Problem-Manipulation: General Chemistry Courses

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Part of the difficulty in learning science and math is learning how to study appropriately and to actually learn the material, as opposed to simply being able to memorize everything you see. **It can be particularly challenging to recognize when you don’t fully understand a concept even though you may be able to do associated problems.** In a typical course, professors try to help you learn the different ways to approach a concept by having you do lots of problems. It is then your responsibility to think about all of the problems and to recognize how they are similar, how they differ, and what types of variations you might see on an exam. In practice, this conceptualization can be extremely difficult to manage.

This handout gives you guidance for applying a particular problem-solving method that has been shown to be effective preparation for exams in problem-solving courses. While the method is broadly applicable to all problem-solving courses (e.g., math, chemistry, biology, physics, economics, statistics, etc.), it is often easier to understand and apply the method when learned in the context of the courses you are taking. Thus, this handout uses a chemistry example to specifically target those students who are in introductory chemistry courses at Duke.

**You are also encouraged to work directly with an ASIP instructor to master these study strategies and other academic skills.**

We will focus on a sample question as a way of gaining insight about the problem-manipulation method. The questions used in this handout were contributed by faculty in the Duke Chemistry Dept. Even if you don’t remember this material, try the example anyway.

A glass bulb of volume 189ml was filled with HCl gas to a pressure of 108 torr at 25ºC. How many moles of gas were in the bulb?

Whether you think you understand the question or not, it is important to learn how to read questions so that you don’t make silly errors. The first thing to do is to **verify that you actually know what all of the terms mean.** For example, what is a torr?

Next, **verify that you actually understand what the question is asking for.** In this case, the meaning is pretty straightforward, assuming you know what “moles” are. Nevertheless, it is worth considering the context of the question as well…. why are you being asked about the moles of gas? Why is this a reasonable question? Often, you can zero in on the meaning by asking yourself the question, “As opposed to what?”

Next, you should try to write out (or at least carefully think through) the steps involved in solving the problem **in words.** For example:

*We are given three values: P, V, and T, which correspond to pressure, volume, and temperature, respectively. We already know R, since it is a constant. R = 8.314 J/(mol K). We first need to convert P, V, and T to match units of the constant. Then, we need to consider how...*
we can use these values to find the moles of HCl gas. In this case, the correct equation is $PV = nRT$. Solve for “$n$” to find the moles of HCl gas.

If you successfully complete all of these steps, then: $n = X_{\text{moles}} = 0.001098$ moles

Most students are capable of doing this much, either with or without help. And most students would be happy to see that they got the answer correct and would move on to a new problem. However, you are missing a lot of opportunities to truly test your understanding of this problem when you just move on. Instead, there are a few follow-up exercises that you must do in order to be sure that you really get it.

First: Ask yourself what concepts are being tested by the problem.

There are a number of concepts and terms that are relevant to this problem, and it is not necessary to think of every last possibility. These concepts include:

- Understanding terminology: Volume, Pressure, Torr, Moles.
- Unit conversions.
- Ideal gas law.
- Nature of gasses.
- Etc.

Next: Try to manipulate the problem in some way that challenges your understanding of the concepts you just listed.

Don’t just think about it; actually write out the new question using explicit manipulations and see if you can make sense of your new question.

Here are some possibilities:

i. Try other units and numbers.
   - A glass bulb of volume 1.8 oz was filled with HCl gas to a pressure of 10 torr at 87ºF. How many moles of gas were in the bulb?

ii. Try mixing what is known and unknown (playing with the Ideal Gas Law).
   - 0.055 moles of HCl gas is pumped into a glass bulb of volume 200ml and at 25ºC. What is the pressure inside the bulb?
   - 0.0003 moles of CO$_2$ gas is pumped into a bulb of unknown volume, but you know the temperature is 30ºC and the pressure in the bulb is 200 torr. What is the volume of the bulb?

iii. Try introducing additional calculations.
   - Assume the gas is in a box, not a bulb, and only give the dimensions of the box (must calculate volume).
   - Assume the bulb is outside and it is raining, but the rain is beginning to freeze (must infer temperature).
iv. Try to challenge your understanding of the nature of gasses. For example, give
temperature and pressure of one scenario, then change the temperature of the system and
ask for the new pressure.
- The temperature of the bulb (in the problem above) is quickly lowered to 15ºC. What
is the corresponding change in the pressure?

Obviously, you can perform similar explorations of the problem for any concepts you
might have listed. Perhaps the most important question of all to ask yourself is the following:

Under what conditions would your original answer to this problem be incorrect?

Note that this process does not require advanced knowledge of math. You should be able
to think up most of these manipulations on your own, though it can be especially useful to study
in this manner with a group.

Some additional comments:

- Studying in this manner will take more time than simply blasting through the problems. However, if you are not currently understanding the material or doing well on the exam (or even if you are), simply doing more problems will probably not be sufficient to improve your performance. Ultimately, you can get far better understanding by manipulating one
problem exhaustively than you can by doing ten different problems that test similar
concepts. The key difference is the amount of thought you put into the problem, especially with
reference to the concepts that the problem is supposed to be testing.
- When you manipulate problems in this manner, you are mimicking the process by
which the professor designs the exams. Professors usually use pre-existing problems as
templates and then manipulate them in some way to further test certain concepts. By anticipating
the concepts being tested, and then doing the manipulations yourself, there’s a good chance
you’ll predict possible test questions by accident.
- You’ll find that you remember how to do these problems for a much longer time
than otherwise. Retaining the knowledge is especially important when you have many other
classes competing for your time and for final exams, when much of the material was covered
many months previously.
- You’ll find that you can relate the material you are learning to real-world
situations more easily than otherwise, which can make the course more meaningful to you.
The ultimate payoff comes many years later when you realize that you actually learned
something in your intro courses rather than simply trying to get through them with a high grade.
It may be hard to remember in the thick of it, but ostensibly the reason to go to college is to learn
something.
Quick flow chart for manipulating problems

1. Read the problem
2. Does the problem make sense?
   - Yes: Answer the problem. Check your answer to be sure it’s correct.
   - No: Examine the problem closely. Check your understanding of the terms. Try to rephrase the question.
3. What concepts are covered by the problem?
   1. __________________________
   2. __________________________
   3. __________________________
   Etc.
4. Manipulate the problem to test your understanding of each of the concepts you listed. Generally, this requires making the problem more complicated. Answer the new problem(s).
5. Repeat as needed.
6. Ask yourself the following questions:
   - “How can I change the problem so that I get a different answer from before?”
   - “What information matters? What doesn’t?”
7. Move on to a new problem…

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