1 Cognitive reasoning in the chemical sciences 4.8

Some of the following questions are similar to questions which have been asked before. Others are exactly the same as previous questions. Some are brand new. Please do all of these problems without referring to any prior work or class notes.

1. The combustion of 72.6 grams of a compound which contains only C, H, S, and F yields 80.77 grams of carbon dioxide and 33.05 grams of water. Another sample of the compound with a mass of 22.48g is found to contain 9.122 grams of sulfur. What is the empirical formula of the compound?

2. The nuclear charge experienced by an electron in an atom is affected by the shielding by the other electrons. Here are two rules for estimating the shielding. (i) An electron with the same principal quantum number shields 0.25 | e | of nuclear charge. (ii) An electron with lower principal quantum number shields 1 | e | of nuclear charge. *An atom of P absorbs light, taking a 3p electron to a 4s orbital. Calculate the frequency in Hz of light absorbed.*

3. Based on the data below, please deduce the correct proportionality relationship between distance from the Sun and mean planetary velocity.

Table 1: Planetary Orbital Properties.

Planet	Mean Distance from Sun (km)	Mean Velocity (km/s)
Mercury	5.8×10^7	48
Venus	1.1×10^8	35
Earth	1.5×10^8	30
Mars	2.3×10^8	24
Jupiter	7.8×10^8	13
Saturn	1.4×10^9	10
Uranus	2.8×10^9	6.8
Neptune	4.5×10^9	5.4
Pluto	5.9×10^9	4.7

4. Please answer the following three problems:

   (a) Rank from lowest (on left) to highest (on right) Z_{eff}: Pb, Rn, Cs.

   (b) Rank from lowest (on left) to highest (on right) the electronegativity: radon, astanine, and sulfur.

   (c) Rank from lowest (on left) to highest (on right) the atomic radii of the neutral element: calcium, arsenic, germanium.

   (d) You are snatched by aliens from an alternate universe. In their universe, there are four spin states for an electron: $\frac{3}{2}$, $\frac{1}{2}$, and $-\frac{1}{2}$, and $-\frac{3}{2}$. The Pauli exclusion principle is still obeyed and the same rules apply for all the other quantum

numbers. Assuming the same element names for a given Z, what would be the electron configuration for Zn.

5. Please draw the Lewis structure and the molecular shape of the molecule $H_2S_2O_4$.

   Hint: In problems such as this one, it helps to initially assign potential oxidation states for each atom based solely on the stoichiometry. Generally the most electropositive element achieves its highest positive stable oxidation state and the most electronegative element reaches its most negative stable oxidation state.

6. A 2L flask is opened and closed on the surface of the planet *Titania*. Titania has a temperature of 250 K. The only gases in the atmosphere are He and N_2. This sealed flask is then brought to Earth. At 0^oC, the pressure in the flask is measured at 1.4 atm. The density is measured at 0.8 g/L. What is the partial pressure of He on Titania?

7. All metal atoms at the same temperature have roughly the same kinetic energy. To one significant figure, how many times slower are the Pb atoms in a piece of lead travelling than the Fe atoms in a piece of iron, assuming that both pieces of metals are the same temperature?

8. Please draw a balloon diagram for the atomic orbital $\psi_{(2x-y)(2x+y)}$.

9. Please draw a plausible structure for the yellow molecule realgar, As_4S_4. All bonds are either between As and S atoms or As and As atoms. All As atoms are in the same chemical environment and all S atoms are in the same chemical environment.

10. An industrial solid catalyst can convert sucrose, table sugar, $C_{12}H_{22}O_{11}$ dissolved in water into ethanol, CH_3CH_2OH, plus carbon dioxide. But not all the sucrose is converted to ethanol by this reaction; some remains as sugar. A 100.0 g sample of 2.00 M sucrose solution with density 1.05 g/ml produces a 96.3 g ethanol, sucrose and water solution. This final solution has 1.02 g/ml density. What is the molarity of both the ethanol and the sucrose in the final solution?