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The Interactive Anonymous "Must-have" Quiz: A Simple Method to Enhance Students Concept Learning in Organic Chemistry Course

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ABSTRACT. Effective mastering and learning of basic organic chemical concepts is pivotal to ensure students continue to excel to the higher levels of organic chemistry learning. Concept learning is crucial for first-year organic chemistry students so that they can comprehend and understand a concept better and able to make connection to problems. In the present paper, the authors have implemented the Interactive Anonymous Quiz (IAQ) with "must-have" features in the organic chemistry course as a teaching tool to instill students' interest and enhance conceptual understanding in organic chemistry. The effectiveness of this activity was examined and evaluated through students' reflective writing. Students showed positive learning outcome on the implemented activity as reflected by the reflective writings. In addition, this activity could be employed as an activity to check on students' concept understanding, to instill students' interest in organic chemistry course and to improve on students' weakest topic in organic chemistry in the future classes.

Key words: Interactive anonymous quiz, Must-have, Organic chemistry, Reflective writing

INTRODUCTION

The learning of basic chemical concepts is important for students starting their first year organic chemistry program. Students will be exposed to specific chemistry vocabulary and employ them throughout the chemistry learning journey especially when engaging with peers and course instructors.[1] For students majoring in chemistry, basic chemical concept understanding is useful when they enroll into advanced organic chemistry course. Besides that, the introductory organic chemistry course is also a pre-requisite for other degree programs, such as biology, microbiology, pharmacy, dentistry, medicine and so on. For these reasons, an understanding of the basic chemical concepts is important irregardless of program specialization of these scientific fields. The ability to comprehend the concepts and relate it to the tasks or problems given requires a deeper understanding of a concept.[2] Hence, the research of concept teaching has been the focus of many educators for the past decades.[3–7]

Traditionally, organic chemistry is regarded as a challenging subject and students sometimes fail to comprehend the fundamental concepts learnt in the lecture. As a consequence, students continue to lag behind and avoided this subject.[8–10] In addition to this, students regard chemistry as irrelevant to their daily lives and thus difficult to study the content of chemistry taught in lecture more meaningfully.[11–14] As a result, students use just rote memorization as a way to pass chemistry tests.[15] Apart from the relevance problems, Gilbert and Treagust (2009) showed that science is difficult to be comprehended by students due to triplet interconnected factors; misconception in sub-micro level, difficulty to link the sub-micro to macro level and difficulty in understanding the general rules at representation level.[16] As such, there is a compelling need to help students to learn more effectively in organic chemistry and to consolidate their basic chemical concepts rather than employing the rote memorization technique.

Over the years, various concept-teaching activities has been reported, such as the incorporation of Concep Tests during lecture,[17] concept maps for teaching organic reactions,[18] Jigsaw for teaching acid-base theories,[19] use of mnemonic tool to aid students' understanding in tautomerization mechanism[20] and so on. Students who seek understanding in organic chemistry led to better problem solving skill rather than those who employ just rote memorization.[21] Students' interest in learning is linked to lecturers' teaching method.[22] The introduction of new pedagogy in organic chemistry in combination with active learning environment is imperative to reinforce learning and energize students to continue to display interest in organic chemistry learning.[23] Besides that, the use of Interactive Anonymous Quizzes (IAQ) also showed positive outcome in both teaching and student learning in the classroom. IAQ is a useful tool to probe students' understanding in concept learning even if it is in a large classroom setting. In IAQ, questions are in the form of multiple choice and designed to review lesson learnt in a previous lecture.[24] Undoubtedly, one of the main problems identified in large classroom teaching is the lack of communication between lecturers and students when the lecture is presented. Typically, a good two-way communication in the classroom leads to a better understanding, grades and satisfaction in the lesson learnt.[25] As such, both the concept test and IAQ serve to enhance the interaction between lecturers and students, to reinforce students' learning and reveal their weakest area in a subject taught and enable lecturers to cover it in the future lessons.

Previously, the authors have implemented the Uncritical Inference Test (UIT) in the large classroom setting to enable students to learn deeper in organic chemistry.[26] Inspired with the successful implementation of interactive and active learning method used in the author's classroom, herein, we would like to report the use of IAQ with "must-have" features to reinforce students' basic chemical concept learning, encourage students' engagement in learning and also attendance in class. In the previous IAQs,[24,25] students' confident level and their multiple choice answers were collected, without supplementing them with the method of concept learning. The "must-have" features in the present IAQ serve as a cue for first-year students to write and think deeper about the critical attributes possessed by a concept in the subject of chemistry. In addition, the study of the "must-have" features together with the examples and non-examples would enable students to revise and learn a concept more critically, and at the same time enables the course instructor to tackle their fundamental problem more effectively. This systematic concept learning method will eventually drive students towards the concept learning in the subject of chemistry.

METHODOLOGY

Subjects

The current study was directed to the 2015/16 session batch of students majoring in environmental analytical chemistry at the Universiti Malaysia Terengganu, who were in their first semester and first year of study. The basic organic chemistry course is a compulsory subject for all first year science students. A total of 97 students attended this course that was conducted as a two one-hour lessons per week for 14 weeks. One of the IAQ was depicted as shown in *Fig.* 1 and the rest of the IAQs can be found in the *Appendix.*

IAQ #1.

Determine which of the following that is not an organic co mpound? List the "must-have features" for organic and inor ganic compounds.

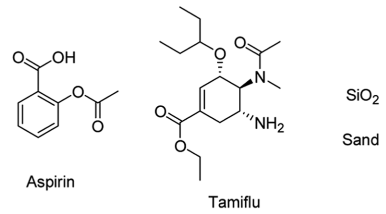

***Figure* 1.** IAQ for the introductory chapter in the *basic organic chemistry* lecture.

Procedure

The IAQ was conducted at the last 15 minutes before the lecture ended once a week. One IAQ was directed to students at a time to review on the concepts taught in the previous lecture. A total of 10 sets of IAQs were developed by using Microsoft PowerPoint.

The IAQ developed is based on the basic chemical concept that students learnt in the *basic organic chemistry* course. In this activity, slight modifications were made to the classical IAQ which employed multiple choice questions, whereby students were required to discriminate between examples and non-examples of a class of concepts and followed by the "must-have features" write-up. The "must-have features" are critical features that must be possessed by an item, so that it can be classified as a member of a concept class.[1]

During this activity, a closed book activity was conducted and students were allowed 5 minutes discussion with their peers and submit their answers in the form of a write-up. After 5 minutes, student's answer scripts were collected in anonymous form for data analysis and the course instructor will invite students for discussion on the answers. The answers on the previous quiz will be presented again in the following lecture to reinforce their learning in the class.

In order to study the effectiveness of this activity, students were also encouraged to write an anonymous reflective writing and it was done at week 11 to assist the instructor to further improve on this activity. Though the reflective writing was not a compulsory, about 78 students submitted their writing assignment to the course instructor.

Data analysis

Students' answers to the IAQ were collected, and graded

***Table* 1.** Scoring rubric of IAQ

Degree of understanding	Scoring criteria	Score
No scientific understanding (NU)	Response that provide incorrect answers or without explanation.	0
Partial understanding containing misconception (PM)	Response that provide correct answers but containing misconception explanation	1
Sound understanding (SU)	Response that provide correct answers with no misconception explanation	2

carefully after group discussion and analyzed according to the scoring rubric (*Table* 1), which was developed based on the rubric for Chemistry Concept Test.[27] Answers that were correct and with no misconception were graded as "Sound Understanding (SU)". On the other hand, answers that were correct, but provided a misconception were graded as "Partial Understanding containing misconception (PM)". Finally, students' answers that were incorrect or provide no explanation were graded as "No Scientific Understanding (NU)". The rating scale can be divided into three categories, with NU=0; PM=1 and SU=2.

Apart from this, students' learning experience towards this activity was explored using reflective writing. A systematic network was built to understand the learning outcomes contributed by this activity as expressed in the students' feedback. Students' answers to the IAQs and reflective writings were analyzed by two of the authors. In the analysis of IAQs, the percentage of agreement of inter-coders using the rubric was calculated to be 99%. After reaching consensus on the overall analysis, descriptive data and systemic network were confirmed.

RESULTS AND DISCUSSION

Students' answers to the IAQ

Based on the students' overall scores in the IAQs (*Table* 2), students' conceptual understanding was found to be weak in the subject of arrow pushing (M=1.26), with merely 31 out of 97 students' answers were graded as "SU". In addition, students performed average in the subjects such as dipole moments and molecular polarity (M=1.59) and chirality (M=1.59). In contrast, students displayed good conceptual understanding in the subjects such as oxidation (M=1.90), stereoisomerism (M=1.92), Lewis acids and bases (M=1.94) and hydrogen interaction (M=1.96). The purpose of this activity is to evaluate students' understanding on certain subjects and reveals their weakest topic, so that the course coordinator can rectify this in the next lesson. By implementing more conceptual learning activities such as the "must-have" quiz, this exercise can serves as a potential source to improve and strengthen students' conceptual understanding. Overall, students' scores were found to be high in most items, with the mean score (M=1.73) close to the full score (M=2.0).

A closer examination on the data analysis shown in *Table* 2 revealed that most students performed above average, in the topic of organic and inorganic compounds when comparing to the total mean score (M=1.84 vs. 1.73). This may be due to the topic had been introduced during their high school learning and students find no difficulty to understand these concepts. In the following topic which involves the geometry of a molecule, students found this IAQ to be challenging judging from their mean score and the total mean (M=1.69 vs. 1.73). It was observable that 24 students' answers were graded as "PM" which may be due to students have not been frequently exposed to this type of activity,

***Table* 2.** Students' degree of understanding and overall scores in the IAQs (N=97)

No	Topic	Grading			Mean scores, M
		SU (2)	PM (1)	NU (0)	
#1	Organic/Inorganic compounds	83	12	2	1.84
#2	Geometry of a molecule	70	24	3	1.69
#3	Hydrogen interaction	93	4	0	1.96
#4	Dipole moments and molecular polarity	69	16	12	1.59
#5	Arrow pushing	31	60	6	1.26
#6	Lewis acids and bases	94	0	3	1.94
#7	Chirality	77	0	20	1.59
#8	Stereoisomerism	93	0	4	1.92
#9	Oxidation	87	10	0	1.90
#10	Aromaticity and anti-aromaticity	70	18	9	1.63
Total					1.73

which require the practice of concepts reasoning. Next, almost all students' perform well in the topic of hydrogen interaction as they have learnt this concept during their high school learning and the mean score of this IAQ marked the highest compared to other IAQs (M=1.96). In contrast, students' understanding on the topic of dipole moments and molecular polarity was found to be below average (M=1.59 vs. 1.73). A careful analysis showed that a total of 28 answers were graded in the categories of "PM" and "NU", which showed that a quarter of all students had either developed misconception or show no understanding that needs immediate intervention and remediation from the course coordinator. The students' degree of understanding for IAQ#5 recorded the lowest mean score when compared to other IAQs' mean scores. In this IAQ, the concept of arrow pushing was not included in the high school syllabus and the majority of students found it difficult to reason these concepts, which witnessed a total of 60 students' answers classified as "PM". On the other hand, students showed good understanding for the Lewis acid and bases concept as this topic was repeatedly taught during their high schools and at university level, with the mean score for this item was found to be the second highest (M=1.94). In contrast, students' concept on chirality was found to be below average (M=1.59 vs. 1.73). It was noteworthy that there was no misconception reported in this IAQ. However, as the questions directed to the students was not straightforward from their handout, students performed poorly, with 20 students' answers recorded as "NU", which is the highest "NU"s amongst all IAQs. This trend showed that students were not able to relate their knowledge due to their surface understanding of the concepts.[26]

For IAQ#8 and #9, the mean score for these two items was found to be close to full score (M=2.0), in which it indicates that students have no difficulty in understanding the topic of stereoisomerism and oxidation, with minority of the students developed misconception on the latter topic. Finally, students performed average in the concept of aromatic and anti-aromaticity as reflected in the students' mean score when comparing to total mean (M=1.63 vs. 1.73). Again, some students have difficulty in understanding the concept of aromatic, non-aromatic and anti-aromatic due to the complexity of these concepts which requires deep understanding, which witnessed a quarter of the total students' answers graded as "PM" and "NU".

Students' conception on each IAQ item

In IAQ#1, majority of the students showed no difficulty to understand the concept behind IAQ#1 and their answers were graded as "SU", as evident in both the classroom discussion and collected data (86%), by correctly identified the inorganic compound as SiO_2 and provided their reasoning that organic is a substance that contains carbon, while inorganic is a substance that contains element other than carbon. On the other hand, the authors also found that some students used alternative conceptions to solve the IAQ#1. This was later confirmed by the collected data (*Table* 2) which showed 12% of the students gave partially correct answer (*Table* 3), in which 8% of the students stated that the "must-have" feature for organic compounds was pharmaceuticals and non-pharmaceuticals for inorganic compounds. Out of the "PM" answers, 4% of the students even relate the organic and inorganic compounds with their solubility in organic solvents, in which they stated that organic compounds dissolve in organic solvent, while inorganic compounds were immiscible. The course instructor had to emphasize the significance of study meaningfully as oppose to rote memorization to the class.

Similar situation was also encountered in IAQ#2, where 25% of the students have developed misconception. When analyzing these students' misconception, 16% of the students have stated that the geometry of a molecule is related to the arrangement of electron pairs, which is incorrect. The other 9% of the students who have developed misconception in this IAQ have either stated that it must have a 109.5° bond angle or steric number of four, without mentioning the key word which is four atoms bonded to a center element. The correct answer for IAQ#2 is ammonia

***Table* 3.** Students' misconception on the IAQs

Topic	Students' misconceptions
Organic/Inorganic	• Organic compound is pharmaceuticals and inorganic compound in non-pharmaceutical. • Organic compound dissolves only in organic solvents, while inorganic compounds were immiscible.
Molecular geometry	• The geometry of a molecule is related to the arrangement of electron pairs.
Hydrogen interaction	• Higher boiling point for hydrogen interaction to occur.
Dipole moment	• Possess non-symmetrical geometry or polar bond only.
Arrow pushing	• Only double bonds participate in arrow pushing.
Aromaticity and anti-aromaticity	• Planar structures or delocalized electrons, without mentioning the Hückel's rule.

and the "must-have" feature of a tetrahedral compound is four atoms bonded to a center element, sp^3 and with a bond angle of 109.5°. The course instructor then explained that the geometry of a molecule is determined by the arrangement of atoms. In IAQ#2, molecules that arranged in a tetrahedral geometry are sulfate ion and chloroform whereas ammonia is in a trigonal pyramidal geometry.

In IAQ#3, students' answers that were graded as "SU" had responded that the "must-have" feature for a hydrogen interaction was the hydrogen atom bonded to heteroatoms and form dipole-dipole interactions with neighboring heteroatoms. Other answers were also accepted, such as the hydrogen attached to oxygen atom in a compound and hydrogen atom that attached to an electronegative atom. In this IAQ, only 4% of the students' answers were graded as "PM", whereby they stated that the "must-have" feature for hydrogen interaction is higher boiling point. Students' answers were analyzed and categorized based on a previous literature.[28]

In IAQ#4, 17% of the students' answers were graded as "PM". Of the 17%, 12% of the students responded that the "must-have" features to exhibit molecular dipole moment was due to non-symmetrical geometry, without mentioning the key word that the dipole moments do not cancel out each other. Through discussion, the course instructor realized that some students tended to not predict the geometry of the molecules. The course instructor provided a step-by-step explanation by using ammonia as an example. Firstly, the steric number of ammonia is four and the arrangement of atoms for ammonia must be sp^3 or tetrahedral in geometry. After determining the geometry of ammonia, the course instructor showed all the dipole moments in ammonia to check whether they fully cancel out each other. The ammonia, in this case, the dipole moments did not cancel out fully. The same protocol was used to explain dipole moments in a water molecule. The correct answer for this IAQ is CCl_4, which does not exhibit molecular dipole moment due to cancelation of dipole moments. The remaining 5% of the students' answers were graded as "PM" as they merely stated that the "must-have" feature was a polar bond, without mentioning the key word.

In the following IAQ#5, about 6% of the students have marked **A** as the answer and were thus graded as "NU". After analyzing the answer and from the open discussion with students, it was observable that these students have not properly considered the octet rule. In contrast, more than half of the students' answers were graded as "PM" as they only mentioned that the "must-have" feature is the presence of double bonds. In contrast, no students chose **B** as an answer as interviewed students revealed that it was very uncommon to break single bond in a resonance structure, which is indeed true. Nevertheless, the correct explanation to this IAQ is that the "must-have" features in arrow pushing are to obey the octet rule and avoid single bond breakage. The conceptual understanding on Lewis acids and bases was evaluated in IAQ#6. About 3% of students' answers were graded as "NU", in which these students marked the wrong answer without any explanation in the collected data. In IAQ#7, about 20% of the students' answers were graded as "NU". Students with the incorrect answers explained that the wrong carbon position on aspartic acid was identified, in which they focused on C-3 which showed no chirality and therefore they have marked aspartic acid as non-chiral. The same explanation was received from students who have chosen cysteine as the answer as they focused on C-3 which led to the misinterpretation that this compound was non-chiral. The course instructor then encouraged students to study deeper about a question before marking their answers.

In IAQ#8, the majority of students understood well on the concept of *E*- and *Z*-isomers, where they explained that isomers with both highest group priorities on the same side or at the opposite side of a double bond are termed as *Z*-isomers and *E*-isomers, respectively. Similar observation was also noted in IAQ#9, when majority of the students managed to grasp the concept of the oxidation process, in which students responded that the substrates needed at least an alpha hydrogen attached to the carbon to be oxidized.

The final IAQ#10 was targeted to enhance the understanding of aromaticity and anti-aromaticity. 72% of the students marked the correct answer which is **A** and stated the accurate "must-have" features. Aromatic compounds have features of $4n+2$ π-orbital electrons, a fully conjugated ring with overlapping π-orbitals, cyclic and planar; while anti-aromatic compounds consist of $4n$ π-orbital electrons, a fully conjugated ring with overlapping π-orbitals, cyclic and planar. About 19% of the students' answers were graded as "PM" and they either stated that the "must-have" feature for aromaticity was planar structures or delocalized electrons, without mentioning the Huckle's rule. About 9% of the students did not provide their answer and remarks in the "must-have" feature, thus were graded as "NU".

Analysis on students' reflective writing

A systemic network (*Fig.* 2) was built in attempt to learn about students' learning experience towards the activity based on the students' reflective writing assignment. On the individual level, about 50 students have benefited in

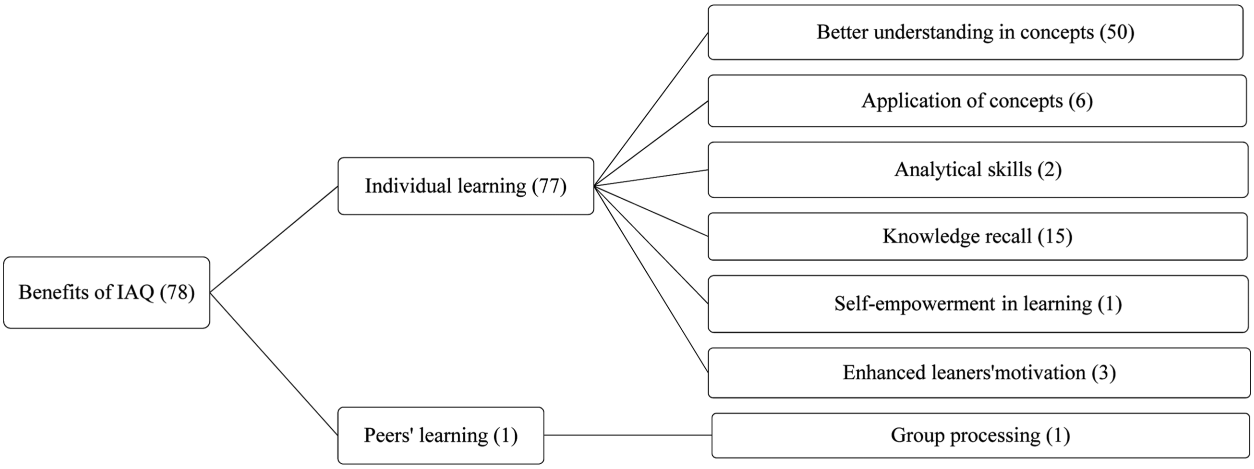

***Figure* 2.** The network diagram of students’ feedback on the IAQ activities.

understanding the following concepts; arrow pushing (30 students), *E*- and *Z*- isomers (8 students), molecular dipole moment (3 students), Lewis acids and bases (5 students), organic and inorganic compounds (2 students) and aromaticity and anti-aromaticity (2 students). Majority feedback that this activity aided them in understanding the concept of arrow pushing and this is indeed reflected from their submitted write-up after the IAQ activity; where only 31% of students’ answers were graded as “SU”.

Based on the students’ reflective writing, about 6 students were benefited by knowing how to apply the concepts learnt in problem solving. Besides that, two respondents have feedback that they benefited by improving their analytical skill, in which through listing down and analyzing the “must-have” features, they were more aware about the critical attributes for a class of concepts and thus able to solve the problem in a given question. In the students’ reflective journal, 15 students responded that this activity has flashback their previous knowledge in the lecture. It was noteworthy that, one of the students reflected that this activity promote self-learning. Finally, three students’ reflective writing responded that they experienced more fun and challenges through learning in this activity.

On the peers’ learning dimension, one student feedback (*Fig.* 2) that this activity enables them to solve a given problem in group and the comment was as follows;

“*In my personal opinion, I like this kind of class activity so do with the exercises. This is real discussion what should be organized in every class. All of this pressure and stressful atmosphere at the moment made all the students gather their mindset together to solve the problem instead of doing nothing at the corner. For me, a good way to practice or discuss is a very important in class, it will be very effective to both lecturer and students as well.*”

CONCLUSION

The main objective of this activity was to reinforce students’ basic chemical concept learning and as well as to encourage students engagement in classroom learning. In this activity, 10 IAQs were developed based on the basic chemical concepts, ranging from molecular geometry, hydrogen interaction, molecular polarity, Lewis acids and bases, stereoisomerism and chemical reaction to aromaticity. Most of the students showed positive learning outcomes towards the implemented activity as evident in the reflective writings. Besides that, the change of pedagogy in classroom teaching has motivated the leaners’ participation in classroom learning as reflected in the students’ reflective writings.

The IAQ activity was introduced to students to understand a concept deeper and by learning the “must-have” features of a concept, students are able to effectively solve a given problem. In addition, the course coordinator could rectify their misconception in these subjects by careful analysis on the students’ “must-have” features. As a whole, the “must-have” IAQ in the context of fundamental organic chemistry serves two purposes; to deepen students’ understanding about a concept and to probe students’ misconception.

In the future, more interactive classroom chemistry learning actives will be explored in the author’s classroom teaching to enhance students’ interest and experience in the journey of learning chemistry.

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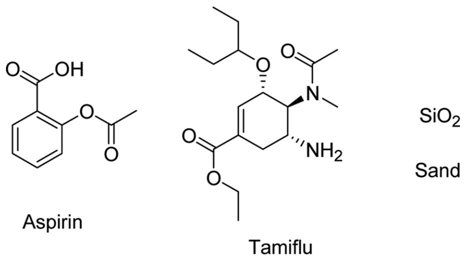
APPENDIX

The Interactive Anonymous “Must-have” Quiz

1. Determine which of the following that is not an organic compounds? List the “must-have” features for organic and inorganic compounds.



2. Determine which of the following that is not tetrahedral in geometry? List the “must-have” features for tetrahedral compounds.

SO_4^{2-}, $CHCl_3$, NH_3

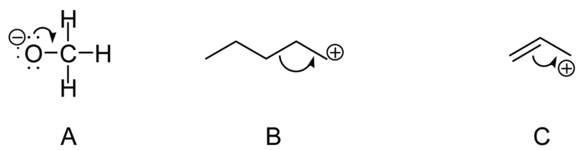
3. Determine which of the following does not form intra- and inter-molecular hydrogen interactions? List the “must-have” features for intra- and intermolecular hydrogen interaction to occur.

$CH_3CH_2CH_2OH$, H_2O, $CH_3CH_2CH_2CH_3$

4. Determine which of the following does not exhibit molecular dipole moment. List the “must-have” features to exhibit molecular dipole moment.

NH_3, H_2O, CCl_4

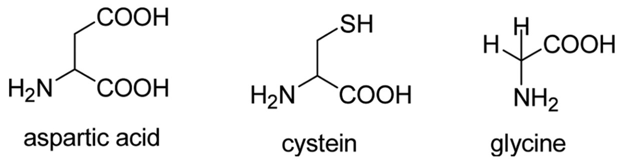
5. Determine which of the following obey the arrow pushing rule. List the “must-have” features for drawing arrow pushing.



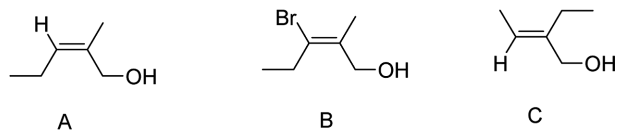
6. Determine which of the following is not a Lewis acid? List the “must-have” features for Lewis acids and Lewis bases.

$AlCl_3$, ^{-}OH, BF_3.

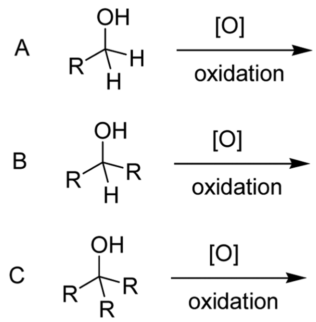
7. Determine which of the following that is not a chiral molecule? List the “must-have” features for chiral compounds.



8. Determine which of the following is *E*-isomer? List the “must-have” features for *Z*- and *E*-isomers.



9. Determine which of the following does not undergo oxidation reaction? List the “must-have” features for oxidation reaction to occur.



10. Determine which of the following is an aromatic molecule? List the “must-have” features for aromatic and anti-aromatic compounds.