

SATLC APPLICATIONS AS EXAMPLES FOR SYSTEMIC CHEMISTRY EDUCATION REFORM IN THE GLOBAL AGE

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ABSTRACT

Systemic Approach to Teaching and Learning [SATL] has evolved in the field of teaching and learning chemistry starting in 1997, as a fruitful cooperation between Fahmy, AFM (Egypt) and Lagowski, JJ (USA). It is focused on the students and their good teaching and learning and encompasses instruction that encourages active learning, reciprocity and cooperation between students, and between students and their local and global contexts. It is also used as a vehicle to engage the students in a deep learning that focuses on relating ideas and making connection between new and prior knowledge. As applications of SATLC I present here systemic chemistry related units experimented in Egyptian secondary schools and universities with examples on systemic assessment. [*AJCE 4(2), Special Issue, May 2014*]

INTRODUCTION

After the wide spread of systematization in various activities including tourism, commerce, economy, security, education, health etc., and after globalization became a reality that we live and survive with its positive and negative impacts on our life, and after the current educational systems deals quite intensively with the impact of the “globalization’ on educational planning and decision making, SATL became a must for preparation of citizens. SATL is a new way of teaching and learning, based on the global idea that nowadays everything is related to everything [1-5]. It is considered as a way of teaching and learning that intensify deep learning which differs from surface learning that focuses on rote memorization and superficial understanding of concepts. The following table (1) shows the comparison between students achievements and outcomes when they treated by either DLA (deep learning approach) or SATL strategies.

Deep Learning Approach [DLA]	Systemic Approach to Teaching and Learning [SATL]
<p><u>Enables student to do the following:(6)</u></p> <ol style="list-style-type: none"> 1.Retain Knowledge and apply it in new and different contexts. 2.Focus on relating ideas and making connections between new and prior knowledge. 3.Come to see concepts, ideas and/or the world differently. 4.Engage in independent, critical, analytical thinking in a quest of personal meaning. 5.Engage in active learning by interacting with others and course material in learning. 6.Rely on intrinsic motivation to learn. 	<p><u>Enables student to do the following :(5)</u></p> <ol style="list-style-type: none"> 1. Retain knowledge and apply it in a new global context. 2. Focus on relating concepts and making interconnections between them and between prior knowledge. 3. See the relations between concepts beside concepts in a pattern of cognition. 4. Engage students in analytic- synthetic thinking [systemic thinking] enable them to solve the daily life systemic problems. 5. Engage in active learning by interacting with themselves, and with teachers and course materials. 6. Rely on the ease of teaching and learning to increase motivation of students to learn.

From the above mentioned table we can say that SATL strategy coincides with deep learning strategy in most of the above mentioned items. So SATL strategy covers deep learning strategy, i.e., student treated with SATL will go in a deep learning. However, DLA doesn't cover all aspects of SATL strategy.

WHY SATL IN CHEMICAL EDUCATION REFORM? [2]

SATL:

1. Helps students to understand interrelationships between concepts in a greater context.
2. Engages students in a deep learning.
3. Assures that students attain the major goals of education helping them to acquire the higher order cognitive skills.
4. Provides new forms of educator evaluation that include outputs (student learning results) in addition to inputs.
5. Provides the basis for systemic thinking.

WHAT IS THE MENING OF SATL?

By "systemic" we mean an arrangement of concepts or issues through interacting systems in which all relationships between concepts and issues are made clear up front to the teachers and learners in contrast to the usual linear method of teaching the same topics. In systemic chemistry education we arrange the course content materials in a systemic way [5]. This means arrangement of concepts or issues through interacted systemic in which all relationships between concepts and issues are clear (Fig.1).

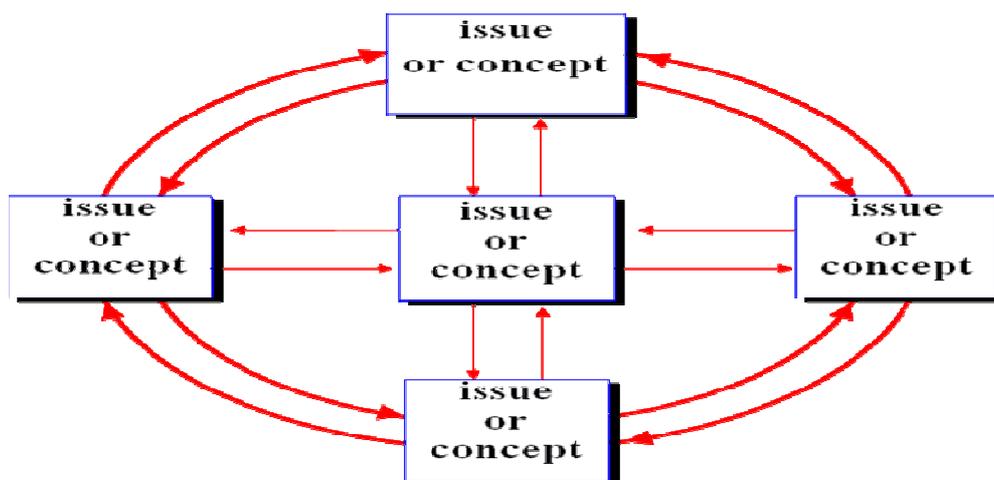


Fig.1: The idea of systemic arrangement of chemistry course materials

However, linear presentation of chemistry course materials means arrangement of chemistry issues and concepts in a sequential presentation as in (Fig.2).

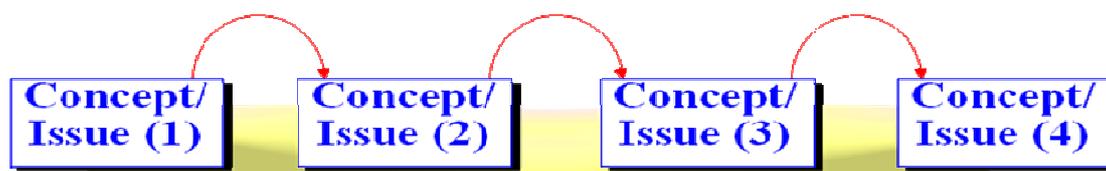


Fig.2: The idea of linear arrangement of chemistry course materials

In practice, the systemic building strategy allows the teacher to build up sequentially a single concept map starting with prerequisite concepts required for the student before he/she starts on a systemic approach to learning. Fig.3 shows this systemic strategy for building the closed cluster of chemistry concept maps (systemic; SD1-SD5) involving the five concepts entitled E, F, X, Y, Z (2).

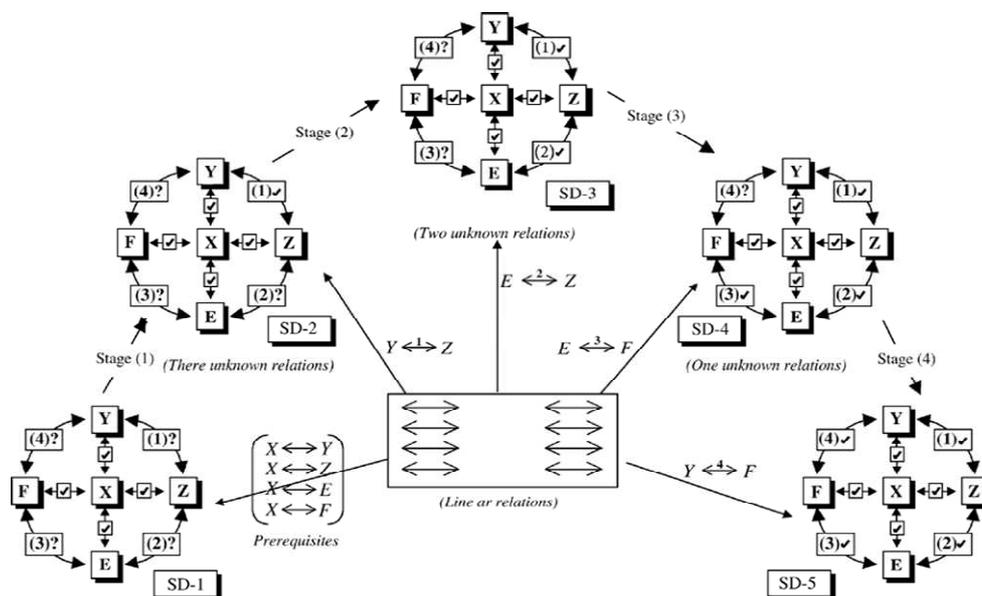


Figure 3. The evolution of a completed closed chemistry concept cluster from a starting point

The instructor has in mind the concept linear structure shown in Figure 2, which he/she wants to develop into the closed cluster (systemic) shown as Figure 1. The prerequisites are simple bi-directional relationships between the concepts. Thus, initially, there are four unknown (to the student) relationships in the final cluster of concepts (Fig.3). The full closed cluster concept map [SD5] can be developed in four stages by sequentially introducing the (initially) four unknown concepts. At each step another part of the final closed concept cluster is added and developed. This process clearly illustrates the systemic constructivist nature of systemic arrangement of the course content materials. This building strategy could be used in teaching different branches of chemistry.

SATL EXPERIMENTS IN EGYPT

We have conducted numerous experiments in Egypt which we attempted to establish the effectiveness of SATL methods not only in chemistry, but also in other basic sciences, medicinal sciences, engineering sciences, agriculture, and pharmaceutical sciences. In chemistry we conducted a series of successful SATL-oriented experiments at the pre-university and the university levels of education. We have created SATL units in General, Analytical, Aliphatic, Aromatic, Green, and Heterocyclic Chemistry. These units have been used in Egyptian universities and secondary schools to establish the validity of the SATL on an experimental basis.

I-PRE-COLLEGE EXPERIMENTS

Our experiments probing the usefulness of SATL to learning Chemistry at the pre-college level was conducted in Egypt at Cairo and Giza school districts.

I-1-SATL CARBOXYLIC ACIDS AND THEIR DERIVATIVES

Our initial experiment probing the usefulness of the SATLC to learning chemistry was conducted at the pre-college level in the Cairo and Giza school districts [5]. Nine SATL-based lessons in organic chemistry (Fig. 4) taught over a two-week period were presented to a total of 270 students in the Cairo and Giza school districts. The achievement of these students was then compared with that of 159 students taught the same material using linear methods (Fig. 5).

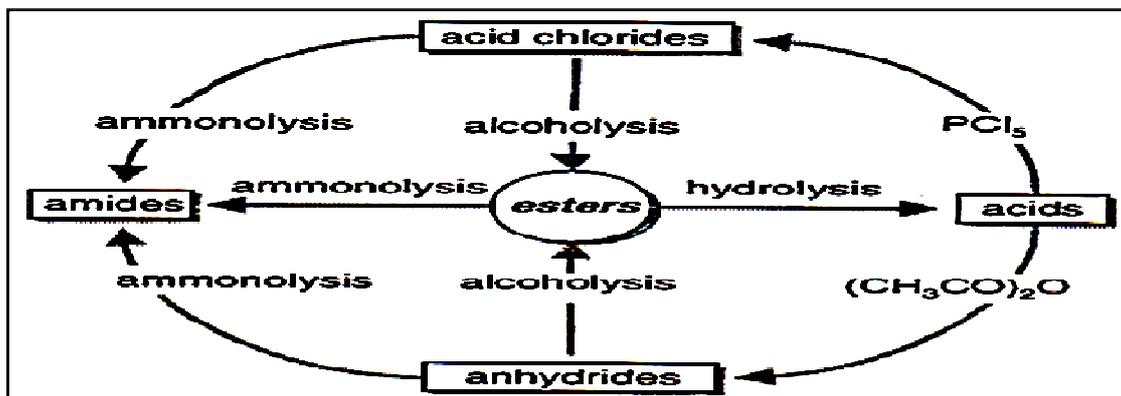


Fig.4: Systemic based Teaching and Learning material

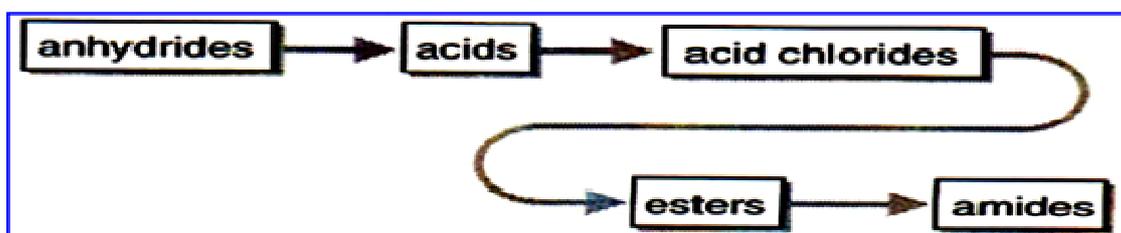


Fig.5: Linearly based teaching and learning material

The results indicate that a greater fraction of students exposed to the systemic techniques, the experimental group, achieved at a higher level (Fig.6) than did the control group taught by conventional linear techniques (Fig.7).

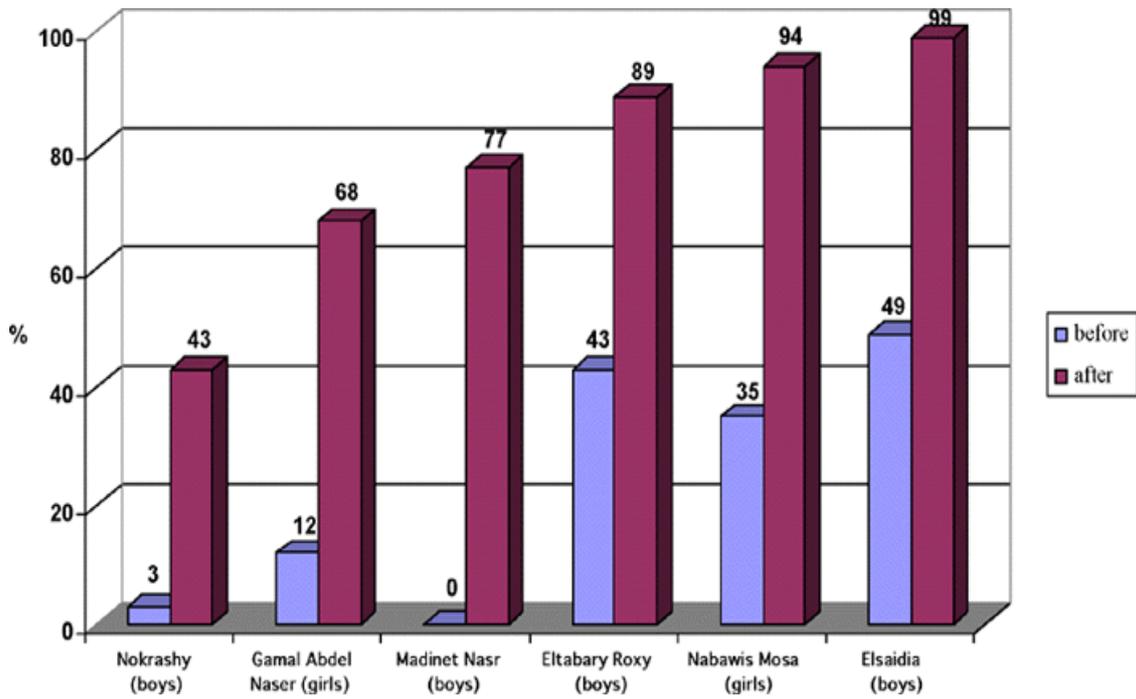


Fig.6: Percent of students in the experimental classes who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the systemic intervention period.

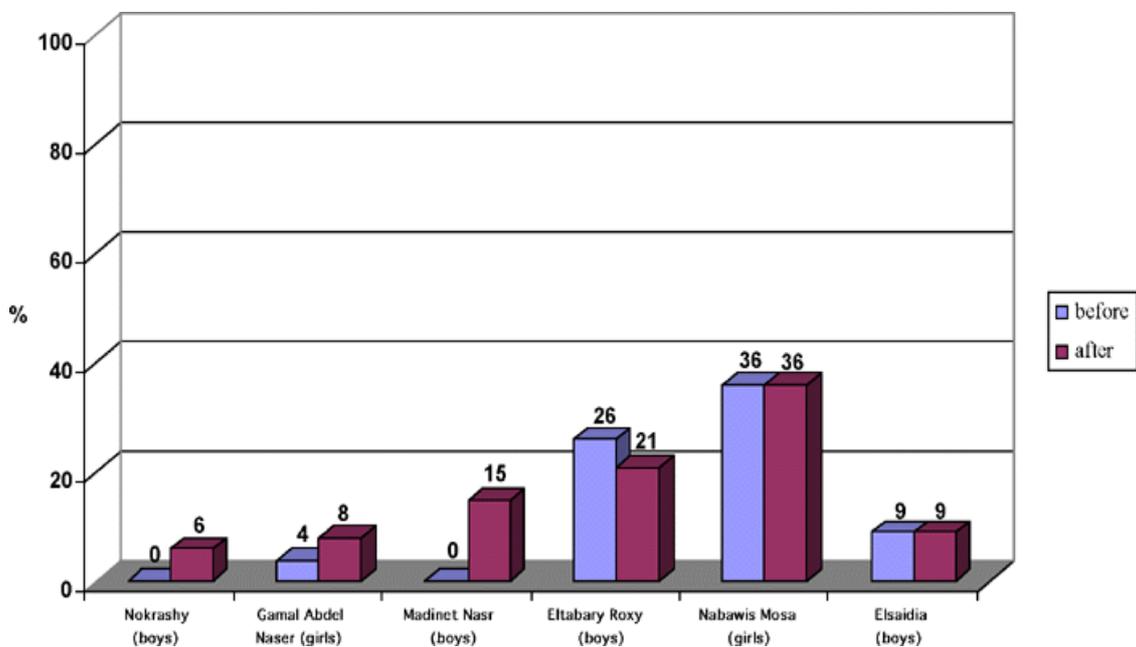


Fig.7: Students in the control classes who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the linear intervention.

The experimental group was taught by SATL-trained teachers using SATL techniques with specially created SATL materials, while the control group was taught by traditional teachers using the conventional (linear) approach with the conventional materials.

I-2:- SATL-CLASSIFICATION OF ELEMENTS

Our second experiment about the usefulness of SATL to learning Chemistry at the pre-college level was conducted in the Cairo and Giza school districts. Fifteen SATL- based lessons in inorganic chemistry taught over a three-week period were presented to a total 130 students. The achievement of these students was then compared with 79 students taught the same material using standard (linear) method. The periodicity of the properties within the linear horizontal periods and within the vertical groups in the periodic table was illustrated systemically [5, 7].

LINEAR AND SYSTEMIC PERIODS

In the periodic table the graduation in properties are studied in a linear method from left to right increasing or decreasing.

e.g.: In period -2: The linear graduation of the properties in the second period starting from lithium to neon increasing or decreasing as in (Fig.8).

Li	Be	B	C	N	O	F	Ne
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Fig.8: Linear Period .2 [LP-2]

But in systemic period-2: The graduation in the properties is studied systemically starting from any element in the period to any other element as shown in the (Fig.9).

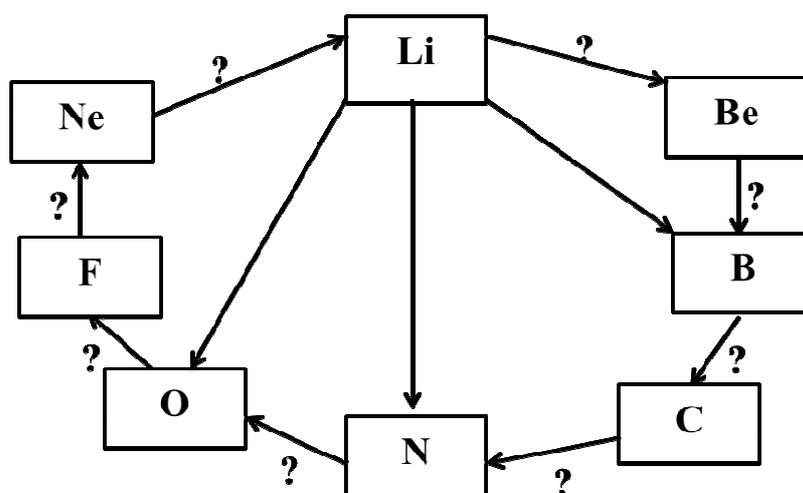


Fig.9: Systemic Period.2 [SP-2]

It shows increasing or decreasing in the given property (?) on moving from one element to another through the systemic period. The systemic period [SP] is characterized from the linear period [LP] in the following:

- 1- Find a relation between any element of the period and all the other elements.
- 2- Solve the abnormality in the periodicity of some properties because it finds the relation between each element and the next element in a certain property till the end of the period.

e.g.: Periodicity of electron affinity

The electron affinity increases by increasing atomic number with the exception of Beryllium, Nitrogen and Neon. (table.2)

Table.2: Periodicity of electron affinity in linear period-2 [LP-2];

Li	Be	B	C	N	O	F	Ne
-58.5	+66	-29	-121	+31	-142	-332	+99
	↓			↓			↓
	(abnormal)			(abnormal)			(abnormal)

However, the periodicity of electron affinity in the systemic period -2 [SP-2] shows that the relation takes place between any two elements from the point of electron affinity as in Fig.10.

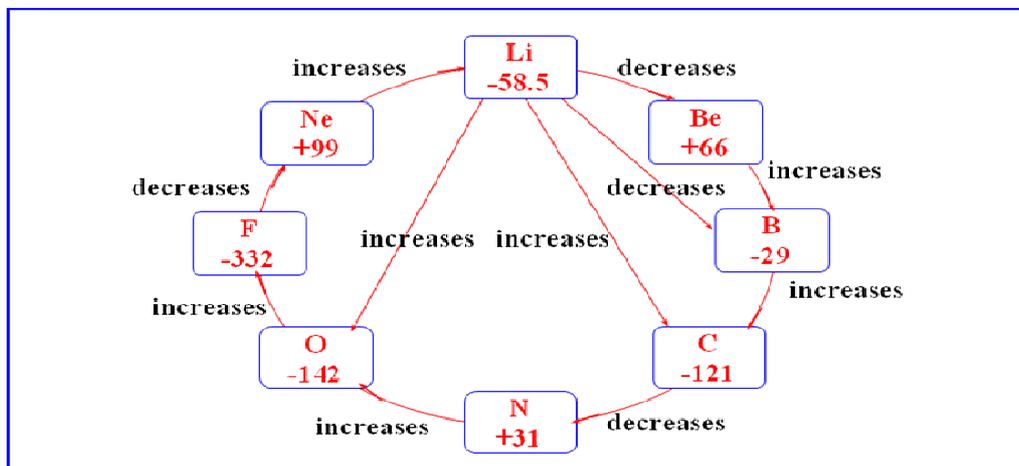


Fig. 10: Periodicity of electron affinity in systemic period -2 [SP-2]

As the (-ve) value increases the amount of energy released increases so the electron affinity increases.

GENERAL SHAPE OF THE SYSTEMIC PERIODS [GSP]

Generally the systemic period (SD-P) can be drawn as follow.

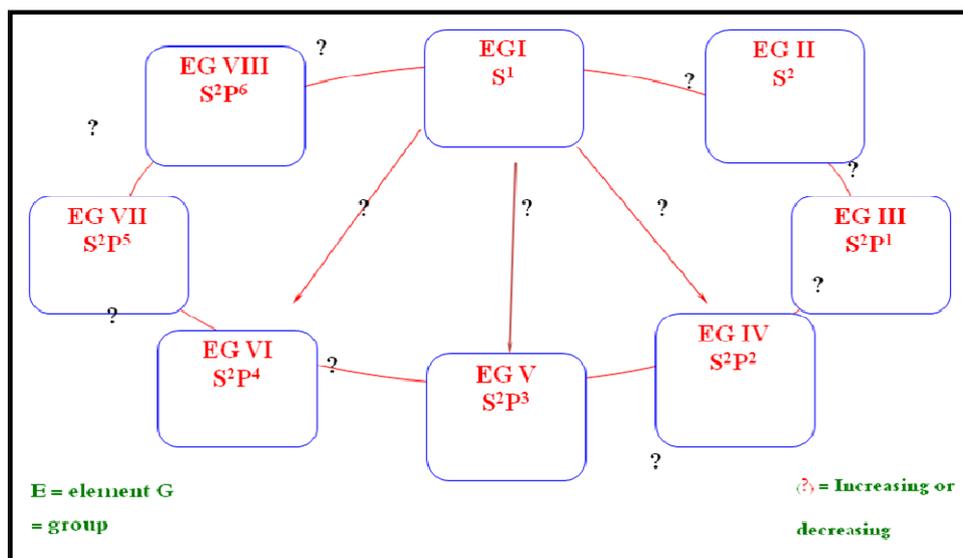


Fig. 11: Periodicity of properties in general systemic period (GSP)

LINEAR AND SYSTEMIC GROUPS

The graduation in the properties through groups in the periodic table are studied in linearity from top to bottom as shown in the general linear group (Fig. 12)

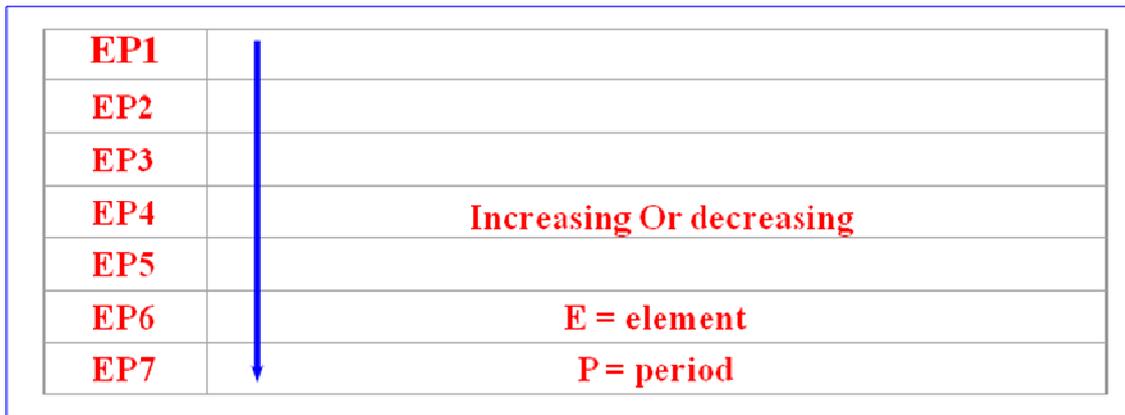


Fig. 12: Periodicity of prosperities in general linear group (GLG)

But in case of systemic group the graduations in the properties are to be studied systematically starting from any element to another. It can be represented by the following systemic diagram of GSG as shown in Figure (13).

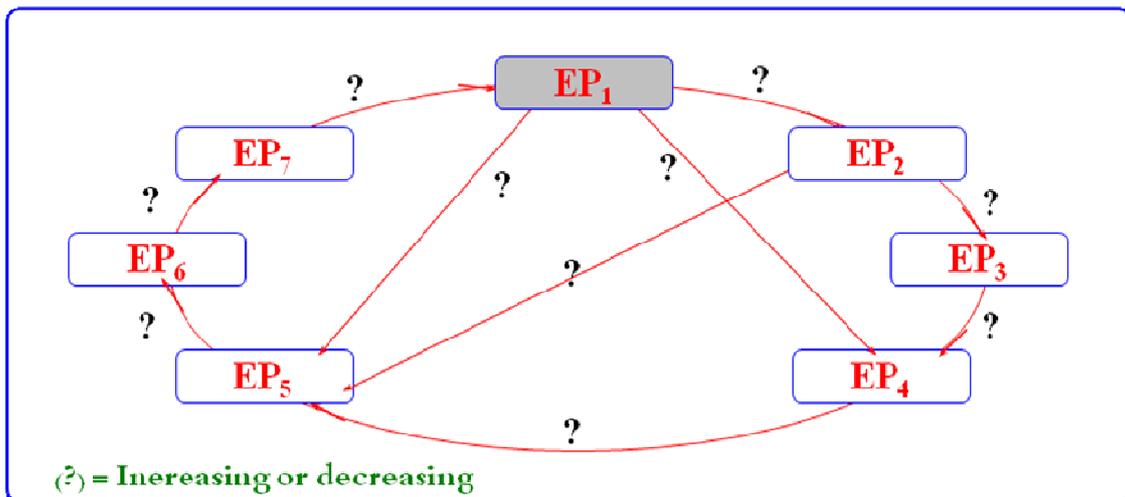


Fig.13: General Systemic Group (GSG)

The characteristics of the systemic groups are the same as in the systemic periods.

Example

Periodicity of properties of (atomic radius - Ionization potential - electro negativity) through systemic group (SG-1)

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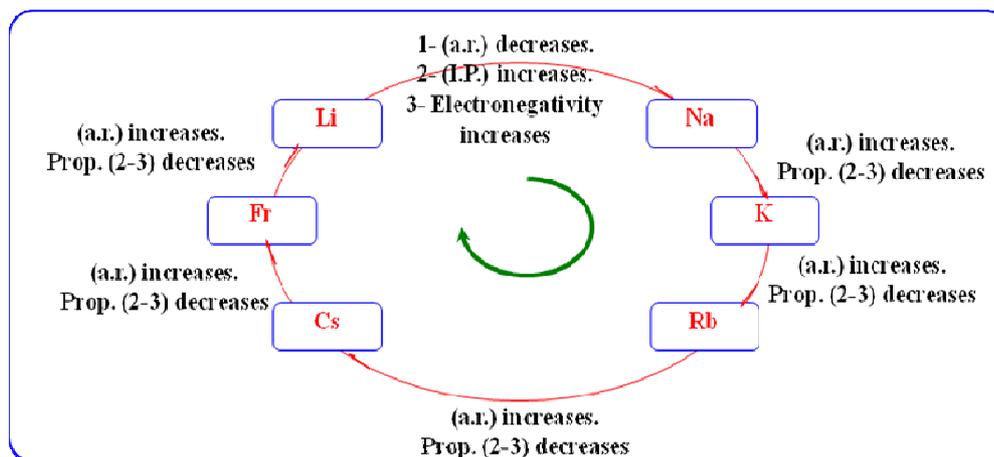


Fig.14.Periodicity of some properties in SG-1

The results of experimentation indicated that a greater fraction of students exposed to systemic techniques in the experimental group achieved at a higher level than did the control group taught by linear techniques. The overall results are summarized in Figs. 15 and 16.

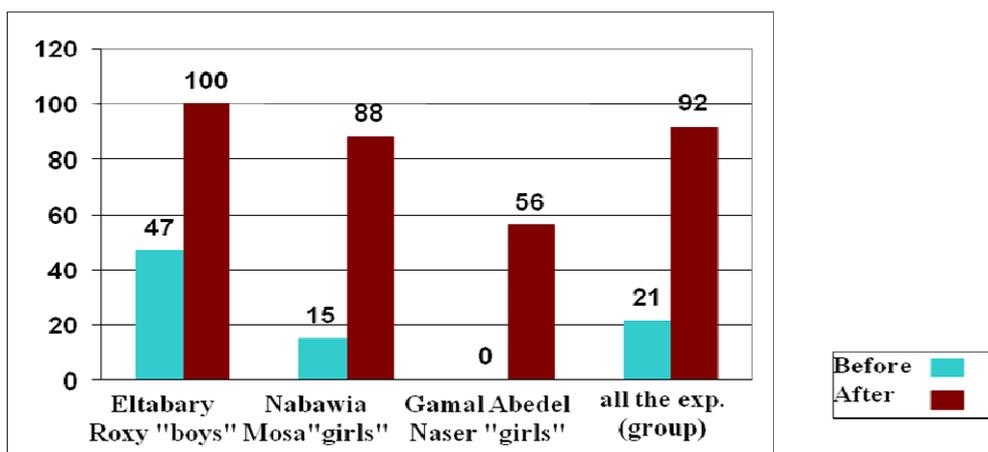


Fig.15: Percent of students in the experimental groups who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the systemic intervention period.

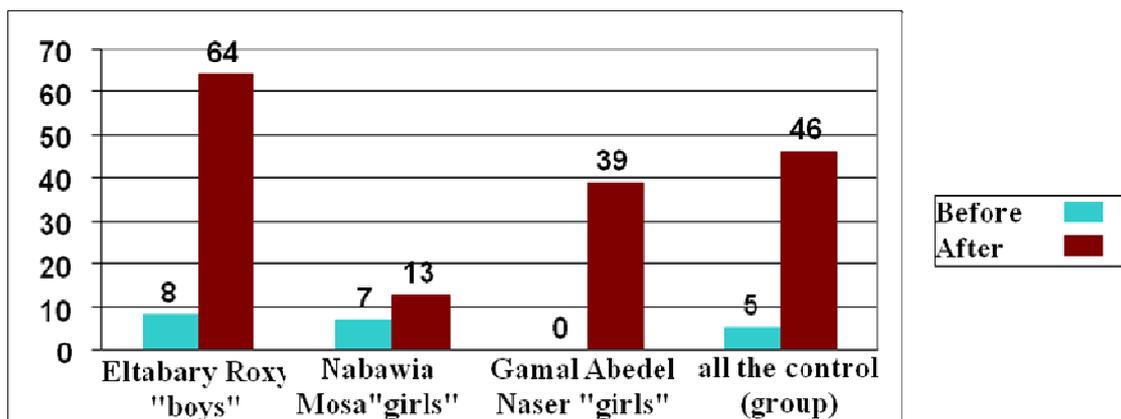


Fig. 16: Percent of students in the control groups who succeeded (achieved at a 50% or higher level). The bars indicate a 50% or greater achievement rate before and after the linear intervention period

Conclusions: Our results from the Secondary Level experiment point to a number of conclusions that stem from the qualitative data, from surveys of teachers and students, and from anecdotal evidence.

1. Implementing the systemic approach using one unit of general chemistry within the course has no negative effects on the ability of the students to continue their linear study of the remainder of the course using the linear approach.
2. Teachers from different experiences, professional levels, and ages can be trained to teach by the systemic approach after a short period of training.
3. After the experiment both teachers and learners retain their understanding of SATL techniques and continue to use them.

II-UNIVERSITY EXPERIMENTS

II-1:-SATL-ALIPHATIC CHEMISTRY

A study of the efficacy of systemic methods applied to the first semester of the second year organic chemistry course (16 lectures, 32 hours) at Zagazeg University was conducted. The

experiment was conducted within the Banha branch, Faculty of Science, Department of Chemistry with second year students. The experiment involved 41 students in the control group, which was taught using the classical (linear) approach; 122 students formed the experimental group, which was taught using SATL methods. The details of the transformation of the usual linear approach used to teach this subject to the corresponding systemic closed concept cluster that represents the systemic approach were presented.

Stage-1: Linear arrangements of the chemical properties of Alkanes

The usual linear approach used to teach alkanes involves separate chemical relationships between alkanes and other related compounds as shown in (Fig.17).

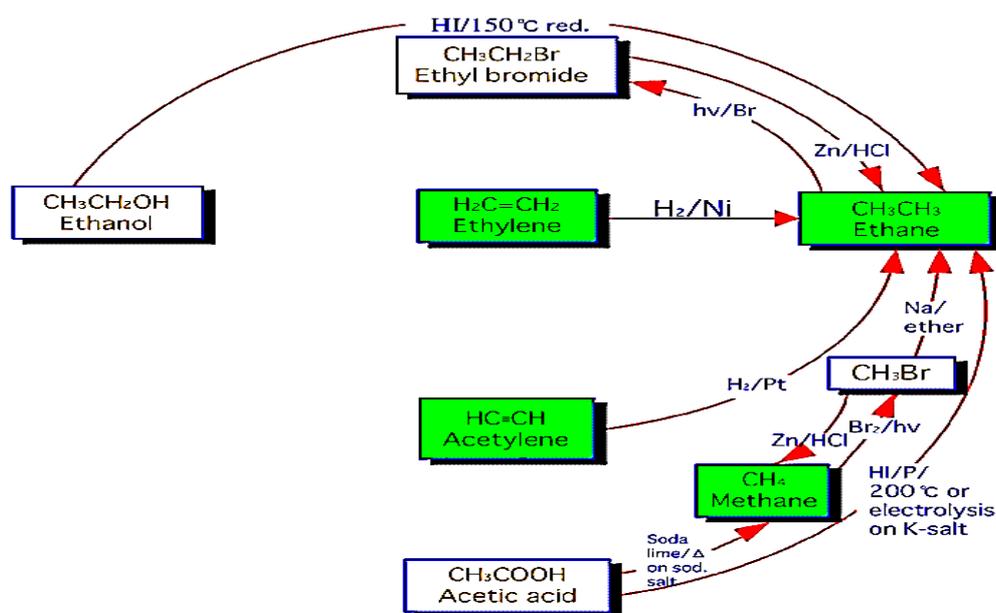


Fig. 17: The classic linear relationship involving the chemistry of the alkanes organized to begin to create a systemic diagram of that chemistry

Stage-2: Systemic arrangements of the chemical properties of Alkanes:

The synthesis and chemical properties of Alkanes can be arranged systemically by changing the linear arrangement in the linear diagram (Fig.17) to systemic arrangement as illustrated in the systemic diagram (SDO) (Fig.18).

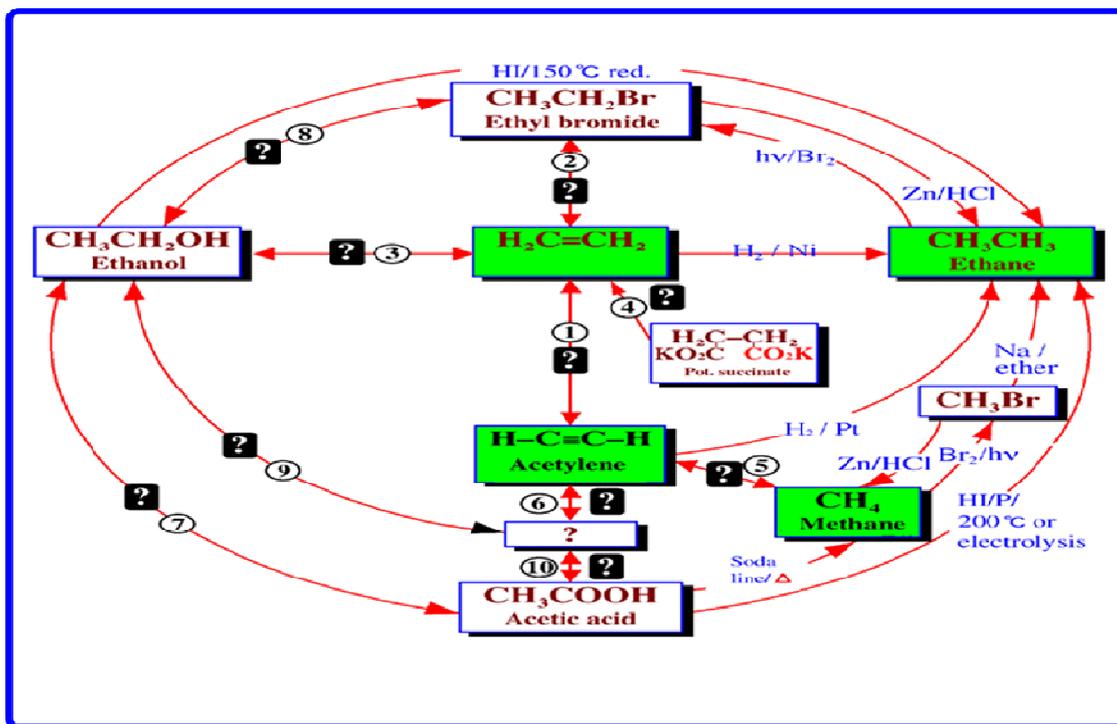


Fig.18: Systemic diagram (SD0) that represents some of the major chemistries of alkanes

In the systemic diagram SD0 some chemical relationships are defined whereas others are undefined. These undefined relationships are developed sequentially.

Stage-3: Systemic arrangement of the chemical properties of Alkenes

After using the diagram shown in Fig. 18 as the basis for the study of the synthesis and reactions of alkenes, and alkynes, we can modify this systemic diagram (SD0 in Fig. 18) to accommodate chemistries of Alkenes as shown in (SD1) (Fig. 19).

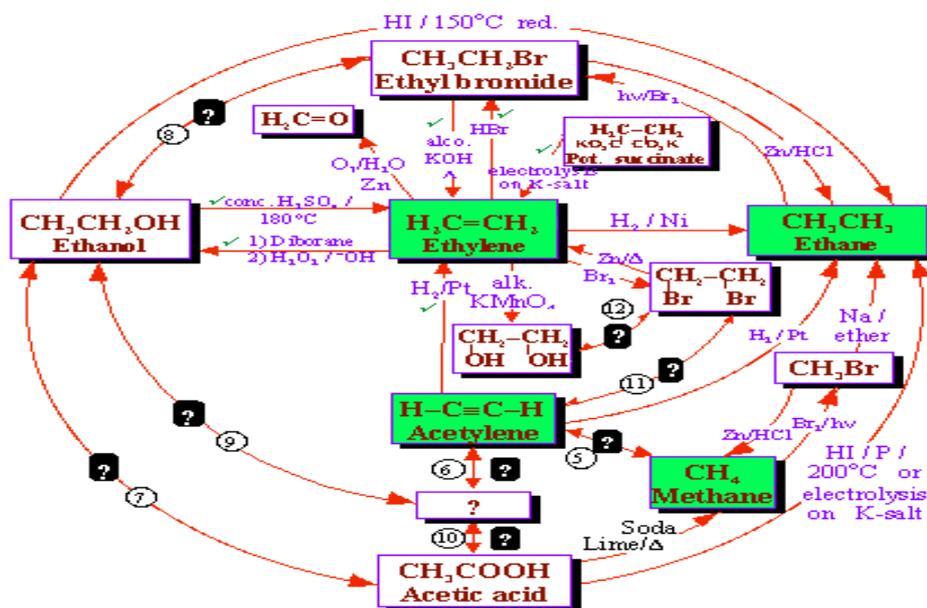


Fig.19: Systemic diagram (SD1) that represents some of the major chemistries of alkenes

Stage-4: Systemic arrangement of the chemical properties of Alkynes:

After the study of the chemistry of Acetylene we can modify the systemic diagram SD-1(Fig.19) to SD-2 (Fig.20) by accommodating chemistry of Acetylene (Alkynes).

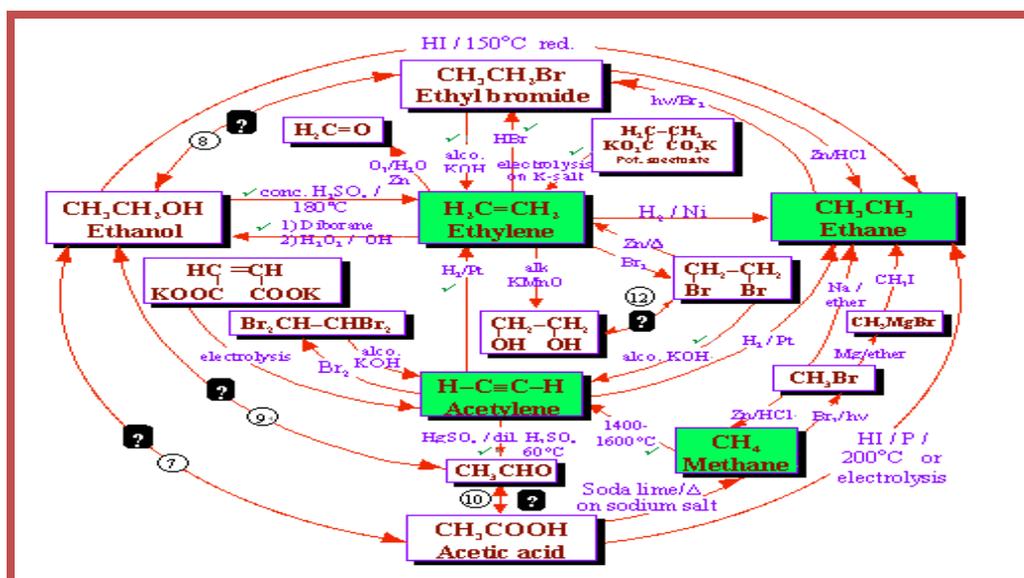


Fig.20: The Systemic relationship between the aliphatic hydrocarbons and their derived compounds.

Systemic diagram (SD2) shown in Figure 20 can accommodate to the chemistries of ethyl bromide and ethanol yielding a new systemic diagram.

The results of experimentation

Figures 21 and 22 show the final data in terms of student achievement in experimental and control groups, respectively.

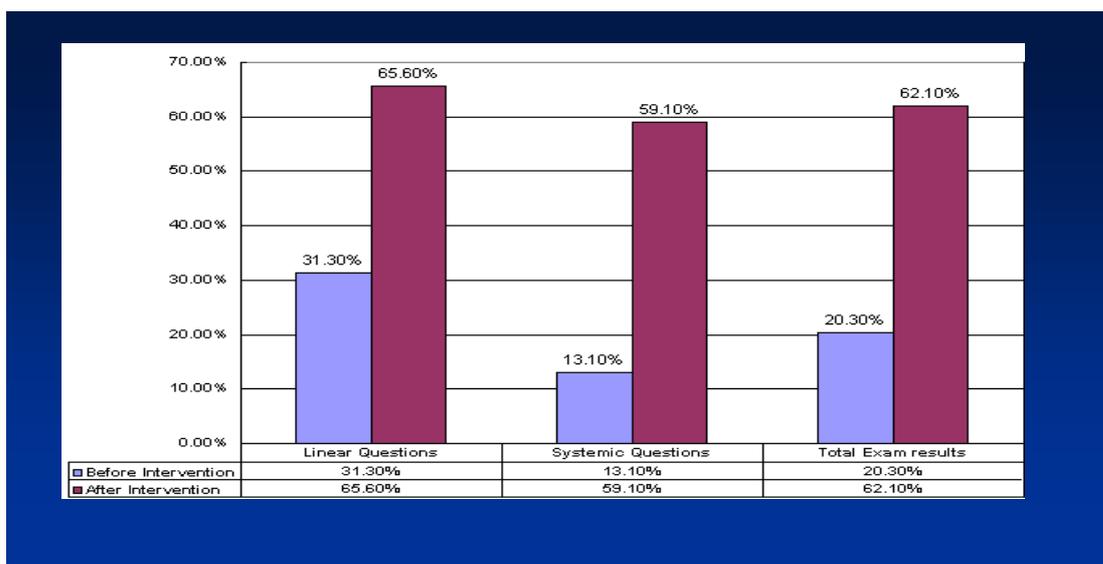


Fig. 21: Average scores for experimental group before and after intervention

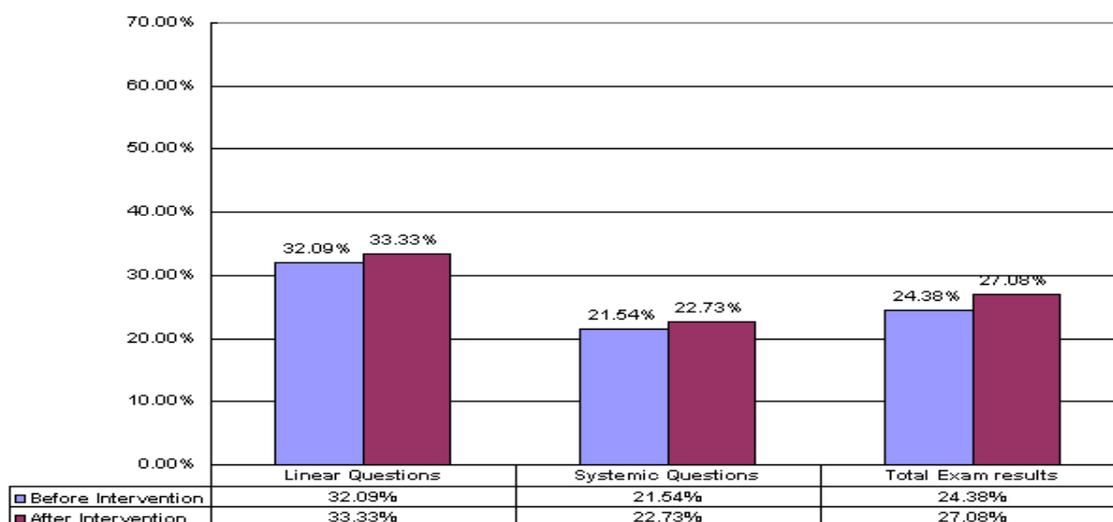


Fig. 22: Average scores for control group before and after intervention

The data indicate a marked difference between the control and experimental groups.

II-2: SYSTEMICS TO LABORATORY INSTRUCTION [BENIGN ANALYSIS]

We have created qualitative benign analytical chemistry course for the first-year students of Faculty of Science, Benha, Zigzag University, and Faculty of Education, Helwan University, Cairo, Egypt [8]. The Systemic based course materials were presented in 24hrs (2hrs period/ per week) From September-December 2001.

In contrast to the linear approach of learning chemistry of cations from a laboratory experience, a systemic approach has been developed that focuses attention on individual species (Fig.23).

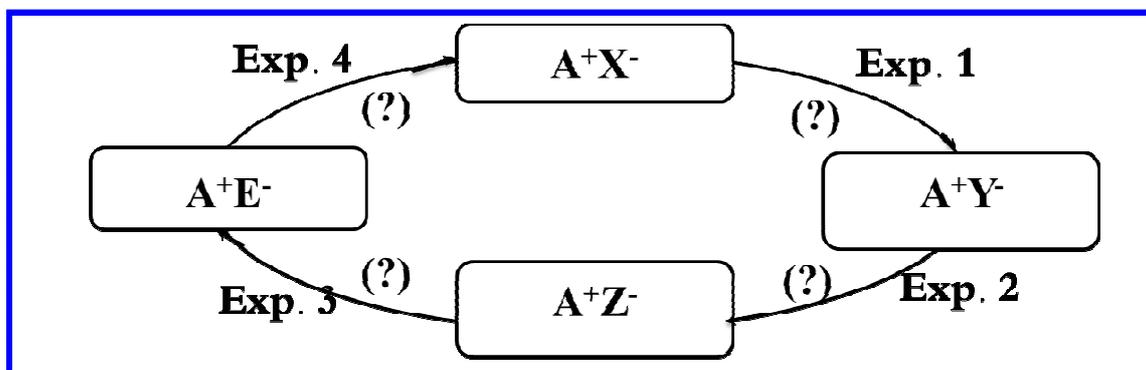


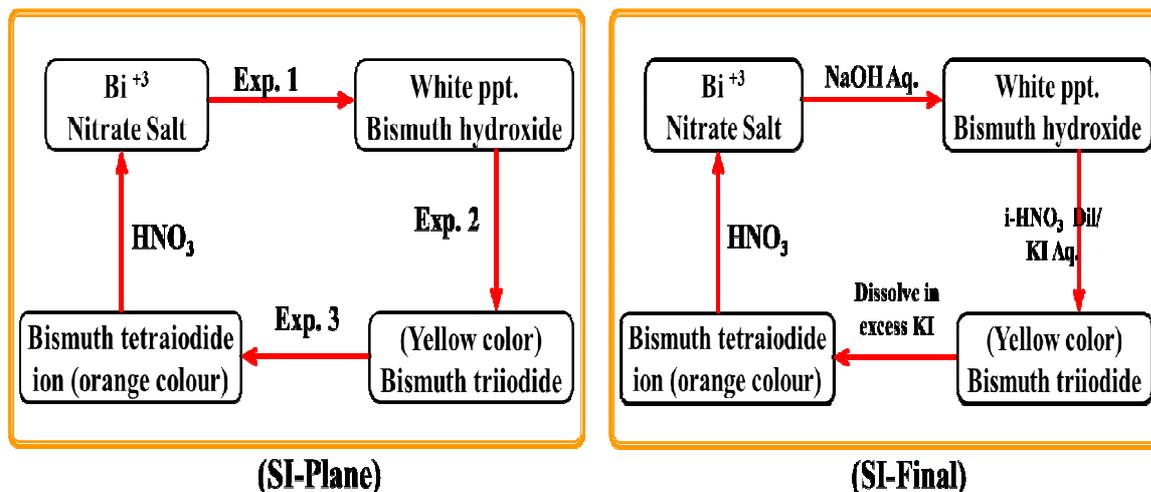
Fig. 23: Systemic Investigation of species A^+ (SI-Plane)

The diagram shows the plane for qualitative investigation of the species (A^+), the preparation of (A^+) compounds, and the interconversion of the species. This laboratory instruction allows students to experience the colors of chemical species, their solubility characteristics, and their redox behavior.

Examples:

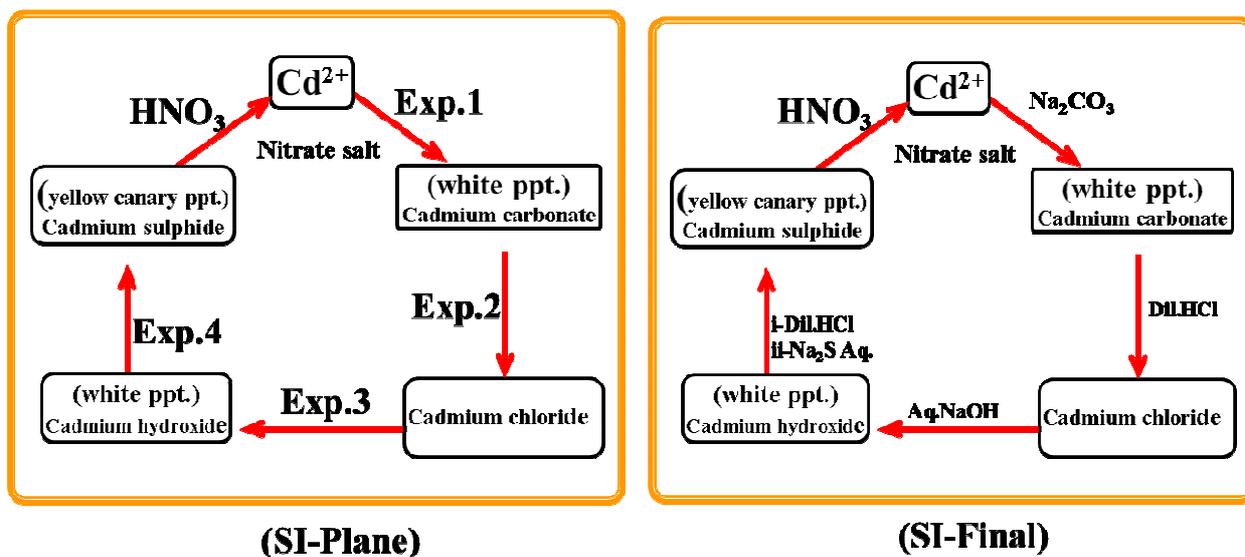
Systemic Investigation of $[Bi^{+3}]$ (SI): Bismuth Cycle

The students follow the (SI-Plane) to investigate (Bi^{+3}) in a series of experiments (1-3), then recycle the product of (Exp.3) to $Bi(NO_3)_3$ (Cf. SI-Final).



Systemic Investigation of $[\text{Cd}^{2+}]$ (SI): Cadmium Cycle

The students follow the (SI-Plane) to investigate (Cd^{2+}) in a series of experiments (1-4), then recycle the product of (Exp.4) to $\text{Cd}(\text{NO}_3)_2$ (Cf. SI-Final).



Results of Experimentation

Applying the Systemic Approach to laboratory instruction reveals the following advantages, which constitute to the principles of benign analysis [8]:

- Smaller amounts of Chemicals are used.

- Recycling of Chemicals.
- Experiments are done with fewer hazards, and more safety.
- Experiments are done more rapidly.
- Students easily acquire a working sense of the principles of green chemistry.

Statistical data showed that the students of the experimental group are significantly improved towards the principles of qualitative Benign Analysis and achieved higher cognitive levels (Analysis, synthesis, evaluation) (Table3).

Table 3: Means, Standard Deviations, (t) value and Effect Size of the results of students in the final practical observation scale for the experimental and control groups

Groups	No. of students	Means	SD	t value	Effect size
Experimental group	60	23.81	1.95	10.77	2.26 large effect
Control group	33	20.30	1.22		

* Significant at < 0.01

The experimentation results showed that the benign scheme reduces the consumption chemicals in comparison with the classical scheme as shown in table (4). This means low cost, and less pollution.

Table 4: Amount of salts needed for Experimental group (Benign scheme), and Reference group (Classic scheme)

Salts	Amount required (gm / 50 Students)	
	Classic Scheme Solid (g)	Benign Scheme 0.1M Solution (1.2 liter)
$Pb(NO_3)_2$	100	16.5
$Al(NO_3)_3$	200	11.0
$CrCl_3 \cdot 6H_2O$	200	13.5
$NiCl_2 \cdot 6H_2O$	200	12.0
$Co(NO_3)_2 \cdot 6H_2O$	200	15.0
$CdCl_2 \cdot 5H_2O$	150	13.5
$BaCl_2 \cdot 2H_2O$	200	12.0
$MgSO_4 \cdot 7H_2O$	200	12.0

CONCLUSION

- SATLC improved the student's ability to view the chemistry from a more global perspective.
- SATLC helps the students to develop their own mental framework at higher-level cognitive processes such as application, analysis, and synthesis.
- SATLC increases student's ability to learn subject matter in a greater context.
- SATLC increases the ability of students to think systemically.
- SATLC in Egypt could be used as a successful model for teaching and learning Chemistry in other African countries.

IV-SYSTEMIC ASSESSMENT [9]

Systemic Assessment is a new tool to assess student achievement.

- It measures the cognitive structure from the cumulative (quantitative) to the interactive and tuned (qualitative).

- Assess students higher-order thinking skills in which students are required to analyze, synthesize, and evaluate.
- Measures the students' ability to correlate between concepts.
- Develop the ability to think systemically, critically and creatively, to solve problems.

IV-1-Types Systemic Assessment Questions: [SAQ, s]

- 1- Systemic Multiple Choice Questions [SMCQ, s].
- 2- Systemic True, False Questions [STFQ, s].
- 3- Systemic Matching Questions [SMQ, s].
- 4- Systemic Sequencing Questions [SSQ, s].
- 5- Systemic Synthesis Questions [SSynQ, s].
- 6- Systemic Analysis Questions [SAAnQ,s].

We will illustrate examples on the first three types.

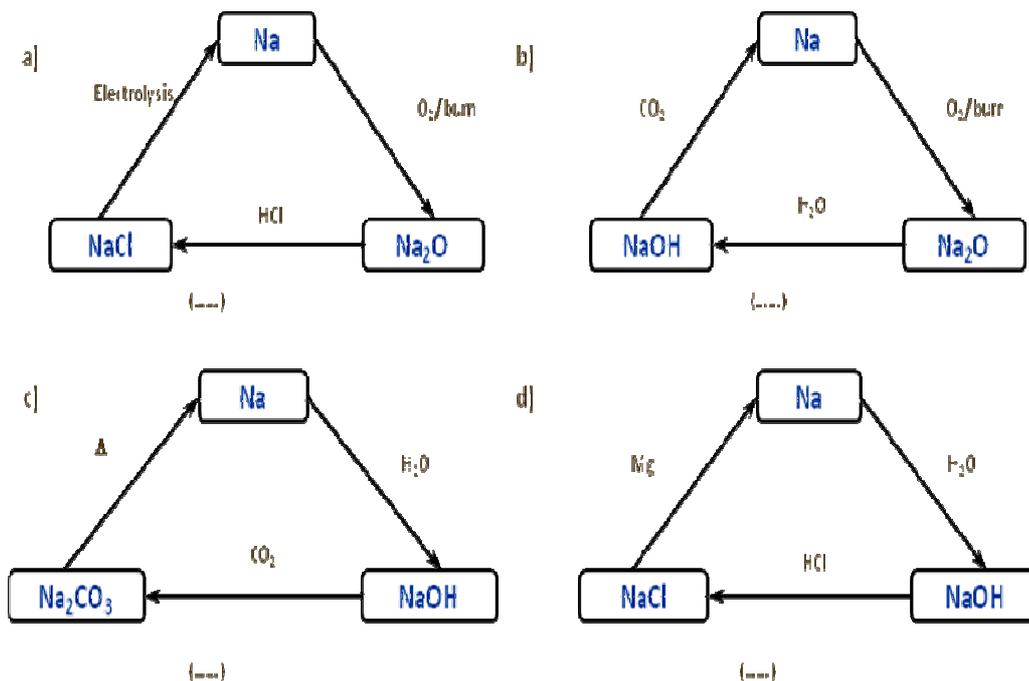
IV-1-1: Type-1: Systemic Multiple Choice Questions [SMCQ, s]

Form (I): Choose From Triangular Systemic:

Put (✓) in front of the correct systemic diagram:

Examples

Q1. The systemic diagram represents the correct chemical relations between (Na) and its related compounds are one of the following:



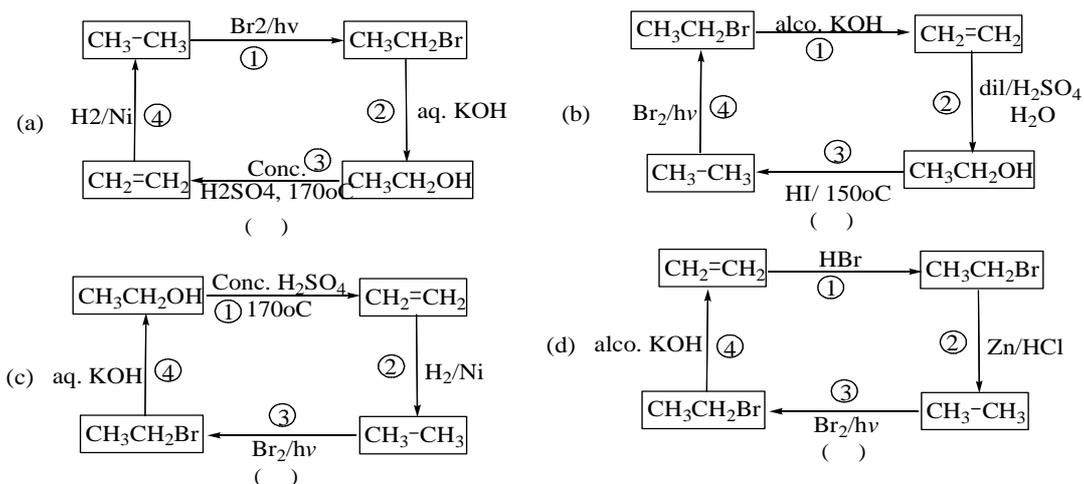
Answer: (a) ✓

Form (II): Choose From Quadrilateral Systemic:

Put (✓) in front of the correct systemic diagram

Q2. The systemic diagram represents the following reactions sequence.

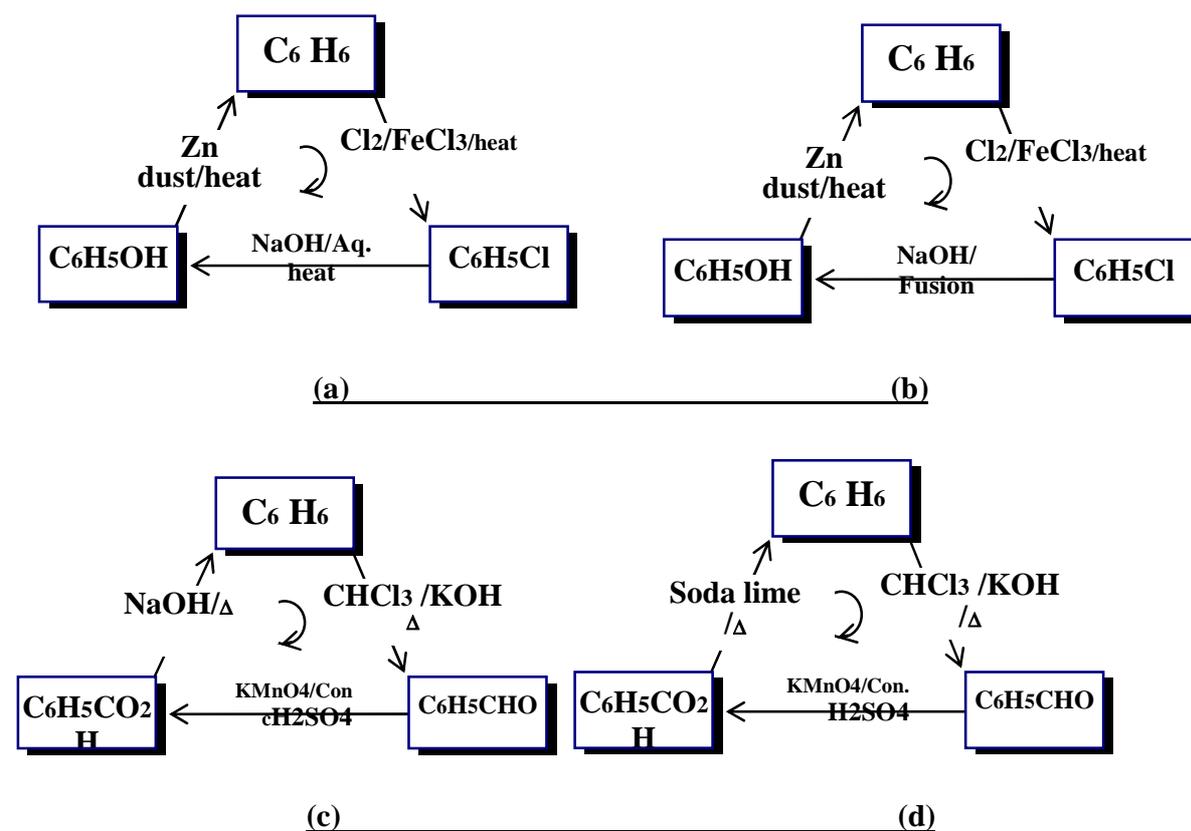
[Substitution –Substitution- Elimination –Addition-] is one of the following:



Answer: (a) ✓

IV-1-2: Type-2: Systemic True False Questions [STFQ, s]

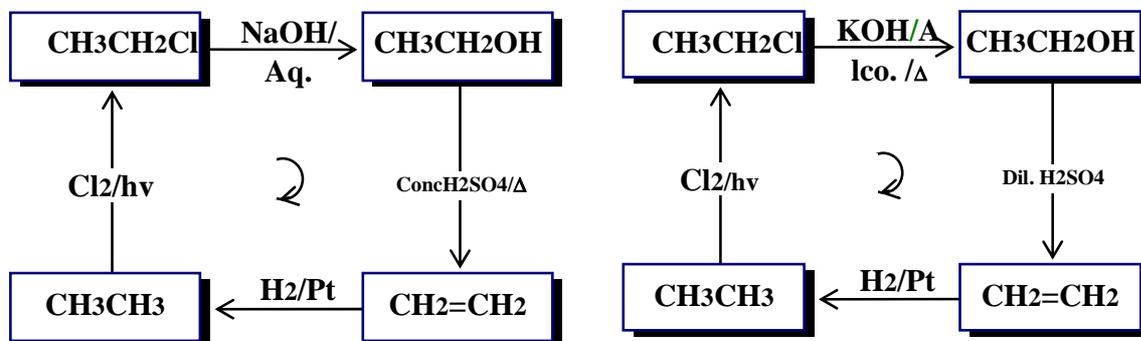
STFQ, s are well suited for testing student comprehension, synthesis and analysis, and require a student to assess whether the systemic is true or false.

Form-I: Choose From Triangular SystemicsExamples

Answer: True systemics (b, d) (✓); False Systemics (a, c) (X).

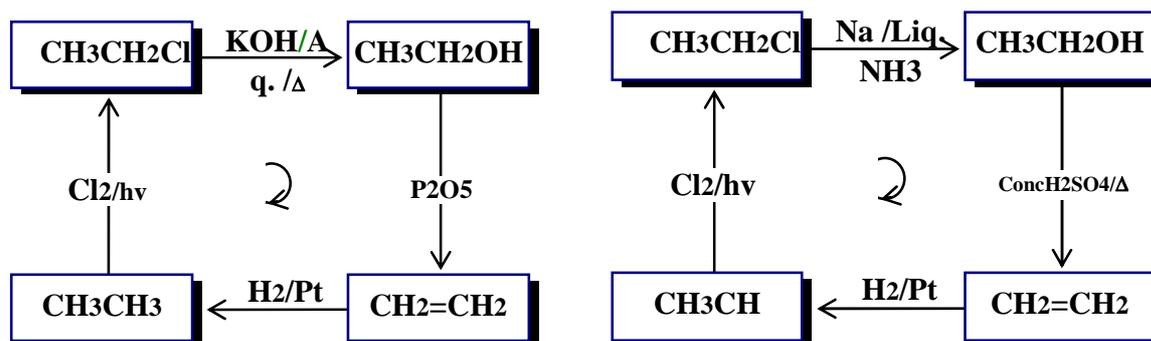
Form-II: Choose from Quadrilateral Systemics

Q-2 : Which of the following systemics are true and which are false?



(a)

(b)

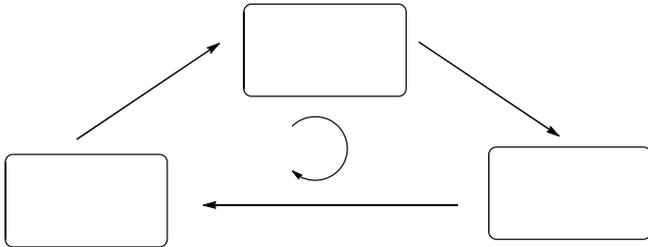


(c)

(d)

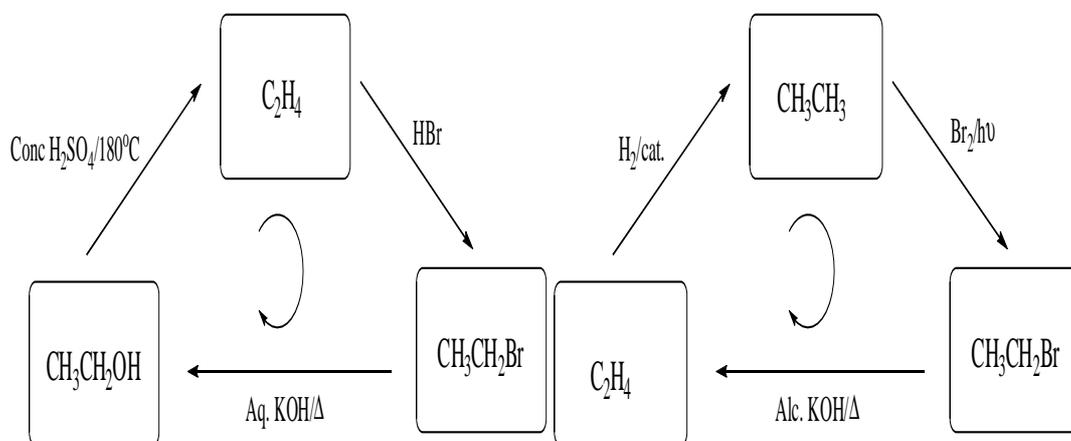
Answer: True systemics (a, c) (✓); False Systemics (b, d) (X)**IV-1-3:Type.3: SYSTEMIC MATCHING QUESTIONS: [SMQ, s]**Form I: Matching on Trigonal Systemics

Q1: Choose aliphatic compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C).

(A)	(C)	(B)
C_2H_4 CH_3CH_3 CH_3CH_2OH CH_3CH_2Br		dil. H_2SO_4 Conc. $H_2SO_4/180^\circ C$ PBr_3 Alc. KOH/Δ Aq. KOH/Δ HBr $H_2/cat.$ $Br_2/h\nu$

Answer (1)

Other Answer (2)



Form II: Matching on Quadrilateral Systemics

Q₂) Choose elements and compounds from column (A) and reaction conditions from column (B) to build the systemic diagram in column (C):

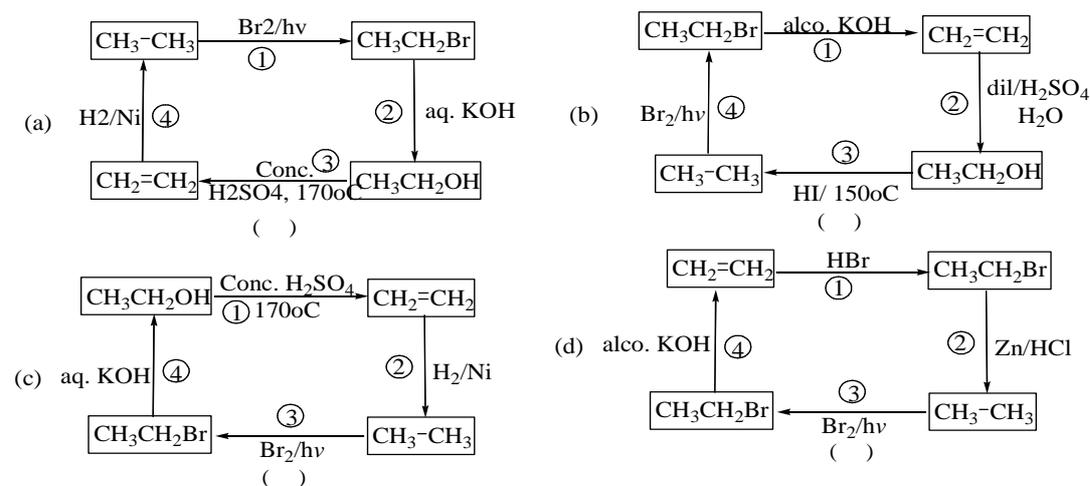
(A)	(C)	(B)
Na		H ₂ O
KOH		O ₂ /heat
NaCl		CO ₂
Na ₂ CO ₃		HCl
NaNO ₃		Electrolysis
Na ₂ O		HNO ₃
NaOH		
K		

Form (II): Choose From Quadrilateral Systemic:

Put (✓) in front of the correct systemic diagram

Q₂. The systemic diagram represents the following reactions sequence.

[Substitution –Substitution- Elimination –Addition-] is one of the following:



Answer: (a) ✓

REFERENCES

1. Fahmy, A.F.M.andLagowski, J.J. (2014). Systemic Chemical Education Reform [SCER] in the Gobal Era], AJCE, 4(1) 19-42.
2. Lagowski, J.J. and Fahmy, A.F.M. (2011). The systemic approach to teaching and learning, [SATL]: A 10- year’s review, AJCE, 1(1) 29-47.
3. Fahmy, A.F.M.andLagowski, J.J. (2003). Systemic Approach to teaching and learning chemistry [SATLC] in Egypt [1998-2011], AJCE, 2 (2) 92-97.
4. Fahmy, A.F.M. and Lagowski,J.J.(1999). The uses of systemic approach to teaching and learning in 21st century, Pure Pure Appl. Chem., 1999, 71(5) 859 – 863. [15th ICCE, Cairo, Egypt, August, 1998].
5. Fahmy, A. F. M.; Lagowsik. J. J.(2003). J. Chem. Educ., 80, (9), 1078.
6. Final report (2011). The task force on innovative teaching practices to promote deep learning at the University of Waterloo.
7. Fahmy, A.F.M., El-Shahaat, M.F. and Saied, A. (2003). International Workshop on SATLC, Cairo, Egypt, April (2003).
8. Fahmy, A. F. M., Hamza, M. A., Medien, H. A. A., Hanna, W. G., Abdel-Sabour, M. : and Lagowski, J.J.(2002). From a Systemic Approach in Teaching and Learning Chemistry (SATLC) to Benign Analysis, Chinese J.Chem. Edu. 23(12), 12 [17th ICCE, Beijing, August 2002].
9. Fahmy, A.F.M., and .Lagowski, J.J. (2012): Systemic assessment as a new tool for assessing students learning in Chemistry using SATL methods: Systemic true false [STFQs] and systemic sequencing [SSQs] question types, AJCE. 2(2) 66-78.