USES OF SYSTEMIC APPROACH AND CHEMIST'S TRIANGLE IN TEACHING AND LEARNING CHEMISTRY: SYSTEMIC CHEMISTRY TRIANGLE [SCT] AS A TEACHING & LEARNING STRATEGY

Fahmy, A.F.M.

Chemistry Department, Faculty of Science, in Shams University, Cairo, Egypt
Email: afmfahmy42@gmail.com Website: www.satlcentral.com

ABSTRACT

This paper describes uses of the systemic chemistry triangle [SCT] in which we get the benefits of both systemic approach and chemist's triangle in teaching and learning chemistry. SCT creates active learning environment enable students to gain high mental and professional skills, correct cognition, positive attitudes towards chemistry, and environment, and finally systemic thinking. At the end of the learning process by SCT the student gain systemic learning outcomes of the concept in which the MAC- level interrelated to Symbolic-level and both are explained by MIC-level in a pattern of knowledge. *[African Journal of Chemical Education—AJCE 6(2), July 2016]*

INTRODUCTION

Systemic Approach to Teaching and Learning (SATL) is a teaching model that has been developed during the past decade by Fahmy & Lagowski [1-5]. They recognized that the basic goal of SATL is the achievement of meaningful understanding by students and suggest that this goal can be attained through the development of systemic thinking, in a context of constructivist and systemic oriented learning tasks (SATL techniques) [1-5]. Meaningful understanding of chemistry concepts includes the ability of student to link related chemical concepts resulting in making judgments, creating relationships, drawing conclusions, predicting what should happen, also includes the student abilities to draw chemical information from a chemical representation and to construct a chemical representation using chemical information [6]. SATL 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 [3]. On the other hand learning chemistry requires modeling ability and representational competence enable to use multi-Model representational form that are explanatory tool. Gilbert [7] and Johnoston [8] stated that the triangle has become the theoretical framework in understanding how chemistry concepts are presented. Commonly, students are exposed to all three learning levels of chemical representation of matter simultaneously. The model has also been found to be of great use to chemistry education researchers like Gilbert & Treagust [9]; and consists of three domains of knowledge as shown in Fig.1a. (i) Macroscopic, a tangible and visible level of thought and experiences comprising what students can experience or observe (ii) ‘‘Sub-microscopic’’ it refers to the molecular domain, and (iii) “Symbolic” which refers to ‘‘symbols, formulae, equations, and graphs’. The planar triangle of chemistry, Fig.1a, has proven to be of great benefits in designing of secondary and post-secondary school curriculum, including textbooks, lab manuals.

Mahafy [10-11] modified the chemist’s triangle to the tetrahedron by adding a fourth learning level (human contexts) for learning chemistry as in Fig.1b. However, Bradley [12] stated that some authors converted the chemist's triangle to a tetrahedron to take account of the interaction of chemistry with the environment. This seems to be a confusion rather than improvement. The environment is important, but they do not lie at the core of the discipline and would be better taken into account by a circle around the triangle. Bradley also stated that the triangle may be viewed as a core closed-cluster concept map of the type advocated in the systemic approach to teaching and learning of chemistry and used to get thoughts on any chemistry topic or theme. He postulated that chemist's triangle alone is an aide-memoire that can be understood after experiencing its use [12].

Johnstone and his group [13].have demonstrated the reducing effect of working memory overload on learning achievement. They note that novice learners have great difficulty in working at all three learning domains of chemistry at one and the same time because of information overload. Deliberate use of the chemist’s triangle has clear potential in this regard as do closed cluster concept maps in general. It can serve as an advance organizer and/or as a meaningful summarizing framework [13]. In the same time systemics were used as an advance organizer models for the successful teaching and learning chemistry [3, 6].

In continuation of our work on the uses of SATLC in different educational settings, herein we will combine both systemics and chemist’s triangle models to get benefits of both in teaching and learning chemistry. So, we make use of triangle as triangular systemic in which the three learning domains of concepts located at the corners. We name it as systemic chemistry triangle (SCT). If we imagine that the student stand at the center of the chemistry triangle, he/she will recognize the three corners of the triangle in a pattern of [Macroscopic-Microscopic-Symbolic]. If we start learning of any chemistry concept from MAC level (the student can describe physical and chemical changes of matter), then he/she will write the balanced equation as part of symbolic level description of MAC level. Then the student comes to explanation of his/her observations on the atomic and molecular level- MIC. At the end of the learning process the student gain systemic learning outcomes of the concept in which the MAC- level interrelated to Symbolic-level and both are explained by MIC-level in a pattern of knowledge.

This systemic interaction between the three learning levels (domains) of SCT leads to meaningful understanding of chemistry concepts resulted from active learning environment represented by a circle around the triangle. The expected learning outcomes of SCT are correct cognition, positive attitudes towards chemistry and environment, high skills and systemic thinking [3], Fiq.1c. It could be presented by Quadrilateral around SCT. The growing ability of the systemic way of thinking of our students is one of the most important characteristics of Global Era [14]. The following diagram represents the evolution of chemistry triangle from planar triangle (Fig.1a) to tetrahedron (Fig.1b) then to our systemic triangle (Fig.1c).

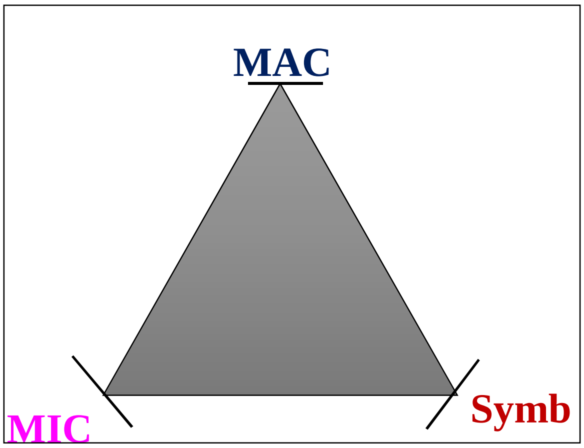

Fig.1a: Planar Chemistry Triangle

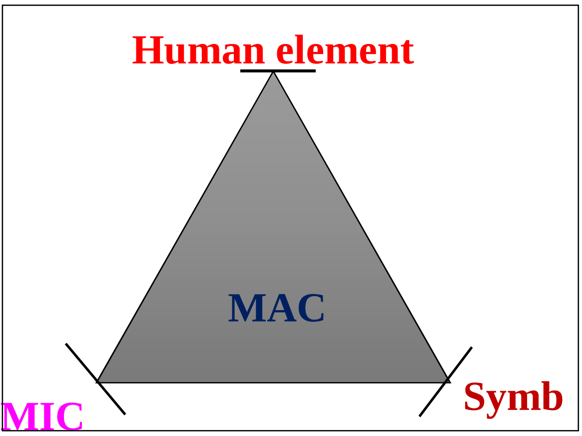

Fig.1b: Tetrahedral Chemistry Triangle

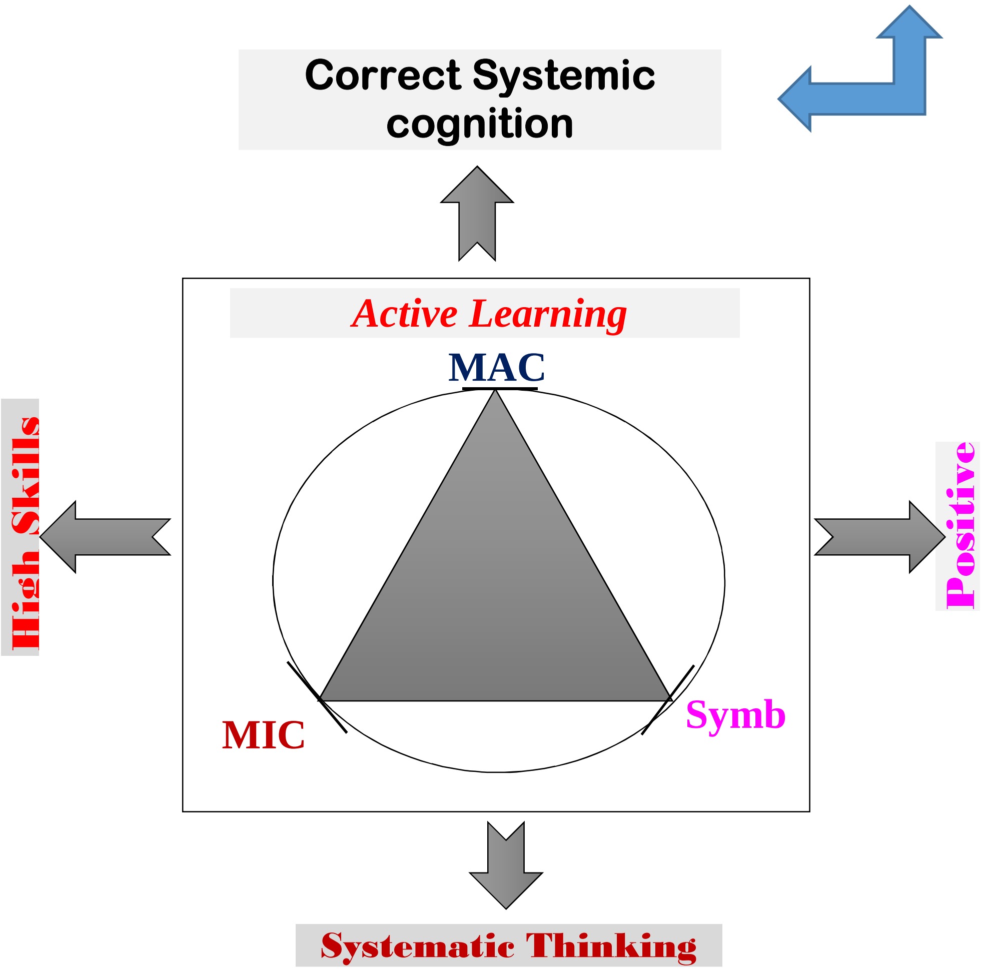

Fig.1c: Systemic Chemistry Triangle
Fig.1a-c: Evolution of Chemistry Triangle Strategy

STC - strategy emphasizes that more than one teaching strategies are used under this umbrella (eg. Systemic, problem solving, active learning, and cooperative learning. etc).

USES OF SCT IN TEACHING AND LEARNING GENERAL CHEMISTRY CONCEPTS

In the present work we make use of SATL & Chemists triangle as teaching and learning methodologies to introduce the systemic triangle [SCT] as an easy model for new teaching strategy of general chemistry concepts. As presented in [ST0;Fig.2] the three learning levels of the matter are systemically interacted and you can't teach one apart from the two others or even teach two apart from the third level otherwise we will go to surface & rote learning. ST0 represents the general strategy for teaching and learning chemistry concepts in a pattern of knowledge of the three learning levels (domains)

[MAC (Describe) –SYMB (Symbolic representation) - MIC (Interpretation)]

For instance, if we teach chemistry concepts of matter at the [MAC-SYMB.] Levels and we ignored [MIC] level. This will lead to rote & surface learning due to the absence of any microscopic interpretation at [MIC-Level].

In the following part of this paper we will use systemic chemistry triangle SCT as a facile strategy for teaching and learning some general chemistry concepts listed in the following Table.1.

Table.1: Chemistry Concepts Learned by SCT Strategy

No.	Concepts	Sub.Concepts
1	Physical changes	Changes in color,Volume, Temperature-boling point-Melting Point-Dipole moment μ -PH,
2	Solubility	Exo-thermic,Endo-thermic
3	Acid	Aq. Solutions of acids, Hydration of **H+** ions to **H3O+**
4	Base	Aq. Solutions of Bases
5	Acid –Base reactions	Neutralization reactions , End point .Indicators.
6	Redox Reactions	Oxidation - Reduction
7	Haber-Process	Reversible reaction, Effect of heat, Pressure on the reversible reaction.
8	Substitution reactions	Nucleophilic Substitution Reactions, **SN2**-Mechanism.
9	Photo - chlorination of Alkanes	Radical substitution reactions of alkanes. Chain Reaction .Initiation step -Propagation steps-Termination step.
10	Addition Reactions	Electrophilic Addition of HBr to the **π** –bonds of Alkenes.E2-mechanism. Addition of hydrogen on the π –bond of C=O groups

Note: All figures are presented in a separate file at the end of the text.

I. Use of SCT in Teaching and Learning

Exothermic Solubility: eg. Solubility of NaOH in water (SCT1 –Fig.3).

Teachers follow up the following scenario for teaching solubility of

NaOH in water [Fig. 3];.

1. The scenario of teaching started by asking the students to carry out the following

Experiment:

- Add 10 ml of water to 0.5 gm of solid NaOH in a test tube and shake the tube.
- Then teacher asks students to describe the observed changes.
- **Observation [MAC-Level]**
- **Physical changes.**
- Sodium hydroxide (solid) dissolved in water to give homogeneous solution.
- The solubility is accompanied by liberation of heat (exothermic).
- Increase of the pH of water to a strong alkaline (alkaline effect on litmus paper).

2. Then teacher asked students to write the equation as Symbolic - Level description of the MAC- level.
3. Then teacher ask students to use MIC-Level to explain both MAC & Symb.

Descriptions

- Hydration of Na+ and -OH ions to give hydrated Na+ (aq.) and –OH (aq.) ions.
- Solubility is Exothermic because hydration energy is greater than lattice energy.
- ➢ *So the student started learning by MAC-Level then use Symb to represent the changes of matter in MAC, then finally use MIC to explain both MAC & Symb descriptions.*

II. Use of SCT in Teaching and Learning

Endothermic Solubility: eg. Solubility of NaCl in water (SCT2-Fig.4).

Teachers follow up the following scenario for teaching solubility of solid NaCl in water [Fig.4]:

1. The scenario of teaching started by asking the students to carry out the following

Experiment:

- Add 10 ml of water to 0.5 gm of solid NaCl in a test tube, then shake the tube.
- Then teacher asked students to describe the observed changes.
- **Observation: [MAC-Level]**
- **Physical changes**
- • Sodium chloride (solid) dissolved in water to give homogeneous solution.
- • The solubility is accompanied by absorption of heat (Endothermic).
- • The pH of the solution =7 (neutral effect on litmus paper).

2. Then teacher asks students write the symbolic equation as symbolic-Level description of MAC- level.
3. Finally teacher asks students to explain both MAC and Symb descriptions.

- Hydration of Na+ and Cl- ions to give hydrated Na+ (aq.) and Cl- (aq.) ions.
- Solubility is Endothermic because hydration energy is less than lattice energy.
- ➢ *So, the students started learning at MAC-Level to describe changes in matter then use Symb-Level to represent changes in a symbolic equation then finally use MIC-level to explain MAC & Symb descriptions.*

III. Use of SCT in Teaching and Learning Solubility of HCl Gas in water [SCT3-Fig.5].

Teachers follow up the following scenario for teaching solubility of HCl (gas) in water [Fig.5]:

1. The scenario of teaching started by asking students to carry out the following

Experiment:

- Hydrogen chloride HCl gas is prepared from the action of moderately conc. H_2SO_4 (aq.) on solid NaCl (s).Then the gas passed into water via inverted funnel.
- Then teacher asked students to describe the observed changes.
- **Observation: [MAC-Level]**
- **Physical changes**
- Hydrogen chloride (gas) dissolved in water to give homogenous solution.
- The pH of the solution less than 7 (acidic effect on litmus paper).

2. Then teacher asked students to write the Symbolic Presentation [Fig.5] (symbolic equation) to represent changes described in the MAC-Level
3. Finally teacher asked students to explain both MAC& Symbolic descriptions by making use of MIC-Level [Fig. 5]

IV. Use of SCT in Teaching and Learning Dilution of Concentrated Sulphuric Acid in Water (SCT4-Fig.6)

Teachers follow up the following scenario for dilution of conc. sulphuric acid with water [Fig.6]:

1. The scenario of teaching started by asking students to carry out the following:

Experiment:
- Add 1 ml of conc. sulphuric acid (98%) to 5 ml. of water in a test tube.
- Then teacher ask students to describe the observed changes.
- Observation: [MAC-Level, Fig.6].
- Exothermic solubility of the acid.

2. Then teacher asked students to write the Symbolic Presentation [Fig.6] (symbolic equation) to represent changes described in the MAC-Level.
3. Finally teacher asked students to explain both MAC& Symbolic descriptions by making use of MIC-Level [Fig.6]

V. Use of SCT in Teaching and Learning Oxidation of Fe2+ to Fe3+ by chlorine (SCT5-Fig.7)

Teachers follow up the following scenario for teaching and learning Oxidation of Fe2+ to Fe3+ by chlorine [Fig.7]:

1. Teacher started the scenario of teaching by opening discussion about the concepts of Oxidation, Reduction and Redox-reactions. Then asked students to describe the changes in the oxidation of Fe2+ to Fe3+ by chlorine. [MAC-Level; Fig.7].
2. Then teacher asked students to write the Symbolic Presentation [Fig.7] (symbolic equation) to represent changes of the MAC-Level.
3. Then student move to [MIC-Level; Fig.7] to explain both MAC &Symbolic descriptions.

VI. Use of SCT in Teaching and Learning Acid-Base Reaction of HCl with NaOH (SCT6-Fig.8)

Teachers follow up the following scenario for teaching Acid-Base reaction between HCl, and NaOH [Fig.8]:

1. Teacher asked students to carry out Titration of (0.1N) solution HCl with approximately (0.1N) NaOH solution using ph.ph as indicator to determine the end point.

- Observation: (Students Describe changes) [MAC-Level; Fig.8]

- At the end point the solution becomes neutral PH =7 due to the transformation of NaOH to NaCl Salt.

2. Then teacher asked students to write the symbolic representation [Fig.8] the symbolic equation for neutralization reaction) to represent changes of MAC-Level.
3. Then teacher asked students to explain both MAC& Symb descriptions by making use of MIC-Level [Fig.8].

VII. Use of SCT in Teaching and Learning of Haber Process for Industrial Preparation of Ammonia (SCT7-Fig.9)

Teachers follow up the following scenario for teaching Haber process [Fig. 9]:

1. Teacher open discussions with students about use of Haber process in industrial preparation of ammonia, then asked them to describe the changes in the Process.[MAC-Level; Fig.8].
2. Then teacher asked students to write the symbolic equation of Haber Process Symbolic Presentation –Level [Fig.9] to represent the changes of MAC-Level.
3. Then teacher asked students to explain descriptions of both MAC& Symbolic by using MIC-Level [Fig.9].

VIII. Uses of SCT in Teaching and Learning Synthesis of Methanol from Methyl Chloride (SCT8-Fig.10)

Teachers follows up the following scenario for teaching synthesis of Methanol [Fig10]:

1. After discussions in the class room about the synthesis of methanol from methyl chloride by Bimolecular Nucleophilic substitution reaction. Teacher ask the students to describe the physical and chemical changes in this process [MAC-Level; Fig.10].
2. Then teacher asked students to write the Symbolic and Mechanistic equations of (SN2 mechanism) Symb-level Fig.10 to represent the changes of the MAC-Level.

3. Then student move to MIC-Level [Fig.10] to explain both MAC and Symbolic description levels.

IX. Use of SCT in Teaching and Learning Reaction of Sodium with Methanol (SCT9-Fig.11)

Teachers follows up the following scenario for teaching [Fig11]:

1. After discussions in the class room about the reaction of sodium metal with methanol. Teacher asked the students to describe physical and chemical changes in this reaction [MAC-Level; Fig11].
2. Then teacher asked the students to write the symbolic equation representation Level [Fig.11] of MAC-Level description.
3. Then teacher ask students to go to [MIC- Level; Fig.11] for explanation of both MAC& Symbolic descriptions.

X. Use of SCT in Teaching and Learning of Photo- Chlorination of Methane to Methyl Chloride (SCT10-Fig.12)

The teachers follows up the following scenario for teaching [Fig.12]:

1. After discussions in the class room about photo-chlorination reactions. Teacher ask the students to describe the physical and chemical changes in this process [MAC-Level; Fig.12].
2. Then teacher asked the students to write the symbolic equation [representation-Level; Fig .12] of the MAC-Level description.
3. Then teacher ask students to go to MIC- Level [Fig.12] for explanation of both MIC& Symbolic descriptions.

XI. Use of SCT in Teaching and Learning Reaction of Ethylene with HBr (SCT11-Fig.13)

Teachers follow up the following scenario for teaching [Fig.13]:

1. Teacher open discussions about electrophilic addition reaction of HBr on the π –bond in ethylene molecule then teacher asked students to describe the changes in this process [MAC-Level; Fig.13].
2. Then teacher asked the students to go to [Symb-Level; Fig.13] to write the symbolic and mechanistic equations of MAC – Level description.
3. Then students go to [MIC-Level; Fig.13] for explanation of both MAC& Symbolic descriptions.

XII. Use of SCT in Teaching and Learning of Synthesis of Isopropanol from Acetone (ST12-Fig.14)

Teachers follow up the following scenario for teaching [Fig.14]:

1. After discussions in the class room about the addition of hydrogen on the carbonyl groups of aldehydes and ketones to give alcohols. Teacher asked students to describe the changes in this process [MAC-Level; Fig.14].
2. Then teacher asked students to move to [Symb.-Level; Fig.14] to write the symbolic presentation for MAC-Level description.
3. Then students move to [MIC-Level; Fig.14] to explain MAC& Symbolic descriptions.

CONCOLUTIONS

At the end of teaching this unit by SCT, we expect from our students the following:

- Improving their ability to view chemistry from a more global perspective.
- Increases their ability to think systemically.

- SCT helps them to develop their own mental framework at higher-level of processes such as application, analysis, and synthesis.

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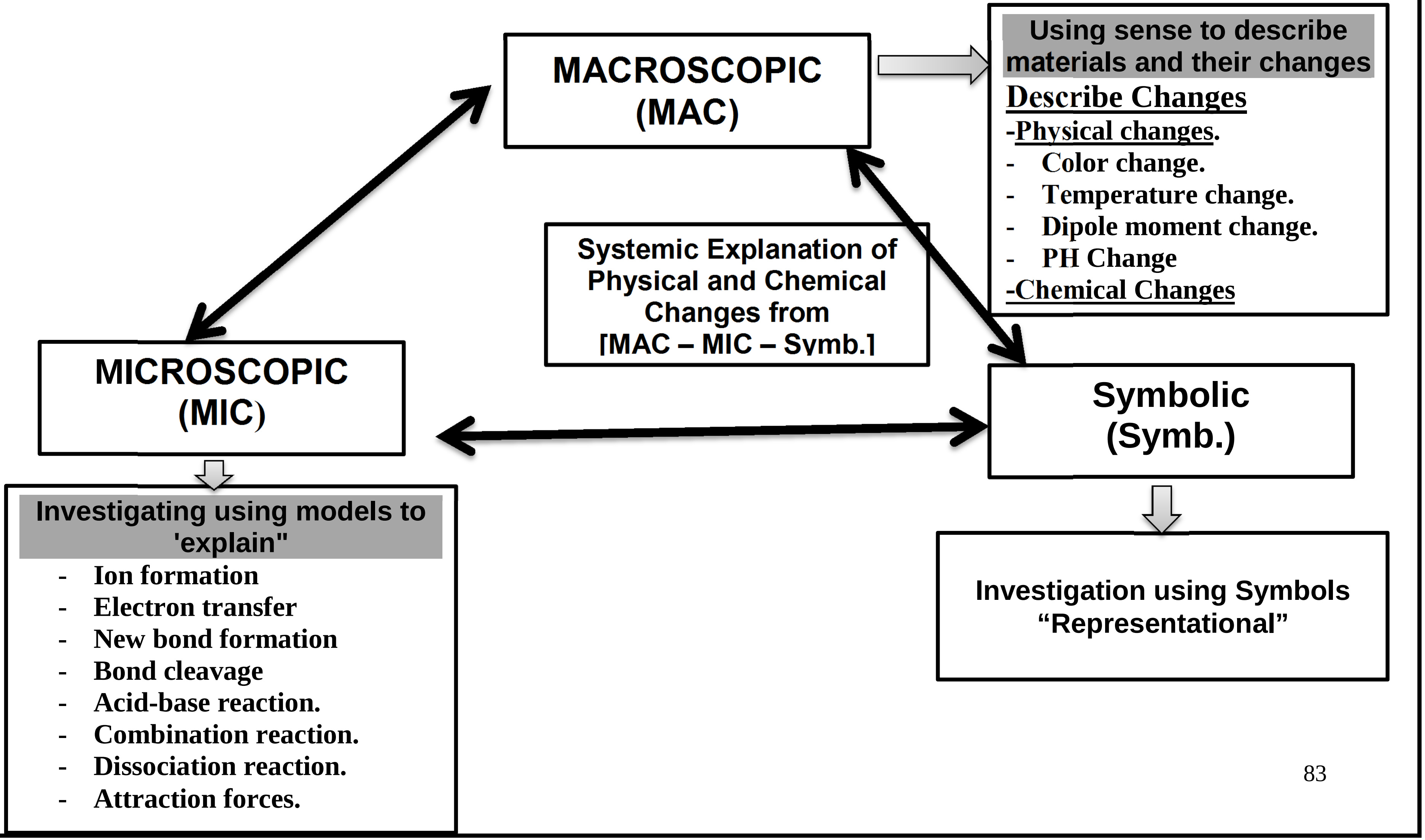
The Systemic Chemistry Triangles Figures [SCT 0-12] Fig.2-13] are listed in the following pages as appendices.

Systemic Triangle to Teaching and Learning Physical and Chemical Processes (General Systemic Triangle) (ST0-Fig.2)



MACROSCOPIC (MAC)

Using sense to describe materials and their changes

Describe Changes

-Physical changes.

- **Color change.**
- **Temperature change.**
- **Dipole moment change.**
- **PH Change**

-Chemical Changes

Systemic Explanation of Physical and Chemical Changes from [MAC – MIC – Symb.]

MICROSCOPIC (MIC)

Investigating using models to 'explain"

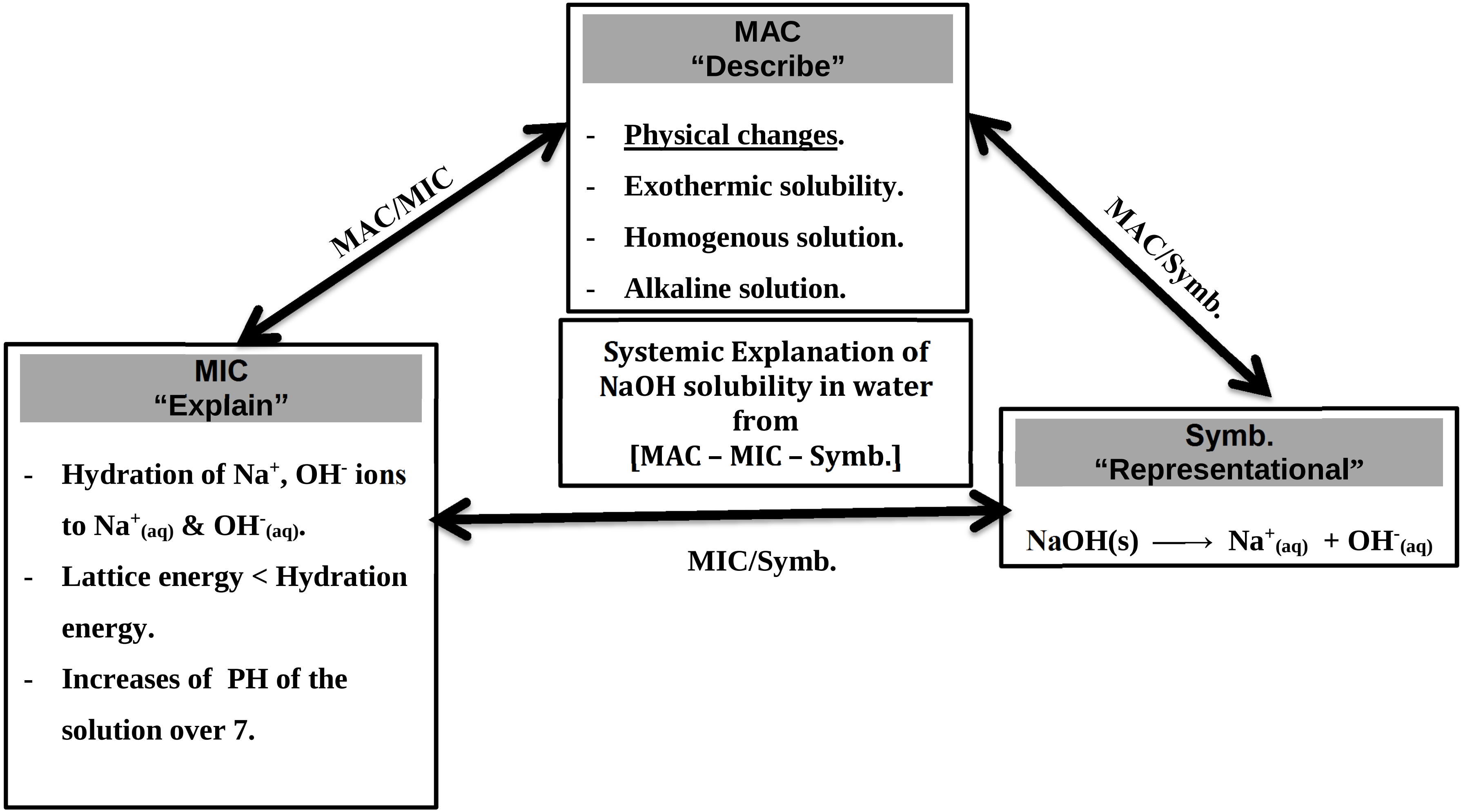
- **Ion formation**
- **Electron transfer**
- **New bond formation**
- **Bond cleavage**
- **Acid-base reaction.**
- **Combination reaction.**
- **Dissociation reaction.**
- **Attraction forces.**

Symbolic (Symb.)

Investigation using Symbols "Representational"

Systemic Triangle of Solubility of NaOH in Water (ST1-Fig.3)

CONCEPT: Solubility



MAC
“Describe”

- Physical changes.
- Exothermic solubility.
- Homogenous solution.
- Alkaline solution.

MIC
“Explain”

- Hydration of Na^+, OH^- ions to $Na^+_{(aq)}$ & $OH^-_{(aq)}$.
- Lattice energy < Hydration energy.
- Increases of PH of the solution over 7.

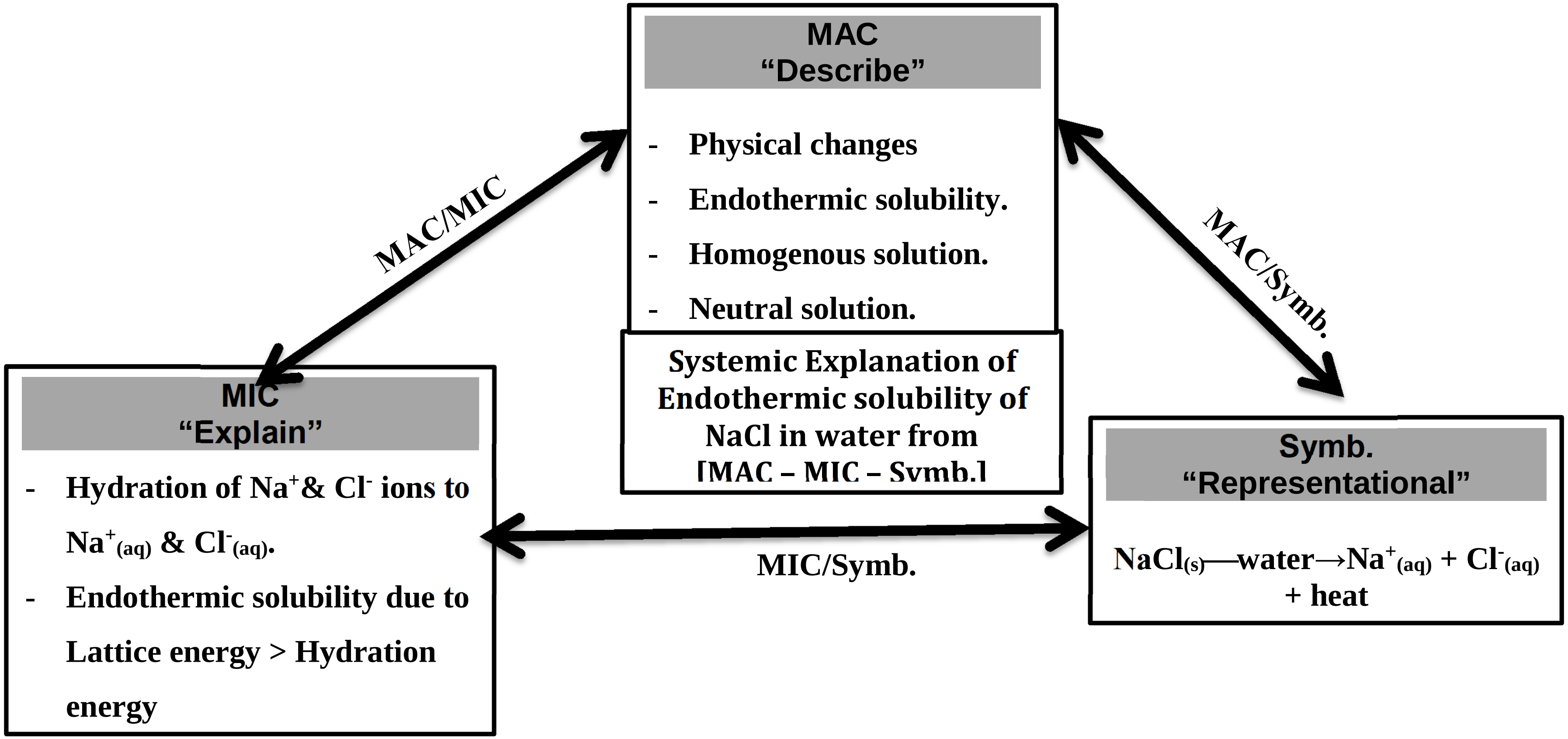
Systemic Explanation of NaOH solubility in water from [MAC – MIC – Symb.]

Symb.
“Representational”

$NaOH(s) \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Systemic Triangle of Solubility of NaCl Salt in Water (ST2-Fig.4)

CONCEPT: Solubility



MAC
"Describe"

- **Physical changes**
- **Endothermic solubility.**
- **Homogenous solution.**
- **Neutral solution.**

Systemic Explanation of Endothermic solubility of NaCl in water from [MAC – MIC – Symb.]

MIC
"Explain"

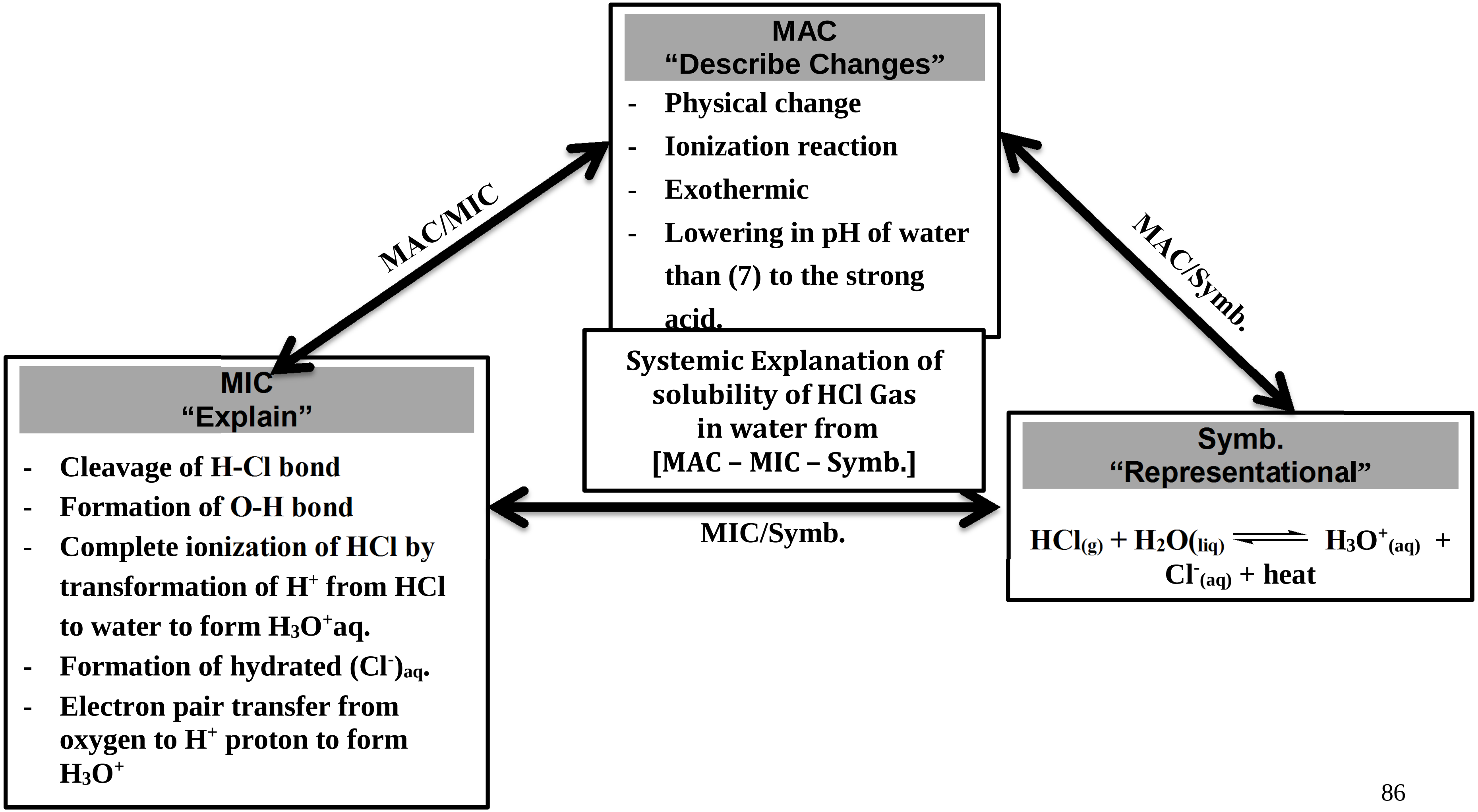
- **Hydration of Na^+& Cl^- ions to $Na^+_{(aq)}$ & $Cl^-_{(aq)}$.**
- **Endothermic solubility due to Lattice energy > Hydration energy**

Symb.
"Representational"

$NaCl_{(s)} \xrightarrow{water} Na^+_{(aq)} + Cl^-_{(aq)}$ **+ heat**

Systemic Triangle of Solubility of HCl Gas in Water (ST3-Fig.5)

CONCEPT: Solubility



MAC
"Describe Changes"

- Physical change
- Ionization reaction
- Exothermic
- Lowering in pH of water than (7) to the strong acid.

MIC
"Explain"

- Cleavage of H-Cl bond
- Formation of O-H bond
- Complete ionization of HCl by transformation of H^+ from HCl to water to form H_3O^+aq.
- Formation of hydrated $(Cl^-)_{aq}$.
- Electron pair transfer from oxygen to H^+ proton to form H_3O^+

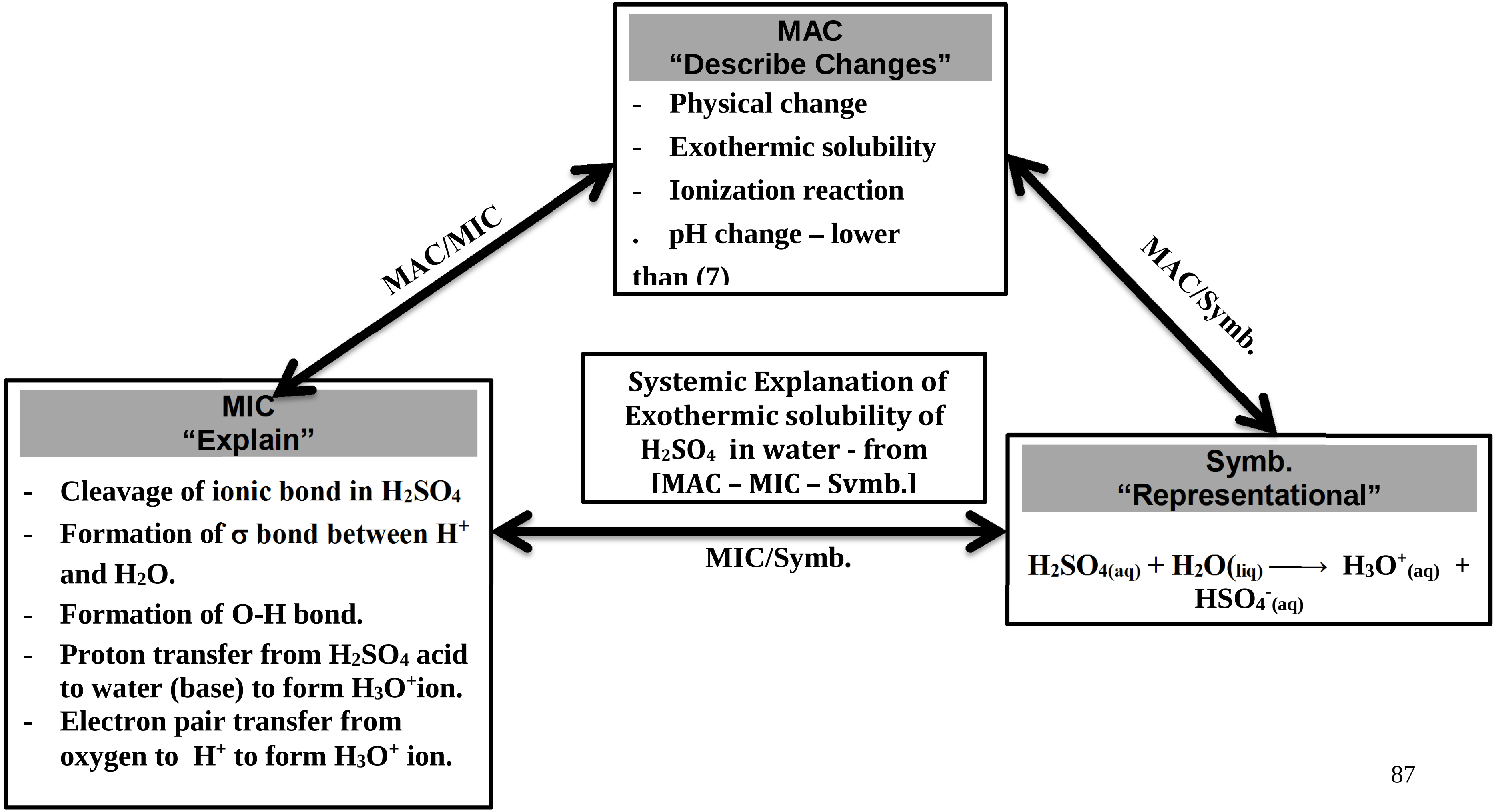
Symb.
"Representational"

$$HCl_{(g)} + H_2O_{(liq)} \rightleftharpoons H_3O^+_{(aq)} + Cl^-_{(aq)} + heat$$

Systemic Explanation of solubility of HCl Gas in water from [MAC – MIC – Symb.]

Systemic Triangle of Dilution of Conc.Sulphuric Acid withWater (ST4-Fig.6)

CONCEPTS: Solubility-Dilution



MAC
“Describe Changes”

- Physical change
- Exothermic solubility
- Ionization reaction
- pH change – lower than (7)

MAC/MIC

MAC/Symb.

MIC
“Explain”

- Cleavage of ionic bond in H_2SO_4
- Formation of σ bond between H^+ and H_2O.
- Formation of O-H bond.
- Proton transfer from H_2SO_4 acid to water (base) to form H_3O^+ion.
- Electron pair transfer from oxygen to H^+ to form H_3O^+ ion.

Systemic Explanation of Exothermic solubility of H_2SO_4 in water - from [MAC – MIC – Symb.]

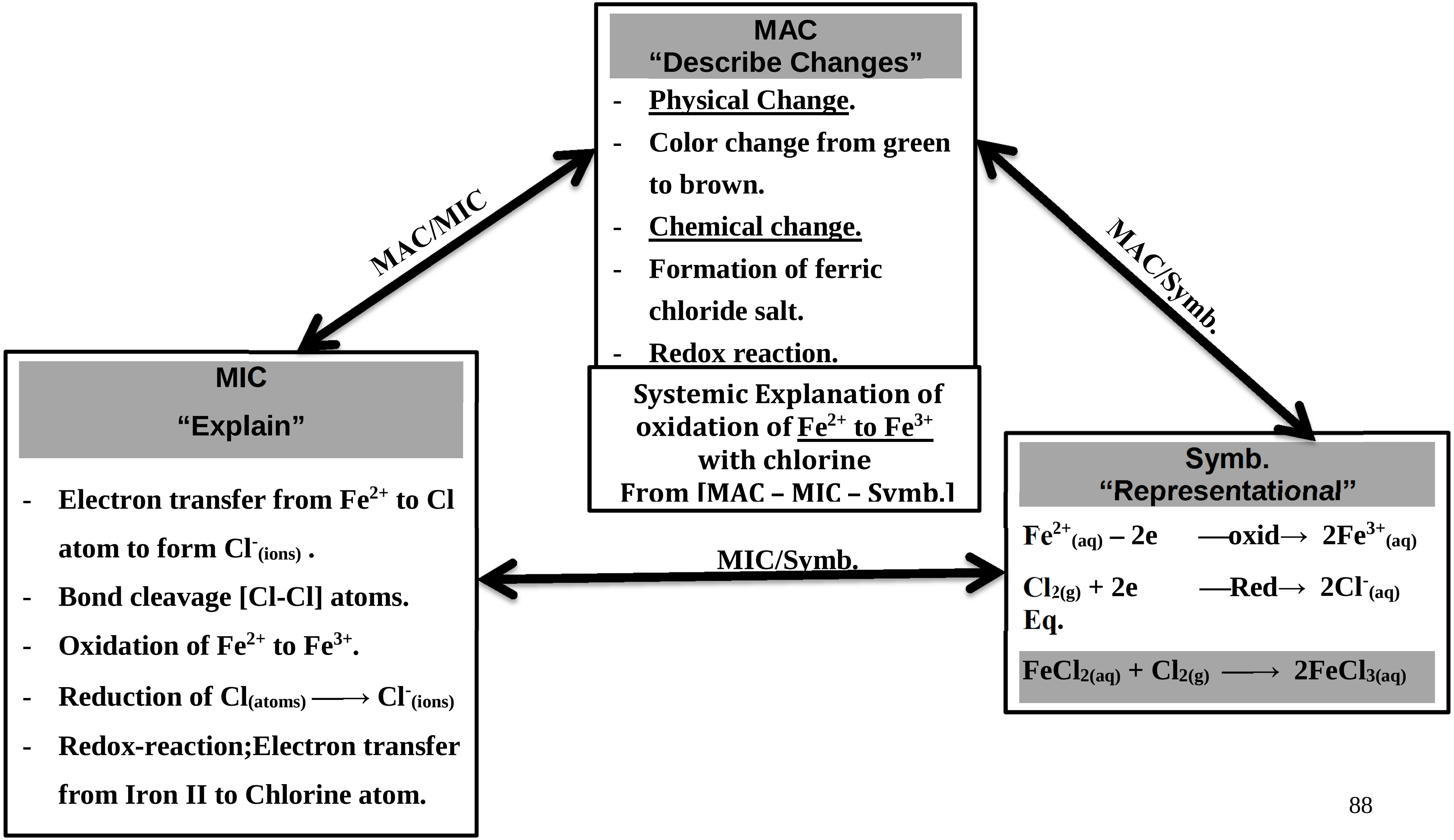
MIC/Symb.

Symb.
“Representational”

$H_2SO_{4(aq)} + H_2O_{(liq)} \longrightarrow H_3O^+_{(aq)} + HSO_4^-{}_{(aq)}$

Systemic Triangle of Oxidation of Fe^{2+} to Fe^{3+} by Chlorine (ST5-Fig.7)

CONCEPTS: Oxidation/Reduction/Redox Reaction



MAC
"Describe Changes"

- Physical Change.
- Color change from green to brown.
- Chemical change.
- Formation of ferric chloride salt.
- Redox reaction.

Systemic Explanation of oxidation of Fe^{2+} to Fe^{3+} with chlorine
From [MAC – MIC – Symb.]

MIC
"Explain"

- Electron transfer from Fe^{2+} to Cl atom to form $Cl^{-}_{(ions)}$.
- Bond cleavage [Cl-Cl] atoms.
- Oxidation of Fe^{2+} to Fe^{3+}.
- Reduction of $Cl_{(atoms)} \longrightarrow Cl^{-}_{(ions)}$
- Redox-reaction;Electron transfer from Iron II to Chlorine atom.

Symb.
"Representational"

$Fe^{2+}_{(aq)} - 2e \xrightarrow{oxid} 2Fe^{3+}_{(aq)}$

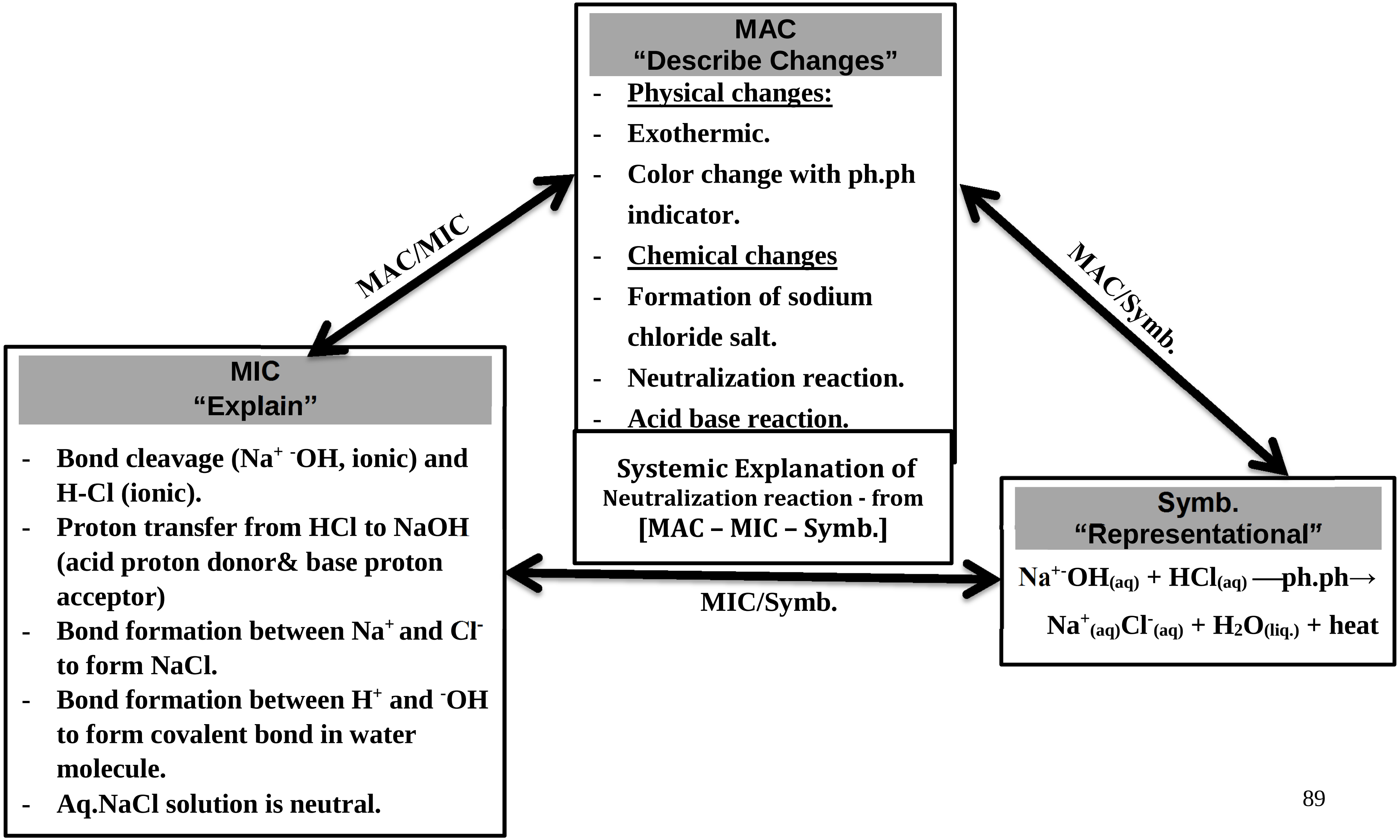
$Cl_{2(g)} + 2e \xrightarrow{Red} 2Cl^{-}_{(aq)}$

Eq.

$FeCl_{2(aq)} + Cl_{2(g)} \longrightarrow 2FeCl_{3(aq)}$

Systemic Triangle for the Acid-Base Reaction of HCl with NaOH(ST6-Fig.8)

CONCEPTS: ACID/BASE/Neutralization Reaction



MAC
"Describe Changes"

- **Physical changes:**
- **Exothermic.**
- **Color change with ph.ph indicator.**
- **Chemical changes**
- **Formation of sodium chloride salt.**
- **Neutralization reaction.**
- **Acid base reaction.**

Systemic Explanation of
Neutralization reaction - from
[MAC – MIC – Symb.]

MAC/MIC

MIC
"Explain"

- **Bond cleavage (Na^{+} ^{-}OH, ionic) and H-Cl (ionic).**
- **Proton transfer from HCl to NaOH (acid proton donor& base proton acceptor)**
- **Bond formation between Na^{+} and Cl^{-} to form NaCl.**
- **Bond formation between H^{+} and ^{-}OH to form covalent bond in water molecule.**
- **Aq.NaCl solution is neutral.**

MAC/Symb.

MIC/Symb.

Symb.
"Representational"

$$Na^{+-}OH_{(aq)} + HCl_{(aq)} \xrightarrow{ph.ph} Na^{+}_{(aq)}Cl^{-}_{(aq)} + H_2O_{(liq.)} + \text{heat}$$

Systemic Triangle for Industrial Preparation of NH_3 by "Haber Process" (ST7-Fig.9)

CONCEPTS: Haber Process/

Reversible Reactions/ Equilibrium

MAC
"Describe Changes"

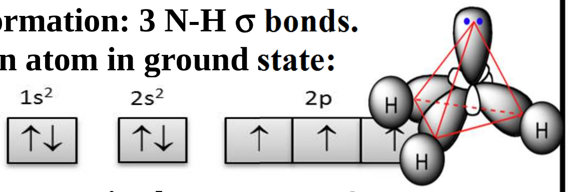
- **Physical changes**
- **Exothermic.**
- **Accompanied by change in volume & heat.**
- **Chemical change .**
- **-Formation of Ammonia.**
- **Combination reaction.**
- **Reversible.**

MAC/MIC

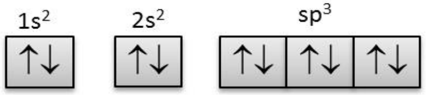
MAC/Symb.

MIC "Explain"

- **Bond cleavage: (N≡N), 2π, one σ bond and 3 H-H σ bonds.**
- **Bond formation: 3 N-H σ bonds.**
- **Nitrogen atom in ground state:**



- **Nitrogen atom in the sp3 state of hybridization gained (3) electron from chairing (3) hydrogen atoms**



- **The reaction is accompanied by decreasing in volume, thus increases in pressure increases the probability of collision and tends to reduce volume and therefore tends to shift the equilibrium to the side of reducing volume (forward reaction).**

Systemic Explanation of "Haber Process from [MAC – MIC – Symb.]

MIC/Symb.

Symb.
"Representational"

$$N_{2(g)} + 3H_{2(g)} \underset{[500^{o}C]}{\overset{Fe/P200-300}{\rightleftharpoons}} 2NH_{3(g)} + heat$$

4 volume **2 volume**

Systemic Triangle for the Synthesis of Methanol from Methyl Chloride (ST8-Fig.10)

CONCEPTS:Nucleophilic Substitution Reaction/SN2-Mechanism

MAC
"Describe Changes"

- **Physical change:**
- **Change in dipole moment.**
- **Chemical change:**
  - **Transfer of Methanol to Methyl chloride**
- **Nucleophilic displacement**

MAC/MIC

MAC/Symb.

MIC
"Explain"

- **Bond cleavage of σ C-Cl and ionic Na^+ ^-OH bond.**
- **Formation of σ C-OH and ionic Na^+Cl^-.**
- **Nucleophilic displacement of Cl^- with ^-OH via TS.**
- **S_N2 mechanism.**

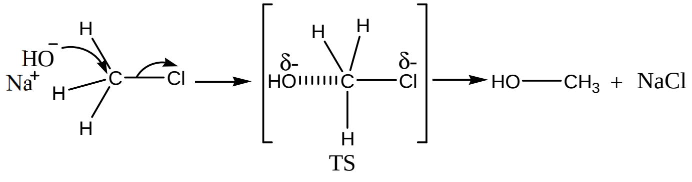
Systemic Explanation of formation of Methanol from Methyl chloride by Nuclephilic Substitution reaction
[MAC – MIC – Symb.]

MIC/Symb.

Symb.
"Representational"

$CH_3Cl + NaOH \longrightarrow CH_3OH + NaCl$

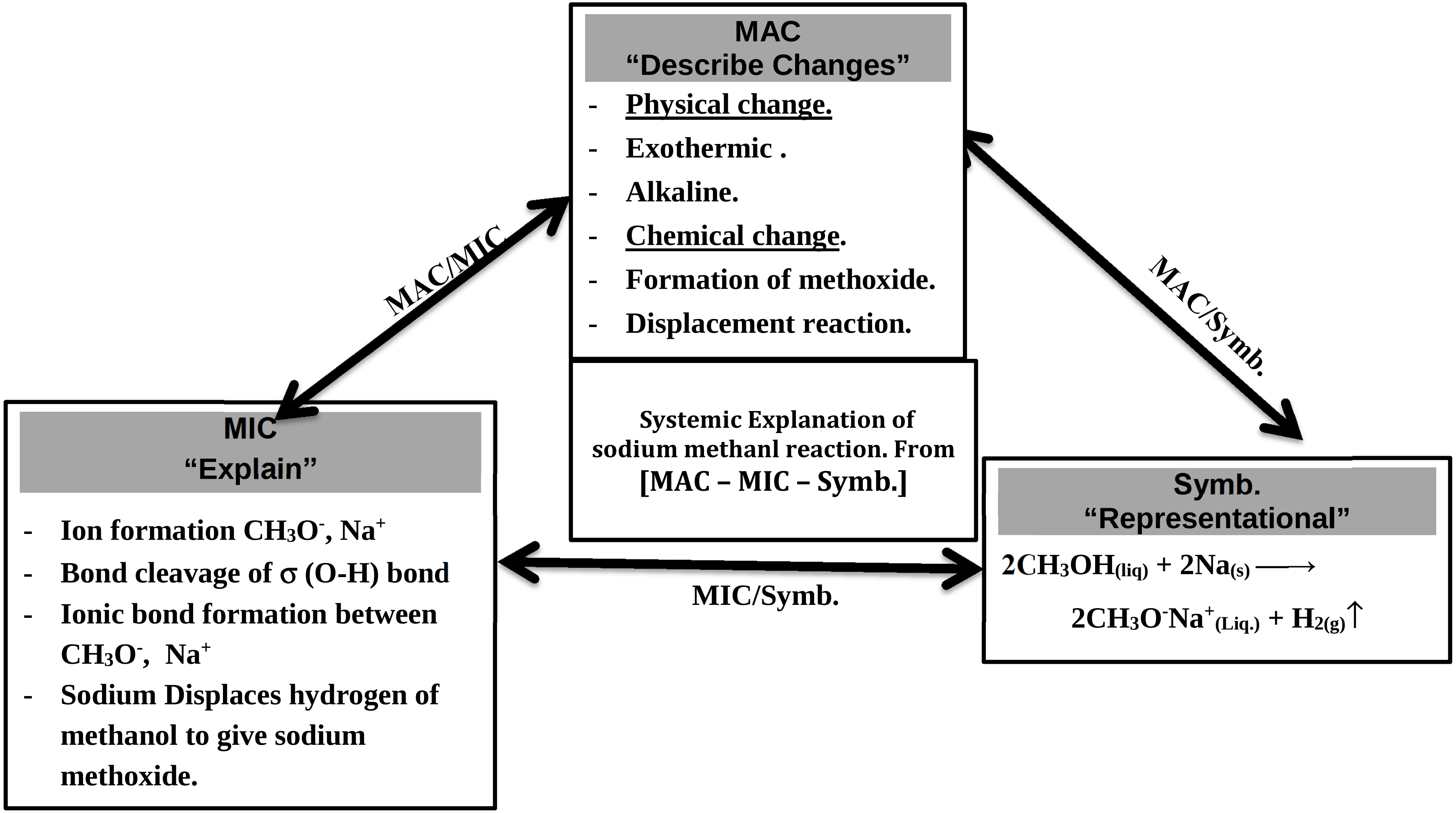
Mechanism



Systemic Triangle for the Reaction of Sodium with Methanol

(ST9-Fig.10)

CONCEPTS: Displacement Reaction



MAC
"Describe Changes"

- Physical change.
- Exothermic .
- Alkaline.
- Chemical change.
- Formation of methoxide.
- Displacement reaction.

Systemic Explanation of sodium methanl reaction. From [MAC – MIC – Symb.]

MIC
"Explain"

- Ion formation CH_3O^-, Na^+
- Bond cleavage of σ (O-H) bond
- Ionic bond formation between CH_3O^-, Na^+
- Sodium Displaces hydrogen of methanol to give sodium methoxide.

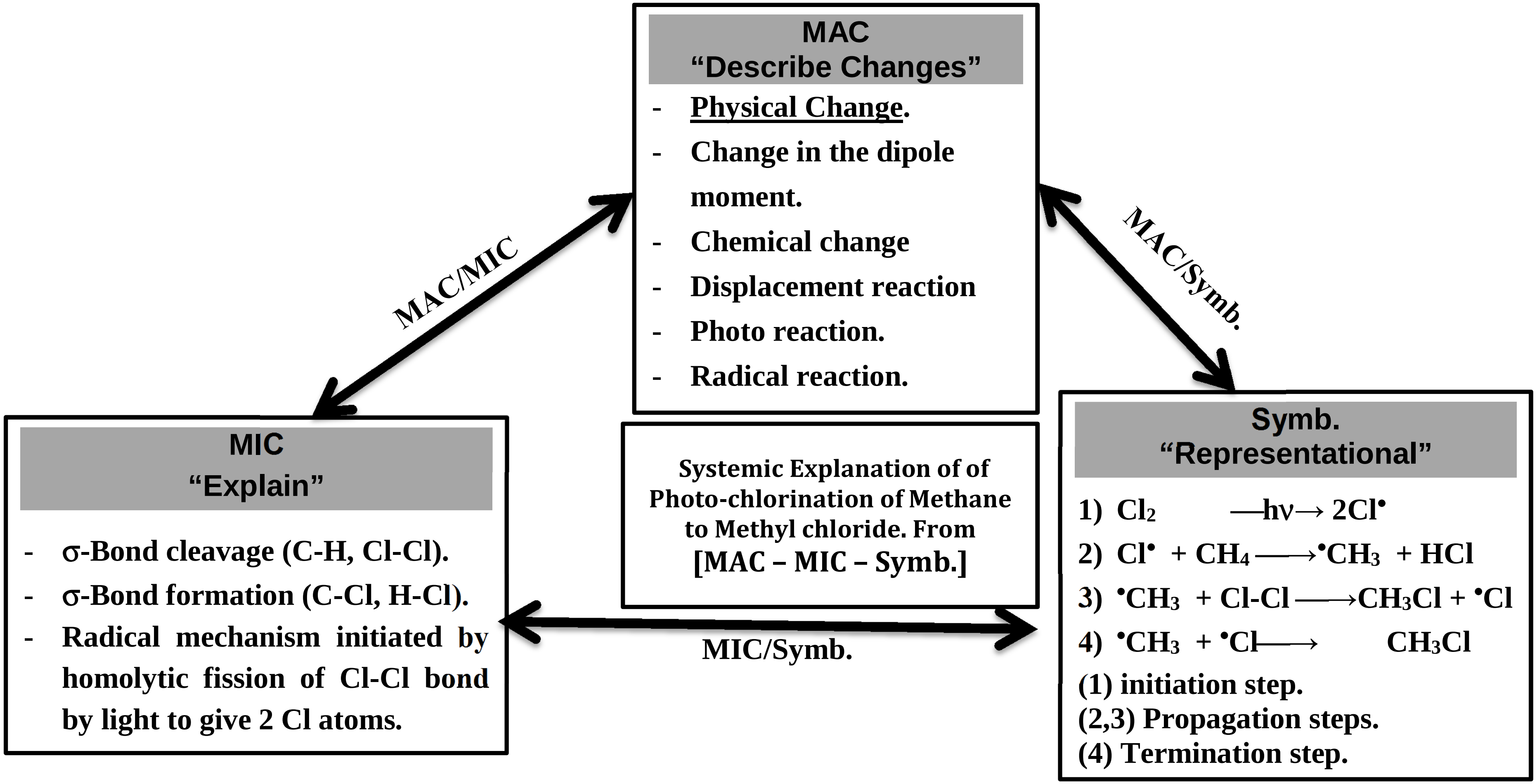
Symb.
"Representational"

$$2CH_3OH_{(liq)} + 2Na_{(s)} \longrightarrow 2CH_3O^-Na^+_{(Liq.)} + H_{2(g)}\uparrow$$

Systemic Triangle for Photo Chlorination of Methane to Methyl Chloride

(ST10-Fig.11)

CONCEPT: Photo- Chlorination/Radical Chain Reaction



MAC
"Describe Changes"

- Physical Change.
- Change in the dipole moment.
- Chemical change
- Displacement reaction
- Photo reaction.
- Radical reaction.

MAC/MIC

MAC/Symb.

MIC
"Explain"

- σ-Bond cleavage (C-H, Cl-Cl).
- σ-Bond formation (C-Cl, H-Cl).
- Radical mechanism initiated by homolytic fission of Cl-Cl bond by light to give 2 Cl atoms.

Systemic Explanation of of Photo-chlorination of Methane to Methyl chloride. From [MAC – MIC – Symb.]

MIC/Symb.

Symb.
"Representational"

1) $Cl_2 \xrightarrow{h\nu} 2Cl^{\bullet}$
2) $Cl^{\bullet} + CH_4 \longrightarrow {}^{\bullet}CH_3 + HCl$
3) ${}^{\bullet}CH_3 + Cl\text{-}Cl \longrightarrow CH_3Cl + {}^{\bullet}Cl$
4) ${}^{\bullet}CH_3 + {}^{\bullet}Cl \longrightarrow CH_3Cl$

(1) initiation step.
(2,3) Propagation steps.
(4) Termination step.

Systemic Triangle for the Reaction of Ethylene with HBr (ST11-Fig.12)

CONCEPT: Electrophilic Addition Reaction

MAC
"Describe Changes"

- Physical changes.
- Gas into liquid.

.Increase in dipole moment
(μ zero to 2.05).

Chemical Change.

Formation of ethyl chloride.

Addition reaction.

MAC/MIC

MAC/Symb.

MIC
"Explain"

- Bond cleavage : C=C π bond, H-Br σ-Bond.
- Bond formation: σ C-H, σ C-Br.
- Electrophilic addition to C=C π bond.
- Rehybridization of C from sp^2 to sp^3

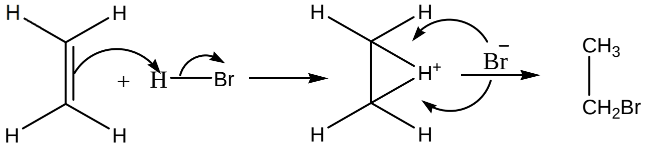
Systemic Explanation of Addition of HBr on Ethylene, From
[MAC – MIC – Symb.]

MIC/Symb.

Symb.
"Representational"

$H_2C{=}CH_{2(g)} + HBr_{(aq)} \longrightarrow CH_3\text{-}CH_2Br_{(aq)}$

Mechanism: E_2-mechanism:



Systemic Triangle for the Synthesis of Isopropanol from Acetone

(ST12-Fig.13)

CONCEPT: Reduction of the ketones/Addition of H_2 to the Carbonyl group of Ketones

MAC
"Describe Changes"

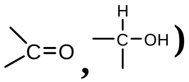
- **Physical change:**
- **Change in (b.p.)**
- **Change in dipole moment (μ)**
- **Chemical change**
- **Formation of isopropanol.**
- **Addition reaction**

MAC/MIC

MAC/Symb.

MIC
"Explain"

- **Bond cleavage : (C=O π) bond and (σ H-H)-bond.**
- **Bond formation: (2 σ bonds formed (C-H, O-H).**
- **Functional groups:**

Transformation:( **)**

- **Reduction reactions.**
- **Change in dipole/dipole attraction leading to change in B.P.**

Systemic Explanation of Addition of Catalytic reduction of acetone. From [MAC – MIC – Symb.]

MIC/Symb.

Symb.
"Representational"