LABORATORY JARGON OF LECTURERS AND MISCONCEPTIONS OF STUDENTS

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ABSTRACT

Lecturers mostly use a "laboratory jargon" in their lectures and the question comes up whether student teachers are taking this jargon for their own terminology, or developing "school-made misconceptions", or even transfer them later into Chemistry instruction. One example: "2 hydrogen react with 1 oxygen to form 2 water" is often to hear – instead of pointing out that 2 H_2 molecules and 1 O_2 molecule are forming 2 H_2O molecules. This last statement is totally clear and the learner will develop applicable mental models. An empirical pilot study will show first results: about half of the investigated participants could reflect and correct given jargon statements – but even after three years of studying Chemistry, the other students are staying with that jargon or other alternative conceptions. *[African Journal of Chemical Education—AJCE 8(1), January 2018]*

INTRODUCTION

Chemistry experts at universities may use an incorrect terminology called “laboratory jargon”.: The expert wants to change information by short statements and he or she can be sure that the colleague will understand what it means – but the learner will be irritated and doesn’t know what is meant. Because the Broensted theory is introduced nearly in all lectures the jargon reaches also the acid-base topic. One example: “Water can be an acid or base” is a well-known jargon [1] and the expert knows that the H_2O molecule is meant. The learner knows pure water with the melting point of 0 ^oC, the boiling point of 100 ^oC, the density of 1 g/mL or the pH of 7.0. Should he/she believe that pure water may change to the pH of 5 or pH of 10? If lecturers would take the correct term according to the Broensted theory [2], the statement would be: “The H_2O molecule can react as an acid particle or as a proton donor (donor of H+ ions), with another partner it may react as a basic particle or a proton acceptor:

H_2O molecule as a *donor*: H_2O molecule + NH_3 molecule $\rightarrow$ NH_4^+ ion + OH^- ion

H_2O molecule as an *acceptor*: H_2O molecule + HCl molecule $\rightarrow$ H_3O^+ ion + Cl^- ion

We want to know how chemistry-teacher students are influenced by the laboratory jargon concerning Broensted‘s acid-base theory or if they even develop misconceptions [3]. Our hypothesis: Students after studying three years Chemistry at University of Muenster in Germany, are mostly not able to reflect or to correct statements on base of the jargon [4].

BROENSTED ACID-BASE REACTIONS AND DIDACTICAL CONCLUSION

In his essay "On the theory of the acid-base function" [5] Broensted alluded already in the title to the *function* of acid and base molecules and left out the usual discussion of the properties of acidic and alkaline solutions. In particular, he identified the function through a central mental model:

$$\begin{array}{ccccc} A & \leftrightarrows & B & + & H^+ \\ \text{acid} & & \text{base} & + & \text{proton} \end{array}$$

By donating a proton, the acid changes to a base: "The A and B molecules are called corres-ponding acids and bases. By this definition, the OH^- ion loses the special position of the bases: by losing a proton, any molecule A is transformed to a minus-charged base molecule". When HCl molecules react with NH_3 molecules, both molecules react to ions: NH_4^+ (corresponding acid to NH_3 molecule) and Cl^- (corresponding base to HCl molecule). Broensted also deals with "free H^+ ions" that do not exist in solution. He therefore states: "An acid molecule A only releases a proton when the proton is simultaneously assimilated by a base molecule":

$$\begin{array}{ccccccc} A1 & + & B2 & \rightarrow & A2 & + & B1 \\ \text{acid1} & & \text{base2} & \rightarrow & \text{acid2} & & \text{base1} \end{array}$$

All these statements show that Broensted is discussing molecules and ions – not substances! Suposing that a free proton does not exist in solution, the formulation of the hydronium ion H_3O^+ is the result:

$$\begin{array}{ccccccc} A & + & H_2O & \rightarrow & B & + & H_3O^+ \\ \text{acid1} & & \text{base2} & & \text{base1} & & \text{acid2} \end{array}$$

He furthermore states: "Whenever a proton is transferred from an electrically neutral molecule to another electrically neutral molecule, two ions of opposite charge arise". So if H_2SO_4 molecules react with H_2O molecules, in the first step H_3O^+ and HSO_4^- ions are formed. Concerning the neutralization reaction, Broensted argued: “When hydrochloric acid (H_3O^+ + Cl^-) and sodium hydroxide (Na^+ + OH^-) are mixed in aqueous solution, the formation of the salt (Na^+ + Cl^-) seems only a purely mechanical mixing process ...... the typical process of neutralization of strong acids and bases is thus not the salt formation. Instead, the actual acid-base reaction is:

$$H_3O^+ \quad + \quad OH^- \quad \rightarrow \quad H_2O \quad + \quad H_2O$$

$$\text{acid1} \qquad \text{base2} \quad \rightarrow \quad \text{base1} \qquad \text{acid2”.}$$

The famous "Chemical Triangle" (see figure 1) by Johnstone [6] shows the level of substances ("macro level"), separated from the level of the smallest particles and chemical structures ("sub-micro level"), finally goes to the level of symbols and equations ("representational level").

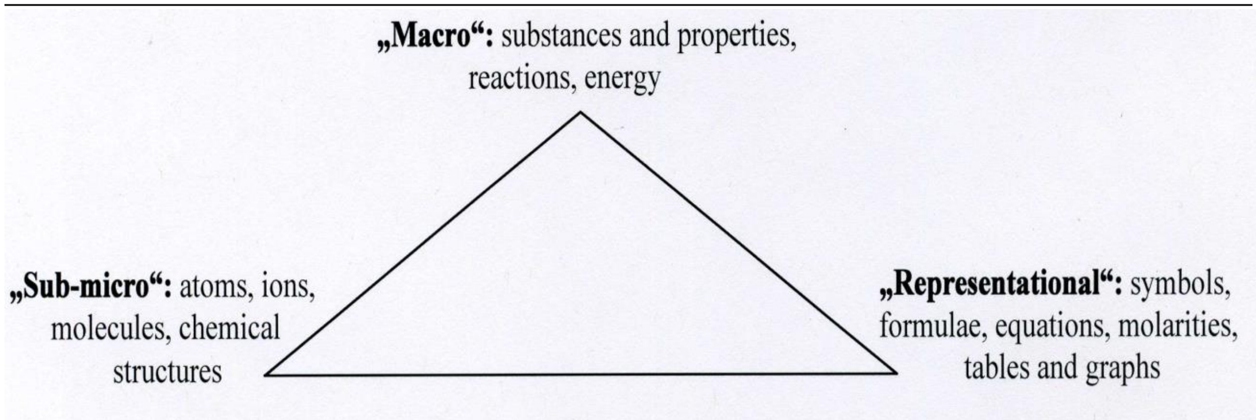

Fig. 1: "Chemical triangle" of Johnstone [6]

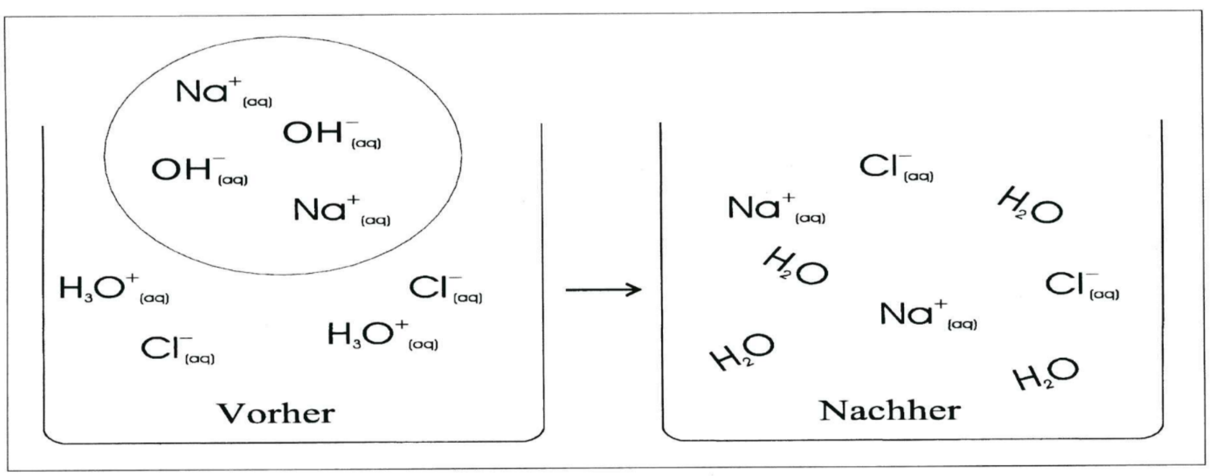

Fig. 2: Beaker model of the reaction “hydrochloric acid with sodium hydroxide solution” [7]

Students work successfully if they observe firstly substances and reactions on the macro level, then interpret those observations by looking at the involved particles and chemical structures on the sub-micro level, and in the third step express those structures by symbols like formulas and equations on the representational level. Johnstone emphasized that the direct transition from the macro level to the representational level with all formulae and equations means learning by heart and only little understanding of Chemistry. Taking the sub-micro level into account with molecular models for molecular structures and sphere packing for crystal structures, chemical understanding is fostered because students can develop applicable mental models [7].

One other way to get right ideas are special beaker models that help to understand separated ions in solutions (see figure 2). Models of diluted hydrochloric acid, sodium hydroxide solution and sodium chloride solution are shown: $H_3O^+(aq)$ ions as acid particles, and $OH^-(aq)$ ions as base particles. $Na^+(aq)$ ions and $Cl^-(aq)$ ions are not reacting – they stay as so called “spectator ions”. The (aq) symbol helps learners to deepen the idea that the charge of hydrated ions is shielded and those ions can move without much attraction in the solution.

PILOT STUDY ACCORDING LEARNER’S LABORATORY JARGON

Following our hypothesis, we created a questionnaire which should show how students work with jargon statements: they would reflect the statement and will find the correct answer? – or they will stay on jargon representing mostly incorrectly mixtures of substances and particles?

Questionnaire. We constructed 10 multiple-choice problems with a jargon statement in the beginning and the task is to mark from four possible alternatives the correct terminology on the basis of Broensted’s theory. One example [4]:

2) Lab. Jargon: "Hydrochloric acid gives off a proton"

a) Hydrochloric acid can be deprotonated.

b) Hydrochloric acid can also absorb protons.

c) $H_3O^+(aq)$ ions are present in hydrochloric acid, they can emit protons.

d) HCl molecules are present in hydrochloric acid, they release protons.

The right answer is of course (c): “$H_3O^+(aq)$ ions are present in hydrochloric acid, they can emit protons”. We took the famous misconception (d) and were waiting of “HCl molecules”. Because of the well-known idea of “deprotonation” we took alternative (a), answer (b) is a fake [4].

Realization. We have chosen a group of about 50 chemistry-teacher students which are studying at the end of their 6th semester. They have the knowledge of three years of studying Inorganic, Organic and Physical Chemistry to be a high-school teacher in their future. During one hour in a special seminar in June 2017 they marked the two-page questionnaire (see attachment).

RESULTS

Nearly in every task more than 50 % of students marked the right answer – they can successfully reflect statements in the jargon and are thinking in the scientific way of acid-base terminology. In detail there are the following differences.

In **Task 1** we offered the common statement “carbon dioxide consists of carbon and oxygen”. Statements (a) and (c) are a mix of substances and particles, (b) points out that carbon dioxide is composed of carbon and oxygen – crystals of carbon and bubbles of oxygen? The only correct answer should be “(d) the CO_2 molecule consists of one C atom and two O atoms”: 68 % of students took it, each other answer is reaching about 10 % of markings.

In **Task 2** we offered the right answer (c) which is chosen by 40 % of participants, the real misconception about “HCl molecules in hydrochloric acid” is taken by only 5 %. But answer (a) has reached the majority of 55 %: many students are thinking of scientifically good sound of “deprotonation” – but how the “substance hydrochloric acid” should be deprotonated?

In **Task 3** we offered “water dissociation”. Of course the autoprotolysis of H_2O molecules is meant – so answer (c) is the right answer, chosen by 90 % of students. In this case nearly all students have reflected the jargon statement in the right way – only a few answers were going to the other alternatives.

In **Task 4** we offered “Ammonia is a weak base”. Also in this case most students (77 %) argued in Broensted’s way: “(a) NH_3 molecules are weak bases”. The other answers are taken by only few students.

In **Task 5** we offered the famous statement “the concentration of water equals 55.5 mol/liter”. The mole idea deals with high numbers of particles – and only with that special number of particles it makes sense to state: “(b) the concentration equals 55.5 mol H_2O molecules/liter”. This answer was given by only 55 %. The other students (45 %) may think about masses in the way that “1 mol water means 18 g water” – and 1000 g of water contain 55.5 times 18 g. Answer (c) and (d) are not chosen by any participant.

In **Task 6** we offered the “dissociation of sodium hydroxide” as the jargon statement and were waiting of those students which have not the mental model of ions in solid sodium hydroxide – which may have the scientifically wrong mental model of “NaOH molecules” or “Na^+OH^- ion pairs” in their mind. And really: 62 % of students were taking “a) NaOH molecules”, 13 % the answer “c) Na^+OH^- ion pairs”. Only 22 % right answers (b) occurred, (d) was chosen by 3 %.

In **Task 7** we offered the neutralization “by substances to salt and water” and wanted the description according to Broensted’s theory (d). This answer was marked by 50 % of students. The other half of students are thinking of “(c) ion groups” by about 30 %, of “salt formation” by about 15 %, and 5 % have the mental model of “equal concentrations of acid and base”.

In **Task 8** we offered “strong and weak acids and their pH”. The right answer is of course “(c) pH values indicate concentrations of H^+ ions” – and 82 % of participants decided right. There are 9 % markings of (b) and (d) – “(a) salt formation” is not chosen: a good result.

In **Task 9** we offered “indicator papers indicate the strength of an acid”. The easiest right answer is (d): 64 % have taken this choice. The other students have marked the three other alternatives with low percentages.

In **Task 10** we offered the nice misunderstanding “water can be acid and base”. As discussed before the H_2O molecule can only be called an ampholyte – nicely 55 % of students marked (a). But also the statement “(b) water can be acid and base” is chosen by many students – with about 35 % they took the laboratory jargon without reflecting this statement. About 10 % decided “(c) H_2O is acid and base simultaneously”: we wish to do interviews with those students to know what mental model they have in their mind.

SUMMARY AND COMCLUSIONS

All in all, students have answered in the majority well: more than half of participants reflected the jargon statement in a right way and chose the right alternative. They are able to apply the Broensted theory in a successful way, they are used to think on the sub-micro level [6] and have developed applicable mental models about the structure of matter [7]. So we must reject our hypothesis: The majority of students are capable to reflect and to correct statements on the base of the laboratory jargon. The other students are showing a lack in this aspect. Either they mix substances and particles in a not acceptable way or they are thinking only of substances like “water can be an acid or base" or "concentration of water is 55.5 mol/L". We cannot decide if those students developed the wrong conception from laboratory jargon – or they are used to work mostly on the macro level and have never reflected their "mixtures of substances and particles".

This study was definitely a pilot study: Only about 50 students were involved and we did no interviews of those students who answered in a wrong way. In a following main study we will add at every question "give reasons": students have to show the reason of their marked choice. We also have to review the questionnaire and should take away those alternatives which are not marked by any participant – they make no sense for evaluation.

And we will plan structured interviews to get more knowledge of kind of misunderstanding or even kind of misconception. Also the question whether misconceptions are developed by laboratory jargon or by other teaching mistakes is not answered yet. The only way to get an answer about the last question will be to watch lectures and to observe, in which extent the lecturer is using the laboratory jargon. So for one of the next studies the investigator has to look to the lecture according acids and bases and should construct the questionnaire according to used jargon statements. If students work with a special textbook the investigator has also to look on jargon expressions which may be existing in the textbook.

In every case the mix of quantitative and qualitative methods of research should be applied and a higher number of students in seminars of universities or even of students in high grades of schools may be investigated. The work with this problem is just starting!

REFERENCES

1. Barke, H.-D., Harsch, N.: Donor-acceptor reactions – Good bye to the laboratory jargon. African Journal of Chemistry Education AJCE 6 (2016).
2. Barke, H.-D., Harsch, N.: Broensted acids and bases: they are not substances but molecules or ions. African Journal of Chemistry Education AJCE 4 (2014).

3. Barke, H.-D.: Misconceptions in Chemistry. Addressing Perceptions in Chemical Education. Heidelberg, Berlin 2006 (Springer).
4. Buechter, J.: Laboratory Jargon and resulting Misconceptions of Chemistry. First Pilot study. Bachelor thesis 2017 (University of Muenster, Germany).
5. Broensted, J.N.: New Theory concerning Acids and Bases. Report of the German Chemical Society (Berichte der Deutschen Chemischen Gesellschaft 61, 1928).
6. Johnstone, A.H.: Teaching of Chemistry – logical or psychological? CERP 1 (2000).
7. Barke, H.-D., Harsch, G., Schmid, S.: Essentials of Chemical Education. Heidelberg, Berlin 2012 (Springer).

APPENDIX: Attachment: Multiple choice questionnaire "Laboratory Jargon"

What would be the correct expression according acid-base reactions? Please check.

1. Laboratory Jargon: "Carbon dioxide consists of carbon and oxygen"
a) CO_2 consists of one C and two O.
b) Carbon dioxide consists of carbon and oxygen.
c) CO_2 consists of one carbon part and two oxygen parts.
d) The carbon dioxide molecule CO_2 consist of one C atom and two O atoms.

2) Lab. Jargon: "Hydrochloric acid gives off a proton"
a) Hydrochloric acid can be deprotonated.
b) Hydrochloric acid can also absorb protons.
c) H_3O^+(aq) ions are present in hydrochloric acid, they can emit protons.
d) HCl molecules are present in hydrochloric acid, they release protons.

3) Lab. Jargon: "Water dissociates, shows equilibrium of H^+ and OH^- ions"
a) The equilibrium of the water yields protons and hydroxide ions.
b) Water can split off both H^+ ion and OH^- ion.
c) Autoprotolysis of H_2O molecules yields H_3O^+ ions and OH^- ions.
d) Water provides protons and hydroxide ions in autoprotolysis.

4) Lab. Jargon: "Ammonia is a weak base"
a) NH_3 molecules are weak bases, they are in equilibrium with corresponding ions.
b) Ammonia solution is weakly concentrated.
c) NH_3 molecules react completely to NH_4^+ ions.
d) Ammonia forms ammonium chloride, NH_4Cl.

5) Lab. Jargon: "The concentration of water is c = 55.5 mol /L"
a) The concentration of H_2O is 55.5 mol / L.
b) The concentration is c = 55.5 mol H_2O molecules per liter.
c) Water consists of 2 mol of hydrogen and 1 mol of oxygen.

d) Water consists of 100% hydrogen and oxygen.

6) Lab. Jargon: "Sodium hydroxide dissociates by water into Na^+ ions and OH^- ions"
a) NaOH molecules dissociate by water into Na^+ ions and OH^- ions.
b) Solid NaOH consists of Na^+ and OH^- ions, in water they form $Na^+(aq)$ and $OH^-(aq)$ ions.
c) Na^+OH^- ion pairs of solid sodium hydroxide are separating into single ions.
d) In water the Na atoms and OH groups transfer electrons to form Na^+ ions and OH^- ions.

7) Lab. Jargon: "Hydrochloric acid neutralizes sodium hydroxide to water and salt"
a) Neutralization means salt formation.
b) After neutralization, equal concentrations of acid and base are present.
c) $H^+Cl^-(aq) + Na^+OH^-(aq) \rightarrow H_2O + Na^+ Cl^-(aq)$.
d) $H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow H_2O + Na^+(aq) + Cl^-(aq)$.

8) Lab. Jargon: "Strong acids have a low pH, weak acids a higher pH"
a) Strong / weak acids are strongly / weakly concentrated.
b) The pH value indicates the concentration of the acid.
c) The pH value indicates the concentration of H^+ ions.
d) Weak acids have a pH between 3 and 6.

9) Lab. Jargon: "Indicator papers indicate the strength of an acid"
a) Indicator papers indicate how strong an acid is.
b) Indicator papers show strong or weak acids.
c) Indicator papers indicate how concentrated an acid is.
d) Indicator papers can indicate whether acid or base is present.

10) Lab. Jargon: "Water is an ampholyte, it can be acid and base"
a) The H_2O molecule is an ampholyte, it can accept a proton, can give a proton.
b) Water can be both acid and base.
c) H_2O is acid and base simultaneously, molecules dissociate to H^+ and OH^- ions.
d) Water can be acidic, basic or neutral.