សង្ខិត្តន័យ—Abstract

អត្ថបទទី៧៖ ការរៀបចំតេស្តដើម្បីវិនិច្ឆ័យគំនិតភាន់ច្រលំរបស់គរុសិស្សកម្ពុជា អំពីអាតូម និងម៉ូលេគុល

សង្ខិត្តន័យ

គោលបំណងនៃការសិក្សានេះគឺដើម្បីបង្កើតតេស្តមួយ ដោយរួមបញ្ចូលការប្រើប្រាស់សំណួរពហុជ្រើសរើស និងសំណួរស្រប ឬមិនស្រប ដើម្បីវិនិច្ឆ័យរកគំនិតភាន់ច្រឡំរបស់គរុសិស្សទៅលើទ្រឹស្តីអាតូម និងម៉ូលេគុលនៅក្នុងបរិបទកម្ពុជា។ ការបង្កើតតេស្តនេះមានបួនជំហានគឺ ១) ការកំណត់រកខ្លឹមសារ ២) ការស្រាវជ្រាវរកអ្វីដែលជាគំនិតភាន់ច្រលំរបស់សិស្ស និងគ្រូដែលមានពីមុនមក ៣) ការបង្កើតសំណួរទាំងឡាយនៅក្នុងតេស្ត និង៤) ការសាកល្បងតេស្តទៅលើទ្រឹស្តីអាតូម និងម៉ូលេគុល។ អ្នកស្រាវជ្រាវក៏បានប្រើសំណួរទម្រង់បើក(បែបពន្យល់) ទៅលើគ្រប់សំណួរទាំងអស់នៃតេស្តផងដែរ។ នៅក្នុងតេស្តមានសំណួរសរុបទាំងអស់ចំនួន១៧សំណួរ ដែលផ្តោតលើបួនសមាសភាគរួមមាន៖ លក្ខណៈរបស់អាតូម ទម្រង់អាតូម អ៊ីសូតូប និងម៉ូលេគុល។ តេស្តនេះត្រូវបានធ្វើការសាកល្បងដំបូងជាមួយនឹងគរុសិស្សចំនួន ៨៣នាក់ បន្ទាប់មកក៏បានអនុវត្តទៅលើគរុសិស្សចំនួន ១០៤៩នាក់ ដែលពួកគេកំពុងសិក្សានៅតាមសាលាគរុកោសល្យ និងវិក្រឹតការខេត្តចំនួនបួន និងវិទ្យាស្ថានគរុកោសល្យចំនួនពីរក្នុងប្រទេសកម្ពុជា។ កម្រិតភាពជឿជាក់របស់តេស្តបានកើនឡើងពី ០.៦០ នៅពេលធ្វើការសាកល្បង ទៅ ០.៨៨ នៅពេលធ្វើការសិក្សាចម្បង។ សម្រាប់ខ្លឹមសារនៅក្នុងតេស្តត្រូវបានត្រួតពិនិត្យ និងកែសម្រួលឡើងវិញដោយផ្អែកលើយោបល់របស់គ្រូឯកទេសគីមីវិទ្យាចំនួន៤នាក់។ លទ្ធផលបានបង្ហាញអោយឃើញថាតេស្តគឺមានភាពអាចជឿជាក់បាន និងមានសុពលភាពក្នុងការវាស់ពីគំនិតភាន់ច្រលំរបស់សិស្សលើទ្រឹស្តីអាតូម និងម៉ូលេគុលនៅក្នុងបរិបទនៃប្រទេសកម្ពុជា។ ការសិក្សានេះរកឃើញថាមានសំណួរចំនួន៥ដែលមានលក្ខណៈត្រិះរិះពិចារណា ដែលសំណួរទាំងនោះមានចម្លើយមិនត្រឹមត្រូវលើសពី៣០% នាំអោយយើងកំណត់បានថាចម្លើយទាំងនោះគឺជាគំនិតភាន់ច្រឡំ។

ពាក្យគន្លឹះ៖ គរុសិស្ស គំនិតភាន់ច្រឡំ តេស្តវិនិច្ឆ័យ អាតូម និងម៉ូលេគុល ប្រទេសកម្ពុជា

The Development of Tests to Diagnose Cambodian Teacher Trainees' Misconceptions about Atoms and Molecules

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Abstract

The purpose of this study is to develop a test with multiple-choice and agree-disagree questions to diagnose teacher trainees' misconceptions about atoms and molecules in a Cambodian context. There were four steps to develop the test: (1) defining the content area; (2) researching students and teachers' misconceptions; (3) developing test items; and (4) piloting the test for the content area of the concepts of atoms and molecules. The researchers also used open-ended questions in each test item. The test consisted of 17 questions covering the four components of characteristics of atoms, atomic structure, isotopes, and molecules. The test was first validated with 83 teacher trainees and then administered to 1,049 teacher trainees who are studying at four Provincial Teacher Training Centers and two Teacher Education Colleges in Cambodia. The reliability of the test increased from 0.600 in the pilot to 0.881 in the main survey. The content of the test was checked and revised according to the comments from 4 chemistry teachers. The results showed that the test was reliable and valid to measure students' misconceptions about the concepts of atoms and molecules in the Cambodian context. We found five critical items, and items that received more than 30% incorrect answers were considered as a misconception.

Keywords: Teacher trainees; Misconceptions; Diagnostic test; Atoms and molecules; Cambodia

1. Introduction

Teachers are always concerned about students' understanding of science lessons. Teachers need to investigate students' misconceptions before or after the lessons. During the learning process, the teachers are trying to impart new knowledge to the students who will try to connect their prior knowledge with the new knowledge. If the students and teachers have misconceptions, they will have difficulties in catching up and linking prior knowledge to the new knowledge. The difficulty and complexity of the concept of atoms and molecules can be

the cause of students' misconceptions about [what?]the basic contents. Many students find it difficult to learn about the abstract concepts of atoms and molecules and many teachers find them difficult to teach as well. As previous studies have shown, many researchers have researched students and teachers' misconceptions on different topics (atoms, molecules, chemical bondings etc.). For example, many students find it difficult to learn chemistry, and they are often unable to build accurate concepts. Nakhleh (1992) claimed that students "cannot fully understand the more advanced concepts that build upon the fundamentals". Students might have held a few misconceptions before they come to class or before learning new concepts. Ouchand Shimizu (2017) mentioned that future studies could identify other misconceptions in other topics in the Cambodian context. Atoms and molecules are abstract and difficult concepts for students or pre-service teachers to understand, and both groups hold misconceptions about this concept (Cokelez & Dumon, 2005; Kiray, 2016; Muştu & Özkan, 2017; Nakiboglu, 2003; Nicoll, 2001; Papageorgiou et al., 2016; Peterson & Treagust, 1989;). A recent report showed that some teacher trainers in Cambodia faced problems such as limited knowledge and misconceptions about the lessons themselves (VVOB, 2016). This report also mentioned that misconceptions existed with chemistry teacher trainers as well as trainees at Provincial Teacher Training Centers (PTTCs). Therefore, the present study aims to develop a test with multiple-choice questions and agree-disagree questions to diagnose teacher trainees' misconceptions on atoms and molecules. The test will enable teacher trainers to use it as a tool to investigate students' misconceptions and enhance their understanding of the concepts of atoms and molecules.

2. Literature review

In order to diagnose students' understanding, various diagnostic instruments have been developed and used. A recent study by Patil et al. (2019) showed that there are eight types of test development for diagnostic tests that can be used to identify students' misconceptions, such as (i) multiple-choice questions, (ii) open-ended questions, (iii) two, three and four tier diagnose tests, (iv) drawing test, (v) word association tests, (vi) conceptual change tests, (vii) concept inventories, and (viii) online diagnostics tests. The common instrument that many researchers used for diagnosing students' understanding and misconceptions is multiple-choice questions (Hufnagel, 2002; Krishnan & Howe, 1994; Martin et al., 2004; Peterson & Treagust, 1986; Tan & Treagust, 1999; Tan et al., 2008; Treagust, 1988). However, multiple-choice questions alone cannot determine what students understand and what they do not. Previous researchers added another part after multiple-choice questions that could be the multiple reasons, called two-tier diagnose tests (Lin, 2004; Tan et al., 2005; Treagust & Haslam, 1986; Widiyatmoko & Shimizu, 2018) or short answers for finding the reasons for their responses.

A study by Cros et al. (1986), which investigated 400 students using unstructured interviews and questionnaires, revealed that first-year undergraduate students provided only a limited explanation of the interactions of sub-atomic particles. A report on misconceptions, using a two-tier diagnostic test of a specific topic "covalent bonding and structure" was easy for teachers to address students' misconceptions in the classroom (Treagust, 1988). Perterson and

Treagust (1988, 1989) who developed two-tier multiple-choice items to test grade 12 students found that students had misconceptions related to bond polarity, the shape of molecules, the polarity of the molecule, intermolecular forces, and the octet rule. Harrison and Treagust (1996) conducted an interview-based study with 48 students from grades 8 to 10, using the mental model of atoms and molecules. The study showed that some students confused: the language use in biology and chemistry (shell and nuclei), models of atoms, atoms can grow and reproduce and atomic nuclei can be divided (Harrison & Treagust, 1996).… As can be seen from the previous studies, there seems to be no study that has measured misconceptions on atoms and molecules through the diagnostic test in multiple components of atoms and molecules concepts, such as characteristics of atoms, atomic structure, isotopes and molecules. The present study aims to fill in this knowledge gap by exploring the development of a test to diagnose Cambodian teacher trainees' misconceptions about atoms and molecules.

1. Methodology

This study followed four stages of procedure of test development such as (1) defining the content, (2) researching on students' and teachers' misconceptions, (3) developing test items, and (4) piloting tests (Figure 1).

The first stage was to define the content. According to 8th grade and 10th grade chemistry textbooks, the concepts of atoms and molecules can be defined into four components: the characteristics of atoms, atomic structure, isotopes, and molecules. The contents of the test were validated by three experienced chemistry teachers and one science professor. Table 1 shows the test items related to four concepts of atoms and molecules.

The second stage was to research students' and teachers' misconceptions on the concepts of atoms and molecules. This stage has drawn from previous studies that focused on students and teachers' misconceptions related to atoms and molecules concepts. The misconceptions found in those studies (e.g., …) were compiled to be used in developing test items.

The third stage was to develop test items. Based on stage 2, the test was categorized into four components of the concepts of atoms and molecules: the characteristics of atoms, atomic structure, isotopes, and molecules (see Table 1). The test comprised multiple choice and agree-disagree questions based on content drawn from chemistry textbooks of grades 8th and 10th. In addition, the researcher added open-ended questions in each question (see Figure 1 and 2).

4. The atomic number of an element is the number of (Atomic Structure)
□A. electrons in its ions
□B. neutrons in the nucleus
□C. protons in the nucleus
□D. neutrons and protons in the nucleus
Explain your answer: ……

Figure 1. Example of multiple-choice questions

9. All chemical bonds occur when there are attractions between the negative and positive atoms. (Molecule)

□ Agree □ Disagree

Please explain: ……

Figure 2. Example of agree-disagree questions in the test

Table 1 shows the four components of the concepts of atoms and molecules of the test items could identify misconceptions.

Table 1

The four components of the test and test items

Components	**Test items**
Characteristics of atoms	QI1, QI2, QII3, QII4
Atomic structure	QI3, QI4, QII1, QII2
Isotopes	QI5, QI6, QII5, QII6
Molecules	QI7, QI8, QII7, QII8, QII9

The fourth stage was to pilot the test. This study conducted a pilot test of twenty items on a sample of 83 teacher trainees (25 males and 58 females) and one teacher trainer from Kampot PTTC to check the reliability of the test. After the pilot study, the test was checked and revised by four chemistry teachers who work at different workplaces, such as secondary school, high school, provincial teacher training canter, and regional teacher training college, respectively . A multistage cluster random sampling was used to select the sample for the main study. The sample was divided into four areas (plain area, coastal area, plateau and mountainous area, and the surrounding Great Lake Tonle Sap area). Each PTTC was randomly chosen from each area with all teacher trainees and trainers teaching science. Then, the test was distributed to four PTTCs and two TECs in Cambodia. The test items were revised from twenty items (pilot) to seventeen items (main study) (see Appendix A). There were a total of 1,049 teacher trainees (312 males and 737 females) who participated in this study.

To score the test, the following scoring rubric was employed:

- If the participants chose the wrong or right answer but provided no explanation, the answer was coded as “no concept” and scored as 0 (no concept).
- If they chose the right answer and provided an incorrect explanation, it was coded as “misconception” and scored as 1 (misconception).
- If they chose the wrong answer but provided a correct explanation, it was coded as “confusion” and scored as 2 (confusion).

- If they chose the right answer and explained correctly, it was coded as the "right concept" and scored as 3 (correct answer).

The data were computed in Excel and pasted into Statistical Package for the Social Science (SPSS) software version 23 for Windows. The reliability in each component and total reliability of the test in pilot test and main study are shown in Table 3.

The contents of the test were checked and revised according to the comments from four chemistry teachers .

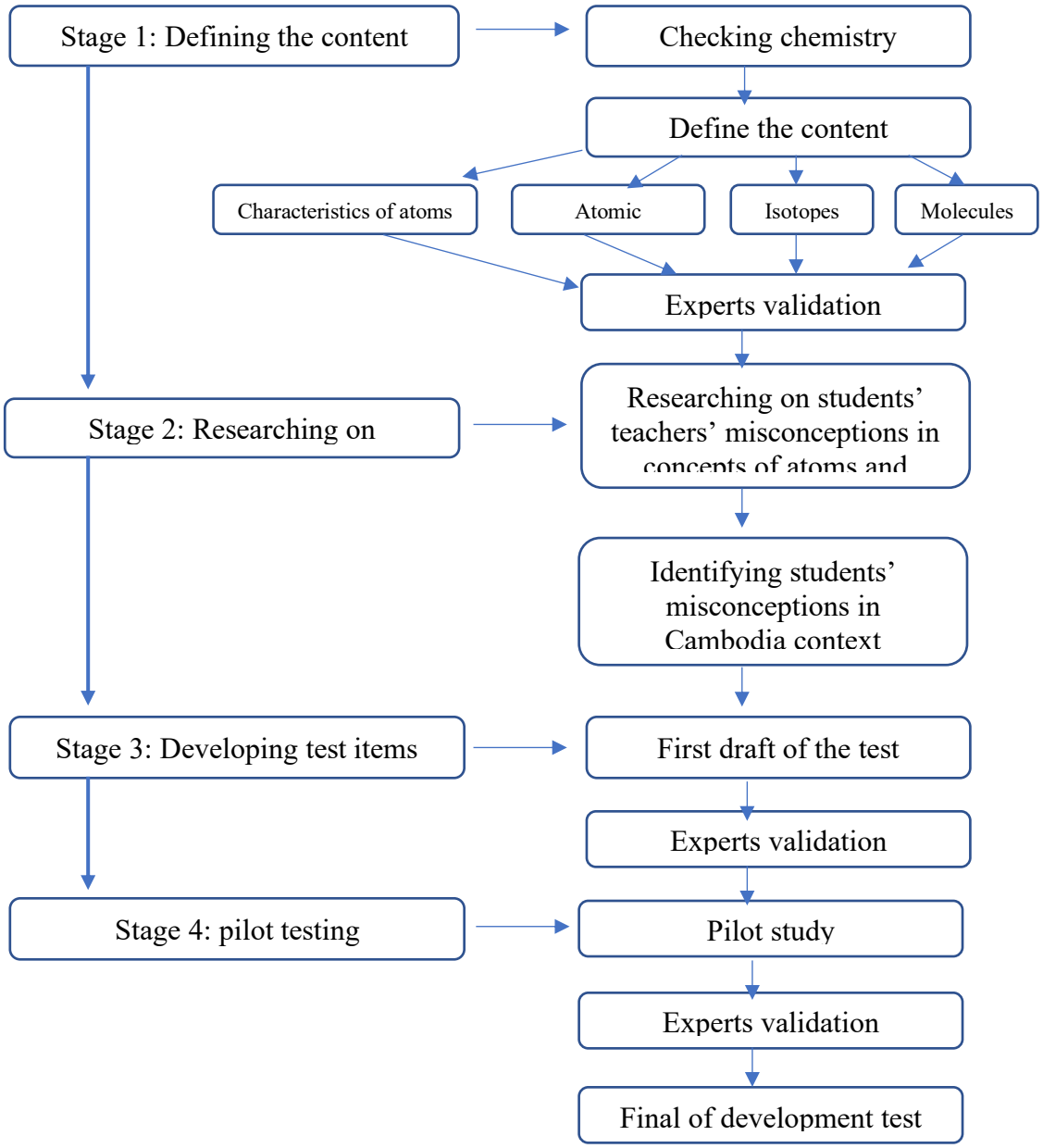

Figure 3. Flowchart of development test on atoms and molecules

2. Results and discussion

The reliability of this test—each component as well as the overall reliability—is shown in Table 2. After we got the reliability from the pilot test, researchers looked for four chemistry experts from different institutions, such as secondary school, high school, provincial teacher training center, and reginal teacher training college, to check the content again and revise those items to be included in the main survey. This could ensure that the test is acceptable in assessing the understanding of the concepts of atoms and molecules and can be used in the Cambodian context.

Table 2
The reliability of the test

Component	Pilot study	Main study
Characteristics of atoms	.285	.638
Atomic structure	.342	.658
Isotopes	.581	.842
Molecules	.214	.646
Total	**.600**	**.881**

Note: The pilot study contains 20 items and the main study contains 17 items.

The test in this study addressed teacher trainees' understanding of four components: the characteristics of atoms, atomic structure, isotopes and molecules. To find out what misconceptions are, the researchers checked teacher trainees' answers with multiple-choice, agree-disagree questions and check their explanations below each item. First, the researcher calculated the percentages of each item to find out what questions are difficult. Table 3 shows the percentages for the multiple-choice questions and Table 4 shows the percentages for the agree-disagree questions. As seen in Tables 3 and 4, 90.6%, 58.1%, 41.4%, and 87.7% of the teacher trainees respectively showed their understanding in the part about the characteristics of atoms (I1, I2, II3, and II4). Meanwhile, 85.4%, 59.1%, 81.7%, and 57.2% of the teacher

Table 3
Percentage of teacher trainees by multiple-choice responses

Test item	Percentage			
	A	B	C	D
I1	1.4%	6.4%	1.6%	90.6%
I2	15.1%	58.1%	3.3%	23.5%
I3	85.4%	2.1%	8.1%	4.4%
I4	33.1%	2.0%	59.1%	5.8%
I5	89.1%	1.9%	5.2%	3.7%
I6	2.6%	95.8%	1.0%	0.6%
I7	2.5%	19.8%	21.4%	56.3%
I8	48.1%	13.3%	28.6%	9.9%

Note: The highlighted percentages refer to the correct answers.

trainees showed their understanding in the component of atomic structure (I3, I4, II1, and II2),

respectively. For the understanding of the component of isotopes (I5, I6, II5, and II6), teacher trainees' understanding was89.1%, 95.8%, 95.0%, and 85.3%, respectively. Moreover, 56.3%, 48.1%, 90.6%, 43.5%, and 21.7% of the teacher trainees respectively showed their understanding in the component of molecules (I7, I8, II7, II8, and II9).

Table 4
Percentage of teacher trainees by agree-disagree responses

Test item	**Percentage**	
	Agree	Disagree
II1	81.7%	18.3%
II2	42.8%	57.2%
II3	58.6%	41.4%
II4	87.7%	12.3%
II5	95.0%	5.0%
II6	14.7%	85.3%
II7	9.4%	90.6%
II8	56.5%	43.5%
II9	78.3%	21.7%

Note: (The highlighted percentages refer to the correct answers).

After examining the percentages of each item, this study picked the critical items, i.e., the items with more than 30% incorrect answers. Out of a total of 17 test items, five (I4, II2, II3, II8, and II9) had a percentage of more than 30% inaccuracy. These critical items are shown in Table 5. Among the five items, question number II9 has the highest percentage of inaccuracy (78.3%), which shows that teacher trainees had difficulty choosing the correct answer for this question.

To reveal teacher trainees' understanding of the correct and acceptable scientific answers for the concepts of atoms and molecules, the researcher looked for their explanations in the second part of the test items (Table 6).

To measure teacher trainees' misconceptions, the authors examined the teacher trainees' explanations in each item that they misapplied the general principles of atoms and molecules as a conceptual misunderstanding. Conceptual misunderstandings or misconceptions occur when the students are taught the scientific information in a way that does not allow them to challenge conflicts resulting from nonscientific beliefs and their own preconceived notions (Patil, Chavan, & Khandagale, 2019). To know the conceptual misunderstanding of teacher trainees regarding the concepts of atoms and molecules, the researcher analyzed teacher trainees' explanations of their answers. As can be seen in Table 6, the highest percentage is 52.24% of the teacher trainees, showing their conceptual misunderstanding of the molecules concepts. However, the lowest percentage is 0.57% of the atomic structure.

These results indicated that a number of teacher trainees did not know the correct concepts as an acceptable scientific answer and hold some misconceptions about atoms and molecules

concepts. The test used in this study can assess teacher trainees' conceptual misunderstanding and analyze their misconceptions about atoms and molecules. The test not only can be used

Table 6
Percentage of teacher trainees' reasons to their choices

Teacher trainees' reasons	**Percentage**
1. Atoms with the same charge will repel each other but atoms which have different charges will attract each other to form molecules.	52.24%
2. All molecules are made up of different types of atoms.	18.68%
3. Chemical bonds come from the attraction between metal and non-metal atoms.	5.14%
4. Atoms have positive and negative poles. Atoms with the same pole cannot form chemical bonds but atoms with different poles can do so.	0.85%
5. All chemical bonds are linked by positive ions & negative ions. For e.g., $H^+ + Cl^- \rightarrow H–Cl$ $Na^+ + Cl^- \rightarrow Na–Cl$	1.71%
6. Atoms are around the nucleus.	8.96%
7. Atoms are in the nucleus.	6%
8. Atoms have the same size as their ions when they have the same electron shells or the numbers of electrons.	11.63%
9. The atomic numbers = number of protons = number of neutrons	0.57%
10. The atomic number represents the number of electrons in the outer shell.	6.86%

with teacher trainers but it may also be used with secondary school students. Classroom teachers might use the test before and after teaching the concepts of atoms and molecules to examine the gradual change of students' understanding.

Two-tier multiple-choice tests were developed and have been used to identify alternative concepts and misconceptions in science, as seen in previous studies (Adodo, 2013; Kanli, 2015; Treagust, 1988; Treagust & Haslam, 1986; Yusrizal & Halim, 2017). It has been found that teachers had an easy way to evaluate students' ideas with the two-tier multiple-choice test (Chen et al., 2002). Moreover, the use of two-tier multiple-choice tests allows teachers to explore and identify students' misconceptions about weight, sound, heat and light … (Tsai & Chou, 2002). This study has also found that multiple-choice and agree-disagree questions with students' explanations behind their answer choices can be used to explore students' understanding of science topics such as atoms and molecules.

3. Conclusion

Based on the results of the current study, it is concluded that the test with multiple-choice questions and agree-disagree questions is reliable and valid to assess teacher trainees' understanding and diagnose their misconceptions about atoms and molecules. Chemistry teachers can also use this test to identify their students' understanding of the concepts of atoms and molecules. They also can use it as an instructional approach to emphasize correct scientific concepts.

The findings of this study suggest that teacher trainees have difficulty in learning and lack a clear understanding of the concepts of atoms and molecules. Therefore, training programs are needed to help improve their content knowledge and understanding of the concepts of atoms and molecules as well as other important topics in chemistry. In light of this study's findings, future studies can use this test to identify what learners and teachers' misconceptions about atoms and molecules are. This test may be used as a model test to diagnose students' misconceptions about other concepts.

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Appendix

Table 5
Critical items for teacher trainees' answers

Test Item	Incorrect answer	Percentage
I4. The atomic number of an element is the number of: ☐A. electrons in its ions ☐B. neutrons in the nucleus ☐C. protons in the nucleus ☐D. neutrons and protons in the nucleus	☑A. electrons in its ions	33.1%
II2. The radius of a chlorine atom has the same size radius of a chloride ion because it has the same number of electron shells (3 electron shells). ☐ Agree ☐ Disagree	☑ Agree	42.8%
II3. Atoms move around the nucleus. ☐ Agree ☐ Disagree	☑ Agree	58.6%
II8. All molecules are made up of different types of atoms linked together. ☐ Agree ☐ Disagree	☑ Agree	56.5%
II9. All chemical bonds occur when there are attractions between the negative and positive atoms. ☐ Agree ☐ Disagree	☑ Agree	78.3%