

## Chemistry 105

### Solutions to Homework Set # 1 (25 points)

#### Scientific Notation, Unit Conversions and the scientific method.

1. Write the following numbers in standard notation: (*See text, Appendix A.2 and Discussion 1 Notes*)

- |                          |                     |                            |                       |
|--------------------------|---------------------|----------------------------|-----------------------|
| (a) $1.90 \times 10^5$   | <i>Ans: 190,000</i> | (f) $6.40 \times 10^{-4}$  | <i>Ans: 0.000640</i>  |
| (b) $2.8 \times 10^{-3}$ | <i>Ans: 0.0028</i>  | (g) $7.3 \times 10^{-3}$   | <i>Ans: 0.0073</i>    |
| (c) $3.77 \times 10^2$   | <i>Ans: 377</i>     | (h) $8.2 \times 10^6$      | <i>Ans: 8,200,000</i> |
| (d) $4.6 \times 10^{-2}$ | <i>Ans: 0.046</i>   | (i) $9.111 \times 10^{-1}$ | <i>Ans: 0.911</i>     |
| (e) $5.05 \times 10^4$   | <i>Ans: 50,500</i>  |                            |                       |

2. Write each of the following measured numbers in scientific notation with the correct number of significant figures. (*See Notes for Discussion 1 and text, Appendices A.2 and A.4, page A-9*)

- |               |   |             |  |
|---------------|---|-------------|--|
| (a) 0.00022   | <i>Ans : <math>2,2 \times 10^{-4}</math></i>  | (e) 0.01010 | <i>Ans : <math>1.010 \times 10^{-2}</math></i> |
| (b) 4,400,000 | <i>Ans : <math>4.4 \times 10^6</math></i>     | (f) 0.12    | <i>Ans : <math>1.2 \times 10^{-1}</math></i>   |
| (c) 0.0000601 | <i>Ans : <math>6.01 \times 10^{-5}</math></i> | (g) 14,200  | <i>Ans : <math>1.42 \times 10^4</math></i>     |
| (d) 88,000    | <i>Ans : <math>8.8 \times 10^4</math></i>     | (h) 1600    | <i>Ans : <math>1.6 \times 10^3</math></i>      |

3. Chapter 1 discusses the steps involved in the scientific method. Describe the scientific method in your own words.

*consult text - important points include observation, hypotheses, experiments and theories and laws. Some mention of the cyclic nature of scientific inquiry is also necessary*

4. Describe the difference between a hypothesis and a theory. Include the characteristics of a scientific hypothesis.

*A hypothesis is an educated guess that is informed by one's observations. An important characteristic of a hypothesis is that it is falsifiable - that is one could design an experiment to disprove the hypothesis - it is testable. A theory is the best current explanation for a set of physical phenomena. One can use a theory to make predictions. Theories may be modified or tossed aside when new observations contradict predictions based on the theories. Neither theories nor hypotheses are ever proven absolutely.*

5. Review Sections 1.10 (pages 16-21) and Appendix A.3 (pages A-5 through A-8) in the text and complete the following problems. Show all your work, including conversion factors.

(a) Convert 180 eggs into dozens.

$$\frac{180 \text{ eggs}}{1} \times \frac{1 \text{ dozen}}{12 \text{ eggs}} = 15 \text{ dozen}$$

(b) Convert 500 millimeters into meters.

$$\frac{500 \text{ mm}}{1} \times \frac{1 \text{ m}}{1000 \text{ mm}} = 0.5 \text{ m}$$

(c) Convert 4.2 liters into milliliters.

$$\frac{4.2 \text{ L}}{1} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 4200 \text{ mL}$$

(d) Convert 12 centimeters into millimeters.

$$\frac{12 \text{ cm}}{1} \times \frac{10 \text{ mm}}{1 \text{ cm}} = 120 \text{ mm}$$

(e) Convert 3 pints into liters.

$$\frac{3 \text{ pints}}{1} \times \frac{1 \text{ quart}}{2 \text{ pints}} \times \frac{0.946 \text{ L}}{1 \text{ quart}} = 1.42 \text{ L}$$

(f) Convert 1.45 meters into inches.

$$\frac{1.45 \text{ m}}{1} \times \frac{100 \text{ cm}}{1 \text{ m}} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 57.1 \text{ in}$$

(g) Convert 65 miles per hour into kilometers per second.

$$\frac{65 \text{ mi}}{\text{hr}} \times \frac{1 \text{ hour}}{60 \text{ min}} \times \frac{1 \text{ min}}{60 \text{ s}} \times \frac{1 \text{ km}}{0.621 \text{ mi}} = 0.029 \text{ km/s}$$

(h) At a speed of 60 miles per hour, how many minutes will it take to drive 250 kilometers? (hint: start with 250 kilometers and use 60 miles = 1 hour as a conversion factor, then convert hours to minutes.)

$$\frac{250 \text{ km}}{1} \times \frac{0.621 \text{ mi}}{1 \text{ km}} \times \frac{1 \text{ hr}}{60 \text{ mi}} \times \frac{60 \text{ min}}{1 \text{ hour}} = 155 \text{ min}$$

### Light: Frequency, Wavelength and Energy

Review the notes for Discussion 1 before completing these problems. Some additional information is provided here:

As we have seen in the notes for Discussion 1, light has a dual nature. Sometimes it is convenient to think about light as a wave, and sometimes we must think about light as composed of particles. Photons, or light particles, were introduced to explain puzzling experimental results that could not be explained by the wave model. These experiments suggested that light consisted of small packets of energy, rather than appearing as a continuum of energy. Energy from light was found to be transferred in these small discrete clumps, rather than in arbitrary amounts.

The energy of a photon ( $E$ ) is related to its wavelength ( $\lambda$ ) by:

$$E = h\nu = \frac{hc}{\lambda}$$

Where  $h$  is a constant known as Planck's constant with a value of  $6.626 \times 10^{-34} \text{ J s}$  ( $J$  = Joules, an energy unit). Note the inverse relationship between wavelength and energy. A shorter wavelength corresponds to a higher energy, whereas a longer wavelength corresponds to a lower energy. This particle-like nature of light becomes very important when we consider how light interacts with matter. The amount of energy a photon has dictates how the photon can interact with atoms and molecules.

*Example: What is the energy of a photon with a wavelength of 400 nm?*

Convert nm to m:

$$\frac{400 \text{ nm}}{1} \times \frac{1 \times 10^{-9} \text{ m}}{1 \text{ nm}} = 4.0 \times 10^{-7} \text{ m}$$

Use the equation above to calculate  $E$ :

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J s})(3.00 \times 10^8 \text{ m/s})}{4.0 \times 10^{-7} \text{ m}} = 5.0 \times 10^{-19} \text{ J}$$

6. Convert 535 nm into meters. What color of light does this correspond to?

$$\frac{535 \text{ nm}}{1} \times \frac{1 \times 10^{-9} \text{ m}}{1 \text{ nm}} = 5.35 \times 10^{-7} \text{ m}$$

7. Ultraviolet light has wavelengths in the  $4 \times 10^{-4}$  m to  $1 \times 10^{-9}$  m range. Convert this range to micrometers ( $\mu\text{m}$ ).

$$\frac{10^{-4} \text{ m}}{1 \text{ m}} \times \frac{1 \times 10^6 \mu\text{m}}{1 \text{ m}} = 100 \mu\text{m}$$

$$\frac{10^{-9} \text{ m}}{1 \text{ m}} \times \frac{1 \times 10^6 \mu\text{m}}{1 \text{ m}} = 0.001 \mu\text{m}$$

The range is 100-0.001  $\mu\text{m}$

8. Angstroms ( $\text{\AA}$ ) is a length unit commonly used in chemistry. There are  $1 \times 10^{10}$   $\text{\AA}$  in one meter. Convert the visible wavelength range of 400-700 nm into Angstroms.

$$\frac{400 \text{ nm}}{1 \text{ nm}} \times \frac{1 \times 10^{-9} \text{ m}}{1 \text{ m}} \times \frac{1 \times 10^{10} \text{\AA}}{1 \text{ m}} = 4000 \text{\AA}$$

$$\frac{700 \text{ nm}}{1 \text{ nm}} \times \frac{1 \times 10^{-9} \text{ m}}{1 \text{ m}} \times \frac{1 \times 10^{10} \text{\AA}}{1 \text{ m}} = 7000 \text{\AA}$$

The range is 4000-7000  $\text{\AA}$

9. Light travels at a speed of  $3.00 \times 10^8$  m/s. Convert this to miles per hour.

$$\frac{3.00 \times 10^8 \text{ m}}{\text{s}} \times \frac{3600 \text{ s}}{1 \text{ hr}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{0.621 \text{ mi}}{\text{Km}} = \frac{6.7 \times 10^8 \text{ mi}}{\text{hr}}$$

10. What is the frequency of light ( $\nu$ ) associated with a wavelength of 620 nm? (See Discussion 1 Lecture Notes)

$$\frac{620 \text{ nm}}{1 \text{ nm}} \times \frac{1 \times 10^{-9} \text{ m}}{1 \text{ nm}} = 6.2 \times 10^{-7} \text{ m}$$

$$\nu = \frac{c}{\lambda} = \frac{3.00 \times 10^8 \text{ m/s}}{6.2 \times 10^{-7} \text{ m}} = 4.84 \times 10^{14} / \text{s}$$

11. What is the wavelength of light associated with a frequency of  $8.22 \times 10^{14}$  per second? (Discussion 1 Lecture Notes)

$$\nu = \frac{c}{\lambda}$$

rearranging:

$$\lambda = \frac{c}{\nu} = \frac{3.00 \times 10^8 \text{ m/s}}{8.22 \times 10^{14} / \text{s}} = 3.65 \times 10^{-7} \text{ m} = 365 \text{ nm}$$

12. What is the energy (in Joules) of a photon with a wavelength of 420 nm?

$$\frac{420 \text{ nm}}{1 \text{ nm}} \times \frac{1 \times 10^{-9} \text{ m}}{1 \text{ nm}} = 4.2 \times 10^{-7} \text{ m}$$

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J s})(3.00 \times 10^8 \text{ m/s})}{4.2 \times 10^{-7} \text{ m}} = 4.73 \times 10^{-19} \text{ J}$$

13. What is the energy (in Joules) of a photon with a wavelength of 590 nm (orange light)?

$$\frac{590 \text{ nm}}{1 \text{ nm}} \times \frac{1 \times 10^{-9} \text{ m}}{1 \text{ nm}} = 5.9 \times 10^{-7} \text{ m}$$

$$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J s})(3.00 \times 10^8 \text{ m/s})}{5.9 \times 10^{-7} \text{ m}} = 3.37 \times 10^{-19} \text{ J}$$

14. Which has more energy: yellow light or orange light? Explain. *Yellow light has a shorter wavelength than orange light, therefore yellow light has more energy.*

15. Which has more energy: ultraviolet light or gamma rays? Explain.

*Gamma rays have a shorter wavelength than UV light, therefore gamma rays have more energy.*

### Atomic Structure

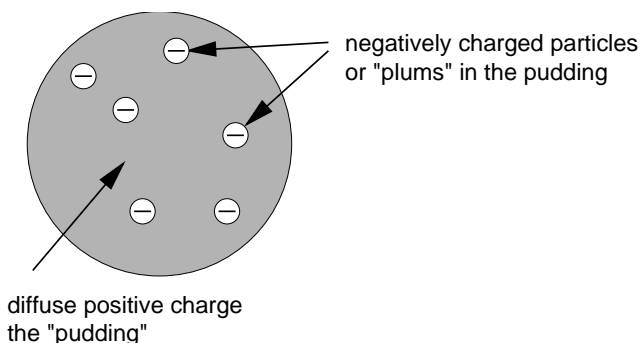
16. The element potassium has three naturally occurring isotopes:  $^{39}\text{K}$ ,  $^{40}\text{K}$  and  $^{41}\text{K}$ . How many protons, neutrons and electrons does each isotope have? (See text, section 3.5)

isotope	atomic # = # p <sup>+</sup>	# e <sup>-</sup> = # p <sup>+</sup>	# n <sup>0</sup> = mass # - # p <sup>+</sup>
$^{39}\text{K}$	19	20	19
$^{40}\text{K}$	19	21	19
$^{41}\text{K}$	19	22	19

17. Complete the following table for electrically neutral atoms of the given isotope: (See text, section 3.5)

Symbol	Atomic number	Mass number	number of protons	number of neutrons	Number of electrons
$^{38}_{18}\text{Ar}$	18	38	18	20	18
$^{15}_7\text{N}$	7	15	7	8	
$^2_1\text{H}$	1	2	1	1	1
$^{34}_{16}\text{S}$	16	34	16	18	16
$^7_3\text{Li}$	3	7	3	4	3
$^{84}_{38}\text{Sr}$	38	84	38	46	38

18. In the early 1900's a common model for the structure of the atom was the plum pudding model. In this model, negatively charged electrons reside in the atom surrounded by a diffuse, continuous medium of positive charge (like plums in a pudding, or for a more modern analogy, like chocolate chips in a cookie).



- (a) In 1911 Earnest Rutherford carried out an experiment that changed the way we view the atom. Describe this gold foil experiment. (See Section 3.4 in the text) *consult text*
- (b) How is the plum pudding model inconsistent with Rutherford's experimental findings? Approach this by considering the plum pudding hypothesis, and then predict what you would have expected to happen in Rutherford's experiment if the plum pudding model was true. (See Chapter 1, Section 1.3 for information regarding the scientific method.)

*In the plum pudding model, negatively charged electrons reside in the atom surrounded by a continuous medium of positive charge. At the time, it was believed that this continuous medium of*

*positive charge was very diffuse both in terms of charge and mass. The “pudding” was viewed as having the same amount of charge as the electrons, but that charge was spread out over the whole atom, as was the mass of the atom. Thus, Rutherford’s hypothesis was that the alpha particles would pass right through the foil. As they did not all do this, but many were deflected or bounced back, he had to revise the initial hypothesis to account for this. He did this by proposing that the atom has a positively charged nucleus that contained most of the mass of the atom.*

- (c) Draw a picture of Rutherford’s model of the atom. Use your picture to describe why most of the alpha particles pass through the gold foil in Rutherford’s experiment.  
*consult text*