

Predicting the direction of incomplete chemical changes: grade 12 students' reasoning

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Context

Numerous studies showed that students fail to predict equilibrium shifts (Hackling & Garnett, 1985; Banerjee, 1991; Quilez-Pardo & Solaz-Portoles, 1995; Tyson et al., 1999; Kousathana & Tsaparlis, 2002). Others stressed students' difficulties to predict the direction of change in the case of any chemical system i.e. not after an equilibrium state has been disturbed (Niaz, 1995; Stavridou & Solomonidou, 2000). Teaching a systematic and rigorous procedure such as calculating the reaction quotient of the system and comparing it to the equilibrium constant - that we shall call 'the change criterion'- appeared then to be an opportunity to avoid such difficulties (Kousathana & Tsaparlis, 2002). In France a new curriculum has been implemented in grade 12 introducing a new way of studying incomplete chemical changes and the change criterion.

Theoretical background

According to the methodology of didactic engineering (Artigue, 1988) and the model of educational reconstruction (Duit et al., 2005) a preliminary analysis of the subject matter is necessary to clarify the content to be taught, and is as important as the analysis of the students' reasoning. We made a content analysis in terms of models and phenomena firstly to determine to what extent the didactic intentions expressed by the authors of the curriculum – making a clear distinction between experimental facts and models (Davous et al., 2003) – were achieved and secondly to provide a grid to interpret students' reasoning. According to Tiberghien et al. (1995) three interrelated levels may be considered: the theoretical level, the model level and the empirical level. Our present analysis focuses on what we called the thermodynamic model deriving from the thermodynamics of irreversible processes. The thermodynamic model comprises a pair of opposing reactions, symbolized by a chemical equation, and the change criterion. Predicting the direction of a chemical change may be summarized with five steps describing how the thermodynamic model functions and illustrating what can be an elementarisation of the chemical content (Duit et al., 2005).

Our aim is to determine whether the students use the change criterion to predict the direction of a chemical change and whether they make a clear distinction between the empirical level and the model level.

Methodology

Therefore we designed written tests composed of a chemical equation and an equilibrium constant, the description of the system and its composition, and a question: would the mixture change or not? Three kinds of systems were proposed: one with all the chemical species involved in the chemical equation, a second one with a missing solute and a third one with a missing solid. These open-ended questionnaires were administered to French students (N=102 or N=144) after teaching.

Results

A majority of students used the criterion to predict the direction of chemical changes (63% to 71%). Nevertheless in the case of a missing reactant two typical mistakes were found.

If a solute is missing some students (one out of four using the criterion) removed the solute concentration from the expression of the reaction quotient instead of writing zero for this concentration. For them, a missing solute in the beaker seems to be the same thing as a

missing concentration in the formula. The most significant feature of the empirical level is reproduced in the model as if it were a copy of the experimental situation.

If a solid is missing some students (33%) predicted a change in spite of the lack of this solid reactant. Applying the change criterion may lead to a direction of change that cannot be achieved (a limit of the model), therefore it is more crucial to look at the composition of the system to check whether a change is possible.

Conclusion

These results show that students do not seem to make proper links between the model level and the empirical level. Special attention should be paid to explaining the differences between these two levels and determining the significant features of each level.

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Keywords

Model - students' reasoning – reaction quotient –incomplete chemical change -