2004 U.S. NATIONAL
CHEMISTRY OLYMPIAD
KEY FOR NATIONAL EXAM – PART III

Problem 1. You have been given a vial containing either maleic acid, $C_4H_4O_4$, fumaric acid, $C_4H_4O_4$, or tartaric acid, $C_4H_6O_6$. Your lab instructor will identify the acid you have been given.

Design and carry out an experiment with the materials provided to determine the number of ionizable H^+ ions possible for each molecule of the acid given.

This is a solid acid titration experiment. Students had to determine the number of moles of NaOH base present given a 0.25M solution, then perform a titration against a weighed sample of the solid maleic, fumaric, or tartaric acid. The endpoint is detected using phenolphthalein as the indicator. All of these solid organic acids have two ionizable protons.

Experimental Plan:

An experiment plan had to describe the steps needed to carry out a successful, microscale titration.

Data and Observations:

The recording of data and observations needed to include information about the mass of the acid used and the volume of the base used. Where the quantity was obtained by difference, both observations used to determine the amount should be shown. Significant figures had to be used appropriately.

Sample Calculations and Conclusions:

Students needed to provide calculations that supported their conclusions.

An example of excellent student work:

Plan:

Dissolve a pre-weighed acid sample in distilled water adding two drops phenolphthalein. Fill the 10.0 ml graduated cylinder with .25M NaOH. Add base gradually until a permanent pink color. Record total volume of base used. Repeat.

Data:

Acid used: Maleic MM=116.0 g/mol

	Trial One	Trial Two
Mass of vial + acid	4.50g	4.00 g
Mass of vial less acid	4.00 g	3.48g
Mass of acid	.50g	.52g
Volume base	34.4 ml	35.0 ml

Calculations:

Moles acid = mass acid/MM	.0043	.0045
Moles base= (liters base x M_{base})	.0086	.0088
Mole base/moles acid	2.0	2.0

Conclusion:

For maleic acid, there are two moles of ionizable protons/mol acid. It is diprotic.

An example of good student work:

Plan:

Dissolve maleic acid in water. Add phenolphthalein and titrate with .25M NaOH. Calculate.

Data:

1.462g maleic in 125 ml solution. Molarity solution = .101
Use 25 ml of solution and titrate. 19.5 ml NaOH used.

Calculations:

Mol Maleic = .0025	(Work not shown)
Mol NaOH = 19.5ml/1000ml/L(.25mol/L) = .004875	(Poor use sig. fig)
Mol NaOH/Mol Maleic = 2	(Only one trial)

Conclusion:

Maleic acid is diprotic.

Problem 2: You have been given 4 (four) black pens. Design and carry out an experiment to determine whether the dye used in each pen is a *compound* or a *mixture*. You will need to provide evidence to justify your conclusions.

This is a paper-chromatography identification experiment. Ammonia and water are provided as the carrying liquids. Students had to create an experiment using pieces of filter paper to observe a possible separation of the black ink dyes from each of the four pens provided. Situating the filter paper on or in provided beakers allowed the solvent front to rise, showing a possible separation.

<u>Experimental Plan</u>

The experimental plan needed to identify a way to use paper chromatography to investigate the inks in the various pens. Some detail about how to carry out the experiment – marking the filter paper above the liquid level, for example, was useful in this component of the exercise.

<u>Observations and results:</u>

Students needed to summarize observations about the chromatography experiment. Students who did an excellent job carried out more than one trial to verify results and included detail about separations. A table of probable observations includes,

Pens	**Water**	**Ammonia**	**Conclusions**
#1 Crayola ®	Separation	Separation	= a mixture
#2 Gel-Pen ®	No separation or movement	No separation	= a compound
#3 Papermate ®	Separation	Separation	= a mixture
#4 Sharpie ®	No separation	No separation	= a compound

An example of excellent student work:

Using Ammonia as solvent:

- Pen 1: Different colors appear: orange, blue, green and purple
- Pen 2: Solid black color only appears.
- Pen 2 (again): Still shows only solid black color.
- Pen 3: Different colors appear, but they are light: green, blue and purple
- Pen 3 (again): Different colors appear again, darker than previous run.
- Pen 4: Mark does not move, only black color appears.
- Pen 4 (again): Mark does not move, only black color.

Using water as solvent – retry #2 and #4.

- Pen 2: Solid black color only appears
- Pen 4: No movement observed.
- Pen 4 (again): No movement observed.

Conclusions:
Pen 1 is a mixture because different colored pigments are observed.
Pen 2 is a compound because only one color is observed even though the ink moved along the filter paper.
Pen 3 is a mixture because different colored pigments are observed. The pigments used are different than those used in Pen 1.

Pen 4 can not be determined in this experiment because no solvent was found that dissolved the ink. Based on the fact that separation of color is not observed, the ink might be a single compound.

An example of good student work:

Pen 1: Mulitple layers form. Fastest moving layer is light blue green. A darker blue-green is next and a purple color is the slowest.
Pen 2: One dark black layer that doesn't seem to move at all. One light black layer that moves slowly. One gray layer that moves faster.
Pen 3: One black layer doesn't move much. One light black layer that moves slowly. One blue-purple layer that doesn't move at all.
Pen 4: Black mark doesn't move at all and remains dark black.

Conclusion:
The pens with multiple layers in the paper chromatography were mixtures – in this case pens 1, 2 and 3. The pen with a single layer in the paper chromatography, pen 4, was a single compound.