TEACHING ATOMIC CHEMISTRY TO YOUTUBE GENERATION

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ABSTRACT

YouTube, arguably the most powerful website for video-sharing, is popular not just for entertainment, but for education as well. Next to social networking sites, YouTube is the most visited site by millennials on a daily basis. Given its power and popularity among the screen generation, educators now tap it as valuable teaching resource not just for online and distance learning but for blended and regular face-to-face classroom set ups too. This study took a closer look at the impact of YouTube-available videos among high school students. It specifically measured the effect of these supplement materials to student conception of atomic chemistry, particularly the history and development of atomic models and theories which is one of the most difficult topics to teach in high school general chemistry. This research used five YouTube-available videos about atomic chemistry, chosen based on content, relevance, delivery, and running time. A total of 82 students were purposively chosen as subjects of the experiment and were randomly assigned to particular video to watch. Using a pre-and-posttest scheme to measure students' understanding of chemistry concepts, triangulated with their perceived effectiveness and teacher observations during the conduct of experiment, this research shows that the five chosen YouTube videos were effective in enhancing student conception by visually showing how the experiments helped explain the structure of the developing atomic models, and promote positive attitude towards learning chemistry through its clarity, simplicity, organization, audio-visual appeal, and humor which students find enjoyable and interesting to learn from.

Keywords: Atomic chemistry, 21st century learning, mobile learning, technology-enhanced learning, YouTube education.

INTRODUCTION

Two important questions a teacher must ask himself: how do my students learn and why learning occurs? Known today as *21st century learners*, students are now described as having these three most basic skills: the life and career skills, the ICT skills, and the leaning and innovation skills known as 4Cs to us educators: critical thinking, communication, collaboration, and creativity. This framework put together by the organization called Partnership for 21st century learning suggests that schools today should move beyond traditional space-and-time-bound classrooms toward virtual environments that serve children as the demands of their lives require (Franklin and Kariuki, 2009).

The transition from traditional chalk-and-talk lecture method, where the teacher is the source and students are passive receivers of information, to modern teaching that is learner-centered and output-based, is one of the milestones in the history of education. Teaching strategies has never been so varied, innovative, and engaging than what we have today. Though there is not one effective teaching strategy for everybody, we cannot deny the fact that in this digital age where everything moves fast-paced, e-learning is getting our attention, especially in educational research.

According to UP Open University, e-learning is referred to as the intentional use of networked information and communication technology (ICT) in teaching and learning. From its humble beginning in 1924 when the first testing machine was used, to computer-based and computer-assisted instruction in 1960s, now it's becoming wireless and students are now called *mobile learners* (Alfonso, n.d.). With the use of internet from their personal computers (PCs), now learning can happen anytime, anywhere as long as they are "connected". Mobile devices are now equipped with programs and applications that can be both useful and entertaining. In a recent survey, YouTube which got activate only in February 2005, is among the most downloaded and most used mobile applications with over 5 billion users to date. Serving as the biggest host of videos on the planet, it is now the world's second largest search engine, and third most visited site after Google and Facebook. With over 1 billion mobile views per day, it is estimated that people spend twice as much time watching YouTube than on their television (Smith, 2019). YouTube and other internet-based sources are fresh and innovative technology media that teachers use to have a new educational tool that speaks to the students of the new millennium and is geared towards the learning style of those who are more comfortable and accustomed to the online environment (Burke, Snyder, and Rager, 2009).

This paper aims to discuss the initial steps of exploring the impact using YouTube educational videos to supplement classroom instruction in teaching chemistry by quantifying its effect on student understanding of atomic models and theories. Most importantly, it intends to contribute to the promotion and strengthening of innovations in teaching chemistry by tapping the remarkable power of Web 2.0.

OBJECTIVES

This research aimed to determine the effect of YouTube videos as supplement materials to student conception of atomic chemistry, particularly the history and development of atomic models and theories. Specifically, this study sought to answer the following questions:

1. How did YouTube videos affect the students' conceptual understanding of atomic chemistry?
2. How did YouTube videos affect student attitude?

METHODOLOGY

This study used a mixed method type research that incorporates quantitative data and qualitative data for a more thorough investigation of the effect of YouTube videos on student learning and engagement. To attain the objectives of this research, a pre-and-post-test design illustrated in figure 1 is adopted to measure the effect of YouTube videos on student conceptual understanding. The results of perception survey to determine the perceived effectiveness of these video materials on student's conceptual understanding as measured by Spearman rho correlation.

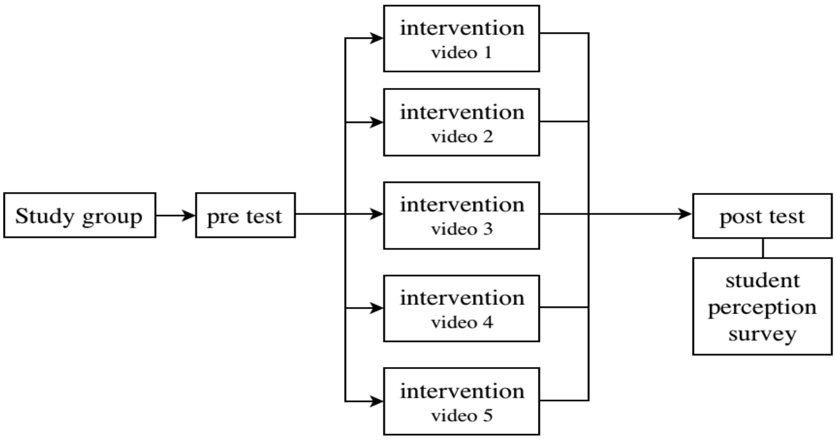

Figure 1. Conceptual Framework of the study

While YouTube offers vast materials as a teaching tool, Burke, Snyder, and Rager (2009) noted that this new technology does have some limitations and challenges, particularly searching for appropriate or content-specific clips. This, according to them may be challenging and time consuming for teachers as YouTube has over 5 billion videos uploaded every day. Through several years of teaching chemistry the researcher has curated several digital resources, including YouTube videos used for instructional content. In order to shortlist which videos to use for this particular study, Beaudin and Quick (1996) recommend that videos used for viewing requires evaluation based on reliable, accurate, and complete information to be more effective and useful material for students. For the purpose of this experiment, a researcher-made checklist is done based on the instructional video evaluation instrument developed by Beaudin and Quick, but modified to suit the lesson objectives and what the users need for the class (see appendix A), as Burke, Snyder, and Rager (2009) noted, instructors should be discriminating regarding the selection of videos to be used in their subject.

Students were given a 19-item multiple choice type test (see appendix B) at the beginning of the class period. Then, they were randomly assigned to watch a video about history and development of atomic models and theories. The table below shows the shortlisted five YouTube videos used in this study as well as their sources.

Table 1. Student assignment to five YouTube videos used in the study

Group No	Video tag	Title of the YouTube video	Source (YouTube channel)
1	video 1	How protons, electrons, neutrons were discovered	Ian Stuart
2	video 2	Chemistry and Physics History of the atom	Socratica
3	video 3	History of the atom (atomic theory)	The Science Classroom
4	video 4	Models of the atom timeline	Tyler DeWitt
5	video 5	The history of atomic chemistry	CrashCourse

Thirty minutes were allotted for the intervention, after which a post-test and perception survey were administered to the students. Since the materials used differ in video length (time), and that video materials offer control of learning experience (Duffy, 2008), the students were instructed to make use of the 30-minute time allotment to pause, take down notes and replay within the duration.

RESULTS AND DISCUSSIONS

Characteristics of the Research Subjects

This research was conducted among 81 grade 8 students of a laboratory high school in Laguna taking up Chemistry in Integrated Science 8. Their ages range from 13 to 15 years (M = 13.5, s = 0.57) They were randomly assigned to each section upon enrollment. The table below summarizes the demographics of student participants.

Table 2. Demographics of research participants

Characteristics		N	%
Gender	Male	37	45.68%
	Female	44	54.32%
Age	13	43	53.08%
	14	35	43.21%
	15	3	3.71%
Smart phone user	Yes	72	86.75%
	No	11	13.25%

Data summarized in Table 2 show that majority of the research sample are early teenagers who own and use mobile phones in surfing the internet, and spend an average of 17.52 hours a week surfing the internet mainly for research and social networking. This information tells how technologically-dependent students are when it comes to studying. Survey results show that most students utilize the smartphones and tablets in taking down notes, capturing images from the board or presentation slides, downloading lecture handouts uploaded on the internet and using social networking sites to virtually meet with groupmates for take home group works among many other requirements. These characteristics are what constitutes a *screen generation*, or the *digital natives*. They are the native speakers of technology, fluent in the digital language of computers and the internet who prefer on-demand" access to media and expect instant responses and feedback (Prensky, 2001) and who want freedom in everything they do, particularly freedom of choice or control over their environment (Kay, 2012). The most recent title given to them are the *YouTube generation* and *Gen C* or *generation connected*. This generation is swiftly and radically changing learning approaches by engaging with internet-based learning materials and sharing their knowledge freely using online platforms, by creating and publishing blogs, podcasts, and videos mostly in social media and in YouTube (Barry, Marzouk, Chulak-Oglu, Bennett, Tierney, O'Keeffe, 2016).

The primary objective of choosing five YouTube videos as intervention is to find suitable teaching strategy that will suit the kind of students described above. The impact of these five videos on students' conceptual understanding and attitude will be discussed in the following sections.

Effect on Conceptual Understanding

Comparison of the pre- and post-test scores showed that all five videos resulted to increase in conceptual understanding for most students, as measured by the knowledge gain. As reflected in high percentage of students in each group, group 3 has the lowest positive knowledge gain (n=13 or 81%) and group 5 has the highest with 100% of students obtaining positive knowledge gain. Overall, 71 out of 81 or 89% of students have positive knowledge gain after integrating

YouTube videos in science class. In addition, there is an average of 3.81 point increase in the student test scores (out of 19 test items), which translates to an average of 62.17% increase of student's pretest score. Using test scores as basis to measure students' conceptual understanding, it can be inferred that students in group 2 and group 5 gained the most knowledge with 4-point or 75-78% increase in their test scores after watching the chosen videos assigned to them [Group 2: *Physics and chemistry history of the atom* (Socratica, 2014); Group 5: *The history of atomic chemistry* (Crashcourse, 2013)].

Table 3. Percentages of conceptual understanding measured as knowledge gain

Knowledge gain	Percentage Vid 1 n=16	Vid 2 n=16	Vid 3 n=16	Vid 4 n=18	Vid 5 n=15	Overall n=81
positive	81	94	81	89	100	89
zero	6	6	9	5.5	0	7
negative	13	0	0	5.5	0	4
mean score gain	2.88	4.88	3.50	3.72	4.11	3.81
mean percentage gain	49.06	74.86	56.3	54.50	78.11	62.17

To further this analysis, the pre- and post-test results of the students were compared and analyzed using paired t-test. Table 4 shows the statistical analysis for all the videos used in this study. At 95% level of confidence, the result of the paired t-test showed that all videos resulted to a significant increase in students' scores. This implies that the use of the five chosen YouTube videos is effective in increasing conceptual understanding of the students.

Table 4. Descriptive statistical analysis of pre- and post-test results

	Mean	N	SD	Std Error Mean	Paired Diff mean	t	df	Sig (2-tailed)
of students who watched video 1								
Pre-test	7.6875	16	2.6763	.66907	2.8750	4.505	15	0.000*
Post-test	10.5625	16	2.4213	.60532				
of students who watched video 2								
Pre-test	7.3750	16	1.8574	.46435	4.8750	7.800	15	0.000*
Post-test	12.2500	16	2.1756	.54391				
of students who watched video 3								
Pre-test	7.1875	16	2.2574	.56435	3.5000	5.317	15	0.000*
Post-test	10.6875	16	2.9826	.74565				
of students who watched video 4								

Pre-test	8.6667	18	2.6568	.62622	3.7222	4.858	17	0.000*
Post-test	12.3889	18	2.8726	.67707				
of students who watched video 5								
Pre-test	6.9333	15	2.2824	.58932	4.1333	6.469	14	0.000*
Post-test	11.0667	15	2.2824	.58932				

*p<0.05

As all five videos were proven effective in increasing conceptual understanding, data were analyzed using one-way analysis of variance to establish whether there is significant difference on the impact these five videos bring. Table 5 shows that the obtained p-value is 0.122 which is less than 0.05. From this, it can be inferred that, at 95% level of confidence, the test scores of students who watched these five different videos are not significantly different.

Table 5. Analysis of Variance of the five YouTube videos used in the study

	SS	df	Mean Square	F	p value
Between Groups	50.142	4	12.536	1.884	0.122
Within Groups	505.586	76	6.652		
Total	555.728	80			

*p<0.05

The results of this study were supported by the research of Choi and Johnson (2005) According to them, video-based instruction was more memorable than the traditional text-based instruction as videos convey information or knowledge in a more interesting way that help learners remember the content more easily. The use of audio and visual symbols in videos provide complementary information that aids memory and learning. This, according to them may be because the representations derived from both auditory and visual symbol systems serve as building mental models, hence the information obtained visually becomes more memorable. In addition, videos that allow for interaction kept students motivated and engaged, which positively influenced student learning. Their study implies that context-based videos have the potential to enhance learners' attention, retention, and motivation.

It important to note that the effect of educational videos on conceptual understanding varies depending on the level of cognition. The result of the pre- and post- test in different level of cognition is presented in Table 6. Using Bloom’s taxonomy, the test items were categorized depending on the level of cognition. As this taxonomy offers a spectrum of the process of learning and identifies learning progression, it definitely helps distinguish between the different types of knowledge involved in knowledge acquisition in line with educational and instructional objectives (Krathwohl, 2002). The 19-item multiple choice conceptual test were then categorized into three, (1) remembering level - which tests for recalling facts, (2) understanding level - for examining, interpreting, and arranging ideas chronologically, and lastly (3) applying level, which measures student interpretation and translation of ideas. As shown in table 6, there are positive mean differences between pre and post test scores for remembering (MD = 21.16) and understanding levels (MD = 31.44), meaning the YouTube videos used to supplement chemistry classes were very effective in increasing knowledge gain for test items that assess student cognition that require them to recognize, recall, interpret, compare and explain information retrieved from their memory. Note, however, that there is larger difference for understanding level where students are asked to arrange discoveries in chronological order, than with declarative knowledge or recall of facts. This result is supported by a similar study conducted by Höffler and Leutner in their 2007 meta-analysis study of instructional animation versus static pictures where they found that animation was significantly more effective than static graphics for learning factual and conceptual knowledge, and for the cognitive activities of remembering, understanding and applying.

Table 6. Descriptive statistics of pre- and post-test result in the different cognition level

Cognitive Levels	Items in the Test	Mean Percentage		Mean Difference
		Pre-test	Post test	
REMEMBERING retrieving relevant facts (definition, description, association)	1, 2, 3, 4, 5, 6,7,9, 10,11,12,13,15	37.45	58.61	21.16
UNDERSTANDING interpreting, explaining (arranging ideas in chronological manner)	16-19	43.45	75	31.44
APPLYING implementing/translating ideas to predict or infer	8,14,	44.05	40.26	-3.79

Furthermore, there is negative 3.79 mean difference for applying level test. This result suggests that some students even got their previously correct answer, incorrect after watching the video. It means they either got confused, or they misinterpret something from the video material they consumed. The interpretation or translation of ideas requires higher order thinking skills. Berney and Bétrancourt (2016) suggest that while animation should be particularly beneficial for memorizing and understanding dynamic systems by depicting how its parts or elements are integrated to build organized representation, animations can also be challenging because of the amount of information to be processed that could lead to difficulty perceiving all the simultaneous stimuli animations present. In order to avoid misconceptions and misinterpretations, ideas and inferences need to be communicated through actual discussions which require guidance from a teacher. In addition, Pekdağ (2010) suggested that designs for educational tools that use ICT must be appropriate to the student's level of knowledge, and must also consider students' prior knowledge so as not to cause a disconnect and cognitive overload.

Learning environments that involved information and communications technology (ICT), as Pekdağ (2010) thoughtfully synthesized from various researches, allow students to be able to form successful relationships among the macroscopic, molecular, and symbolic levels of representation in chemistry. This is because ICT provide students the opportunity of improving their conceptual understanding and forming mental models of high quality. In addition, ICT supports student-centered learning that improves student comprehension, and promotes more effective and meaningful way of learning.

Effect on Student Attitude

Results from perception survey revealed students have positive attitude towards the use of YouTube videos in class. Most students have positive perception of the YouTube videos shown by an overall median score of 4 of a 5-point Likert scale perception survey questionnaire which looked into the learning effectiveness, motivation, and emotional engagement. The highest reported feedback is generated from the learning effectiveness the videos bring which earned 3.5-4.5 median rating as shown in the table 7. *Tyler DeWitt's models of the atom timeline* (2012) is perceived to be the most effective among the five, mostly attributed for the logical and organized manner of discussion of atomic chemistry concepts that help students acquire new knowledge, understand concepts easily, and clarify misconceptions. Meanwhile, *CrashCourse's history of atomic chemistry* (2013) is perceived to be the most motivating and engaging as shown by the consistent high rating median rating in 5 five specific descriptions summarized below. All in all, students recommend all the five videos to be used again as teaching-learning tool for chemistry class.

Table 7. Student perception on the use of YouTube videos

Criteria	Median Rating					
	Vid 1	Vid 2	Vid 3	Vid 4	Vid 5	Overall
LEARNING EFFECTIVENESS	4.0	4.1	3.8	4.3	4.0	4.0
discussing concepts clearly	4	4	4	4	4	4
conveying lessons logically and in organized manner	4	4.5	4	5	4	4
helping acquire new knowledge in atomic chemistry	4	4	4	4.5	4	4
making students understanding concepts easily	4	4	3.5	4	4	4
clarifying misconceptions	4	4	4	4	4	4
helping improve performance in test	4	4	3.5	4	4	4
MOTIVATION	3.0	3.0	3.0	3.8	4.0	3.0
increasing interest in atomic chemistry	3	3	3	4	4	3
encouraging to learn further	3	3	3	3.5	4	3
EMOTIONAL ENGAGEMENT	3.7	3.7	3.5	3.7	4.0	3.7
has good audio-visual impact	4	4	3.5	4	4	4
is enjoyable to watch	3	3	3	3	4	3
is recommendable tool for teaching/learning chemistry	4	4	4	4	4	4

As synthesized by Turkgoguz (2012), a number of studies proved that using visual media tools in the general chemistry laboratory provides a positive contribution to students' behaviors and improves students' interest in learning and attitude towards chemistry. As seen in table 8, students in group 3 seem to agree that *the science classroom's history of the atom* video assigned to them is effective in discussing concepts clearly as shown in its strong positive correlation with student's post test scores. However, students' positive attitudes towards these educational YouTube videos do not necessarily mean they would get higher scores in test. These are shown by mostly weak positive correlation between students' test scores and answers in perception survey computed using spearman rho correlation in the other four videos used in the study. Nonetheless, it is still worth considering the positive effects of videos to students' motivation and engagement as they both influence learning and retention.

Table 8. Correlation between post test result and student perception

Perceived effectiveness of the educational videos in:	Spearman rho (r^s) Vid 1	Vid 2	Vid 3	Vid 4	Vid 5	Overall
discussing concepts clearly	0.05	0.19	0.74#	0.24	0.04	0.21
conveying lessons logically and in organized manner	0.14	0.34*	0.35*	0.28	0.08	0.27
helping acquire new knowledge in atomic chemistry	0.31*	0.28	0.34*	-0.38*	0.52*	0.24
making students understanding concepts easily	0.14	0.22	0.44*	-0.08	0.61*	0.25
clarifying misconceptions	-0.04	0.38*	0.27	0.02	0.53*	0.24
helping improve performance in test	-0.27	0.29	0.50*	0.18	0.33*	0.26
increasing interest in atomic chem	0.45*	0.52*	0.04	0.61*	0.29	0.34*
encouraging to learn further	-0.13	0.48*	-0.07	0.46*	0.30	0.18

Strength of correlation: #strong *moderate weak

CONCLUSIONS AND PEDAGOGICAL IMPLICATIONS

The results of this study have positive implications in education, particularly toward enhancing the 4Cs of the 21st century learning. As Chemistry is a field that benefits the most from visualizations among other natural sciences because it often requires understanding complex systems which consist of many components evolving over time (Berney and Bétrancourt, 2016), videos now become valuable tools in teaching and learning chemistry concepts. As Isman Yaratan, and Caner (2007) pointed out, "[the] key to the success of science education is the use educational technology which can greatly enhance a student's understanding of science concepts. This study proves that use of video promoted positive attitude and enhanced student conception as it concretizes the abstractness of chemistry concepts. This and other educational technology tools can take a difficult to learn science concept easier to understand and remember. The fact that all of the participants in this study recommend the use of educational videos in chemistry class mean that educators should consider this in lesson and curriculum planning in order to cater to the needs of the learners (Pekdağ, 2010). When appropriate teaching strategies suit the needs and preferences of the students, learning becomes more student-centered as students gain control over their own learning (Burke, Snyder, and Rager, 2009), like their choice to pause and repeat certain parts of the video in order to understand better or to interact with it. In the part of the teacher, videos support innovations in teaching chemistry, and it bridges the gap between the X-generation teachers and the 21st century learners. This study encourages the use of videos in chemistry classes, especially on topics that deal with atomic and molecular levels. The need to provide continuing education for teachers in integrating videos and other ICT tools in their classes if of greatest importance, today more than ever. The goal is not just to teach faculty how to use the technology but more importantly how to choose the right methods and strategies to be used in the teaching environment where technological tools are employed. As teachers are the forefront of pedagogical change, they should be the first to use and experience the benefits of using technology in their classrooms.

RECOMMENDATIONS

This research is limited to the use of YouTube videos in studying atomic chemistry which usually last for 1-2 sessions only. In this regard, the researcher recommends the following (1) to employ the same intervention method for a longer period of time, (2) considering other topics in chemistry perceived to be most difficult to learn; (3) similar study may seek to establish the effect of multiple viewing time on student conception and perception towards the video material; future studies may include (4) gender, (5) age and (6) ICT skills as intervening factor.

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APPENDICES

Appendix A: Instructional video evaluation instrument

Criteria	Rating
accuracy (up to date)	
bias-free	
met the objectives of the lesson	
completeness of intended content	
1. atomic theory	
2. models of the atom	
3. experiments that led to the discovery of subatomic parts	
learner interaction	
learner reflection	
visual quality	
audio quality	
audio-visual relationship	
use of time	

Appendix B: Conceptual Test

Direction: Choose the letter that corresponds to the BEST ANSWER. Write the CAPITAL LETTER on the blanks before each number.

_______ 1 Experiments with *cathode rays* led to the discovery of the

A. proton B. nucleus C. neutrons D. electrons

_______ 2 Who explained the behavior of positively charged particles being deflected from a metal foil as the nucleus?

A. Earnest Rutherford B. John Dalton C. Neil Bohr D. Joseph John Thomson

_______ 3 The gold foil experiment led to the discovery of the

A. proton B. nucleus C. neutrons D. electrons

_______ 4 In the gold foil experiment, most of the particles fired at the foil

A. bounced back B. passed through the foil C. were absorbed by the foil D. combined with the foil

_______ 5 What did Earnst Rutherford conclude about the structure of the atom?

A. An atom is indivisible
B. Negatively charged electrons are scattered in an atom
C. An atom carries a positive charge
D. Atom contains a small, dense, positively charged central region

_______ 6 What did Joseph John Thomson conclude about the structure of the atom?

A. An atom is indivisible
B. Negatively charged electrons are scattered in an atom
C. An atom carries a positive charge
D. Atom contains a small, dense, positively charged central region

_______ 7 A subatomic particle that has about the same mass as a proton,but with no electrical charge is called __________.

A. nucleus B. electron C. neutron D. isotope

_______ 8 Bohr's theory helped explain why __________.

A. electrons have negative charge
B. most of the mass of the atom is in the nucleus
C. excited hydrogen gas gives off certain colors of light
D. atoms combine to form molecules

_______ 9 Most of the volume of an atom is occupied by the __________.

A. nucleus B. electron cloud C. neutron D. proton

_______ 10 Who explained the nature of matter being made up of indivisible particle, called *atomos*?

A. Democritus B. John Dalton C. Aristotle D. Joseph John Thomsor

_______ 11 Whose experiment led to the discovery of the protons?

A. Joseph John Thomson B. Ernst Rutherford C. Neil Bohr D. John Dalton

_______ 12 Who among the following is attributed for the *plum pudding model* of the atom?

A. Democritus B. John Dalton C. Neil Bohr D. Joseph John Thomsor

_______ 13 The *planetary model* of atom is proposed by __________.

A. Earnst Rutherford B. Neils Bohr C. Erwin Schrodinger D. Werner Heisenberg

_______ 14 An atom is electrically neutral because __________.

A. the numbers of protons and neutrons are equal
B. the numbers of protons and electrons are equal
C. the numbers of neutrons and electrons are equal
D. charges in the nucleus are balanced

_______ 15 The total number of protons and neutrons in the nucleus of an atom is its __________.

A. average atomic mass B. atomic number C. electrical charge D. mass number

Direction: Choose among the following which one came first. Write the CAPITAL LETTER on the blanks before each number.

_______ 16 discovery of: A. nucleus B. neutron C. electron

_______ 17 experiments: A. gold-foil B. cathode ray tube C. oil drop

_______ 18 atomic models: A. planetary B. plum pudding C. quantum mechanical

_______ 19 idea that atoms: A. have negative charges B. have energy levels C. are indivisible