Experiment Question: Sample Question

Task Maximum Score: 600

*The sample question serves only as a reference; the format is subject to change.
*Only English version is available for sample question, but both Chinese and English will be available in the final round of the competition.

Preparation time: 12 mins
Maximum Presentation time: 5 mins + 2-3 mins of Q&A session
Materials: 3 A4 paper with any stationery (participants' own stationery)

Task:

With the common apparatus available in a secondary school laboratory, please design an experiment to determine the equilibrium constant of the esterification reaction of ethanol and ethanoic acid.

Guidance:

1) If you wish to apply the concept(s) mentioned in the information sheet, reading through the whole passage may help increase the depth of your presentation and guide your thinking.
2) This task emphasizes on the method but not the actual numbers, just write down the required equations with relevant symbols
3) This task includes calculation part. Although it is not necessary to calculate the exact value, you may need to suggest a method of how finding (a) certain value(s) can help get the whole math done.
4) Think of the expected observation(s) of your experiment so as to prove that your experiment has achieved the task aim.
5) You may consider drawing a labeled diagram for clearer illustration of your set up.
6) You can think of the organization of your presentation, like explaining the principles before the experiment details or the reverse.

You may (but not compulsory) apply the information in the information sheet to your task.

Information Sheet

Reversible, Irreversible Reactions and Dynamic Equilibrium

Some chemical reactions proceed in one direction only. The reactants keep converting to products until at least one of the reactants (limiting reagent) is used up. These reactions are called irreversible, they proceed in one direction and they will go to completion. Examples include acid-alkali neutralization, rusting of iron.

On the other hand, some reactions do not go to completion. They are called reversible reactions and has a ⇋ sign indicating that the reaction is irreversible. Examples include esterification (formation of esters), thermal decomposition of calcium carbonate. These reactions can proceed in either direction, the reaction proceeding from left to right is called the forward reaction, and the reverse is called the backward reaction.

Chemical equilibrium is the state reached by a chemical system when the rates of forward and backward reactions become equal, but the reactions of both sides are still continuing, so it is called dynamic equilibrium. Characteristics of dynamic equilibrium are summarized as followed:

1) Equilibrium can only be established in a closed system, when no substances can enter or leave the system.
2) Equilibrium can be reached from either the forward or the backward direction of the reversible reaction.
3) At equilibrium, the rate of forward reaction is equal to the rate of the backward reaction.
4) At equilibrium, both reactants and products are present and their concentrations remain unchanged. Hence, there are no observable changes of the reaction mixture.

More about Equilibrium

Suppose a reaction has an equation as shown below:

$$aA + bB \leftrightharpoons cC + dD$$

It has a equilibrium constant expressed as below,

$$\frac{[C]_{eqm}^{c}[D]_{eqm}^{d}}{[A]_{eqm}^{a}[B]_{eqm}^{b}}$$

With products (of the forward reaction) in the nominator and reactants in the denominator, and the concentrations of the species are expressed inside brackets.

An equilibrium in which all the reactants and products are of the same phase is a homogeneous equilibrium. An equilibrium in which two or more phases are present is a heterogeneous equilibrium. In heterogeneous equilibrium, the concentrations of solids and liquids do not appear in the expression of equilibrium constant. Apart from this, in homogeneous equilibrium, if the concentration of a species do not change significantly during the reaction, we omit is in the equilibrium constant expression.

To determine the equilibrium constant of a certain reaction, we usually set up an ICE Table (initial-change-equilibrium) table for clearer calculations, where we write down all the known concentrations and set up some unknowns and then solve the equation. The ratio of change of different species in the reaction is based on their mole ratios, and this is an important clue to our calculation, that we do not need to determine the concentration of every species in the reaction. Hence, we usually find out the reactant/product in which its concentration can be determined in the easiest way/ most observable way. For instance, if the reaction involves an acid/ base, we will do an acid-base titration to determine its equilibrium constant.