INVESTIGATING THE ABILITY OF 8TH GRADE STUDENTS TO DESIGN AN EXPERIMENT THROUGH GUIDELINES AS A PART OF THE NATIONAL CHEMISTRY COMPETITION TEST

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Abstract. A study was conducted to test the ability of 8th grade students to design an experiment using previously provided guidelines. The sample comprised 64 students chosen to participate at the National chemistry competition in 2016/17 school year. The students were tested on the following topics: state of matter; metals and non-metals; elementary substances, compounds and mixtures; chemical reactions and introduction to organic chemistry. An analysis of students' scores was performed, but the qualitative analysis of their answers and drawings was of great importance in uch way that it helped the authors to get deeper insight into students' thinking processes and to further understand the origin of their misunderstandings. The findings showed quite high achievements. Still, many misunderstandings, erroneous notions and lack of conceptual and procedural knowledge were detected among students. Most problems were observed in answering the item III-3, while the greatest success was noticed in the item II. Many students did not have firm knowledge and clear awareness about the process of boiling – they did not appreciate the presence of both liquid and gaseous form of the substance at the boiling point, could not determine the boiling point of a liquid using the heating curve and were not able to locate the point on the curve where boiling occurs.

Keywords: conceptual understanding, heating curve, lower-secondary education, designing an experiment, National chemistry competition

Introduction

Chemistry is considered as one of the most demanding school subjects and some students find chemistry tasks difficult. It is a subject based on concepts, many of which are abstract and hard to grasp and learn. Incomplete understanding of chemistry concepts can evolve into misconceptions and create obstacles in students' further education (Canpolat, 2006; Pabuçcu & Geban, 2006). Connection between chemistry and everyday life is more than obvious and many authors insist on involving everyday examples and activities in chemistry teaching. Thus, Demircioğlu et al. (2005) state that chemistry concepts last longer in students' minds if they are being taught not only in chemistry context but also using real-life situations. On the contrary, in the Oloruntegbe et al. (2010) investigation, students were not able to connect the scientific concepts learned in school to everyday activities. If anything can be concluded from the above opposite results, it is that, most probably, the final outcome depends strongly on the individual that teaches the students.

A lot of effort is needed to understand the chemistry concepts in its essence and to gain the ability to use all three levels of thinking: macroscopic (what can be seen, touched and/or smelt), the sub-microscopic (atoms, molecules, ions and structures) and the representational (symbols, formulae, equations, mathematical manipulation, graphs, etc.) (Johnstone, 2000). The appearance of certain misconceptions lays in the simultaneous introduction of all three levels of thinking thus blocking the 'working space' in students' minds (Sirhan, 2007) or direct transition from macroscopic to representational level and avoiding the sub-microscopic one. It is also important to distinguish between macroscopic and sub-microscopic levels (Brown et al., 2012; Silberberg, 2006) and to introduce these levels of thinking progressively based on the constructivist approach (Taber, 2001; Pelech, 2010).

In the chemistry teaching, the usage of the three levels of thinking should be interconnected to the tendency to stimulate higher-order thinking skills. In this manner, conceptual questions are of great importance both during teaching and learning. A recent study in this field in Macedonia (Mijić, 2017) shows that, unfortunately, in many upper-secondary schools the teaching process is conducted in very traditional manner and in such way, reinforces only low-level knowledge. It is well known (Dhindsa & Treagust, 2009; Salame et al., 2011) that the low-level knowledge stimulates only memorizing and/or recognizing thinking skills.

Conceptual questions are used as a necessary part of chemistry competitions for school students that are organized in Macedonia.[1)] These competitions are joint activity of the Society of Chemists and Technologists of Macedonia and the Chemistry Department in Skopje and are organized as an annual event. Chemistry competitions are known to offer students (and their teachers) a mechanism for being more involved in chemistry through the excitement of competition (Lipeles, 1980).

The main goal of the chemistry competitions in Macedonia is raising the interest in chemistry. This is, generally, valid for competitions in other countries as well (Řezanka et al., 2013; Tomkins et al, 2003; Khalil et al., 2015). For students, the greatest motivation for competing is self-education and improvement of chemical knowledge. There are three levels of the chemistry competition in Macedonia: municipal, regional and national competitions. The format of the test for the municipal and regional competitions consists of multiple-choice questions (that examine, more or less, all levels of cognitive tasks) and conceptual questions and problems of different type. Additionally, the national competition test contains one more part that includes imagined experiment. Local organizers are making an effort to enable practical part of the competition involving lab activities but this is rather difficult to realize due to the insufficient resources and poorly-equipped laboratories (if any) in schools.

The Bureau for the Development of Education in the academic year 2014/2015 introduced a new curricula of mathematics and natural science subjects in primary education, according to the adapted curricula of the Cambridge International Examination Center. The chemistry curriculum implies a well-equipped laboratory and inquiry-based activities for successful realization of the teaching goals. Unfortunately, requisites to successful implementation can be found only on paper. In Macedonia the equipment in many school is not very good and not all of the experiments can be performed. In many schools, experiments take place in traditional classrooms. Teachers prepare experimental setup and carry out experiments without a help of an assistant.

One of the main things the teacher should know before starting to plan a lesson is things available, such as laboratory equipment, chemicals and other resources. There is no sense in planning a "perfect" lesson using modern equipment and individual experiments by students if the school does not have the resources (Markić & Childs, 2015).

One way to replace the lack of resources needed is to search the internet. However, most of the resources available on net are English and not all teachers can use them due to the language limitations. Furthermore, considering the lack of financial support for schools and teachers, authors have suggested a designing chemistry laboratory using everyday chemicals and re-using the same experimental set-up and chemicals for many times (Monković et al, 2006a; Petruševski et al., 2007; Petruševski & Stojanovska, 2011) or preparing short video-clips applicable in chemistry teaching (Petruševski et al, 2006; Monković et al., 2006b). Teachers, in their practice, are constantly using low-cost experiments because they provide several advantages: (1) they save money; (2) are easy and safe to transport; (3) make the disposal easier, and (4) can be performed in a traditional classroom.

Authors, during their teaching practice, always advise pre-service teachers to use the process of inquiry in teaching whenever possible because learning science through inquiry is a very effective way to construct knowledge among students. This advice is also given to in-service teachers who attend the seminars organized by the Society of Chemists and Technologists of Macedonia and the Chemistry Department in Skopje. Undoubtedly, chemistry teachers need to be well versed in inquiry, but, on the other hand, inquiry is used very seldom in their university education. Instead of inquiry, they are faced with direct laboratory instructions or cookbook manuals in many courses. So, firstly teachers should develop the knowledge and skills related to inquiry and then they could effectively employ this technique in their classrooms.

Methodology

Objectives of the study

The main objective of this study was to investigate the ability of 8th grade students to design an experiment through guidelines provided by the competition organizers. This investigation was based on the National chemistry competition test realized in 2016/17 school year. The competition was realized to test the students' knowledge about the chemistry topics defined in the 8th grade national curriculum in Macedonia:[2)] state of matter; metals and non-metals; elementary substances, compound and mixtures; chemical reactions and introduction to organic chemistry (only alkanes are considered as well as fossil and alternative fuels). The third part of the test based on a designing an experiment in organic chemistry topic was considered for this analysis.

Research instrument

The abilities of students to design an experiment was tested through the National chemistry competition test. All test items were revised by two university professors and verified by a national chemistry counselor from the Bureau for the Development of Education. The test itself consisted of three parts – the first part comprised ten multiple-choice questions covering concepts within all mentioned topics, while the second and the third part dealt with different type of questions involving short-answer questions, classification-type questions, fill-in-the-gap questions, open-ended questions seeking for argumentation for a given answer etc. Furthermore, the third part of the test (Appendix) asked for deeper understanding of organic chemistry topic and required additional skills and creative thinking to design an experiment. Also, guidelines were provided by authors and the revision committee which leaded students through the process.

Research sample

The National chemistry competition test was administered to 64 8th grade students (≈13 years old) participating at the National chemistry competition in the 2016/17 school year. Students were tested according to the adopted curriculum of the Cambridge International Examination Center introduced by the Bureau for the Development of Education[2)] in the academic year 2014/2015 and suggested textbook (Forbes et al., 2016).

Data analysis

The guidelines for the experiment design consisted of three sections (Appendix). The overall score was 10 and the test scores ranged from 2.6 to 10 points. Students were warned they will get 0 points if they use pencil instead of ball-point pen, circle two or more answers or cross out the answer. Information on point scale is given in the Table 1. In the further analysis, test items I-1 and I-2 will be considered as one item. The items II-1 and II-2 were treated analogously.

Table 1. Information on point scale

Section	I		II		III				
Test item	I-1	I-2	II-1	II-2	III-1	III-2	III-3	III-4	III-5
Max item points	1	1	0.5	0.5	1	2	2	1	1
Max section points	2		1		7				
Total points	10								

Results and discussion

Analysis of the students' scores shows that 73.4 % of students were assigned 5 or more points, the scores gradually increasing towards higher values (Table 2). This is not unexpected because competitors are students who are not only high-achievers in chemistry but also the best students in the country.

Table 2. Frequency of students' scores

Points	Frequency	Percentage
0.0 – 2	0	0.0
2.1 – 4	11	17.2
4.1 – 6	15	23.4
6.1 – 8	18	28.1
8.1 – 10	20	31.3
Total	64	100.0

Students had most problems in answering the item III-3 and were the most successful in the item II. Details concerning students' efficiency on the test are given in Table 3.

Table 3. Information on students' efficiency on the test

Section	I	II	III				
Test item	I	II	III-1	III-2	III-3	III-4	III-5
Percentage per	55.5	99.2	68.8	77.7	46.9	52.3	85.2
Percentage per	55.5	99.2	65.1				
Total percentage	66.6						

In the first section, students were supposed to evaluate the given graph showing the melting points and the boiling points of alkanes as a function of the number of C-atoms in the corresponding alkane's molecule and provide the appropriate answers. This question tests students' capability to work with graphical data in order to provide required information. The maximum points for this section was 2; each individual answer was valued 0.5 points. It was found that 21.9 % of students received 0 points to this item, 23.4 % had maximum points, and little more than half of students gave partial answers. The correct answers expected by students are: (1) At 20 °C in liquid state are alkanes that contain from 5 to 17 C-atoms in the molecule. (Numbers 16 and 18 were also considered correct since some minor mistakes could have been done due to the copies of the graph); (2) At 20 °C in gaseous state are alkanes that contain from 1 to 4 C-atoms in the molecule.

In the second section, the task of students was to make an assessment of the physical properties of octane (i.e. to estimate its melting and boiling point and chose one of the four given options) if melting and boiling points of its neighboring members of the homologous series are given. Achievements of students on this test item was the highest – 63 out of 64 students gave a fully correct answer and one student had 0.5 points. It seems that students performed better on questions involving tables and numerical data than those which asked for graph manipulation.

Next, a short explanation about the meaning of the heating curve and experimental procedure were given (section III). The main goal of this imagined laboratory exercise was investigation of the different states of matter and phase transitions as well as tabular and graphic presentation of the experimentally obtained data using the heating curve. Also, the needed laboratory equipment was listed in the guidelines.

Item III-1 required a drawing of the lab assembly that was constructed at the beginning of the experiment using all of the laboratory pieces/equipment listed: thermometer, hot plate, beaker, ring stand with clamp and glass rod. Most students did not draw the ring stand with clamp. The reason is, perhaps, that they were not using this piece of equipment before either in the planning experiments or in performing real experiments. Large number of students drew the glass rod aside, away from the lab assembly (Fig. 1) which shows that they didn't know its role in the experiment. Few students drew all pieces of the equipment separately, indicating lack of procedural knowledge. Namely, students may have solid theoretical knowledge and they may know the look and the application of laboratory equipment, but they meet a problem when it comes to designing an experiment and application of higher-order thinking tasks (analyzing, evaluating and creating).

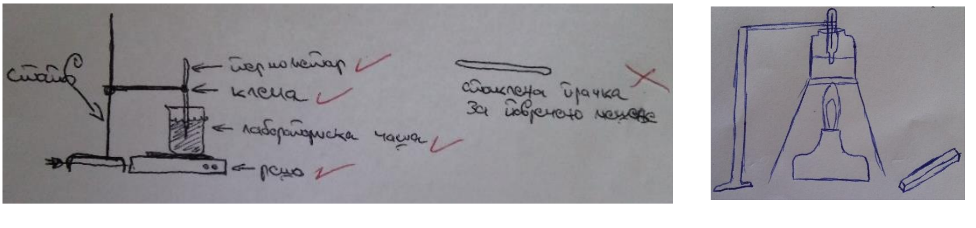


Figure 1. Examples of students' drawings – test item III-1

The item III-2 tested students' ability to represent obtained data graphically. Attention was paid to properly labeling the axes. Furthermore, in task III-3 students had an assignment to choose which of the given terms (solid, liquid, gas, solid+liquid, liquid+gas, melting, boiling) are appropriate and to locate them on the heating curve. From Table 3 it is obvious that the performance of students was much lower in the item III-3. One third of students received 4 or 3.5 points (out of maximum 4) for the items III-2 and III-3 i.e. 35.9 % presented high achievements on these two tasks. An excellent drawing of a student is given in Fig. 2a.

Some common mistakes of students involved: (i) Switching the *x*- and *y*-axis. This was noticed in only few responses and these drawing were taken as correct if other elements were well implemented (Fig. 2b); (ii) Incorrect denoting of the axes. Many students did not pay attention to equivalence in the assigning values at the temperature axis in order to make the interval between two values (previously given in table) the same (Fig. 2c and 2e); (iii) Using all three states of matter. Some students thought that the heating curve must always start with solid melting and only then a vaporization of a liquid could take place (Fig. 2c, d, e, and h). Apparently, these students did not take into consideration the facts tested in the item II on which they had the highest achievement (almost all students gave correct answer). Unfortunately, they were not able to transfer their knowledge in the new situation that involved higher-order thinking skills and usage of graphs (iv) Positioning the melting and the boiling points at the curve plateau. In some drawings, we noticed T_m and T_b marks at the beginning and at the end of the plateau, respectively (Fig. 2d). This is also related to the previous misunderstanding about using all three states of matter in the heating curve; (v) Incomprehension of the boiling concept. Most students had difficulties in finding the part of the curve representing the process of boiling. Thus, some students placed boiling at the very beginning of the plateau (Fig. 2c) or at its end (Fig. 2d), some – at the last point of the curve i.e. the last value from the table (Fig. 2e) or at the last part of the curve (Fig. 2f). Moreover, several students indicated that the boiling process starts at the beginning of the plateau and remains indefinitely (Fig. 2g). Incomprehension of the boiling concept was also observed in those drawing in which only 'boiling' or 'liquid+gas' was denoted at the plateau (Fig. 2b and 2g); (vi) Linear graph. Few students had drawings like the one presented at Fig. 2h. These graphs are not in any correlation with tabular data given in the task. Yet, they involve solid, liquid and gaseous state and a density of a liquid as well.

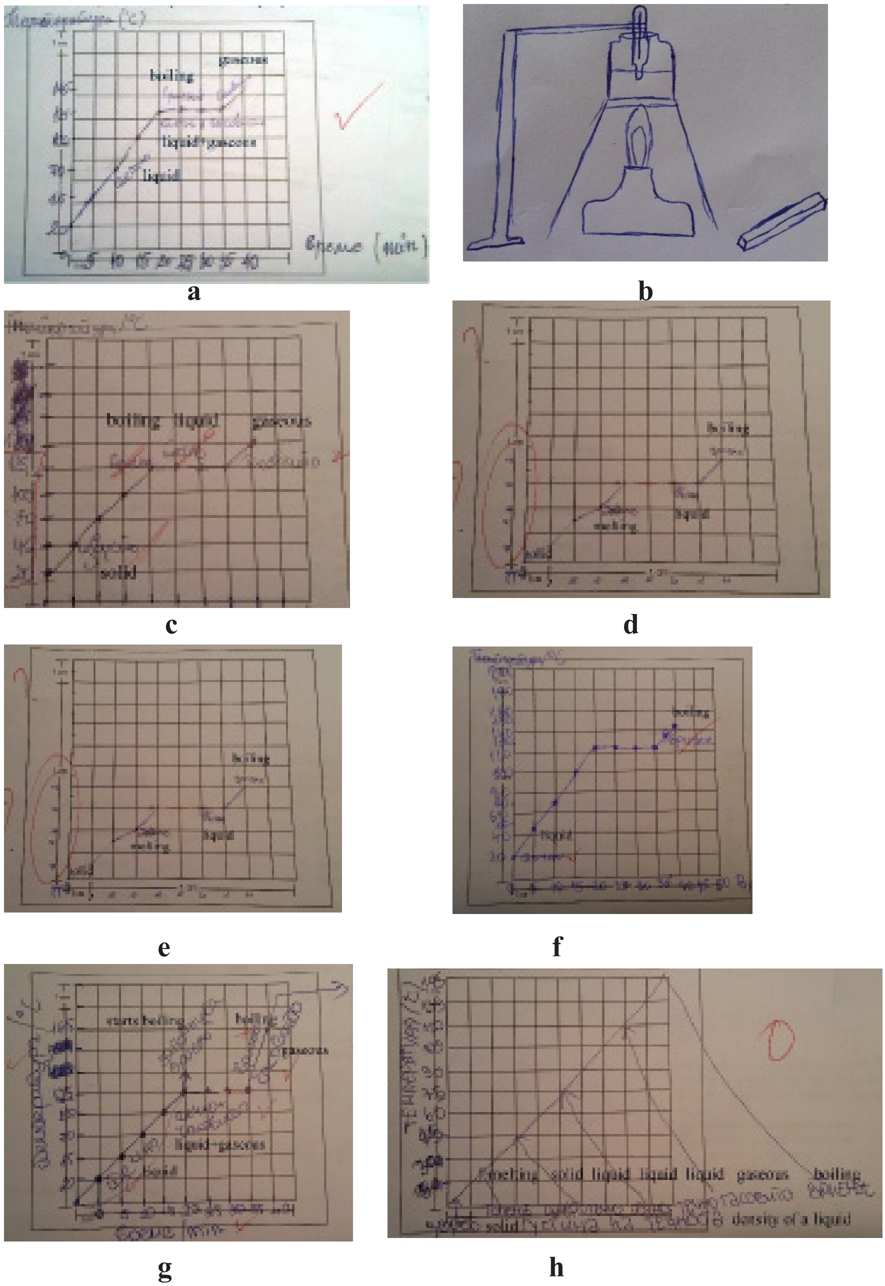


Figure 2. Examples of students' drawings – test item III-2 and III-3

Next, the ability of students to determine the boiling point of octane using the heating curve was tested. Students were supposed to give the correct answer (125 °C) but also an argumentation for their answer was necessary to get 1 point. For partial answers, 0.5 points were given. Exactly 50.0 % of students gave fully correct response, 4.7 % partially answered the question, whilst 45.3 % had incorrect answers or did not answered the question at all.

Only three students received 0.5 points to this item; one did not give any explanation and others wrote the following:

– Student 1: "*The boiling point of octane is 125 °C. The boiling point coincide to the 125 °C point mark.*" and

– Student 2: "*Octane boils at 125 °C because at 100 °C is liquid and the increase of temperature causes the particles to start moving very fast and chaotic, so the change of the state is observable – boiling.*"

In the second answer, one can notice the value of 100 °C which is characteristic for water. This indicates that water is the common example of substance given by teachers to explain phase transitions, thus many students attribute the properties of water to other liquid substances.

Eighteen students (around 28 %) thought that octane boils at 130 °C or 135 °C. Some of their reasoning are:

– Student 1: "*Octane boils at around 130 °C because already at 125 °C there is both liquid and gaseous state of the substance.*"

– Student 2: "*Octane boils at 130 °C because before it reaches 135 °C it has been boiling for several minutes (it is not possible for octane to boil at 125 °C since it has stood at that temperature for 15 minutes, and due to the answer of item II).*"

– Student 3: "*Octane boils at 135 °C and reaches this temperature during the 40 minutes period; after the boiling point has been outreached, the temperature decreases.*"

– Student 4: "*Octane boils at 135 °C. It reaches the boiling point first and then, become gaseous.*"

– Student 5: "*Octane boils at 135 °C. The end of the heating curve shows the boiling point in this case.*"

– Student 6: "*Octane boils already at 135 °C, but it reaches the boiling point at 145 °C (the highest temperature).*"

These explanations clearly show misunderstandings of students regarding the concept of boiling and, generally, the concepts related to the states of matter and phase transitions. It is worth to mention the answer of the second student who relies on his/her answer for test item II which is only an estimation. In fact, it was given as such purposively, so we can test the ability of students to evaluate the graphical representation as well as to draw conclusions from the heating curve, not from ready-made tables and offered data.

Another erroneous notion that arose from this question was that octane boils at 145 °C. This is the last one of the tabular data given in the premise of the question, so perhaps students were misled to think that this is the boiling point of octane. Some excerpts from the tests are given below:

– Student 1: "*The boiling point of octane is 145 °C. This can be seen from the graph; it is the highest value of the temperature. No matter how strong we are heating above this temperature, its temperature will not change.*"

– Student 2: "*The boiling point of octane is 145 °C. When it boils, it reaches the maximal temperature of boiling. In this case, Ana should have stopped heating after the octane had been boiling for several minutes. Therefore, the final temperature is 145 °C.*"

There was one student who claimed that the boiling point of octane is 40 °C, probably having the misconception mentioned above, but confusing the values for time and temperature in the table.

Finally, the last demand in the test was about the lab safety. Namely, students should have listed two precautions important to take care during carrying this experiment. Students were quite successful in responding this question. The most common safety measures they mentioned were about wearing safety googles, gloves and lab coat, taking care when working with boiling liquids or flammable substances, working in a presence of an adult and having a fire extinguisher nearby.

Conclusion

This study was aimed to investigate the ability of 8th grade students (N = 64) to design an experiment through guidelines provided by the competition organizers. This investigation was based on the National chemistry competition test realized in 2016/17 school year. Students were tested on the following topics: state of matter; metals and non-metals; elementary substances, compound and mixtures; chemical reactions and introduction to organic chemistry.

The findings indicate that students showed high performance on some test items, but also many misunderstandings, erroneous notions and lack of conceptual and procedural knowledge was detected among them. Students had most problems in answering the item III-3 and were the most successful in the item II. The most imposing (and, at the same time, the most disappointing) information that the authors received as a feedback from this testing was the fact that students did not have firm knowledge and clear awareness about the process of boiling. Many students did not realize the presence of both liquid and gaseous form of the substance at the boiling point, could not determine the boiling point of a liquid using the heating curve and were not able to locate the position on the curve where boiling happens.

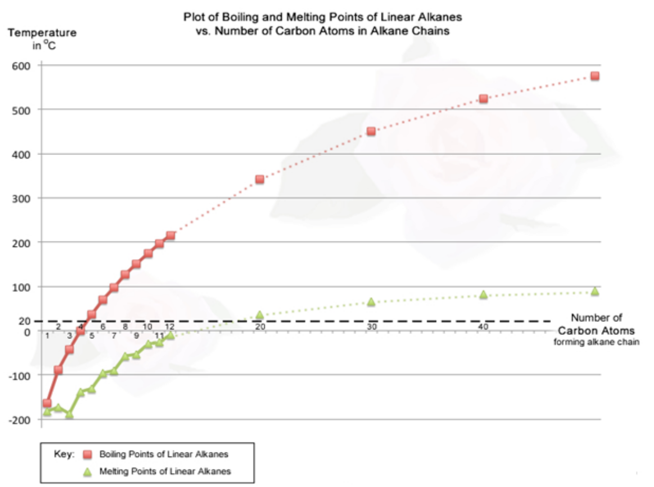
It is worth mentioning that tested students were selected in a two-level competition process involving students from all parts of the country, thus they had the biggest achievements in chemistry and their interest and motivation in the subject were at very high level. It is likely that the situation is much worse among other students in Macedonia.

The tests from all three levels of the chemistry competitions are available for wider population[1]. Authors believe that all participants in the education process who are interested in chemistry competitions and similar activities (students, in-service chemistry teachers and competition organizers) will benefit from this testing. Furthermore, by organizing competitions authors hope to motivate, educate and interconnect students from Macedonia thus encouraging them to consider further education and careers with chemistry. Moreover, the learning environment and available resources must be considered in everyday teaching practice. Also, the opportunities to learn science through inquiry should be enabled to achieve the lesson's objectives in the most efficient way.

APPENDIX. The third part of the National chemistry competition test

PART THREE – Design experiment

Read the questions carefully and answer them NEATLY according to the given requirements. You will get 0 points if you use pencil or if the answer is crossed out.



1.

A graph is given that shows the melting and boiling points of alkanes as a function of the number of C-atoms in the corresponding alkane molecule. Using this graph provide the appropriate answers: **(2 points)**

At 20 °C in liquid state are alkanes that contain from ____ to ____ C-atoms in the molecule.

At 20 °C in gaseous state are alkanes that contain from ____ to ____ C-atoms in the molecule.

Carefully analyze the data in the following table and then make an assessment of the physical properties of octane that are given in the questions below. **(1 point)**

Name of alkane	Melting point / °C	Boiling point / °C
Heptane	-90	99
Nonane	-51	151

The melting point of octane is around:
-100 °C
-60 °C
-50 °C
0 °C
The boiling point of octane is around:
100 °C
130 °C
170 °C
200 °C

The heating curve shows what happens with the temperature of the substance as it is heated. These curves are used for determination of temperature at which the solid substance is converted into liquid, and also the temperature at which the liquid turns into gas.

Ana was given an assignment to experimentally determine the boiling point of octane and to draw/construct the corresponding curve based on the obtained data. The main goal of this laboratory exercise was an investigation of the different states of aggregation and phase transitions, and also tabular and graphic presentation of the experimentally obtained data.

Ana needed the following laboratory equipment: thermometer, hot plate, beaker, ring stand with clamp, glass rod. This is the procedure:

– Place the corresponding substance (in this case octane) in the beaker.

– Place the beaker on the hot plate and turn on the heating.

– Immerse the thermometer into the corresponding substance in such a way that it does not touch the bottom of the beaker or the side walls.

– Note the starting temperature and immediately start measuring/recording the time using stopwatch.

– From time to time stir the liquid using a glass rod.

– Record the values for the temperature after each minute elapses. As soon as the temperature reaches around 135 °C, and after it already boils for several minutes, stop the heating.

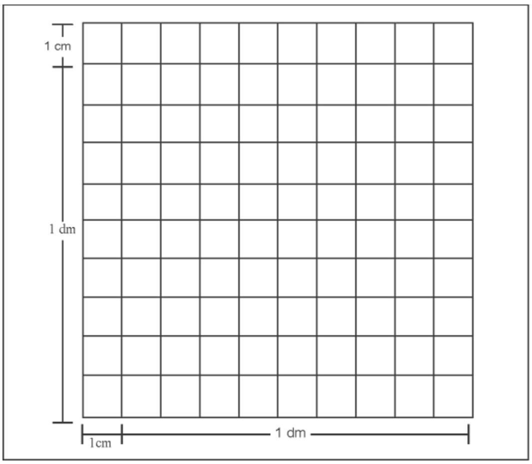
– Let the beaker cool to ambient temperature.

Ana has obtained the following data:

Time/min	0	5	10	15	20	25	30	35	40
Temperature/°C	20	45	70	100	125	125	125	125	145

Draw the lab assembly that was constructed at the beginning of the experiment. Use all of the laboratory pieces/equipment that was mentioned above. **(1 point)**

Draw the heating curve. Do not forget to properly label the axes. **(2 points)**



On the heating curve choose which of the following terms are appropriate and place them on the proper place on the curve: solid, liquid, gas, solid+liquid, liquid+gas, melting, boiling. **(2 points)**

What is the boiling point of octane? Explain how you came to this conclusion using the heating curve. **(1 point)**

Name two safety measures that you must undertake during the course of this experiment? **(1 point)**

________________________ and ________________________

NOTES

1. http://sctm.mk/index-mk.htm
2. http://www.bro.gov.mk/docs/nastavni-programi/Cambridge/VII-IX/Nastavna%20programa-Hemija-VIII%20odd%20devetgodisno.pdf

REFERENCES

Brown, T.L., LeMay, H.E., Bursten, B.E., Murohy, C. J. & Woodward, P.M. (2012). *Chemistry, the central science*. Boston: Prentice Hall.

Canpolat, N. (2006). Turkish undergraduates' misconceptions of evaporation, evaporation rate, and vapour pressure. *Int. J. Sci. Educ., 28*, 1757 – 1770.

Demircioğlu, G., Ayas, A. & Demircioğlu, H. (2005). Conceptual change achieved through a new teaching program on acids and bases. *Chem. Educ. Res. Pract., 6,* 36 – 51.

Dhindsa H.S. & Treagust D.S. (2009). Conceptual understanding of Bruneian tertiary students: chemical bonding and structure. *Brunei Int. J. Sci. & Math. Educ.*, *1*(1), 33 – 51.

Forbes, D., Fosbery, R., Fullick, A., Newman, V., Norris, R. & Ryan, L. (2016). *Essential science for Cambridge secondary 1 stage 8 pupils book (chemistry)*. Skopje: Ars Lamina (translation into Macedonian).

Johnstone, A.H. (2000). Teaching of chemistry – logical or psycho-logical. *Chem. Educ. Res. Pract.*, *1*, 9 – 15.

Khalil, L.I., Chahine, K.M. & Kaafarani, B.R. (2015). International Organic Chemistry Competition: a thrilling, unique experience. *J. Chem. Educ., 92*, 401 − 404.

Lipeles E.S. (1980). How to organize a state-wide competition in chemistry. *J. Chem. Educ. 57,* 449 − 450.

Markić, S. & Childs, P.E. (2015). Planning a good chemistry lesson (pp. 67 – 84). In: Maciejowska, I. & Byers, B. (Eds). *A Guidebook of good practice for the pre-service training of chemistry teachers*. Krakow: Jagiellonian University.

Mijić, I. (2017). *Testing conceptual knowledge in chemistry among high-school students: MSc thesis*. Skopje: Ss. Cyril and Methodius University.

Monković, M., Petruševski, V.M. & Bukleski, M. (2006a). The economic demonstrator: prepare it once, use it many times I: continuous thermochromism in the NO_2–N_2O_4 system – equilibrium shifts induced by temperature changes. *Chemistry,15*, 256–264.

Monković, M., Petruševski, V.M. & Najdoski, M. (2006b). Alternative demonstrations of slow processes IV: video clips presenting difusion in gases and liquids. *Chem. Educator, 11*, 259 – 261.

Oloruntegbe, K.O., Ikpe, A. & Kukuru, J. D. (2010). Factors in students' ability to connect school science with community and real-world life. *Educ. Res. & Rev., 5*, 372 – 379.

Pabuçcu, A. & Geban, Ö. (2006). Remediating misconceptions concerning chemical bonding through conceptual change text. *Hacettepe Univ. J. Educ., 30*, 184 – 192.

Pelech, J. (2010). *The comprehensive handbook of constructivist teaching.*

Charlotte: Information Age Publishing.

Petruševski, VM. & Stojanovska, M. (2011). Prepare it once, use it many times: the leveling tube. *Chem 13 News, 382*, 18.

Petruševski, V.M., Bukleski, M. & Monković, M. (2007). The economic demonstrator: Prepare it once, use it many times II: continuous thermochromism in aqueous solutions of transition metal chlorides. *Chemistry, 16*, 20 – 28.

Petruševski, V.M., Monković, M. & Najdoski, M. (2006). Alternative demonstrations of slow processes III: a demonstration and video clip showing effusion in liquids. *Aust. J. Ed. Chem., 66*, 24 – 26.

Řezanka, P., Šimůnek, O, Zajícová, M., Míka, L, Bartoň, J. & Řezanka, M. (2013). Fast and attractive chemical education: a chemical competition for high school students in the Czech Republic. *J. Chem. Educ*. *90*, 1259 − 1262.

Salame I.I., Sarowar, S., Begum, S. & Krauss, D. (2011). Students' alternative conceptions about atomic properties and the periodic table. *Chem. Educator*, *16*, 190 – 194.

Silberberg, M. S. (2006). *Chemistry, the molecular nature of matter and change.* Boston: McGraw-Hill.

Sirhan, G. (2007). Learning difficulties in chemistry: an overview. *J. Turkish Sci. Educ., 4*(2), 2 – 20.

Taber, K. (2001). Building the structural concepts of chemistry: some considerations from educational research. *Chem. Educ. Res. Pract.*, *2*, 123 – 158.

Tomkins, R.P.T., Knox, D., Grow, J.M. & Bilash II, B. (2003). The New Jersey Chemistry Olympics revisited. *J. Chem. Educ*. *80,* 1161 − 1164.

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