# Analysis of Understanding of First-Year Chemistry Education Students on Intermolecular Forces (IMFs) Topic

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**ABSTRACT:** This study aims to investigate the concept of understanding of first-year students of Undergraduate Program Chemistry Education. The method used was descriptive, and data collection using a multiple choice question type was applied to 49 first-year Chemistry Education student. The results show that students found difficulties in connecting between kinds of Intermolecular Forces (IMFs) and molecular examples. Student's understanding of first type questions which is to emphasis predicting the IMFs type are intermediate, 52.48%, while the second type of questions to show the ability in predicting molecular examples are low, 29.93%.

**Keywords:** intermolecular forces (IMFs), student's understanding, chemistry education student

## INTRODUCTION

Chemistry as one of the most important parts of science has been studied both in theory and application or in other words chemistry can be studied as pure science and as engineering. Philosophically, chemistry provides an understanding of everything around us, as well as being a kind of tool to meet our needs. In the textual definition, chemistry is part of natural science that studies the nature of matter, the structure, composition of matter, changes, and energies that accompany changes in the matter. Chemistry is generally studied since junior high school and will be specifically studied at university as the highest level of education.

Since the beginning of the 21th century, studies highlighted chemistry learning had been carried out. Some studies attempted to study patterns of students difficulty in understanding chemistry. The difficulty arises because some studies of chemistry are abstract, one of the reasons, according to Johnstone (1984) is that natural science itself makes it inaccessible [1,2]. Intermolecular forces (IMFs) is one of the topics in chemistry that is considered an abstract topic. The IMFs topic is an integrated and a crucial topic due to its position, which connects several other topics such as topic of chemical bonds with topic of physical and chemical properties of substances. Besides, IMFs are also crucial due to it provides understanding of how and why molecules interact with others [3].

The topic of IMFs includes the concept that involves the representative phenomena at the macroscopic, symbolic, and microscopic level. A thorough understanding of a chemistry topic generally depends on the ability of students to integrate the three levels. This level of representation is interconnected and has explained in a triangle shape as Figure 1.

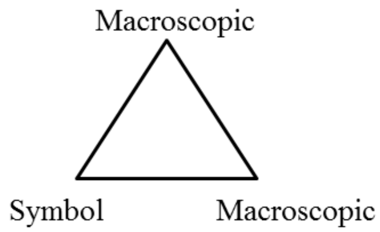


**FIGURE 1**. Three representative levels of chemistry concepts [4,5].

These three levels cannot stand alone, to understand a concept well, students need to master these three levels. Student difficulties at a microscopic level will affect student understanding at the symbolic and macroscopic level. Macroscopic levels in the chemistry related to the physical and chemical properties of substances. The physical and chemical properties of a substance can be accessed with senses such as boiling point phenomena of substances as the consequences of intermolecular forces. In general theory, the boiling point of a liquid is related to the molecular weight of the liquid constituent. In one class of compounds, the increase in boiling point is proportional to the increase in molecular weight, for example, in the aliphatic hydrocarbon compounds, the longer the carbon chain, the higher the boiling point. However, in certain cases, the boiling point phenomenon cannot be explained using molecular weight approach. The boiling point of water at 1 atm is 100 $^oC$ and ethanol is 77 $^oC$, whereas the molecular weight of water is 18 g/mol and ethanol is 46 g/mol. The other fact is about the acidity of substances, aromatic compound derivatives substituted by para isomer are more acidic than ortho isomer, this phenomenon is also related to IMFs [3].

Representation at the symbolic levels relates to chemical and phase symbols of substances or a chemical reaction, as the example is a reaction of changing the phase of water where water symbol is written as $H_2O$ with the different phases.

$$H_2O_{(s)} \rightarrow H_2O_{(l)} \rightarrow H_2O_{(g)}$$

Symbols that written as subscripts s, l and g which are acronyms of solid, liquid and gas that accompany the $H_2O$ symbols indicate the state of phase involved. Although the substances are the same ($H_2O$), however, the phases of the three substances are different. While the representation of the microscopic level of IMFs related to the force that occurs between the constituent particles of substances. The forces of molecules are the effect of free and random movements of molecules which are not accessible directly by senses.

One other case to show the microscopic level of IMFs is the acidity of 4-Nitrophenol or p-Nitrophenol, which is higher than 2-Nitrophenol or o-Nitrophenol. The formation of hydrogen bonds between the –OH group and –NO2 group in the same o-Nitrophenol molecule prevents the o-Nitrophenol releasing ion H+ from the –OH group, it leads the o-Nitrophenol liquid is less acidic. While in the p-Nitrophenol, hydrogen bonds between the same molecules do not occur due to the distance between –OH group and –NO2 group is not too close. The hydrogen bonding between different p-nitrophenol molecules does not inhibit the p-Nitrophenol from releasing ion H+ from –OH group, so that p-Nitrophenol is more acidic than o-Nitrophenol. The example shows that some IMFs phenomena are abstract [3]. Difficulties in understanding concept sometimes arise because of abstract parts even though this part is unavoidable. An Education researcher, J. Dudley Herron defines abstract phenomena as “no perceptible instances”, a phenomenon that cannot be directly understood due to unavailability of examples that explain the attributes of the phenomena [3].

Since the IMFs contains some abstract concepts, misconceptions are often unavoidable. Some reports support the view of interplay between microscopic and macroscopic level that lead difficulties for many students such as electrochemistry [6,7], thermodynamics [8], chemical bonding [9], covalent bonding [10], ionic bonding [11] and IMFs [12-19] Study about misconception of IMFs topics conducted by Henderleiter et.al (2001) revealed that students still face difficulties in classifying the IMFs of different molecules.

This paper will investigate students understanding of IMFs topics at microscopic level representation in the first-year chemistry education students. The microscopic level is the most difficult part because most are abstract. Therefore the student understanding will be investigated after students have previously received IMFs material by lecture method. This investigation has been conducted using multiple-choice instruments due to it was simple, fast and reliable, so students can provide answers spontaneously without doing deep scientific thinking. By knowing the student understanding level, the lecture will be easier to prepare teaching material and method to increase the student understanding level so that student have a better understanding.

## METHODS

### Experimental Design

The steps carried out in this study include instruments preparation in the form of multiple-choice questions, examining instruments with several test methods, conducting experiments, and collecting data. This study uses a descriptive research method with samples taken by cluster random sampling method. The sample used is 49 first-year chemistry education students, Faculty of Mathematics and Natural

Sciences, Universitas Islam Indonesia (UII), Yogyakarta, Indonesia. In this study, the following assessment categories are used: 0% - 30% = low, 30% - 70% = intermediate, 70% - 100% = high and the questions have classified into two general class namely question number 1 – 7 to identify kinds of IMFs and 8 – 10 to identify molecules example of IMFs.

**Experimental Design**

The instrument used to examine this misconception is a multiple choice question consisting of 10 questions, with five answer choices. Before this instrument has used, the test of validity and reliability of the problem using the SPSS 16 program for windows is conducted. Test the validity of using Pearson correlation analysis method while the reliability test uses the Cronbach Alpha analysis method. Based on the results of the test it is known that the ten questions are valid, and the Cronbach Alpha value is 0.59, which means the questions are reliable.

**Data Collection**

The steps of collecting data in this study include: (1) giving a score, (2) calculate the percentage of correct answers on each question, (3) create a group of questions that have the same type and (4) calculate the percentage of correct answers on questions of the same type.

## RESULT AND DISCUSSION

This study will investigate student understanding of IMFs concept use 10 multiple choice questions with 5 answer choices. Question 1-7 students are asked to identify the type of IMFs from the examples of the molecules given. The answer choices provided are all types of intermolecular force and one other question that is not one type. Question 8-10 students are asked to identify molecules example of intermolecular force given.

**TABLE 1**. Percentage of the correct answer on each question

| No | Question 1 | Percentage (%) of correct answer | Category |
|---|---|---|---|
| 1 | Which interactions might occur between two chloromethanes?<br>[A] London dispersion force<br>[B] Dipole – induced dipole<br>[C] Momentary dipole – induced dipole<br>[D] Dipole – dipole<br>[E] Hydrogen bond | 85.71 | High |
| 2 | Which interactions might occur between $I_2$ and other polar molecules?<br>[A] London dispersion force<br>[B] Momentary dipole – induced dipole<br>[C] Dipole – dipole<br>[D] Hydrogen bond<br>[E] A and B correct | 12.24 | Low |
| 3 | Which interactions might occur between dichloromethane and chloromethane?<br>[A] London dispersion force<br>[B] Dipole – induced dipole<br>[C] Dipole – dipole<br>[D] Hydrogen bond<br>[E] A and B correct | 59.18 | Intermediate |

| | | | |
|---|---|---|---|
| 4 | What interactions occur between molecules ($F_2$) composed of atoms which have high electronegativity (F)?<br>[A] London dispersion force<br>[B] Dipole – induced dipole<br>[C] Dipole – dipole<br>[D] Hydrogen bond<br>[E] Covalent bond | 36.73 | Low |
| 5 | What interactions occur when $Cl_2$ has dissolved in chloromethane solution?<br>[A] London dispersion force<br>[B] Dipole – induced dipole<br>[C] Dipole – dipole<br>[D] Hydrogen bond<br>[E] Covalent bond | 61.22 | Intermediate |
| 6 | Which interactions might occur between $H_2O$ and HF?<br>[A] London dispersion force<br>[B] Dipole – induced dipole<br>[C] Dipole – dipole<br>[D] Hydrogen bond<br>[E] Covalent bond | 89.80 | High |
| 7 | What interactions occur between methanes containing H atoms<br>[A] London dispersion force<br>[B] Dipole – induced dipole<br>[C] Dipole-dipole<br>[D] Hydrogen bond<br>[E] Covalent bond | 22.45 | Low |
| 8 | In which of the following compound(s) is hydrogen bonding likely to occur between the same molecules?<br>[A] $CH_4$<br>[B] $CHCl_3$<br>[C] $CH_3F$<br>[D] $CH_3OH$<br>[E] $H_2$ | 44.90 | Intermediate |
| 9 | Which hydrogen bond is the strongest?<br>[A] $H_2O$ – HF<br>[B] $H_2O$ – $H_2O$<br>[C] HCl – HBr<br>[D] HF – HCl<br>[E] $H_2$ – $H_2O$ | 26.53 | Low |
| 10 | Which molecular forces below is the strongest?<br>[A] $CH_3Cl$ – $I_2$<br>[B] $F_2$ – $F_2$<br>[C] $CHCl_3$ – $CF_4$<br>[D] $CH_4$ – $H_2O$<br>[E] $CH_3OH$ – $H_2O$ | 18.37 | Low |

Based on Table 1, the percentage of correct answer the first question was 85.71%. The first question is simple and the majority of students answer correctly, this is due to only one molecule given in the question, chloromethane. Students can immediately remember the interactions between chloromethane molecules. Armed with an understanding of polarity, students can easily conclude that the interaction that occurs is dipole-dipole. While in number 2, only 12.24% of students answered correctly because in the answer choices there was an outrageous answer. London force is also known as the force which involves between two non-polar molecules which have no permanent poles [19]. Students generally focus on the fact that interactions between the same non-polar molecules are London force, but do not use the basic logic that the interaction of non-polar molecules is due to the momentary dipole force in the non-polar molecule itself. London force or sometimes known as London dispersion force is sometimes quite ambiguous due it used in several different fields in chemistry, namely organic and biochemistry. In both fields, London force associated as the Van der Waals force [20]. To ease understanding the differences in forces between molecules, Effendy has classified the IMFs in Figure 2.

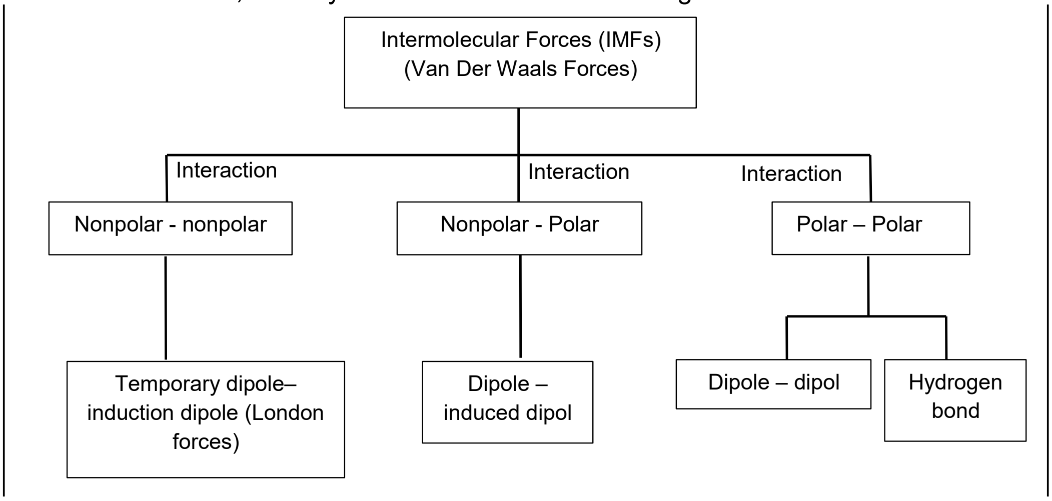


**FIGURE 2.** A general term of Intermolecular Forces (IMFs) [20]

To differentiate with terms used in other fields such as organic chemistry and biochemistry, the London forces in this topic is interpreted more specifically as an interaction between nonpolar molecules, whereas Van der Waals forces have a more general meaning namely forces involving inter molecules. The understanding category of question number 3 is classified as intermediate, 59.18%. The question given is the same type as question number 1, but when one molecule sample is changed, almost half of the students answer incorrectly. This fact shows that students do not understand well the properties of molecules when viewed from the composition of their constituent atoms. In number 4, the discussion is about the interaction between non-polar molecules. However, students focus on electronegative terms that are identical to the polarity of a substance. Electronegative atoms contribute to the polarity of a molecule because it has the property of attracting electrons in a molecule that causes polarity. Since the electronegative term has mentioned in the problem, many students do not choose answers based on molecular interactions. In problem number 5, $Cl_2$ is a nonpolar molecule, and chloromethane is a polar molecule, the interaction of both is dipole – induced dipole. The percentage correct answers is 61.22 % shows the level of student understanding at the intermediate level. Interaction formed between $H_2O$ and HF in number 6 is hydrogen interaction. The presence of H atoms visible in both molecules and the electronegative atoms shows the tendency of the two molecules to form hydrogen bonds. A hydrogen interaction or hydrogen bonds is a primary attraction between hydrogen (H) atom which bond covalently to a more electronegative atom or group [21] The level student understanding of this problem reached 89.80% which means their understanding was high.

The interaction between the methane molecules in question number 7 is London dispersion forces because methane is a nonpolar molecule. The correctness of the answer in number 7 is quite low, which is 22.45%. The mention of the H atom in the problem might make students choose the answer identical to number 6 which is related to hydrogen bonds. The percentage of correctness in number 8 – 10 is low level on average as given in Table 2.

**TABLE 2.** The average percentage of the correctness of student answer

| No | Concept | Question number | Pecentage | Category |
|---|---|---|---|---|
| 1 | To predict IMFs from molecules example | 1 | 85.71 | |
| | | 2 | 12.24 | |
| | | 3 | 59.18 | |
| | | 4 | 36.73 | Intermediate |
| | | 5 | 61.22 | |
| | | 6 | 89.80 | |
| | | 7 | 22.45 | |
| | | Average | 52.48 | |
| 2 | To predict molecules from IMFs | 8 | 44.9 | |
| | | 9 | 26.53 | Low |
| | | 10 | 18.37 | |
| | | Average | 29.93 | |

In the second type of questions that emphasize students to predict molecules example from IMFs has given show percentage of 29.93%. Students are less able to give examples of molecules of the type of IMFs provided in the problem. When compared with the first type of questions, the percentage of the second type of questions is relatively low. Students need to be given many opportunities and exercises to connect molecular examples with types of IMFs.

## CONCLUSION

This study was conducted in the form of multiple-choice questions so that students can answer quickly with an understanding they already have before and the results of students' understanding (average in percentages) in predicting types of IMFs are intermediate (52.48%) while to predict molecular examples from the types of IMFs given, student ability is still low (29.93%). Students are still unable to connect the types of IMFs with molecular examples, so in the future, lecturers must pay more attention to give the basics of IMFs by connecting them with molecular examples.

## REFERENCES

1. A. H, Johnstone, Chem. Educ, 61 (10), 847 – 849, (1984).
2. L. Cardellini, Educacion Quimica, 23 (2), 305 – 310, (2012)
3. M. Muchson, Jurnal Pendidikan Sains Malang, 1 (1), 14 – 25, (2013)
4. D. F. Treagust, G. Chittleborough, T. Mamiala, Int. J. Sci. Educ, 25 (11), 1353 – 1368, (2003)
5. A. H. Johnstone, J. Chem. Educ, 70, 701 – 704, (1993)
6. P. J. Garnett, and D. F. Treagust, JRST, 29 (2), 121 – 142, (1992)
7. M. J. Sanger and T. J. Greenbowe, JRST, 34 (4), 377 – 398, (1997)
8. H. Ozmen and A. Ayas, Chem. Educ. Res. Pract, 4, 279 – 290, (2003)
9. S. Unal, M. Calik, A. Ayas, and R. K. Coll, Res. Sci. Technol. Educ, 24 (2), 141 – 172, (2006).
10. G. Nicoll, Int. J. Sci. Educ, 23 (7), 707 – 730, (2001)
11. R. K. Coll and D. F. Treagust, JRST, 40 (5), 464 – 486, (2003)
12. D. F. Treagust, Int. J. Sci. Educ, 10 (2), 159 – 169, (1988)
13. R. F. Peterson and D. F, Treagust, J. Chem. Educ, 66 (6), 459 – 460
14. R. F. Peterson and D. F, Treagust, P. Garnett, JRST, 26 (4), 301 – 314, (1989)
15. K. S. Taber, Sch. Sci. Rev, 78 (285), 85 – 95, (1997)
16. H. K. Boo, JRST, 35 (5), 569 – 581, (1998)
17. K. C. D. Tan and D. F. Treagust, 81 (294), 75 – 84, (1999)
18. V. Barker and R. Millar, Int. J. Sci. Educ, 22 (11), 1171 - 1200
19. N. Becker, K. Noyes, and M. Cooper, J. Chem. Educ, 93, 1713 – 1714, (2016)
20. Effendy, Molekul, Struktur dan Sifat-Sifatnya, (Indonesian Academic Publishing, Malang, 2017), 321 - 333
21. R. S. DeFever, H. Bruce, G. Bhattacharyya, J. Chem. Educ. 92, 415 – 426 (2015)