CHM 3411, Dr. Chatfield, Spring 2018

Problem Set 1

Due Friday, Jan 19

Suggested "warmups" (not to turn in): Discussion questions 7A.1-4; Exercises [all (b)] 7A.1,2,5,6,8,9

In this problem set you will explore several failures of classical mechanics [Problem 1, blackbody radiation; Problem 2, photoelectric effect], and a one of the principles of quantum mechanics developed in Chapter 7 [Problem 3, de Broglie relation (relates momentum and wavelength)]. The last problem will introduce you to the use of computational chemistry software, which will be used throughout the course.

1. The Planck distribution law for blackbody radiation is

$$\rho(\lambda,T)\,d\lambda = (8\pi hc/\lambda^5)\,[\exp(hc/\lambda kT) - 1]^{-1}\,d\lambda \qquad (1.1)$$

Starting with eq 1.1, do the following:

a) Show explicitly that, as we discussed in class, the Planck distribution law reduces to the classical (Rayleigh-Jeans) expression

$$\rho(\lambda,T)d\lambda = (8\pi kT/\lambda^4)d\lambda \qquad (1.2)$$

in the limit $\lambda \to \infty$. (Hint: Recall that the Taylor series expansion for e^x is $e^x = 1 + x + x^2/2! + x^3/3! + ...$)

b) Determine the value of λ_{max}, the wavelength of maximum light intensity, predicted from the Planck distribution law. You may assume $\exp(hc/\lambda_{max}kt) >> 1$. (Test your result for consistency with this assumption.)

c) Wien established a famous relationship between temperature, T, and λ_{max}, showing that their product is a constant, A_W. This relationship is called the Wien displacement law:

$$T\,\lambda_{max} = A_W \qquad (1.3)$$

Based on your result in (b), calculate A_W, the Wein displacement constant. Google "Wien displacement constant" and compare your value with what you find.

2. In a particular study of the photoelectric effect, an unknown metal surface was illuminated with light of wavelength λ = 254. nm. Electrons were ejected from the metal. The maximum kinetic energy of the ejected electrons was 0.42 eV. Based on this information find Φ_0 (the work function for the metal, in eV) and λ_0 (threshold wavelength for production of electrons, in nm).

3. Atkins Exercise 7A.9(a)

4. Summarize the evidence that led to the introduction of quantum mechanics. Pretend that your audience is another student, a friend, who is studying a subject in the humanities (history perhaps).