ASSESSING THE EFFICACY OF COMPUTER SIMULATION IN IMPROVING PRE-SERVICE TEACHERS' CONCEPTUAL UNDERSTANDING OF CHEMICAL BONDING: A CASE STUDY

Solomon Boachie
St. Ambrose College of Education
P. O. Box 25 Wamfie
Ghana-West Africa
Email:solomonboachie@yahoo.com

Francis Quansah
Foso College of Education
P. O. Box 87 Foso
Ghana- West Africa
Email:azambus@gmail.com

Rita Asano
Agogo Presbyterian Women'
College of Education
P.O. Box 26
Agogo- Asante Akyemi
Email:ritaasano6@gmail.com

ABSTRACT

This study used computer simulation to enhance pre-service science teachers' proficiency in chemical bonding. The study's design was a case study employing a single group pre-test and post-test action research approach. A total of forty-four (44) first-year pre-service science teachers from St. Ambrose College of Education (SACE) who were enrolled in the general chemistry course made up the sample. The study involved a sample of forty-four (44) 100-level pre-service science teachers. Out of the 44 pre-service science teachers, 24 (54.56%) were men and 20 (45.46%) were women who participated. The pre-service science teachers in an intact class were chosen using a purposive sampling technique of the non-probability sampling procedure. For the intervention activities, lesson plans, worksheets, and computer simulation models were used as the teaching resources. The mean performance for the pre-intervention tasks was 3.14 (SD=1.07), and it climbed to a mean score of 6.60 (SD=1.15). This implied that the use of the computer simulation had enhanced pre-service teachers' conceptual understanding of chemical bonding as their average performance improved significantly following the intervention. The study found that the students' conceptual grasp of chemical bonding was improved by the incorporation of computer simulation. To demystify the abstractness of chemistry concepts and allay students' fears about studying chemistry, it is advised that computer simulation be employed in the teaching and learning of chemical concepts.

Keywords: Chemical- bonding, computer, simulation, improve, performance.
Corresponding Author:solomonboachie@yahoo.com

INTRODUCTION

The theory of multiple intelligences suggests that teachers need to widen their repertoire of teaching techniques and approaches in order to advance beyond the conventional verbal and logical approaches. According to Suleiman (2011), interactive simulation can be utilised as an organisational tool that supports and improves current educational pedagogy in addition to being a specialised treatment for one-sidedness in teaching and learning. Interactive computer simulations are a wonderful technique to teach kids at risk for learning challenges since they demand active participation, have a multisensory feel, and may capture all kids' attention. Studies show that in order to achieve the best results, students should actively participate in scientific classroom learning and must be able to apply the scientific principles they learn in the classroom to their everyday lives. By bridging the gap between chemistry as a molecular science and students' understanding, new approaches like computer simulation and molecular modelling are emerging tools that help students build molecular models of interest and visualise multiple representations like bond angles, lone pairs, and molecular shapes. This enables the transmission of explanations of a phenomenon in a variety of ways, conceptual comprehension is unquestionably a goal in science learning. In scientific education courses, computer simulations are widely used to help students get an early understanding of concepts and encourage problem-solving (Akpan, 2000). Strangman and Hall (2003) found that students who used computer simulations performed noticeably better on conventional topic knowledge tests. Although research suggests that computer simulation improves learning outcomes, little is known about how it is used in Ghanaian Colleges of Education to teach and learn about chemical bonding. In the light of this, this study is conducted to evaluate the effects of computer simulation in the chemistry teaching and learning process.

Statement of the Problem

Poor students' performance in chemistry is frequently attributed to a lack of practical experience during the teaching of chemistry due to the abstract character of several chemical concepts. Researchers are still working for a teaching method that will enable them to get around this practical hurdle. Although chemistry has received a lot of attention, students' performance in national exams remains poor in many countries (Mihindo et al., 2017). Unfortunately however, such poor performance have been attributed to the use of inappropriate teaching methods and the lack of hands-on experience as the main reasons for students' low performance in chemistry. Since chemistry is an activity oriented in nature, it should be taught experimentally. Undoubtedly, some chemical concepts cannot be taught in the classroom for low level kids through hands-on activities because of the experiments' inherent danger. These kinds of experiments can be demonstrated and viewed using video projections in the classroom. Some academics including Apkan (2002) and Lunce (2006) have therefore, campaigned for the use of computer simulations in scientific and mathematics classrooms that incorporates inquiry and cooperative learning. Following the administration of a diagnostic test on chemical bonding to pre-service teachers, the researchers found that the average performance of the research participants was below average. The researchers investigated how computer simulation may be utilized to enhance students' performance in chemical bonding in order to address students' problems.

Purpose of the Study

The purpose of this study is to determine the effectiveness of computer simulation in helping pre-service teachers better comprehend chemical bonding.

Research Questions

The following question guided the study:

1. How effective is the use of computer simulation approach in bettering pre-service science teachers' performance in the concept of chemical bonding?

A REVIEW OF THE RELEVANT LITERATURE

In today's climate, the learner's obligations have substantially increased. In a traditional classroom, the teacher stands in front of the group of students as they sit and pay attention. In some professional situations, learning by rote was sufficient, but today's technological world demands that employees apply higher-order reasoning skills to solve complex problems. Learners must now be viewed as active participants in their own education who are actively looking for new ways to scrutinise, probe, analyse, and comprehend their constantly changing surroundings (Carreon, Prieto, & Vega, 2006). Thanks to the diversity of scholars, technology advancements, and various instructor perspectives, innovative teaching is one of the solutions to the global demand for quality education (Bilbao et al., 2006). Chemistry instruction must include practical laboratory experiences, therefore technology should be used in addition to, not in substitute of, lab time. Computers can be utilised in the classroom to assist pre-service teachers in learning fundamental skills, according to research findings. These can be achieved by fusing text and multimedia, as well as by exemplifying curriculum goals via simulations and animations (Abdullahi, 2007). Computers can be utilised in three different ways, according to Usman (2002): as a tool, a tutee, and a tutor. When used as a tutor, the computer adapts to the student by choosing the best learning materials and monitoring academic progress. The computer receives and follows instructions from the student as a tutee (in the form of programming language). The computer is a useful instrument for calculations, graphic presentations, animations, simulations, and games. Varied authors have given simulations different interpretations; but, in a general sense, simulations are system imitations. Simulations are computer representations of real or imagined scenarios or natural phenomena that allow users to experiment with the effects of changing or altering parameters (Clark et al., 2009).

According to Plass et al. (2009), a simulation is dynamic as opposed to a static visualisation (for example, a figure in a textbook). Additionally, it enables for user engagement, which is another way it varies from a dynamic visualisation (animation). Therefore, computer simulations are computer-generated replicas of real-world objects. For task-based learning, computer simulations offer a nearly authentic setting, context, and situation (Chen et al., 2013). Learners can view events, processes, and actions that they would not otherwise be able to by actively participating in computer simulations. Previously, practical applications of computer simulations, such as in aviation and medical imaging, predominated; however, science classrooms are now using them more regularly.

In South Africa, it has been shown that using computer simulations to teach physics and electromagnetics improves student learning outcomes (Kotoka & Kriek 2014).

In their study, participants' outcomes in the experimental (N = 30) and control (N = 35) groups were compared. The experimental group considerably outperformed the control group on the post-test, according to the results of the t-test for independent samples (t-statistic = 3.58, degrees of freedom = 63, p 0.05). The experimental group performed superior to the control group when the test questions were broken down into their separate themes. Smetana and Bell (2012) assessed the merits of using computer simulations and hands-on (manual) laboratory exercises to support science instruction and learning, they provide detailed, evidence-based recommendations for optimal practices. In their recommendations, they indicated that computer simulations work best when they are employed as add-ons, high-quality support structures are included, student reflection is encouraged, and cognitive dissonance is encouraged. Computer simulations can engage students in inquiry-based, real-world scientific discoveries when used properly. Furthermore, as educational technology advance, benefits like flexibility, security, and effectiveness should be highlighted.

A similar study was carried out in Nigeria by Ezeudu and Okeke in 2013. The major goal of the study was to ascertain how computer simulation affects chemistry students' academic performance. As part of their quasi-experimental study design, the researchers adopted a non-equivalent control group design. Two coed secondary schools in the Awka Education Zone of Anambra State provided the 78 students for the sample, with 38 of them being in the experimental group (18 males and 20 females) and 40 being in the control group (16 males and 24 females). The Chemistry Achievement Test, which underwent a week-long pilot testing in a different zone, served as the instrument for data collection. The results were used to calculate the instrument reliability, which was calculated using Kuder Richardson Formula 20 to be 0.78. Koosom *et al* (2020). Another study found that using computer simulations helped students in Ghana understand more about hybridization. The study found that teaching and learning about hybridization were enhanced by computer simulation and computerised molecular modelling tools. In cooperative group settings, students performed better than they did in those that prioritise individualised instruction. The study advised that chemistry teachers be encouraged to employ computer simulation and computerized modeling software in a cooperative learning setting when teaching and learning hybridization in senior high schools.

Theoretical Framework

This study's theoretical foundation was social constructivism. Lev Vygotsky developed the social constructivist theory, which emphasises the value of culture and environment in comprehending what happens in society and building knowledge based on this understanding (Mckinley, 2015). The underlying presuppositions of social constructivism relate to reality, knowledge, and education (Kalina, 2009). Inter-psychological refers to the level of social interaction between individuals. Intra-psychological refers to the level of the individual within the kid. In the inter-psychological level, children learn through contact and interaction with others, and in the intra-psychological level, they assimilate and internalise this knowledge, giving it their own unique perspective.

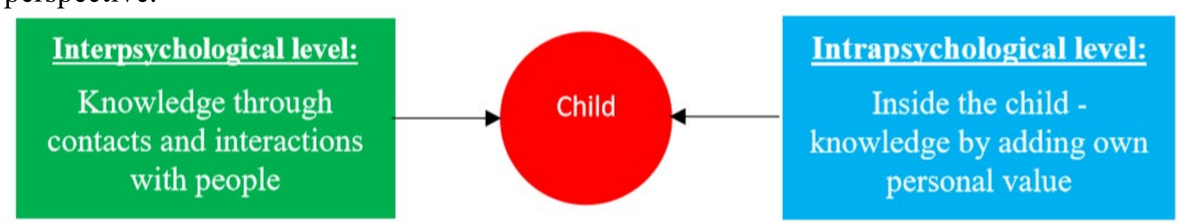


Figure 4: Social Constructivists Theory
Source: Jones and Araje (2002)

It is crucial to grasp the underlying assumptions of social constructivist instructional methods in order to apply and comprehend them.

- Reality: Social constructivists contend that human behaviour shapes reality. The characteristics of the world are jointly created by members of a community. According to social constructivism, reality cannot be discovered because it was created by society (Kalina, 2009).
- Knowledge: According to social constructivists, knowledge is socially and culturally formed and is also a human product. Through their relationships with others and their surroundings, people build meaning in their lives.
- Learning: Social constructivists believe that education is a social process. It does not simply occur within a single person, nor does it result from passively allowing one's behaviour to be moulded by outside factors. People learn more effectively when they participate in social activities.

METHODOLOGY

In order to change a condition that affected the entire class in a proactive and cooperative way, a case study with an in-class action research approach was used. A case study design enables in-depth research of an existing situation. Furthermore, it is helpful for determining if a theory or model accurately predicts phenomena in the real world. This image was carved onto a background upon which the investigation was built, Cohen and co. (2007). On the other hand, the action research offered opportunities for growth in both the teaching and learning. It has a cyclical structure and enables participants and researchers to continuously learn from one another. As it promotes a greater awareness of a situation with conceptualization and progresses through several intervention and evaluation phases, this offers opportunity for ongoing reflection. Again, it has the capacity to apply research and practice to address a challenge through enhancing student learning and classroom instruction. Additionally, it promotes the development of teachers' careers. This study's main objective was to improve pre-service science educators' performance and conceptual understanding of chemical bonding (Goodnough, 2010). The study used quantitative methods to collect and analyse data from two tests, the "Pre-Service Science Teachers' Chemical Bonding Concept Diagnostic Test (PTHCBDT)" and the "Pre-Service Science Teachers' Chemical Bonding Concept Achievement Test (PTHCBAT)," in order to ascertain how well the computer simulation would work to improve the pre-service science teachers' performance in chemical bonding. For pre-service teachers, lesson plans, worksheets, and computer simulation models were used as teaching aids. The primary goal of this study was to collectively enhance the performance of pre-service science instructors and their conceptual comprehension of chemical bonding (Goodnough, 2010). To determine how well the computer simulation would work to improve the pre-service science teachers' performance in chemical bonding, the study used quantitative methods to gather and analyse data from two tests: the (PTHCBDT) and the (PTHCBAT). The three types of computer simulation models used were ionic, covalent, and metallic bonding. The three simulations were modified from interactive simulations that were made available online by Physics Education Technology (PhET) (https://phet.colorado.edu/en/simulations/category/chemistry). Instead of the pre-service teachers operating the simulations individually, the teacher projected the simulations on the white board and created a virtual environment for the principles he presented. The concepts of ionic, covalent and metallic bonding were addressed in class.

Sample and Sampling Procedure

The study's primary audience was pre-service science instructors in the 100-level because the idea of chemical bonding was a required chemistry topic at this level. The research participants were sampled using a purposive sampling strategy with an intact class. The study involved a total of forty-four (44) 100-level pre-service science teachers, who gave informed consent and fully participated in the study. Of the 90 pre-service science instructors, 24 men (or 54.56%) and 20 women (or 45.46%) participated. The respondents' ages ranged from 20 to 24, with an average age of 22.

Research Instruments

Tests were the primary tool utilised to gather the data. Five weeks were employed for the study in total. Pre-intervention activities took up two of the weeks, while intervention activities—using computer simulation—took up the remaining three weeks. There were multiple choice questions in the tests. These inquiries were chosen with care from General Chemistry course code EBS 132 end-of-semester examination questions from the University of Cape Coast for the 2018–2021 academic year. There were two (2) sets of questions, consisting of ten (10) multiple choice items each for both pre-test and post-test covering the areas of ionic, covalent and metallic bonds. Each accurate response received one mark and a total score of 10 marks for each test. The pre-intervention test and post-intervention test each had a 30-minutes time duration.

Data Collection Procedure

The students took the Pre-Service Science Teachers' Chemical Bonding Notion Diagnostic Test (PTHCBDT) to ascertain their prior knowledge of the concept of chemical bonding. This was noted, scored, and kept track of. In order to give pupils a visual representation of chemical bonding, students were also led through computer simulations during the intervention stage. After the intervention activities which lasted for three (3) weeks, the same students were given the "Pre-Service Science Teachers' Chemical Bonding Concept Achievement Test" (PTHCBAT) to compare the pre-test scores and the post-test scores. This was done to ascertain the effectiveness of the computer simulations as interventional tool. The tests were graded, recorded, and marked.

Data Analysis

Data from the tests, (PTHCBDT) and (PTHCBAT), were analyzed quantitatively using descriptive statistics. Statistical Package for Social Science version 20.0 for window was used for data analysis.

RESULTS AND DISCUSSIONS

Analysis of Research Question (RQ)

Research Question One: How effective is the use of computer simulation approach in bettering pre-service science teachers' performance in the concept of chemical bonding?

In addressing the research question, students' test scores for both pre-intervention and post intervention were summarized in Table 1 and compared.

Table 1. Students' scores for pre-intervention test and post intervention test scores

Total, n=44	Pre-intervention Test Scores	Post-intervention test Scores
Mean	3.14	6.60
Median	3.5	6
Mode	4	6
SD	1.07	1.15
Range	3	4
Minimum	1	5
Maximum	4	9

SD= standard deviation

From the Table 1, pre-intervention test scores (activities) ranged from 1 to 4, with a mean of 3.14 (SD=1.07), whereas post-intervention test scores (scores) ranged from 5 to 9, with a mean of 6.60 (SD=1.15). The pre-intervention test (PTHCBDT), which was designed to establish the students' level of comprehension and entry behaviour for the concept of chemical bonding, showed that almost the entire class was unable to get an average score of 10. After the researchers helped the students with the computer simulation to learn chemical bonding, there was an improvement in their performance. A mean performance of 3.14 (SD=1.07) was obtained from the pre-intervention activities, and this increased to the mean score of 6.60 (SD=1.15). This suggested that pre-service teachers' conceptual comprehension of chemical bonding and overall performance had both increased as a result of the usage of computer simulation. This study's conclusions are consistent with those of numerous other global investigations ((Smetana & Bell, 2012; Ezeudu & Okeke, 2013; Koosom *et. al.,* 2020). This shows how the results of computer simulations can help solve problems. Finally, according to research by Koosom *et al.* (2020) and supported by the study's findings, the use of computer simulations increased students' learning outcomes in Ghana's hybridization programme. The study found that teaching and learning about hybridization were enhanced by computer simulation and computerised molecular modelling tools. In cooperative group settings, students performed better than they did in those that prioritise individualised instruction. When teaching and learning hybridization in senior high schools, it is encouraged that chemistry teachers use computer simulation and computerised modelling software in a cooperative learning context.

CONCLUSION

From the analysis of the study results, the computer simulation intervention technique has had positive effect on pre-service teachers' understanding of the concepts of chemical bonding (ionic, covalent and metallic), and this is evident in their improved performance in the post-test. This is a result of the teaching strategy's practical aspect and the three-dimensional figure's visual depiction of the principles. The study also showed that the addition of computer simulation improved students' conceptual knowledge of chemical bonding. To demystify the abstractness of chemistry concepts and allay students' fears about studying chemistry, it is advised that computer simulation be employed and adapted in chemistry teaching and learning.

REFERENCES

Abdullahi, L. (2007). Procedural knowledge in the presence of a computer algebra system: Rating the drawbacks using a multi – factorial evaluation approach*. International Journal for Technology in Mathematics Education, 14*(1), 14 – 20.

Akpan, J. P., & Andre, T. (2000). Using a computer simulation before dissection to help student learn anatomy. *Journal of Computers in Mathematics and Science Teaching, 19* (3), 297-313

Apkan, J.P. (2002). Which comes first: Computer simulation of dissection or a traditional laboratory practical method of dissection. *Electronic Journal of Science Education, 6*(4), 1-20.

Bilbao, P. D., Corpuz, B. B., Llagas, A. T., & Salandanan, G. G. (2006). *The teaching profession*. Lorimar Publishing Co, Inc.

Carreon, M.L., Prieto, N. G., & Vega, V.A. (2006). *Social dimensions of education*. Quezon City: Lorimar Publishing Co, Inc.

Clark, D.B., Nelson, B., Senguta, P., & D'Angelo, C. (2009). Rethinking science learning through digital games and simulations: Genres, examples and evidence. Paper Presented at the National Research Council Workshop on Gaming and Simulation, Washington, DC.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education*. London, United Kingdom: Routledge.

Ezeudu, F.O., & P.E. Okeke, 2013. Effect of simulation on students' achievement in senior secondary school chemistry in Enugu East local government area of Enugu State. *Journal of Education and Practice, 4*(19), 84 – 89.

Goodnough, K. (2010). Teacher Learning and Collaborative Action Research: Generating 'knowledge-of-practice' in the context of science education. *Journal of Research Science Teacher Education, 21*, 917-936

Jones, M., & Araje, L. (2002). Vygotsky's social constructivists theory of learning. *American Communication Journal*, *5*(3), 1–3.

Kalina, C. (2009). Cognitive and social constructivism: developing tools for an effective classroom. *Education*, *130*(2), 241–250.

Koomson, C. K., Safo-Adu G., & Antwi, S. (2020). Utilising Computer Simulation and Computerised Molecular Modeling Software to Enhance the Teaching and Learning of Hybridisation in Senior High Schools. *International Journal of Chemistry Education, 4*(1), 044-055.

Kotoka, J., & Kriek, J., (2014). The impact of computer simulations as interactive demonstration tools on the performance of grade 11 learners in electromagnetism. *African Journal of Research in Mathematics, Science and Technology Education, 18*(1), 100 – 110.

Mckinley, J. (2015). Critical Argument and writer identity : social constructivism as a theoretical framework for EFL academic writing. *Critical Inquiry in Language Studies*, *12*(September), 184–207.

Mihindo, W.J., Wachanga, S.W., & Anditi, Z.O. (2017). Effects of computer based simulations teaching approach on students' achievement in the learning of Chemistry among secondary school students in Nakuru sub country, Kenya. *Journal of Education and Practice, 8* (5), 65 – 75.

Plass, J.L., Homer, B.D., & Hayward, E.O. (2009). Design factors for educationally effective animations and simulations. *Journal of Computing in Higher Education, 21*(1), 31 – 61.

Smetana, L. K., & Bell, R. L. (2012). Computer simulations to support science instruction and learning: A critical review of the literature. *International Journal of Science Education*, *34*(9), 1337-1370.

Strangman, N., & Hall, T. (2003). *Virtual reality/simulations*. Retrieved September 16, 2019, from http://www.cast.org/publications/ncac/ncac_textrans.htm

Suleiman, M. A. (2011), Students integrated science achievement as predicator of later achievement in chemistry. A case study of selected schools in Zaria Metropolis, Scholar Research library, *Achieves of Applied Science Research 3(4). Retrieved from http:/ scholar research library.com/html*

Usman, K.O. (2002). Computer competencies required of mathematics teachers for the use of computer in teaching mathematics in Nigeria. (Unpublished Doctoral Dissertation). University of Nigeria, Nsukka.

Appendix I: Pre-Service Science Teachers' Chemical Bonding Concept Diagnostic Test" (PTHCBDT). This pre-test seeks to find out your conceptual understanding of chemical bonding through the use computer Simulation. This exercise is being conducted for research purposes only; and because of this, marks obtained on the test will be treated confidentially. Thank you for your co-operation.

Bio-data of the respondent: Pre-service Science Teachers'

Code……………………………………………………… Gender: Male ☐ Female ☐ Age

Instruction:

Circle the correct option to each item provided. Answer all the questions on this paper for 0 marks.

Duration: 30 minutes

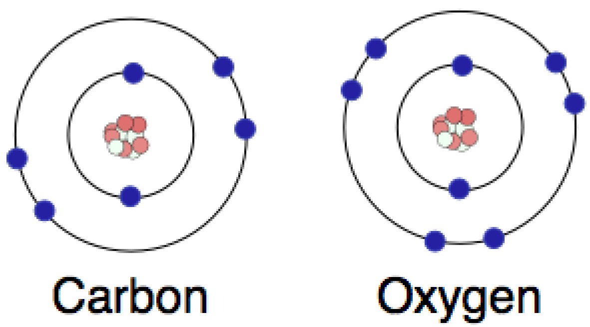
. Which of the following statement is true about ionic compounds?
A. Ionic compounds conduct electricity when dissolved in water.
B. Ionic compounds are not soluble in water.
C. Ionic compounds are crystalline solids.
D. Only A and C √

2. Which of the following property is not of ionic compound?
A. Solubility in water
B. High melting and boiling points √
C. Electrical conductivity in solid state
D. Electrical conductivity in molten state

3. What is an ionic bond?
A. Ionic bond is formed by sharing of electrons between two atoms.
B. It is a bond formed by the transfer of electrons from one atom to another. √
C. Both A and B are correct
D. None of the above

4. Which one of the following pairs atoms is most likely to form an ionic bond?
A. Na and F √
B. C and F
C. N and F
D. O and F

5. Oxygen has six electrons in its outer shell and needs two more to have a full outer shell. Carbon has four electrons in its outer shell and needs four more electrons to fill its outer shell. How many atoms of oxygen will combine with one carbon atom so that each has a full outer shell of electrons?



A. Three oxygen atoms
B. One oxygen atom
C. Two oxygen atoms √
D. Neither of the other answers is correct

6. What is meant by a covalent bond?
A. The sharing of protons between atoms.
B. The transfer of electrons between two atoms.
C. The attraction between two oppositely charged ions.
D. The sharing of electrons between atoms. √

7. Of the following molecules listed below, which of them contains a triple covalent bond?
A. H_2
B. N_2 √
C. O_2

D. NH_3

8. Covalent bonds are least likely to be formed................................
   A. between atoms of the same element
   B. between atoms of different elements on the right of the periodic table
   C. by head of the group elements with high ionisation energies
   D. between an element in Group I and an element in Group VII √
9. A mixture of two or more metals is called……..
   A. solution
   B. mixture
   C. alloy √
   D. compound
10. Why do metals conduct electricity?
    A. they are shinny
    B. electrons become delocalized and are able to move √
    C. electrons are held tightly within the lattice
    D. electrons are shared between two metal ions 1

Appendix II: "Pre-Service Science Teachers' Chemical Bonding Concept Achievement Test" (PTHCBAT) Purpose: This pre-test seeks to find out your conceptual understanding of chemical bonding through the use computer Simulation. This exercise is being conducted for research purposes only; and because of this, marks obtained on the test will be treated confidentially. Thank you for your co-operation.

Bio-data of the respondent: Pre-service Science Teachers'

Code…………………………………………….…Gender: Male ☐ Female ☐ Age

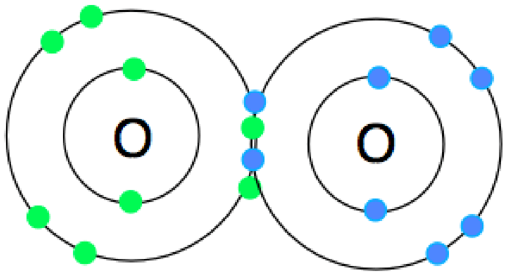
Instruction:

Circle the correct option to each item provided. Answer all the questions on this paper for 10 marks. Duration: 30 minutes

1. A chemical bond formation that involves the complete transfer of electrons between atoms is ________
   A. ionic bond √
   B. covalent bond
   C. metallic bond
   D. partial covalent bond
2. Ionic bonds easily form when electron when ionization energy of the metallic atom is _____ comparatively.
   A. negative
   B. constant
   C. more
   D. less √
3. Which of the following molecule's formation doesn't include ionic bond?
   A. LiCl
   B. MgO
   C. $SnCl_4$
   D H_2O √
4. The atomic number of four elements P, Q, R, S are 6, 8, 10 and 12 respectively. The two elements which can react to form ionic compounds are:
   A. P and S

B. Q and R
C. P and R
D. Q and S √

5. Which one of the following properties does not belong to a covalent substance?
   A. Soft solid and a very poor conductor of electricity.
   B. Insoluble in water and does not conduct electricity.
   C. High melting point and a brittle solid. √
   D. Liquid with a low boiling point.
6. In covalent compounds, electrons are ...., while in ionic compounds, electrons are .... What two words are missing?
   A. Shared and transferred respectively √
   B. Gained and lost respectively
   C. Shared and gained respectively
   D. Transferred and shared respectively
7. How many electrons are shared in a double covalent bond?



   A. 1
   B. 2
   C. 4 √
   D. 6
8. Which one of the following is not true of metallic bonding?
   A. it gives rise to excellent electrical conductivity
   B. electrons are free to move throughout the structure
   C. the strength of metallic bonds increases down a group √
   D. the strength of metallic bonding affects the boiling point of metals
9. I can hit a metal with a hammer without the metal shattering because of its
   A. ductility
   B. conductivity
   C. malleability √
   D. lustrousness
10. Metals like to ………………………………… electrons
   A. gain
B. lose √
   C. juggle
   D. anhilate