

V25.0109: General Chemistry I (Honors)

Practice problems for midterm II

1. The allowed energies (in Rydbergs) of an electron in a hydrogen atom are given by the formula

$$E_n = -\frac{1}{n^2}$$

Suppose a photon of frequency 2.7×10^{15} Hz strikes the electron hydrogen atom's electron. The electron is ejected and strikes a photosensitive detector with a velocity of 2.113×10^6 m/s. In what energy level was the electron before it was struck by the photon? The conversion from Rydbergs to Joules is $1 \text{ Ry} = 2.18 \times 10^{-18} \text{ J}$. Planck's constant is $h = 6.626 \times 10^{-34} \text{ J}\cdot\text{s}$, and the mass of an electron is $9.109 \times 10^{-31} \text{ kg}$.

2. (25 points)

The electron in a hydrogen atom is described by the following wave function

$$\psi(r, \theta, \phi) = \frac{4}{81} \left(\frac{1}{4\pi a_0^3} \right)^{1/2} (6\sigma - \sigma^2) e^{-\sigma/3} \sin \theta e^{i\phi}$$

where $\sigma = r/a_0$, and a_0 is the Bohr radius.

- a. (5 points)

What are the quantum numbers of the electron?

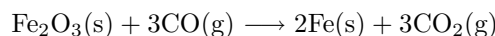
- b. (10 points)

What is the probability that a measurement of the electron's location will yield a value in a cone of infinite length, whose apex is at the origin and whose central axis is the positive z -axis, described by $0 \leq \theta \leq \pi/8$. You might find the mathematical identities at the back of the exam useful for this one. You must express your final answer as a numerical percentage, e.g. 15%.

- c. (5 points)

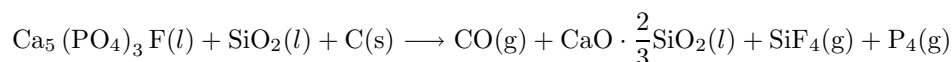
The atom is now struck by a photon of frequency 2.9×10^{15} Hz. If a photosensitive detector is used to determine if the electron is ejected, will the detector register a hit? If so, with what velocity does the electron reach the detector?

3. Iron (Fe) can be produced from iron oxide (Fe_2O_3) by reaction with carbon-monoxide gas (CO) according to:



When 7.56 kg of CO gas are combined with 15.02 kg iron oxide in a furnace, it is observed that 9.54 kg of iron are produced. What is the percentage yield of this reaction?

4. Phosphoric acid H_3PO_4 is produced in a three-step process called the *furnace process*, the first step of which is described by the unbalanced reaction



in which three gaseous species, including white phosphorous $\text{P}_4(\text{g})$, are produced. Write the balanced reaction.