IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

STRENGTHENING STUDENTS' KNOWLEDGE OF BASIC THERMODYNAMIC CONCEPTS USING STRUCTURED INQUIRY-BASED INSTRUCTION

Ikeoluwa Folasade ADEOYE (Ph. D)

Department of Integrated Science

School of Secondary Education (Science Programmes)

Emmanuel Alayande University of Education, Oyo.

Oyo State, Nigeria.

Abstract

The study compared the achievement of Senior Secondary School Two (SSS2) chemistry students in basic thermodynamic topics between structured inquiry-based instruction and the traditional method of teaching chemistry. One hundred and nine sampled students were randomly selected from six secondary schools, who actively engaged in six weeks of structured inquiry-based instruction and participated in pre-test post-test were samples for the study. The structured inquiry-based instruction was constructed in line with the identified students' learning difficulties in thermodynamics. The inquiry-based instruction featured meaningful engagement in tasks, problem solving, group work, exploration, investigation, questioning, discussion and communication. The test was constructed to determine the students' critical reasoning in application, analysis, synthesis and evaluation of basic thermodynamic concepts rather than memorization of the concepts. The test and the structured inquiry-based instruction were validated by two chemistry educators and the test reliability coefficient was highly positive using pre-test post-test technique. The study identified students' learning difficulties in thermodynamic concepts. The result showed that, the structured inquiry-based instruction improved students' achievement in thermodynamic concepts. There was a significant difference in the students' achievement between the traditional method and inquiry-based instruction using paired t-test statistical method in favour of inquiry-instruction. The study recommended provision of learning resources and chemistry teachers' adequate knowledge of learning pedagogy and chemistry contents in implementing well-structured chemistry curriculum.

Keywords: Inquiry-based instruction, learning difficulties, students' achievement, thermodynamic concepts, chemistry.

I BACKGROUND TO THE STUDY

Thermodynamics in chemistry is the study of the relations between heat, work, temperature and energy. Thermodynamics is concerned with transfer of energy from one place to another and from one form to another. Energy transformations accomplish both the physical and chemical processes. Chemistry is the study of the nature of matter; its compositions, properties, uses, transformations and energies that accomplish the transformations. Chemistry gives explanations to everything in the physical world we live in. Chemistry is central and basic foundation for all sciences and technology. It has links with medicine, industries, earth, and everyday life activities. Chemistry is relevant and have made essential contributions to human life, society, industry and civilization.

The study of Chemistry starts from Senior Secondary School in Nigeria and its major objectives are to develop students' interest in chemistry, science, technology and mathematics, acquire basic theoretical and practical knowledge and skills in Science, Technology and Mathematics (STM) and adequately prepared students for further studies in chemistry and chemistry related courses among others. The contents of chemistry are organised around four themes of the chemical world, chemistry and environment, chemistry and industry and chemistry and life. The chemistry curriculum is structured around these themes to address the three major issues identified as globalization, information communication technology and entrepreneurship. The globalization, information communication technology and entrepreneurship are the major factors that shape the development of nations worldwide and influence the today's world of knowledge.

The Nigerian Chemistry Curriculum is packaged with contents that will lead to self-actualization by the students. The curriculum contents are to be taught with practical activity in order to inculcate the learners with the spirit of enquiry (Federal Ministry Education, 2007). If the chemistry curriculum is effectively implemented, it will enable the learners to achieve the maximum potentials in the subject and its various applications. The effectiveness of the implementation of the chemistry curriculum is relied heavily on the chemistry teachers' ability to facilitate learning of the contents and to motivate students to learn.

The learning of the principles and concepts of chemistry should be related to constructivism learning theories for effective implementation. The cognitive constructivists view learning as an active, contextualized and complex process of constructing knowledge from environment rather than acquiring knowledge by being told by the teachers. (Dewey, 1949; Bruner, 1967; Ausubel, 1968 and Piaget, 1983). Similarly, to social constructivists, knowledge is a human product which is socially and culturally constructed from experience (Vygotsky, 1978). The constructivists assert that active involvement of learners in constructing knowledge from the environment is critical in learning. For a child to know and construct knowledge of the world the child must act on objects and it is this action which produces knowledge of these objects. Piaget (1983)'s intellectual growth or cognitive development theorizes that learning is a complex process comprising three principal processes that affect the developmental process, namely: assimilation, accommodation and equilibration which lead to the formation of schemata (cognitive structure). The process of assimilation in Piaget theory, involves the incorporation of new events into pre-existing cognition. Accommodation means changing the existing structures to fit in new information while equilibration involves the learner striking a balance between him and the environment (information). When a child experiences a new event, disequilibrium and perturbation of cognitive structure set in until the child is able to assimilate and accommodate the new information and thus attains equilibrium. For Piaget, equilibration is the major factor why some children advance more quickly in the development of logical reasoning than do others.

Just like Piaget, Bruner (1967), proposed that a learner constructs new ideas or concepts based upon existing knowledge. Learning is an active process that includes selection and transformation of information, decision making, generating hypotheses, and making meaning from information and experiences. Bruner opposed Piaget's motion of readiness (cognitive development/ maturity). Bruner believed that a child of any age is capable of understanding complex information. However, learner cognitive maturity is important to be able to understand the fundamental ideas in learning scientific concepts / topics

Bruner stressed that learners' construct knowledge from the environment and do this by symbolizing, organizing and categorizing experience / information using a coding system. The most effective way to develop a coding system is to discover it rather than being told by the teachers. Bruner believed that teachers are facilitators of learning.

Ausubel (1968) also emphasized that practical work creates a *discovery-reception continuum* as opposed to a meaningful rote learning experience. He argued that use of science process skills; measuring, observing, classifying and predicting are crucial for the development of fruitful understanding of scientific concepts, propositions for a meaningful use of scientific procedures, problem solving and applying scientific understanding to one's own life.

According to Vygotsky (1978), knowledge is not individually constructed but co-constructed among people. Vygotsky's Zone of Proximal Development (ZPD) was used to refer to the difference between what learners can do and what they could do with the assistance of others. Interactions with adults and peers in the zone of proximal development help learners move to higher levels of mental functioning within the classroom. Vygotsky believed that cognitive development is a result of speech and practical activities. That is, learning is experienced, activity-based and a dialogical process.

Quality education should be experienced and should be a necessity of life. The traditional teaching that is conventional employed in the delivering knowledge is authoritarian, strict, pre-ordained knowledge are not enough for students' understanding of concepts and principles in chemistry (Adeoye and Ajeyalemi, 2018). Inquiry-based learning is a student-centred teaching method. Inquiry-based learning is an activity-based learning and teaching process with multifaceted approach to teaching that gives students the opportunity to understand the processes of inquiry in science. Inquiry-based learning allows students to have meaningful understanding of scientific concepts and to acquire scientific skills in critical thinking, deductive reasoning, problem solving, creativity and communication (Adeoye, 2016; Ajeyalemi and Adeoye, 2018). The studies of Iryani, Iswendi and Patra (2021), Singh and Kaushik (2021) and Annisa and Rohaeti (2021) also showed that inquiry-based learning signifies improvement on students' learning outcomes in chemical bonding modules, chemical kinetics and chemical equilibrium.

The structured inquiry-based learning in the study adopts approaches of meaningful engagement in tasks / practical work, problem solving, group work, exploration, investigation, questioning, discussion and communication to determine its effect on improving students understanding of thermodynamics concepts in chemistry.

II STATEMENT OF THE PROBLEM

Chemistry learning involves students understanding of chemical concepts, have abilities to present these concepts using signs, symbols, diagrams and use the chemical concepts to solve quantitative and qualitative problems. Many secondary school and university students experience difficulties with the understanding of fundamental concepts in chemistry. They hold inconsistent knowledge with chemistry concepts being taught (Kamisah and Nur, 2013; Royal Society of Chemistry, 2019). Research findings have shown that chemistry students perceived certain chemistry topics difficult to learn and chemistry teachers also find it difficult to teach some chemistry concepts. (Adeoye, 2016 and Kyado, 2021). Most of the identified factors for the students' learning difficulties are abstract nature of chemistry, students' disinterest in chemistry, teachers' methods of teaching chemistry, lack of motivation from the teacher for students to learn and inadequate teaching resources. Students learning difficulties have resulted into students' poor performance in school examinations and consequentially reduce the manpower in Science and Technology.

Chemistry teachers hardly use practical activity to foster enquiry as recommend for the teaching of chemistry. The conventional method which involve the lecture method and teacher demonstration method are widely used in teaching chemistry. Hence, this study used structured inquiry-based learning to determine its effect in improving chemistry learning.

III PURPOSE OF THE STUDY

The purpose of the study is to identify the seemingly difficult basic thermodynamic concepts in Senior Secondary School Two (SSS2) chemistry ccurriculum, expose the students to structured inquiry-based instruction on the identified difficult areas and report the effect of this mode of learning on the students' understanding and performance in chemistry.

IV. RESEARCH QUESTION

The research questions for the study are:

1. What are the learning difficulties the Senior Secondary School Chemistry Students in Form Two (SS2) have in thermodynamics concepts?
2. What is the effect of inquiry-based learning on the Senior Secondary School Chemistry Students Form Two (SS2) achievement in thermodynamics concepts?

V. METHODOLOGY

The samples for the study were randomly selected from six Public Senior Secondary Schools in one of the Local Government Areas in Oyo, Oyo State, Nigeria. The chemistry students in Senior Secondary School Form Two constituted the samples for the study. The students in their intact classes in the randomly selected schools were used for the study.

The sampled students in each of the randomly selected schools were grouped into small discussion group of five members in a group. The structured inquiry-based instruction incorporated the basic components of inquiry-based learning composed of small group discussion, questioning, exploration, experimenting, analysing, problem-solving and reporting were used to engage the students in thermodynamics concepts learning. The structured inquiry allowed the students take possession of their learning. The students learnt from their peers in the group, discussed their conceptions on some the basic thermodynamics concepts; forms of energy, energy conversions, endothermic, exothermic and enthalpy determination. The study commenced immediately after the students in the sampled schools had been taught thermodynamics by their chemistry teachers. The chemistry teachers with the researcher served as learning facilitators in the inquiry-based learning. They motivated the students to learn, setting up class activities, assigning roles to the students, ensuring students active participation in the learning, moderate their discussions, modifying students' inadequate conceptions in chemistry during the learning processes.

The research was for eight weeks; six weeks for the learning activities, a week for pre-test and a week for post-test. The structured learning and the thermodynamics test items were validated by two chemistry educators and found valid before use. The reliability of the test was determined using pre-test post-test technique with reliability coefficient of 7.89. The test was administered to the students before and after the learning activities. The students' responses to pre-test were used to identify and determine students' learning difficulties. Sequel to the determined learning difficulties, the structured inquiry-based instruction was developed. The scores of one hundred and nine (109) chemistry students that participated actively in the inquiry-based learning for the six weeks, that did the pre and post-test were analysed. The scores of the students were analysed using mean and t-test. The total score of the test was twenty marks.

VI. FINDING AND RESULT

The following were the learning inadequacies that most SS2 chemistry students had before the treatment are:

1. Inability to identify types of systems in thermodynamics.
2. Concept of concentration of reactants on the enthalpy change in chemical reactions was not adequately understood.
3. Inability to determine the temperature rise of mixture and rise in temperature of neutralization of NaOH and HCl solutions.
4. Inability to determine the heat of dissolution of substances in $KJmol^{-1}$ from experimental data.
5. Physical determination of endothermic and exothermic in reaction of substances base on temperature change was difficulty for the students.
6. Application of law of conservation of energy was not adequately understood by the students.

Table 1: Students' Pre-test Post-test Scores and Paired T-values on Basic Thermodynamic Concepts

Treatment	Mean Score	Standard Deviation	t (108) Calculated	t-critical
Pre-test	7.51	1.39	28.90	1.98
Post-test	14.17	2.0		

0.05 level of significance.

VII. DISCUSSION OF THE FINDINS AND RESULTS

The structured inquiry-based instruction has great improvement on the students' achievement in thermodynamic concepts with 14.17 mean score of the students while their mean score was 7.51 for the conventional method. The mean score of the students in inquiry-based instruction almost double their mean score on the conventional method. The students had mean gain score of 6.66 after the treatment. This improvement in the achievement of the students in thermodynamics concepts after treatment may be that the students had moved from knowledge level of memorisation of chemistry concepts to higher reasoning levels of application, analysis, synthesis and evaluation in chemistry. The improvement in the students' achievement could also be that the inquiry-based instruction gave the students the opportunity to take control of their learning, actively participation in the practical activities and their discussions with their peers might have promoted their critical reasoning, reflection of the learning process, acquisition of correct conceptions in thermodynamics and interest in learning chemistry. This finding is supported by Singh and Kaushik (2021) and Annisa and Rohaeti (2021) who found that inquiry-based learning improved students learning outcomes in chemistry.

The further analysis of the students' scores using paired t-test showed significant difference between the conventional method and inquiry-based instruction at 0.05 level of significance for two-tailed test. The t-calculated value of 28.90. The t-calculated was greater that t-critical value of 1.98 at 0.05 level of significance. The result indicates that there is significant difference between the conventional method of teaching chemistry and inquiry-based instruction in favour of in inquiry instruction. This finding is in support with the findings of Adeoye (2016) and Adeoye and Ajeyalemi (2018) that found inquiry- based learning to significantly promote students learning of chemistry concepts. The researcher envisages that the more of the inquiry-based instruction that chemistry students are engaged with, the more the students get acquitted to the inquiry-based instruction processes. This will result in significant learning outcomes in chemistry, not necessarily on the area of conceptual achievement.

VIII. CONCLUSION

Inquiry-based instruction is multifaced method which required adequate preparation for its use in the classroom. Chemistry teachers should be ready to motivate the students to learn in inquiry to improve the students' learning outcomes. In engaging students in inquiry-based learning effectively, chemistry teachers should structure the learning materials to incorporate the act of practical activities, questioning, problem solving, small group discussion, experimenting, exploration and recording which are essential components of inquiry in chemistry.

IX. RECOMMENDATION

Most of the students memorise scientific concepts without understanding the concepts and inability to use the knowledge to solve both qualitative and quantitative problems in chemistry. The curricula in science subjects are well structured but the implementation of the contents in inquiry is a huge problem for science teachers. Most science teachers find in it difficult to organise and engage their students in inquiry because of their inadequacies in learning pedagogy and content knowledge of the science subjects. The following are therefore recommended:

- Qualified teachers in pedagogy and content knowledge areas should be employed to teach chemistry.
- There should be training and retraining for chemistry teachers in inquiry-based learning and other students-centred methods of teaching for students' active engagement in teaching and learning.
- Provision of learning resources in the science laboratories.
- Adequate supervision and monitoring of teaching and learning process by the educational agencies for proper implementation of the chemistry curriculum.

X. RESEARCH INSRUMENTS

9.1 The Structured Inquiry-based Learning

Activity 1

Aim: To demonstrate forms of energy and their conversions.

Materials: battery cells, electrical bulb, radio, torchlight, clock, pressing iron

Procedure:

a. Put battery cells in the clock, radio and torchlight.
b. Fix an electric bulb into an electric bulb holder and switch on the electric switch.
c. Plug a pressing iron, radio and electric fan into electric socket and switch them on.

Discuss and record your observations on each activity.

Observation and Explanations

In the procedure a. above, the battery cells have a stored energy called potential energy. The energy has performed a work on clock by counting seconds and given the sound of ticking. The radio gives sound when it is switched on and light is produced on torchlight. The energy conversion is from chemical energy in the battery cells to sound and light energy.

In the procedure b. above, the electric bulb produces light from the electrical energy. The energy conversion is from electrical energy to light energy

In the procedure c. above, the electrical energy is converted to heat energy in pressing iron and sound in radio. The electrical energy has caused the electric fan to rotate and the type of energy involved is mechanical energy.

Activity 2

Aim: To identify and explain thermodynamic terms; system, surrounding, isolated system and open system

Materials: Beakers, vacuum flasks containing hot water, concentrated tetraoxosulphate (VI) acid, H_2SO_4, crystal of ammonium chloride, NH_4Cl, distilled water and a reaction involving the collection of gas over water, closed hot coffee cup.

Procedure:

a. Add about 1 cm^3 of concentrated H_2SO_4 to about 5 cm^3 distilled water in a beaker and touch the beaker to observe the resulting solution.
b. Add spatula full of NH_4Cl to about 10 cm^3 distilled water in a beaker and touch the beaker to observe the resulting solution.
c. Touch the back of the vacuum flasks containing hot water and closed hot coffee cup.
d. Record your observations and observe a reaction set-up involving the collection of a gas over water.
e. Use the observations to explain system, surrounding, isolated system, open system and closed system in thermodynamics.

Observations and explanations

The resulting solution in a. becomes hot while that of b. become very cold. Heat energy is released from the reaction (system) to surrounding in a. while heat energy is absorbed from the surrounding to the system in b. Both reactions in beakers are the systems while any space outside the reaction content in the beakers is the surrounding. The reactions in beakers in a. and b. are open systems because they exchange both matter and heat energy with their surroundings. The vacuum flask containing hot water is isolated system because there is no exchange of both matter and heat energy between the its system and surrounding. The reaction involving collection of a gas over water and a closed hot coffee cup are closed system because they only exchange heat energy to the surrounding not matter. Energy is not destroyed during physical and chemical processes but it is been converted from one form to another during the processes.

Activity 3

Aim: To demonstrate energy changes that accompany physical and chemical processes (exothermic changes).

Materials: Sodium hydroxide (NaOH) pellets, potassium hydroxide (KOH) pellets, calcium (II) oxide, CaO, 2.0 $moldm^{-3}$ of HCl, concentrated hydrochloric acid, concentrated tetraoxosulphate (VI), H_2SO_4, distilled water, test tube, boiling tube, thermometer, iron fillings, zinc metal.

Procedure:

a. Put about 10 cm^3 of distilled water in a test tube and take its initial reading temperature, T_1. Add 3 or 4 pellets of sodium hydroxide into the water, carefully stir the mixture with a thermometer, and then, record the highest temperature as T_2 of the mixture.
b. Repeat the experiment with KOH and CaO.
c. Repeat the experiment carefully by adding 2 cm^3 of concentrated HCl.
d. Repeat the experiment carefully by adding 2 cm^3 of concentrated H_2SO_4.
e. Repeat the experiment by put 15 cm^3 of 2.0 $moldm^{-3}$ HCl into a boiling tube and take its initial temperature T_1. Add a spatula full of iron fillings or 3 granules of zinc metal. Stir the mixture carefully with a thermometer and record the highest temperature, T_2.

Observations and explanations

In each of the experiment, the final temperature T_2 is greater than the initial temperature T_1. That is $T_2 > T_1$. There is a rise in the temperature of the mixture in each case. Hence the mixture becomes warm or hot. The temperature change, ΔT is positive, the processes are exothermic. That is, heat energy is given off by the reactants to the surrounding.

Activity 4

Aim: To illustrate energy changes that accompany physical and chemical processes (endothermic changes).

Materials: Ammonium chloride, NH_4Cl, ammonium trioxonitrate (V), NH_4NO_3, potassium trioxonitrate (V), KNO_3, sodium ethanoate, CH_3COONa, barium hydroxide, $Ba(OH)_2$, distilled water, test tube, boiling tube, thermometer.

Procedure:

a. Put about 10 cm^3 of distilled water in a test tube and take its initial temperature, T_1. Add a spatula full of ammonium chloride, NH_4Cl, crystals into the water. Stir the mixture carefully with a thermometer, and record the lowest temperature as T_2 of the mixture.
b. Repeat the experiment with: i. ammonium trioxonitrate (V), NH_4NO_3 ii. potassium trioxonitrate (V), KNO_3 iii. sodium ethanoate, CH_3COONa.
c. Put 10 cm^3 of distilled water in a test tube and take its initial temperature T_1. Place a spatula full each of crystals of barium hydroxide and ammonium chloride in a boiling tube, and add the water from the test tube into it. Stir the mixture with a thermometer, and record the lowest temperature, T_2 of the mixture.

Observations and explanation

In each of the experiments, the final temperature T_2 is less than the initial temperature of the mixture, as a result, the mixture becomes cold. That is, $T_2 < T_1$ and the temperature change, T_2 - T_1, ΔT is negative. Therefore, these processes are endothermic, that is heat energy is absorbed by the reactants from the surroundings.

Activity 5

Aim: To determine the heat of solution of substances in water.

Materials: simple calorimeter or bomb calorimeter, ammonium chloride, NH_4Cl, sodium hydroxide (NaOH) pellets, thermometer, beaker.

Procedure:

a. Measure 50 cm^3 of distilled water into bomb calorimeter (or an insulated beaker by lagging) and record its temperature T_1. Add 10 pellets (1.0g) of NaOH into the water, stir the mixture carefully with a thermometer, and record the highest temperature T_2 of the mixture.

Assumption: The following assumptions should be made:

i. the mass of 1cm^3 of the solution is 1.0 g.
ii. the heat gained or lost by the plastic cup or insulated beaker is negligible.
iii. the specific heat capacity of the solution formed is 4.2 $Jg^{-1}K^{-1}$.

Note: Specific heat capacity is the heat required to raise 1 g of a substance by 1 k temperature.

b. Repeat the procedure for ammonium chloride, NH_4Cl
c. Determine the heat change and standard heat change for the dissolution of each of the substances.
d. Identify and explain the energy changes that accompanying each dissolution.

Explanation and observations

Calculation from dissolution of NaOH in water from data obtained from an actual experiment:

Temperature T_1 of water = 27.0 ^{0}C = 300 K

Highest temperature T_2 of solution = 31.0 ^{0}C = 304 K

Change in Temperature = $T_2 - T_1$ = (304 - 300) ^{0}C = 4 K

Heat evolve = Total mass of solution x rise in temperature x specific heat capacity

= 50.0 g x 4.0 K x 4.2 J = 840.0 J

That is, 1.0 g of NaOH evolved 840.0 J

Molar mass of NaOH = 23 +16 +1 = 40 $gmol^{-1}$

40.0 g (1 Mole) of NaOH evolved 840 x 40 J = 33600 J per mole = 33.6 $kJmol^{-1}$.

The dissolution of NaOH in water is exothermic because change in temperature is positive. That is, heat energy is liberated from the system to the surrounding. For the dissolution of ammonium chloride, NH_4Cl, is endothermic because temperature change is negative. Heat energy is absorbed from the surrounding to the system.

Note: The above procedure can be used to calculate heat change of the NH_4Cl if the experimental data are known. Molar mass of NH_4Cl = 14 + (1x4) +35.5 = 53.5 $gmol^{-1}$

Activity 6
Aim: To determine the heat of neutralization.
Materials: Simple calorimeter or bomb calorimeter, 1.0 $mol.dm^{-3}$ NaOH, 2.0 $mol.dm^{-3}$ NaOH, 1.0 $mol.dm^{-3}$ HCl, 2.0 $mol.dm^{-3}$ HCl, thermometer, beaker, measuring cylinders.
Equation for the reaction: NaOH + HCl $\rightarrow$ NaCl + H_2O
Procedure:

a. Measure 50 cm^3 of 1.0 $mol.dm^{-3}$ NaOH into a simple calorimeter or bomb calorimeter and record the temperature T_1 of the solution. Measure 50.0 cm^3 of 1.0 $mol.dm^{-3}$ HCl into the beaker and record temperature T_2 of the solution. Pour the HCl solution at once and as quickly as possible into the NaOH solution inside the simple or bomb calorimeter. Stir the mixture carefully with thermometer and record the highest temperature T_3 of the mixture.

Assumption: The following assumptions should be made:

iv. the mass of 1cm^3 of the solution is 1.0 g.
v. the heat gained or lost by the plastic cup or insulated beaker is negligible.
vi. the specific heat capacity of the solution formed is 4.2 $Jg^{-1}K^{-1}$.

Note: Specific heat capacity is the heat required to raise 1 g of a substance by 1 k temperature.

b. Determine the heat change and standard heat change for the neutralization.
c. Identify and explain the energy changes that accompanying the neutralization.

Note: Repeat the experiment with 2.0 $mol.dm^{-3}$ NaOH and 2.0 $mol.dm^{-3}$ HCl

Calculation and observation:
The following data obtained from actual experiment is used as an illustration.
Temperature T_1 of NaOH solution = 25.4 ℃ = 298.4 K
Temperature T_2 of HCl solution = 25.6 ℃ = 298.6 K
The highest temperature T_3 = 32.3 ℃ = 305.3 K
Volume of 1.0 $mol.dm^{-3}$ NaOH used = 50.0 cm^3 = 50 g
Volume of 1.0 $mol.dm^{-3}$ HCl used = 50. 0 cm^3 = 50 g
The average temperature of the two solution = (298.4 + 298.6) K ÷ 2 = 298.5 K
The temperature change = (305.3 – 298.5) K = 6.80 K
To calculate the heat evolved when one mole of HCl is neutralized by one mole of NaOH:
Heat evolved = total mass of the solution x change in temperature x specific heat capacity
= 100 g x 6.8 K x 4.2 J $g^{-1}K^{-1}$
= 100 x 6.8 x 4.2 = 2856 J.
That is 50.0 cm^3 of 1.0 $mol.dm^{-3}$ HCl evolve 2856 J
1000 cm^3 of 1.0 $mol.dm^{-3}$ HCl evolve (2856 x1000) ÷ 50 = 57120 J
Since 1000 cm^3 of 1 $mol.dm^{-3}$ HCl contain 1 mole of HCl, then the heat of neutralization of 1 mole of NaOH by 1 mole of HCl will be 57120 J ÷ 1000 = 57.12 kJ.
The reaction is exothermic because there is a rise in temperature during the reaction.

Note: For 2.0 $mol.dm^{-3}$ NaOH and 2.0 $mol.dm^{-3}$ HCl with the same 50 cm^3
The change in temperature of the neutralization will be greater than 6.80 K hence the heat of neuralization will be greater than 57.12 kJ. This is because of the increase in the concentration of both NaOH and HCl

Adapted from Ojokuku (2017).

9.2 Test Items on Thermodynamics Concepts
1a. In a thermodynamic reaction, what is the reaction conducted in a beaker or test tube called?
b. Give reason for you answer.
2a. What is an enthalpy change, ΔH that is recognised by a fall in the temperature of a system is called?
b. Give reason for your answer
3a. Will the heat liberated when 1.0 g of NaOH pellets dissolves in 20 cm^3 of distilled water be less or greater than when 2.0g of NaOH pellets dissolve in the 20 cm^3 of distilled water?
b. Give reason for your answer.

4a. What is the solution temperature of solution of N 6.80 K 6.80 KOH with 25.5 ^{0}C and HCl solution of 25.7 ^{0}C?
b. Give reason for your answer.
5a. What is the change in temperature of a neutralization reaction with the of KOH solution 26.0 ^{0}C, HNO_3 solution 25.3 ^{0}C and the highest temperature is 32.3 ^{0}C?
b. Give reason for your answer
6a. The heat of vaporisation of water liberated is $\Delta H = +410$ kJmol$^{-1.}$ What is the corresponding condensation?
b. Give reason for your answer
7a. What is the enthalpy change in the dissolution of sodium ethanoate, CH_3COONa?
b. Give reason for your answer
8a. Is the ionization of ethanoic acid exothermic or endothermic?

$$CH_3COOH_{(aq)} \rightleftharpoons H^{+}_{(aq)} + CH_3COO^{-}$$

b Give reason for your answer.
9a. What kind of system will you classify a vacuum flask?
b. Give reason for your answer
10a. If 1.10 g of calcium chloride dissolved 50 cm^3 of water caused a rise in temperature of 3.4^{0}C, determine the heat if solution in kJmol^{-1}. [Ca =40, Cl = 35.5; specific capacity of water = 4.18 JK^{-1}.
b. Give reason for the answer

REFERENCES

Adeoye, I. F. and Ajeyalemi, D. (2018). Effects of inquiry-based learning strategies on chemistry students' conceptions in chemical kinetics and equilibrium. *American Journal of Humanities and Social Science Research*, 5(10), 57 - 70.

Adeoye, I. F. (2016). *Effects of Inquiry-based Learning Strategies on Secondary School Students' Learning Outcomes in Chemistry*. Unpublished Ph. D Thesis submitted to Department of Science Education and Technology, University of Lagos, Lagos.

Annisa, D. and Rohaeti, E. (2021). *The Effect of Inquiry-based Learning on Students Understanding of the Chemical Equilibrium Concepts*. The 8th Annual Basic Science International Conference. AIP Conference Proceedings 2021 https://doi.org/10.101063/1.5062823.

Ausubel, D. P. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston.

Bruner, J. S. (1967). *On knowing: Essays for the left hand*. Cambridge, MA: Harvard University.
Dewey, J. (1949). *Knowing and the known*. Boston: Beacon Press.

Federal Ministry Education (2007). *National curriculum for senior secondary school Science.* Lagos: NERDC Press.

Iryani, I. B., Iswendi, I. and Patra, R. F. (2021). Effect of using guided inquiry-based chemical bonding modules on student learning outcomes. *Journal of Physics: Conference series.* 1788 (2021) 012022. doi:10.088/1742-65961/1788/012022.

Kamisah, O. and Nur, S. (2013). Conceptual understanding in secondary school chemistry: A discussion of the difficulties experienced by students. *American Journal of Applied Sciences*, 10(5), 433-441.

Kyado, J. (2021). Identification of difficult concepts in chemistry by some secondary school students and teachers in Nigeria. *Journal of the International Centre for Science, Humanities and Education Research*, 5(1), 85-98.

Ojokuku, G. O. (2017). *Understanding Chemistry for Schools and Colleges*. PRESS-ON CHEMBOOKS.

Piaget, J. (1983). *To understand is to invent*. New York: The Viking Press, Inc.

Royal Society of Chemistry (2019). Chapter 1: The Challenge of Teaching and Learning Chemical Concepts in *The Nature of the Chemical Concept: Re-constructing Chemical Knowledge in Teaching and*

Learning. Advances in Chemistry Education Series, 1-13. DOI:10.1039/978178813611-00001. https://www.pubs.rsc.org.

Singh, J. and Kaushik, V. (2021). A study on the effectiveness of the inquiry-based process. *Journal of Engineering and Technology*, 7(1). https://www.gyanvihar.org.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Woldeamanuel, M. M., Atagana, H. and Engida, T. (2014). What makes chemistry difficult? *AJCE, Special Issue Part 1*, 4(2), 13-43.