1 Cognitive reasoning in the chemical sciences 3.8

1. *In this section you will be given pairs of problems. After solving the problems, you will be required to state in what way the problems are identical.*

   (a) **Marathon dancers vs. Ar atoms**

      i. A huge dance hall is filled with dancers. Every hour 10% of the remaining dancers quit. What percent of the initial group of dancers are dancing after 11 hours?

      ii. A huge flask is filled only with Ar atoms. Every hour 5% of the Ar atoms effuse from the flask. Assuming temperature is kept constant and that no gas effuses back in, what is the reduction in pressure after 20 hours?

      iii. In what way are problems (i) and (ii) the same? in what ways different?

   (b) **Dancing iguana and rabbit couples vs. ^{235}U and ^{238}U**

      i. A huge dance hall, A, is filled with rabbit couples and iguana couples dancing. In the first hour 10% of the rabbit dancers and 11 % of the original iguana dancers leave the room to dance in dance hall B. After an hour the doorway between dance halls A and B are shut, but the door between B and C are opened. In the next hour 10% of the couples dancing in hall B leave the room to enter dancing hall C, again with 10% of the rabbit and 11% of the iguana couples leaving. Every hour a new doorway to a totally new and initially empty dance hall opens up and the old open doorway is shut. After 10 hours what percent of the original rabbit dancers are still dancing? What percent of iguana dancers are still dancing?

      ii. *Flasks in flasks or how to make an atom bomb:* UF_6 turns from a solid to a gas at 56 ^{o}C. The initial sample of uranium is 10% ^{235}U and 90% ^{238}U. It is placed in the inner-most flasks. Nuclear weapons require uranium which is at least 50% ^{235}U. How many flasks need to be placed inside flasks, which are placed inside flasks, etc... for the collected sample to be just over 50% ^{235}U?

      iii. In what way are problems (i) and (ii) the same? in what ways different?

2. *In this section you will study how placing information on the right drawing helps solve Dr. Johnson's orbital energy problems*

   (a) For Dr. Johnson's problem shown below, draw for each of Dr. Johnson's entries atomic orbital (shelf) diagrams. Shelf diagrams should state the n,l, and m_l values of the lines. Your shelf diagrams should explictily draw as arrows all electrons, and wherever possible indicating the electron's m_s value. State briefly how the diagrams you have drawn indicate which of Dr. Johnson's sets are disallowed.

Which of the following sets of quantum numbers are not allowed? For each incorrect set, state why it is incorrect.

(a) n=3, ℓ=3, m_ℓ=0, m_s=-1/2

(b) n=4, ℓ=3, m_ℓ=2, m_s=-1/2

(c) n=4, ℓ=1, m_ℓ=1, m_s=+1/2

(d) n=2, ℓ=1, m_ℓ=-1, m_s=-1

(e) n=5, ℓ=-4, m_ℓ=2, m_s=+1/2

(f) n=3, ℓ=1, m_ℓ=2, m_s=-1/2

(b) Draw a Bohr energy (shelf) diagram for the problem below specifying the various n values. Draw on this diagram:

i. the initial location of the electron
ii. a possible vertical line corresponding to the light photon which is absorbed.
iii. a possible vertical line corresponding to the light photon which is emitted.
iv. a vertical line corresponding to the change in the energy of the electron.
v. State in words how you would go about calculating the length of each of the three vertical lines.
vi. Does drawing this diagram help clarify the processes described in this problem?

A hydrogen atom in its ground state absorbs light with wavelength 97.2 nm and then emits light with wavelength 486 nm. What is the final energy level (n) of the electron?

(c) In this next exercise you will be asked to draw an orbital energy (shelf) diagram for a surface. While we do not know exactly what this diagram is, please make up a hypothetical one filled with a number of small horizontal lines and the long $E = 0$ horizontal line.

i. Draw a hypothetical orbital energy (shelf) diagram which could correspond to the problem
ii. Draw a vertical line and the wavy arrow corresponding to the light of wavelength 230.0 nm.
iii. State the equation which will allow you to determine the position of this line.
iv. Draw a line corresponding to the work energy.
v. Draw an additional line which corresponds to a light of wavelegnth 300.0 nm.
vi. State the equation which will allow you to determine the position of this line.
vii. Describe briefly how your diagrams aids you in visualizing the process of solving the problem.

Irradiating a silver surface with light of wavelength 230.0 nm causes electrons to be ejected with kinetic energy 77.67 kJ/mole (a) Determine the threshold frequency for silver. (b) If light of wavelength 300.0 nm shines on a silver surface will electrons be ejected? (Show work to justify our answer.)