SYSTEMIC ASSESSMENT AS A NEW TOOL FOR ASSESSING STUDENTS LEARNING IN CHEMISTRY USING SATL METHODS: SYSTEMIC MATCHING [SMQS], SYSTEMIC SYNTHESIS [SSYNQS], SYSTEMIC ANALYSIS [SAN Q, S], SYSTEMIC SYNTHETIC – ANALYTIC [SSYN-ANQ, S], AS SYSTEMIC QUESTIONS TYPES

Fahmy, A.F.M.*and Lagowski, J.J**[1]
Department of Chemistry, Faculty of Science, Ain Shams University, Cairo, Egypt.
E-mail: afmfahmy42@gmail.com ; www.satlcentral.com
**Department of Chemistry, University of Texas at Austin, Austin, Texas USA*

ABSTRACT

Systemic Assessment [SA] has been shown to be highly effective new vehicle in raising the level of students academic achievements, increasing equity of students learning outcomes, and improving students' ability to learn by enhancing the process of teaching and learning, and involving the student as an active candidate in this process. Systemic Assessment [SA] assess students higher-order thinking skills in which students are required to analyze, synthesize, evaluate, and measures the students' ability to correlate between concepts. The Systemic Assessment Questions [SAQ] is a novel assessment tool which combines the ideas from systemic and constructivism and adjusts them in a concept map like structure .It was found to be a valuable strategy for assessing meaningful understanding of chemistry concepts. SAQ, s are the building unites of the systemic assessment. In this issue we use SAQ, s as a tool to assess the student achievement in chemistry. We use four new types of systemic assessment questions, namely Systemic Matching Questions [SMQ,s], Systemic Synthesis Questions [SSynQ,s], Systemic Analysis Questions [SAnQ, s], and Systemic Synthetic-Analytic Questions [SSyn-A Q,s]. *[AJCE 4(4), July 2014]*

[1] Prof Lagowski passed away after submission of this article for publication. I lost a great chemist and a great friend. His contribution to chemistry education will stay alive forever! I want to offer my deepest condolences to chemistry education community.

INTRODUCTION

Developing thinking skills in students requires specific instruction. Teachers should address analysis, synthesis, and evaluation using advance organizers that encourage students to operate at higher level of abstraction, strengthening their cognitive structures and helps students retain information longer [1]. Ausubel claims that by presenting a global representation of knowledge to be learned, advance organizers might foster integrative reconciliation of the sub domains of knowledge - the ability to understand interconnections among the basic concepts in the domain [2].

In the SAQ, s the valid analysis followed by synthesis of a novel systemic diagrams with unique characteristics is used as a good tool to train our students to think systemically. So, we have proposed systemic assessment (SA) of learners, aiming to a more efficient evaluation of the systemic- oriented objectives in the SATL model [3-5] & effective tool for assessing students' meaningful understanding of chemistry as well as systemic thinking in secondary and tertiary levels [6-8]. Systemic diagrams are the building unites of SA. In systemics all concepts are interrelated, directly or indirectly, creating a closed conceptual structure which emphasizes the interactions between concepts.

The main aim of SA strategy is to enhance, support and improve both teaching and learning processes via;(i) *help teachers* to use evidence of student learning to assess student achievement against goals and standards of the courses and programs and improve their teaching performance, also helping them to guides the student through a solving situation that utilizes higher order thinking skills, (ii) *enable students* to make feedback and feed forward during their study of any course materials, and help them in making maximum connections between Chemistry concepts, compounds, and reactions. The student should be able to think in a systemic way when he develop his important thinking skills, like the abilities of creating new relationships in order to organize a conceptual systemic , namely, to analyze the systemic into its fundamental components and to synthesize these components into interconnected novel systemic [9-10].

In our previous publications about systemic Assessment we illustrated three types of [SAQ, s] namely Systemic Multiple Choice Questions **[SMCQ,** s] [6-7], Systemic True/False Questions **[STFQ, s**], and Systemic Sequencing Questions **[SSQ, s] (**8). Our goal of this issue is to develop another four types of systemic assessment questions [SAQ,s] can be used by students to assess meaningful understanding of chemical changes .Also it might lead to a better understanding of the systemic relations between chemistry concepts and chemical reactions.

CORE IDEA

Linear Assessment vs Systemic Assessment

In the linear (Traditional) Assessment [LA] we ask our students to represent the different types of inorganic or Organic reactions by chemical equations. The student can write the symbolic chemical equations,but,however, he couldn,t correlate between reactants and resultants or chemical processes.So, he just write separate chemical equations without any comprehension or appreciating significance of these relationships representing the chemical reactions [rote learned materials]. According to Ausuble [11] rote learned materials are discrete and isolated entities which have not been related to established concepts in the learner's cognitive structure. Because rote learning is not anchored to existing concepts, it is more easily forgotten and consequently assesses our students at lower learning outcomes [Memorization].

In the Systemic Assessment [SA] we assess our student's meaningful understanding. According to Ausubel [11] meaningful learning promotes meaningful understanding of scientific concepts. Meaningful learning is a constructive process in which the learner strives to formulate links among concepts, information, and observation to accomplish understanding. In SA strategy we ask our students to construct systemics with new relations between reactants, resultants, and chemical reactions. We can ask our students about chemical reactions by using four types of systemic assessment questions [SAQ, s], namely Systemic Matching Questions [SMQ, s], Systemic Synthesis Questions [SSynQ, s], Systemic Analysis Questions [SAnQ, s], and Systemic Synthetic-Analytic Questions [SSyn-A Q, s].

What students gain in answering SAQ, s?

Students answering SAQ, s are able to; (i) Connect several concepts at once, applying them in a new situation, and synthesize them to create a comprehensive meaningful conceptual structure, (ii) Select specific concepts that fit the particular item and combine them into integrated meaning in their systemic cognitive structure,(iii) Illustrate systemic meaningful understanding of scientific concepts,(iv) converted from surface learning to deep learning of chemistry concepts and chemical processes,(v) enhance their abilities to construction, or analysis of a novel systemic diagrams using chemical information, (vi) develop their thinking skills towards systemic thinking.

Types Systemic Assessment Questions: [SAQ, s]

SAQ, s are the building Questions of any systemic objective test [SOT]; namely Systemic Multiple Choice Questions [SMCQ, s] [6-7], Systemic True, False Questions [STFQ, s] [8], Systemic Sequencing Questions [SSQ, s] [8], Systemic Matching Questions [SMQ, s], Systemic Synthesis Questions [SSynQ, s] [10], Systemic Analysis Questions [SAnQ, s], and Systemic Synthetic-Analytic Questions [SSyn-AQ, s]. In this issue we will illustrate the last four types. Most of these question types were experimented successfully in secondary and tertiary levels.

Type-1: Systemic Matching Questions [SMQ, s]

Measure the student's ability to find the relationship between a set of similar items, each of which has two components. Assess students learning outcomes at synthesis level.

Guide lines for Writing [SMQ, s]:

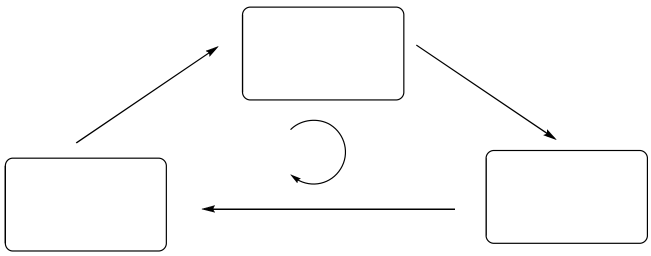
1. The items in the left (Column A) are usually called *premises* and assigned numbers (1, 2, 3, etc.).
2. The items in the right (Column B) are called *responses* and designated by capital letters (A, B, C etc).
3. The arrangement of premises and responses are in the given systemic diagram (Column C, in the middle).
4. The given systemic diagram could be triangular, quadrilateral or Pentagonal.
5. All of the premises and responses for matching items should appear at the same page with the given systemic diagram.

AJCE, 2014, 4(4), *ISSN 2227-5835*

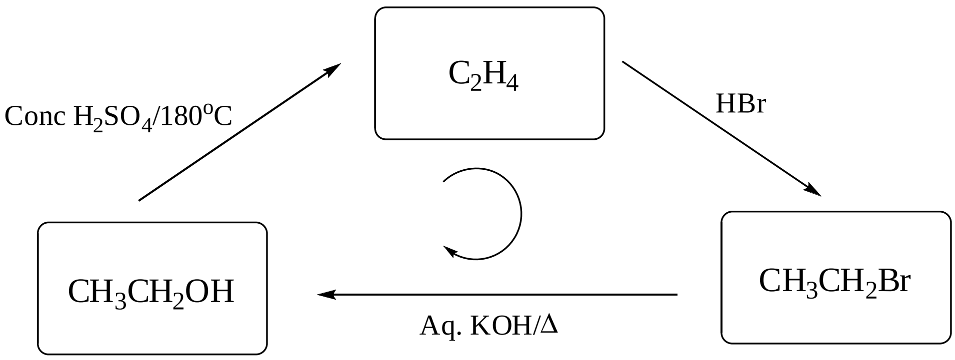
Answer the following SMQ, s

Form I: Matching on Triangular Systemics

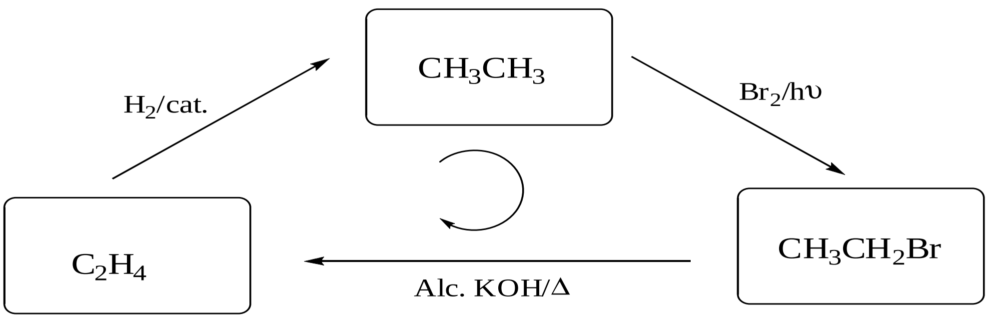
Q_1) Choose aliphatic compounds from column A and reaction conditions from column B to build the systemic diagram in column C:

A	C	B
C_2H_4 **CH_3CH_3** **CH_3CH_2OH** **CH_3CH_2Br**		**dil. H_2SO_4** **Conc. $H_2SO_4/180^{O}C$** **PBr_3** **Alc. KOH/Δ** **Aq. KOH/Δ** **HBr** **H_2/cat.** **Br_2/hν**

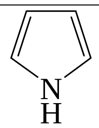
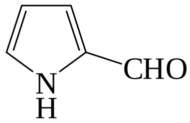
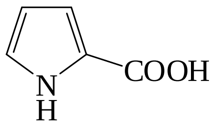
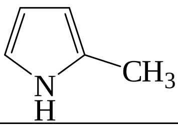
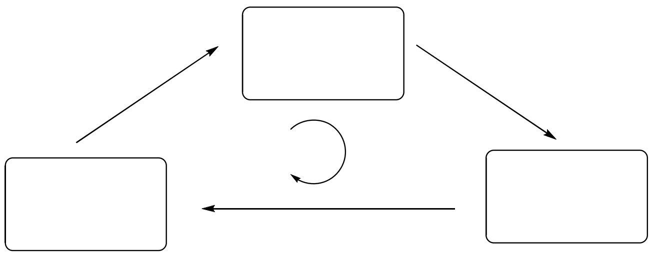
Answer (1)



OR

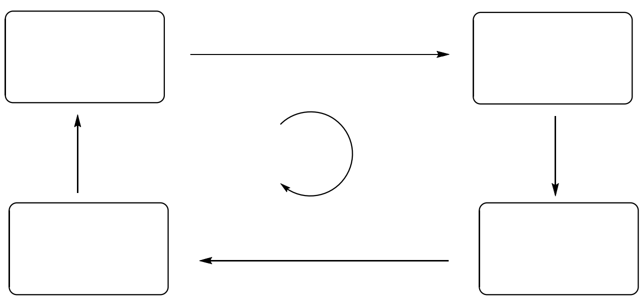


Q$_2$) Choose heterocyclic compounds from column A and reaction conditions from column B to build the systemic diagram in column C:

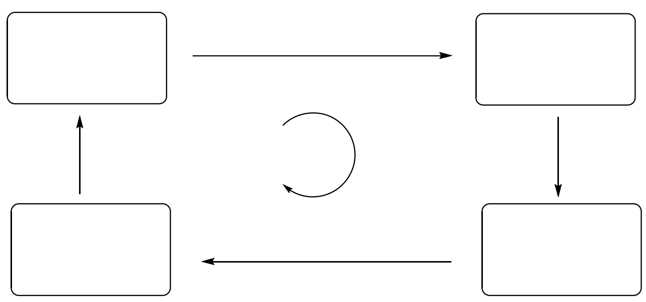
A	C	B
   		**DMF/POCl$_3$** **Aq. Na$_2$CO$_3$** **H$_2$/Pd** **Alk. KMnO$_4$** **Heat 200^{o}C**

Form II: Matching on Quadrilateral Systemics

Q$_3$) Choose elements and compounds from column A and reaction conditions from column B to build the systemic diagram in column C:

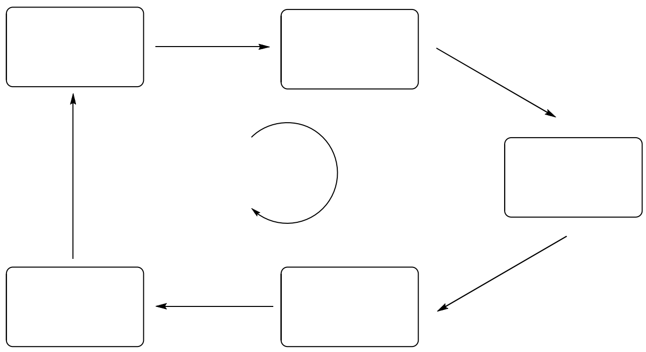
A	C	B
Fe **Cu** **Mg** **FeCl$_2$** **Fe$_2$(SO$_4$)$_3$** **FeCl$_3$** **FeO**		**HCl gas/Δ** **Air/heat** **Conc. H$_2$SO$_4$** **dil. HCl** **Conc. HCl**

Q4) Choose compounds from column A and reaction conditions from column B to build the systemic diagram in column C:

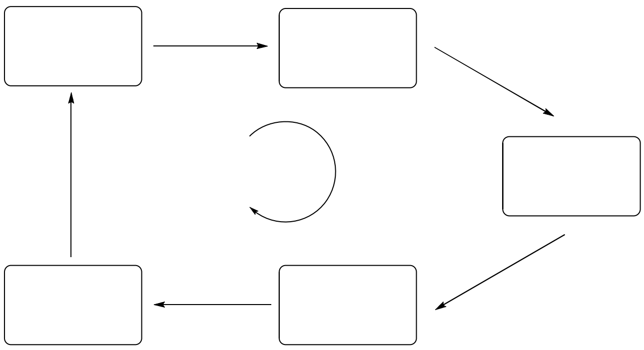
A	C	B
CH_4 **CH_3COOH** **CH_3CHO** **CH_3CH_2Cl** **CH_3Cl** **CH_3CH_2OH** **CH_3-CH_3** **CH_3CN**		**Soda lime/heat** **$KMnO_4$/ H_2SO_4** **Cl_2/hν** **Aq. KCN/heat** **HI/P-200^{o}C** **Dil. HCl/heat**

Form III: Matching on Pentagonal Systemics:

Q5) Choose aliphatic compounds from column A and reaction conditions from column B to build the systemic diagram in column C:

A	C	B
CH_3CH_2Br **CH_3CHO** **CH_3CH_2OH** **CH_3CH_3** **CH_2=CH_2** **CH≡CH**		**Alc. KOH** **Dil. H_2SO_4** **$KMnO_4$/conc. H_2SO_4** **Br_2/hν** **Zn/conc. HCl** **aq. KOH**

Q_6) Choose calcium and related compounds from column A and reaction conditions from column B to build the systemic diagram in column C:

A	C	B
Ca **CaO** **$CaSO_4$** **$CaCO_3$** **$CaCl_2$** **$Ca(OH)_2$** **$Ca(NO_3)_2$**		**O_2** **H_2O** **CO_2** **Dil. HCl** **Electrolysis** **Dil. HNO_3** **Dil. H_2SO_4** Δ

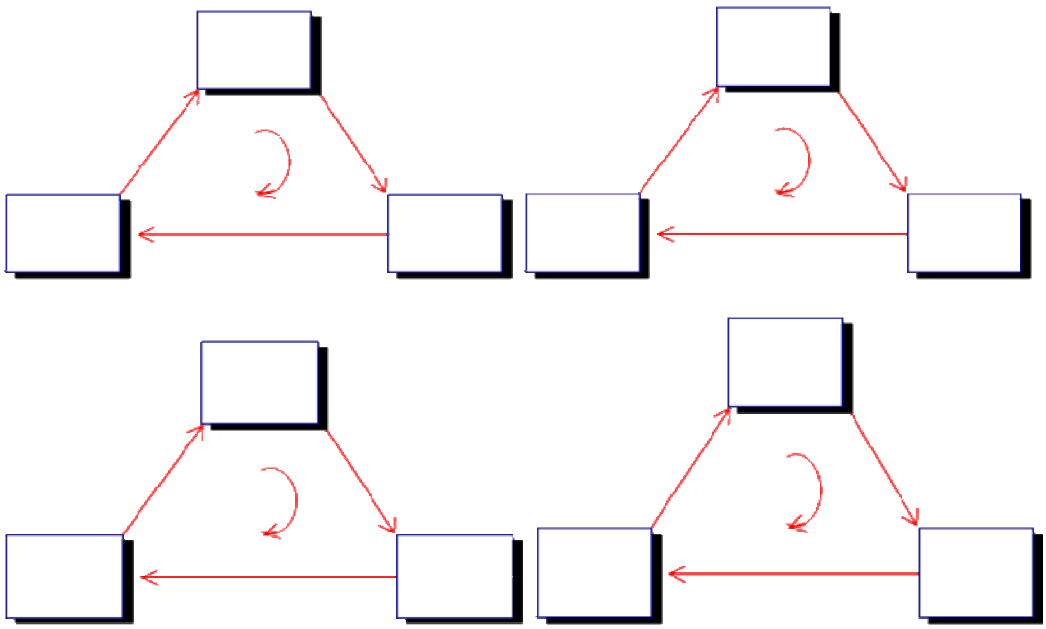
Type-II: Systemic Synthesis Questions [SSynQ, s]

Requires from the student to synthesize systemics from the given chemicals [10] and assess the student learning outcomes at synthesis level. Requirements for building [SSnQ,s]: (i) The stem of the questions contains 3-6 components, (ii) Components could be atoms, molecules, or both Formulas, (iii)The components should be correlated in a systemic diagram, (iv)The size of the systemic diagram depends on the number of Components.

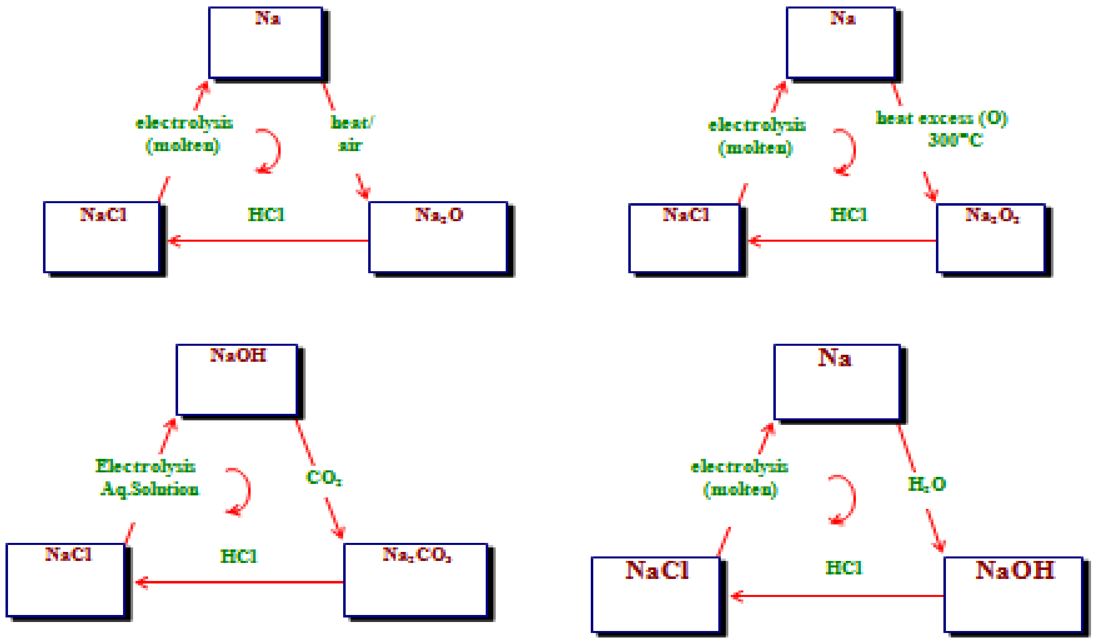
Type-II-A: Synthesize clockwise Systemic *from* the given chemicals to give the correct possible chemical relations

Q1) Use the following triangular diagrams to construct the clockwise Systemic chemical relations between:

[Na, Na2O, Na2O2, NaOH.NaCl.Na2CO3]



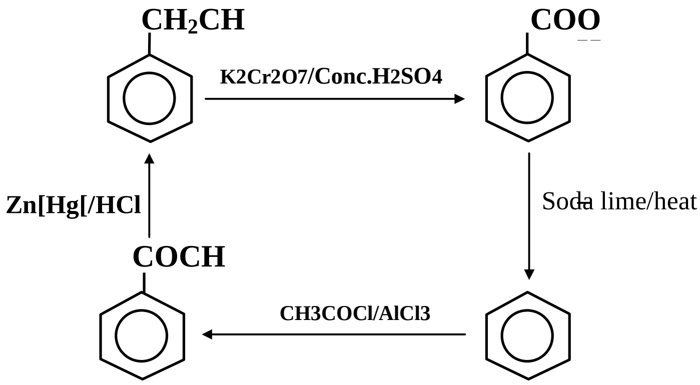
A1)


Na
electrolysis (molten)
heat/ air
NaCl
HCl
Na_2O
Na
electrolysis (molten)
heat excess (O) 300°C
NaCl
HCl
Na_2O_2
NaOH
Electrolysis Aq.Solution
CO_2
NaCl
HCl
Na_2CO_3
Na
electrolysis (molten)
H_2O
NaCl
HCl
NaOH

Q 2: Draw Quadrilateral clockwise systemic diagram illustrating the systemic relations between the following aromatic compounds:

[Benzoic acid, Benzene, Ethyl benzene, Acetophenone]

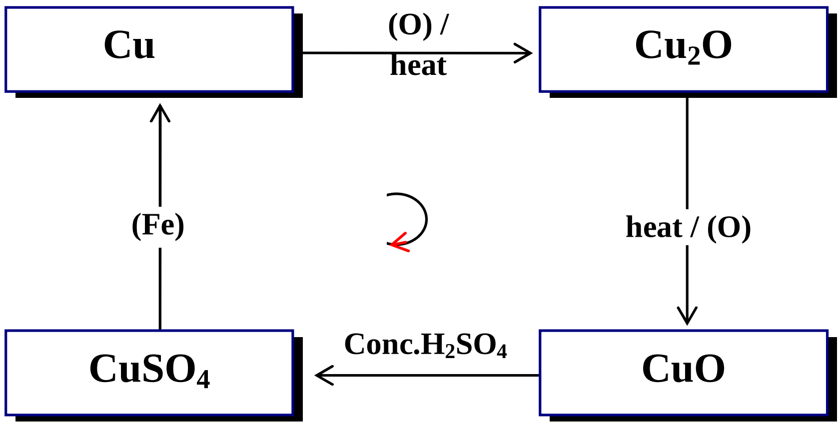
Answer (2)



Q 3: Draw Quadrilateral clockwise systemic diagram illustrating the systemic chemical relations between cupper and the following related compounds:

[Cu2O, CuSO4, CuO]

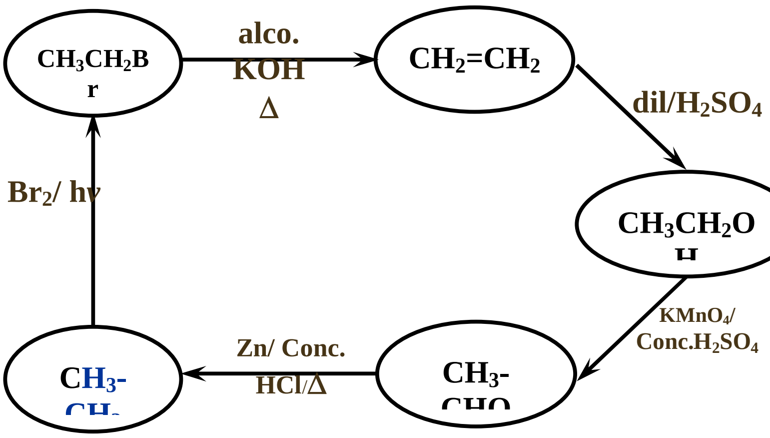
Answer (3)



Q 4: Draw Pentagonal clockwise systemic diagram illustrating the systemic chemical relations between the following compounds:

[C2H5Br,C2H4,C2H6,CH3CHO,C2H5OH]

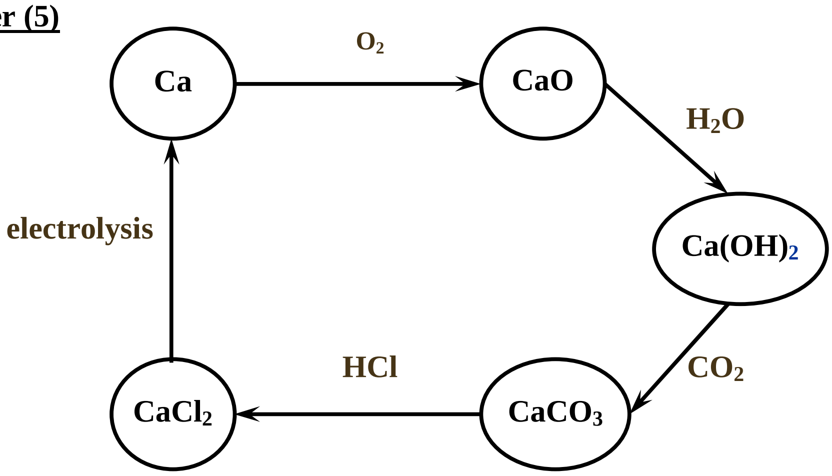
Answer (4)



Q 5: Draw Pentagonal clockwise systemic diagram illustrating the systemic chemical relations between calcium and the following related compounds:

[CaO, CaCO3, CaCl2, Ca ,Ca(OH)2]

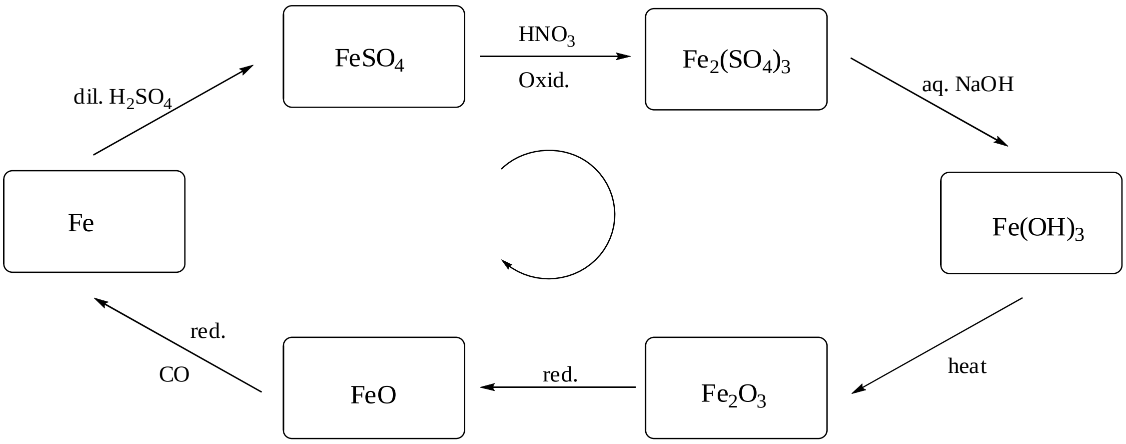
Answer (5)



Q6: Draw Hexagonal clockwise systemic diagram illustrating the systemic chemical relations between Iron and the following related compounds.

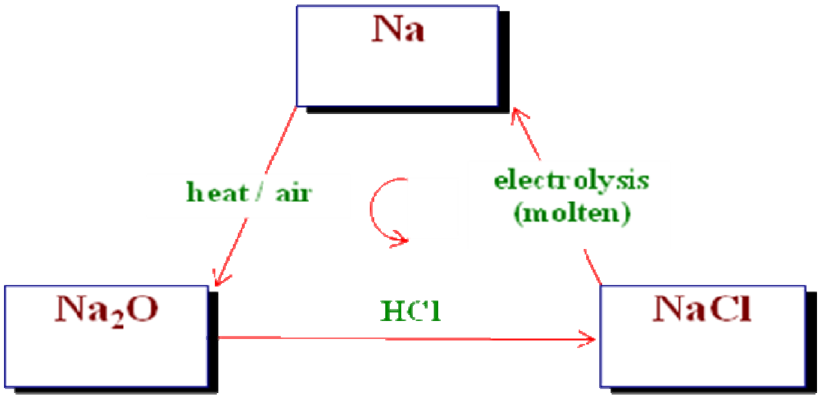
[$Fe_2(SO_4)_3$, $FeSO_4$, Fe, FeO, Fe_2O_3, Fe(OH)3]

Answer (6)



Q7: Draw triangular anticlockwise systemic diagram illustrating the systemic chemical relations between: [Na-Na2O-NaCl]

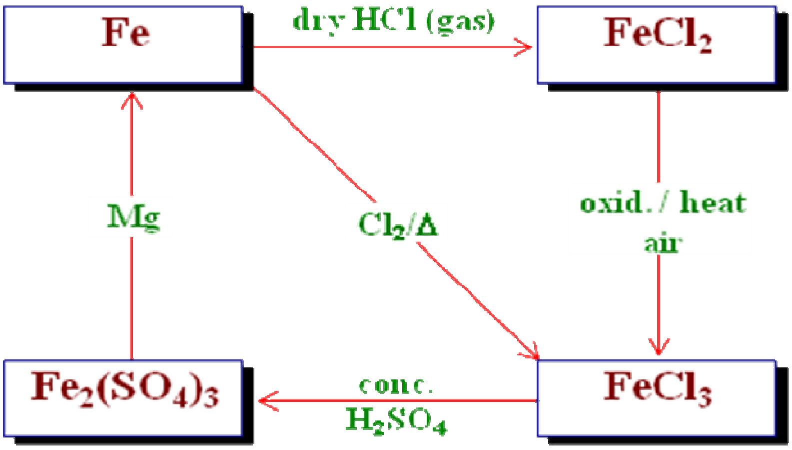
Answer (7)



Type-II-B: Synthesize systemic from the given chemicals to give m*aximum possible chemical relations*

Q8*:* Draw the maximum possible systemic chemical relations between Iron and the following related compounds: [FeCl2-FeCl3-Fe2(SO4)3] in a Quadrilateral diagram.

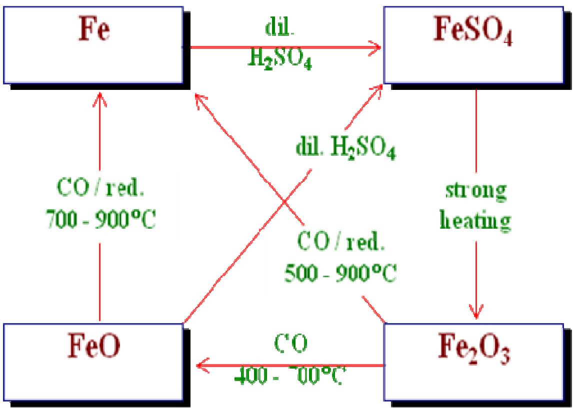
Answer (8)



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

Q9*:* Draw the maximum possible systemic chemical relations between Iron and the following related compounds: [Fe2O3-FeO-FeSO4] in a Quadrilateral diagram.

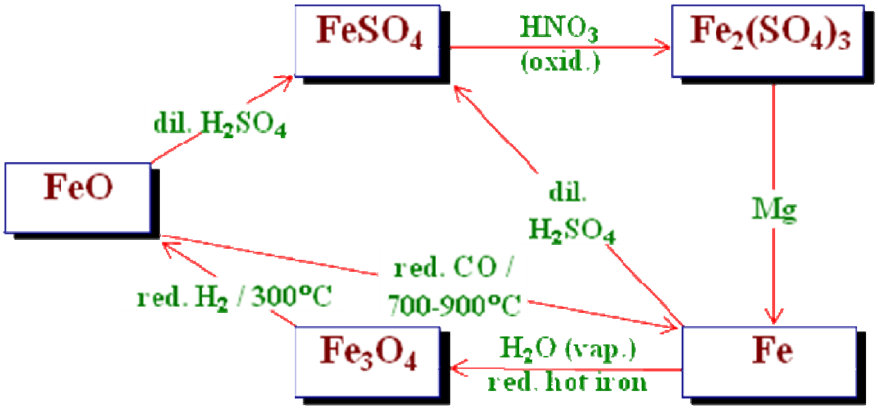
Answer (9)



Note: There are six possible chemical relations instead of four in the clockwise quadrilateral chemical relations.

Q10: Draw the maximum possible systemic chemical relations between Iron and the following related compounds: [Fe3O4-FeO-FeSO4 -Fe2(SO4)3] in a Pentagonal diagram

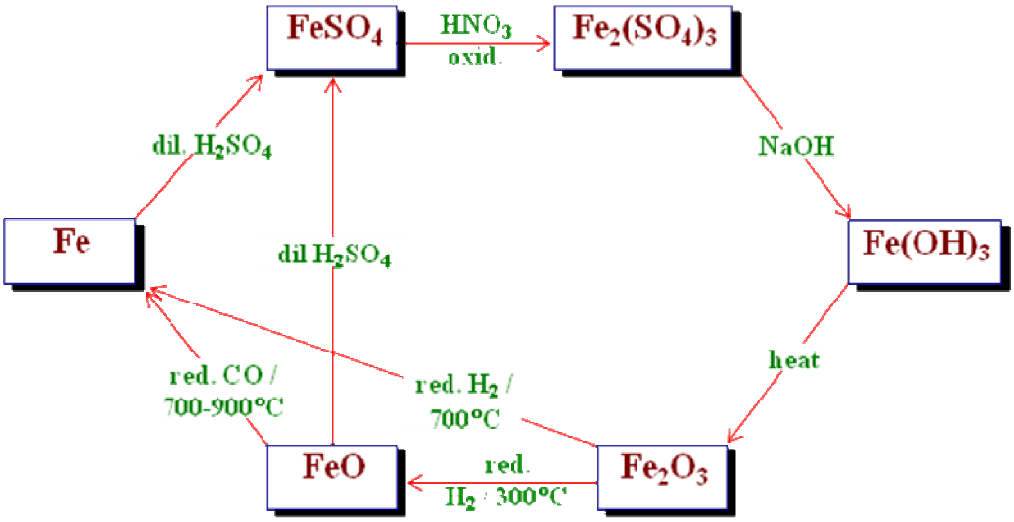
Answer (10)



Note: There are seven possible chemical relations instead of five in the clockwise pentagonal chemical relations.

Q11: Draw the maximum possible systemic chemical relations between Iron and the following related compounds: [Fe(OH)3-Fe3O4-FeO-FeSO4 -Fe2(SO4)3] in a Hexagonal diagram.

Answer(11)



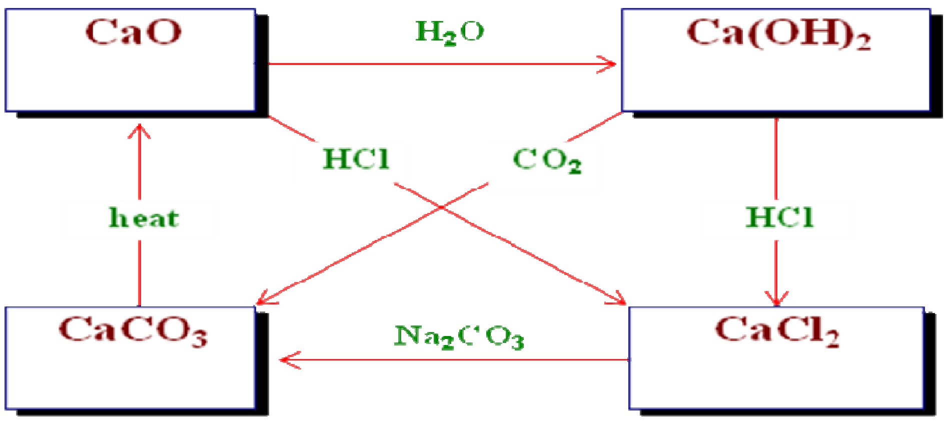
Note: There are eight possible chemical relations instead of six in the clockwise Hexagonal chemical relations.

Type-III: Systemic Analysis Questions [SAnQ,s]

Assess the student learning outcomes at Analysis level.

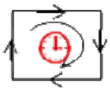
Type-III-A: [Analyze systemic into another systemics]

Q1) Analyze the given Quadrilateral systemic diagram to *the maximum possible clockwise systemic chemical relations*.



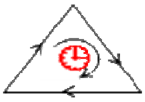
Answer (1)

1- Clockwise quadrilateral systemic chemical relations

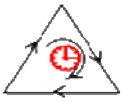


$CaO \longrightarrow Ca(OH)_2 \longrightarrow CaCl \longrightarrow CaCO_3$

2- Clockwise triangular chemical relations

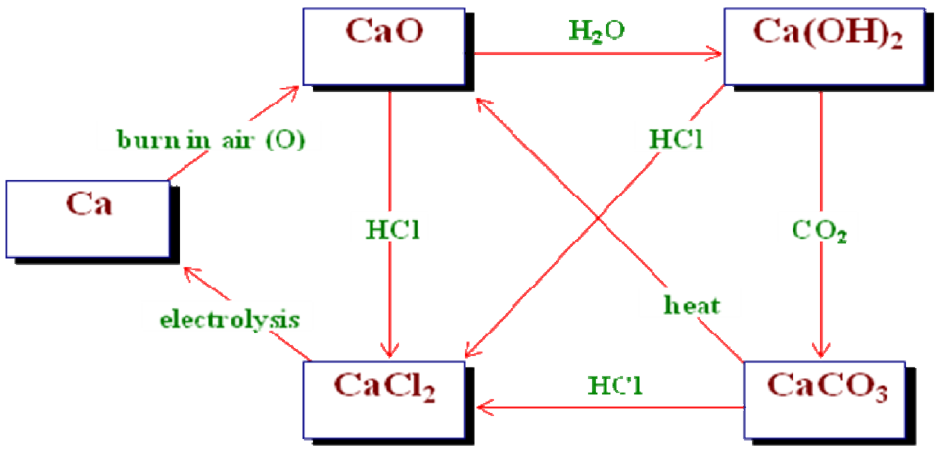


$CaO \longrightarrow CaCl_2 \longrightarrow CaCO_3$



$CaO \longrightarrow Ca(OH)_2 \longrightarrow CaCO_3$

Q2) Analyze the given Pentagonal systemic diagram to *the maximum possible clockwise systemic chemical relations*.

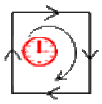


Answer (3)

1- Clockwise pentagonal systemic chemical relations

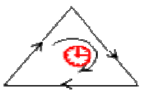
$Ca \longrightarrow CaO \longrightarrow Ca(OH)_2 \longrightarrow CaCO_3 \longrightarrow CaCl_2$

2- Clockwise quadrilateral systemic chemical relations

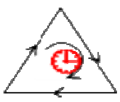


$Ca \longrightarrow CaO \longrightarrow Ca(OH)_2 \longrightarrow CaCl2$

3- Clockwise triangular chemical relations



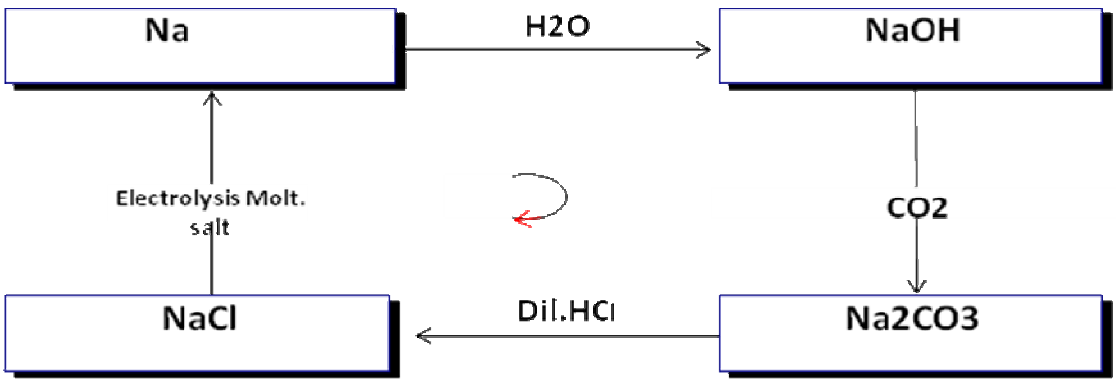
$Ca \longrightarrow CaO \longrightarrow CaCl_2$



$CaO \longrightarrow Ca(OH)_2 \longrightarrow CaCO_3$

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

Q3) Analyze the given Quadrilateral systemic diagram illustrating the systemic chemical relations between Sodium and its related compounds into Chemical equations.



A3)

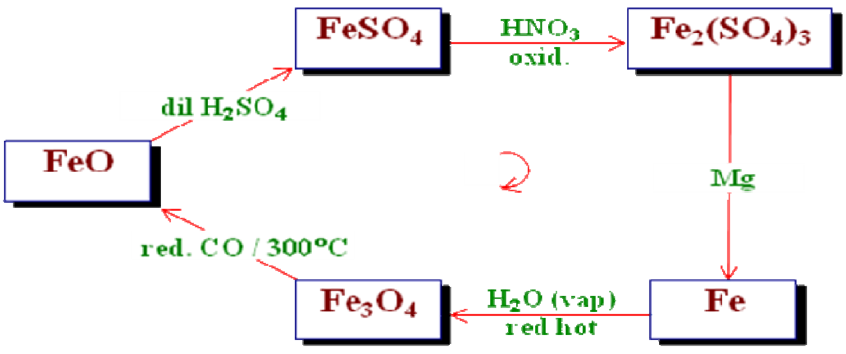
$2Na + 2H_2O \longrightarrow 2NaOH + H_2$

$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$

$Na_2CO_3 + \text{Dil.}\ 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$

$2NaCl\ [\text{Molten}] \longrightarrow 2Na + Cl_2$

Q4) Analyze the given Pentagonal systemic diagram illustrating the systemic chemical relations between Sodium and its related compounds into Chemical equations



$3Fe \xrightarrow{\text{H2O (Vap.) /red. hot tube}} Fe_3O_4$

$Fe_3O_4 + CO \xrightarrow{\text{red. [300]}} 3FeO + CO_2$

$FeO + H_2SO_4\ [\text{Dil.}] \longrightarrow FeSO_4 + H_2O$

$3FeSO_4 + HNO_3 \xrightarrow{\text{Oxid.}} Fe_2(SO_4)_3 + NO_2 + H_2O$

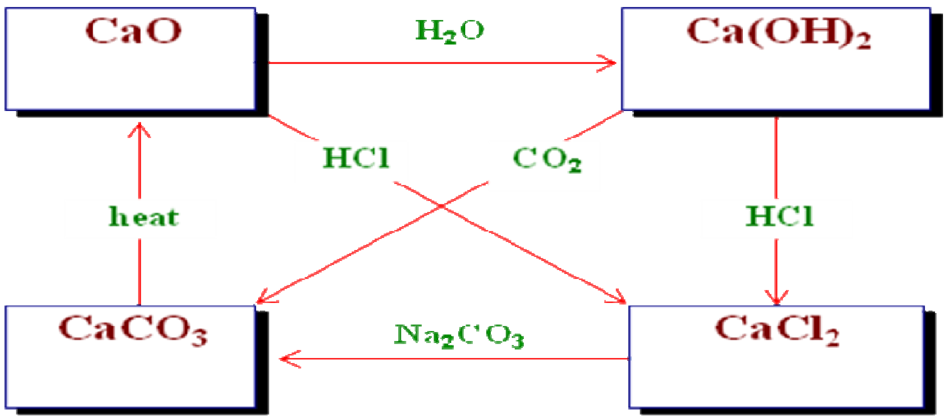
$Fe_2(SO_4)_3 + 3Mg \longrightarrow 3MgSO_4 + 2Fe$

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

This type is integration between Systemic Synthesis Questions [SSynQ, s] and systemic Analysis questions [SAnQ, s]. So, we assess the student learning outcomes at 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) Draw the maximum possible systemic chemical relations between the following Calcium compounds: [CaCO3-CaO-CaCl2 –Ca(OH)2] in a Quadrilateral diagram and then analyze to the corresponding chemical equations.

A1-1: Synthesis:

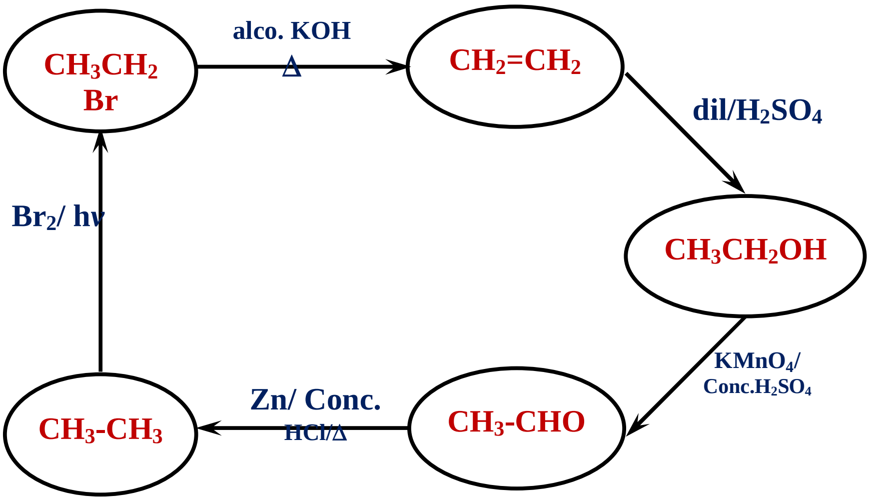


A1-2: Analysis: To six chemical equations

$$CaO + H_2O \longrightarrow Ca(OH)_2$$
$$Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + H_2O$$
$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$
$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + 2NaCl$$
$$CaCO_3 \xrightarrow{heat} CaO + CO_2$$
$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

Q 2) Draw Pentagonal clockwise systemic diagram illustrating the chemical relations between the following aliphatic compound and then analyze to the corresponding chemical equations: [C2H5Br,C2H4,C2H6,CH3CHO,C2H5OH]

<u>A2-1: Synthesis</u>



A2-2: Analysis: To five chemical equations

CH3-CH3 + Br2 $\xrightarrow{h\nu}$ CH3-CH2-Br + HBr

CH3-CH2-Br + KOH $\xrightarrow{\text{Alco.}}$ CH2 = CH2 + KBr + H2O

CH2 = CH2 + H2O $\xrightarrow{\text{Dil.H2SO4}}$ CH3-CH2-OH

CH3-CH2-OH $\xrightarrow{\text{Oxid.[KMnO4/H2SO4]}}$ CH3 CHO + H2O

CH3 CHO + 2 H $\xrightarrow{\text{Red.[ZnCl2/Conc. HCl/Heat]}}$ CH3-CH3

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