# What's the Diagnosis? An Inquiry-Based Activity Focusing on Mole−Mass Conversions

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Inquiry-based methods are highly regarded instructional strategies at the K−12 level in the United States, as indicated by their significant presence in national criteria *(1−3)*. Inquiry-based instruction is a type of teaching that allows students to investigate a phenomenon, work with data, and come to conclusions *(1−4)*. *Inquiry and the National Science Education Standards (2)* lists "essential features of classroom inquiry" (*2*, p 25), which include students investigating "scientifically oriented questions" (*2*, p 25), using evidence to explain and support answers to their inquiries, evaluating their explanations, considering alternative hypotheses, and communicating their findings (*2*, p 25).

One of the many difficulties facing students who are learning chemistry for the first time is the flood of new terminology and meanings including the mole *(5)*. The misconceptions surrounding the mole concept are well established including confusion based upon its definition as a number of particles rather than a mass *(6)*, Avogadro's hypothesis *(7)*, and "the phonetic similarity between mole, molecule, molecular weight, and molar mass (*6*, p 721)." Research has also demonstrated that students struggle with complex mass-to-mass stoichiometry calculations *(8)*. Beyond misconceptions, students may have difficulty understanding the relevance or significance of specific calculations such as determining the number of moles of $MgCl_2$ in a given mass.

To aid students in developing an understanding of the mole and Système International d'Unités (SI) units and to make the concept of the mole more relevant to students, an inquiry-based activity was developed. *Inquiry and the National Science Education Standards (2)* comment that,

> Inquiry in the classroom can take many forms. Investigations can be highly structured by the teacher so that students proceed toward known outcomes... Or investigations can be free-ranging explorations of unexplained phenomena... The form that inquiry takes depends largely on the educational goals for students (*2*,pp 10−11).The learning objectives of this inquiry activity were for the students to (i) use dimensional analysis to perform conversions of moles to mass and (ii) compare concentrations of minerals in the blood to known values.

## Preparation for Inquiry

Prior to the inquiry-based activity, the students were introduced to the SI system and the mole concept. The students learned definitions of Avogadro's number, mole, molar mass, and conversion factors. Students had the opportunity to practice dimensional analysis, thus, ensuring that students had received an introduction to and engagement in the concepts and calculations prior to the inquiry-based activity.

A recent publication in this *Journal* focusing on preparing students for inquiry-based activities suggests that students need ample time to learn content and concepts, and their understanding needs to be assessed before engagement in an inquiry-based activity *(9)*. Implementing these suggestions helped to ensure that students were prepared for an inquiry-based activity that had less guidance. Homework and classroom observations of students working on mole-to-mass conversions allowed the instructor to tailor instruction by addressing gaps in understanding and correctly completing calculations. Whole class discussion was used as a method of strengthening the student's understanding of concepts. Once the students had demonstrated an understanding of the concepts and calculations, they were ready for an inquiry activity.

## Activity Design

Many examples of inquiry provided in *Inquiry and the National Science Education Standards (2)* take place in everyday real-world settings. A recent article in this *Journal* required students to compare two values for blood cholesterol levels as noted by the U.S. National Heart and Lung association *(10)*. Thus, building on the desire for inquiry and a real-world connection, the setting chosen for this activity was a physician's office.

The students in two honors chemistry classes (14 and 20 students) were allowed to form groups of three or four students for this activity. Each group received case files for two patients (see the supporting information) containing a description of the patients' physical symptoms and simulated laboratory results from analysis of minerals in the patients' blood. Student groups were allowed to choose which patient to analyze and diagnose, because one of the criteria for inquiry is that students have options *(4)*. Scientific papers *(11)* and medical textbooks *(12, 13)* that report recommended daily intake values of vitamins and minerals (in units of grams, milligrams, or micrograms) were provided as reference materials to assist students in comparing concentrations of minerals in the blood (see the supporting information). In addition, nutritional labels from multivitamins *(14−16)* were also available to students as references.

The blood analysis laboratory results were reported in units of moles per deciliter, whereas reference materials reported values in grams, milligrams, or micrograms per deciliter. Students had to

 
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Table 1. Post-Activity Discussion Questions

| Questions |
| --- |
| What part of this activity was most difficult? Why? |
| This activity demonstrates that chemistry is important, even to people who are not chemists in laboratories. How does this make you think about chemistry in the real world? |
| Are there any careers in science that interest you that may use chemistry? How? |

recognize that they must convert moles to appropriate mass units to compare their values to the tables in the reference materials. This task required students to formulate a plan, execute the plan by utilizing the skills they learned in an earlier mole–mass lesson, and then propose explanations for the symptoms by using the medical reference materials. This activity was designed in accordance with descriptions from national criteria and published research *(2–5)*:

> Students establish connections between their current knowledge of science and the scientific knowledge found in many sources; they apply science content to new questions; they engage in problem-solving, planning, decision-making, and group discussions; and they experience assessments that are consistent with an active approach to learning (*2*, p 20).

## Student Responses to the Activity

The activity was carried out in a normal 70-min class period with an honors chemistry class. Initially, the majority of the students were unsure how to begin. The instructor guided the student groups with questions as a way to help students understand where to begin their calculations. Questions such as, "What would you need to do to diagnose this patient based upon this data?" or "How might the reference materials be used?" were typical of the interactions between the instructor and students. This strategy worked well and served to gently move the students toward developing a productive plan to answer the questions posed in each case.

Within the class period, all student groups were able to complete the activity. For their presentations, many groups were creative in their approaches, and examples included skits, drawings, and explanations at the board. All students had achieved the learning objectives of carrying out mole–mass conversions and comparing and interpreting the data.

After the activity, three questions were provided for the students to answer and to discuss with the class (Table 1). In responding to the first question, many students commented that even though they found the activity frustrating, they enjoyed it. They felt like they were doing something that "mattered" or that "someone would do in the real world." Several groups reported the activity increased their confidence in performing mole-to-mass conversions. Other groups commented once they deduced the steps that needed to be taken to solve the problem, they did not perceive the mathematical aspect as overbearing. One student commented that the process was "like solving a puzzle".

With regard to the second question, the students voiced many encouraging responses. Three groups commented that they had never thought about the applicability of chemistry to blood work or considered the diagnostic applications of chemistry. Another pair of students reported that chemistry could serve as a useful tool in the medical field. These were encouraging responses. They indicated to the instructor students had emerged with knowledge of the mathematical manipulations and gained an appreciation of the value of chemistry in the world. These comments were also considered encouraging because they were in agreement with criteria for scientific literacy found in the *National Science Education Standards (1)*, which comment, "Scientific literacy also includes understanding the nature of science, the scientific enterprise, and the role of science in society and personal life" (*1*, p 21).

In the third question, television shows that utilize chemistry as a problem-solving tool were voiced most frequently as examples of interesting careers that use chemistry. The majority of responses in this category were either crime scene or medically related programs. It was unclear if the students found these careers "interesting" because of the chemistry involved or because of the popularity of the shows.

## Conclusion

This inquiry-based activity successfully made mass–mole conversions more relevant and engaging to students. The activity is easy to prepare and carry out within the length of one 70-min block using the supporting information accompanying the article. For schools with shorter class periods, this activity can be split across two or three class periods or students can be assigned to work on the analysis as homework. This activity can be completed by having students work individually or in teams and can be used to assess student learning of mole–mass conversions and mole concepts.

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## Supporting Information Available

Case files for two patients; reference materials to assist students. This material is available via the Internet at http://pubs.acs.org.

 