General Chemistry Peer Tutoring Department
University of California, Irvine
Sarina Rai (sarinr1@uci.edu)
Yana Khetiya (ykhetiya@uci.edu)

Midterm 1 Review Packet Answer Key

Topics Covered:

LECTURE 1:
- Atoms: Proton, Neutron, and Electron; Atomic Number, Mass Number, and Isotopes; Atomic Mass
- Ions: Common Monatomic Ions
- Periodic Table
- Mass Spectroscopy

LECTURE 2:
- Average Atomic Mass
- The Mole, Molar Mass, and Formula
- Covalent and Ionic Compounds

LECTURE 3:
- Properties of Waves: Reflection and Refraction; Interference; Diffraction
- Electromagnetic Radiation
- Two-Slit Interference
- Plank's Quantum Theory
- Einstein's Theory of Light

LECTURE 4:
- The Photoelectric Effect: Emission Spectra
- Bohr Model of the Hydrogen Atom

LECTURE 5:
- The Dual Nature of Matter: de Broglie Wavelength, Electron Diffractions, X-Ray Diffraction and Electron Diffraction, and Electron Microscopy

LECTURE 6:
- Quantum Mechanics
- Probability of Finding the Electron
- Quantum Numbers

LECTURE 7:
- Quantum Numbers: Shells and Subshells of Orbitals
- Energy of orbitals in a single electron system
- Nodes in S Orbitals and Electron Radial Probability in S Orbitals
- Nodes in P Orbitals and Electron Radial Probability in P Orbitals
- Nodes in D Orbitals

General Chemistry Peer Tutoring Department
University of California, Irvine
Sarina Rai (sarinr1@uci.edu)
Yana Khetiya (ykhetiya@uci.edu)

Chem 1A
Professor Ge
https://sites.uci.edu/gcptutoring/

Practice Problems

1. Determine the number of protons and the number of neutrons in each isotope (Tro. 1st Ed., Ch.1 #65)
   The atomic number (the bottom number) tells us the number of protons. The mass number tells us the number of protons and neutrons, so to find the number of neutrons, we subtract the atomic number from the mass number.
   a. ${}^{14}_{7}N$ **7 protons and 7 neutrons**
      Neutrons = 14 protons and neutrons - 7 protons = 7 neutrons
   b. ${}^{23}_{11}Na$ **11 protons and 12 neutrons**
      Neutrons = 23 protons and neutrons - 11 protons = 12 neutrons
   c. ${}^{222}_{86}Rn$ **86 protons and 136 neutrons**
      Neutrons = 222 protons and neutrons - 86 protons = 136 neutrons
   d. ${}^{208}_{82}Pb$ **82 protons and 126 neutrons**
      Neutros = 222 protons and neutrons - 82 protons = 126 neutrons

2. Bromine has two naturally occurring isotopes (Br-79 and Br-81) and has an atomic mass of 79.904 amu. The mass of Br-81 is 80.9163 amu, and its natural abundance is 49.31%. Calculate the mass and natural abundance of Br-79. (Tro. 1st Ed., Ch. 1 #77)
   50.69% natural abundance and atomic mass of 78.92 amu

   The natural abundances of all isotopes equals 100%, so since there are only 2 isotopes, we can solve for the natural abundance of Br-79: 100% = 49.31% + x; x = 50.69%

   Average atomic mass = **Σ**(fraction of isotope i)(mass of isotope i)
   80.9163 amu = (0.5069)(x amu) + (0.4931)(80.9163 amu)
   x = 78.92 amu

   **note: the lowest number of significant figures is 4, so the final answer should only have 4 significant figures

3. Calculate the number of atoms in each sample (Tro. 1st Ed., Ch. 2 #53).
   a. 5.18 g P: $5.18\ g\ P\ x \frac{1\ mol\ P}{30.97\ g\ P} x \frac{6.022\ x\ 10^{23}\ atoms}{1\ mol\ P}$ = **1.01 x 10^{23} atoms P**
   b. 2.26 g Hg: $2.26\ g\ Hg\ x\ \frac{1\ mol\ hg}{200.6\ g\ Hg}\ x\ \frac{6.022\ x\ 10^{23}\ atoms}{1\ mol\ Hg}$ = **6.78 x 10^{21} atoms Hg**
   c. 1.87 g Bi: $1.87\ g\ Bi\ x\ \frac{1\ mol\ Bi}{209.0\ g\ Bi}\ x\ \frac{6.022\ x\ 10^{23}\ atoms}{1\ mol\ Bi}$ = **5.39 x 10^{21} atoms Bi**
   d. 0.082 g Sr: $0.082\ g\ Sr\ x\ \frac{1\ mol\ Sr}{87.62\ g\ Sr}\ x\ \frac{6.022\ x\ 10^{23}\ atoms}{1\ mol\ Sr}$ = **5.6 x 10^{20} atoms Sr**

Sarina Rai (sarinr1@uci.edu)
Yana Khetiya (ykhetiya@uci.edu)

4. Calculate the frequency of each wavelength of electromagnetic radiation: (Tro. 1st Ed., Ch. 3 #39)

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

**MAKE SURE TO CONVERT NANOMETERS TO METERS

a. 632.8 nm (wavelength of red light from helium-neon laser): **4.728 Hz**

$\lambda = 632.8\, nm\, x \frac{10^{-9}\, m}{1\, nm} = 6.328\, x\, 10^{-7}\, m$

$\upsilon = \frac{2.9979\, x\, 10^{8}\, \frac{m}{s}}{6.328\, x\, 10^{-7}\, m} = 4.738\, x\, 10^{14}\, Hz\ or\ 4.738\, x\, 10^{14}\, \frac{1}{s}$

b. 503 nm (wavelength of maximum solar radiation): **5.96 Hz**

$\lambda = 503\, nm\, x \frac{10^{-9}\, m}{1\, nm} = 5.03 x\, 10^{-7}\, m$

$\upsilon = \frac{2.9979\, x\, 10^{8}\, \frac{m}{s}}{5.03\, x\, 10^{-7}\, m} = 5.96\, x 10^{14}\, Hz\ or\ 5.96\, x 10^{14}\, \frac{1}{s}$

c. 0.052 nm (wavelength contained in medical X-rays): **5.8 Hz**

$\lambda = 0.052\, nm\, x \frac{10^{-9}\, m}{1\, nm} = 5.2\, x\, 10^{-11}\, m$

$\upsilon = \frac{2.9979\, x\, 10^{8}\, \frac{m}{s}}{5.2\, x\, 10^{-11}\, m} = 5.8\, x\, 10^{18}\, Hz\ or\ 5.8\, x\, 10^{18}\, \frac{1}{s}$

5. Determine the energy of 1 mol of photons for each kind of light (assume 3 significant figures) (Tro. 1st Ed., Ch.3 #45)

$E_{photon} = \frac{hc}{\lambda}$

a. Infrared radiation (1500 nm): **7.98 x 10^4 J/mol**

$\lambda = 1500\, nm\, x \frac{10^{-9}\, m}{1\, nm} = 1.50\, x\, 10^{-6}\, m$

$E_{photon} = \frac{(6.6256\, x\, 10^{-34}\, J*s)(2.9979\, x\, 10^{8}\, \frac{m}{s})}{1.50\, x\, 10^{-6}\, m} = 1.32\, x\, 10^{-19}\, \frac{J}{photon}$

$(1.32\, x\, 10^{-19}\, \frac{J}{photon})\, x\, (\frac{6.022\, x\, 10^{23}}{1\, mol}) = 7.98\, x\, 10^{4}\, \frac{J}{mol\ of\ photon}$

b. Visible light (500 nm): **2.39 x 10^5 J/mol**

$\lambda = 500\, nm\, x \frac{10^{-9}\, m}{1\, nm} = 5.00\, x\, 10^{-7}\, m$

$E_{photon} = \frac{(6.6256\, x\, 10^{-34}\, J*s)(2.9979\, x\, 10^{8}\, \frac{m}{s})}{5.00\, x\, 10^{-7}\, m} = 3.97\, x\, 10^{-19}\, \frac{J}{photon}$

$(3.97\, x\, 10^{-19}\, \frac{J}{photon})\, x\, (\frac{6.022\, x\, 10^{23}}{1\, mol}) = 2.39\, x\, 10^{5}\, \frac{J}{mol\ of\ photon}$

c. Ultraviolet radiation (150 nm): **7.98 x 10^5 J/mol**

$\lambda = 150\, nm\, x \frac{10^{-9}\, m}{1\, nm} = 1.50\, x\, 10^{-7}\, m$

$E_{photon} = \frac{(6.6256\, x\, 10^{-34}\, J*s)(2.9979\, x\, 10^{8}\, \frac{m}{s})}{1.50\, x\, 10^{-7}\, m} = 1.32\, x\, 10^{-18}\, \frac{J}{photon}$

$(1.32\, x\, 10^{-18}\, \frac{J}{photon})\, x\, (\frac{6.022\, x\, 10^{23}}{1\, mol}) = 7.98\, x\, 10^{5}\, \frac{J}{mol\ of\ photon}$

General Chemistry Peer Tutoring Department
University of California, Irvine
Sarina Rai (sarinr1@uci.edu)
Yana Khetiya (ykhetiya@uci.edu)

6. An electron in the n = 7 level of the hydrogen atom relaxes to a lower energy level, emitting light of 397 nm. What is the value of n for the level to which the electron relaxed? (Tro. 1st Ed., Ch. 3 #71)
   n = 2

   $\Delta E = -R_H(\frac{Z^2}{n_f^2} - \frac{Z^2}{n_i^2})$

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

   First convert nm to m: $\lambda = 397\, nm\, x \frac{10^{-9}\, m}{1\, nm} = 3.97\, x\, 10^{-7}\, m$

   $E = \frac{(6.6256\, x\, 10^{-34}\, J*s)(2.9979\, x\, 10^{8}\, \frac{m}{s})}{3.97\, x\, 10^{-7}\, m} = 5.00\, x\, 10^{-19} J$ ** energy EMITTED is NEGATIVE

   $-5.00\, x\, 10^{-19} J = -(2.178\, x\, 10^{-18} J)(\frac{1^2}{n_f^2} - \frac{1^2}{7^2})$

   n_f = 2.00 = 2

7. According to the quantum-mechanical model for the hydrogen atom, which electron transition produces light with the longer wavelength: 2p → 1s or 3p → 1s? (Tro. 1st Ed., Ch. 3 #67)
   2p → 1s

   You could do the math OR you can apply the Bohr model, which will save you a LOT of time on an exam.

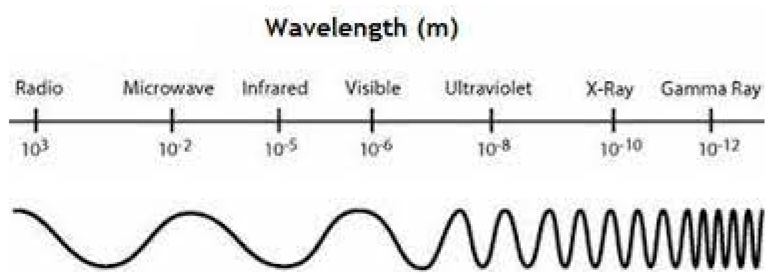
   Recalling the Bohr model, we know that when moving from a higher energy level to a lower energy level, the higher the initial energy level is, the shorter the wavelength emitted will be. We know that the quantum number n refers to energy level, so we don't have to worry about p or s orbitals. So when we move from n = 2 → n = 1, the wavelength emitted will be longer than n = 3 → n = 1.

8. List these types of electromagnetic radiation in order of (i) increasing wavelength and (ii) increasing energy per photon:

   a. radio waves
   b. microwaves
   c. infrared radiation
   d. ultraviolet radiation

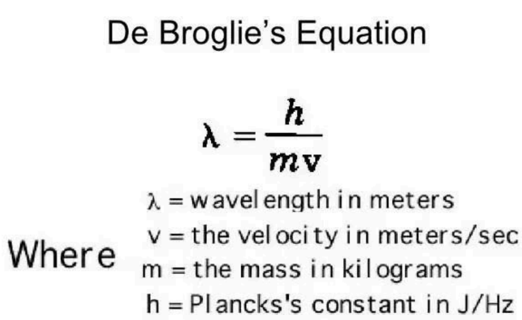
   i)UV < IR < Microwaves < Radio Waves
   ii) Radio < Microwaves< IR< UV

Wavelength is inversely proportional to frequency. Frequency is a direct measure of the energy within each photon. Therefore, as wavelength increases, frequency (and energy) decreases.



9. Answer the following questions about quantum numbers
   a. Is it possible to have an electron with these quantum numbers: $n=2$, $l=1$, $m_l=3$ $m_s=1/2$? Why or why not?
   No, because m_l is dependent on l, in this case because $l=1$, m_l can only be -1, 0, 1.
   b. Is it possible to have two electrons with the same n, l, and m_l ?
   Yes. Note however that two electrons may not have the same m_s, as the spin must be opposite.

10. What is the de Broglie wavelength of an electron traveling at $1.35 * 10^5$ m/s?



$$\frac{6.626\ x\ 10^{-34} Js}{(9.11\ x\ 10^{-31} kg)(1.35\ x\ 10^{5} m/s)} = 5.39 \times 10^{-9} \text{ or } 5.39 \text{ nm}$$

11. A nitrogen gas laser pulse with a wavelength of 337 nm contains 3.83 mJ of energy. How many photons does it contain?

General Chemistry Peer Tutoring Department
University of California, Irvine
Sarina Rai (sarinr1@uci.edu)
Yana Khetiya (ykhetiya@uci.edu)

Use the equation: E = hc/ƛ. First, calculate the energy for one photon. Then, divide the given energy emitted from the pulse by the energy for one photon to find the number of photons.

$$\lambda = 337\ \cancel{\text{nm}} \times \frac{10^{-9}\ \text{m}}{1\ \cancel{\text{nm}}} = 3.37 \times 10^{-7}\ \text{m}$$

$$E_{\text{photon}} = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ \text{J}\cdot\cancel{\text{s}})\left(3.00 \times 10^{8}\frac{\cancel{\text{m}}}{\cancel{\text{s}}}\right)}{3.37 \times 10^{-7}\ \cancel{\text{m}}}$$

$$= 5.8985 \times 10^{-19}\ \text{J}$$

$$3.83\ \cancel{\text{mJ}} \times \frac{10^{-3}\ \text{J}}{1\ \cancel{\text{mJ}}} = 3.83 \times 10^{-3}\ \text{J}$$

$$\text{number of photons} = \frac{E_{\text{pulse}}}{E_{\text{photon}}} = \frac{3.83 \times 10^{-3}\ \cancel{\text{J}}}{5.8985 \times 10^{-19}\ \cancel{\text{J}}}$$

$$= 6.49 \times 10^{15}\ \text{photons}$$

12. Which set of quantum numbers cannot occur together to specify an orbital?
   a. n = 2, l = 1, m_l = -1
   b. n = 3, l = 2, m_l = 0
   c. n = 3, l = 3, m_l = 2

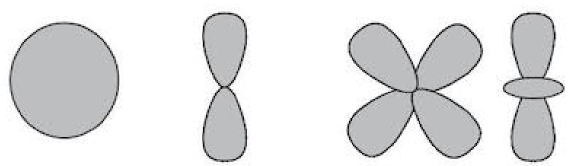
Symbol	Name	Values	Role
n	Principal	1,2,3,...	Determines energy (size)
l	Angular momentum	0,1,2, …, n-1	Contributes to shape
m_l	Magnetic	… -2,-1,0,1,2,...	Determines orientation in space
m_s	Spin	-2,-1,1,2	Determines electron spin

a. If n = 2,
   i. l has to be n-1 = 1.
   ii. Ml has to be -l to +l, so -1, 0, 1 are eligible values.
   iii. This combo works
b. If n = 3,
   i. L has to be n-1 = 2
   ii. M_l has to be -l to +l, so -2, -1, 0, 1, 2
   iii. This combo works

c. If n = 3,
   i. L has to be n-1 = 2
   ii. In this case, l is 3, so this combo is not valid.

13. What are the possible values of l for each given value of n?
    We know that l = 0, through (n-1)
    a. 1: l = 0
    b. 2: l = 0,1
    c. 3: l = 0,1, 2
    d. 4: l = 0,1, 2, 3

14. Describe the shapes of s, p, and d orbitals. How are these orbitals related to the quantum numbers n, l, and m_l?



s orbital p orbital d orbitals

s orbital: symmetrical, no nodes
p orbital: 2 lobes, 1 node
d orbital: 4 lobes, 2 nodes

The principal quantum number (n) describes the size and energy of an orbital. The angular momentum QN (l) describes the shape of an orbital. The magnetic QN (m_l) describes the orientation of an orbital in space.