WUCT: Chemistry of Movies Sample Questions

1. Colored fire is commonly used in movies as a special effect. In order to make different colors of fire, different metals must be put in the fire. The energy from the fire causes the electrons to move up to orbitals of higher energy, and then light of a certain frequency is produced giving way to different colors as electrons relax back down to their ground states.

    a. Different metals produce different colors because of their differing ground state electron configurations and emission spectrums. Give the ground state noble gas electron configuration for lithium and barium.

Lithium's ground state configuration is $1s^2 2p$ and Barium's ground state configuration is [Xe]$6s^2$.

    b. Lithium gives a red color in a flame, whereas barium produces a green color. Which energy change (lithium or barium) from the ground state to the various excited states is greater?

Since red has a longer wavelength than green light in the visible spectrum, the energy change must be greater for barium due to the equation $E = \frac{hc}{\lambda}$ (the shorter the wavelength, the larger the energy).

OR

Since red has a shorter frequency than green light in the visible spectrum, the energy change must be greater for barium due to the equation $E = h\nu$ (the higher the frequency, the larger the energy).

    c. The energy change between lithium's first excited state and ground state is 1.81 eV. Calculate the wavelength (in nm) of the photon that is released as the electron relaxes to the ground state.

$$E = \frac{hc}{\lambda} \rightarrow \lambda = \frac{hc}{E} = \frac{(6.626 \cdot 10^{-34} Js)(3.0 \cdot 10^{8} m/s)}{1.81\ eV} \cdot \frac{1\ eV}{1.602 * 10^{-19} J} = 686\ nm$$

d. Determine which orbital filling rule(s) is broken by each of the following configurations for Barium:
   i. [Xe] $6s^2$; Total spin = 1
   ii. [Xe] $7s^2$; Total spin = 0
   iii. [Xe] $6s^1 5d^1$; Total spin = 0

i. Pauli Exclusion Rule
ii. Ground State rule
iii. Ground State rule and Hund's rule

e. Which color flame is hotter: blue or red? Explain.

The blue flame is hotter. Since blue light has a higher frequency and energy than red light, the blue flame must be hotter than the red.

Alternate solution: A blue flame represents complete combustion as opposed to a red flame, which means that the blue flame would create more heat than the red flame.

2. Fake blood is often used in movies for fighting scenes. The unbalanced equation for the chemical reaction that makes fake blood is $FeCl_3 + KSCN \rightarrow K_3[Fe(SCN)_6] + KCl$.

a. Write the balanced equation of this chemical reaction.

$$FeCl_3 + 6KSCN \rightarrow K_3[Fe(SCN)_6] + 3KCl$$

b. If you start with 10.00 g of $FeCl_3$ and 40.00 g of KSCN, what is the limiting reactant?

$$10.00 g\ FeCl_3 \cdot \frac{1\ mol\ FeCl_3}{162.2\ g\ FeCl_3} = 0.0617\ mol\ FeCl_3$$

$$40.00 g\ KSCN \cdot \frac{1\ mol\ KSCN}{97.18\ g\ KSCN} = 0.412\ mol\ KSCN$$

$$0.412\ mol\ KSCN \cdot \frac{1\ mol\ FeCl_3}{6\ mol\ KSCN} = 0.0686\ mol\ FeCl_3$$

This means that 0.0686 mol of $FeCl_3$ is required to react with all of the KSCN. Since the mole of $FeCl_3$ required to react with all of the KSCN is greater than the given amount of mole $FeCl_3$, $FeCl_3$ is the limiting reactant.

c. How many grams of KCl would be produced with the starting conditions given in part b?

$$10.00g\ FeCl_3 \cdot \frac{1\ mol\ FeCl_3}{162.2\ g\ FeCl_3} \cdot \frac{3\ mol\ \text{KCl}}{1\ mol\ FeCl_3} \cdot \frac{74.55\ g\ \text{KCl}}{1\ mol\ \text{KCl}} = 13.79\ g\ \text{KCl}$$

d. A chemistry student performed this experiment with the values in part b and calculated a percent yield of 65%. How many grams of $K_3[Fe(SCN)_6]$ did they produce?

$$10.00g\ FeCl_3 \cdot \frac{1\ mol\ FeCl_3}{162.2\ g\ FeCl_3} \cdot \frac{1\ mol\ K_3[Fe(SCN)_6]}{1\ mol\ FeCl_3} \cdot \frac{521.6\ g\ K_3[Fe(SCN)_6]}{1\ mol\ K_3[Fe(SCN)_6]} \cdot 65\% = 20.90\ g\ K_3[Fe(SCN)_6]$$

e. What is the oxidation number of Fe in the compound $K_3[Fe(SCN)_6]$?
The S is -2, C is +4, N is -3, and K is +1. The whole compound is neutral, so Fe must have an oxidation number of +3.