

Fall 2008 CH301--The TA's gift to you—Answer Key for practice exam 1

1. What is the energy (E) of a photon that has a wavelength (λ) of 70 nm?

- A. **2.84x10⁻¹⁸ J** Correct
- B. 6.51x10⁻¹⁹ J
- C. 7.52x10⁻¹⁹ J
- D. 1.28x10⁻¹⁸ J
- E. 3.27x10⁻¹⁷ J

Explanation: First convert the unit of nm to m, 70 nm = 7x10⁻⁸ m. Then solve for frequency (ν) using $\nu = c/\lambda$, where $c = 3 \times 10^8 \text{ m}\cdot\text{s}^{-1}$, and λ is the given wavelength. Finally solve for energy (E) using $E = h\nu$, where h is plank's constant (6.626x10⁻³⁴ J·s). Alternatively, do the calculation in a single step using $E = hc/\lambda = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} \cdot 3 \times 10^8 \text{ m}\cdot\text{s}^{-1} / 7 \times 10^{-8} \text{ m} = 2.84 \times 10^{-18} \text{ J}$.

2. Which if the following statement(s) is/are true?

- I. Since it is observed experimentally that blackbody radiators emit less power at higher frequencies, the power radiated must be inversely proportional to the square of the frequency.
 - II. The failure of classical mechanics to predict the behavior of blackbody radiators is called the photoelectric effect.
 - III. After the threshold frequency is reached, further increasing the frequency of light would increase the velocity of ejected electrons.
 - IV. The quantized energy levels of electrons result in the continuous absorption/emission spectra of gases.
- A. I and III
 - B. I, II, IV
 - C. **III only** Correct
 - D. II only
 - E. II, III, IV

Explanation: Classical mechanics predicted that the power radiated by a blackbody radiator would be proportional to the square of the frequency at which it emitted radiation, and thus approach infinity as the frequency increased. This was false since at higher frequencies (like ultraviolet), blackbody radiators emit less, not more power. This is called the “ultraviolet catastrophe.” Classical mechanics also predicted that the energy (speed) of electrons emitted from a metal surface is proportional to the intensity of light. In reality, the energy (speed) is only dependent upon the frequency of light. Once the threshold frequency is reached, however, the number of emitted electrons is proportional to the intensity of light. Classical mechanics also failed to explain the discrete (rather than continuous) lines in absorption/emission spectra, which are due to the discrete energy levels of electrons in atoms.

3. For the hydrogen atom, emitted light with a frequency of 2.35×10^{14} Hz corresponds most closely to an electronic transition between which two energy levels?

- A. 2 and 3
- B. 1 and 2
- C. 1 and 3
- D. **3 and 5** Correct
- E. 4 and 5

Explanation: Solve by using the Rydberg equation: Frequency (ν) = $R (1/n_1^2 - 1/n_u^2)$, where R is the Rydberg

constant (3.3×10^{15} Hz), n_l is the lower energy level, and n_u is the upper energy level. By taking the ratio of the frequency and the Rydberg constant, you can determine the value of the parenthetical term, $\nu/R = (1/n_l^2 - 1/n_u^2) = 2.35 \times 10^{-14} \text{ Hz} / 3.3 \times 10^{15} \text{ Hz} = 0.0712 \sim (1/9 - 1/25)$.

4. Which of the following statement(s) is/are true regarding Particle in a Box?

- I. The Energy of the particle is nonzero and continuous.
 - II. The number of possible wavelengths is limited by boundary conditions
 - III. Within a given energy level, as the length of the box increases, the energy of the particle decreases
- A. I, II, and III
 - B. I only
 - C. II only
 - D. I and II
 - E. **II and III Correct**

Explanation: The energy of the particle is quantized and nonzero. The wavelength is limited by boundary conditions (fixed points on the edge of the box). The energy $[E = n^2 h^2 / (8mL^2)]$, as well as the difference in energy $[\Delta E = (2n+1)h^2 / (8mL^2)]$, is inversely proportional to the length of the box.

5. If we know the position of an electron (mass: 9.1×10^{-31} kg) with an uncertainty of 10^{-7} m, what would be the minimum uncertainty in the electrons' velocity?

- A. **580 m·s⁻¹ Correct**
- B. 610 m·s⁻¹
- C. 670 m·s⁻¹
- D. 750 m·s⁻¹
- E. 800 m·s⁻¹

Explanation: $\Delta x (m\Delta v) \geq h/(4\pi)$, where Δx is the given uncertainty in position, m is the mass of the electron, h is plank's constant (6.626×10^{-34} J s), and Δv is the uncertainty in electron's velocity by rearranging the inequality $\Delta v \geq h/(4\pi m\Delta x)$. $\Delta v \geq 580 \text{ m}\cdot\text{s}^{-1}$.

6. What is the deBroglie wavelength (λ) of an 800g object traveling at $30.0 \text{ m}\cdot\text{hr}^{-1}$?

- A. $5.25 \times 10^{-32} \text{ m}$
- B. **$9.94 \times 10^{-32} \text{ m}$ Correct**
- C. $6.23 \times 10^{-32} \text{ m}$
- D. $7.59 \times 10^{-32} \text{ m}$
- E. $8.37 \times 10^{-32} \text{ m}$

Explanation: Using the deBroglie equation, $\lambda = h/(mv)$, where h is plank's constant (6.626×10^{-34} J·s), m is the mass of object in kg, v is the object's velocity in m/s. Convert grams to kilograms and $\text{m}\cdot\text{hr}^{-1}$ to $\text{m}\cdot\text{s}^{-1}$. $800 \text{ g} = 0.8 \text{ kg}$. $30.0 \text{ m}\cdot\text{hr}^{-1} = 0.0083 \text{ m}\cdot\text{s}^{-1}$. $\lambda = h/(mv) = 6.626 \times 10^{-34} \text{ J}\cdot\text{s} / (0.8 \text{ kg} \times 0.0083 \text{ m}\cdot\text{s}^{-1}) = 9.94 \times 10^{-32} \text{ m}$.

7. Which of the following statement(s) is/are true regarding the Schrödinger and wave equations?

- I. The exact location of the electron can be calculated using the Schrödinger equation.
- II. Three dimensional solutions to the Schrödinger equation are done using polar coordinates because it simplifies the math.
- III. Every solution to the Schrödinger equation contains at least one repulsive potential energy term.

- A. **II only** **Correct**
- B. I only
- C. III only
- D. I and III
- E. II and III

Explanation: Solutions to the Schrödinger equation are wave functions, which when squared express the probable location of electrons; but, the exact location cannot be known. Attractive potential energy terms are found in all solutions for all atoms. Repulsive potential energy terms are found only in atoms that have more than one electron, i.e. everything beyond hydrogen. Polar coordinates are preferred for 3-D solutions because they simplify the math.

8. Which of the following is not a possible set of quantum numbers?

- A. $n = 4, l = 3, m_l = -1, m_s = 1/2$
- B. $n = 1, l = 0, m_l = 0, m_s = 1/2$
- C. $n = 3, l = 1, m_l = -1, m_s = -1/2$
- D. **$n = 5, l = 4, m_l = -5, m_s = -1/2$ Correct**
- E. $n = 9, l = 8, m_l = 6, m_s = 1/2$

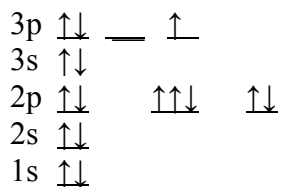
Explanation: The principle quantum number (n) can be any integer from 0 to infinity. The azimuthal quantum number (l) is any integer from 0 to $n-1$. The orientation (m_l) is any whole number from $-l$ to l . The spin (m_s) can be either positive or negative $1/2$. Applying these rules, when l is 4, m_l can be no smaller than -4 .

9. Which of the following is not a possible set of quantum numbers?

- A. $n = 3, l = 2, m_l = -2, m_s = -1/2$
- B. $n = 2, l = 1, m_l = -1, m_s = 1/2$
- B. **$n = 5, l = 0, m_l = 2, m_s = 1$ Correct**
- C. $n = 7, l = 5, m_l = -5, m_s = -1/2$
- D. $n = 8, l = 0, m_l = 0, m_s = 1/2$

Explanation: The principle quantum number (n) can be any integer from 0 to infinity. The azimuthal quantum number (l) is any integer from 0 to $n-1$. The orientation (m_l) is any whole number from $-l$ to l . The spin (m_s) can be either positive or negative $1/2$. Applying these rules, 1 is not a valid value for m_s .

10. The following configuration violates which rule(s)?



- I. Aufbau Principle
- II. Pauli Exclusion Principle
- III. Hund's Rule

- A. I and II
- B. I only
- C. II only
- D. III only

E. **II and III** **Correct**

Explanation: The Aufbau principle states that electron orbits need to be filled from low to high energy levels (no skipped electrons from bottom to up). Pauli Exclusion Principle requires that no more than 2 paired electrons can be in an orbit, clearly violated by the 2nd 2p orbital. Hund's rule states that each orbital must have one electron before any orbital has a second electron, clearly violated by the 3p subshell.

11. The electron configuration [Ar]4s²3d¹⁰4p⁴ could be the electron configuration of which of the following?

1. **Se** **correct**
2. As²⁻
3. S
4. Te
5. None of them

Explanation: To do this problem, you must know how to interpret the abbreviated electron configurations, how to write basic electron configurations and be able to relate them to positions on the periodic table. [Ar] serves as an abbreviation for the electron configuration of Ar, which has 18 electrons. Adding the electrons in the rest of the configuration, 4s²3d¹⁰4p⁴, we end up with a total of 34 electrons. The only one of the choices corresponding to 34 electrons is Se.

12. The electron configuration [Ar]4s²3d⁹ could be the electron configuration of which of the following?

- D. Ag
- E. Ni
- F. Cu
- G. Zn
- H. None of them** **correct**

Explanation: Because of the enhanced stability of having a full d subshell (d¹⁰), d⁹ atoms will "borrow" an electron from the s subshell. In reality, we only find atoms with an s¹d¹⁰ configuration, NEVER with an s²d⁹ configuration.

13. The electron configuration [Kr]5s¹4d⁵ could be the electron configuration of which of the following?

1. Nb
2. Tc
3. **Mo** **correct**
4. Cr
5. None of them

Explanation: Kr has 36 electrons. Adding in the 6 from the rest of the electron configuration, we have a total of 42 electrons. Only Mo has 42 electrons of the given choices. Note that there is only 1 electron in the 5s shell because Mo has "borrowed" its electron to become d⁵.

14. Which of the following correctly describes period(s) and group(s) in the periodic table?

- III. Periods are the eighteen columns, groups are the seven rows.
- IV. Groups are the eighteen columns, periods are the seven rows.** **correct**
- V. Groups and periods are synonyms for the columns.
- VI. Groups and periods are synonyms for the rows.
- VII. The group is the main block of the period table while the period includes only the lanthanide series

and actinide series.

Explanation: It's just vocabulary, you need to memorize it.

15. What best explains the increase in ionization energy up and to the right of the periodic table?

- 1. Increasing effective nuclear charge. correct**
2. Decreasing electron affinity.
3. Increasing electronegativity.
4. Increasing atomic radius.
5. Decreasing shell stability.

Explanation: Effective nuclear charge is basically just a measure of how much positive charge an electron "feels" from the nucleus. When ENC is high, the electron has a lot of positive charge pulling on it and it becomes very hard to rip off the atom. In other words, it requires more ionization energy. The other answer choices are also results of the changing ENC and while they may correspond to IE, they are not the underlying cause.

16. Rank the following species from least to greatest ionization energy: Oxygen (O), Potassium (K), Sulfur (S) and Sodium (Na).

- J. $S < O < Na < K$
- K. $Na < K < O < S$
- L. $K < Na < O < S$
- M. **$K < Na < S < O$ correct**
- N. $O < S < K < Na$

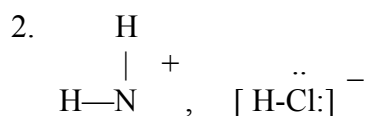
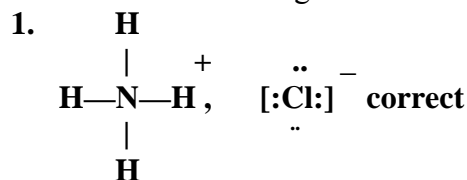
Explanation: IE increases going up and to the right of the periodic table.

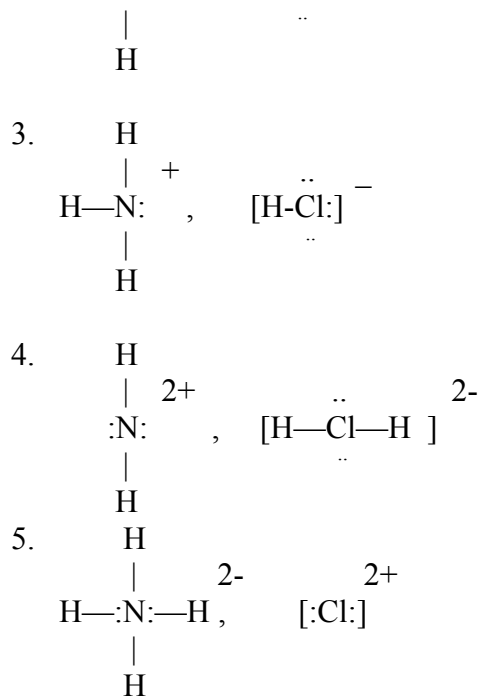
17. Rank the following from least to greatest ionization energy: C, N, O

1. $O < C < N$
2. $O < N < C$
3. $C < N < O$
- 4. $C < O < N$ correct**
5. $N < C < O$

Explanation: Although ENC would predict a $C < N < O$ ordering, you must remember that having a half-full subshell is stabilizing. It is more difficult to ionize N because it would no longer be half-full. It is less difficult to ionize O because it would become half full. It turns out, this effect is strong enough to outweigh the increase in IE with increasing ENC. This exact problem was in your course notes.

18. Which of the following is the correct lewis structure for NH_4Cl ?





Explanation: First, you should recognize the ammonium ion NH_4^+ and the chloride ion Cl^- . You then expect this to be an ionic pairing. The chloride ion already has a full octet by itself, so you simply draw its four lone pairs. For ammonium, N is the only atom that can be in the center because hydrogens always form duplets. The only way to satisfy the octets and duplets of all the atoms is by having four singly bonded hydrogens to nitrogen.

19. Using charge density, rank the lattice energy of the following compounds from least to greatest: KF, BeO, MgS, MgBr₂.

- B. $\text{BeO} < \text{MgS} < \text{MgBr}_2 < \text{KF}$
- C. $\text{KF} < \text{BeO} < \text{MgS} < \text{MgBr}_2$
- D. $\text{BeO} < \text{KF} < \text{MgBr}_2 < \text{MgS}$
- E. $\text{MgBr}_2 < \text{MgS} < \text{BeO} < \text{KF}$
- F. **$\text{KF} < \text{MgBr}_2 < \text{MgS} < \text{BeO}$ correct**

Explanation: Wherever larger charges are involved, the bonding will be greater between the atoms and thus the lattice energy will be larger. Bonds between smaller smaller atoms are also stronger.

20. Which of the following species would have three resonance structures?

- 1. CH_3COO^-
- 2. NO_2^-
- 3. **NO_3^- correct**
- 4. HCN
- 5. SO_2

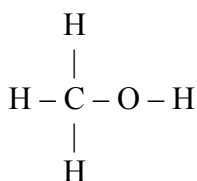
Explanation: Draw all the lewis structures. Only nitrate NO_3^- has three resonance structures. The structures of all of these are given in the worksheets.

21. How many single and double bonds are in the correct Lewis structure methanol (CH_3OH)?

- 1. **5 single bonds and 0 double bonds. correct**

2. 3 single bonds and 1 double bond.
3. 4 single bonds and 1 double bond.
4. 6 single bonds and 0 double bonds.
5. 5 single bonds and 1 double bond.

Explanation: The Lewis structure for methanol looks like this (only bonding electrons are shown):



22. Based on their Lewis structures, which of the following atoms would be considered radicals?

- I. C
 - II. N
 - III. O
 - IV. F
1. **II and IV** correct
 2. I and III
 3. I, II and III
 4. II, III and IV
 5. II and III
 6. I and IV

Explanation: A radical is any species with unpaired electrons (i.e. an odd number of valence electrons). Carbon and Oxygen have 4 and 6 valence electrons respectively and thus are not radicals. Nitrogen and Fluorine have 5 and 7 valence electrons respectively and thus are radicals.

23. Which group on the periodic table contains at least one element likely to form stable covalent compounds that have fewer than 8 valence electrons on their central atom?

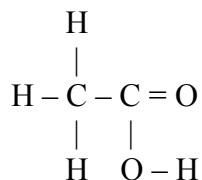
1. Group 4
2. Group 7
3. Group 6
4. **Group 3** correct
5. Group 5

Explanation: Group three contains Boron, which has only 3 valence electrons and thus can form only 3 bonds. It cannot satisfy the octet rule. All of the other listed groups can form sufficient bonds to satisfy the octet rule.

24. How many double bonds are found in the Lewis structure of ethanoic acid (CH₃COOH)?

1. 6
2. 0
3. 2
4. 5
5. **1** correct

Explanation: The correct Lewis structure for ethanoic acid is (only bonding electrons are shown):



25. Which of the following electronic geometries is reserved for hypervalent compounds?

1. linear
2. trigonal planar
3. **trigonal bipyramidal correct**
4. tetrahedral
5. dodecahedral

Explanation: The two electronic geometries that require a hypervalent central atom are trigonal bipyramidal and octahedral.

26. What would be the electronic geometry of Br_3^- ?

1. **trigonal bipyramidal correct**
2. square pyramidal
3. octahedral
4. tetrahedral
5. icosahedral

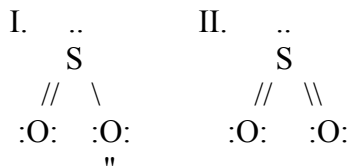
Explanation: The correct Lewis structure for Br_3^- is identical to I_3^- .

27. What is the formal charge on the Xenon atom (Xe) in XeF_2 ?

1. -2
2. 2
3. **0 correct**
4. 6
5. -4

Explanation: In the correct Lewis structure for XeF_2 , Xe has 6 non bonding electrons and 2 bonds, therefore its formal charge is 0.

28. Based on formal charge considerations, which of the following is a better Lewis structure for sulfur dioxide (SO_2)?



1. **Structure 2 is better based on formal charge considerations. correct**
2. Structure 1 is better based on formal charge considerations.
3. Both structure are equivalent based on formal charge considerations.
4. Neither structure is a correct Lewis structure for SO_2 .

Explanation: In structure 2, every atom has a formal charge of zero, which is preferable to structure one in which Sulfur has a formal charge of +1 and the singly bound Oxygen has a formal charge of -1.

29. Rank the following diatomic molecules in terms of decreasing electronegativity difference (ΔEN): HI, HF, HBr, HCl,

1. $\text{HI} < \text{HF} < \text{HCl} < \text{HBr}$
2. $\text{HI} < \text{HBr} < \text{HCl} < \text{HF}$
3. $\text{HCl} < \text{HBr} < \text{HI} < \text{HF}$

4. **HF < HCl < HBr < HI** correct

5. all have the same electronegativity difference.

Explanation: Hydrogen has an electronegativity of 2.2 and Fluorine has an electronegativity of 4.0. Their ΔEN is 1.8. Because electronegativity decreases down a given family, ΔEN will also decrease for these compounds.

30. Which of the bonds below is **not** correctly paired with its electronegativity difference (ΔEN)?

1. C-H ; 0.3

2. **B-F ; 2.5** correct

3. C-O ; 0.5

4. N-N ; 0

5. Si-Si ; 0

Explanation: A B-F bond would have an electronegativity difference of 2.0.