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Questions that Science Teachers Find Difficult (I).

PREGUNTAS CONSIDERADAS DIFICILES POR LOS PROFESORES DE CIENCIAS (I)

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Abstract:

In this paper the author confesses to finding the answers to some fairly basic science questions difficult. Some of the questions were asked by able and interested students and could not simply be brushed aside. Three questions for which he has some answers are presented for critical evaluation. Hopefully these will stimulate debate and readers will contribute questions and their answers from their own experience. It is intended that further questions will appear in later issues.

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Keywords : Difficult concepts, science, chemistry, physics.

Resumen :

El autor encontró que algunas respuestas para preguntas básicas de ciencias no son tan simples. Algunas de estas preguntas las hicieron estudiantes con altas capacidades y por esta razón no se pueden omitir. Tres preguntas con las respuestas del autor se presentan para evaluación crítica y se espera que esto pueda estimular el debate y opinión de los lectores con sus propias preguntas difíciles para que continuemos la publicación de preguntas en los siguientes números.

Palabras Clave : conceptos difíciles, ciencias, química, física.

Introduction

The process of teaching science, especially at an introductory level frequently throws into high relief questions for which the teacher feels he/she should have a ready answer. However, closer examination shows that the answers given (while they may baffle the student) are *qualitatively* not convincing to the teacher and turn out to be controversial when discussed with fellow scientists and science teachers. When I started teaching science I felt guilty that I was learning so much and that there were so many things that I did not really understand. (Even though I usually thought I knew the right answers.) I now find it fascinating that, when discussing the answers to 'difficult' with colleagues my ideas frequently lead to more discussion and controversy than the original question.

It seems to me that such discussions are more like doing 'real science' than is learning information, which is 'on the syllabus' and 'for the examination' but which is not critically explored, by the learner, for sense or longer-term purpose? Of course preparing for examinations is an important part of science education, but this is NOT the main purpose of learning. Surely the main purpose is to become able to do science or at least to be able to understand and critically appraise the science and technology that we meet throughout our lives. For this to be possible what we learn must 'make sense' to us and we must be able to examine our understandings (and those of others) in the light of evidence. Our ideas can then be defended or developed. I hope that my students and colleagues remain critical of my teaching until they convince themselves that it makes sense and has value. They must never accept that something is true *just because* I, or even a well-known authority in science, tell them.

I expect that there are many people who may wish to argue with this point of view. However, learning something *that does not make sense* and/or *that does not have personal value* seems to me to be a complete waste. I will concede that, in the beginning, it is necessary to take teaching on trust, but if learning does not become meaningful and fruitful fairly quickly there is no long-term future in the enterprise. Here it is not possible to debate the issue at length, but there are many texts available that explore the issue at length e.g. Ausubel (1968), Gagné (1985) and Gardner (1991). Much can also be gleaned from the wide literature on 'Alternative Conceptions' and 'Constructivism' (e.g. Bodner (1986); Driver (1994). The only point I which I take real issue is when the inference is that only students have such alternate conceptions – we all do – we are ALL learners – and it is when we are sure we are right that we are likely to make the biggest errors. (Goodwin (2001)) In the context of Mathematics education this point was well made by John Mason and colleagues (1983)

"*The first step is to convince yourself. Unfortunately that is all too easy*!"

The second step is to convince a friend or colleague and the third to convince an enemy.

"*Learning to play the role of enemy yourself is an extremely important skill, if only because other suitable enemies may be hard to find.*"

pp.106

I explore below three examples of questions that I have been chosen from a growing collection that I started a couple of years ago. Each one is followed by a short discussion of what I think is a reasonable explanation *for myself.* However, you may have more or less experience on the topic than I have and so may not find the explanation convincing or even meaningful. Convincing myself is only the first stage in teaching, but if this cannot be done I am unlikely to convince *anyone.*

Hopefully this will be the first of a number of short papers on this topic. Please let the Editor, or me have your views on the questions, the answers or on the practical educational issues raised. Please also consider whether you have examples of 'difficult science questions' (and your answers) that you can submit to the journal.

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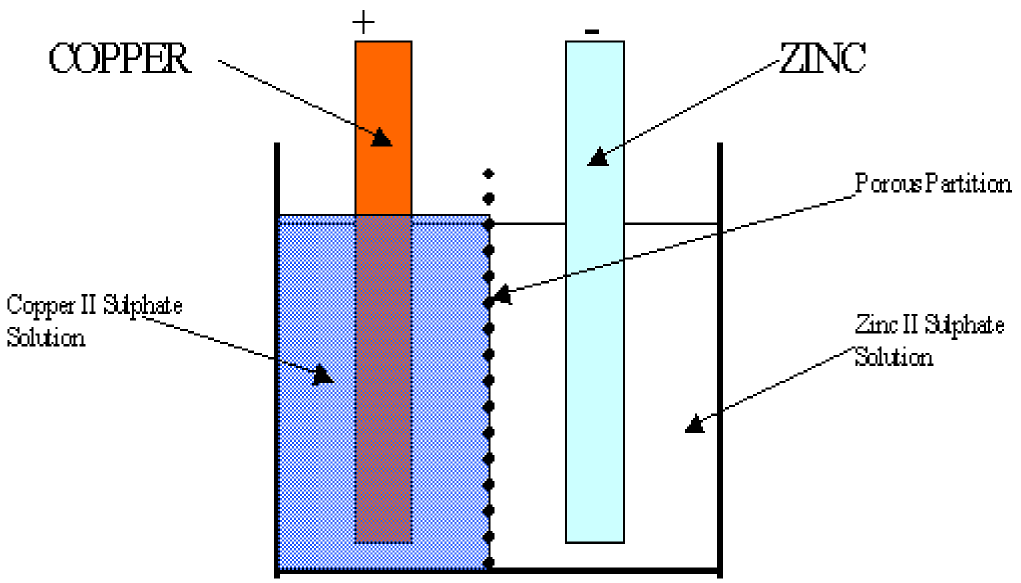
Difficult question 1: The Daniel Cell.

A student aged 17 years asked this when I was trying to explain the working of a Daniel Cell. The diagram below and the equations that follow indicate the sort of 'correct' explanation I had provided. The student asked, "How can it be that copper is deposited on the positive electrode? Surely positive ions will be repelled?"



Electrode reactions (when the plates are connected)

$$Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e$$

$$Cu^{2+}_{(aq)} + 2e \rightarrow Cu_{(s)}$$

(NB: It is just as difficult for students to see why positive Zn^{2+} ions should leave the negative electrode.) Unfortunately I had never noticed this difficulty. I had learned and taught about electrolysis completely separately from electrochemical cells and had not made a 'connection' previously. (Even it textbooks (e.g. Freemantle 1995) that explicitly treat these two aspects of electrochemistry together this issue seems to have been missed.)

<u>My answer to myself:</u> Before the copper and zinc rods are connected together the two metals are in equilibrium with the aqueous solutions of their salts. (This ignores the very slow diffusion of ions that will be taking place across the porous partition.) The difference in reactivity of the metals means that *at equilibrium* the copper rod is positively charged relative to the zinc rod. When the rods are connected electrons flow from Zn to Cu. This disturbs the electrode equilibrium, which has been established at both electrodes. At copper Cu^{2+} are deposited in order to (attempt to) restore the equilibrium electrode potential and at the zinc rod the same number of Zn^{2+} ions enter the solution. The essence of the answer to the student's question seems to lie in the fact that in the case of cells the charges on the metal rods do *not* drive the movement of the ions as they do in electrolysis. (Ogude & Bradley (1996)).

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<u>Difficult Question 2:</u> Since molecules evaporating from a liquid surface have *much* higher kinetic energy than the average, how is it that the temperature of the vapour is *not* higher than that of the liquid? (It <u>is</u> the same?)

This is another question from a perceptive student passed on to me by a colleague. Students can be aware that scalds from live steam are much more severe than those from the same amount of boiling water. This can be (falsely) attributed to the higher temperature of the steam. However, IF the temperature were higher it WOULD be a nice explanation and it seems to fit in with the kinetic theory interpretation given in the question. Unfortunately the idea that a liquid and the vapour *in equilibrium* with it could be at different temperatures is fundamentally problematic in any further development in science.

<u>My answer to myself:</u> Molecules leaving the liquid state gain substantially in potential energy as they separate from the much more intense intermolecular forces in the liquid. This gain is at the expense of kinetic energy of the evaporating molecules whose average kinetic energy (temperature) is then (exactly?) the same as that of molecules in the liquid when they are both in equilibrium. This still leaves room for debate and I find that many science teachers and students find the *idea* that molecules in the vapour have a higher *potential* energy than the same molecules at the same temperature to be objectionable.

<u>Difficult Question 3:</u> What is the difference between evaporation and boiling of a pure liquid?

All chemists know the answer to this one? However, it is a question that caused me significant problems when I tried to teach this topic. (I now use it as a question to ask graduate scientists at interview for entry to teacher training courses.) Although there is general agreement that evaporation takes place when molecules of a liquid at the surface happen to gain sufficient kinetic energy to allow them to overcome the forces of attraction, common 'explanations' include:

1. 'Boiling takes place when ALL the molecules in the liquid have sufficient kinetic energy to escape.'

2. Boiling takes place at the temperature at which the Saturated Vapour Pressure (SVP) of the liquid is equal to atmospheric pressure. (This is essentially 'correct' but does not convey a qualitative explanation to a student, nor to many teachers as to why something special can happen at this temperature.)

<u>My answer to myself:</u> Initially I had not appreciated the importance of *bubbles* in understanding the special nature of boiling. I remember learning, and teaching, that 'evaporation takes place only at surface of a liquid, whereas boiling occurs throughout the liquid'. This and statement 2 above make more sense when they are connected with the idea that under these conditions the SVP is sufficient to support a *bubble* of vapour within the liquid. Thus *provided that bubbles can <u>form freely</u>* evaporation can take place from liquid surfaces *into* bubbles within all parts of a liquid. These escape and carry away energy from the system as fast as it is supplied. Hence boiling point is constant at constant pressure.

I have not finished with difficult questions concerned with 'simple' kinetic theory and phase changes, but these will need to wait until a future article.

Please let us have your response to these difficult questions. Perhaps you have some better examples (Especially from Biology)? Perhaps you did not find any of the questions difficult at all?

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