THE LEARNING OF CHEMISTRY THROUGH ICONIC MODELS: THE FUNCTION OF THE CATALYST IN HABER´S REACTION

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INTRODUCTION

The significance of constructing models of abstract chemical phenomena enhances student's conceptual understanding and diminishes misconceptions (Gilbert 2002). Also models and modelling, particularly in 'school science' framework (Izquierdo, 2003) provides a crucial and relevant context through which philosophical aspects of chemistry can be promoted in the classroom (Erduran, 2001).

Bruner (1966) identified three types of models: enactive, iconic and symbolic. The second ones are based on summarizing images. Kleinman suggests (1987) that students can be incapable to learn chemistry because they cannot relate concepts to appropriate images.

In previous research, molecular representations have been used of how the students interpreted the meaning of coefficients and subscripts in chemical formulas and equations (Yarroch, 1985; Lythcott, 1990) but its extension to very important catalyzed reactions (like Haber´s process for the synthesis of ammonia) is, to where we know, unpublished.

AIMS

By means of the application of a questionnaire and a didactic strategy that uses the construction of molecular models, we tried to recognize if modelling Haber´s reaction could help students:

i) To correctly relate coefficients and subscripts in chemical reactions.
ii) To have a clearer idea of the function of catalyst in chemical reactions.

METHODS AND SAMPLE

A questionnaire (12 multiple choice questions) was developed. It contains three sections (misconceptions about the particulate nature of chemistry, chemical language, and Haber´s reaction). The eight questions for the first two sections come from previously published research (Mulford 2002) and the third one was designed *ad hoc*. The questionnaire has been tested with a chemistry university group of 20 students. Its confidence coefficient through the method of "split-halves" was of 0.95. Finally the questionnaire was applied to two groups that were finishing a university level course of General Chemistry in the Faculty of Chemistry in Puebla. Both groups had different teacher, (both got a diploma in science teaching last year). Only in one of them, (G1, 45 students), was applied the strategy of modelling Habers´s reaction. The other group (G2, 46 students), follow traditional (blackboard) teaching procedures. One week after G1 worked the modelling strategy (in one, two hours session) the questionnaire was applied to both groups. The comparison between the results (Table 1) obtained was made through a t test. For all the questionnaire $t_{measured}$ (5.66045) > t_{tables} (1.7959) at $p<0.05$. Particularly for the Haber´s reaction four questions $t_{measured}$ (3.76904) > t_{tables} (2.3534) can be said that there is a difference significant at $p<0.05$ (95% confidence) between G1 and G2.

Table 1 Percentage of correct answers related to Haber´s reaction

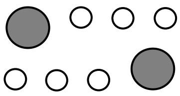
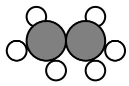
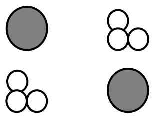
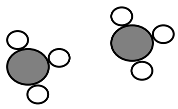
Question	**Percentage of correct answers**		**Difference (G1-G2)**
	G1	**G2**	
1	93.3	65.2	28.1
2	46.7	23.9	22.8
3	66.7	26.1	40.6
4	53.3	21.7	31.6
Mean	**65**	**34.2**	**30.8**
Mean of complete questionnaire	**74.6**	**54.2**	**20.4**

Didactic strategy in G1.

Haber´s reaction equation is written in the blackboard and it is requested to pairs of students working together that represent it without additional indications from the teacher in two ways: using Plasticine and small sticks, using drawings. The students to each other discuss the way to work and arrive at a consensus displaying their finished models. The teacher emphasizes the differences between the constructed models and he requests opinions to them to the diverse work parties to arrive at a common point, looks for the discussion and the possible most general participation. Is not which the teacher gives "the correct" answer but that students, valuing other constructions and argumentations can improve the fact previously. In the development of the strategy, the teacher indicates some rules to follow to represent the process of transformation of reagents to products. In the closing of the strategy, the students stick in the walls of the hall their drawings; compare the constructed models and the passages of the reaction by means of chemical formulas.

DATA ANALYSIS AND RESULTS

After showing the general results the brief following analysis was centred in each one of the questions:

1 ***$2NH_3$ are represented like:***	**% of answers**	
	G1	**G2**
a) 	0.0	0.0
b) 	6.7	32.6
c) 	0.0	2.2
d) 	93.3	65.2
e) I do not know	0.0	0.0

Is interesting to observe that the coefficient represents difficulties for some students. In G2, 15 of 46 students think that the 2 molecules of ammonia must be together as if they were a single one.

2 What phrase describes better the function of iron in Haber´s reaction?	**% of answers**	
	G1	**G2**
a) Nitrogen and hydrogen react in the presence of iron to produce ammonia	2.2	23.9
b) Nitrogen and hydrogen interact with iron, weakening their bonds and making the rupture and formation of new bonds easier.	37.8	17.4
c) Iron helps to break the bonds of nitrogen and hydrogen to form new bonds and to produce ammonia	46.7	23.9
d) Nitrogen and hydrogen react with iron and they discomposed to bonded later to let ammonia	13.3	17.4
e) I do not know	0.0	17.4

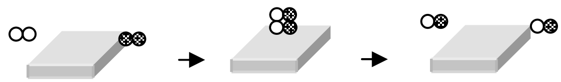
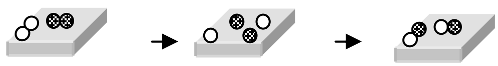
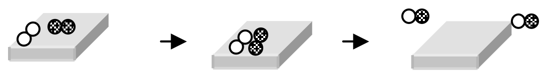
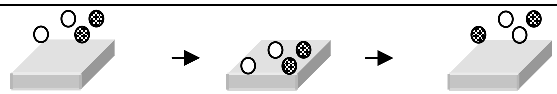
In order to verify the idea about catalyst action two questions related to this concept were designed; the first question has the purpose of investigating how the students conceive the action of the catalyst:

In option a) does not attribute a specific function to it but its presence is only required, as if it was something magical.

In option b) the catalyst has an action a little more direct interacting with hydrogen molecules and nitrogen.

Option c) could consider the option nearest to the scientific accepted model at the moment.

The results showed more that 20 percentage points between G1 and G2 in options b) and c) in favour of assigning a more specific function to the catalyst.

3	**In a reaction $A_2 + B_2 \rightarrow 2\,AB$, the scheme that better represents the function of the catalyst**  **are:**		**% of answers**	
	REACTIVES	PRODUCTS	**G1**	**G2**
a)			8.9	34.8
b)			22.2	13.0
c)			66.7	26.1
d)			0.0	0.0
e)	I do not know		2.2	26.1

This question was designed under the idea that the students do not assign a specific role to catalyst in the chemical reactions. In option a) in the intermediate state is no contact between the reagents and the catalyst. The products are obtained independently from this one. In options b) and c) a contact exists, the difference is that in the intermediate state in b) there are free atoms in the catalyst and not in c). The result for option a) is to call the attention, a difference of 26 percentage points between both groups. 34,8 % of students of group G2 selected the option in where there is no contact between the reagents and the catalyst. Options b) and c), in where by means of the drawings, a more active paper is assigned to the catalyst, were selected altogether by 88,8 % of students in group G1 against 39,1 % of group G2.

4 When we wrote $2NH_3$ we are representing:	**% of answers**	
	G1	**G2**
a. A molecule formed by six atoms	2.2	2.2
b. Two molecules formed by three atoms each one	17.8	10.8
c. Two molecules formed by four atoms each one	53.3	21.7
d. Two atoms of nitrogen and three atoms of hydrogen	0.0	2.2
e. Two nitrogen atoms and six of hydrogen	26.7	63.0

In this question two types of language are related: the formulas and their verbal description, although are referred a very simple formula, the results differ both from remarkable way in groups. Group G1 mainly (53,3 %) considers that $2NH_3$ are two molecules formed by four atoms each one, in resistance group G2 (63%) thinks that it is two nitrogen atoms and six of hydrogen.

CONCLUSIONS

In agreement with the obtained results, the strategy of construction of models significantly helps to improve the understanding of the students on the meaning of coefficients and subscripts in the chemical formulas of compounds involved in Haber´s reaction, as well as the function that catalyst in a chemical reaction carries out.

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