Conception, threshold concept, and troublesome knowledge in redox reaction

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Abstract. This study aims to analyze the conception, threshold concept, and troublesome knowledge in redox reactions. This research used a descriptive qualitative method which included analyzing several journal articles about conception and conducting interviews with five chemistry teachers to get information about threshold concepts and troublesome knowledge. Based on a journal analysis related to the conception for redox reactions, the majority of students correctly answered questions about the concept of defining oxidation numbers based on the binding and releasing of oxygen, determining reducing and oxidizing agents. Conversely, most students experienced misconceptions on the concepts of oxidation and electron transfer, such as in assuming the charge on polyatomic molecules and ions is an oxidation number, changes in ion charge and polyatomic molecules to identify the oxidation and reduction reaction species. Meanwhile, the threshold concept for redox reactions comprised of the symbol of elements, chemical formulas, nomenclature, chemical materials, the constituent particles, and electronegativity. Whereas troublesome knowledge for redox reactions included complexity in determining oxidation numbers, complexity in using definitions, and language use.

1. Introduction
In recent years, research has shown that redox reactions are one of the difficult chemical concepts for students to learn, this is because the concept of redox reactions has the characteristics of abstract concepts that lead to many conceptual errors when studying the material. More specifically, students have difficulty learning the concept of redox reactions based on electron transfer, explaining the process of releasing and receiving electrons that cannot be seen with the eye but can only be imagined. In addition, students also have difficulty using three levels of representation to describe and solve problems related to redox reactions. This happens because when studying chemistry in schools it is not accustomed to using three levels of representation. As a result, students often have difficulty connecting the three levels of representation in explaining chemical concepts so that the understanding gained by students is only limited to the surface [1].

To understand the concept of chemistry as a whole, a student must have the ability to connect the three levels of representation, namely macroscopic, submicroscopic, and symbolic. Macroscopic is a chemical representation obtained through phenomena that can be observed (seen, felt, and smelled) in real terms, such as changes in color, temperature, pH of solution and gas formation. Microscopic is a
chemical representation that explains the structure and terms of the movement of particles, such as electrons, atoms, ions, and molecules. While symbolic is a chemical representation to connect between macroscopic and submicroscopic phenomena, which includes chemical formulas, chemical symbols, chemical equations, diagrams, graphs, and mathematical calculation [2–10].

The ability of students to connect the three levels of representation reflects the mental models that students have [11]. A mental model is an illustration of a person's mental representation of an idea or concept such as a conceptual model, mental representation, mental image, mental process, difficult to observe construction, and personal cognitive representation [10,12]. For students to have a complete mental model, the teacher must apply the right learning strategies. To determine the right strategy the teacher must analyze various things related to the concept are conception, threshold concept, and troublesome knowledge.

Conception namely the application of ideas (theory, patterns, relationships) chemistry into chemical situations, skills to explain chemical idea/concepts in depth that are not just memorizing, situational knowledge for predict or explain the behavior of chemical systems, critical thinking and involve reasoning in solving problems [13]. A threshold concept is a cognitive gateway to the way of thinking in new domains that have not been previously accessible [14]. Troublesome knowledge is conceptual knowledge that has the potential to be a problem for students to understand the concept so that it becomes a major obstacle to learning a particular concept [15]. Knowledge of these concepts can help teachers to determine the right strategy, media, and teaching materials so that there is no mismatch in the learning process. The purpose of this research is to find out the conceptions of various research studies (review articles) and to see the Threshold concepts and troublesome knowledge from interviews with teachers.

2. Methods
This research uses descriptive qualitative method by analyzing articles that present research studies on conceptions in the concept of redox reactions which include models of conceptions that fit scientific concepts (true concepts) and models of conceptions that are misconceptions (wrong concepts).

The conception model that fits the scientific concept (true concept), includes the concept of defining oxidation numbers based on the binding and release of oxygen, determination of reducing and oxidizing agents [16]. Misconception conception models (incorrect concepts), including students experiencing misconceptions that assume the charge on polyatomic ions are oxidation numbers [17,18], changes in polyatomic ion and molecular ion charges can be used to identify the species of oxidation and reduction reactions [16,19], electron transfer occurs when the bond between the cation and the ion of the audience breaks / is formed [17]. In addition, this study also conducted interviews with five chemistry teachers to get information about the concept of threshold and troublesome knowledge based on their experiences during teaching.

3. Result and Discussion
3.1. Conception in a redox reaction
Students' conception of the redox reaction was identified based on several results of previous research studies. Students' conceptions are grouped into three models, namely conception models that fit scientific concepts (correct concepts), conception models that are misconceptions (wrong concepts), and conception models that are not known to be based on understanding (not understanding concepts). Based on studies from several journals, two conception models will be discussed, namely, the conception model that fits the scientific concept (the correct concept) and the conception model that is misconception (wrong concept).

In this article conception models that fit scientific concepts (true concepts) are identified from research studies conducted by Chiang, the majority of students answer questions correctly regarding the concept of the definition of oxidation numbers based on binding and release of oxygen, determination of reducing agents and oxidizers [16]. Whereas the conception model that is misconceptions (wrong concepts) is identified from the research study conducted by Brandriet and Brietz, most students
experience a misconception that considers the charge in the polyatomic ion as an oxidation number. Students are given questions that aim to distinguish between oxidation and charge numbers by identifying whether sulfur and sulfate have an oxidation number, charge, or both. The first question of first semester students experienced a misconception as much as 31.4% and second-semester students experienced misconception as much as 28.2%. Students assume that sulfur and sulfate in CuSO₄ compounds both have a charge and an oxidation number. Students answer so because these students cannot distinguish between the concept of oxidation number and charge [17]. Research conducted by Garnett and Treagust also identified that students cannot distinguish concepts of oxidation and charge numbers such as determining oxidation numbers in polyatomic molecules or ions [18]. Schmidt and Volke report that students assume changes in the charge of polyatomic and molecular ions can be used to identify specific oxidation and reduction reactions. Schmidt and Volke conducted surveys and interviews with students in Germany to determine whether students could identify acids, bases, oxidizing agents, and reducing agents in several reactions, as well as what mechanisms students used to identify reaction species. For example, reaction NO₃⁻ → NO. Nitric acid is expressed as a reducing agent. This is because students consider changes in the charge from -1 to 0 [19]. Brandriet and Bretz also found the same thing that students assumed changes in charge in polyatomic ions could be used to identify specific oxidation and reduction reactions. For example, in the CO₃²⁻ + 2H⁺ → H₂O + CO₂ reaction, students identify that the charge changes from -2 for the carbonate ion to 0 for carbon dioxide, and decides that the carbonate ion is oxidized. Garnett and Treagust, also examined misconceptions in students, namely changes in the charge of polyatomic and molecular ions to identify oxidized and reduced species. For example in the reaction of CO₃²⁻ + 2H⁺ → H₂O + CO₂. Students identify that the charge changes from -1 to 0 [17].

Another misconception in a redox reaction is that electron transfer occurs when the bond between the cation and the spectator ion breaks/ forms. Brandriet and Bretz gave two questions to see students' understanding of the electron transfer process. The first question was asked to describe which species were involved in electron transfer in the reaction of Fe(s) + CdSO₄(aq) → FeSO₄(aq) + Cd(s). The correct response is the transfer of electrons from iron to cadmium, the first semester students choose the right answer as much as 33.2% and the second-semester students choose the correct answer as much as 31.2%. The second question, students are asked to describe how the process of electron transfer occurs. Students choosing a response that experiences electron transfer is a bond between cadmium and sulfate, and the bond of iron to sulfate. The responses of students had many misconceptions with presentations for first semester students 69.7% and second-semester students as much as 68.6%. These results indicate that students are better able to identify where electrons are transferred, but cannot describe the particulate processes that underlie symbolic equations [17].

Barke et al identified students' understanding of determining the redox reaction of the phenomenon, students were given the phenomenon of a folded copper plate such as an envelope and heated on a hot fire, on the outside of the copper being black and the inside red. Black is produced from ash deposits on the outside. The student presentation answered this phenomenon including a redox reaction of 59%. Some students' opinions about this phenomenon are that black is produced due to precipitation of ash and as a result of combustion reactions. In addition, other students think that high temperatures change the color of copper atoms to black [20]. The same study was conducted by Al-Balushi et al. The percentage of students who could correctly identify whether this was a redox reaction was 55.7% [21]. Conception is a person's interpretation of a concept. Whereas a concept is not influenced by the mind of the person who receives it. So, between one student and another student may have a different conception, depending on the interpretation of each student towards the conceptions received [22]. There are 5 sources of causes of misconception, namely teachers in schools, teachers outside of school, daily experience, social environment, and intuition [23]. Misconception develops not only due to students' mistakes but can come from previous knowledge, for example the use of terms in everyday life [24], besides that the misconceptions experienced by students can also be caused by students not being able to distinguish macroscopic, submicroscopic and symbolic explanations from a reading in textbooks [25].
3.2. Threshold concept in redox reactions
The threshold concept in redox reaction was identified based on the results of interviews with chemistry teachers. Information is obtained from the results of interviews with chemistry teachers based on teaching experience that the threshold concept for redox reactions are symbol of elements, chemical formulas, nomenclature, chemical materials, the constituent particles of matter, and electronegativity. The elemental symbol aims to recognize the chemical elements found in nature. The chemical formula aims to find out what elements make up the compound and the ratio of its atoms. Nomenclature to find out the names of chemical compounds and to write the reaction equation more easily. Chemical substances function to classify whether a substance is classified as a mixture, compound, element. Whereas the constituent particles of matter aim to find out what are the constituents of chemical material, including molecules, ions, and atoms. Electronegativity aims to determine the oxidation number of an element by looking at which elements are electropositive and electronegative elements.

The teacher said that the threshold concept is very important before studying the redox reaction, this is because the threshold concept is a cognitive gate for students to learn the concepts to be learned. If students do not understand the threshold concept, we can be sure students will experience difficulties in learning. The threshold concept can be understood as a cognitive gateway to new ways of thinking that have not been accessed before [14]. The main objective in identifying the threshold concept for scientific disciplines is to provide a first step to designing a curriculum because an effective approach to teaching threshold concept can improve student learning outcomes [26,27].

3.3. Troublesome knowledge in redox reactions
Troublesome knowledge of redox reactions was identified based on the results of interviews with chemistry teachers. Information obtained from interviews with chemistry teachers based on teaching experience that troublesome knowledge for redox reactions is abstract concepts, complexity in determining oxidation numbers, complexity in using definitions, and use of language. The concept is abstract students cannot see directly and imagine the process of occurrence of oxidative changes or the process of electron transfer in submicroscopic. However, students can only see the products produced. This makes it difficult for students to imagine how the actual process happened.

The complexity in determining oxidation numbers occurs when students determine oxidation number on a polyatomic compound or ion that has more than 2 elements. Because students must fully understand the rules for determining oxidation, not just memorizing. The complexity of using definitions occurs when students determine the definition of a redox reaction based on the concept of oxidative changes, based on binding and release of electrons, based on binding and release of oxygen. The use of language is found in the index term. In redox reaction material, an index is defined as a number whose position is slightly lower on an atom which states the number of atoms. Whereas in everyday life the index is a list of important terms contained in the book (usually at the end of the book) that provide information about the page where the word or term is found. The teacher said that troublesome knowledge is a characteristic of the concept that becomes an obstacle for students to understand the concept to be learned so that the teacher must really explain the concept in depth so that the conceptual characteristics of the concept do not become obstacles for students to understand the concept. Troublesome knowledge is a characteristic concept that has the potential to be problematic for students so that it becomes the main obstacle to learning a particular concept [15].

4. Conclusion
In general, there are two conceptions found in students, namely the conception model that is scientifically suitable consists of the definition of oxidation numbers based on the binding and release of oxygen determination of reducing agents and oxidizers while the wrong conception model (misconception) regarding the concept of oxidation and electron transfer is to assume charge Polyatomic ions are oxidation numbers, changes in the charge of polyatomic ions can be used to identify specific oxidation and reduction reactions, and electron transfer occurs when the bond between the cation and
the ion of the audience breaks up. Meanwhile, the threshold concept for redox reactions is the layout of elements based on groups, Proust laws, electronegativity, symbols and names of elements, nomenclature, and chemical material. Whereas troublesome knowledge for redox reactions is abstract concepts, complexity in determining oxidation numbers, complexity in using definitions, and use of language.

5. References

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