CH301H – Principles of Chemistry I: Honors
Fall 2017, Unique 50135

Homework, Weeks 1 – 2

1. Although the SI unit of energy is the Joule, scientists tend to use the unit that has been traditionally the most convenient unit for the problem at hand. It is important to be very comfortable with rapid mental units conversion in order to understand the magnitude of energies under discussion. Make an energy conversion table between units of J, cal, and eV. Keep this table handy – we will be adding to it throughout the semester.

2. Is energy an intensive or extensive property? How do you convert energy from an extensive to an intensive property?

3. Pure iron can be obtained from iron ore by heating the ore above the melting temperature of iron, 1538˚C. An iron smelting plants heats the iron ore to a molten state, then pours off the liquefied iron into 100 kg ingots. The ingots then cool to room temperature, releasing 5.6×10^7 J of energy. How much mass is lost in one ingot during cooling?

4. In this problem, you will need to use constants to at least 8 significant figures (unlike most of the problems we encounter in this class). In nuclear fusion atomic nuclei are combined. Examine the following reaction of two isotopes of hydrogen to make an isotope of helium. Deuterium (^{2}H) and tritium (^{3}H) combine to form helium-4 and a neutron (n):

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{1}_{0}n + {}^{4}_{2}He$$

a) Find the masses of each of these to at least 8 significant figures (Table 19.1 will be helpful).
b) Find the change in mass that accompanies this reaction and convert that mass change to a change in energy using Einstein's theory of relativity ($E = mc^2$).
c) How much energy is released per mole of helium?
d) Compare this to covalent bond formation. For reference, the energy of formation of molecular hydrogen (H_2) from two atoms of hydrogen is 436 kJ mol^{-1}.

5. In Rutherford's experiment, alpha particles (Z = 2) were aimed at a sheet of gold foil with an initial kinetic energy of 2.0 MeV; from this he estimated the radius of the Au nucleus to be 11.4×10^{-14} m. Repeat this experiment with a piece of aluminum foil to determine the size of the Al nucleus.

6. Metallic gold has a density of 19.3 g cm^{-3}. Using the atomic mass of gold, determine the approximate volume of one gold atom, then use this to determine its atomic radius. Repeat for molecular calcium (density of 1.54 g cm^{-3}). What does this tell you about atomic size?

7. The most common, non-SI, unit for dipole moment is the Debye (D). 1 Debye is defined as 3.34×10^{-30} Cm. Determine the magnitude of the dipole moment in units of Debye for the

charge on 1 electron separated over 1 Å of space. Why might scientists persist in using the Debye, even though it is a non-SI unit?

8. In words, explain why there is confusion in the literature about whether the sign of EA should be greater than or less than zero.

9. What is the relationship between the force and potential energy of two interacting charges?

10. A gold nucleus is located at the origin of a coordinate system. An electron is brought to a position 2 Å from the origin. Determine the force between the Au nucleus and the electron, and the potential energy of the system (nucleus + electron).

11. A gold nucleus is again located at the origin of a coordinate system. A helium nucleus initially 2 Å from the origin is moved to a new position 1 Å from the origin. Calculate the change in force between the two nuclei, the change in potential energy of the system, and the change in kinetic energy of the He nucleus, assuming its value at 2 Å is 20 keV.

12. Guided only by the periodic table and your chemical intuition (i.e. no peeking at electronegativity tables), arrange these atoms in order of increasing electronegativity: O, F, S, Si, K, V, C.

13. In the physical sciences, having a good intuitive grasp of the magnitude of particular phenomena in length, time, and energy is absolutely critical. For each of these three quantities, construct a table with the following ranges:

> length: 10^{-18} to 10^{28} meters
> time: 10^{-18} to 10^{18} seconds
> energy: 10^{-20} to 10^{36} Joules

For each of these tables, indentify at least 10 phenomena that span as much of this range as possible. For example, what is the size (in meters), age (in seconds), and yearly energy output (in Joules) of the Sun? Or another example, what is the size of the hydrogen atom (in meters), the lifetime of the $n = 2$ excited state of the hydrogen atom (in seconds), and the energy emitted in the transition from the $n = 2$ to $n = 1$ state in the hydrogen atom (in Joules)? Please use the interwebs to help you out with this, and chose physical phenomena that actually interest you (i.e. if you are interested in biology, think about processes that occur inside a cell; if you are interested in computers, think about processes that occur inside a processor or battery; *etc.*).