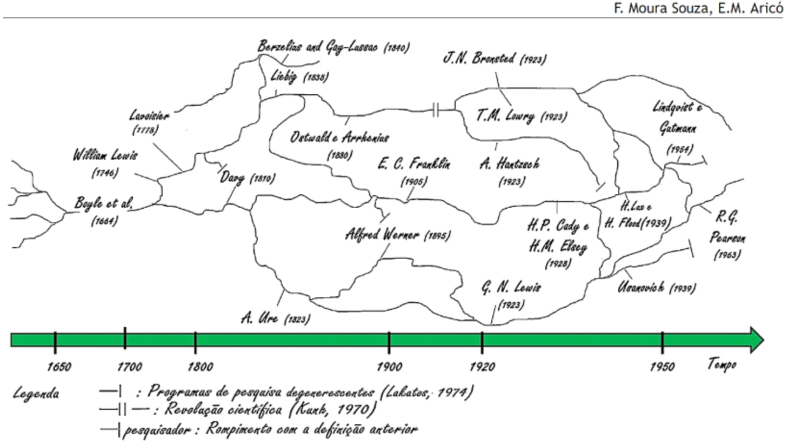
However, at that time, the association between oxygen and acidity seemed reasonable, since all known acids contained oxygen. Only later, after the research of scientists such as Davy, Gay-Lussac and Thernard, among others, was the existence of acids that did not contain oxygen recognized. The search for an acidifying principle other than oxygen led Davy to suggest that hydrogen could play this role, since it, and not oxygen, seemed to be present in all acids whose composition was known. The discovery that hydrogen and chlorine formed an acid shifted the focus from the presence of oxygen to hydrogen in the acids (CHAGAS, 2006).

In the first half of the nineteenth century, Jons Jacob Berzelius used the concept of electrochemical dualism to define acids and bases. Berzelius developed his dualistic system by assuming that in all cases a salt was a combination of an acid and a base. He and William Hisinger demonstrated that salts, in solution, could be broken down by an electric current into their bases and component acids. This concept was intrinsically linked to electrical polarity. For Berzelius, bases were electropositive oxides, while acids were electronegative oxides, that is, electropositive and electronegative substances, respectively (CHAGAS, 2006).

Berzelius concluded that acid-base reactions were fundamentally the result of electrical attractions, and he extended this idea to other types of chemical reactions. For him, his dualistic theory explained chemical interactions in terms of the neutralization of opposite electric charges (MAAR, 1999).

Figure 1 below, prepared by Souza and Aricó (2016), brings in a didactic way the chronology of the evolution of definitions from Boyle (1664).

Figure 1 – Acid-Base Chronology by authors, based on Boyle.



Source: by Souza and Aricó (2016).

Other authors reinforce the discussions already raised here. For example, Bell (1947) states that after Boyle, in the late seventeenth century, several researchers began to identify distinctive properties of acids compared to other substances. For example, in 1746, William Lewis (1708-1781) defined that the properties of acids included a sour taste and the ability to effervesce when in contact with lime. As a result, the bases were categorized with characteristics opposite to those of the acids. Based on a theory of combustion, in 1789, Antoine Laurent Lavoisier (1743-1794) stated that "oxygen is the acidifying principle", that is, that acidic substances should contain oxygen in their molecular structure.

A notable aspect of Lavoisier's description is that, two years before his statement, Claude Louis Berthollet (1748-1822), in 1787, had already identified several acids that did not contain oxygen, such as hydrogen cyanide and hydrogen sulfide (Jensen, 1980). Surprisingly, Lavoisier's definition received support from Jöns Jacob Berzelius (1779-1848) and Joseph Louis Gay-Lussac (1778-1850) until 1840, despite the existence of several studies on acids that did not contain oxygen published in this period. This episode illustrates how science is often influenced by political considerations and how famous scientists can sustain theories that later turn out to be incorrect (MARTINS, 2006).

Humphry Davy (1778-1829) also described several acids that did not contain oxygen in 1810 (CHAGAS, 2000). Before he even identified these acids, he questioned the belief that chlorine contained oxygen simply because it was an acid. He also stated that acidity was not linked to any specific elementary substance, but rather to the peculiar configuration of various substances (BELL, 1947).

CHAGAS (1998) elaborates that in 1983 Andrew Ure (1778-1857) stated: "... There is no fundamental acidifying element, nor an absolute criterion for the strength scale between different acids... acidity and alkalinity depend more on the way the components are combined than on the nature of the components themselves." It should be noted that this statement corroborates a well-accepted definition for acids and bases, proposed by Lewis and Usanovich.

Jensen (1980) notes that Justus von Liebig (1803-1873), in 1838, expressed that the categorization of acids as substances that harbor hydrogen was in line with the behavior of organic acids and characterized acids as "... substances that include hydrogen, in which hydrogen has the ability to be replaced by metals...".

In the period between the 1880s and 1890s, the research conducted by F. W. Ostwald and S. A. Arrhenius in the field of electrolytic dissociation brought to light reflections of great importance. These considerations emphasized that only chemicals with the ability to generate hydrogen ions in aqueous solutions can confer acidic properties to these solutions. In addition, these investigations introduced the concept of the dissociation constant as a parameter that quantifies the intensity of acidity (Arrhenius, Caldwell, and would, 2008). Keeping in this context, the definition of acids proposed by S. A. Arrhenius, who delimited the term "acid" to substances that release hydrogen ions in aqueous solutions, deserves to be highlighted (JENSEN, 1980).

However, in 1895, Alfred Werner (1866-1919), a prominent figure in the field of coordination chemistry, challenged the definition of acids and bases outlined by S. A. Arrhenius, criticizing the views of Arrhenius and J. V. Liebig (JENSEN, 1980).

Despite Werner's objections, the definition of acids formulated by S. A. Arrhenius continues to be taught and widely accepted in chemistry textbooks. It is important to emphasize that, to this day, most chemistry textbooks for high school present this definition without delving into the limitations inherent to its application (CHAGAS, 2000).

Thus, with the work on electrolytic dissociation by Ostwald and Arrhenius, important doors were opened for new research and discussions on the concepts of acid-base and its reactions. These new and important ideas in the field of chemistry and biology extended into the twentieth century.

ACID-BASE THEORIES FROM THE TWENTIETH CENTURY ONWARDS

The first theory to be considered is Arrhenius' theory (from 1887), which emerged as a component of the Electrolytic Dissociation Theory. This theory encompasses a vast set of previously recognized events and paved the way for the emergence of various spheres of research (CHAGAS, 1998).

According to Arrhenius' perspective, an acid is a substance that, when dissolved in water, generates H+ ions, while a base is a substance that, in an aqueous solution, produces OH- ions. Neutralization, in turn, is the chemical process that occurs when these two species react, resulting in the formation of water (CHAGAS, 1998).

Arrhenius' theory, which posits the reaction between H+ and OH- to produce H2O, encompassed a wide range of phenomena and facilitated the development of various directions of research. This includes obtaining Ostwald's Dilution Law, formulating Nernst's Equation, which establishes the connection between the electromotive force and H+ and OH- ions, understanding the buffer effect, and introducing Soren's pH concept for the analysis of aqueous solutions. Despite the great usefulness of Arrhenius' theory, it has limitations in its application to solid systems and does not address analogous reactions that occur in non-aqueous solvents (PINHEIRO et al., 2016).

In 1905, Edward Curtis Franklin (1862-1937) proposed an alternative definition for acids and bases, challenging the theory of S. A. Arrhenius. This approach, known as acid and base solvent systems, adopted a more flexible and relative perspective, contrasting with the prevailing definitions of the time (PINHEIRO et al., 2016).

E.C. Franklin formulated a theory in which he considered the possibility of ammonia undergoing autoionization, producing NH+ and NH-. He suggested that these species would have an acidic and basic nature, respectively, and that the reaction between them would be similar to the reaction between H+ and OH-. According to this theory, a neutralization reaction between the NH+ and NH- species, as exemplified by the NH4Cl + NaNH2 -> NaCl + 2NH3 reaction, would result in the formation of ammonia (CHAGAS, 1998).

According to E. C. Franklin's definition of acids and bases, an acid is any substance that increases the concentration of the solvent's characteristic cation, while a base is one that increases the concentration of the solvent's characteristic anion. Neutralization, in this context, is the process of solvent formation from the interaction of these cations and anions. This definition received later support from Hamilton Perkins Cady (1874-1943) and Howard McKee Elsey (1891-1982) in 1928, with minimal modifications (JENSEN, 1980).

The year 1923 was notable for a growing interest among scientists in the definition of acids and bases, leading to the presentation of four independent definitions in a short time. The researchers involved in this debate were J. N. Bronsted, T. M. Lowry, G. N. Lewis and Arthur Rudolf Hantzsch (1857-1935) (JENSEN, 1980).

In 1923, both Bronsted in Copenhagen and J.M. Lowry in Cambridge independently introduced a new perspective on the characterization of acids and bases. They postulated that an acid is a chemical species that acts as a proton donor (H+), while a base is one that acts as a proton receptor. It is crucial to note that, under this theory, solvents, such as water, are considered reactive agents and have the ability to perform functions both as acids and bases. Substances that can manifest this duality, acting in some cases as a base and in others as acid, are identified as amphiprotic (PINHEIRO et al., 2016).

T. M. Lowry, a British scientist, shared his research in the Journal of Society of Chemical Industry, under the title "The uniqueness of hydrogen", with the aim of establishing connections between the variety of characteristics of hydrogen (JENSEN, 2016).

The scientist from Denmark, J. N. Brönsted, shared the results of his investigations in an article entitled "Observations around the concept of acids and bases" published in the journal Recueil des Travaux Chimiques des Pays-Bas. In that publication, he identified the limitations in the definition proposed by S. A. Arrhenius and offered recommendations for resolving the discrepancies among the researchers. Brönsted expressed his disagreement with the idea that acid or base depends on the characteristics of the solvents present in the reaction. This event was recorded in his scientific work (ARICÓ and SOUZA, 2016).

J. N. Brönsted played a prominent role in formulating the concepts of conjugate bases and conjugated acids in chemical reactions, while the definition of acid or base based on proton donation or acceptance is attributed to the publications of Lowry, who also recognized the contribution of other researchers (JENSEN, 2016).

A less recognized scientist in modern times is A. R. Hantzsch, of German nationality. He developed a definition of pseudo-acids based on several experimental results, which led to him being cited by other researchers. However, its interpretations and terminology have been questioned by several authors (BELL, 1947).

In the same year of 1923, Gilbert Lewis, as a result of his theory of the electron pair, presented an innovative approach to the definition of acid-base. According to Lewis, an acid is any chemical entity capable of receiving a pair of electrons, while a base is the one that donates this pair of electrons. All the reactions mentioned above can be interpreted as acid-base reactions according to Lewis' perspective, but his concept also encompasses other chemical substances that do not fit the previous definitions of acids and bases (PINHEIRO et al., 2016).

Also according to Pinheiro et al. (2016), Lewis revised the concept of acid-base by developing macroscopic criteria that characterize this behavior, encompassing: 1. The rapid occurrence of the neutralization reaction between an acid and a base; 2. The ability of an acid (or base) to displace a weaker acid (or base) from its compounds; 3. The possibility of titration between acids and bases by means of indicators; 4. The ability of acids and bases to serve as catalysts in chemical reactions.

G. N. Lewis, published the book "Valence and the structure of atoms and molecules." In this work, he explores several alternatives to define acids and bases, presenting arguments for and against different approaches, until he arrives at the widely accepted definition today. In the book's preface, Lewis clarifies to readers that the work is the result of a collaboration between several scientists in his laboratory, where he played the role of editor of the group (HILDEBRAND, 1958).

In 1928, H. P. Cady and H. M. Elsey presented a new conception of acids and bases, taking into account the anions and cations present in specific solvents. It is important to note that this definition was not pioneering, as it expanded the concept of solvent systems previously introduced by E. C. Franklin. Therefore, in chronological terms, his contributions came after those of E. C. Franklin, although his definitions have not been widely adopted internationally.

In 1939, there was a further broadening of the definitions of acids and bases, under the heading of "solvent systems", influenced by the proton approach. In this context, Hermann Lux (1904-1999) and Hakon Flood (1905-2001) presented a perspective that extended the systems of definition of acids and bases. However, in the definition proposed by H. Lux and H. Flood, the transferred entity is not the proton, but rather the O2− anion.

According to them, an acid is one that receives the O2- oxide anion, while a base is one that donates this anion (FLOOD AND FORLAND, 1947).

Pinheiro et al. (2016) explain the approach proposed by Lux and Flood in 1939. According to this approach, acids are substances that receive O2-, while bases are species that donate O2-. This theory has proven to be especially useful in describing reactions involving ionic liquids, such as molten salts and oxides, present in metallurgical processes, in the manufacture of glass and ceramics, as well as in geochemical systems.

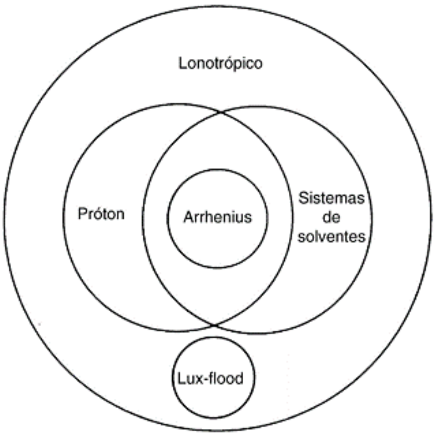
Around the same time, Usanovich (1894-1981) presented a theory intended to encompass all the theories discussed earlier. He defined acid as a substance that, when reacting with a base, leads to the formation of salts, being able to donate cations, accept anions or electrons. Base, in turn, was described as a substance that, when reacting with an acid, also results in the formation of salts, being able to donate anions, electrons or combine with cations. However, this theory had a limited impact on the generation of subsequent research (ARICÓ and SOUZA, 2016).

Another theory that had a minimal influence on research was the Ionotropic theory, proposed by Lindqvst and Gutmann in 1954. His objective was to generalize the protonic theories, solvent systems and Lux (CHAGAS, 1998).

In 1963, Ralph G. Pearson (1919-1987) presented his theory of hard and soft acids and bases, which further expanded the understanding of Lewis's concepts of acids and bases, especially in the context of metal complexes. His theory was heavily influenced by notable scientists such as Alfred Werner, G. N. Lewis, F. I. Lindqvist, and several other researchers. This theory has contributed significantly to the field of coordination chemistry, deepening the understanding of principles related to acids and bases (ARICÓ and SOUZA, 2016).

ARICÓ and SOUZA (2016) also state that Jensen (1980), in his book, employed a Venn scheme to illustrate the interconnection of the various ionic conceptions related to acids and bases, as exemplified in Figure 2 below. This graphic representation is often adopted in chemistry teaching materials intended for high school.

Figure 2 – Venn diagram illustrating the interrelationship of acid-base definitions (adapted).



Source: by Souza and Aricó (2016).

Souza and Aricó (2016) argue that although it works as an effective tool to represent the progression of definitions as chemical knowledge develops, the diagram can inadvertently induce alternative conceptions that result in conceptual errors on the part of students. This is due to the underlying assumption in the diagram that every Arrhenius acid is also a Brönsted–Lowry acid, since this relationship is termed the "proton definition" in the diagram. However, this assumption is incorrect, since not all Arrhenius acids are Brönsted-Lowry acids. For example, consider the following reaction system: NH3(g) + H2O(l) → NH4+(aq) + OH^-(aq). According to Arrhenius' definition, the H2O molecule is considered a base, as it releases OH^- in aqueous solution. However, under the Brönsted-Lowry definition, the H2O molecule is an acid, as it donates protons. Therefore, these authors argue that it is crucial for chemistry teachers to address this complexity in the classroom to clarify the limitations of a scientific theory, which is not immediately evident when examining the Venn diagram proposed by Jensen (1980).

STRONG ACID AND BASE NEUTRALIZATION REACTIONS

In Arrhenius's theory of aqueous solutions, an acid is a substance that increases the concentration of the hydronium ion when dissociated in water. A base, on the other hand, is a substance that increases the concentration of the hydroxyl ion $((H_3O^+)OH^-)$ when dissociated in water (HARRIS, 2008). For the sake of simplification, the ion will be written as $(H_3O^+)H^+$, hydrated hydrogen ion.

Strong acids are those that dissociate completely when in contact with the solvent. That is, there are virtually no undissociated molecules in solution. Strong foundations are similar (SKOOG et. al, 2006).

Strong acids and strong bases are also strong electrolytes in water. That is, aqueous solutions formed by strong acids and bases are strong electrolyte solutions.

When aqueous solutions of acids and bases are mixed, an important reaction takes place: the neutralization reaction. These are reactions between an acid and a base, usually producing salt and water. Here, the interest is focused on the reaction between a strong acid and a strong base in an aqueous medium (HARRIS, 2008).

Be a generic strong acid defined as HA and a generic strong base defined as BOH, where A and B represent their conjugated ions, respectively. A neutralization reaction can theoretically be expressed in a general way as $\mathrm{HA} + \mathrm{BOH} \leftrightarrow \mathrm{BA} + \mathrm{H_2O}$. With "BA" it represents salt. The salt formed is also a strong electrolyte (VOGEL, 1981).

Knowing that the neutralization reaction shown above occurs in an aqueous medium and that the strong acid, the strong base and the salt are totally dissociated, the equation is better represented in the form: $\mathrm{H^+} + \mathrm{A^-} + \mathrm{B^+} + \mathrm{OH^-} \leftrightarrow \mathrm{B^+} + \mathrm{A^-} + \mathrm{H_2O}$. In a simplified way: $\mathrm{H^+} + \mathrm{OH^-} \leftrightarrow \mathrm{H_2O}$(VOGEL, 1981).

The reaction shows that the essential thing in a neutralization reaction, in aqueous solution, is the formation or dissociation of water. In other words, it shows that in the union of aqueous solutions of a strong acid and a strong base, what really occurs is the disturbance of the ionic balance of water. Thus, if the concentration of the hydronium ion is greater than the concentration of the hydroxyl ion, the medium will become acidic. However, if the highest concentration is of the hydroxyl ion, the medium becomes basic. Finally, if the concentrations of these ions are equal or if the water is pure, the medium will be neutral (SKOOG et. al, 2006).$\mathrm{H^+} + \mathrm{OH^-} \leftrightarrow \mathrm{H_2O}$

As mentioned, the balance of the water formation/dissociation reaction is fundamental for neutralization, because if a titranting agent (of a basic character) is added to an acid solution, the increase in the concentration of will displace the reaction given by to the formation of at the expense of the consumption of . If the consumed, that is, removed from the medium, it produces an increase in the pH of the system.$\mathrm{OH^-}\mathrm{H^+} + \mathrm{OH^-} \leftrightarrow \mathrm{H_2O}\mathrm{H_2O}\mathrm{H^+}\mathrm{H^+}$

It is known that the species $\mathrm{H^+}$, and $\mathrm{OH^-}\mathrm{H_2O}$ will always be present in aqueous solutions, whether acidic, basic or neutral. The difference is the concentration of each species in the three types of solutions mentioned. The reaction $\mathrm{H^+} + \mathrm{OH^-} \leftrightarrow \mathrm{H_2O}$ can be rewritten in two, explaining the direct () and reverse () reactions. In these reactions,

$\mathrm{H_2O} \overset{\mathrm{k_1}}{\rightleftarrows} \mathrm{H^+} + \mathrm{OH^-}\mathrm{H^+} + \mathrm{OH^-} \overset{\mathrm{k_2}}{\rightleftarrows} \mathrm{H_2O}$k1 and k2 are the speed constants of the inverse and forward reactions, respectively.

Eigen (1954) showed that the values for k1 and k2 are, at 25ºC, equal to: $\mathrm{k_1} = 2{,}6\mathrm{x}10^{-5}\ \mathrm{s}^{-1}$ and . $\mathrm{k_2} = 1{,}5\mathrm{x}10^{8}\ \mathrm{m^3.mol^{-1}.s^{-1}}$Analyzing the values of the velocity constants, it can be seen that k1 is much smaller than k2, implying that the reaction is strongly directed towards the formation of water.$\mathrm{H^+} + \mathrm{OH^-} \leftrightarrow \mathrm{H_2O}$

This important observation regarding the speed of the neutralization reaction, shown quantitatively by Eigen (1954), has already been commented on by Lewis, as already discussed in this text.

Another interesting aspect was discussed by Tanaka (2010). The author argued that if an electric potential difference is applied to pure water, the constant k1 is increased and the constant k2 remains unchanged. In other words, the potential difference favors the ionization of water.

The strong-base acid neutralization reaction is very important in various biological system as well as in the food and pharmaceutical industry. The approach from this aspect, unlike the form usually approached in chemistry textbooks, shows the influence of kinetic aspects in the formation of this ionic equilibrium, which increases the perspective of this important phenomenon.

OBSERVATIONS ON ACID-BASE CONCEPTS PRIOR TO AND FROM THE TWENTIETH CENTURY ONWARDS

The evolution of the conceptualizations of acids and bases throughout history demonstrates that new approaches often represent an extension of the previous theory or clarify phenomena that the previous theory could not explain. These new definitions rarely conflict with previous definitions, but instead complement them. It is remarkable how a different interpretation of the concept of acids and bases in the nineteenth century has influenced research directions to the present day. This is evidenced in the historical timeline, where the ideas of A. Ure and J.V. Liebig are regarded as "enlargements" of current definitions.

Throughout history, definitions of acids and bases have often diverged. At certain times, one definition was valued to the detriment of the other, even if the latter provided a more comprehensive explanation of the phenomena studied. This highlights that the study of the evolution of acid-base definitions provides a significant opportunity to discuss with students the nature of science, especially in the context of the discipline of chemistry and its history.

However, after these historical considerations, what is evident in educational practice is the massive approach to the theories of Arrhenius, Brönsted-Lowry and Lewis. These researchers are cited naturally and their theories are defended as "the most important". This phenomenon can be understood by the spontaneous fitting that the acids and bases of Arrhenius, Brönsted-Lowry and Lewis perform in the facilitated understanding of chemical reactions, in the generalizations achieved in the organization of compounds and also in the simplicity they provide in the study of acidity and basicity of organic compounds (it is known that most of the known compounds are organic, including more than eighteen million chemical species), to the simplicity they provide to the understanding and application of the most varied physical-chemical and analytical methods, such as volumetry and methods of identification and quantification of cations and anions, without neglecting to highlight the biochemical acid-base reactions, which explain the biological processes of plants and animals.

FINAL CONSIDERATIONS

The study of acids and bases represents a fundamental pillar in chemistry, being essential to understand a wide range of chemical phenomena and their practical applications. The definitions of these concepts serve as a foundation for understanding chemical reactions, enabling the identification of substances, the prediction of behaviors, and the understanding of the products formed. This is crucial for the synthesis of compounds, the resolution of chemical problems, and the development of innovative materials, drugs, and chemicals.

The role of acids and bases extends to several fields, including biochemistry, where acid-base reactions are vital to understanding the functionality of enzymes, pH in biological systems, and metabolic processes. In addition, these concepts find application in industry, chemical analysis and environmental protection, contributing to the identification and control of pollutants. Understanding these principles is essential to the advancement of chemistry, playing a significant role in our quality of life.

In addition, neutralization reactions, involving acids and bases, play a crucial role in industrial processes, such as the production of salts and the purification of substances. In addition to their relevance in medicine, contributing to the formulation of drugs and treatments, these reactions are essential in daily practical applications, such as the treatment of water for human consumption, ensuring the absence of acidic or alkaline contaminants harmful to health. In short, understanding the behavior of acids and bases, including their neutralization reactions, is vital for chemistry education, chemical diffusion, and plays a central role in our modern society.

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