Supplementary Data

This supplementary data is a part of paper entitled "Chemical Literacy: Performance of First Year Chemistry Students on Chemical Kinetics".

APPENDIX. Example of Items and Their Contexts of MC-CLTI

READINGS MATERIAL FOR PROBLEMS NUMBER 1 - 8: BREAD DOUGH FERMENTATION

Bread dough is made from flour (starch), salt, yeast, butter, oil and water. To make it, all ingredients are mixed together and stirred to make it homogeneous. The dough is then put into a container and stored in a room at 25 °C for two hours. In this phase, yeast (fungi) converts some carbohydrates of flour (starch), such as glucose, into alcohol and carbon dioxide. This process is called alcoholic fermentation. The simplified of alcoholic fermentation reactions can be symbolized by the equation:

$$\mathbf{C_6H_{12}O_6}(s) \rightarrow \mathbf{2\ CO_2}(g) + \mathbf{2\ CH_3CH_2OH}(l)$$

Glucose carbon dioxide alcohol

25. Bread dough is made from flour, salt, yeast, butter, oil and water. Explain, what makes the volume of the mixture expand?

A. Fermentation produces gases whose particles volume are greater than the particles volume of solids and liquids
B. Fermentation produces ethanol so that the mass of the dough increases
C. Fermentation produces gas which causes a hollow dough
D. Fermentation causes the ingredients of the dough to be arranged so that the volume expands
E. Yeast binds substances in the air so that the size of the dough expands

5. Glucose ($C_6H_{12}O_6$) can be obtained from the hydrolysis of sugar sucrose ($C_{12}H_{22}O_{11}$) using a hydrochloric acid catalyst. In simple terms, the reaction equation can be written:

$$C_{12}H_{22}O_{11}(aq) + H_2O(l) \xrightarrow{HCl} 2\ C_6H_{12}O_6(aq)$$

Glucose water sugar

An experiment on the relationship between the initial concentration of the reactants and the initial rate of the reaction provides the following data:

Experiment Number	Initial Concentration (M)		Initial Rate ($M\ s^{-1}$)
	[HCl]	$[C_{12}H_{22}O_{11}]$	
1	0,010	0,010	0,024
2	0,010	0,015	0,036
3	0,020	0,010	0,048

According to the data, what is the law of the rate of sucrose sugar hydrolysis?

A. $r = k\ [C_{12}H_{22}O_{11}][HCl]$
B. $r = k\ [C_{12}H_{22}O_{11}]^2[HCl]$
C. $r = k\ [C_{12}H_{22}O_{11}][HCl]^2$
D. $r = k\ [C_{12}H_{22}O_{11}][H_2O]$

E. $r = k [HCl][H_2O]$

8. To find out the effect of HCl concentration on the rate of sugar hydrolysis, a group of students made the concentration of sugar $[C_{12}H_{22}O_{11}]$ as a control variable. Why do they make concentration $[C_{12}H_{22}O_{11}]$ as a control variable? Explain!

   A. The sugar concentration also influences the concentration of HCl added to the reaction mixture
   B. The sugar concentration also affects the reaction rate
   C. The sugar concentration does not affect the concentration of HCl added to the reaction mixture
   D. The sugar concentration does not affect the reaction rate
   E. The sugar concentration also affects the concentration of HCl added to the reaction mixture and reaction rate

READINGS MATERIAL FOR PROBLEMS NUMBER 9 – 15: CARBON DIOXIDE IN LIFE

Carbon dioxide (CO_2) is a colorless gas whose density is 53% higher than dry air. At low concentrations this gas is odorless, while at high concentrations smells sharp and sour. Carbon dioxide is widely used as an inert gas in fire engine, supercritical solvents in the manufacture of low caffeine coffee, chemical process raw materials, carbonated beverage making materials, and as a refrigerant. The main source of carbon dioxide is combustion, organism respiration, fermentation, and acidification of limestone. Limestone reacts with hydrochloric acid according to the equation:

$$\mathbf{CaCO_3}(s) + 2\ \mathbf{HCl}(aq) \rightarrow \mathbf{CaCl_2}(aq) + \mathbf{H_2O}(l) + \mathbf{CO_2}(g)$$

9. A group of students intends to conduct research on the effect of surface area on the rate of reaction $CaCO_3$ and HCl (see the equation of reaction in the reading material). If the research is carried out at a fixed pressure, which variable must be controlled?

   A. Mass of $CaCO_3$
   B. Volume of H_2O and CO_2
   C. Volume of CO_2
   D. Volume of H_2O
   E. Size of granules of $CaCO_3$

10. Note the equation of $CaCO_3$ and HCl reaction in the text above. You are asked to do research with the question, "How does the reactant surface area affect the reaction rate?"

    Which component do you choose as an independent variable?

    A. Concentration of HCl
    B. Particle size of $CaCO_3$ granules
    C. Volume of CO_2
    D. Concentration of $CaCl_2$
    E. Mass of $CaCO_3$

11. For reaction: $CaCO_3(s) + 2\ HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$
What magnitude should be measured to answer the question, "How does the effect of the reactant surface area on the reaction rate?"

    A. Concentration of HCl
    B. Mass of $CaCO_3$
    C. Volume of CO_2
    D. Volume of H_2O and CO_2
    E. Time of reaction

12. The results of a research showed that the higher concentration of reactants was the higher rate of reaction. How is the claim explained?

    A. The higher concentration of reactants, the greater volume of reaction, the faster rate of reaction
    B. The higher concentration of reactants, the wider touch area of the reaction, the faster rate of reaction
    C. The higher concentration of reactants, the higher temperature of reaction, the higher frequency of collision, the faster rate of reaction
    D. The higher concentration of reactants, the greater particle size of HCl, the easier the particles collide, the faster rate of reaction
    E. The higher concentration of reactants, the greater frequency of collision, the higher rate of reaction

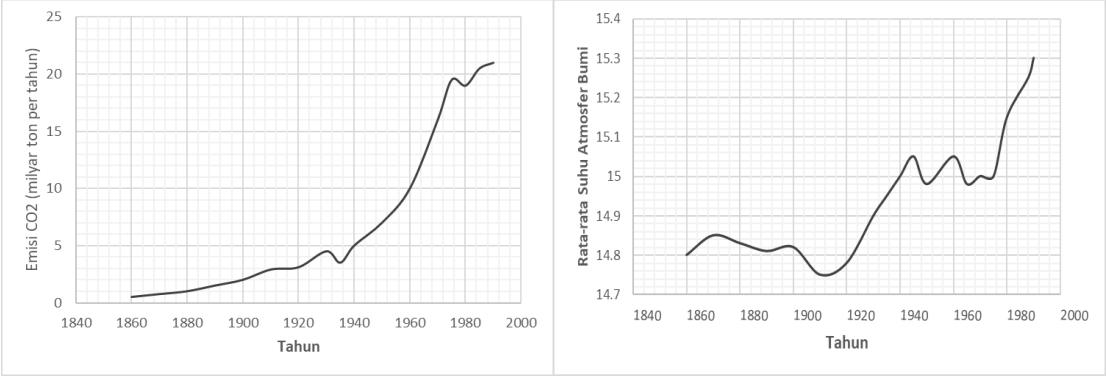
13. Based on the findings of an investigation "the higher temperature of reaction the higher rate of the reaction", a group of students explained:

    "The increase of reaction temperature increases the frequency of collisions of reactant particles so that the reaction rate also increases."

    Evaluate the explanation!

    A. True, the higher the temperature, the particles of reactants having similar properties are close to each other, the higher frequency of collision
    B. True, the higher temperature, the higher kinetic energy of the particle, the higher the effective collision frequency producing reaction
    C. True, the higher temperature, the higher activation energy of reaction, the higher frequency of collisions of reactant particles, the higher rate of reaction
    D. False, even though the reaction temperature is increased but if it does not reach the activation energy, the reaction rate will also not increase
    E. False, even though the reaction temperature is increased but if the collision frequency does not rise, the reaction rate will also not increase

15. Based on literature search, a student found a graph of carbon dioxide emissions into the atmosphere and changes in atmospheric temperature in the period 1860 s.d. 1990 as follows:



Based on the two graphs above a student confidently concluded that the increase in the average temperature of the Earth's atmosphere was caused by an increase in carbon dioxide gas emissions.

Is the conclusion in accordance with the available data? Explain!

A. It is appropriate, because the average carbon dioxide emissions into and the average temperature of atmosphere in 1990 are higher than in 1860B.
B. It is appropriate, because the average carbon dioxide emissions into and the average temperature of atmosphere are measured in the same timeframes
C. It is appropriate, because the both of data describe the atmospheric conditions, namely the mass of carbon dioxide gas emitted into the atmosphere and atmospheric temperature
D. It is not appropriate, the increase in carbon dioxide emissions into the atmosphere is not always followed by an increase in atmospheric temperature
E. It is not appropriate, because the related variables are not similar, carbon dioxide is a chemical in the form of gases while the atmosphere temperature reflects the kinetic energy of air

READING MATERIAL FOR PROBLEMS NUMBER 16 – 23: H_2O_2 AND ASEPTIC TECHNOLOGY

Through decades of observation and investigation, scientists finally found a food packaging technology involving no preservatives. The technology was known as aseptic technology. This technology can preserve food and drinks more than 6 months without damage. The principle of this technology is the manufacture of sterile packaged foods (free from destructive microbes), both the food, the packaging, and the packaging processes.

The packaging sterilization process involves a solution of 30% of hydrogen peroxide (H_2O_2) ~~30%~~. At 70 °C, H_2O_2 sterilizes material in six seconds. This compound kills microbes by oxidizing the materials composing of the microbial tissue.

Mammalian bodies also contain H_2O_2 as a byproduct of metabolism. This compound is toxic but easily decomposes according to the equation:

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

In the body this decomposition is catalyzed by the catalase enzyme, whereas in the laboratory is carried out by iodide (I^-) ion.

16. You are asked to find out the answer of the question:

"What is the effect of the reactant concentration on the rate of hydrogen peroxide decomposition carried out using iodide ions as catalyst?"

How do you make a design of the investigation?

A. Putting $[H_2O_2]$ and $[I^-]$ as independent variables
B. Placing $[H_2O_2]$ and $[I^-]$ as independent variables, and $[H_2O]$ and $[O_2]$ as dependent variables
C. Putting $[H_2O_2]$ and $[I^-]$ as independent variables and the rate of reaction as the dependent variable
D. Placing $[I^-]$ as a control variable
E. Placing $[I^-]$, temperature and pressure as control variables

17. What data are needed to answer the question "What is the effect of reactant concentration on rate of hydrogen peroxide decomposition catalyzed by iodide ions"?

A. Variation in concentration of $[H_2O_2]$ and $[I^-]$
B. Variation in concentration of $[H_2O]$ and volume of O_2
C. Variation in concentration of $[H_2O_2]$ and volume of O_2
D. Variation in concentration of $[H_2O_2]$ and time of reaction
E. Variation in concentration of $[H_2O]$ and time of reaction

18. If all control variables are controlled, what data do you need to answer the question:

"What is the effect of catalyst concentration of $[I^-]$ on the rate of hydrogen peroxide decomposition?"

A. Concentration of H_2O_2 and time of reaction
B. Concentration of H_2O_2 and the rate of reaction
C. Concentration of I^- and time of reaction
D. Concentration of I^- and the rate of reaction
E. Concentration of H_2O_2 and I^- and the rate of reaction

19. The results showed that the higher the concentration of the **I**$^-$ catalyst the shorter the time of decomposition of H_2O_2.

What does the conclusion mean?

A. The higher concentration of catalyst, the higher rate of reaction, regardless of the concentration of reactants and the conditions of reaction
B. The higher the concentration of catalyst, the higher the rate of reaction, regardless of the concentration of reactants and the conditions of reaction
C. At a certain reactant concentration, the higher concentration of catalyst the higher rate of reaction
D. Under a certain reaction conditions, the higher concentration of catalyst the higher rate of reaction
E. At a certain concentration of reactants and the conditions of reaction, the higher concentration of catalyst the higher rate of reaction

20. The decomposition of hydrogen peroxide is estimated to occur in two stages following ~~to~~ the mechanism of:

Stage I (fast) : $H_2O_2 + I^- \rightarrow H_2O + IO^-$
Stage II (slow) : $H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-$

Based on the mechanism, what is the rate of the reaction law?

A. $r = k[H_2O_2]^2$
B. $r = k[H_2O_2][I^-]$
C. $r = k[H_2O_2][IO^-]$

D. $r = k[I^-][IO^-]$
E. $r = k[H_2O_2]^2[I^-][IO^-]$

21. According to the hydrogen peroxide decomposition mechanism (see problem number 20), which of the following species acts as an intermediate?

A. H_2O_2 D. I^-
B. H_2O E. IO^-
C. I^- and IO^-

22. A company promotes the benefits of hydrogen peroxide for food products as follows:

- sterilizes packaging
- cleans food products from sulfur dioxide and chlorine residues
- can be used as food bleaching
- can be used as microbial activating compounds in cheese making
- can be used as an oxidizer in drying of egg whites

Which of these scientific evidences below supports the claim that hydrogen peroxide is a useful compound?

A. decomposes at room temperature
B. available in the market
C. a strong reducing agent
D. decomposes into environmentally friendly water and oxygen
E. killing bacteria

23. Which of the following statements is a theory?

A. The higher temperature of reaction, the higher decomposition rate of hydrogen peroxide
B. Reactions only occur when the reacting particles collide with one another with sufficient energy and appropriate orientation
C. The higher the concentration of reactants, the lower the rate of reaction
D. Chemical reaction can be observed from the formation of gas, changes in color, formation of sediments and changes in temperature
E. Reactions of gases can be observed from changes in pressure

READING MATERIAL FOR PROBLEMS NUMBER 24 – 30: CATALYTIC CONVERTER CONTROLS EMISSION OF CAR EXHAUST POLLUTANT

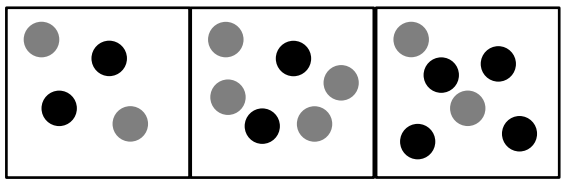
Air pollution has become a global problem. About 92% of the world's population lives in areas with air pollution above the threshold determined by the WHO. Some air pollutants such as SO_2, NO_x, and CO come from burning fossil fuels that occur inside motor car engines. To reduce exhaust emissions of air pollutants, scientists construct a catalytic converter, a device that is installed between the engine and the exhaust of motor cars. This device contains a catalyst for catalytic reaction of the toxic exhaust gases to non-toxic compounds. In air, nitrogen oxide (NO, N_2O_5) reacts according to the equation:

$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$; $2\ N_2O_5(g) \rightarrow 4\ NO_2(g) + O_2(g)$

Whereas carbon monoxide (CO) follows the equation:

$2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$

24. The following three submicroscopic representations represent the mixture of reaction between NO gas (black marbles) and O_2 gas (gray marbles).



(A) **(B)** **(C)**

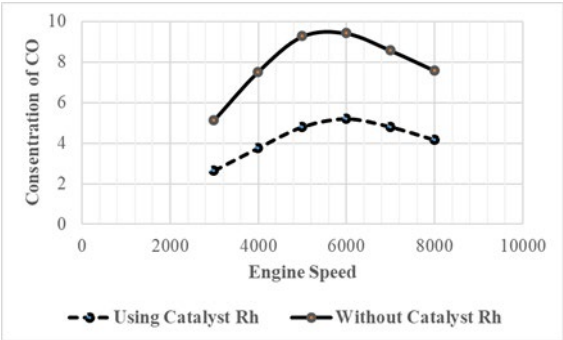
If the ratio of reaction rate of mixture (A):(B):(C) is 1:2:4, what is the total reaction order of NO_2 formation from NO and O_2?

A. 1
B. 3
C. 5
D. 2
E. 4

25. In accordance with the submicroscopic representation of NO and O_2 gases (see problem number 24), what factors influence the rate of that reaction?

A. Pressure
B. Catalyst
C. Kind of substances
D. Temperature
E. Surface area

26. Investigations about the effect of using the "Catalytic Converter" inside of motor car exhausts on CO gas emissions carried out in various engine speed provide the following data:



Which does of the following claims correspond to those data?

A. The higher the engine speed, the higher the CO concentration in the exhaust gas
B. The higher the engine speed, the lower the CO concentration in the exhaust gas
C. Catalytic converters are not effective in reducing CO concentrations in the flue gas
D. Catalytic converters reduce CO concentration in the flue gas
E. The catalytic converter does not affect the CO gas concentration in the exhaust gas

28. You are asked to answer the question: "Which is more effective in reducing pollutants contained in the exhaust gas of motor vehicles, platinum converter or rhodium converter?"

Which of the following research designs do you choose?

A. Take three different types of cars; the first type was installed with a platinum converter, the second type was installed with a rhodium converter, and the third type was not installed with a catalytic converter. Measurement of exhaust emissions is carried out at the same engine speed.
B. Take three different types of cars; the first type was installed with a platinum converter, the second type was installed with a rhodium converter, and the third type was not installed with a catalytic converter. The measurement of exhaust emissions is carried out at different engine speed.
C. Take the same three cars; The first is a platinum converter, the second is a rhodium converter, and the third is not installed with a catalytic converter. The measurement of exhaust emissions is carried out at the same engine speed.
D. Take the same three cars; The first is a platinum converter, the second is a rhodium converter, and the third is not installed with a catalytic converter. The measurement of exhaust emissions is carried out at different engine speed.
E. Take the same three cars; The first is a platinum converter, the second is a rhodium converter, and the third is not installed with a catalytic converter. The measurement of exhaust emissions is carried out for three different types of fuel.

29. N_2O_5 can be broken down according to the equation:

$$2\ N_2O_5(g) \rightarrow 4\ NO_2(g) + O_2(g)$$

A student found that the rate of N_2O_5 decomposition can be determined by two ways, i.e., the initial rate of reaction way and the concentration as a function of time way. Both of the ways can be used to determine the reaction order.

Based on this information, what do you think about the scientific method?

A. The scientific method actually does not exist. Always can be used to find knowledge
B. There is only one scientific method that can be used to find scientific knowledge
C. The scientific method is diverse, all the ways that can be used to find scientific knowledge are scientific methods
D. The same scientific knowledge can be obtained using different scientific methods
E. Determination of the order of N_2O_5 gas decomposition reaction can be done using two methods

30. Pay your attention to the equation of decomposition reaction of N_2O_5 gas as shown in number 29. If the initial concentration of N_2O_5 is 0.620 M, what is its concentration after 3 half-life periods?

A. 0,0825 M
B. 0,3100 M
C. 0,1030 M
D. 0,0775 M
E. 0,2070 M