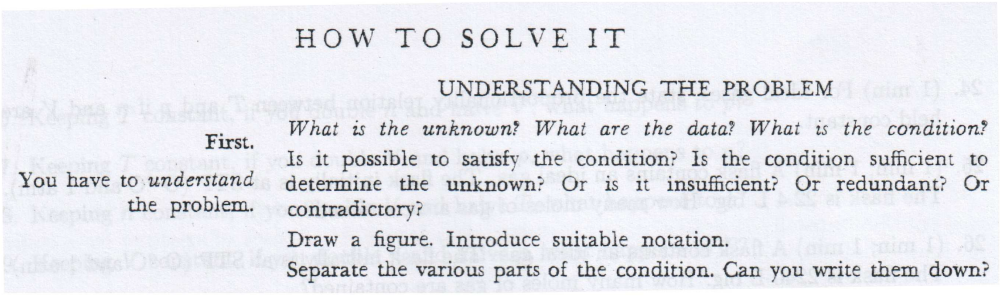
# 1 Cognitive reasoning in the chemical sciences 4.1

*Some formulas and constants useful in solving some of the problems listed below:* $E_n = \frac{-R_H Z^2}{n^2}$, $E = h\nu$, *and* $c = \lambda\nu$. $R_H = 2.179 \times 10^{-18} J$. $h = 6.62 \times 10^{-34} J\ s$. $c = 2.998 \times 10^8\ m/s$. $m_{elec} = 9.109 \times 10^{-31}\ kg$. $A_o = 6.022 \times 10^{23}$.

1. We are half-way through this course. Let's briefly discuss what we have learned in the last three weeks about the solving of chemistry problems. Listed below are Polya's first and fourth steps of solving problems. Please discuss what you have learned about these steps.



HOW TO SOLVE IT

UNDERSTANDING THE PROBLEM

**First.**

You have to *understand* the problem.

*What is the unknown? What are the data? What is the condition?*
Is it possible to satisfy the condition? Is the condition sufficient to determine the unknown? Or is it insufficient? Or redundant? Or contradictory?
Draw a figure. Introduce suitable notation.
Separate the various parts of the condition. Can you write them down?

LOOKING BACK

**Fourth.**

*Examine* the solution obtained.

Can you *check the result?* Can you check the argument?
Can you derive the result differently? Can you see it at a glance?
Can you use the result, or the method, for some other problem?

2. I have placed four different books on a bookshelf which fits exactly four books. While all the books have been placed so that one of their thin sides is in contact with the bookshelf, they are placed upside-down, sideways etc. How many different ways are there of placing the books onto the shelf?

3. Two questions about NaOH, HF, and $H_2SO_4$.

   (a) A $c$ g mixture of $H_2SO_4$ and HF is neutralized with $d$ mL of $w$ M NaOH. The final solution contains no $HSO_4^-$. The values $c$, $d$, and $w$ are given to you. Explain an exact procedure by which you would use the values of $c$, $d$ and $w$ to determine the molar ratio of sulfuric acid to HF in the original mixture.

   (b) A 34.22 g mixture of $H_2SO_4$ and HF is neutralized with 227.3 mL of 5.12 M NaOH. The final solution contains no $HSO_4^-$. What was the molar ratio of sulfuric acid to HF?

4. A person carries two genes which determine the letter of their blood type. And these genes come in three flavors: A, B, and O. People with AA genes have A blood, AO genes A blood, BO genes B blood, BB genes B blood, AB genes AB blood, and OO genes O blood. Each parent gives a single one of their two genes to their children.

   I have A blood and my eldest daughter has AB blood. There are six gene scenarios (AA, AO, BB, BO, OO, and AB). Determine the probabilities for each of these six possibilities for my daughter's mother. (Please make the false but simplyfying assumption that each gene type has, by itself, equal frequency of occurence.)

5. Some questions about atomic orbitals

   (a) Please draw the balloon diagram and a radial wavefunction for the Mo $4d_{xy}$ orbital.

   (b) Draw the balloon diagram and a radial wavefunction for the Tc $4d_{xy}$ orbital. (Tc is a smaller atom than Mo.)

(c) On the same graph, compare the two radial functions.

(d) State the difference between the two contour maps of these orbitals when drawn on the $xy$ plane.

(e) Place arrows on both contour maps and radial functions indicating the points where the probability of finding the electron is greatest.

6. Draw six line segments of equal length to form eight equilateral triangles.

7. Please answer the following related problems:

   (a) A $Li^{2+}$ ion is in an excited state. It emits a photon. Shortly thereafter this same Li ion emits a second photon. What is the shortest possible wavelength for the first emitted photon?

   (b) A $Li^{2+}$ ion is in an excited state. It emits a photon. Shortly thereafter this same Li ion emits a second photon. What is the longest possible wavelength for the first emitted photon?

   (c) A $Li^{2+}$ ion is in an excited state. It emits a photon. Shortly thereafter this same Li ion emits a second photon. What is the shortest possible wavelength for the second emitted photon?

   (d) A $Li^{2+}$ ion is in an excited state. It emits a photon. Shortly thereafter this same Li ion emits a second photon. What is the longest possible wavelength for the second emitted photon?

8. State the exact procedure by which you would solve the following problem: If for a certain hydrogen-like atom, the $n = 3$ to $n = 2$ transition is $3.026 \times 10^{-19}$ J, what is the threshold energy of this hydrogen-like atom in its ground state?

9. What is the smallest $Z$ value for an element in which a $5g$ orbital is occupied in the ground electronic state?

10. An *E. Coli* bacteria divides every 20 minutes. If one begins with 37 *E. Coli* how many *E. Coli* are there after four hours?

11. Two hydrogen-like ions have a number of their emission frequencies in common. To keep matters clear, let us call the two ions $A$ and $B$. $n_A$ refer to the various principal quantum numbers of the $A$ ions, while $n_B$ are the principal quantum numbers of the $B$ ion. It turns out that the $n_A = 2$ to $n_A = 1$ transition is exactly equal in frequency to the $n_B = 4$ to $n_B = 2$ transition.

    (a) What is $Z_A/Z_B$?

    (b) Which of the two hydrogen-like ions, $A$ or $B$, has a greater $n = 2$ to $n = 1$ transition frequency? What is the ratio of the two $n = 2$ to $n = 1$ frequencies?