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Summary

Defining priorities is crucial in designing and developing pre-service teacher training programmes. Prospective chemistry teachers must possess a sound knowledge and understanding of the subject matter to be taught. Research results concerning the nature and main features of alternative conceptions (AC) in chemistry provide evidence for concern regarding prospective chemistry teachers' alternative conceptions. Therefore, pre-service chemistry teacher training programmes should aim the identification of AC and suggest teaching strategies to overcome them as one major priority.

The study herein presented was carried out with student teachers (N=66, representing 50% of the total population) in their last year of initial chemistry teacher training (5-year course) and involved all Portuguese Universities concerned (Continent only). The aim of this study was to determine the extent to which AC already identified in other student populations (namely at secondary level), regarding basic chemical concepts, were also shared by prospective chemistry teachers. The AC concerned basic concepts of thermodynamics and chemical equilibrium. A written structured questionnaire was used for data gathering. The results show that over 55%, on average, of the students involved shared the majority of the AC tested. Just as an example, for an exothermic reaction (butane combustion) 54.5% of the students indicate the following statement as being true: "the heat given off comes mainly from the butane because in the reactant system the total C-C and C-H bonding energy is higher than the 0=0 bonding energy".

The paper explores the argument that AC in chemistry have to be considered (nature, features, diagnostic instruments and teaching strategies to overcome them) in the training of chemistry teachers as a basic requirement to increase the educational impact of these training programmes.

Objective of the Study: To determine the extent to which alternative conceptions, already identified in other student populations, concerning concepts of elementary thermodynamics and chemical equilibrium are shared by prospective secondary school chemistry teachers.

The Sample: All Portuguese Universities (Continent) providing chemistry teacher training were involved in the study. In each University 50 % of the students in their 5th year - last year of initial chemistry teacher training - were randomly selected (N=66) to answer the test specifically designed for the purpose.

Data Collection: A structured written questionnaire composed of four items was individually administered to students without any time constraint. Each question consisted of an initial true assertion concerning a situation known to the students followed by three different interpretations, most of which contained alternative conceptions identified with younger students and already described in the literature. Each student teacher was required to decide whether or not each given explanation was true or false. In the latter situation - false explanation - the student was required to give his/her own explanation.

The items used are presented below.

1. To boil water, at 100 º C and 1 atm, continuous heating is necessary because...
   a) ... it is necessary to increase the kinetic energy of the water molecules in order to obtain the gaseous state.
   b) ... it is necessary to increase the space between the water molecules to obtain the gaseous state.
   c) ... it is necessary to break down the intermolecular bonds in the water in order to keep the vapour pressure equal to the atmospheric pressure.

2. Consider the reaction between butane and oxygen which is an exothermic reaction.
   a) The heat given out comes from butane because it is the fuel in this reaction.
   b) The heat given out comes mainly from butane because each butane molecule has more chemical bonds than each oxygen molecule.
   c) The heat given out comes mainly from butane because in the reactant system the total C-C and C-H bonding energy is higher than the O=O bonding energy.

3. The thermal decomposition of calcium carbonate takes place by continuous heating at 850 º C or higher because...

a) ... it is a chemical reaction with high activation energy.

b) ... it is an endothermic reaction.

c) ... if the temperature is lower than 850 º C the free Gibbs energy increases.

4. Consider an insulated container with a gaseous mixture of chlorine, water, hydrogen chloride and oxygen in equilibrium:

$$2\ Cl_2(g) + 2\ H_2O(g) \ == \ 4\ HCl(g) + O_2(g) \qquad \Delta H^0 = -113\ kJ\ mol^{-1}$$

a) If the volume of the container decreases, keeping the temperature constant, the number of collisions between Cl_2 and H_2O increases; consequently the rate of the reaction increases and the Cl_2 concentration diminishes.

b) If a catalyst is added to the system the variation of $[Cl_2]$ depends on the catalyst, if being a positive or a negative one; in the former case the $[Cl_2]$ diminishes because the catalysts makes the rate of reaction increase and in the latter case the $[Cl_2]$ increases because the catalyst makes the rate of reaction decrease.

c) If the temperature of the system increases the rate of reaction increases too; consequently the $[Cl_2]$ diminishes.

Results

The percentage of the students teachers' responses for each question is presented in table 1.

Taking into account that the concepts tested are at an elementary level, the percentage of student teachers who did not answer is high. This is in itself an indication of a problem.

The explanation put forward in question 1-a) corresponds to the alternative conception that *the physical state of a substance is determined by the average kinetic energy of its particles*. Then, in spite of the temperature being constant, heating the system while boiling is to increase the average kinetic energy of its molecules. The results herein presented indicate that 59.1 % of the student teachers tested did not make a correct choice.

Table 1. Percentage of the student teachers´ responses

Question / Explanation	Response (%)		
	True(T)	False (F)	No answer
1-a)	59.1	30.3 *	10.6
1-b)	53.0	36.4 *	10.6
1-c)	62.1 *	21.2	16.7
2-a)	33.3	60.6 *	6.1
2-b)	31.8	51.5 *	16.7
2-c)	54.5	31.9 *	13.6
3-a)	72.7	9.1 *	18.2
3-b)	66.7	22.7 *	10.6
3-c)	34.8	28.8 *	36.4
4-a)	39.4	53.0 *	7.6
4-b)	47.0	39.4 *	13.6
4-c)	47.0	45.4 *	7.6

* accepted / correct response.

The choices made in question 2 reveal the alternative conception that *butane is a reactant which is more important than oxygen as far as energy evolved is concerned.* This idea is particularly evident at the molecular level. In fact 31.8 % of the student teachers tested did not consider the statement "the heat comes mainly from butane because each butane molecule has more chemical bonds than each oxygen molecule" as false. In addition 54.5 % of the student teachers tested did not consider that "the heat comes mainly from butane because in the reactant system the total C-C and C-H bonding energy is higher than the O=O bonding energy" was a false idea.

It seems that the common idea underlying the explanations presented in 2-b) and 2-c) is that so as to explain the energy evolved in the combustion reaction it is enough to consider the system of reactants and in this the chemical bondings work as energy reservoirs from which one can get energy when they are broken. There is not a correct understanding of the bonding energy concept as well as of the energy involvement in breaking and forming chemical bonding processes. Common use statements as "fuel energy" may reinforce this idea.

As to question 3, it tested two alternative conceptions. In the former (3-a)) it is considered that *the very high activation energy (Ea) requires continuous heating of the reaction system* . 72.7 % of the student teachers tested considered this as a correct explanation. This idea indicates that kinetic and thermodynamic spontaneity are not seen as different.
The second alternative conception (3-b)) consists of *continuous heating was necessary because it was an endothermic reaction* .Two thirds of the sample considered this as a correct explanation. The use of a number of operational definitions for endothermic reaction adopted in textbooks when introducing this concept (e.g. "endothermic reactions are those which need energy to be supplied for them to occur") might be an important contribute for this state of affairs.

As to the forseen modifications of a system in chemical equilibrium sujected to external disturbances (question 4), it was found that 39.4 % of the student teachers tested considered as true the idea that *the extent of the reaction increased because the system pressure was increased*; 47.0 % considered as true the idea that *adding a catalyst makes the system composition change*; 47.0 % considered as true the idea that *in spite of the reaction under analysis being an exothermic one ($\Delta H<0$), increasing the temperature makes the rate of reaction increase*. These results clearly indicate that the forward reaction is the reaction to look at and also that changing the composition of the system in equilibrium necessarily means changing the extent of the reaction. The idea underlying all these explanations is that *the faster the reaction, the more extensive it is*.

Conclusions and Educational Implications

The results of this study indicate that it is necessary to rethink current approaches used in Portuguese chemistry teacher training programmes in order to improve teachers' understanding of fundamental concepts as the ones used in the present study. Although the study herein reported was carried out in Portugal, there is no reason to believe that the sate of affairs concerning alternative conceptions on the topics tested is different elsewhere.

If quality and efficiency is sought in our schools then a new teaching approach of chemistry content in teacher training programmes is regarded as a necessary condition. The main idea in which work of this type is based is that rethinking and restructuring teacher training programmes should be based on research work. This study is a preliminary one. However, it provides a mean to identify difficult topics for prospective teachers. Research work including other topics should be carried out. Following this main stream, we regard as useful the following recommendations:

1. To provide adequate opportunities for student teachers to be aware of their own alternative conceptions on various fundamental chemistry topics. For instance student teachers should be given the opportunity to aknowledge their own conceptual views and their disagreement with the ones accepted by the cientific community. They should also aknowledge that some of their inadequate views are shared by other student populations including their future pupils. Then a broad discussion of the various views should be carried out so that conceptual conflict arises.

2. To develop and test new teaching strategies. Once the conceptual conflict arises the discussion should be led so that the conflict is resolved and the desired conceptual change achieved. However, how to make this successful is a problem to be solved. That is, the scientific community conducting research in chemical education has to develop teaching approaches so that suitable models for efficient teaching of the various topics demanding conceptual understanding are achieved.

3. To modify the assessment objectives and procedures in the pre-service teacher training programmes so that the students are given the opportunity to realize their own conceptual understanding or misunderstandings. As an example the overemphasis on the mathematical approach on thermodynamics without a convenient emphasis on the conceptual aspects might be contribute for some of the findings concerning misunderstandings already identified(10, 11).

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