

**SYSTEMIC ASSESSMENT [SA] AS A TOOL TO ASSESS STUDENT  
ACHIEVEMENTS IN INORGANIC CHEMISTRY  
PART-I: SODIUM CHEMISTRY**

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**ABSTRACT**

Systemic Assessment (SA) aims at a more effective evaluation of the systemic oriented objectives articulated by SATL model. SA raising the level of student's academic achievements, increasing students learning outcomes, develops the ability to think systemically, assesses students' higher-order thinking skills in which students are required to analyze, synthesize, and evaluate, measures the students' ability to correlate between concepts with reduced working memory load. Systemic Assessment Questions (SAQ, s) are the building unites of the systemic assessment. In this issue we use SA as a tool to assess the student achievement in inorganic chemistry by taking sodium chemistry as a module. We use four types of systemic assessment questions, namely Systemic Synthesis Questions (SSynQ, s), Systemic Analysis Questions (SAnQ, s), Systemic Synthetic-Analytic Questions (SSyn-A Q, s), and complete Systemics (SComp Qs). [*African Journal of Chemical Education—AJCE 5(1), January 2015*]

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<sup>1</sup> Prof. Lagowski passed away before submission of this article for publication. I lost a good friend and his great support.

## **INTRODUCTION**

Systemic approach to Teaching and Learning Chemistry (SATLC) is a method of arranging concepts in such a way that the relationships between various concepts and issues are made clear. SATL methods have been shown, empirically, to be successful in helping students learn in a variety of settings—pre-college, college, and graduate systems of formal education as well as adult education—in a variety of disciplines such as the sciences (chemistry, biology, physics) [1-4].

A number of statistical studies involving student achievement indicate that students involved with SATL methods taught by teachers trained in those methods achieve at a significantly higher level than those taught by standard linear methods of instruction. However, our studies on Systemic Assessment [SA] [5-8] is an ongoing process of identifying the student learning outcomes, assess the student performance to these outcomes. SA showed that is highly effective in raising the level of students' academic achievements with reduced working memory load, because even highly complex schema (systemics in SA) can be considered as a single element in working memory [9]. Also develop the ability to think systemically, assess students' higher-order thinking skills in which students are required to analyze, synthesize and evaluate, measure the students' ability to correlate between concepts, enables the students to discover new relation between concepts. It is more effective evaluation of the systemic oriented objectives in the SATL model. Systemic Assessment Questions [SAQ,s] are the building units of the systemic assessment [7,8,10].

In inorganic chemistry the usual descriptions of inorganic reactions by chemical equations, represents linear separated correlations between reactants, resultants and reaction conditions. The student taught the six general types of chemical reactions, namely, combustion, single displacement, double displacement, synthesis, decomposition, and acid-base reactions.

Although the students know the six types of chemical reactions, they find difficulties in representing chemical changes by correct chemical equations, and in correlation between reactants and resultants. The student while being taught through a linear approach is asked to present the chemical changes by correct chemical equations , without any comprehension or appreciating significance of these relationships representing the chemical reactions. This leads to memorization of the chemical equations and finally to surface and rote learning. Ausubel [11] distinguishes “rote learning” or memorization from meaningful learning. The process called “assimilation” creates personal meaningful knowledge by restructuring the already existing conceptual frameworks that the learner possesses to accommodate to the new concepts being learned.

Our goal in this issue is to develop systemic assessment [SA] strategies and materials can be used by students to assess their learning of chemical changes of elements. Also it might lead to a better understanding of the systemic relations between elements and their related compounds, between compounds of the same element, and most importantly between types of the chemical changes under consideration.

## PROPOSED LEARNING MODULE

### Domain of learning material

As a material for this study, we take *Sodium metal*, as an example of metals. Sodium metal is the first member of alkali metals [Group-1.A] of the periodic table. The study includes the extraction of the sodium metal and its chemical properties. Also industrial preparations and chemical properties of some sodium compounds are included. This module is considered as a part of general chemistry for secondary school students and presented by systemic methodology.

Table 1. Domain of teaching material

Teaching unit	Teaching themes	Selected contents of defined theme
Alkali Metals [Sodium]	Preparation of Sodium	-Extraction from sodium hydroxide by Electrolysis. - Extraction from sodium chloride by Electrolysis
	Chemical properties of Sodium	-Reactions with oxygen, chlorine, water, acids.
	Sodium hydroxide [Caustic soda]	-Manufacturing of Caustic soda
	Chemical properties of Sodium hydroxide	-Reactions with acids, acidic oxides, amphoteric oxides, halogens, some salts.
	Sodium Chloride	-Preparations of pure sodium chloride. - Reactions of sodium chloride.
	Sodium carbonate and Bicarbonate	-Manufacturing of Sodium carbonate, and bicarbonate -Chemical reactions.

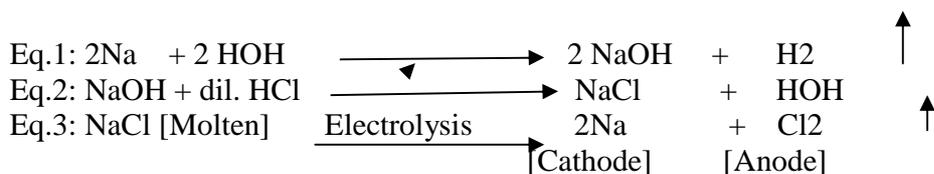
## LINEAR ASSESSMENT VS SYSTEMIC ASSESSMENT

In the **linear (Traditional )Assessment[LA]**\_we ask our students to represent the different types of inorganic reactions by chemical equations.

Example from Sodium chemistry: Write equations for the following reactions:

- 1-Reaction of sodium with water [Displacement reaction].
- 2-Reaction of sodium hydroxide with hydrochloric acid [Acid-Base reaction].
- 3-Electrolysis of molten sodium chloride [Electrolytic-Decomposition reaction].

Answer:



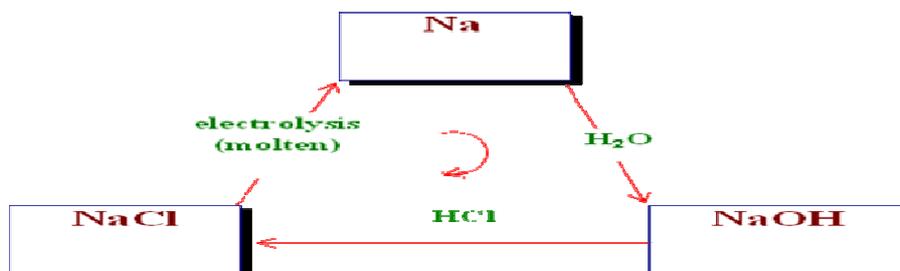
The student can find some difficulties in memorizing the three symbolic chemical equations as above, and he couldn't correlate between either sodium metal and its related compounds (NaOH, NaCl) or the three chemical processes [Displacement, Acid-Base, and electrolysis] of the above reactions. If the students can memorize these equations, this leads to rote learning. Miller [12] points out that a person can recall seven plus or minus two items or elements of information at a particular moment, because of the working memory limitations and capacity. If students choose to learn these chemical reactions by mechanical memorization, they have to memorize 35 individual elements (items) of information (atoms + any digit indicating the number of atoms or molecules + reaction condition). Note that there are 13 items in the first equation, 12 items in the second + 10 items in the third.

According to Miller [12] the memorization of 35 individual items exceeds working memory limitation and provokes working memory overload. The question is how can students overcome working memory overload? Working memory limitation (as well as overload) can be overcome by constructing cognitive schemas; combining simple elements into more complex ones [13]. Cognitive schemas reduce working memory load, because even highly complex schema can be considered as a single element in working memory [9]. This is the basic principle of using SATLC strategy in teaching and learning chemistry based on systemics which is considered as closed schemas. Systemics help students to learn and teachers to assess student's achievements at higher cognitive levels [1,8] with reduced working memory load.

In the **Systemic Assessment [SA]** we can ask our students about the same chemical reactions by using four types of systemic assessment questions [SAQ, S] based on systemics.

**Type (1): Systemic Synthesis Questions [SSynQ, s][8]**

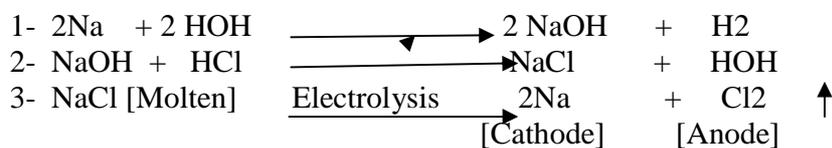
Here we ask students to synthesize trigonal systemic represents the chemical relations between [Na- NaOH - NaCl].



In this type of questions we assess our student's knowledge about relations between (Na, NaOH, and NaCl; 6 items) beside the relations between the three chemical processes [Displacement, Acid-Base, and Electrolysis; 3 items] and reactionns conditions (H2O, HCl, Molten; 6 items). This assesses student learning outcomes in 15 items of information at synthesis level.

**Type (2): Systemic Analysis Questions[SAn Q,s][8]**

In which we give our students the above trigonal systemic (15 items of knowledge) and ask them to analyze to the corresponding chemical equations (35 items). This assess the student learning outcomes in 35 items of information at analysis level.

**Type-3: [SSynQ,s-SAn Q,s] by asking our student to [8]:**

1-Synthesize trigonal systemic shows the chemical relations between [Na-NaOH-NaCl] in a 15 items of knowledge.

2- Analyze the resulted systemic into the corresponding chemical reactions in a 35 items..

Assess student learning outcomes at synthesis followed by analysis level.

**Type-4: Complete the given systemics by adding the missing chemicals [ScompQ,s]**

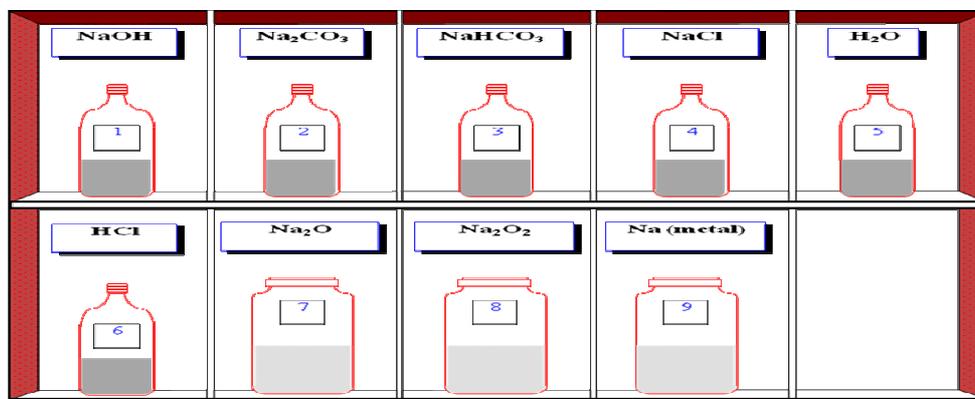
Assess student learning outcomes at synthesis level. By using SA we expect to convert our students from surface learning to deep learning of chemical processes in sodium chemistry.

**DESIGN OF LEARNING MATERIAL**

Learning sheets were prepared in the form of:

1. A diagram of proposed liable bottles of the given element [Sodium] and some of its related compounds,
2. Systemic diagrams representing different types of systemic assessment questions [SAQs] in which the selected chemicals of any reaction were located in the given systemics. [SAQs] have been designed in accordance with the guidelines sated by: Fahmy & Lagowski [5-9] and Tzougraki [10],
3. Then we ask students to choose between sodium and the given compounds to answer the given systemic assessment questions.

You have the following bottles of chemicals:



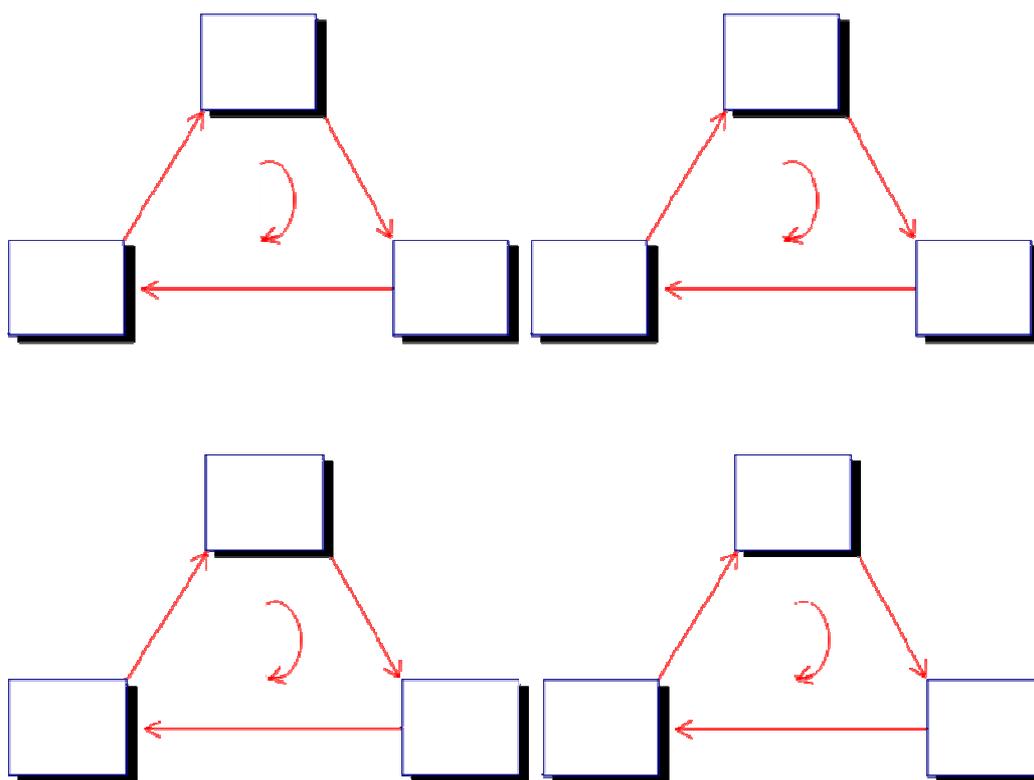
Answer the following questions:

*Type-I: Systemic Synthesis Questions [SSynQ,s](8)*

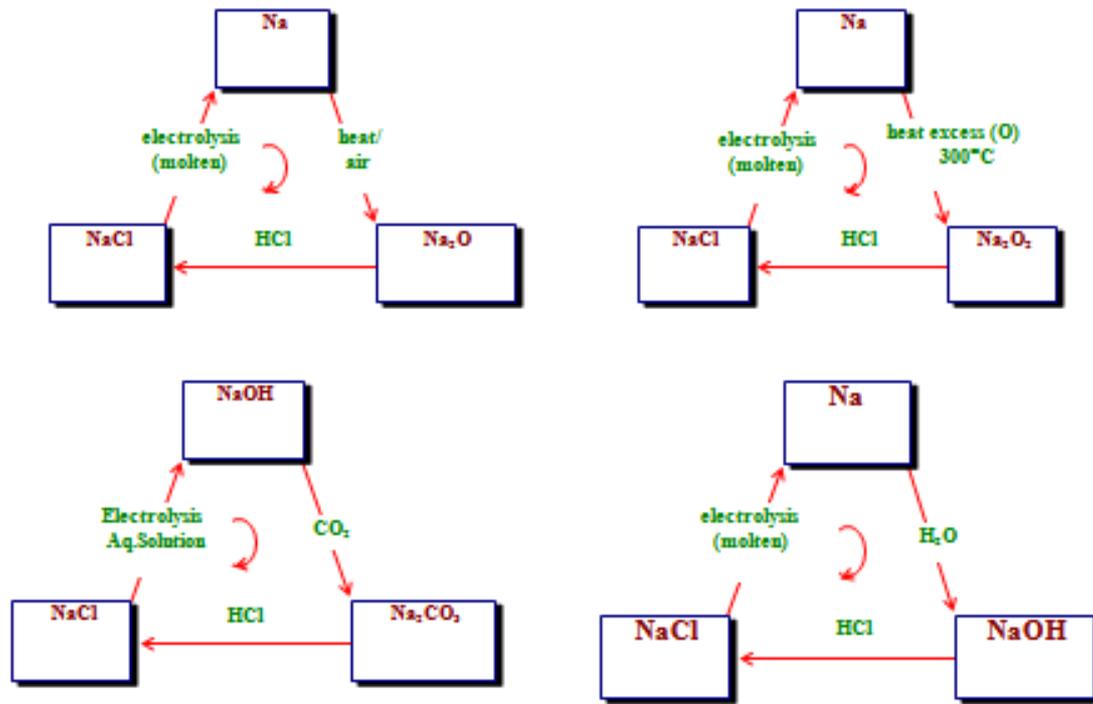
[Synthesize systemics from the given chemicals & assess the student learning outcomes at the synthesis level]

*Type-I-A: Synthesize clockwise or anticlockwise systemic from the given chemicals to give the correct possible chemical relations]:*

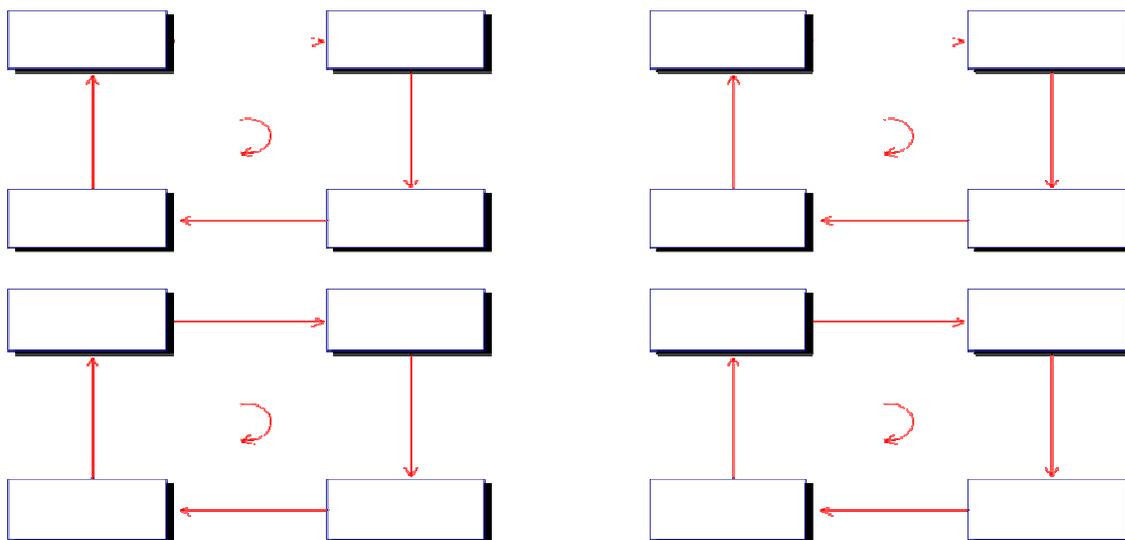
Q1) Use the following triangular diagrams to construct the clockwise systemic chemical relations between the (forgoing) chemicals.



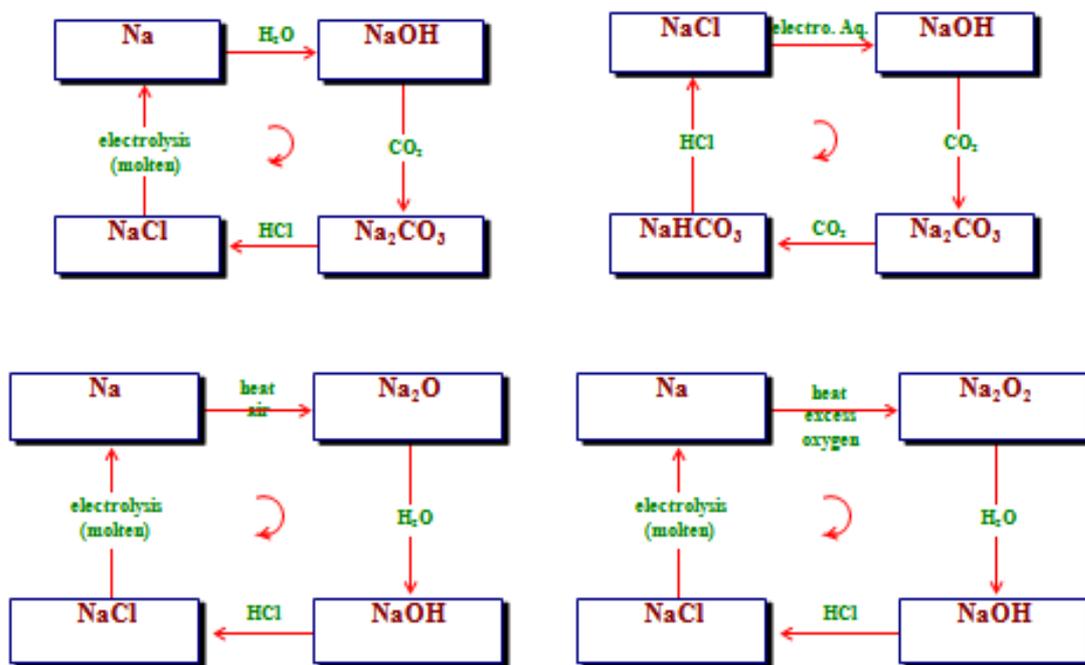
A1)



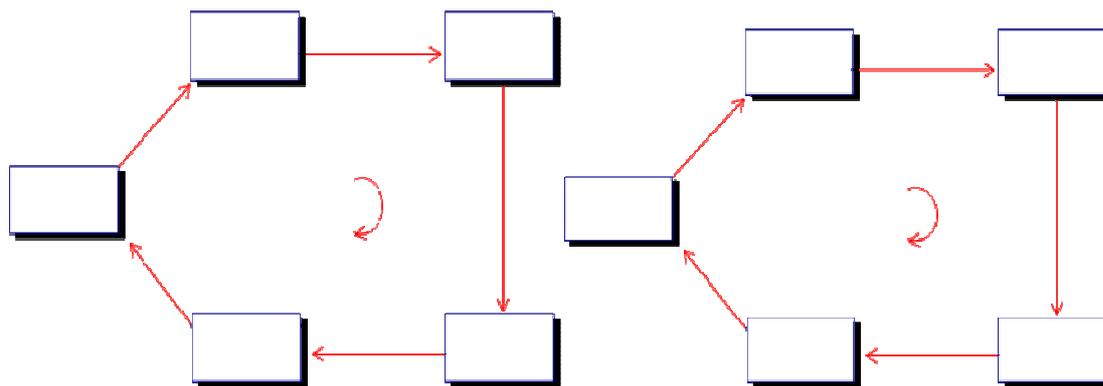
Q2) Use the following quadrilateral diagrams to construct the clockwise Systemic chemical relations between the (forgoing) chemicals.



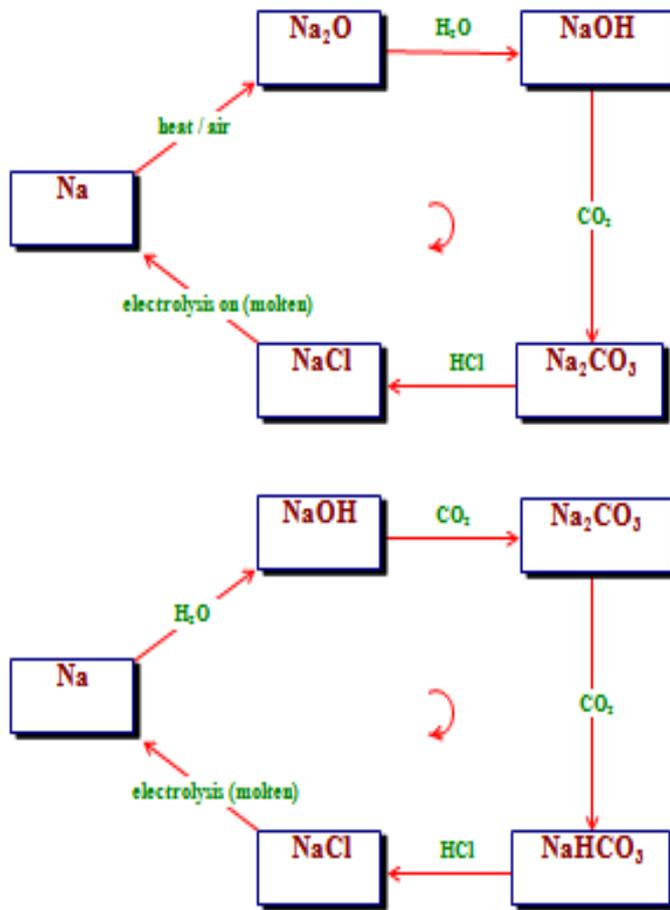
A2)



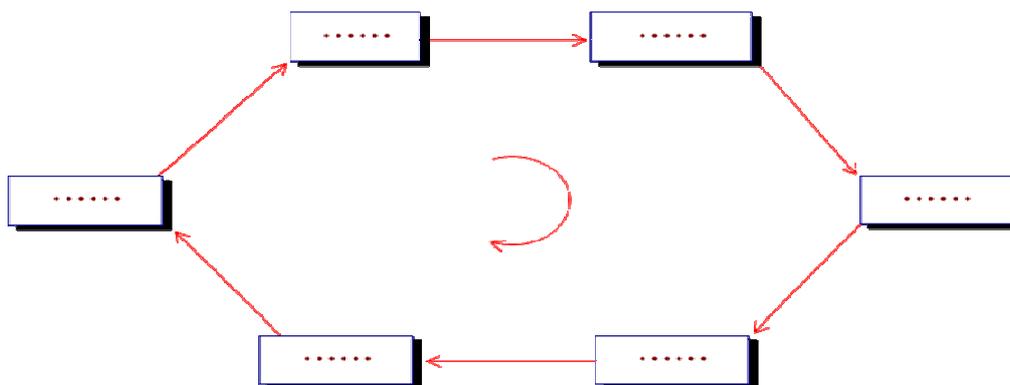
Q3) Use the following pentagonal diagrams to construct the possible clockwise systemic chemical relations between the (forgoing) chemicals.



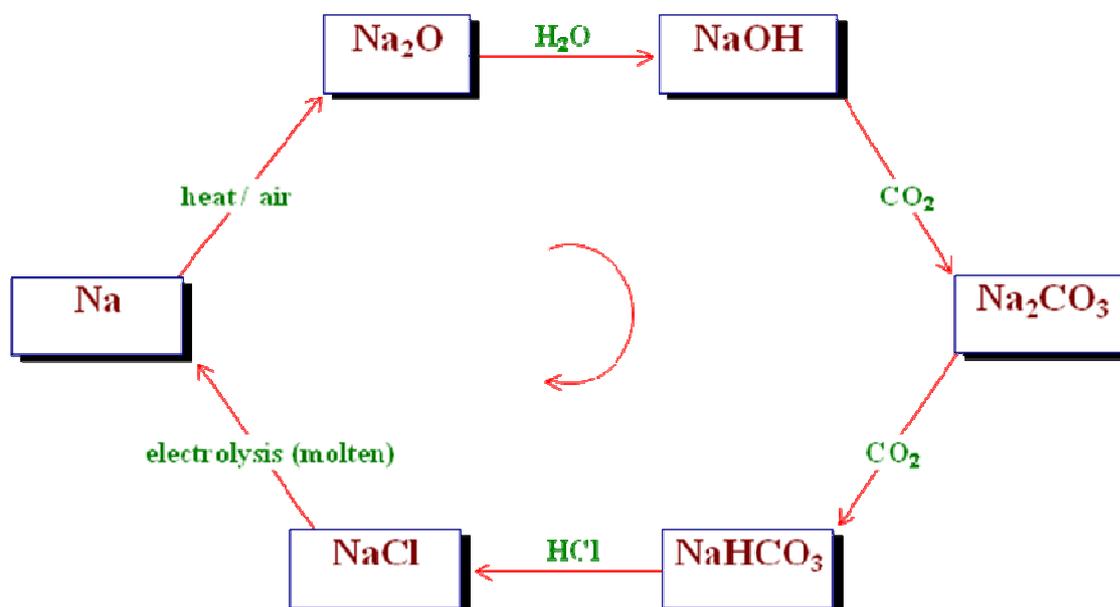
A3)



Q4) Use the following hexagonal diagram to construct the possible clockwise chemical relations between the (forgoing) chemicals.

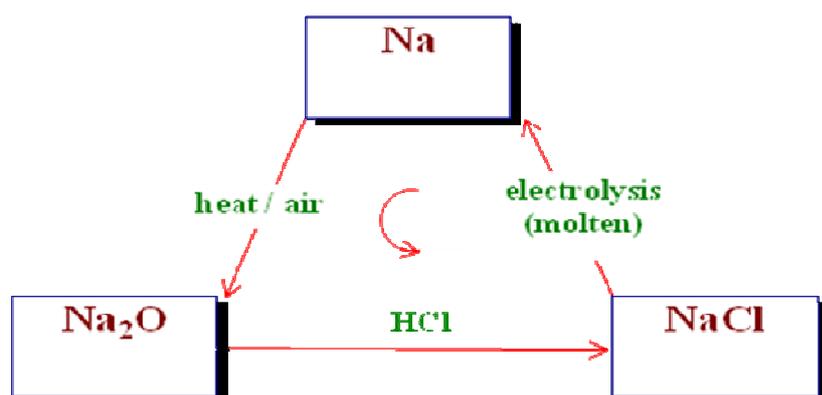


A4)



Q5) Draw one possible *anticlockwise triangular systemic* chemical relations between three of (forgoing) chemicals.

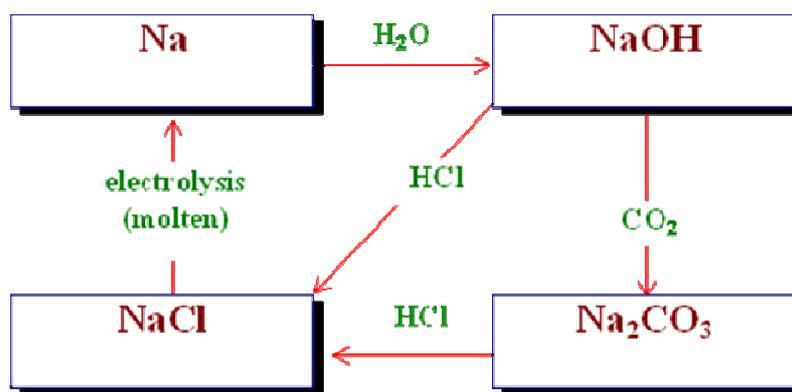
A5)



Type-I-B: Synthesize systemic from the given chemicals to give Maximum possible chemical relations

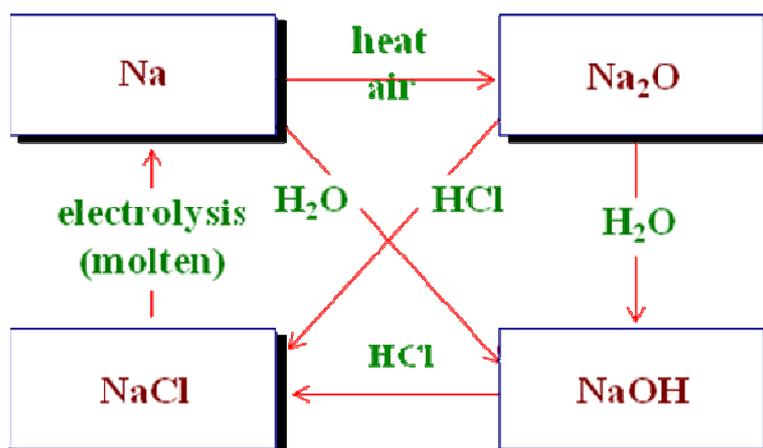
Q6) Draw the maximum possible chemical relations between some of the (forgoing) chemicals in quadrilateral systemic diagrams.

A6-A:



Note: There are five possible chemical relations instead of four in the clockwise quadrilateral chemical relations (Q2).

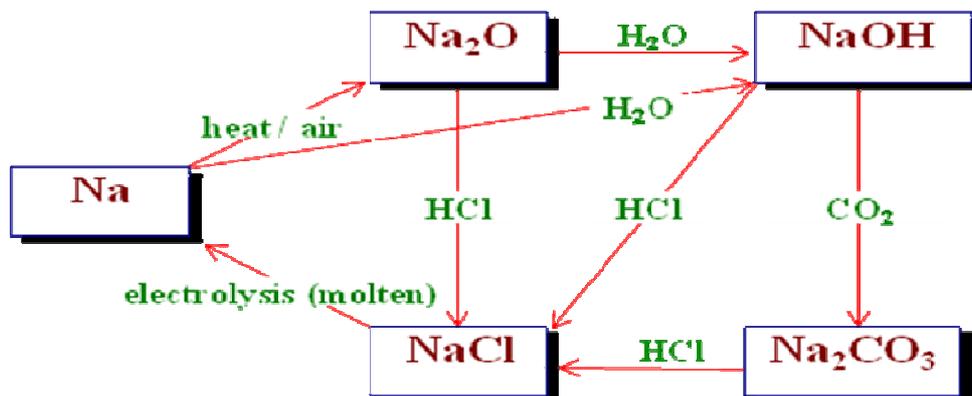
A6-B:



Note: There are six possible chemical relations instead of four in clockwise quadrilateral chemical relations (Q2).

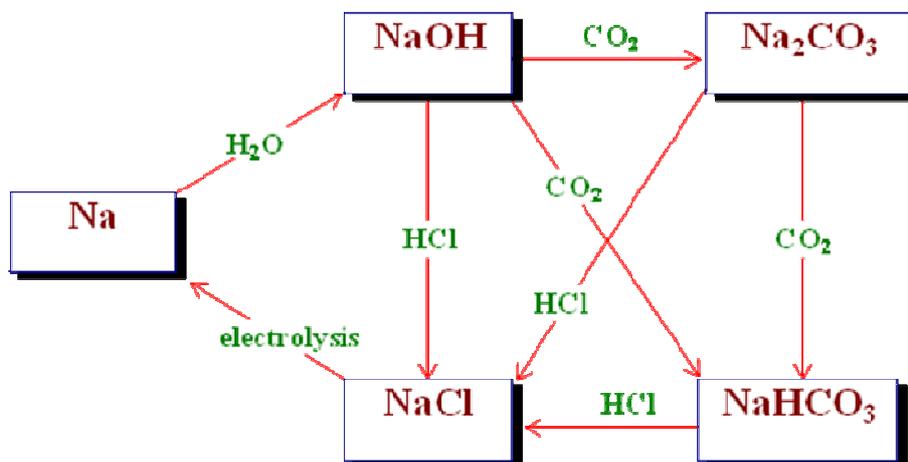
Q7) Draw the maximum possible chemical relations between the (forgoing) chemicals in a pentagonal systemic diagram.

A7-A:



*Note:* There are eight possible chemical relations instead of five in the clockwise pentagonal chemical relations (Q3).

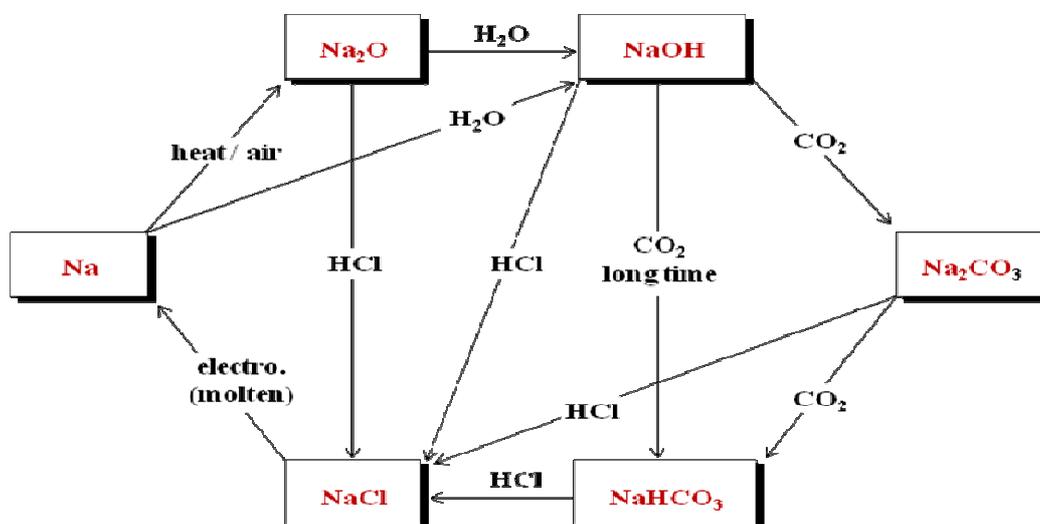
A7-B:



*Note:* There are eight possible chemical relations instead of five in the clockwise pentagonal chemical relations (Q3).

Q8) Draw the maximum possible chemical relations between the (forgoing) chemicals in hexagonal systemic diagrams.

A8:



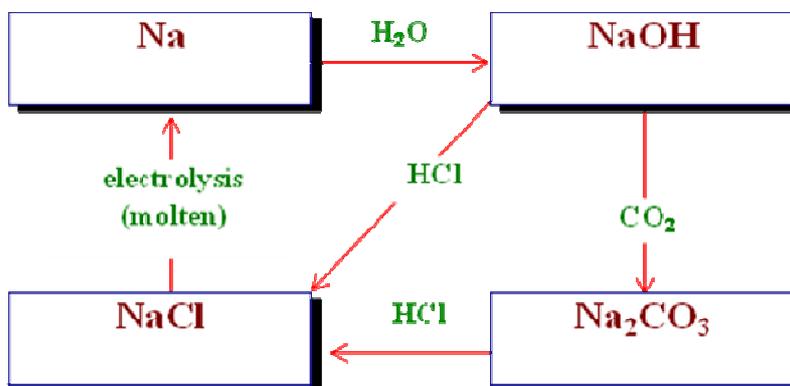
*Note:* There are eleven possible chemical relations instead of six in the clockwise hexagonal chemical relations (Q4).

Type-II: Systemic Analysis Questions [SAnQ,s][8]

Assess the student learning outcomes at analysis level.

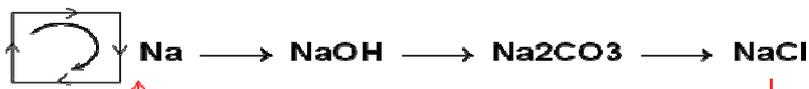
Type-II-A: [Analyze systemics into another systemic]

Q1) Analyze the given systemic diagram from the (forgoing) chemicals to the maximum possible clockwise systemic chemical relations.

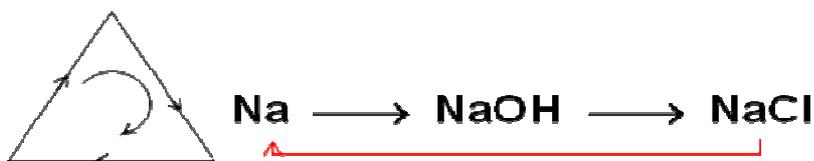


A1)

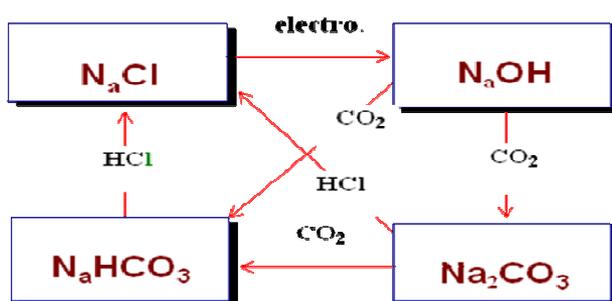
1-Clockwise quadrilateral systemic chemical relations.



2-Clockwise triangular chemical relations.



Q2) Analyze the given systemic diagram from the (forgoing) chemicals to the maximum possible clockwise systemic chemical relations.

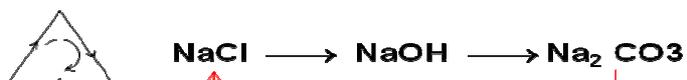
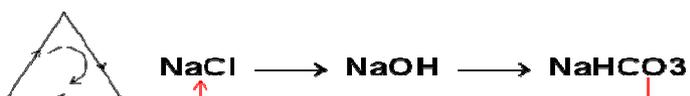


A2

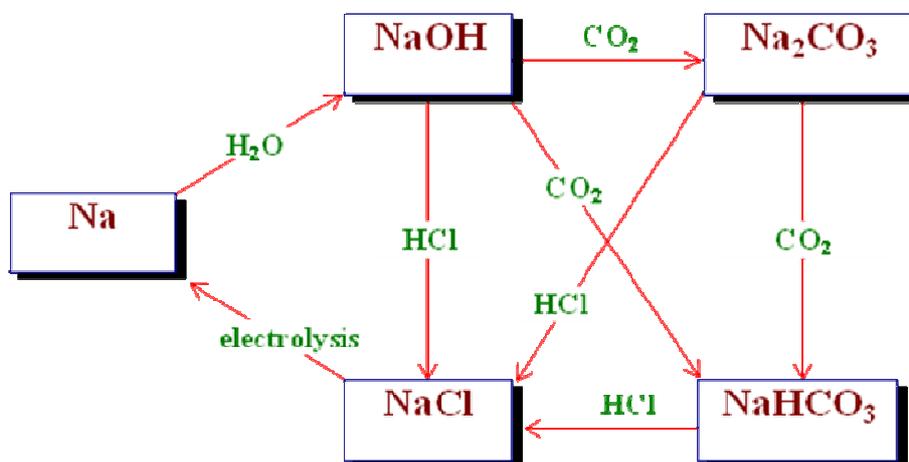
1-Clockwise quadrilateral systemic chemical relations.



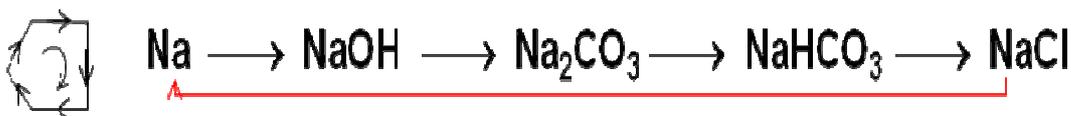
2-Clockwise triangular systemic chemical relations.



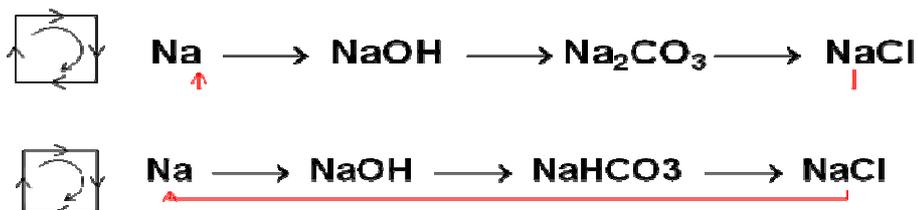
Q3) Analyze the given systemic diagram from the (forgoing) chemicals to the maximum possible clockwise systemic chemical relations.



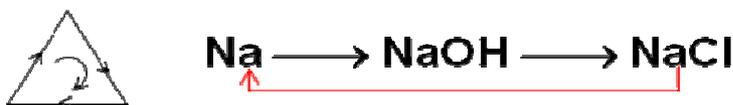
1-Clockwise pentagonal systemic chemical relations.



2-Clockwise quadrilateral systemic c chemical relations.



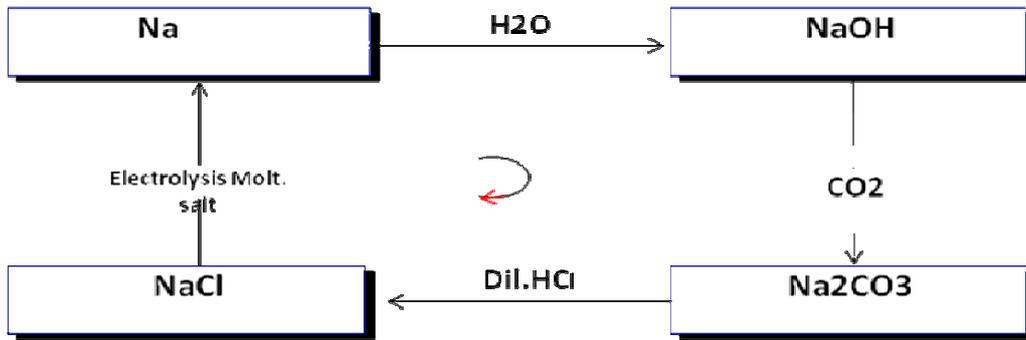
3-Clockwise triangular systemic chemical relations.



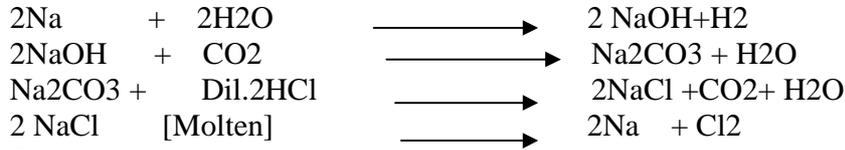
Type-II-B: Analyze systemics into The Corresponding Chemical Equations:

Analyze the following systemic diagrams illustrating the systemic chemical relations between sodium and its related compounds into chemical equations:

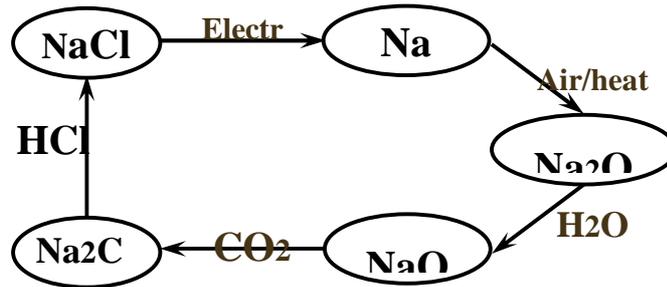
Q1)



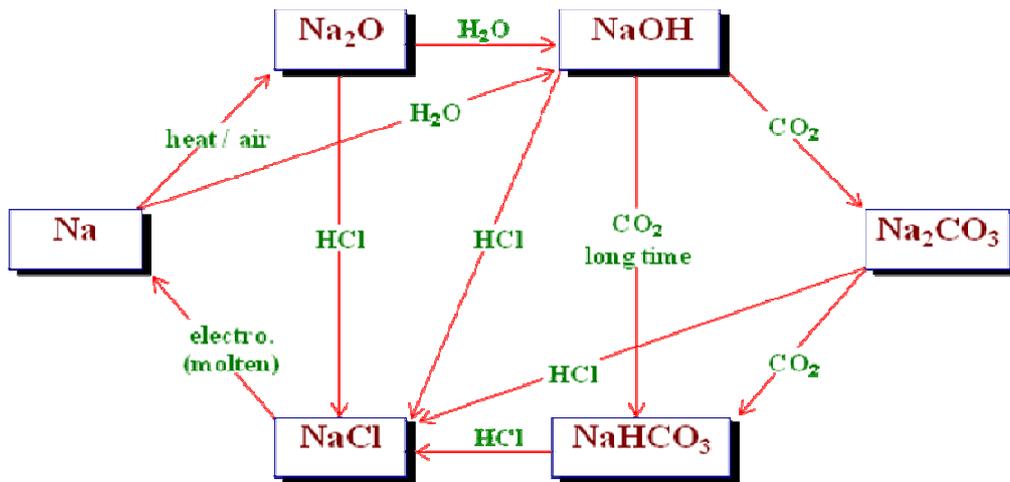
A1)



Q2:



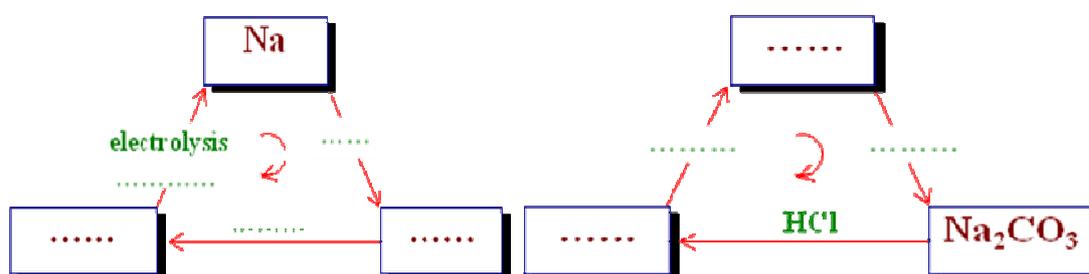
Q3)



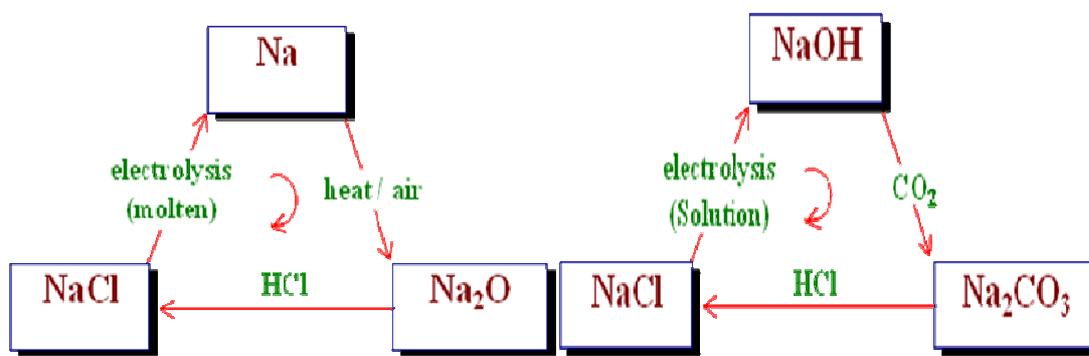
## Type-III: Complete Systemics Questions [SCompQ,s]

[Complete the given unfilled or partially filled systemic diagrams & assess the student learning outcomes at synthesis level]

Q1) From (forgoing) chemicals complete the following clockwise systemic trigonal chemical relations.

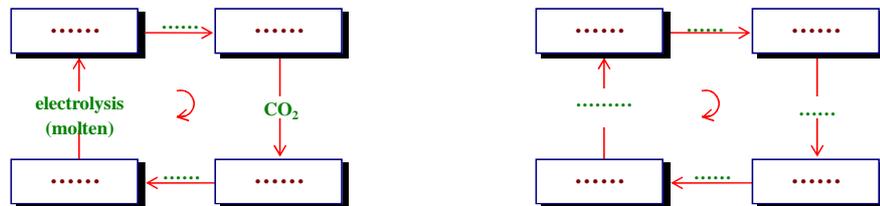


A1)



Q2) From (forgoing) chemicals complete the following quadrilateral clockwise systemic chemical relations.

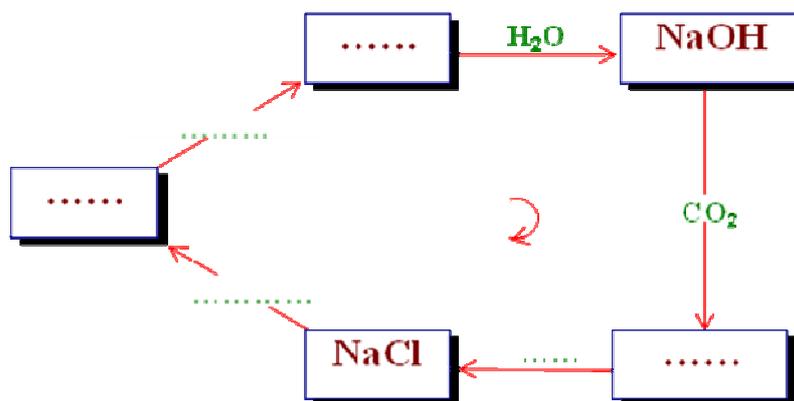
A2:



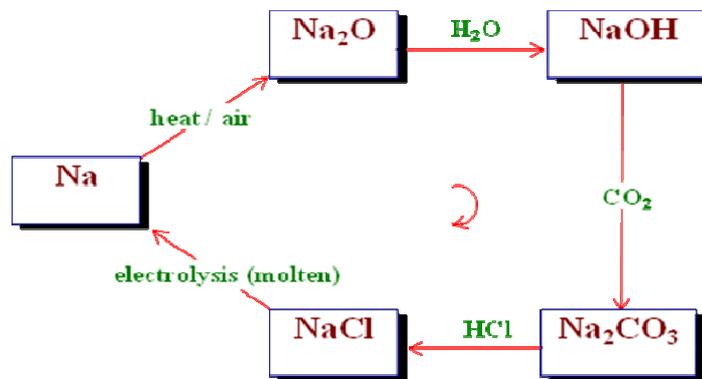
A2)



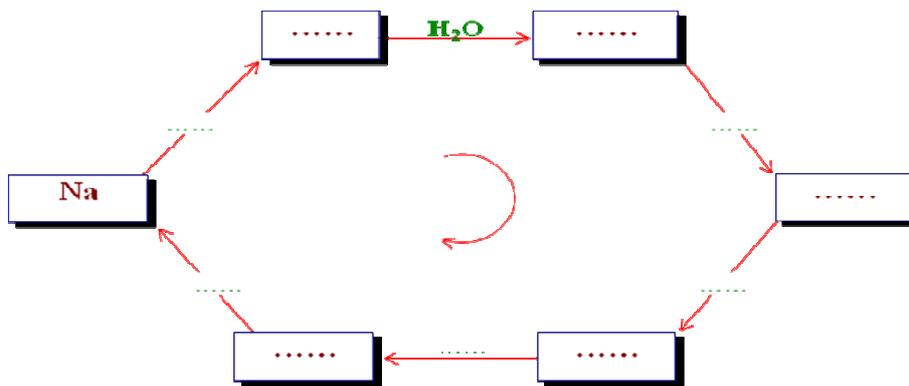
Q3) From (forgoing) chemicals complete the following clockwise systemic pentagonal chemical relations.



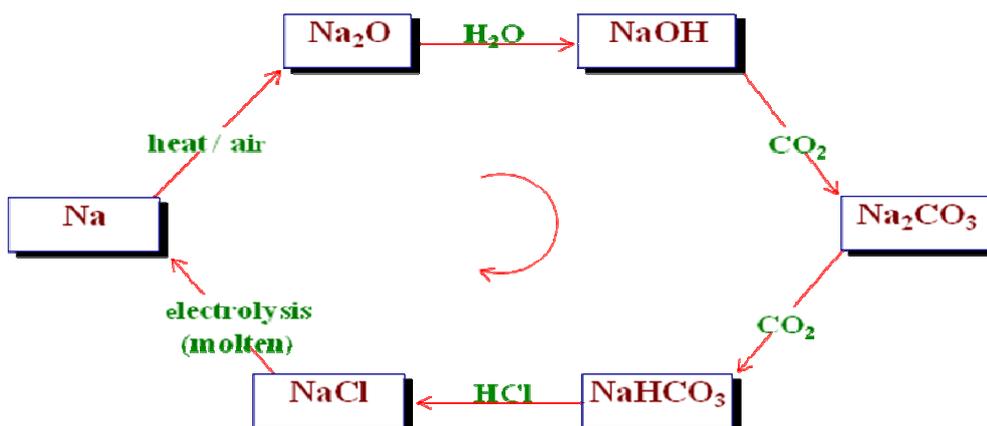
A3)



Q4) From (forgoing) chemicals complete the following hexagonal chemical relations.



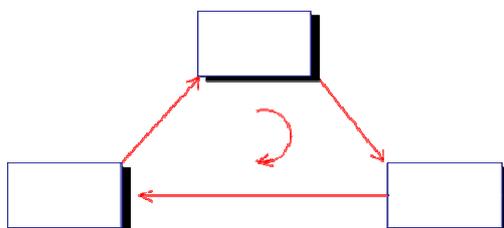
A4)



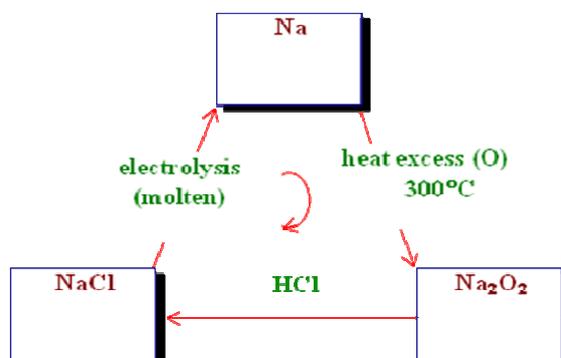
*Type-IV: Systemic Synthetic- Analytic Questions [SSyn -An Q,s][8]*

It is a combination of systemic Synthesis and systemic Analysis questions. So, we assess the student achievements learning outcomes at both the synthesis & analysis levels. We ask our students to synthesize systemic from the given chemicals then ask them to analyze the resulted systemic to the corresponding chemical reactions.

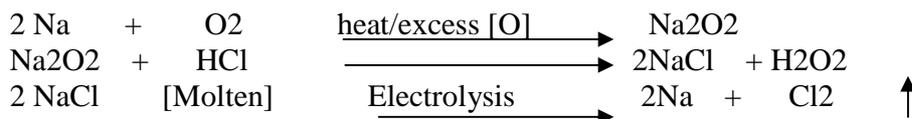
Q1) Use the following triangular systemic diagram to construct the clockwise systemic chemical relations between the (forgoing) chemicals. Then analyze to the corresponding chemical equations



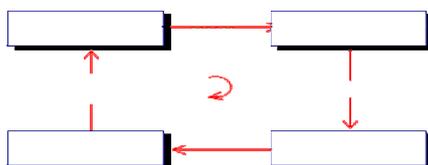
A1-1: Synthesis:



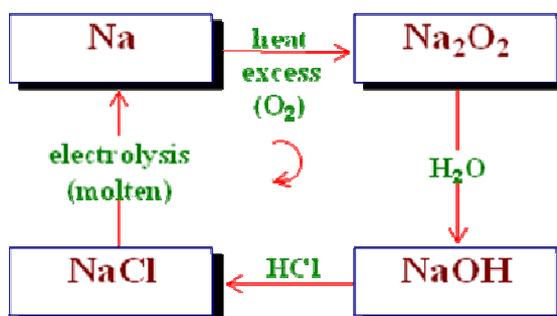
A1-2: Analysis: To three equations.



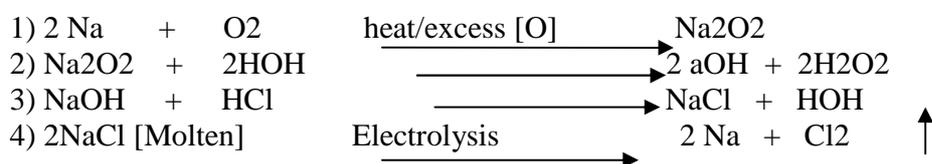
Q2) Use the following the quadrilateral systemic diagram to construct the clockwise systemic chemical relations between the (forgoing) chemicals. Then analyze to the corresponding chemical equations



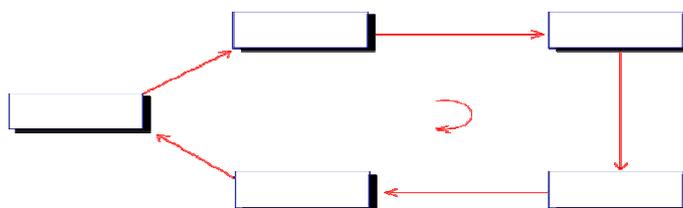
A2-1: Synthesis:



A2-2: Analysis: To four equations.



Q3) Use the following the pentagonal systemic diagram to construct the clockwise systemic chemical relations between the (forgoing) chemicals. Then analyze to the corresponding chemical equations.





8. Fahmy, A.F.M., and .Lagowski, J.J. (2014):Systemic assessment as a new tool for assessing students learning in Chemistry using SATL methods: Systemic Matching questions [SMQs] ,Systemic synthesis questions [SSynQs],Systemic analysis questions[SAnQ,s],and Systemic Synthetic-Analytic questions[SSyn-AnQ,s] as new systemic questions types, AJCE 4(4)35-55.
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