A General Problem-Solving Strategy For Chemistry [1,2,3,4]

Define the Problem

Define the unknown and use an appropriate symbol to represent it.
List the explicit and implicit knowns and represent them with appropriate symbols.
List the chemical and physical concepts represented in the problem.
Make a model of the problem. Sketch a pictorial or graphical representation of the problem. Include unknown and knowns with appropriate symbols and units.
Make a qualitative estimate of the value for the unknown.

Devise a Plan for Solving the Problem (*To aid you in this endeavor, consider the following questions*)

What chemical or physical principles can be used to relate the various knowns and unknown? Are these relationships appropriate for this problem?
If there is more than one unknown or if the above relationships generate additional unknowns, what additional chemical or physical principles can be used to relate the various knowns and unknowns?
What other information is required to evaluate a certain quantity?
Can the problem be reduced to a series of simpler problems?
Are there any simplifying assumptions that can be used to solve the problem?
Is there an analogous or related problem for which the solution is known?

Carry out the Plan

Write mathematical relationships in the general form, algebraically rearrange, and then substitute known numeric values into the general form.
Make sure the units on the right side of the mathematical equation are the same as the units on the left side (units of quantity for which a value is to be calculated).
Write the name or symbol of the quantity for which the value was calculated and express the value in the correct units and significant figures.

Look Back

Is the answer consistent in sign and magnitude with the qualitative estimate?
Were the calculations in the various parts of the solution done correctly?
Which chemical or physical principles were used to solve the problem?
Which chemical or physical principles were overlooked in your initial attempts?
Can you devise a alternate way to solve the problem?

Example

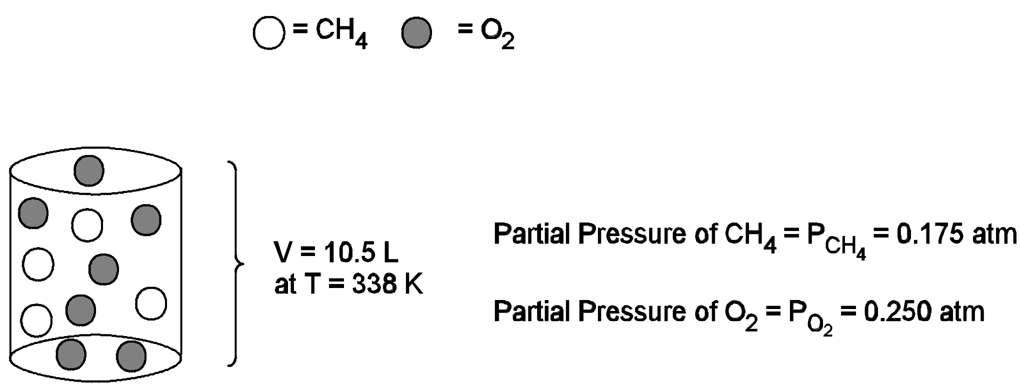
A container with a volume of 10.5 L has a mixture of two gases, CH_4 (methane) and O_2 (oxygen). At 65°C, the partial pressures of the methane and oxygen are 0.175 and 0.250 atm respectively. Calculate the number of grams of each gas in the mixture.

Define the Problem

unkowns: x = wt of CH_4 and y = wt of O_2

knowns: $P_{methane}$ = 0.175 atm, P_{oxygen} = 0.250 atm, V = 10.5 L, T = 65°C + 273, Assume that CH_4 and O_2 are ideal gases.

concepts: Ideal Gas Law (PV = nRT), Dalton's Law of Partial Pressures ($P_T = P_{methane} + P_{oxygen}$), mole = wt/MW



estimate: Since $P_{oxygen} > P_{methane}$ at the same conditions (V and T), then $n_{oxygen} > n_{methane}$. Since $n_{oxygen} > n_{methane}$ and $MW_{oxygen} > MW_{methane}$, then y > x.

Devise a Plan

relationships:

moles of $CH_4 = n_{methane} = x/MW_{methane}$ and moles of $O_2 = n_{oxygen} = y/MW_{oxygen}$

$P_T = P_{methane} + P_{oxygen} = (n_{methane} + n_{oxygen})(RT/V)$

$P_{methane} = n_{methane}(RT/V) = (x/MW_{methane})(RT/V)$

$P_{oxygen} = n_{oxygen}(RT/V) = (y/MW_{oxygen})(RT/V)$

Carry out the Plan

$x = (P_{methane} MW_{methane} V)/RT$
$x = [(0.175 \text{ atm})(16.0 \text{ g/mole})(10.5 \text{ L})]/[(0.0821 \text{ L-atm/mole-}\mathbf{K})(338\ \mathbf{K})]$
$x = 1.06$ g of CH_4

$y = (P_{oxygen} MW_{oxygen} V)/RT$
$y = [(0.250 \text{ atm})(32.0 \text{ g/mole})(10.5 \text{ L})]/[(0.0821 \text{ L-atm/mole-}\mathbf{K})(338\ \mathbf{K})]$
$y = 3.03$ g of O_2

Look Back

Is the answer consistent in sign and magnitude with the qualitative estimate? Yes.
Were the calculations in the various parts of the solution done correctly? Yes.
Which chemical or physical principles were used to solve the problem? Ideal Gas Law, Dalton's Law of Partial Pressures, mole = wt/MW.
Which chemical or physical principles were overlooked in your initial attempts? Dalton's Law of Partial Pressures.
Can you devise a alternate way to solve the problem? Yes.

How Can I Improve My Problem-Solving Skills? [3,5,6,7]

Master the fundamentals of chemistry and look for relationships between the various chemical principles and concepts. Not only must you be familiar with the fundamental principles and concepts but you must also be able to recall easily this information in order to solve the problem. The retrieval of information is facilitated by the storage of "chunks" of related ideas in your memory. One purpose of the Look Back step in the problem-solving strategy is to help you to identify related chemical principles and concepts.

Take time to study the processes that are used by you and others to solve problems. Take advantage of the Look Back step and review the process that you used to obtain your answer. Compare your process with those of others. How do the processes differ?

Think aloud. Whimbey and Lochhead have found that vocalizing your thoughts as you work through a problem helps you to organize and clarify your ideas and reduces the likelihood of careless errors. They have suggested that students work in pairs to solve problems. One partner describes how he or she would solve the problem while the other partner listens. The listener contributes to the process by asking questions for the purpose of clarification. If you prefer to work alone, then subvocalize or write down your thoughts as you solve a problem.

References

1) a) Genyea, J. *J. Chem. Educ.* **1983**, 60, 478. b) Mettes, C. T. C. W.; Pilot, A.; Roossink, H. J.; Kramers-Pals, H. *J. Chem. Educ.* **1980**, 57, 882. c) Gendell, J. *J. Chem. Educ.* **1987**, 64, 523. d) Gilbert, G. L. *J. Chem. Educ.* **1980**, 57, 79.

2) Polya, G. *How to Solve It*; 2nd ed.; Princeton University Press: Princeton, NJ, 1985.

3) Woods, D. R. In *Developing Critical Thinking and Problem-Solving Abilities*, Stice, J. E.,Ed.; New Directions for Teaching and Learning, No. 30; Jossey-Bass Inc.: San Francisco, 1987; p 55.

4) Leibold, B. G.; Moreland, J. L. C.; Ross, D. C.; Butko, J. A. *Engineering Education* **1976**, 67, 172.

5) a) Rubinstein, M. F.; Firstenberg, I. R. In *Developing Critical Thinking and Problem-Solving Abilities*, Stice, J. E.,Ed.; New Directions for Teaching and Learning, No. 30; Jossey-Bass Inc.: San Francisco, 1987; p 23. b) Rubinstein, M. F. *Patterns of Problem Solving*; Prentice-Hall, Inc.: Englewood Cliffs, NJ, 1975.

6) Woods, D. R.; Crowe, C. M.; Hoffman, T. W.; Wright, J. D. *Engineering Education* **1979**, 70, 277.

7) Whimbey, A.; Lochhead, J. *Problem Solving and Comprehension*; 5th ed.; Lawrence Erlbaum Associates: Hillsdale, NJ, 1991.

W. R. Nutt
7/29/97