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The Effects of Problem-Based Learning Instruction on University Students' Performance of Conceptual and Quantitative Problems in Gas Concepts

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This study aimed at investigating effects of Problem-Based Learning (PBL) on pre-service teachers' performance on conceptual and quantitative problems about concepts of gases. The subjects of this study were 78 second year undergraduates from two different classes enrolled to General Chemistry course in the Department of Primary Mathematics Education a State University in Turkey. Nonequivalent pretest-posttest control group design was used. One of the classes was randomly chosen as experimental group (40), took PBL instruction, and the other was control (38) group, took traditional instruction. Students' achievement of conceptual and quantitative problems in chemistry was measured by Conceptual Problems Gases Test (CPGT) and Quantitative Problems Gases Test (QPGT**)** as pre and post-tests. The analysis of results showed that students in experimental group had better performance on conceptual problems while there was no difference in students' performances of quantitative problems. The results of the study are discussed in terms of the effects of PBL on students' conceptual learning.

Keywords: Conceptual Problem, Quantitative Problem, PBL, Conceptual Learning, Science Education

INTRODUCTION

Recent researches into science education have investigated both what students learn and how they learn it. Although much research has examined student conceptual understanding, the connection between conceptual understanding and problem solving skills has not been as well studied. Conceptual learning is the process of acquiring a better understanding in which concepts are exposed to the impacts of new data. It seeks to use the new knowledge to improve the concepts that organize our thoughts. A conceptual problem is a problem of which solution requires understanding of the concepts rather than an algorithm. As for a quantitative problem, it requires the student to manipulate a formula or work through an algorithm to find a numerical solution to the problem (Nakhleh, 1993).

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Chemical educators and teachers have often assumed that success in solving quantitative problems should indicate mastery of a chemical concept (Nakhleh, 1993). However, some researchers (e.g. Nurrenbern and Pickering, 1987; Pickering, 1990; Sawrey, 1990) suggest that there is little connection between solving a quantitative problem and understanding the chemical concept behind that problem. These studies strongly suggested that our current methods of teaching chemistry are, perhaps, not teaching chemistry, but teaching how to get answers to selected algorithmic problems (Nakhleh, 1993; Nurrenbern and Pickering, 1987; Pickering, 1990; Sawrey, 1990). Nurrenbern and Pickering (1987) also pointed out that teaching students how to solve quantitative problems about chemistry is not equivalent to teaching them how to solve related conceptual problems. Therefore, what problem solving is, what purpose it serves in chemistry instruction, and how more students can be enabled to become successful solvers should be reconsidered.

A common complaint heard from the teachers is that their students seem lack the ability or motivation to go beyond factual material to a deeper understanding of course material. The reasons for superficial rather than deep understanding on the part of students are many, including how we test, what expectations we set, and what learning materials we use when we teach. There were some attempts to find materials to help students achieve in-depth knowledge of the concepts. One of this material is problem solving. Standard college textbook problems in science and other disciplines tend to reinforce the students' naive view of learning because they can successfully answer homework end-of-chapter problems through memorization of facts and equations and using novice "pattern-match" problem-solving techniques (Duch, Groh and Allen, 2001). Typical problems do not foster the development of effective problem-solving and conceptual learning (Heller & Hollabaugh, 1992) nor do they challenge students to develop critical thinking skills and logical reasoning (Mazur, 1996).

To better understand what is meant by problem solving it is helpful to examine closely at the nature of problems. Although problems can differ in many ways, they all can be considered as having three characteristics (Johnstone, 2001). First, there is an initial or present state in which we begin. Second, there is a goal state we wish to achieve. Finally, there is some set of actions or operations needed to get from the initial state to the goal state. If one or more of these three components is missing or incomplete, we have a problem. There are eight possible permutations of the three components of a problem (Table 1), but the first of these is not really a problem if we accept the definition above, that one component must be missing or incomplete to constitute a problem (Johnstone, 1993).

However, the situation designated as Type 1 is what we commonly call a problem. Many academic 'problems' are of this kind: all the necessary data is given, the method is familiar and the goal is explicitly stated. They are algorithmic, following well-trodden paths, using familiar formulae and common mathematical techniques.

In order to solve a chemistry problem in an acceptable manner, the problem solver must have both conceptual scientific knowledge and procedural knowledge (Gabel, 1994). However, many studies showed that students frequently do not use conceptual understanding in solving chemistry problems; these studies also provided evidence that students were limited in their ability to solve distant transfer problems without an in-depth understanding of relevant chemistry concepts. Instead of solving problems on the basis of conceptual understanding, they use algorithms and formulas to arrive at correct answers. Hence, chemistry educators have always been interested in enhancing students' understanding of chemical concepts (Gabel, 1994). Different methods have been proposed for doing this. One of these methods is problem-based learning (PBL). It aims to help students develop higher order thinking skills and a substantial disciplinary knowledge base by placing students in the active role of practitioners confronted with a situation that reflects the real world (Maudsley and Strivens, 2000; Şenocak, 2007).

It is a method of instruction that uses ill-structured problems as a context for students to acquire problem solving skills and basic knowledge (Banta et al., 2000). PBL is a way of learning which encourages a deeper understanding of the material rather than superficial coverage, and also it is a problem-oriented learning by which students can not only get basic knowledge while learning, but can also experience how to use their knowledge to solve a real world problems (Yeung et al., 2003; Ram, 1999). Besides PBL aims improve students' ability to work in a team, showing their co-ordinated abilities to access information and turn it into viable knowledge.

A crucial aspect of PBL is the actual design of problem to be solved (Jonassen, 2000). According to

Table 1: Classification of problems (Johnstone, 1993).

Type	Data	Goal	Method
1	Complete	Clear	Familiar
2	Complete	Clear	Unfamiliar
3	Incomplete	Clear	Familiar
4	Complete	Unclear	Familiar
5	Incomplete	Clear	Unfamiliar
6	Complete	Unclear	Unfamiliar
7	Incomplete	Unclear	Familiar
8	Incomplete	Unclear	Unfamiliar

Greenwald (2000), the best way for students to learn science is to experience challenging problems and the thoughts, and actions associated with solving them. In a successful PBL, choosing an appropriate problem is curricial for students to go beyond a superficial understanding of the important concepts and principles being taugnt (Duch, Groh and Allen, 2001; Ram, 1999). If students are given a challenging task (solving of an ill-structred problem) engaging them, they will learn to solve problems and they will acquire the associated knowledge in order to solve the particular problem. At the heart of true PBL is an ill-structured problem that must be based in compelling, real world situations, generates multiple hypotheses, exercises problem-solving skills and requires creative thinking. In other words, ill-structured problems are those where the initial situations do not provide all the necessary information to develop a solution, and there is no one correct way to solve the problem (Chin and Chia, 2006; p.46). Some researchers stated that problem solving using ill-structured problems motivates to students and encourages understanding the epistemology of the discipline (Ram, 1999; Wilkinson and Maxwell, 1991).

In PBL, students work in groups each taking his or her responsibility for a certain part of the task (Sluijsmans et al., 2001). The small group setting used in PBL encourages detailed look at all issues, concepts and principles contained within problem. The time spent outside of the group setting facilitates the development of skills such as literature retrieval, critical appraisal of available information and seeking of opinions of peers and specialists. PBL encourages students to become more involved in, and responsible for, their own learning, and most students and faculty report that this is highly enjoyable way to learn and teach. In PBL process students use self-selected resources such as journals, online resources, text books, other library resources and discus more than traditional students (Albesene and Mitchell, 1993; Vernon and Blake, 1993). It promotes student interaction and teamwork, thereby enhancing students' interpersonal skills (Bernstein et al., 1995; Pincus, 1995; Vernon, 1995) such as working with group dynamic, peer evaluation, and how to present and defend their plans (Delafuente et al., 1994).

The typical learning process followed in a PBL environment is defined by Visser (2002) as follows:

Students begin with the problem - without any prior experience in dealing with the problem. Each group of students will meet with a facilitator to discuss the problem.

The facilitator presents a limited amount of information about the problem, and the group is charged with the task of identifying the different aspects of the problem by asking the facilitator questions to elicit information relevant to the problem.

Students work with the facilitator to generate and refine hypotheses related to the problem's potential solution. The facilitator's role is to model hypothesis-driven reasoning skills.

Students determine "learning issues" that the group decides are relevant and that they need to learn more about to find an acceptable solution to the problem.

The groups are then asked to assign tasks to each member of the group for researching each of the different "*learning issues*" they have identified.

Group members engage in self-directed learning by gathering information related to the assigned learning issues from a variety of different sources.

After each of the group members has conducted the necessary research related to the "learning issue" they were assigned, the group members report their findings to each other. They reconvene and re-examine the problem, applying newly acquired knowledge and skills to generating a formal solution to the problem.

Once the formal solution has been presented to the class and the facilitator, students reflect on what they have learned from the problem and on the process used to resolve the problem presented.

The importance of the teacher in the success of PBL is frequently emphasized in the literature.

The role of the teacher is very different from the usual teachers' role in PBL. For an affective implementation of PBL, teachers must adopt new roles that are frequently very different from those of their past. Rather than being a "context expert" who provides the facts, the teacher is a facilitator, responsible for guiding students to identify the key issues in each case. The teacher also selects the problem, presents it to the students, and then provides direction for student research and inquiry.

PBL was initially designed for graduate medical school programs and then it was adapted for use in other diciplines. Although it is an old and well established approach in medical education, its application in science education could be considered as quite new. In recent years, studies emerged about the use of PBL in science education. For example, there have been studies of PBL in science teacher training (Gallagher et al., 1995; Peterson & Treagust, 1998), teaching chemistry (Ram, 1999; West, 1992; Senocak, Taskesenligil & Sozbilir, 2007)), biochemistry (Jaleel, Rahman, & Huda, 2001), analytical chemistry (Cancilla, 2001; Yuzhi, 2003), electrochemistry (Ying, 2003), and biology (Soderberg & Price, 2003).

One of the studies of the application of PBL in chemistry teaching is by Dods (1997). He investigated the effectiveness of PBL in promoting knowledge acquisition and retention. A total of 30 students from a biochemistry course at the Illinois Mathematics and Science Academy participated. Course content was delivered via PBL, traditional lecture, and a combination of PBL and traditional lecture. Data were gathered using a pre- and post-course self-evaluation of student understanding and a measure of depth of understanding. It was found that content coverage was promoted by lecture, but that PBL was more effective than both traditional lecture and a combination of PBL and traditional lecture in promoting comprehensive understanding of important biochemical content.

Senocak, Taskesenkigil and Sozbilir (2007) carried out a PBL study on teaching gases to procpective primary science teachers through PBL. That study aimed to compare the achievement of prospective primary science teachers in a problem-based curriculum with those in a conventional primary science teacher preparation program with regard to success in learning about gases and developing positive attitudes towards chemistry. The results obtained from the study showed that there was a statistically significant difference between the PBL and conventional groups in terms of students' gases diognastic test total mean scores and, their attitude towards chemistry, as well as PBL has a significant effect on the development of students' skills such as self-directed learning, cooperative learning and critical thinking.

Problem solving is the process used to solve a problem. Since PBL starts with a problem to be solved, students working in a PBL environment should be skilled in problem solving or critical thinking. One indicator of effective problem-solving skills is the ability to transfer reasoning strategies to new problems. Patel et al. (1991) asked traditional and PBL students to provide diagnostic explanations of a clinical problem. They revealed that students in the PBL programme were more likely to use hypothesis-driven reasoning than were students in a traditional curriculum. Another aspect of problem-solving skills is being able to define what the problem actually is, especially with ill-structured problems. This is called problem finding and is the aspect of problem solving that refers to identifying the problem. Gallagher et al. (1992) compared gifted students who were traditionally instructed with students in a PBL class on problem-solving skills, they found that PBL students were more likely to include problem finding as a step when presented with a novel ill-structured problem. Although it is accepted that PBL effects positively students' problem solving skills, but stil researches on the influence of PBL on students' problem solving skills is limited. Therefore, the purpose of this study is to investigate effects of Problem-Based Learning (PBL) instruction on undergraduates' performance on conceptual and algorithmic questions about concept of gases. The study emanates from the hypothesis that PBL has a positive influence on students' achievement in conceptual problem solving. Two research questions investigated were as follows:

1. Is there a significant mean difference between the effect of PBL and traditional instruction on undergraduate students' conceptual problems related to gases law when their pre-CPGT scores were used as a covariate?
2. Is there a significant mean difference between the effect of PBL and traditional instruction on undergraduate students' quantitative problems related to gases when their pre-GPGT scores were used as a covariate?

METHODOLOGY

Subjects

The subjects of this study were 78 second year undergraduates (aged 18 to 21 years; mean=19.20) from two different classes enrolled to General Chemistry course in the Department of Primary Mathematics Education. One class was randomly assigned to the experimental group (n=40) while the other group formed the control group (n=38). Students in the experimental group were instructed with PBL, while students in control group received traditional instruction. General Chemistry is a 5 hour lecture per-week and a compulsory course for all undergraduate students in the second year. Gases Unit is covered during the fall semester. Topics related to gases covered were gas pressure and its measurement, empirical gas laws, the ideal gas law, using ideal gas equation to solve problems, law of partial pressure, diffusion and effusion rates of gases, kinetic-molecular theory and real gases. All students were taught by the same instructor (the first author) and both of the groups received 10 hours instruction.

Instruments

In order to address the research questions, a paired exam which is composed of conceptual and algorithmic problems on gases laws was administered to the subjects before and after teaching. The test used in the study described below.

Conceptual Problems Gases Test (CPGT) and Quantitative problems Gases Test (QPGT) cover the instructional objectives for the unit of gas concepts. Each test included 19 multiple choice items. Some of the test items were taken from Bodner (2001). The tests were evaluated by two instructors to appropriateness of items for content validity. The Cronbach's alpha reliability of the tests was found as 0.84 and 0.77 for QPGT and CPGT respectively. Five examples for each test are given in Appendix C.

Treatment

This study was conducted over a 10 lecture hours. The experimental and control groups were given CPGT and QPGT as pre-tests at the beginning of the study. In the control group, instructor used lecture/discussion methods based on students mostly taking notes and asking questions where they have difficulty in understanding. After instructor's explanation, some concepts were discussed by instructor-directed questions. The instructor also solved some problems during lecturing and worksheets, which included some conceptual and quantitative problems, were also distributed to all students. All completed worksheets were checked, corrected and returned back to the undergraduates to review their responses.

Undergraduates in the experimental group were assigned into ten heterogenic learning teams (four members in each) based on their previous exam results. One week prior to the treatment the instructor provided information about PBL instruction, gave 10 problems cases (scenarios) developed by Şenocak (2004), and the way to solve this kind of problems was explained by the help of an example problem case. Table 1 provides the names, aims and the target concepts of each problem case. The names, aims and the target concepts of each problem cases and three sample problem cases (scenarios) were given as Appendix A and B respectively. Further, sources such as department and university libraries, general chemistry books and several web sites available on the internet were also provided. Students were required to make research on individual bases about every problem case before coming to the class. Only one problem case was covered in each lesson. Students were required to come to a group consensus on the problem case at hand by discussing their individual findings with the findings of the other members in their groups and then to write down their solutions about the problem case into the study sheets. After every group completed this phase, the lecturer asked randomly selected three or four groups to share their findings with the class. Each group is required to change their spokesman when they were given a new opportunity to speak. This process was repeated for every problem case. The remaining lecture time after the investigation of each problem case was spent by solving the related problems from the course textbook.

RESULTS

Based on the data obtained by the CPGT and the QPGT, the students' mean and standard deviation for pre and post test scores for experimental and control groups were shown in Table 2.

The independent sample t-test was used to determine whether there was a statistically significant mean difference between experimental and control groups for the pre-CPGT and pre-QPGT at 0.05 levels. No statistically significant difference between the mean scores of groups with respect to previous achievement of conceptual problems ($t_{(76)}$=0.423; p>0.05) and quantitative problems ($t_{(76)}$=0.636; p>0.05) was found indicating that students in the experimental and the control groups have similar achievement on pre-CPGT and QPGT. In order to investigate the effects of PBL approach on students' achievements on conceptual and quantitative problem about gases, MANCOVA was run on instructions, by taking the pre-tests scores as covariates. Before conducting the analysis of MANCOVA, the covariates were examined. According to Weinfurt (1995), a covariate should be used only if there is a statistically significant linear relationship between the covariate and dependent variables. Therefore, the condition has been tested with Pearson correlation between pre- and post-CPGT scores and pre- and post-QPGT scores. Pre-CPGT scores have significant correlation with post-CPGT scores (r=+0.434, N=78; p<0.01) and pre-QPGT scores have significant correlation with post-QPGT scores (r=+0.321, N=78; p<0.01). Hence, pre-tests scores were used as covariates.

One of the assumptions of MANCOVA is the homogeneity of covariance matrices. In order to test this assumption, Bax's Test was used. This analysis revealed that observed covariance matrices of dependent variables are equal across the experimental and the control groups (*F*=0.383; p>0.05). Therefore, this assumption was not violated. Levene's Test was used to check the assumption that error variance of dependent variables is equal across the experimental and control groups. All significant values for dependent variables, post-CPGT scores (*F* (1, 76)=0.143; p>0.05) and post-QPGT scores (*F* (1, 76)=0.113; p>0.05), were greater than 0.05, suggesting the equality of variances assumption was not violated. After checking whether assumptions were violated, Hotelling's T was used to test the effects of PBL instruction and traditional approach on students' conceptual and quantitative gas problems. The results showed that there were significant differences between the dependent variables in the teaching methods used (Hotelling's T=0,151, *F* (2, 73)=5,502; p<0.05; η^2= 0,131). Therefore, follow up ANCOVA was needed to decide which dependent variable in responsible for this significance. Table 3 and 4 provides the summary of ANCOVA comparing the mean scores of students' performances both in the experimental and the control groups with respect to the post-CPGT and post-QPGT scores, respectively.

The analysis showed that students' pre-CPGT scores have significant effects on their post-CPGT scores (F (1, 74) = 14,744; p<0.05 ;η2 = 0,167). The results also indicated significant treatment effects (*F* (1, 74) = 10,326; p<0.05; η^2=0,122). The students in the

Table 2. Descriptive statistics for pre-post-CPGT and QPGT scores

Group	n	Pre-CQGT		Pre-QPGT		Post-CQGT		Post-QPGT	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
CG	38	10.42	2.24	10.13	2.93	12.55	2.47	15.16	2.14
EG	40	10.23	1.85	10.52	2.52	14.05	2.30	15.80	2.31

CG: Control Group, EG: Experimental group

Table 3. **Summary of ANCOVA comparing the mean post-CPGT scores of the students in the experimental and the control groups.**

Source	df	Mean Square	F	P	η^2
Corrected model	3	50,637	11,598	0,000*	0,320
Intercept	1	110,379	25,282	0,000*	0,255
Instructions	1	45.081	10.326	0.02*	0,122
Pre-CQGT	1	64.589	14.744	0.00*	0,167
Error	74	4.366			
Total	78				
Corrected Total	77				

*Significant at p<0.05

Table 4. **Summary of ANCOVA comparing the mean post-QPGT scores of the students in the experimental and the control groups.**

Source	df	Mean Square	F	P	η^2
Corrected model	3	16,451	3,622	0,017*	0,128
Intercept	1	344,279	75,793	0,000*	0,506
Instructions	1	6,397	1,408	0.239	0,019
Pre-CQGT	1	25,800	5,680	0.020*	0,071
Error	74	4,542			
Total	78				
Corrected Total	77				

*Significant at p<0.05

experimental group who were subjected to PBL instruction demonstrated better performances (adjusted mean = 14,066) on post-CPGT scores than the control group students who were subjected to traditional instruction (adjusted mean=12,536).

The analysis showed that students' pre-QPGT scores have significant effects on their post-QPGT scores (F (1, 74)=5,680; p<0.05 ;η2= 0,071). The results also indicated that there is no significant treatment effects (F (1, 74)=1,408; p>0.05; η2=0,019) on the post-QPGT scores. This means there are no significant differences between the students in the experimental group who were subjected to PBL instruction and students in control group students who were subjected to traditional instruction.

DISCUSSION

The aim of PBL is to help students to think, to solve problems and to enhance their thinking skills by constructing real or resembling situations pertaining the concepts to be learned. This study aimed at investigating effects of Problem-Based Learning (PBL) instruction on pre-service teachers' performance on conceptual and quantitative problems about concepts of gases. The results show that although there is not a statistically significant difference between the quantitative success rates of pre-service teachers, there is a statistically significant difference between the conceptual success rates of pre-service teachers on the topic of gases. One of the most favorite research area among the studies on chemical education is the issue of how chemical topics were learned and how could the level of conceptual learning be increased. Recent studies (Markow and Lonning, 1998; Harrison and Treagust, 2001; Bilgin, 2006) show that the requirement of conceptual learning of chemistry by students is gaining importance. Several chemists perhaps share the opinion that the students have a tendency to memorize solution paths of algorithmic problems without realizing the conceptual knowledge contained in the problems (Beall and Prescott, 1994).

Learning activities prepared by the traditional problem solving approaches generally focus on a small part of a certain topic. PBL activities, on the other hand, require an organization since they have a wider scope. Although students are expected to reach a certain result in learning by problem solving approach, there is not such a definite expectation in PBL. The important point for students is to attain some of the learning objectives by making use of the problem whether or not they reach the certain correct answer (Savin-Baden, 2000). The traditional approach of teaching a concept involves the stages of the provision of the term that denotes the concept to the student, making the definition of the concept, stating the descriptive and discerning properties of the concept in order the definition to be understood, enabling students to find examples both related and unrelated to the concept. This approach is not sufficiently effective in teaching concepts since it is not enough for students to define concepts and memorize them in order for them to see the concepts and the relationships among them. One should enable students to discover scientific knowledge themselves and to discuss them among themselves by creating appropriate circumstances for them to work like scientists (Bodner, 1986). Thus, the students will gain the conceptual learning skills by avoiding the need to memorize them. Researchers have developed a variety of learning approaches, including PBL, in order to reach this aim.

The most prominent aim of the PBL is to make students active, free and self-learning individuals rather than being passive recipients of the knowledge (Barrows, 1986; Gallagher et al., 1995; Boud and Feletti, 1997). PBL also enables students to evaluate themselves while trying to help them to achieve this aim (Sullivan and Dunnington, 1999). Meanwhile, PBL approach requires working cooperatively (Duch et al., 2001). Its justification lies on the fact that gaining merits including trading information, communication and collaborative working skills will be helpful for students in their lives in the future (Cancilla, 2001). Students solve problem situations by working in groups. In this study, the participants of the experimental group were divided into ten heterogenic groups and the participants investigated the problem situations with their groups during the implementation. Students' working collaboratively in groups in PBL creates an appropriate environment for them to learn the concepts by providing them an opportunity to investigate others' comments and to discuss among themselves (Will, 1997).

Based on the findings of the study, following suggestions could be made;

1. The conceptual and quantitative success rates of mathematics pre-service teachers' on the topic of gases in the course of General Chemistry have been investigated by adopting a PBL approach. It is suggested that it might be helpful to investigate the effects of this approach on teaching other concepts in chemistry courses or the success rates of other courses and to examine its effectiveness in practice.
2. It is suggested that one could employ PBL approach in order to help students to develop their communicative and collaborative working skills and their skills on accessing information and utilizing it.
3. It is suggested that PBL could be useful in laboratory teaching since it includes a range of activities such as collaboration, comprehension and analysis of the events, developing hypotheses, collecting information and analyzing it and making experiments.
4. This study was made at undergraduate level. It is suggested that it might be helpful to investigate and collect data on how practical and implementable PBL is in other educational stages (primary and secondary schools).

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Appendix A. Three sample problem cases (scenarios) used in the study.

WATER PUMP

Working processes of water pump and suction pump base on air pocket. When arm of the suction pump is pressed, piston in the cylinder goes to up. The water takes the place of air pocket which occurs when the piston is pulled up. Thus water in the well can rise. Whatever pressure is applied to the arm of the water pump, water can't go up more than 10 m 33 cm..In the 1600's, the scientists began to research why water in the well can't be raised more than 10 m 33 cm. If they had accomplished to increase water level more than 10 m 33 cm, they would have utilized that in many areas. Because technological devices were very poor that days in comparison to today, water pumps were very important devices. One of the scientists studying in this matter was Torricelli who was Galileo's student. Thanks to his researches on this matter, Torricelli put forward that 1 atmospheric pressure equals 76 cmHg. How might be Torricelli attain this idea?

Key Words: Water pump, Torricelli, Atmospheric pressure

BUBBLES

Divers take scuba gear that contains compressed air (nitrogen-oxygen) when they dive in deep water. When actions of a diver who swims in deep sea are examined, it is seen that the bubbles depart from mouth of the diver and these bubbles rise up. It is seen that bubbles' volumes gradually increase while those are rising up and reach several times bigger than that in the beginning. There isn't any change in the chemical construction of the matter or matters inside the bubbles when those rise. What can be the reason(s) of the change of the bubbles' volume? (Assume that the temperature in the sea water remains the same as all points of the sea)

Key Words: Compressed air, Volume

CONFUSION OF AN ENGINEER

A chemical engineer wanted to carry out an experiment. For this experiment he needed nitrogen gas which had 135 atm pressure and 92,4 kg weight. The engineer had a vessel with $1m^3$ in which he could store the gas. But the engineer had 92,4 kg of nitrogen gas at 81 atm pressure at 300 K temperature. The engineer wonders how he could increase the pressure of gas to 135 atm without changing the volume and the amount of gas. In order to solve this problem, he conducted some mathematical calculations assuming that nitrogen behaving as an ideal gas. He found that if he heats up the gas to 500 K, the pressure of gas will reach to 135 atm. Once he heated the gas up to 500 K, the pressure of gas reached to 140 atm instead of 135 atm. The engineer confused and started to think about what was the mistake he made. What do you think about this case? Why the pressure of the gas become 140 atm instead of 135 atm at 500 K? (Assume that the engineer did not make any mathematical calculation mistake)

Key Words: Perfect gas, Pressure, Temperature

Appendix B. The contents of problem cases used in the study

Week	Class Time	Name of Problem Case	Explanations	The Target Concept
First Week	1	Water pump	Comprehension of the gas pressure by the help of open air pressure	Air Pressure Barometre Manometre
	2	Bubbles	Comprehension of the basic gas laws	The relationship between pressure and volume
	3	Soccer ball	Comprehension of the basic gas laws	The relationship between heat and pressure
	4	A journey at A hot weather	Comprehension of the basic gas laws	The relationship between heat and pressure
	5	The doubt of an Engineer	Comprehension of the properties of ideal a absolute gases	Ideal gas Absolute gas
Second Week	1	Balloons	Comprehension of the density relationships of gases Comprehension of the difference among solid, liquid and gas densities and gas densities	Gas densities
	2	Cars and air Pillows	Comprehension of the gas behaviour by investigating the chemical reactions where gases acts as reactants or end-products	Gases in chemical reactions
	3	A Bicycle pump	Comprehension of the events in the theory of gas kinetics	Kinesthetic theory
	4	Missing water	Comprehension of the events in the theory of gas kinetics	Kinesthetic theory
	5	Ammonia and ethyl acetate	Comprehension of the gas properties related to the theory of gas kinetics	Expansion of gases

Appendix C. Examples of Quantitative Problems

1) 0.1 mol hydrogen gas at 2.00 atm and 127 ^oC has 10 L initial volume. If the temperature of hydrogen gas is decreased to -23 ^oC under constant volume, what will be the new pressure of hydrogen gas?

a. 1.25 atm b. 1.5 atm c. 3.25 atm
d. 4.08 atm e. 5 atm

2) There is a helium gas with the volume of 5.51 dm^3 and pressure of 1.015 atm, and a temperature of 24 ^oC in a flexible balloon. When the temperature of the helium is increased to 35 ^0C, the pressure of the helium increases 1.028 atm. In this case, what is the new volume of the helium gas?

a. 4 b. 3.6 c. 4.6
d. 2.8 e. 5.54

3) The equation

$$\mathbf{Zn_{(k)} + 2HCl_{(aq)} \longrightarrow ZnCl_{2(aq)} + H_{2(g)}}$$

represents the reaction between zinc and hydrogen chloride to produce hydrogen. 156 ml of hydrogen is collected over the water at 20 ^oC and 769 mmHg. The pressure of the water vapor is 17.5 mmHg at 20 ^oC. What is the mass of the hydrogen that is formed in the reaction?

a. 0.5 g b. 0.0129 g c. 1.29 g
d. 2.129 g e. 0.789 g

4) A container with three gases, 8 g of methane (CH_4), 1.806 x 10^{23} molecules of nitrogen (N_2) and 0.5 mol hydrogen (H_2) has the temperature of 0 ^oC and the volume of 1.12 L. What is the partial pressure of the nitrogen?

a. 3 b. 4 c. 8 d. 6 e. 12

5) A gas at 350 K and 12 atm has a molar 12 per cent lesser than that calculated from the perfect gas law. Calculate the compression factor under these conditions.

a. 0,88 b. 1,14 c. 1,64 d. 1,25 e. 1,4

Examples of Conceptual Problems

1) Which of the following graphs don't show a linear relationship for an ideal gas?

a. T vs V graph (n and P are kept constant)
b. P vs T graph (n and V are kept constant)
c. 1/V vs P graph (n and T are kept constant)
d. 1/T vs n graph (P and V are kept constant)
e. 1/P vs n graph (V and T are kept constant)

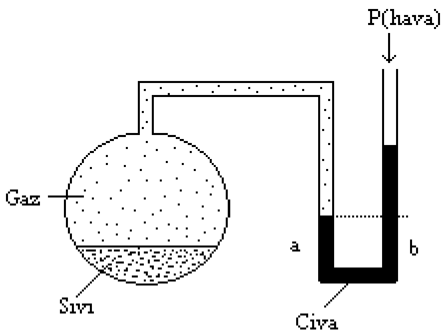
2) The nitrogen (N_2) and oxygen (O_2) with equal masses are placed in two identical containers that have same temperature. In this case, which is the following statement true?

a. The number of the molecules in each container is equal
b. The pressure in the container which contains the nitrogen is more than the pressure in the container which contains the oxygen.
c. The number of the molecules in the container which contains the oxygen is more than the number of the molecules in the container which contains the nitrogen.
d. This question can not be answered without knowing the masses of the nitrogen and oxygen.
e. None of the statement is true

3) Which of the following statements is not one of the basic assumptions related to the kinetic theory of gases?

a. Gases compose of a very large number of minute particles which move freely and rapidly through space
b. The radiuses of gas molecules are very small relative to the average distance between molecules. Therefore, most of the volume of a gas is empty area.
c. Until the gas molecules collide with each other and with the walls of the container, the molecules are in linear motion.
d. The mean kinetic energy of the gas molecules is proportional to the temperature of the gas.
e. All of the statement is true

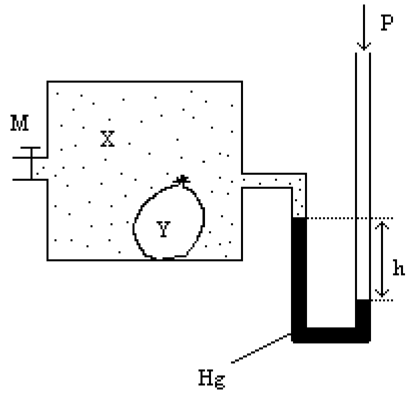
4) It was seen that the level of the mercury in the b arm of the manometer increased as time passed. What can be the reason of this increase?



a. Because the gas liquefied
b. Because the liquid evaporated
c. Because the gas solved in the liquid
d. Because the glass balloon was cooled
e. Because atmospheric pressure was increased

5) X gas and Y gas that is in a flexible closed balloon are in a container which is linked with a manometer. When the M tap is opened,

I. The levels of the mercury (Hg) equal in the arms of the manometer
II. Increases the height of h
III. The balloon in the container puckers



Which is (are) the statement(s) above true?

a) Only I b) Only II c) Only III
d) I and II e) I and III