A Project submitted to the Education University of Hong Kong for the degree of *Bachelor of Education (Honours) (Science)*

Research title:

Effectiveness of Flipped Learning on Addition Polymerisation in Hong Kong Secondary Chemistry Education

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Declaration

This work has not been submitted previously for examination to any tertiary institution.

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Abstract

Nowadays, with the increasing use of flipped learning by many schools, more and more people take a deep interest in this new teaching model which is simply defined as school work at home and homework at school (Network, 2014). It is obvious that the conventional teaching approach could not satisfy the diverse learning needs of students, especially for those students choosing Chemistry as one of their elective subjects. Most students found that learning Chemistry is difficult when compared with other science subjects such as Biology since much content knowledge from the former one is very abstract to them, especially in learning the topic addition polymerisation which requires students to recognise and draw plenty of chemical equations. Although there are numerous studies that are related to flipped learning, no research has been conducted to investigate the effectiveness of flipped learning on addition polymerisation in Hong Kong secondary chemistry education to date. Therefore, this study aims to investigate the relationship between students' academic achievement and intrinsic learning motivation in learning addition polymerisation under flipped learning by using instruments pre-test, post-test, observation and structured-group interview. All the data collected would hence be analyzed and explained in a systematic manner to illustrate the whole picture of the study unbiasedly. The result obtained from this study would provide the public how flipped learning affects students' learning in the topic of addition polymerisation especially in the aspects of academic achievement and intrinsic learning. Meanwhile, detailed information on how to develop suitable learning and teaching materials for flipped learning for addition polymerisation are enclosed.

Chapter 1: Introduction

Learning Chemistry, especially in the topic of addition polymerisation, is not an easy stuff when compared with other subjects as it requires students initially to understand the rationales behind and then perform hands-on and minds-on activities to further prove or deepen their learnt concepts. Majorities of schools choose to follow the traditional model to teach Chemistry where teachers dominate most of the time teaching the concepts throughout classes. One of the limitations is that students might not have sufficient time to do the experiments and most of them are just passively receiving the knowledge that teachers have taught without truly understanding the whole process or the concepts behind. Hence, an innovative model called flipped classroom is being implemented these days. For the flipped classroom, the main operation of it is flipping the conventional instructional routine: Impartation of knowledge is done by watching teacher-created materials at home in advance of lessons and internalization of knowledge is done by having different activities in a cooperatives learning environment during lessons after students watched the learning materials at home (Tucker, 2012; Jinlei, Ying & Baohui, 2012). Thus, class becomes the place to work via tackling high-order thinking questions, advanced and more challenging concepts, as well as engaging in collaborative learning (Tucker, 2012), whereas these elements are all vital for learning the topic addition polymerisation in productive and efficient means.

According to the educationists, flipped learning is generally regarded as student-centered while that of the traditional learning is usually considered as teacher-centered throughout lessons. For the conventional mode of learning, there are numerous limitations. One of them is that the learning diversity of the students within a class cannot be catered as 'one teaching style does not fit all' (Brown, 2003). However, flipped learning can definitely cater for the needs of each individual as this model allows less able students to watch the videos and learning materials pre-recorded by the teachers before lesson at their own pace (pause/fast-forward/rewind as necessary), able students can have the chance to solve challenging problems or open-ended questions during lessons in the collaborative means. As a result, performance of learners could be improved as learning diversity of students are catered. Another limitation of using traditional learning is that essential skills would not be acquired as teachers dominate the class all the time and students just passively received the knowledge without any critical thinking. Nevertheless, flipped learning does not face as many bottlenecks as traditional learning. Flipped learning allows students to gain advanced communicative and cross-cultural skills, lifelong learning skills and meta-cognitive skills via students' personal learning as well as interaction with peers (Kompa, 2012).

Apart from students' perspective, the new teaching model flipped classroom could also make an important contribution to teachers' pre-service learning, skills and affective development, especially in creating a useful and authentic context for learning science (Cabı, 2018). Not covering the basic contents during lesson, teachers could spend more time focusing on less able students in order to help them to improve and, at the same time, teachers could group all students together to work on open-ended questions with the aids provided (Du, Fu & Wang, 2014). And more significantly, this teaching model can be rethought to best maximize the scarcest learning resource which is time (Tucker, 2012).

Although there are many research papers stating that there are many advantages of using flipped classroom to teach Chemistry, not much studies have been done on the effectiveness (based on the students' academic achievements and learning motivation in Chemistry) of implementing flipped classroom on addition polymerisation in Hong Kong secondary education system to date. Moreover, there are not enough qualitative and quantitative studies about the impacts and effectiveness of this new teaching model on students' academic achievements and learning motivation in the topic of addition polymerisation. This proposed study aims to investigate the effectiveness of flipped classroom on addition polymerisation in the HK education system. To measure the effectiveness of flipped learning, data of the students' academic achievements and learning motivation in the study of addition polymerisation by using flipped learning and traditional teaching would be collected and analyzed. Structured interview is planned to be conducted to explore possible reasons to account for any changes in academic achievement and learning motivation over the two aforementioned pedagogies.

Another reason why I choose to evaluate the effectiveness of using flipped classroom in learning the topic addition polymerisation is that most of the students find that it is difficult to recognise the repeating unit from the given section of a long chain polymer, or draw the equation of addition polymerisation from the given monomer to polymer from my observation during the period when I conducted my first block practice. Besides, students' misconceptions were found from their homework that they had submitted to me. For example, missing the big bracket in writing the equation of the repeating unit, placing the 'n' at the wrong side of the equation of polymer, writing carbon-carbon double bond in the equation of the repeating unit and so on. To learn the chapter addition polymerisation in a productive way, students should acquire good linkage among microscopic, macroscopic and symbolic representations as this chapter requires students to write different equations and symbolic representations. According to the research done by Petillion & McNeil (2020), it was stated that there 3 main important elements in Johnstone's triangle when applying flipped learning: symbolic which was narrated screen capture, submicroscopic which included the molecular animations as well as the macroscopic which was the experimental laboratory demonstrations. Therefore, I would like to investigate the difference between the tradition and new teaching methods in the topic of addition polymerisation to evaluate the effectiveness of the innovative teaching method.

- **Research Question**

With the advancement of society and diversity needs of students, traditional teaching is not so suitable to cater for the diverse learning needs of students and develop 21st century skills, especially in learning chemistry. The way to learn and teach chemistry is not that easy when compared with other subjects such as Chinese, English, History and so on. And more, students usually find difficulties when learning the topic "addition polymerisation" as it is too abstract and complicated for them to understand especially under teacher-centered teaching.

In fact, the education system in Hong Kong is highly examination-oriented when compared with that of other countries such as Australia, Britain and America. Based on this learning culture in Hong Kong, the majority of schools choose to follow the traditional teaching pedagogy. However, learning Chemistry is not just focused on the knowledge acquired but also plenty of skills related to experiments, solving challenging problems, peer interaction, collaborative projects and so on. Therefore, more and more schools adopted the new teaching pedagogy flipped learning nowadays in order to strike the balance between teaching content knowledge and vital learning skills. As a result, this study aims to highlight and consider the following key research questions:

1. What are the features of flipped classroom?
2. What are the pre-lesson teaching and learning materials for students to study under flipped classroom on addition polymerisation?
3. To what extent does the flipped classroom affect students' academic achievements in learning addition polymerisation?
4. To what extent does the flipped classroom affect students' intrinsic learning motivation in learning addition polymerisation?
5. What are those benefits that students could acquire by using flipped classroom learning?
6. What are the limitations when introducing flipped classroom learning?

Here is the sub-research questions should be highlighted:

1. What is the definition of effective teaching and learning?
    - It is relatively important to clearly define the meaning of effective teaching and learning in the topic of addition polymerisation before the investigation of effectiveness of flipped learning on addition polymerisation in Hong Kong secondary Chemistry education.

2. What should be prepared in advance when carrying out flipped classroom?
    - It is known that pre-class videos and learning materials are needed to be prepared and distributed to students to revise before the flipped lesson. Hence, how the learning and teaching materials are developed for the flipped classroom in learning addition polymerisation should be addressed.

- **<u>Hypothesis</u>**

1. It is hypothesized that the students will have better academic achievements in the topic addition polymerisation under flipped learning than that of the traditional teaching.
2. It is hypothesized that students' motivation in learning the topic addition polymerisation would be increased by using flipped classroom.

- **Research Objectives**

1. To investigate the correlation between students' achievements (in the topic addition polymerisation) and the teaching model flipped classroom.
2. To investigate the correlation between students' learning motivation in Chemistry (especially in the topic addition polymerisation) in the teaching model flipped classroom.

Chapter 2: Literature Review

a. Definition of effective teaching and learning

It is vital to clearly define what effective teaching and learning is before investigating the effectiveness of flipped learning on addition polymerisation in Hong Kong secondary Chemistry education. Teaching and learning effectiveness could be explained in terms of a focus on students' outcomes and the teacher behaviors throughout the lesson in order to enhance students' learning outcomes (Ko, Sammons & Bakkum, 2013). Parameters measuring the effectiveness of teaching and learning not just focus on students' academic achievements, but also on their learning attitudes on life-long learning, motivation and important skills such as critical thinking, communication, collaboration and so on.

According to the book written by Gurney (2007), there are five factors leading to effective teaching, they include characteristics of teacher (professional, passionate, responsible & knowledgeable), various lesson activities which encourage learning, numerous levels of assessment that encourage learning via experience, effective and immediate feedback which establishes learning progress throughout lesson, and lastly the effective interaction between teacher and students in a respectful and motivated learning atmosphere. In this way, lesson no longer dominated by teacher but students collaborate with each other in order to achieve productive learning. Moreover, students' motivation to learn would be greatly enhanced throughout interaction in lesson. Based on those factors mentioned above, it is no doubt that flipped classroom could be preferred rather than that of the traditional one, and its features would be discussed in the following part.

b. Features of flipped learning

According to the Flipped Class Manifest published by Bennett, Bergmann, Cockrum, Fisch, Musallam, Overmyer, Sams & Spencer (2012), it is stated that all the flipped classrooms shared some common features :

- Dynamic, active and deliberate transfer of chosen parts of topics are delivered outside of the classroom such that in-class time could be spared for face-to-face interaction at school. This is done with online learning materials (videos, handouts) created by the teacher.

- Role of teachers changed to be guides to understanding rather than distributors of content knowledge and students turned to be active learners rather than repositories of information. With the permanent archived and documented tutorials of class content, all students can re-watch the videos as needed. Class time could hence be spare for data collection, active collaboration as well as application.
- Students could have instant and direct access to any subject matter when they have need of, allowing the teacher to have more chances to elaborate on higher order thinking skills as well as enrichment.

c. How the learning and teaching materials for the flipped classroom in learning addition polymerisation are developed

Unlike traditional classroom, flipped classroom requires teachers to prepare learning and teaching materials in advance for students to study before the lesson. Based on the features of flipped classroom mentioned above, suitable teaching and learning materials are developed. The instructional video and handouts include a core content of knowledge about addition polymerisation. All the content knowledge is developed in a simple way which caters for both able and less-able learners. Students can study at their own pace without a time limit. When students come back to lesson, challenging exercise and high-order thinking questions (originally as the take home assignments in the traditional classroom) are prepared for them to solve by collaborative means. After that, proper feedback should be given to students based on their in-class performance and participation.

For the flipped materials for the experimental groups, a PowerPoint in which guiding videos, concepts checking questions and experiment video was developed in a systematic and simple way for students to read and self-study at their own pace before flipped lesson. There were three main vital elements in Johnstone's triangle when applying flipped learning: symbolic which was narrated screen capture, submicroscopic which included the molecular animations as well as the macroscopic which was the experimental laboratory demonstrations. Therefore, the pre-lesson materials for the flipped group must contain these 3 important elements such that students could have a clear understanding on the topic addition polymerisation. Since the topic addition polymerisation required students to have a good linkage among microscopic, macroscopic and symbolic representations, it was necessary to introduce the content knowledge combined with those 3 elements in a clear and logical way. For the pre-lesson PowerPoint, the following contents were included:

- Chemical experiment video about making rayon fiber (macroscopic)
- Animations of chemical equation showing how the electrons are arranged (submicroscopic)
- Narrated screen capture videos showing how to draw the repeating unit, monomer, polymer and equation of addition equation (symbolic)

By doing so, students could have a clear picture of what they were learning especially for low-performing and middle-performing learners.

d. Strengths of flipped learning when compared to traditional instruction

There are numerous benefits by using flipped learning which are not achievable by traditional instruction. One of the advantages is that students' learning diversity could be catered and hence the overall academic performance of the class would be increased with flipped learning. The reason is that students have to prepare the lesson earlier at home by going through all the videos and learning materials created by the teacher, and hence they have more time to interact with both peers and teachers during the lesson. The learning progress is said to be more productive as it involves students' active participation during the learning processes. According to the research done by Olakanmi (2017), it is revealed that flipped classroom facilitates students' performance in understanding the conceptual aspect of the topic rate of reaction when compared with the control group (the group followed the conventional teaching methodology). According to the study on the effects of a flipped classroom model of instruction on academic performance and attitudes of 66 first-year secondary school students towards chemistry done by Olakanmi (2017), all assessment performances done by the flipped class students were found to be higher than average and the positive significant differences were discovered. In his study, a pre-test and post-test was carried out to investigate the effectiveness of using flipped classroom when compared to the traditional classroom. Students are randomly divided into either experimental or control groups. Students in the experimental group were given video lessons as well as reading materials to revise before class while those in the control group followed traditional methodology. Other than that, students were interviewed at the end of the research to concrete his findings. Apart from learning the topic rate of reaction, using the flipped classroom model could also be beneficial in learning the big topic of organic chemistry. Different from the research done by Olakanmi, the studies conducted by Cormier and Voisard (2018) had spent a much longer period of time to observe the students' performance in learning the topic organic chemistry by evaluating the gain on final grade scores in organic chemistry after the implementation of a flipped classroom model. The results were discovered that all 3 groups categorised by students' academic ability in school, from low-achieving to high-achieving students, performed a significant higher final grades in organic chemistry in the experimental group (students followed the flipped classroom model) than that of the control group (students followed the traditional teaching model) (Cormier & Voisard, 2018). The effects were said to be the most significantly for the low-achieving groups among those, with the final scores 10% higher than the control group due to the fact that students might have more time to deal with difficult problems during lesson rather than that at home by themselves (Cormier & Voisard, 2018). In the findings done by Birundha (2020), it was also stated that students in the experimental group acquired better achievements than that of the traditional group in learning organic chemistry through various in-class activities such as Think Pair and Share activity, Quiz Programmes, Teaching based on Blooms taxonomy and e-learning resources. Another recent research done by Munzil, Pandaleke and Sumari (2020, April) also stated that the critical thinking skills of students were greatly enhanced with the implementation of flipped classroom. According to the paper written by Jensen, Kummer and Godoy (2015), it is stated that flipped classroom model allows students to attain the content which was originally taught during lesson before heading to class, while attain the application process which initially has been the take-home assignments with peers and teachers during lesson time. By doing so, learning diversity of each individual could be catered as both types of learners (less-able and able) could revise the learning materials such as educational videos provided by the teachers at their own pace. For example, less-able learners could watch the learning videos many times while able learners could shorten the time for the contents and make use of the remaining time to try the challenging questions. Both learners gather in the lesson for discussions, solving complex questions in the form of groups in order to facilitate the application of concepts.

Another significant benefit of using flipped classroom is that teacher-to-student and student-to-student collaboration within class time could be greatly lengthened (Ahmed, 2016). It allows students to learn and discuss the topic in-depth. Since all the students have watched the pre-recorded videos before class, less able students could ask peers and teachers about the contents that they do not understand, and all students could gather to solve challenging questions with the aid provided by the teacher. Consequently, students are not just acquiring content knowledge, but also those vital life-long learning skills such as critical thinking skills, peer-interaction skills, communication skills, research skills and so on. Flipped learning could allow students to ask questions during class time instead of just copying notes without fully understanding the concepts taught when compared with the traditional teaching.

e. Difficulties on studying addition polymerisation in secondary chemistry by traditional approach

In traditional teaching, teachers usually stand in front of the class and transfer content knowledge directly to the students. Learning new concepts every single class, students usually find difficulties in understanding those newly introduced contents thoroughly as they just quietly jotting down notes and copying down the assignments without critical thinking. If students have some questions to ask, the teacher does not have enough time to explain as most of the class time is occupied by the teacher-centered teaching. This situation is even worse in learning addition polymerisation. Addition polymerisation is one of the chemistry topics which requires students to write a lot of equations. Students usually find it challenging to learn effectively. Moreover, addition polymerisation is an abstract concept where students need a lot of imagination, critical thinking skills and careful observation. Under the traditional approach, it is hard for students to understand the rationale behind, or draw the repeating unit from the given section of a long chain polymer, or write down the equation of addition polymerisation from the given monomer to polymer. Dismissed from the class, most of the students just copying the answer of the assignments from the net as they do not understand the whole picture of this topic, and on the other day back to school, the teacher will transfer other new content knowledge as the class cannot fall behind schedule (Ahmed, 2016). At the end of the school term, students especially those weaker learners, their content knowledge are not concrete due to accumulation of misconceptions. As a result, this bad cycle repeats for weaker students and their learning motivation would decrease.

On the other hand, able students would find the class time boring as the content knowledge taught is relatively easy for them to handle. In the traditional approach, there are not many challenging or open-ended questions for those able learners to think about and the questions printed on the textbooks are relatively easy for them. Some of them would hence chat with peers, sleep or do other subjects' assignments. As a result, able learners could not learn the topic in-depth and at the same time their learning interests and motivation to learn would lower in the near future.

f. Definition of learning motivation

Promoting lifelong learning motivation of students is one of the major significance in flipped learning. According to the book published by Garavan, Carbery, O'Malley & O'Donnell (2010), it is stated that motivation to learn shows that a student desires to participate in, and learn from, a training activity.

Motivation to learn in the reference frame of the theory of planned behavior (TPB) represents an attitudinal variable. There are usually 2 types of student motivation: Intrinsic motivation and extrinsic motivation (Harandi, 2015). An intrinsically motivated learner when he/she is motivated from within. This type of learners greatly commit themselves in learning out of unique matter, interest, or gratification, or in order to achieve their own scholarly and personal goals (Harandi, 2015). For the extrinsically motivated learners, they are likely to put forth the least effort of struggle requirement to achieve the most reward (Afzal, Ali, Aslam & Hamid, 2010).

In this paper, the intrinsic motivation of students would be measured.

Chapter 3: Methodology

A combined way using a pre-test and post-test on addition polymerisation, observations and structured-group interviews were carried out to investigate the effectiveness of using a flipped classroom model to optimize the academic performance of students on learning addition polymerisation and the intrinsic learning motivation of students. Including both of the quantitative and qualitative research methods, this design was used to support and acquire a whole picture of the investigation.

a. Research framework and participants

- Here is the whole picture of the research:

Step 1: 34 students from F4 chemistry class are randomly divided into 2 groups (with 17 students in each of the experimental group and control group) Step 2: Students in both groups complete a 20-minute pre-test in lesson 1, including briefing session Step 3: Students in the experimental group are given a set of pre-lesson material 5 days before flipped lesson Step 4: Flipped lesson for experimental group & conventional teaching approach for control group separately in lesson 2 (1.5 hours) Step 5: Students in both groups complete a 20-minute post-test in lesson 3 Step 6: Students (9 from each group) in both experimental and control groups are invited to participate in structured-group interview

In this study, the Hong Kong Diploma of Secondary Education Examination (HKDSE) curriculum for Chemistry in addition polymerization will be used as the basis for research. This investigation took place in a band one secondary college. The participants of this study are 34 secondary four students who were studying chemistry as one of their elective subjects; the school term 2021/2022. The 34 students are randomly divided into experimental group and control group with each group containing 17 students. Before the lesson, each student in both groups needs to finish a pre-test on addition polymerisation. Students in the experimental group were given a pre-lesson video (inside the PowerPoint), a set of learning materials (PowerPoint) to revise 5 days before the lesson, while that of the students in the control group followed the traditional methodology. Students in both groups were given a virtual lesson (1.5 hours) on the topic addition polymerisation separately. At the end of the last lesson, students in both groups were given a post-test on addition polymerization. There were totally three lessons for both of the groups. The first lesson (20 minutes) was used to finish the pre-test as well as briefing session, the second lesson (1.5 hour) was online class time and the last lesson (20 minutes) was used to finish the post-test. Random sampling was used in order to minimize sample selection bias as well as ensure certain segments of the population are not overrepresented or underrepresented. For students in the experimental group, all of them received the same pre-lesson materials at the same time, and had the real-time online lesson with the same content, the reliability thus maintained. For students in the control group, the reliability was also maintained as they were taught with the same content in the same condition with the same teacher (researcher). Moreover, to be fair to all students (no matter which group they were), all teaching and learning materials were given to both groups with no group receiving extra materials. For example, both group had the same set of worksheet (experimental group received and discussed it during flipped lesson while control group received it as the take-home assignment with explanation after markings).

- Flipped lesson for experimental group
  During the 1.5 hours virtual lesson through zoom, students were given a set of worksheets (which originally was the take-home assignment in the conventional teaching approach). There were 11 questions in total, including 6 multiple-choice questions and 5 long questions. Among all those questions, there are 6 high-order thinking questions, 3 middle-order thinking questions and 2 low-order thinking questions. 3 to 4 students were divided into each group (breakout room) with mixed abilities (depending on the result of the pre-test) in discussion. By doing so, less-able students could be taught by able students, and in the discussion process, able students could have a better understanding while giving a clear explanation to peers. The role of the teacher here became the guidance while students were the active learners. For each question, time was allowed for each

group to discuss. During discussion, students in each group were asked to post their comments in Padlet and the content could be seen by all others. At the same time, I would enter each breakout room to give proper and immediate feedback and advice. Some less-able students would ask about something that they were not sure about; some able-students would ask about some DSE-based questions if time was left. Beside, I would observe the learning attitude and motivation of students by observing their willingness to discuss with peers, activeness to answer and ask questions related to the topic addition polymerisation. At the end of lesson, my feedback toward the whole lesson was distributed to the class in the debriefing session.

- Conventional lesson for control group
  During the 1.5 hours virtual lesson through zoom, students were taught with the topic addition polymerisation using the same pre-lesson material (PowerPoint) of the experimental group. During lesson, most of the class time was teacher-centered learning where I dominated most of the class time. Students here were the passive learners while I was the content knowledge distributor distributing the basic content knowledge of addition polymerisation with little time to focus on high-order thinking questions. After the end of lesson, students were given a set of take-home assignment (same as the worksheet discussed during lesson in the experimental group) and they were required to submit it 3 days after the lesson. The corrected assignment was discussed with students before the post-test.

b. Instruments

i. Pre-test & post-test on addition polymerisation

In this research, pre-test and post-test on addition polymerisation were used to evaluate students' content knowledge on addition polymerisation. Both of the tests were designed based on the Hong Kong Diploma of Secondary Education Examination (HKDSE) curriculum for Chemistry in addition polymerisation. There were 15 questions in each of the tests. The full marks of each test is 18 marks. Among them, there are 14 multiple-choice questions and 1 structured question.

In order to maintain the reliability and validity of both pre-test and post-test, they were developed specifically. To enhance the reliability of both tests, there were two common means to do so. One of them was having a consistent environment for participants. For students in both experimental and control groups, each of them did the same pre-test and post-test under the same conditions, i.e. same environment, same duration to finish the tests. Another method was that all students are familiar with the assessment user interface. Since the format of pre-test and post-test are something that students might have experienced at school, they were familiar with. By doing so, the test anxiety could be greatly reduced and hence influenced reliability. To secure the validity, the content of both pre-test and post-test were the same to ensure the level of difficulties were exactly the same. The content of both pre-test and post-test were about the addition polymerisation and 2 questions were about the previous chapter (Alkene) for linkage. By doing so, even though students had no learnt other chapters, they could answer the questions as both tests were designed specifically for the topic addition polymerisation; and to make sure that the data collected was only due to the effect of using flipped learning on addition polymerisation. Beside, paired-t test could be used to secure the validity of this research study.

ii. Observation

During the second lesson of both the experimental and control groups, students' interactions and performance were observed. This qualitative method of this study greatly increased the data pool and also allowed me to observe the situation which might be unintentionally ignored as well as explore things that students might not mention in the focus group interview.

In the lesson, students' participation in each activity, motivation to collaborate with peers and attitude to learn are planned to be observed. For example, I have prepared some discussion sessions during lesson and students' performances are observed. Besides, challenging questions are given for students to discuss (3-4 students in a group and each group is mixed with able and less able students). Among each discussion session, time is allowed for each group to have the discussion and here, it is the time for observation to see whether able students can solve high-order thinking questions and explain clearly to less-able peers. By this way, I can evaluate the effectiveness of collaboration of learning throughout the lesson. Moreover, this is also the session where I can listen to students' opinion and know more about their learning progress. This is very important as observation of students' learning behaviors throughout the lesson could definitely help me to get more information to answer the research questions: to what extent does the flipped classroom affect students' intrinsic learning motivation in learning addition polymerisation, what are those benefits that students could acquire by using flipped classroom learning and what are the limitations when introducing flipped classroom learning.

iii. Structured- group interview

Through the focus group interview, qualitative data of this study could be enriched greatly. The major aim of carrying out interviews is to find out what participants think or how they feel deeply about the subject under study (Abdullah, Hussin & Ismail, 2019). In this interview, there were totally 9 students from each of the experimental group and the control group respectively. For the experimental group, 9 students were selected and divided into 3 groups of 3 students according to their results in the post-test of addition polymerisation. The students from the first group were from high-performing learners, the second group were from middle-performing learners and the third group were from low-performing learners. For the interview in the control group, the selection and division of students will be the same as that of the experimental group. For the experimental group, there are totally 4 same interview questions for students in each group. For the control group, there are also 4 interview questions for students in each group. The interviews for both of the experimental and control groups are designed to be structured where students from both groups need to answer the 4 predetermined questions. This provides a comprehensive picture for me to recognise the phenomenon of this research from various points of view.

- 4 interview questions for participants in the experimental group
    1. Do you think that it is difficult for you to study all those pre-lessons material (i.e PPT) by yourself? Why/Why not?
    2. Do you think that using the lesson time to participate in activities which require high-order thinking skills (peers discussion/ challenging questions) can help you consolidate the concepts that you have self-studied before the lesson? Why/Why not?
    3. Do you think that all those activities you have participated in the lesson can arouse your interests in learning addition polymerisation (i.e. self-motivated to find more information about addition polymerisation)? Why/Why not?
    4. Which of the modes of learning (flipped learning/ traditional way of learning) you would prefer in learning the topic addition polymerisation? Why/Why not?

- 4 interview questions for participants in the control group
    1. What do you think about being spoon-fed loads of content knowledge on learning addition polymerisation during lesson?
    2. Do you think that the content knowledge covered in the lesson cater to your learning progress? (i.e. Is it too easy or too difficult for you to understand the concepts)
    3. Do you think that using the traditional teaching method can arouse your interest in learning addition polymerisation? Why/Why not?
    4. Do you think that the take home assignments are difficult for you? Why/Why not?

c. Data analysis

Using independent samples t-tests, the results of both pre and post-tests on addition polymerisation were compared statistically in order to reveal the difference in the mean scores between pre and post-tests. In this current research, sample T-test was used to test for the null hypothesis (i.e. there is no significant difference between the overall mean scores of both pre-test and post-test on addition polymerisation). The result of this test illustrates whether the data are consistent with the hypothesis or not. Apart from that, findings are shown and reported based on the research questions mentioned above. Through interpreting the results and signatures of the findings, comparing and contrasting the research data with various literatures, the research questions of this study were answered.

d. Expected outcomes

Since the topic of addition polymerisation is a totally new content knowledge for students, it is expected that the results in pre-test for both experimental group and control group are similar. It is also expected that the results in post-test attained by both experimental group and control group are improved, and higher than that of the pre-test after flipped lesson or conventional teaching approach. By comparing the mean score of post-test, students in the experimental group are expected to attain a higher score than that of the control group. Similarly, the mean score difference between students' pre-test and post-test is expected to be higher in the experimental group than that of the control group.

Chapter 4: Result

There were 34 participants in total and each of them finished the pre-test respectively in the first lesson. Their pre-test were marked after the first lesson, and the results were presented by the bar chart below. 1-17 participants were those from the experimental group while 18-34 participants were those from the control group.

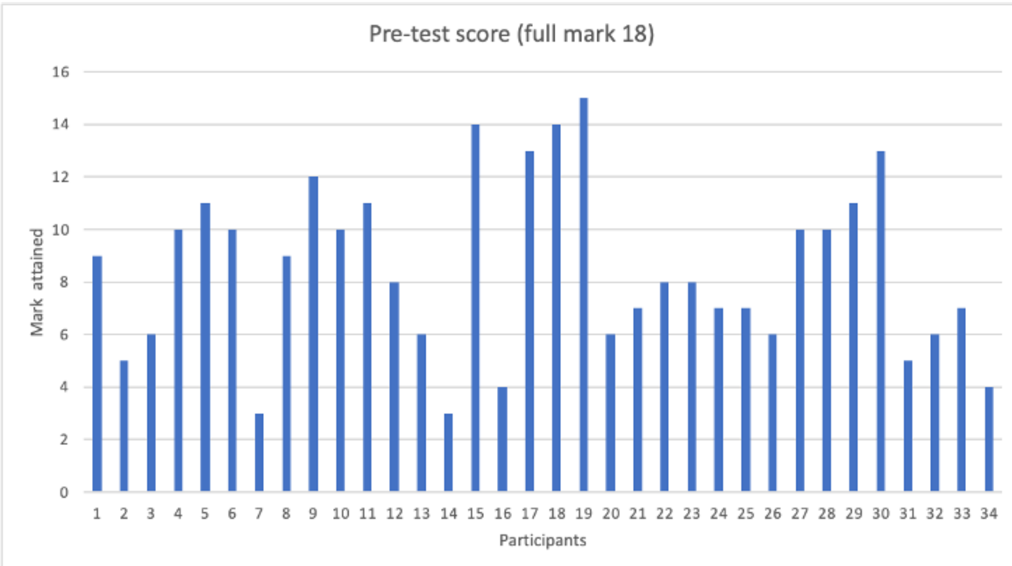

Figure 1: Pre-test score of 34 participants (full mark 18)

The mean score of the pre-test performed by participants in the experimental group was 8.471 while that of the control group was 8.471.

The mean scores of the pre-test performed by the participants were analyzed and illustrated by using normal distribution curves in the following graph.

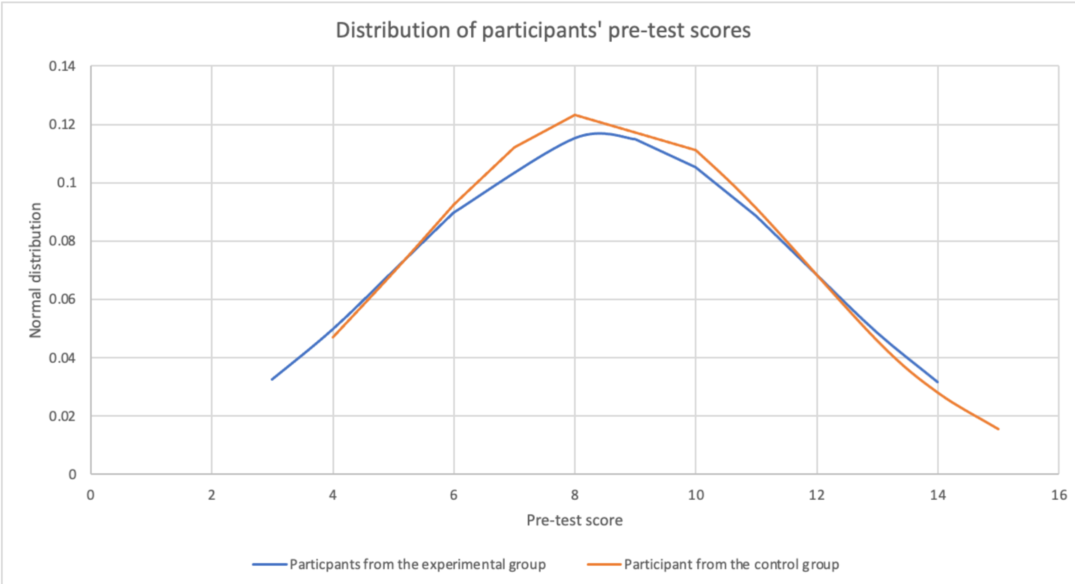

Figure 2: Distribution of pre-test scores of 34 participants

There were 34 participants in total and each of them finished the post-test respectively in the third lesson. Their post-test were marked after the third lesson, and the results were presented by the bar chart below. 1-17 participants were those from the experimental group while 18-34 participants were those from the control group.

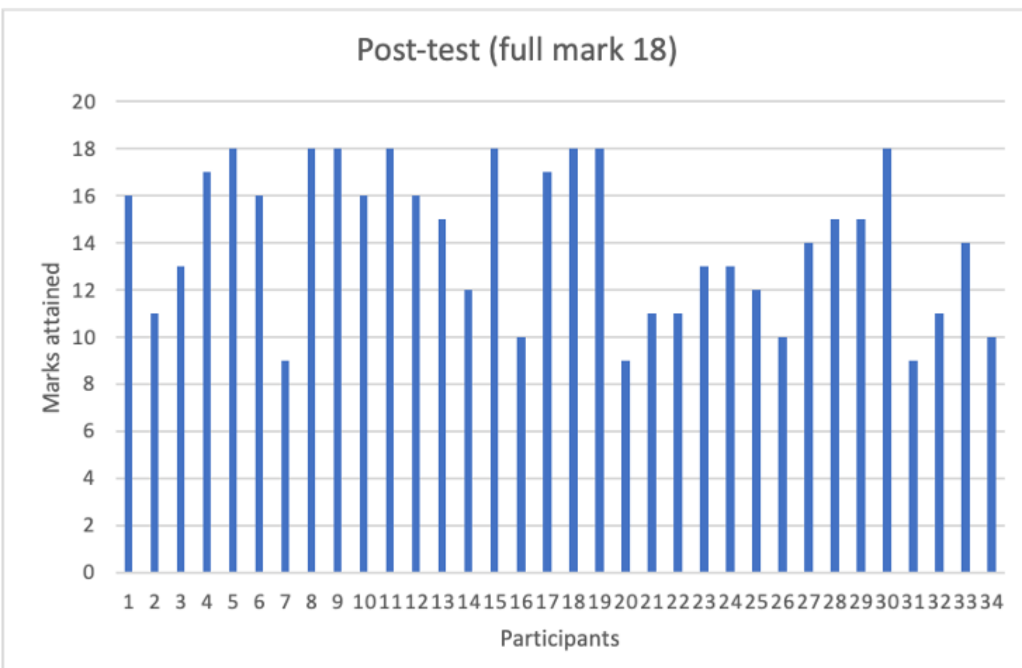

Figure 3: Post-test mark of 34 participants (full mark 18)

The mean score of the post-test performed by participants in the experimental group was 15.176 while that of the control group was 13.000.

Besides, the mean scores of the post-test performed by the participants were analyzed and illustrated by using normal distribution curves in the following graph below.

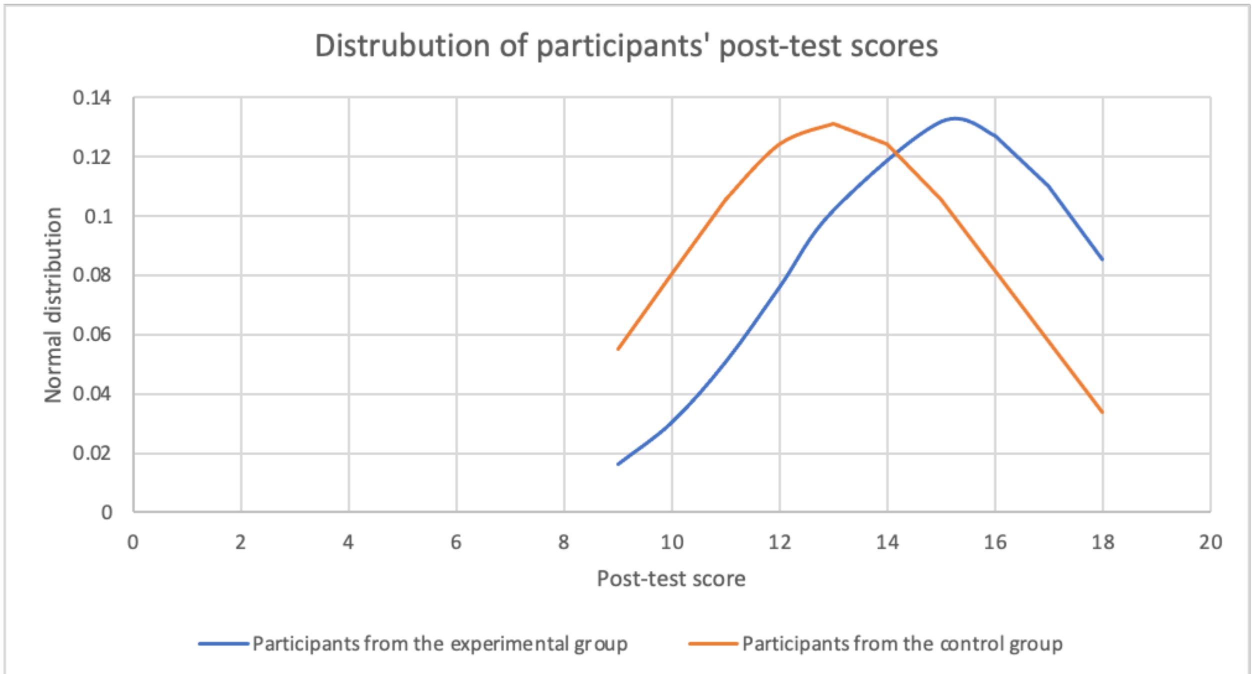

Figure 4: Distribution of post-test scores of 34 participants

The score difference between pre-test and post-test performed by the experimental and control groups analyzed and illustrated by using the bar chart below. 1-17 participants were those from the experimental group while 18-34 participants were those from the control group.

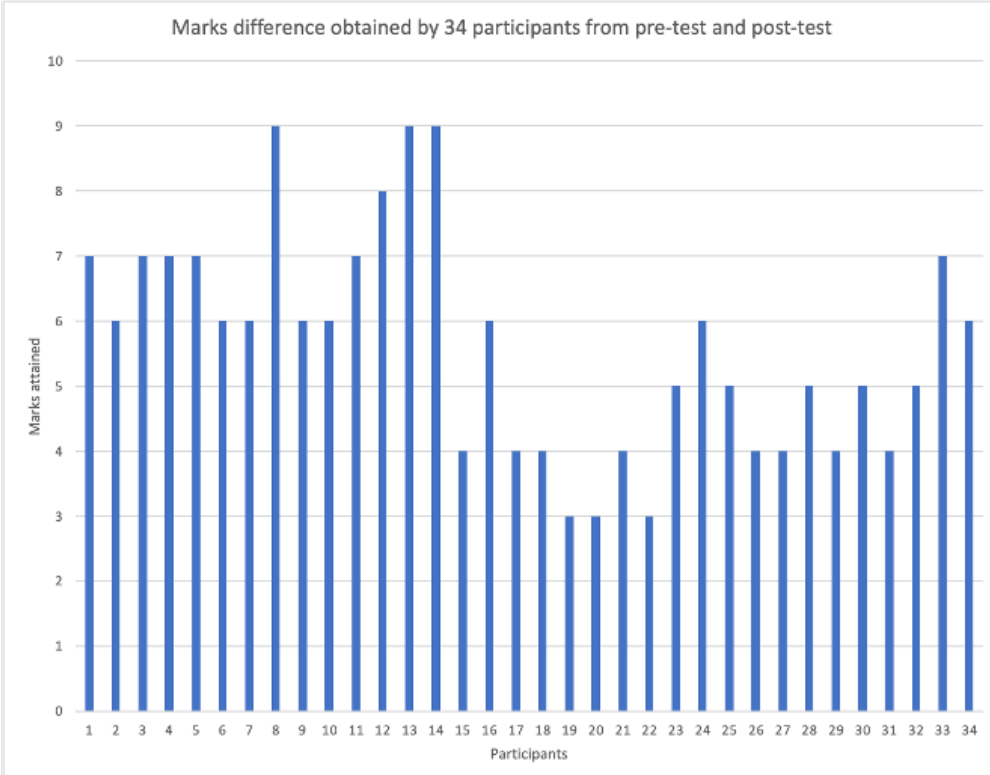

Figure 5: Marks difference obtained by 34 participants from pre-test and post-test

The mean mark of the marks difference from participants of the experimental group was 6.705 while that of the control group was 4.529.

Besides, the mean mark of the marks difference between participants were analyzed and illustrated by using normal distribution curves in the following graph.

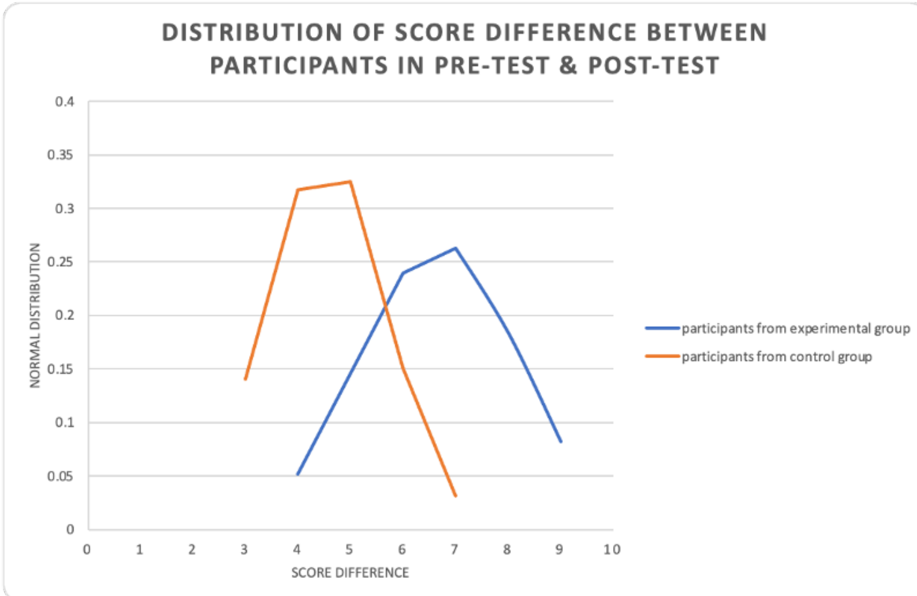

Figure 6: Distribution of score difference between participants in pre-test and post-test

Chapter 5: Discussion

Referring to the data collected from the pre-test (figure 1), it is obvious that the scores attained by participants were relatively low and no one could attain full marks (18 marks). The highest mark for the pre-test was 15 marks and only 1 participant achieved. Only 41.7% of participants attained 50% marks or above (i.e. 9 marks or higher) of the pre-test. In terms of the mean scores of pre-test obtained by participants in the experimental group and that of participants in the control group (figure 2), 2 bell-shaped curves were nearly the same with very similar distributions, which meant that the mean scores of participants in both groups were very similar (i.e. the mean scores of participants in both groups were 8.471 marks). The performance of the pre-test was unsatisfactory since the topic addition polymerisation was something new and unfamiliar to them. They might just guess the correct answers and randomly write them down on the test. The mean scores of both groups were similar due to the fact that they were not familiar with the chapter addition polymerisation, again. By interpreting these results, it could be assured that the validity of this research study was high since no extreme value could affect the results (i.e. both groups included similar numbers of participants with different (able & less-able) abilities).

On average, the mean scores of post-test of participants in both groups was 14.088 marks, which was much higher than that in the pre-test (8.471 marks), with 5.617 marks higher in total. Overall, 19 out of 34 participants (55.9 %) could attain 80% or above of the full marks (14.4 out of 18 marks) of the post-test. It was seen that all participants improved after flipped learning or conventional learning. However, referring to the data collected from the post-test (figure 3), it was concluded that participants in the experimental group performed better than that of the control group. In total, 8 out of 34 participants (23.5%) attained full marks (18 marks) in the post-test, in which 5 participants were from the experimental group. Moreover, in terms of the mean scores of post-test obtained by participants in the experimental group and that of participants in the control group (figure 4), the mean scores of the participants in the experimental group were significantly higher than that of the control group. The mean marks of the participants in the experimental group was 15.176 marks while that of the control group was 13.000 marks only, with the former one 2.176 marks higher than the latter one. Moreover, greater improvement could be seen in the experimental group than that of the control group by comparing the score difference between pre-test and post-test. More than half of the participants in the experimental group (52.9%) have improved 7 marks or above while 64.7% of the participants in the control group had improved 4 and 5 marks only. Furthermore, in term of the mean score difference between participants in pre-test and post-test (figure 5 & 6), the mean score difference of participants in the experimental group was 6.706 while that of the control group was only 4.529, with the former one 2.177 marks higher than the latter one. Based on the data obtained from the result of both pre-test and post-test, it was concluded that the experimental group attained higher overall improvements than that of the control group. The evidence was clear to match with hypothesis 1: students will have better academic achievements in the topic addition polymerisation under flipped learning than that of traditional learning; & research question 3: flipped classroom greatly enhanced students' academic achievements in learning addition polymerisation.

Through observing students' performance in both the experimental and control groups, students from the experimental group were more active and attentive during flipped lesson. They were more willing to answer questions and collaborate with peers, volunteering in participating in different activities such as discussion, drawing equations and so on. Beside, they quickly responded to the questions asked during the lesson as they had prepared and searched for more information before the lesson. It was seen that students' intrinsic motivation to learn addition polymerisation is higher. For conventional learning in the control group, the majority of students were quite passive during lesson. Less volunteers to answer questions and students were less able to answer high-order thinking questions correctly. The result was so obvious that it matched with hypothesis 2 and research question 4: Students' motivation in learning the topic addition polymerisation would be increased by using flipped classroom.

The data collected in the structured-group interviews was also being analyzed here. For the participants from the experimental group, majorities of them (8 out of 9) thought that pre-lesson materials were suitable to study with clear explanations, guiding videos to draw the monomer, repeating unit and polymer, exercises for concepts checking. One participant from the low-performing learner group commented that it was pretty good to read all the pre-lesson materials at her own pace without a time limit as she could revise the content more than once and the pre-lesson materials were user-friendly. Another participant from the middle-performing learner group commented that it was good to include guiding videos with narration on how to draw different monomers, repeating units, polymers and equations, where she could be able to digest and understand the content knowledge before going back to the lesson.

Apart from that, more than half of the participants (7 out of 9) from the experimental group thought that in-class activities could help them consolidate the concepts that they had self-studied before the lesson. During flipped lesson, those in-class activities required students to learn basic concepts learnt before and hence applied them. Participants from high-performing learners group thought that in-class activities could allow them to train critical thinking skills, and that of the middle-performing learners group thought that the learnt concepts could be consolidated through collaboration. Participants from the low-performing learners group found that most of the questions could be answered through collaboration with peers. It was seen that 3 groups of learners could benefit from flipped learning when learning addition polymerisation.

Furthermore, all participants from 3 learners groups thought that all those activities they had participated in the lesson could arouse their interests as they could immediately access all information at home, and thus could have better understanding before going back to class. Those pre-lesson materials were easy to read and interesting. All the elements would in turn give them more motivation to find more extra information before class.

Overall, most of the participants from the experimental group (8 out of 9) said that they preferred flipped learning over traditional learning in learning addition polymerisation. Majority of participants thought that flipped lesson was more interesting, with a lot of collaboration and discussion with peers, which could definitely increase their learning motivation. Participants from 3 learners groups thought that flipped learning was much more effective than traditional one as the former one included many high-order thinking and public examination-typed questions while the latter one only focused on the basic content knowledge printed in the textbook.

According to the structured-group interview in the control group, all participants from three learners groups thought that traditional learning could not cater for their actual learning needs as conventional learning focused on spoon-feeding with loads of content knowledge during lesson. Since the topic is new to students, most of them, especially those in the low to middle performing learners groups, thought that it was difficult for them to digest and fully understand much of the content knowledge within a short period of time. For example, it was difficult to recognize the repeating unit from the given section of a long chain polymer, and drew the equation of addition polymerization from a given long chain of polymer and so on. According to participants in the middle-performing learners group, she thought that assignments were relatively difficult to complete as the content knowledge distributed during class was easy. For the participants in the high-performing learners group, they said that the lesson was so boring with few activities and the content knowledge for them was so easy to understand. It was no doubt that the traditional learning pedagogy no longer catered for the learning diversity within a class.

In addition, participants from the control group thought that the content knowledge covered in the lesson could not cater for their actual learning progress. Participants from high-performing learners group said that the content knowledge was too easy for them such that they found the lesson was boring; that from middle-performing learners group thought that time was not enough for them to do the in-class exercise; and that from the low-performing learners group said that time was not enough for them to fully understand the questions and some even could not answer the questions asked during lesson. Hence, some participants might get distracted easily as they did not understand the content that the teacher was talking about. As a result, most of the participants' learning needs could not be satisfied when using the traditional teaching approach.

Regarding the comments shared by the participants in the control group, the majority of participants (6 out of 9) thought that using the traditional teaching approach could not arouse their interest in learning addition motivation. This is because the lesson was lecture-based learning without many activities. Many of them were not being engaged into the lesson as soke found that the contents were relatively easy to understand while some though that insufficient time was allowed to fully digest loads of information during a short period of time in the traditional learning environment.

Based on the perspectives concluded by the participants in the control group, most of the high-performing learners thought that the questions levels in the take-home assignment were in the middle level while most of the middle to low-performing learners found them difficult to finish by themselves. One of the participants thought that the class time only focus on the relatively low-order to middle-order thinking questions and much time in the lesson was lecture-based without deeply talking about the applied questions or DSE based questions (usually requires students' critical thinking skills). As a result, the performance of the take-home assignments were usually not up-to-standard. Much time was spent talking about the questions in the next lesson of the marked take-home assignments, instead of spending much time learning a new topic. As a result, this bad cycle continued and students' learning motivation as well as the academic performance would be lowered.

Interpreting all the data and results obtained from this research study, it was assured that the design of the content could definitely be the main reasons why students could have learnt better in flipped learning, which flipping the original mode of learning by having school work to be done at home and homework to be finished at school (Network, 2014). Flipped learning allowed students to study the basic content knowledge before class at their own pace without time limit, hence they could digest the content knowledge in sufficient time by reading user-friendly pre-lesson materials. All those pre-lesson materials were specifically designed so as to allow all students, no matter they were able or less-able learners, to read them and understand the topic addition polymerisation much easier (yet all information was being covered in the pre-lesson materials) than that in the conventional learning approach. Learning diversity of students could be catered through flipped learning as students could read the pre-lesson materials without time limit at any time at anyplace, which was something that traditional learning approach could not provide as teacher usually rushed to cover loads of content knowledge during a short period of time (i.e. 35 minutes in a lesson). As students found that it was not difficult to learn new topic like addition polymerisation, they were more willing to search for more information about the topic and be prepared before the flipped lesson. Sometimes, students even discussed with peers in advance of lesson. Thus, it was seen that the intrinsic motivation to learn was much higher when using flipped learning than that of conventional learning. Much time was spent in emphasizing high-order thinking questions which were something that students must learn to achieve remarkable academic results.

Based on all the strong evidence that being stated above, it was undoubtedly that flipped classroom could bring positive effects on learning addition polymerisation where students' could achieve better academic performance and promote higher intrinsic learning motivation in learning the topic addition polymerisation.

Chapter 6: Limitations and possible ways to improve further studies

Although there was much data and research supporting that using flipped classroom could increase the effectiveness of teaching and learning on the topic addition polymerisation in the Hong Kong secondary education system, there were still minor limitations of this research study.

One of the limitations was that the sample size was not large enough. There were only 34 participants in total with 17 participants in each group. The result might be affected by the extreme data and the statistical power might thus be reduced. To solve this problem, more participants from school in similar banding and background might be invited to participate in the research study to gather more data so as to make the result more concrete and trustworthy. Another limitation was that the mode of teaching for both experimental and control groups changed to virtual mode of teaching due to the pandemic situation. Planned face-to-face lessons were replaced by online lessons. Students with less self-discipline might be easily affected and pay less attention during lessons, which would reduce the effectiveness due to 2 different teaching approaches (flipped classroom and conventional classroom). Less immediate feedback could be given during discussion sessions as it was unable to observe all groups at the same time via a virtual model of teaching. In the future, face-to-face learning is preferred or virtual mode of teaching is used with more support. For example, record the performance of each individual and have a debriefing session after class, after-class discussion with each individual if needed, using more online tools such as Quizlet and Padlet for instant comments and after-class discussion. In addition, validity might be altered by the testing effect that came along with the pre-test and post test. As the content of both pre-test and post-test were exactly the same, students might memorize the questions in the pre-test, which might affect the result of the post-test done by both groups of students. The result might not be significant due to 2 different teaching pedagogies but students just memorized the questions and then jotted down the correct answers. To make the outcome more precise (only due to the effect under 2 teaching pedagogies), 'Solomon four-group design' could be able to handle the testing effect. The Solomon four-group design, based on the paper written by Allen (2017), is a study design which considers the effects of the pre-test on the outcomes of the subsequent post-test. Participants will be randomized to one of four groups at random in the design: (1) Pre-test & post-test with treatment, (2) Pre-test & post-test without treatment, (3) Post-test with treatment and (4) Post-test without treatment. For this research study, groups (1) and (2) were carried out. Repeating groups (1) and (2) with the exclusion of pre-test, the effects brought up only due to pre-test could be able to compare and contrast.

Apart from that, there might be intervention that applied to the students in the experimental group from diffusing to that of the control group, especially all the students from both groups were from the same secondary school. At the beginning of the first lesson after the pre-test, students were reminded not to disclose any information and learning materials to peers from another group verbally. However, it was difficult to ensure students would not disclose any information to peers in another group and hence the performance and results in the post-test done by students might not be reflecting the difference only due to the effect under the flipped classroom. To minimize the effect brought by this issue, participants could be recruited from different schools (at least 2) with similar banding and background. Participants accounted for the experimental and control groups could be recruited in 2 different schools to avoid the disclosure of any information and materials, which might have potential risk and impact to the result of the research.

Furthermore, the result might be minimized by the duration of the treatment for both the experimental and control groups. Since the virtual lessons for both of the groups only lasted for 1.5 hours, it was relatively difficult to measure the improvement of the students in learning the topic addition polymerisation in such a short period of time although this was a topic containing relatively little amount of content knowledge. Some students might need more time to digest and consolidate the concepts learnt. As a result, the outcome might be altered. In order to make the research study more concrete, 3 to 5 lessons in which each of the lessons might last for 1 hour could be carried out as a class series to learn the topic of addition polymerisation.

Chapter 7: Conclusion

Due to the advancement and development of the society, the traditional teaching approach cannot cater for the learning diversity of students inside a class, especially when learning chemistry (required students to learn a lot of abstract content knowledge) in the topic addition polymerisation. More and more schools nowadays have adopted a new teaching and learning model flipped classroom. With the increasing use of flipped learning, this research has investigated the effectiveness of flipped classroom on learning addition polymerization in Hong Kong secondary education system. Throughout this study, it was found that students under flipped learning model would have better academic achievement as well as greater intrinsic learning motivation to learn the topic addition polymerisation than that of using the traditional teaching approach. All those evidence has strongly proven that flipped classroom is more effective than traditional teaching model in learning the topic of addition polymerisation. The role of teacher no longer is the content knowledge distributor dominating the whole lesson but acting as a guidance, while students change from passive learners to active one. Although this is an experimental study only showing the result of a chemistry class students, it represents a significant step toward the investigation of the effectiveness of flipped learning on addition polymerisation in Hong Kong secondary chemistry education for future studies.

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Appendix

Template of Pre-test:

Pre-test

English Name: ______________	Chinese Name: ______________	Class & Class No.: ______________

Multiple Choice (14 Marks)

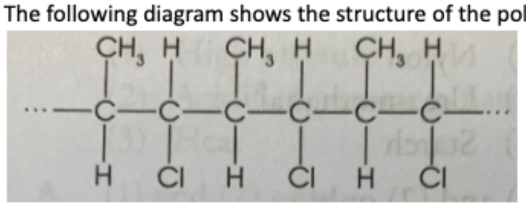
1. Which of the following are synthetic polymers?
   (1) PVC
   (2) Perspex
   (3) Silk
   a. (1) and (2) only
   b. (1) and (3) only
   c. (2) and (3) only
   d. (1), (2) and (3)

2. Which of the following polymers is suitable for making fishing lines?

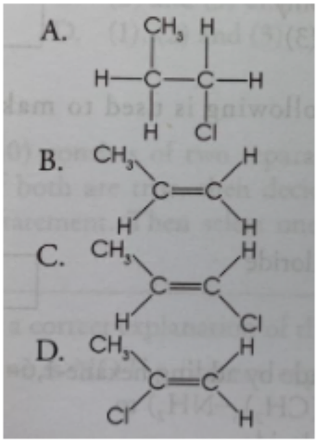
	Polymer	Strength	Behavior in hot water
A.	Polyethene	Easy to bend	Softens easily
B.	Perspex	Difficult to bend	Softens
C.	Nylon	Flexible but strong	Softens easily
D.	Phenol-methanal	Difficult to bend	Does not soften

3. Which of the following statements concerning polystyrene is incorrect?
   a. Polystyrene is formed by the addition polymerization of styrene.
   b. Expanded polystyrene is widely used in fast-food shops as polystyrene is one of the cheapest plastics.
   c. Polystyrene dissolves in sodium hydroxide to form styrene.
   d. Polystyrene is a very good heat insulator.

4. The following diagram shows the structure of the polymer X:

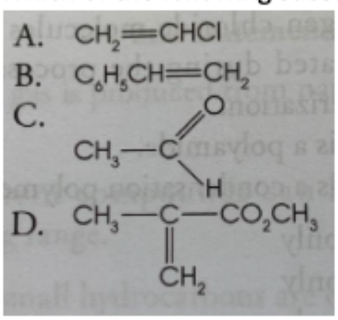


Which of the following is the monomer of polymer X?



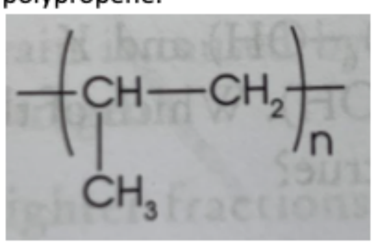
C

5. Which of the following substances does not form addition polymers?



C

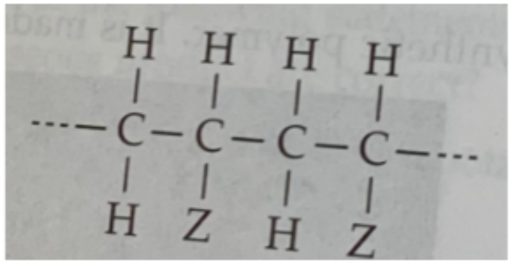
6. Under suitable conditions, propene ($CH_3CH=CH_2$) combines to give the polymer polypropene.



Which of the following statements is incorrect?
a. Propene is the monomer.
b. The reaction is known as addition polymerization.
c. Polypropene is not combustible.
d. The value of n is large and not fixed.

7. Which of the following about addition polymers are correct?
(1) They are man-made polymers.
(2) They form from monomers which are alkenes.
(3) They can decolorize bromine dissolved in an organic solvent.
a. (1) and (2) only
b. (1) and (3) only
c. (2) and (3) only
d. (1), (2) and (3)

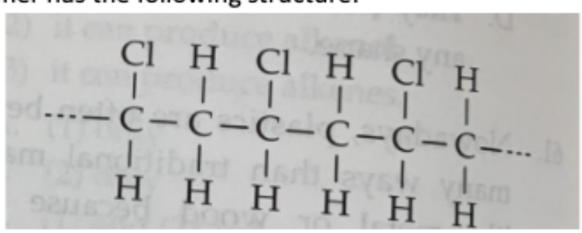
8. The following diagram represents the structure of a polymer, where Z stands for an atom or a group of atoms.



Which of the following combinations is incorrect?

	Z	Name of polymer
a.	Cl	Polyvinyl chloride
b.	CH_3	Polybutene
c.	C_6H5	Polystyrene
d.	H	Polyethene

9. An addition polymer has the following structure:



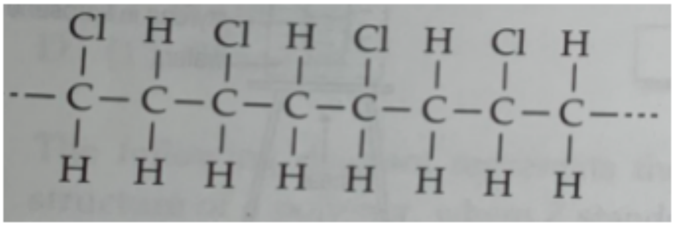
Which of the following combinations about the repeating unit and monomer of the polymer is correct?

	Repeating unit	Monomer
A.	$\left[CCl-CH \right]$	$CCl=CH$
B.	$\left[CHCl-CH_2 \right]$	$CHCl=CH_2$
C.	$CHCl-CH_2$	$\left[CCl=CCl \right]$
D.	$CHCl=CH_2$	$\left[CHCl-CH_2 \right]$

B

10. Which of the following about polythene are correct?
(1) It is a synthetic polymer.
(2) Its monomer contains carbon-carbon double bond.
(3) It is an addition polymer.
a. (1) and (2) only
b. (1) and (3) only
c. (2) and (3) only
d. (1), (2) and (3)

11. The following represents part of the structure of polymer X.



Which of the following statements about polymer X are correct?

(1) The monomer of polymer X is CH_2=CHCl.

(2) Polymer X can be used to manufacture artificial leather.

(3) When polymer X burns, the gas gives off acid rain.

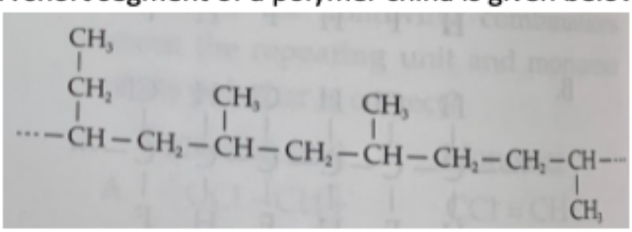
a. (1) and (2) only

b. (1) and (3) only

c. (2) and (3) only

d. (1), (2) and (3)

12. A short segment of a polymer china is given below.



Which of the following monomers can be used to make the above polymer?

(1) CH_3CH_2CH=CH_2

(2) CH_2=CH_2

(3) CH_3CH=CH_2

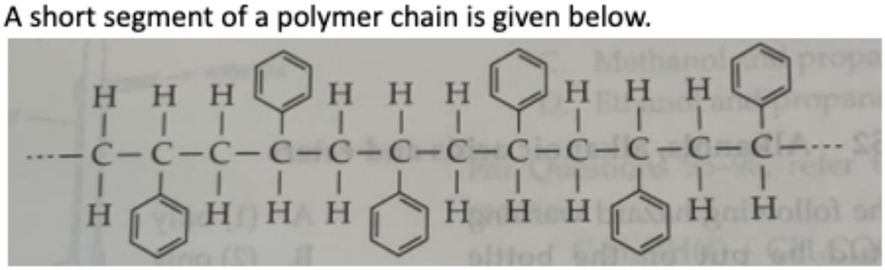
a. (1) only

b. (2) only

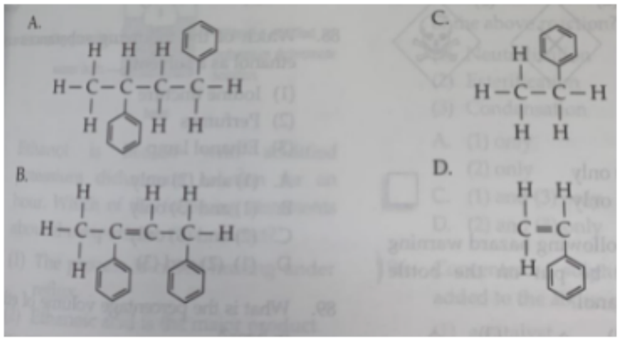
c. (1) and (3) only

d. (2) and (3) only

13. A short segment of a polymer chain is given below.



Which of the following monomers can be used to make the above polymer?



D

14. The following equation shows the cracking of an alkane with 12 carbon atoms:

$$C_{12}H_x \rightarrow 2C_3H_y + C_zH_{14}$$

Which of the following combinations is correct?

a. x=26, y=6, z=6
b. x=26, y=8, z=7
c. x=24, y=6, z=6
d. x=24, y=8, z=7

Structured Questions (4 Marks)

15. Alkenes can be produced by the thermal cracking of alkanes.

(a). Explain why a high temperature is required for the thermal cracking of alkanes.

Ans: The C-C bonds and C-H bonds in alkanes are very strong. Hence, a large amount of energy is needed to break these bonds during cracking.

(2 marks)

(b): What is the general formula of alkenes?

Ans: C_nH_{2n}

(1 mark)

(c) :The cracking of a hydrocarbon with the formula of $C_{13}H_{28}$ produces ethene, propene and a straight-chain alkane. Write a chemical equation for the reaction involved.

Ans: $C_{13}H_{28}$ $C_2H_4 + C_3H_6 + C_8H_{18}$

(1 mark)

Template of post-test:

Post-test

English Name:		Chinese Name:		Class & Class No.:	
	____________		____________		____________

Multiple Choice (14 Marks)

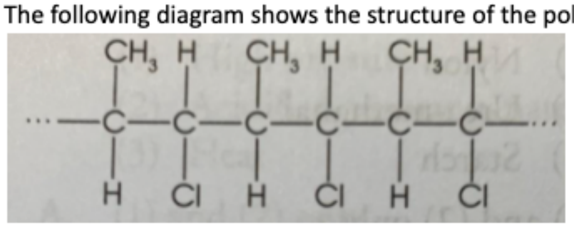
1. Which of the following are synthetic polymers?
   (1) PVC
   (2) Perspex
   (3) Silk
   a. (1) and (2) only
   b. (1) and (3) only
   c. (2) and (3) only
   d. (1), (2) and (3)

2. Which of the following polymers is suitable for making fishing lines?

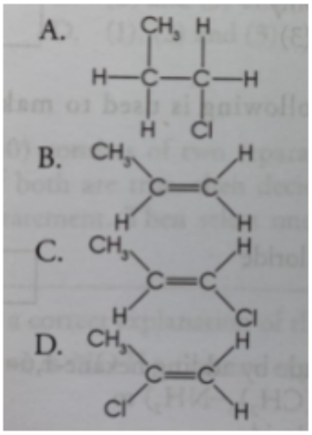
	Polymer	Strength	Behavior in hot water
A.	Polyethene	Easy to bend	Softens easily
B.	Perspex	Difficult to bend	Softens
C.	Nylon	Flexible but strong	Softens easily
D.	Phenol-methanal	Difficult to bend	Does not soften

3. Which of the following statements concerning polystyrene is incorrect?
   a. Polystyrene is formed by the addition polymerization of styrene.
   b. Expanded polystyrene is widely used in fast-food shops as polystyrene is one of the cheapest plastics.
   c. Polystyrene dissolves in sodium hydroxide to form styrene.
   d. Polystyrene is a very good heat insulator.

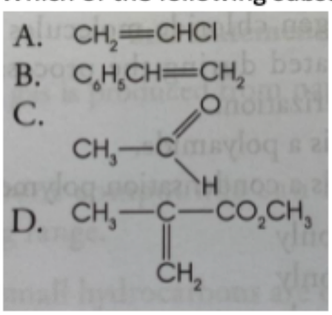
4. The following diagram shows the structure of the polymer X:



Which of the following is the monomer of polymer X?

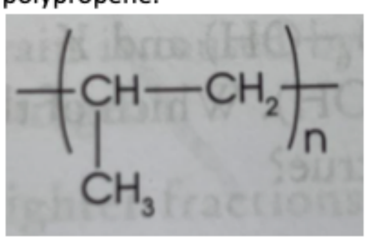

C

5. Which of the following substances does not form addition polymers?



C

6. Under suitable conditions, propene ($CH_3CH=CH_2$) combines to give the polymer polypropene.



Which of the following statements is incorrect?

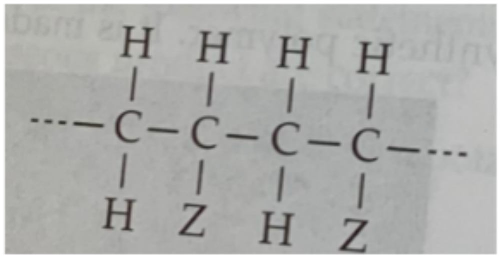
a. Propene is the monomer.
b. The reaction is known as addition polymerization.
c. Polypropene is not combustible.
d. The value of n is large and not fixed.

7. Which of the following about addition polymers are correct?

(1) They are man-made polymers.
(2) They form from monomers which are alkenes.
(3) They can decolorize bromine dissolved in an organic solvent.

a. (1) and (2) only
b. (1) and (3) only
c. (2) and (3) only
d. (1), (2) and (3)

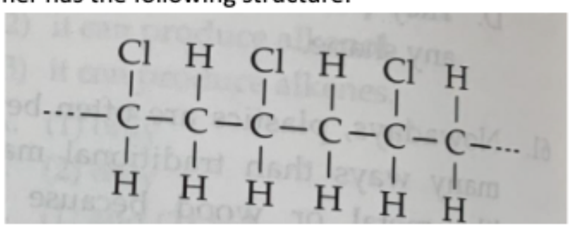
8. The following diagram represents the structure of a polymer, where Z stands for an atom or a group of atoms.



Which of the following combinations is incorrect?

	Z	Name of polymer
a.	Cl	Polyvinyl chloride
b.	CH_3	Polybutene
c.	C_6H5	Polystyrene
d.	H	Polyethene

9. An addition polymer has the following structure:



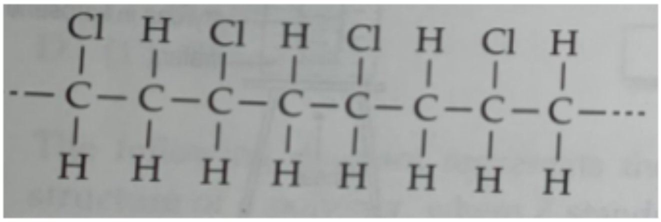
Which of the following combinations about the repeating unit and monomer of the polymer is correct?

	Repeating unit	Monomer
A.	$\{CCl-CH\}$	$CCl=CH$
B.	$\{CHCl-CH_2\}$	$CHCl=CH_2$
C.	$CHCl-CH_2$	$\{CCl=CCl\}$
D.	$CHCl=CH_2$	$\{CHCl-CH_2\}$

B

10. Which of the following about polythene are correct?
(1) It is a synthetic polymer.
(2) Its monomer contains carbon-carbon double bond.
(3) It is an addition polymer.
a. (1) and (2) only
b. (1) and (3) only
c. (2) and (3) only
d. (1), (2) and (3)

11. The following represents part of the structure of polymer X.



Which of the following statements about polymer X are correct?

(1) The monomer of polymer X is CH_2=CHCl.

(2) Polymer X can be used to manufacture artificial leather.

(3) When polymer X burns, the gas gives off acid rain.

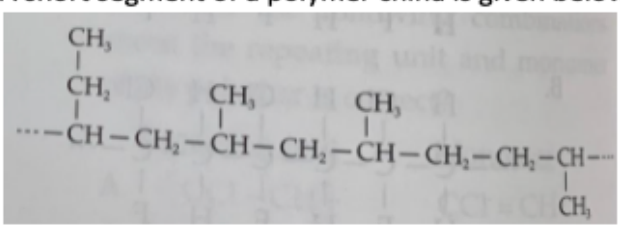
a. (1) and (2) only

b. (1) and (3) only

c. (2) and (3) only

d. (1), (2) and (3)

12. A short segment of a polymer china is given below.



Which of the following monomers can be used to make the above polymer?

(1) $CH_3CH_2CH=CH_2$

(2) $CH_2=CH_2$

(3) $CH_3CH=CH_2$

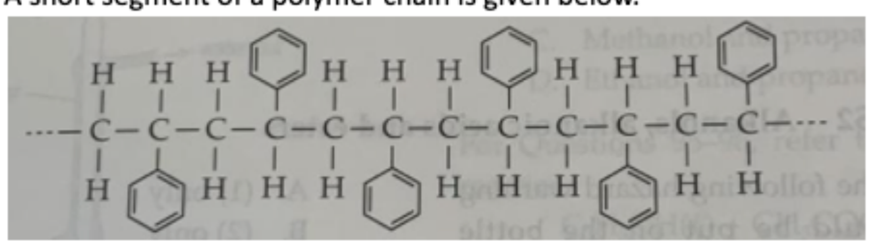
a. (1) only

b. (2) only

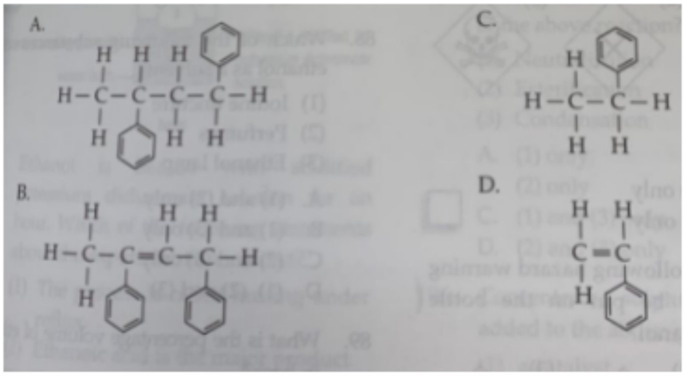
c. (1) and (3) only

d. (2) and (3) only

13. A short segment of a polymer chain is given below.



Which of the following monomers can be used to make the above polymer?



D

14. The following equation shows the cracking of an alkane with 12 carbon atoms:

$$C_{12}H_x \rightarrow 2C_3H_y + C_zH_{14}$$

Which of the following combinations is correct?

a. x=26, y=6, z=6
b. x=26, y=8, z=7
c. x=24, y=6, z=6
d. x=24, y=8, z=7

Structured Questions (4 Marks)

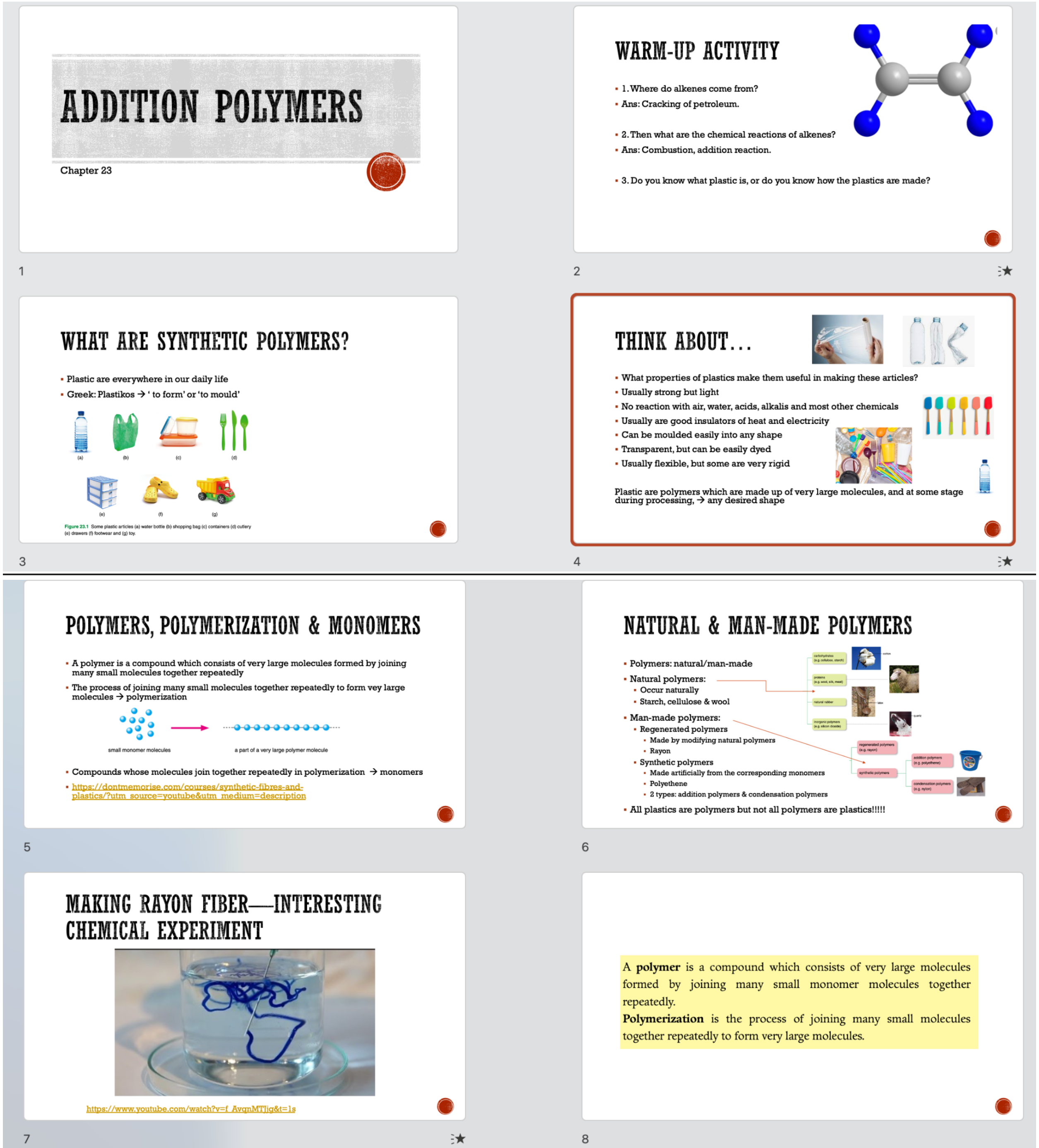
15. Alkenes can be produced by the thermal cracking of alkanes.

(a). Explain why a high temperature is required for the thermal cracking of alkanes.
Ans: The C-C bonds and C-H bonds in alkanes are very strong. Hence, a large amount of energy is needed to break these bonds during cracking.

(b): What is the general formula of alkenes?
Ans: C_nH_{2n}

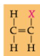
(c) :The cracking of a hydrocarbon with the formula of $C_{13}H_{28}$ produces ethene, propene and a straight-chain alkane. Write a chemical equation for the reaction involved.
Ans: $C_{13}H_{28}$ $C_2H_4 + C_3H_6 + C_8H_{18}$

Pre-lesson materials (experimental group) & conventional teaching materials (control group) :



ADDITION POLYMERIZATION

- A reaction where monomer molecules join together repeatedly to form polymer molecules, without the elimination of small molecules (H_2O/HCl)
- The monomer molecules do not lose atoms and the polymer is the only product
- Monomer molecules involved must contain contain carbon-carbon double bonds
- Undergo repeated addition reactions among themselves → addition polymer
- Monomers can be represented by a general formula:

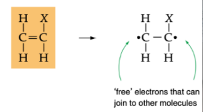


where $-X$ stands for an atom or a group of atoms such as $-H$, $-CH_3$, $-$◎, $-Cl$ and so on.

9

ADDITION POLYMERIZATION

- By breaking open the carbon-carbon double bond, a monomer molecule will have 2 'free' electrons which can join to other molecules



https://www.youtube.com/watch?v=TvaZkGZ7zW0

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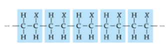
ADDITION POLYMERIZATION

- By repeating this addition process many times → long polymers chains
- Each polymer chain → macromolecules → consists of at least several hundred monomer molecules joined together



- Polymer molecules do not have the same size
- For example: polythene may be represented as $-[CH_2-CH_2]_n-$
- $-[CH_2-CH_2]_{11508}-$ $\quad -[CH_2-CH_2]_{25\,066}-$

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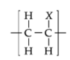
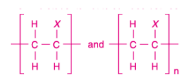
REPEATING UNIT

- A group of atoms in a polymer molecule coming from a monomer (or a set of monomer)
- Repeats to give the whole polymer structure
- Repeating unit:



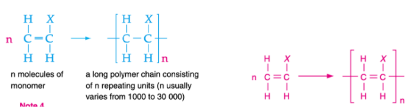
- Be CAREFULLY!!!



12

REPEATING UNIT

- General equation for addition polymerization:



- Do you think it is correct to write the formula of addition polymerization like this? Why?

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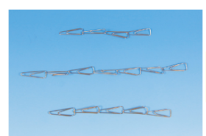
ADDITION POLYMERIZATION



Addition polymerization is a reaction in which monomer molecules join together repeatedly to form polymer molecules, without the elimination of small molecules (such as H_2O or HCl).

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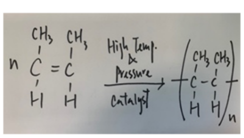
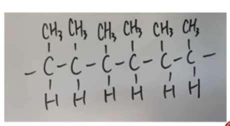
QUESTION 1

$CH_3CH{=}CHCH_3$ can be polymerization.

- 1. Write a chemical equation for the reaction.
- 2. Draw a lengthen of the polymer chain showing 3 repeating units.

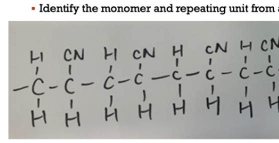


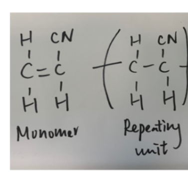


15

QUESTION 2

- Identify the monomer and repeating unit from a lengthened polymer chain.





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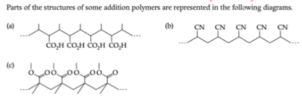
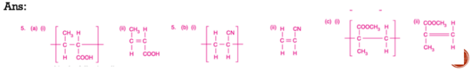
CLASS PRACTICE

5. Parts of the structures of some addition polymers are represented in the following diagrams.



For each of the above polymers,
(i) draw the repeating unit of the polymer, and
(ii) draw the structural formula of its monomer.

- Ans:

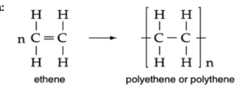


17

STRUCTURE, PROPERTIES & USES OF SOME ADDITION POLYMERS

1. Polythene (PE)

- Made by the polymerization of ethene
- Equation:



In general, polyethene is light, less dense than water & has a low melting point (mp)

- 2 types of polyethene: low-density polyethene (LDPE) & high-density polyethene (LDEP) depends on the manufacturing conditions

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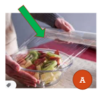
LDPE & HDPE



Low-density polyethene
- It has a mp about 105°C,
- softens in boiling water, flexible

→Make plastic bags, wrapping film for food & flexible cold water pipe

High-density polyethene
- It has a mp about 135°C,
- Quite rigid

→ Make bottles for certain chemicals, bucket & boxes

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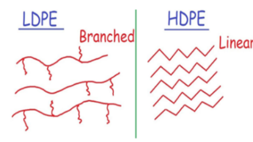
THINK ABOUT...

- LDPE is softer, more flexible and has a lower mp than that of HDPE. Why?
- (Hints: think about their structure)



Ans: LDPE has many branched chains and the chains are packed irregularly. HDPE has very few branched chains and packed more regularly.

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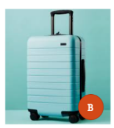
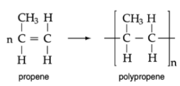
POLYPROPENE (PP)



- Made addition polymerization of propene
- Equations:



- Mp about 165°C
- Density falls between LDPE & HDPE
- Resistant to many chemical solvents, acids & alkalis

→ Ropes, fibres, baskets, boxes, luggage cases, food containers, packaging film

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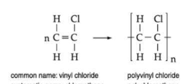
POLYVINYL CHLORIDE (PVC)

- Made by addition polymerization of chloroethene
- Equation:



- PVC itself is stiff & brittle
- Becomes more flexible when mixed with a plasticizer
- Plasticizer is a substance added to plastic to make it softer & more flexible
- Properties of PVC can be varied by the addition of different amounts of plasticizer

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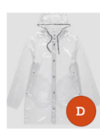
POLYVINYL CHLORIDE (PVC)

- PVC + little plasticizer: quite rigid

→making floor tiles and pipes



- PVC + suitably plasticizer: soft & flexible, water resistance, good insulator of electricity
- → shower curtains, tablecloths, raincoats, artificial leather, making insulating coverings for electric wires

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THINK ABOUT

- Why PVC is not used in making food container?

- Ans: monomers of PVC and plasticizer are toxic which may contaminate the food

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POLYSTYRENE (PS)

- Made by addition polymerization of styrene
- Equation:

$$n\,CH_2{=}CH(C_6H_5) \longrightarrow \left[CH_2-CH(C_6H_5)\right]_n$$

styrene or phenylethene → polystyrene or polyphenylethene

- transparent, hard but brittle
- Make transparent containers such as sample bottles, cups, measuring cups & compact disc cases

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EXPANDED POLYSTYRENE

- Made by heating granular polystyrene with a foaming agent
- White solid foam
- Very low density but still quite rigid
- Excellent heat insulator & good shock-absorbent
- Non-toxic
- Packaging materials, make disposable foam cups and food boxes

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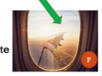
PERSPEX (POLYMETHYL METHACRYLATE OR ACRYLIC)



- Made by addition polymerization of methyl 2-methylpropenoate
- Equation:

$$n\,CH_2{=}C(CH_3)COOCH_3 \longrightarrow \left[CH_2-C(CH_3)(COOCH_3)\right]_n$$

methyl 2-methylpropenoate → Perspex or polymethyl 2-methylpropenoate

- Hard, tough & rigid
- Highly transparent & not easily scratched
- Usually the substitute for glass
- Making aeroplane windows, advertising sign boxes, safety spectacles, illuminated signs & plastic optical fibres

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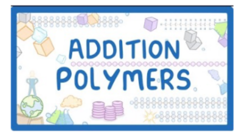
CLOSURE



What we have covered for today's lesson:

- Properties of plastic
- Addition polymerization
- 2 type of polymers: natural polymers & man-made polymers
- Monomer, repeating unit, polymer
- General equation of addition polymerization
- Structure, properties & uses of some addition polymers
- https://www.youtube.com/watch?v=1ZUg6ZC3ltA&t=3s

28

Flipped lesson material (experimetal group) & take home assignment (control group):

Addition Polymerisation Exercise

English Name: ____________ **Chinese Name:** ____________ **Class & Class No.:** ____________

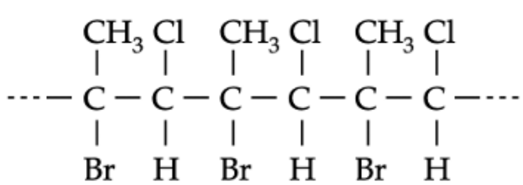
MC

1. Which of the following is/are natural polymer(s)?
    2. Perspex
    3. Cellulose
    4. Rayon

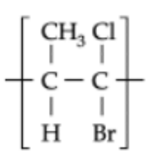
A. (1) only
B. (2) only
C. (1) and (3) only
D. (2) and (3) only

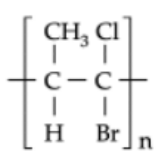
(1): Perspex is a synthetic polymer. (3): rayon is a regenerated polymer.

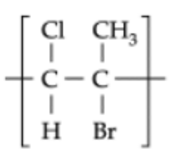
Questions 2 and 3 refers to the following structure, which shows a part of polymer Y.

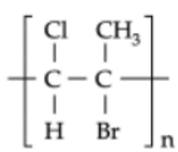


2. Which of the following is the repeating unit of polymer Y?

A. 

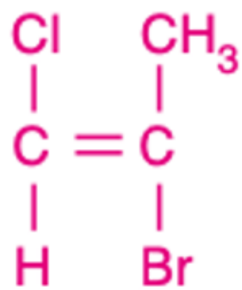
B. 

C. 

D. 

C

3. Which of the following is the systemic name of the monomer of polymer Y?
A. 2-bromo-1-chloro-2-methylethene
B. 1-bromo-1-chloropropene
C. 1-bromo-2-chloropropene
D. 2-bromo-1-chloropropene

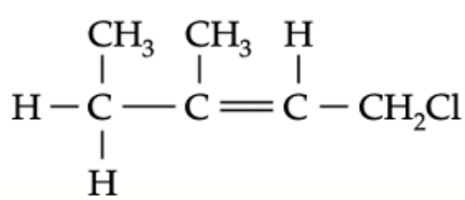


The monomer of polymer Y:
The carbon atoms on the main chain should be numbered from the end closest to the carbon-carbon double bond. We should give the lowest possible numerals to the substituents.

4. Which of the following statements about polypropene are correct?
(1) Its monomer is propene.
(2) It can decolorize acidified potassium permanganate solution.
(3) It can be used to make roped.
A. (1) and (2) only.
B. (1) and (3) only.
C. (2) and (3) only.
D. (1), (2) and (3).

Polypropene does not contain carbon-carbon double bonds in its polymer molecules.

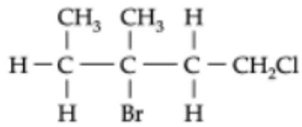
Questions 5 and 6 refer to compound A, which has the following structure:

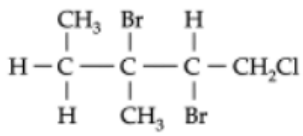


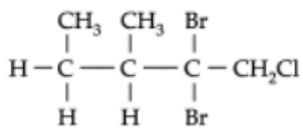
5. What is the systematic name of compound A?
   A. 1-chloro-3,4-dimethylbut-2-ene
   B. 4-chloro-1,2-dimethylbut-2-ene
   C. 1-chloro-3-methylpent-1-ene
   D. 1-chloro-3-methylpent-2-ene

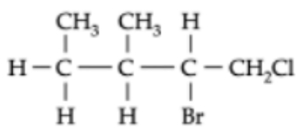
The longest continuous carbon chain contains 5 carbon atoms. When numbering the carbon chain, we should start from the end closest to the carbon-carbon double bond, which is located between C-2 and C-3 for this compound.

6. Which of the following compound is the product of the reaction between compound A and bromine (dissolved in an organic solvent)?

A. 

B. 

C. 

D. 

B

In the reaction, a bromine atom is added to each of the doubly bonded carbon atoms.

LQ

1. Cracking of a hydrocarbon $C_{10}H_{22}$ gives products A and B.

$$C_{10}H_{22} \rightarrow A + B$$

A is a hydrocarbon with 7 carbon atoms and a relative molecular mass 100.0, while B is a hydrocarbon with a relative molecular mass of 42.0. One of the products is used to make an addition polymer. (Relative atomic masses: H=1.0, C=12.0)

(a). Deduce the molecular formulae of A and B.

Let the molecular formula of A be C_7H_y.

$$12.0\times7+1.0\times y = 100.0$$
$$y = 16$$

The molecular formula of A is C_7H_{16}. Since the total number of atoms in the reactant is equal to the total number of atoms in the products, the molecular formula of B is C_3H_6.

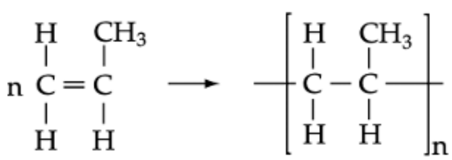
(b). Which one of the products, A or B, is suitable to be used as a monomer to make the addition polymer? Explain your answer.

B is suitable to be used as a monomer to make the addition polymer as it contains a carbon-carbon double bond.

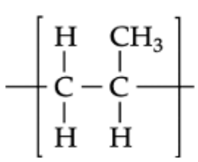
(c). What is the name of the monomer?

Propene.

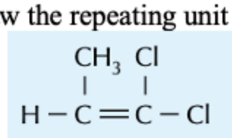
(d). Write a chemical equation for the formation of the addition polymer from the monomer stated in (c).



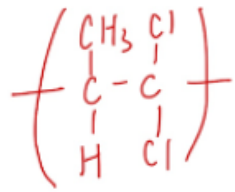
(e). What is the repeating unit of the addition polymer?



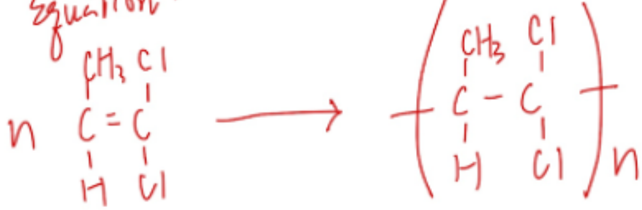
2. Draw the repeating unit and the chemical equation for the addition polymerisation.

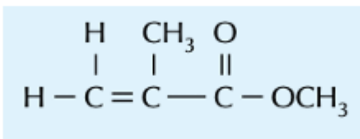
(a) 

2a Repeating unit:



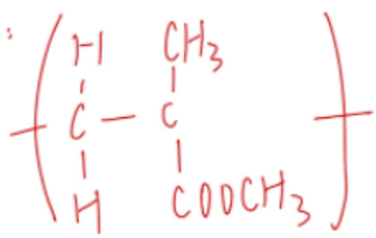
Equation:



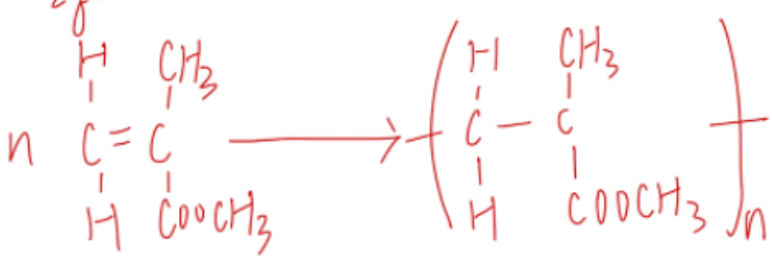


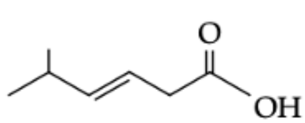
(b)

2b Repeating unit:



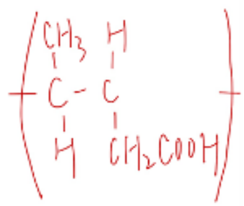
Equation:



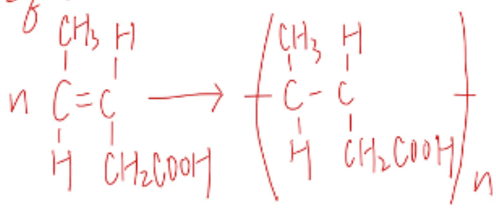


(c)

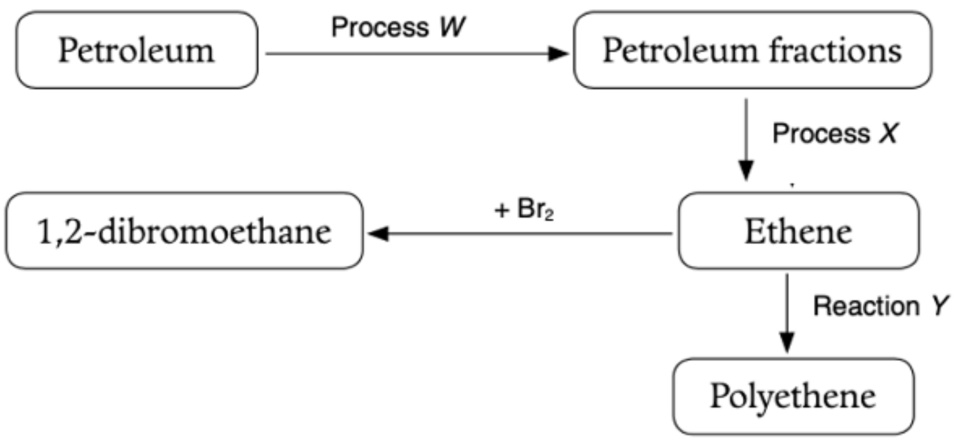
(2c) Repeating unit:



Equation:



3. Many useful chemicals and products can be obtained from petroleum, as shown in the following flow chart.



(a) Petroleum can be refined by Process W.

(i) Name process W.

Fractional distillation

(ii) Explain why different petroleum fractions can be separated from petroleum by Process W.

The hydrocarbons in petroleum have different boiling points.

(b) Ethene can be produced from heavier petroleum fractions by Process X.

(i) Name process X.

Cracking

(ii) Using octadecane ($C_{18}H_{38}$) as an example, write an equations to show how ethene, propene and another alkane are produced in Process X.

$C_{18}H_{38} \rightarrow C_2H_4 + C_3H_6 + C_{13}H_{28}$

(c) Write a chemical equation for the reaction between ethene and bromine (dissolved in an organic solvent).

$CH_2{=}CH_2 + Br_2 \rightarrow CH_2BrCH_2Br$

(d) Polyethene is produced from ethene by Reaction Y.

(i) Name Reaction Y.

Addition polymerisation.

(ii) Suggest one use of polyethene.

Making plastic bags/wrapping film for food/flexible cold water pipes/ bottles for certain chemicals/buckets/box (Any ONE)

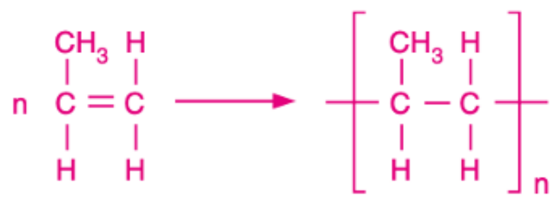
4. Polypropene is commonly used to make carpets. The monomer of polypropene can be obtained from the catalytic cracking of hydrocarbons.

(a) What is the monomer of polypropene?

Propene.

(b) What is the importance of cracking in the production of addition polymers?
Cracking produces alkenes, which are the raw materials for making some kinds of addition polymers.

(c) Write an equation for the formation of polypropene.

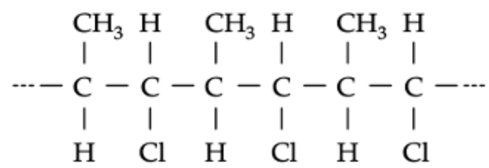


(d) Name the type of reaction for the formation of polypropene from its monomer.
Addition polymerisation.

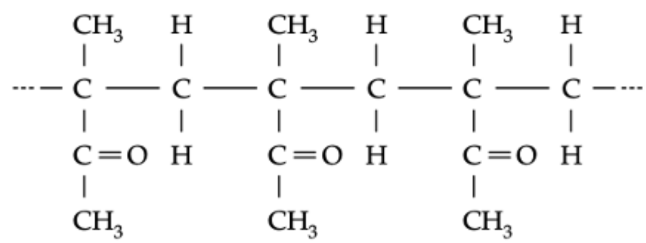
(e) Explain briefly why polypropene is suitable for making carpets.
This is because polypropene is resistant to many chemicals.

5. Parts of the structures of two polymers are represented by the following diagrams.

A



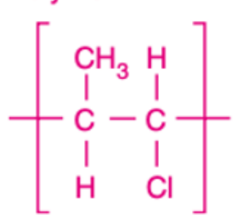
B



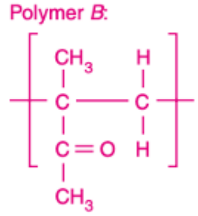
(a) Name the type of polymerization involved in the formation of the above polymers.
Addition polymerisation.

(b) For each of the above polymers,
(i) draw the repeating unit of the polymer, and

Polymer *A*:

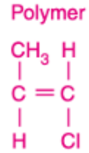


Polymer *B*:

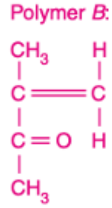


(ii) draw the structural formula of its monomer.

Polymer *A*:



Polymer *B*:



(c) Name the monomer of polymer A.

1-chloropropene

(d) Both polymer A and its monomer are soluble in an organic solvent. Suggest a chemical test to distinguish between these solutions.

Add polymer A and its monomer separately in bromine (dissolved in an organic solvent). Monomer of A can decolorize bromine solution, but polymer A cannot.

School consent form:

THE EDUCATION UNIVERSITY OF HONG KONG
Department of Science and Environmental Studies

CONSENT TO PARTICIPATE IN RESEARCH (FOR SCHOOL)

Effectiveness of Flipped Learning on Addition Polymerisation in Hong Kong Secondary Chemistry Education

My school hereby consents to participate in the captioned project supervised by Dr Chan Chi Keung and conducted by Sit Wing Lam, who are students of Department of Science and Environmental Studies in The Education University of Hong Kong.

I understand that information obtained from this research may be used in future research and may be published. However, our right to privacy will be retained, i.e., the personal details of my students'/teachers' will not be revealed.

The procedure as set out in the attached information sheet has been fully explained. I understand the benefits and risks involved. My students'/teachers' participation in the project are voluntary.

I acknowledge that we have the right to question any part of the procedure and can withdraw at any time without negative consequences.

Signature:
Name of Principal/Delegate*:
Post:
Name of School:
Date:
(please delete as appropriate)*