Instructions for Instrument Administration

To ensure the effective administration of the assessment instrument, please follow the instructions below:

1. Ensure that all students have a clear understanding of the assessment's purpose and structure.

2. Inform students that the assessment will take approximately 120 minutes to complete. Adjust this timing based on the specific needs and pace of your students.

3. Instruct students to answer all questions to the best of their ability and to show their work where applicable.

4. Remind students that there may be multiple correct answers for some questions, and partial credit can be earned.

Multiple Choice Questions (1 point): Each question has only one correct option. Students should select the correct answer from the provided choices.

Multiple Choice Questions (2 points): These questions may have 1-3 correct propositions. Students must select all correct options to earn full points.

Two-Tier Diagnostic Questions (3 points): Students must choose the correct statements and provide detailed reasoning to earn full points.

Open-Ended Questions (4 points): Students should provide comprehensive explanations and show their reasoning for full credit.

5.Carefully review each student's responses, providing partial credit where applicable.

The Instrument for students' chemical thinking

1.Multiple choice questions (1 point)

Each question provided in this section has only one correct option. A correct answer for questions L1A to L1F will earn 1 point.

L1A. Without the addition of any other reagents, which of the following substances cannot be differentiated through mere observation?

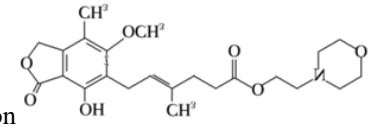
A. Fe_3O_4 (s), AgCl (s), $K_2Cr_2O_7$ (s), Cu (s)

B. SO_2 (g), I_2 (g), NO_2 (g), Cl_2 (g)

C. $CuSO_4$ (aq), $BaCl_2$ (aq), Ca $(NO_3)_2$ (aq), $KHCO_3$ (aq)

D. $FeSO_4$ (aq), $KMnO_4$ (aq), $FeCl_3$ (aq), $NaHCO_3$ (aq)

L1B. Mycophenolate mofetil (MMF) is widely used to inhibit cell proliferation during organ

transplantation due to its structural simplification 

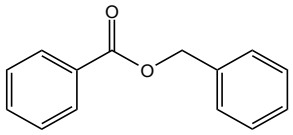
. Which of the following statements regarding MMF is correct?

A. MMF can react with metallic sodium but is not susceptible to hydrolysis.

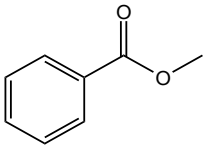
B. MMF can be oxidized by acidic $KMnO_4$ solution when added to bromine water.

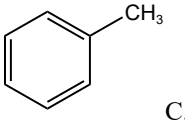
C. MMF can undergo an elimination reaction but is not compatible with bromine water.

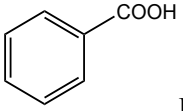
D. MMF can undergo both hydrolysis and elimination reactions.

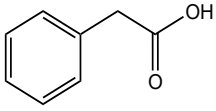
L1C. Benzyl benzoate 

is a food flavoring with a fruity aroma. According to the principle of retrosynthesis, among the following four substances, which one can serve as the starting material for the synthesis of benzyl benzoate?

A. 

B. 

C. 

D. 

L1D. Which of the following statements regarding nitrogen (N), phosphorus (P), and their compounds is false?

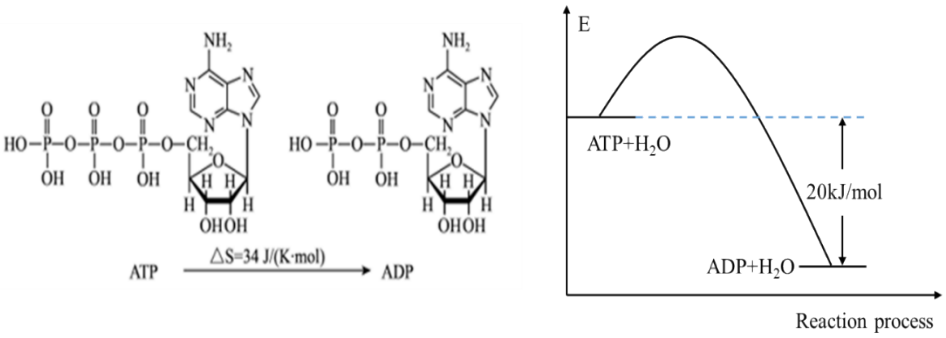
A. The electronegativity of nitrogen is higher than that of phosphorus, resulting in higher polarity of NCl_3 compared to PCl_3.

B. The atomic radius of nitrogen is smaller than that of phosphorus, leading to stronger stability of the N ≡ N bond than the P ≡ P bond.

C. NH_3 molecules can form hydrogen bonds with water molecules, resulting in higher solubility of NH_3 in water compared to PH_3.

D. The intermolecular forces of HNO_3 are weaker than those of H_3PO_4, leading to a lower melting point for HNO_3 than H_3PO_4.

L1E. Adenosine triphosphate (ATP) is a molecule that directly provides energy for cellular processes. The process of ATP hydrolysis (breakdown) into adenosine diphosphate (ADP) releases energy and is an essential part of cellular metabolism. Which of the following statements about this process is incorrect?



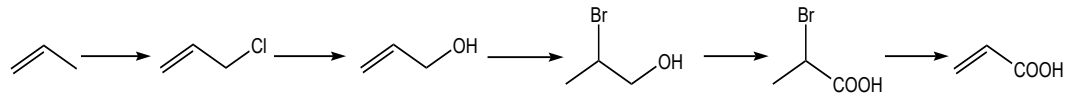
A. ATP hydrolysis into ADP releases energy in the form of heat and tends to drive the reaction towards ADP formation.

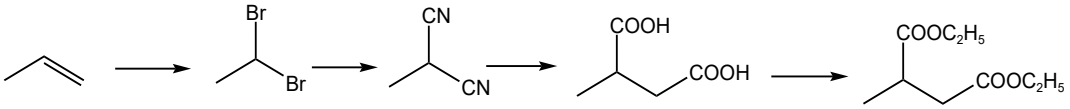
B. The process of ATP hydrolysis increases the degree of entropy (disorder) in the system, contributing to a tendency towards ADP formation.

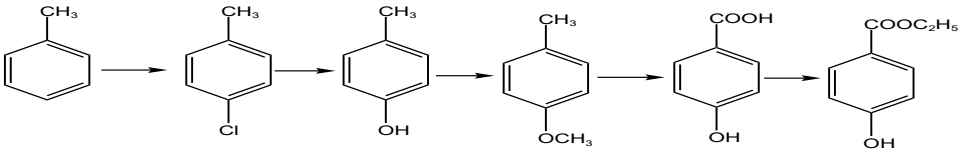
C. The hydrolysis of ATP to ADP is an energetically favorable reaction, with a decrease in Gibbs free energy.

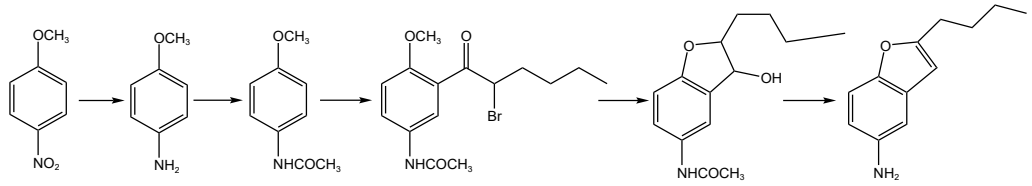
D. The hydrolysis of ATP to ADP typically requires an enzyme catalyst and does not occur spontaneously under physiological conditions at 37°C and neutral pH.

L1F. Which of the following synthesis routes does not require the use of functional group protection?

A.


B.


C.


D.


2.Multiple choice questions (2 points)

In the questions presented below, there might be 1-3 correct propositions among choices ① to ④. Selecting all the correct propositions will earn 2 points, while choosing some of the correct propositions will earn 1 point. Selecting the wrong one earns no points.

L2A. 3.0g of an organic compound is completely burned in excess oxygen, resulting in the production of 4.4g of CO_2 and 1.8g of H_2O. Which of the following statements is incorrect?

① The relative molecular weight of this organic compound cannot be 60.

② This organic compound must contain an oxygen element.

③ The molecular formula of this organic compound must be C4H8O4.

④ The ratio of the number of carbon atoms to the number of hydrogen atoms in the organic molecule must be 1:2.

A. ①② B. ①③ C. ②③ D. ②④ E. ①

L2B. Which of the following propositions about the exothermic reaction of hydrogen peroxide (H_2O_2) decomposition is correct?

① At any temperature above absolute zero, the reaction can proceed spontaneously in the forward direction.

② Manganese dioxide (MnO_2) can reduce the activation energy of the reaction, leading to greater progress in the forward direction.

③The reason why H_2O_2 can dissolve in H_2O in any proportion may be due to the high polarity of both H_2O_2 and H_2O molecules.

④ Based on the molecular structure of H_2O_2, the H_2O_2 solution should not exhibit acidity.

A · ①④ B · ③ C · ②③ D · ①③ E. ④

L2C. Which of the following explanations regarding material properties is reasonable?

① The conductivity of graphite is attributed to the presence of freely movable electrons in its layered structure.

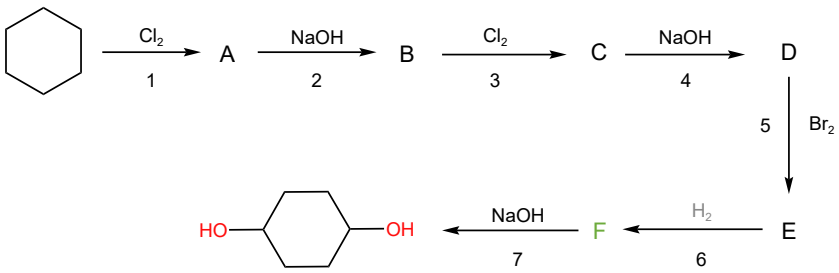
② The increased stability of CH_3CH_3 compared to CH_2=CH_2 is due to the presence of unstable π bonds in ethylene.

③ The higher boiling point of water compared to H_2S is due to the stronger H-O bond compared to the H-S bond.

④ The higher melting point of diamond compared to silicon carbide is attributed to the smaller radius of carbon atoms compared to silicon (Si) atoms, and the greater stability of the C-C bond.

A · ①②④ B · ②③ C · ①③ D · ①④ E. ②

L2D: Which of the following statements about the route for synthesizing 1,4-cyclohexanediol from cyclohexane is correct?



① The reaction types that occur in process 1 and process 3 are consistent.

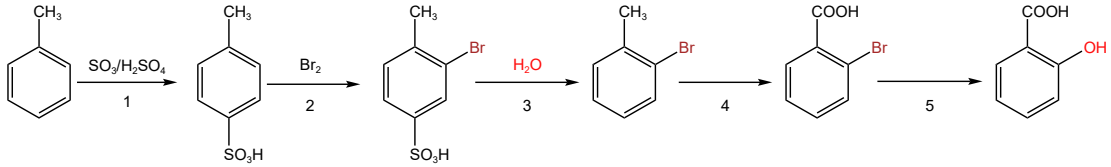
② According to the synthesis route analysis, compound D is  .

③ The introduction and removal of Cl in processes 3 and 4 are aimed at introducing functional groups in the para position of cyclohexane.

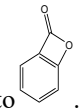
④ Process ⑤ requires the introduction of sufficient Br_2.

A. ①③ B. ③④ C. ③ D. ②③ E. ①②

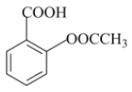
L2E. The diagram provided illustrates the synthesis route of salicylic acid from toluene. Your task is to identify the statement that is incorrect.



① Steps 1 and 2 can be omitted to reduce production steps and improve salicylic acid yield.

② Under certain conditions, salicylic acid can be converted into  .

③ The order of steps 4 and 5 can be interchanged.

④ If the structural formula of aspirin is known as  , then salicylic acid is an important raw material for synthesizing aspirin.

A. ①③④ B. ①③ C. ②④ D. ③ E. ①②

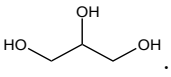
3. Two-tier diagnostic questions (3 points)

There may be multiple correct statements among choices ① to ④ in the following questions. If all correct statements are chosen and detailed reasoning is provided in (2), 3 points will be awarded. Selecting all correct statements but without adequate reasoning will earn 2 points, while choosing some correct statements will earn 1 point. Only selecting a single correct statement will also earn 1 point, whereas selecting an incorrect statement will not receive any points.

L3A. (1) Which of the following statements about identifying an organic substance that is one of the main components of automotive antifreeze is correct?

A. If the substance is heated under the action of concentrated sulfuric acid to generate a gas that can decolorize potassium permanganate solution, then the substance may contain hydroxyl groups.

B. If the mass fractions of elements obtained through combustion analysis are 38.7% for carbon, 9.7% for hydrogen, and 51.6% for oxygen, then the empirical formula for this substance is CH_3O.

C. If the nuclear magnetic resonance hydrogen spectrum of the substance has four peaks, its structural formula may be determined as 

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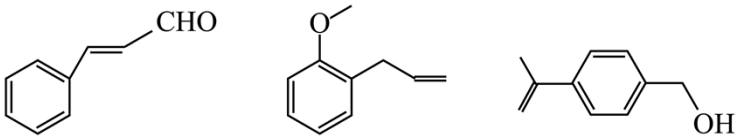
D. If the molecular formula of the substance is $C_3H_8O_3$ and there is an absorption peak of C-O in the infrared spectrum, then there are two isomers of the substance.

A. ①②③ B. ①②④ C. ①④ D. ①② E. ②

(2) Please provide a detailed analysis of the background of the item and explain the reasons for choosing the above options.

L3B · （1）The structures of these compounds are shown in the figure below. Which of the following statements is correct?



a b c

① b and c are isomers of each other.

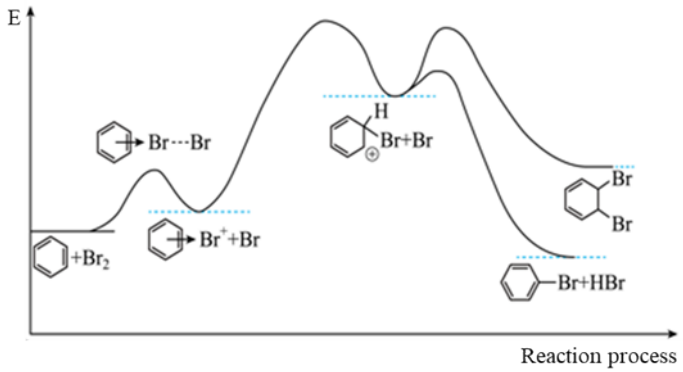
② All carbon atoms in molecules a and c may lie in the same plane.

③ a, b, and c can undergo oxidation, addition, polymerization, and esterification reactions.

④ a, b, and c can cause the fading of acidic potassium permanganate solution and brominated carbon tetrachloride solution.

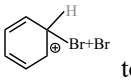
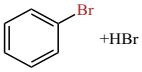
(2) Please provide a detailed analysis of the background of the item and explain the reasons for choosing the above options.

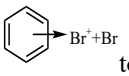
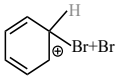
L3C. In the figure, the catalytic reaction process between benzene and liquid bromine is depicted.



(1) Please select the correct proposition about this reaction from the options below:

① Based on the information in the figure, the catalytic reaction between benzene and Br_2 is exothermic.

② Under the influence of the catalyst, the rate of transformation from  to  is faster than the rate of generation to  .

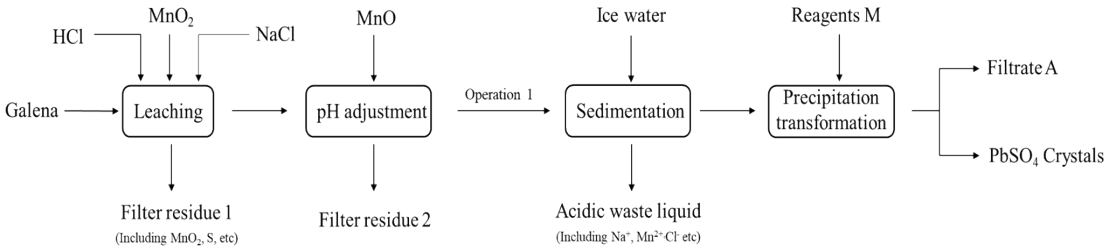
③ The rate of this reaction primarily depends on the step involving the transformation of  to  .

④ The main product obtained from the catalytic reaction between benzene and Br_2 is  .

A. ②③ B. ①② C. ②③④ D. ①④ E. ①③④

(2) Please analyze the reaction in detail and explain the reason for choosing the above option?

L3D.（1）In industrial production, $PbSO_4$ crystals are prepared using galena, which is mainly composed of PbS and contains impurities such as FeS_2. The process flow is shown in the figure below.



Given that $PbCl_2$ is insoluble in cold water and easily soluble in hot water, and $PbCl_2$ (s) + $2Cl^-$ (aq) ⇌ $PbCl_4^{2-}$ (aq) with $\Delta H > 0$, which of the following statements is correct?

① The purpose of introducing MnO is to remove Fe^{3+} from the solution.

② Adding NaCl during leaching is beneficial for increasing the yield of $PbSO_4$ crystals.

③ The main ion reaction during leaching is $MnO_2 + PbS + 4H^+ + 2Cl^- = PbCl_2 + S + Mn^{2+} + 2H_2O$.

④Adding ice water during sedimentation is beneficial for more complete $PbCl_2$ precipitation.

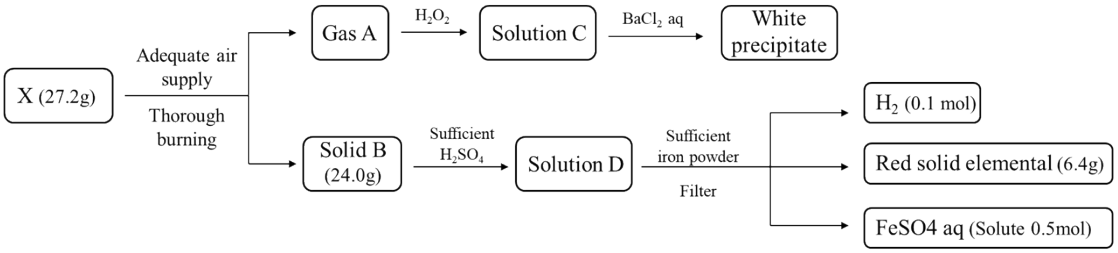
(2) Please provide a detailed analysis of the background of the item and explain the reasons for choosing the above options.

A. ①③④ B. ②④ C. ②③ D.①②④ E. ②

4. Open-ended questions (4 points)

L4A.Solubility is an important property for chemists to consider, as different substances generally exhibit varying levels of solubility under identical conditions. For instance, phosphine displays weaker solubility in water compared to ammonia (both of which release heat upon dissolution), while calcium chloride exhibits greater solubility in water than sodium chloride (with calcium chloride causing a significant temperature increase upon dissolution, whereas sodium chloride does not). Please provide a comprehensive explanation for the reasons behind these phenomena based on different chemical perspectives. Based on the above examples, please think and answer the causes responsible for the differences in solubility observed between different substances.

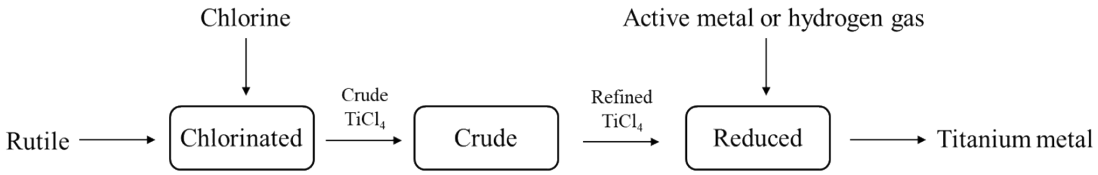
L4B. (1) A researcher has obtained mineral X in nature and determined that it contains only three elements. The researcher plans to test substance X using a specific process. What is the chemical formula for compound X, and what is the reason for your answer? (2 points)



(2) Chemistry is the science of synthesizing and studying substances. If an unknown organic compound is synthesized and purified in the laboratory, what types of evidence must be collected to accurately identify the compound? (2 points)

L4C. Titanium (Ti) and its alloys have advantages such as low density, lightweight, high specific strength, and corrosion resistance, and are known as “versatile metals”.

The process of using rutile to prepare titanium metal in traditional industry is as follows:



Known: There are direct chlorination and carbon chlorination methods for conversion.

a. Direct chlorination: $TiO_2(s)+2Cl_2(g)=TiCl_4(g)+O_2(g)$; ΔH=+180.8 kJ•mol^{-1}

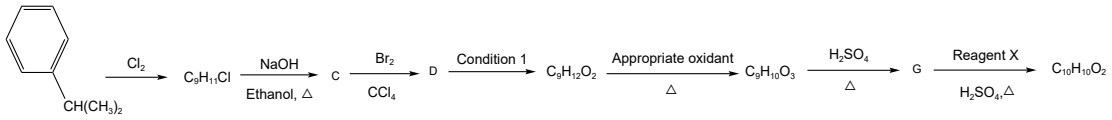
b. Carbochlorination: $TiO_2(s)+2Cl_2(g)+2C(s)=TiCl_4(g)+2CO(g)$

(1) List the factors that may affect the yield of $TiCl_4$ (g) in the direct chlorination process of rutile and provide reasons for each. (1 point)

(2) Analyze whether the direct chlorination method or carbon chlorination method should be chosen in the chlorination process of rutile, given the reaction: C (s) + O_2 (g) = 2CO (g) ΔH = -221 kJ•mol^{-1}. Provide a reason for your analysis. (1 point)

(3) In the early 21st century, laboratory research discovered that metallic titanium could be directly obtained through molten salt electrolysis using molten $CaCl_2$ as the electrolyte, graphite as the anode, and TiO_2 as the cathode. Analyze the advantages of this method compared to the traditional industrial preparation of titanium metal from multiple perspectives (2 or more). Provide reasons for your analysis. (2 points)

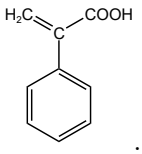
L4D. Organic compound H is an aromatic ester drug used to treat gastrointestinal diseases. The synthesis route for H, starting from compound A as the basic raw material, is illustrated in the figure below. Please answer the following questions:



A B E F H

Given:

a. Compound B has a nuclear magnetic resonance hydrogen spectrum with four peaks.

b. The structural formula of compound G is provided 

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(1) Please provide the molecular formula of compound D and the simplified structural formula of compound E. Additionally, include your reasons for your answer. (2 points)

(2) Compound H has multiple aromatic isomers. Please specify the common isomer(s) that meet the following conditions (excluding cis-trans isomerism). Also, provide reasons for your answer. (1 point)

① Reacts with $NaHCO_3$ solution.

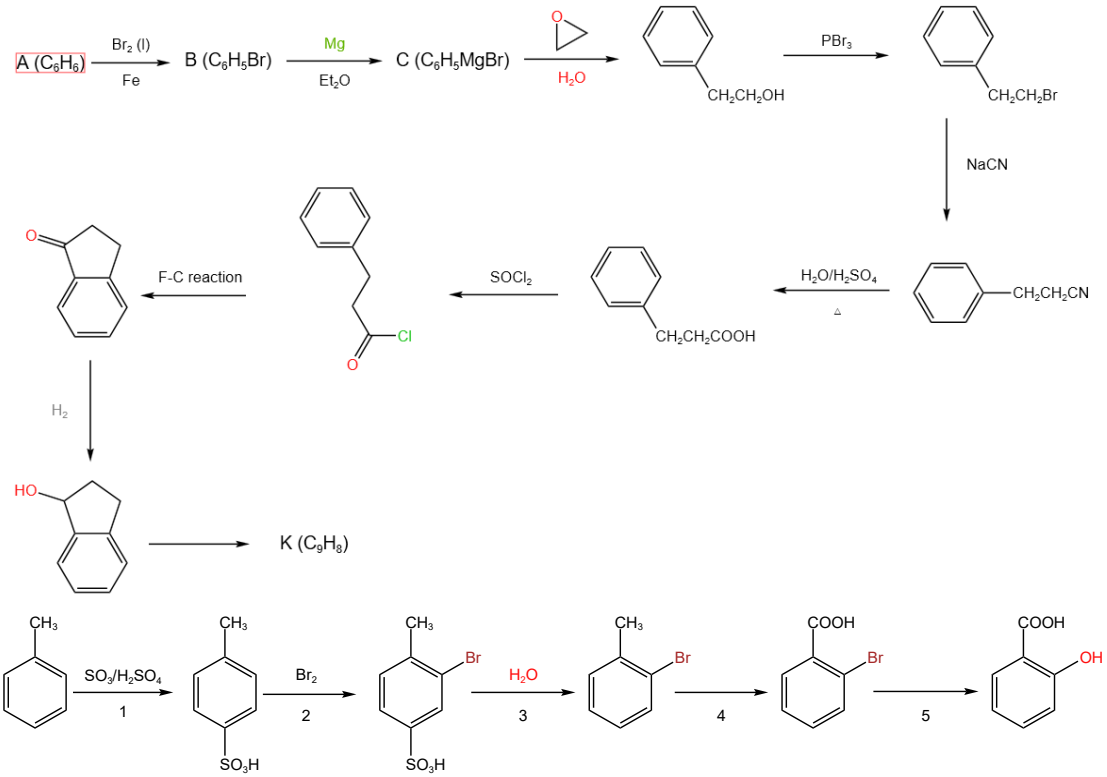
② Causes decolorization of bromine water through chemical reactions.

③ Contains two substituents on the benzene ring.

(3) Chemistry is a science that focuses on substance synthesis. If you synthesize and purify an unknown

organic compound in the laboratory, what types of evidence should you collect to fully identify the organic compound? (1 point)

L4E. Given that the laboratory intends to synthesize organic compounds using benzene as a raw material, please outline the synthesis route (2 points) and provide an explanation for the rationale behind the chosen route (1 point). Using the synthesis plan in this question as an example, describe the fundamental concept of synthesizing an unfamiliar organic compound (1 point).



(The commonly used format for representing synthesis routes is: A → B (target product)

The provided organic synthesis routes and reactions are available as references for this question.