

MC: ( \_\_\_\_\_ - \_\_\_\_\_ / 4)(2.5 pts each) = \_\_\_\_\_ FR: \_\_\_\_\_ / 37 Overall: \_\_\_\_\_ / 75

SECTION I: Multiple Choice (2.5 pts each): Choose the option that is the best answer or completes each question or statement. Write your answers in the blanks provided and erase mistakes completely. In this section, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly.

1. The internal energy of a system is always increased by:
- a. Adding heat to the system
  - b. Having the system do work on the surroundings
  - c. Withdrawing heat from the system
  - d. Compressing the volume
  - e. Measuring the temperature of the surroundings

Ans: a

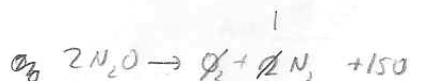
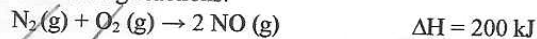
2. Which of the following is not a state function?

- I. Enthalpy
- II. Heat
- III. Work

- a. I only
- b. II only
- c. I and II only
- d. II and III only
- e. I and III only

Ans: d

3. Given the following reactions:



The enthalpy of reaction for  $4 \text{N}_2\text{O}(\text{g}) \rightarrow 4 \text{NO}(\text{g}) + 2 \text{N}_2(\text{g})$  is:

- a. -50 kJ
- b. -350 kJ
- c. 350 kJ
- d. 100 kJ
- e. 700 kJ

300.2

Ans: e

4. Energy transitions in which an "excited" electron returns to  $n = 3$  are associated primarily with:

- a. Infrared light
- b. Radio waves
- c. The Lyman series
- d. The Paschen series
- e. Nuclear charge

BALMER

Ans: a

5. All of the electrons in a given shell have the same value of the:

- ~~I.~~ Angular quantum number
- ~~II.~~ Magnetic quantum number
- III. Principal quantum number
- IV. Spin quantum number

4s  
4p  
4d  
4f

- a. III only
- b. IV only
- c. I and III only
- d. I, II and III only
- e. II and IV only

Ans: a

6. What is a permissible set of quantum numbers for the highest energy electron of a ground state chromium  $3+$  ion?

- a. 1, 0, 0
- b. 3, 1, 0
- c. 3, 2, 0
- d. 4, 1, -1
- e. 4, 2, -1

3d

Ans: c

7. Which of the following would have the smallest first ionization energy?

- a. Ar
- b. Cl
- c. Ne
- d. P
- e. S

Ans: e

8. Which series is ranked in order from of increasing atomic radius?

- a. Mg, Na, P, Si
- b. Si, P, Na, Mg
- c. Si, P, Na, Mg
- d. Na, Mg, Si, P
- e. P, Si, Mg, Na

magnitide

Ans: d

9. The compound with the largest lattice energy is:

- a. Potassium oxide
- b. Potassium sulfide
- c. Sodium oxide
- d. Sodium sulfide
- e. Cannot be determined from the given information.

$$\frac{q_1 q_2}{r_1 + r_2} \quad \frac{(+1)(-2)}{Na+O}$$

Ans: c

10. An aqueous solution of an unknown salt is colorless. The flame test of the solution displays a characteristic yellow color. The unknown is most likely to contain cations of:

- a. Ba
- b. K
- c. Li
- d. Na
- e. Ne

Ans: d

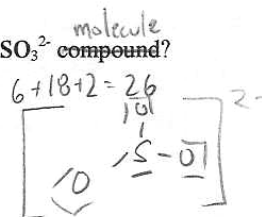
11. Which of the following atoms or ions is largest in size?

- a. Ar
- b.  $\text{Cl}^{-1}$
- c.  $\text{K}^{1+}$
- d.  $\text{P}^{3-}$
- e.  $\text{S}^{2-}$

Ans: d

12. What is the total number of resonance structures for the  $\text{SO}_3^{2-}$  molecule compound?

- a. 1
- b. 2
- c. 3
- d. 4
- e. There are no resonance structures



Ans: e

13. Which of the following series ranks the compounds in order of decreasing bond length?

- a.  $\text{N}_2, \text{O}_2, \text{F}_2, \text{Cl}_2$
- b.  $\text{Cl}_2, \text{F}_2, \text{O}_2, \text{N}_2$
- c.  $\text{F}_2, \text{Cl}_2, \text{N}_2, \text{O}_2$
- d.  $\text{Cl}_2, \text{N}_2, \text{O}_2, \text{F}_2$
- e. Cannot be determined from the given information

Ans: b

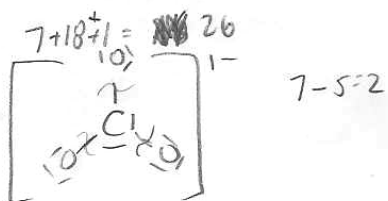
14. The process of breaking a chemical bond:

- a. Absorbs energy
- b. Can absorb or release energy, depending on the particular reactant-reaction
- c. Creates a stable compound
- d. Is a measure of the ionization energy
- e. Releases energy

Ans: a

15. In  $\text{ClO}_3^{-1}$ , carbon has a formal charge of:

- a. -2
- b. -1
- c. 0
- d. 1
- e. 2



Ans: e

**SECTION II: Free Response (37 pts)**

16. (8 pts) The quantum numbers listed below represent four different electrons in the same atom. Note that a "capital L" is used instead of the normal "lowercase l" for one of the quantum numbers, to distinguish it from the "number one."

Electron W	$n = 4$	$L = 0$	$m_l = 0$	$m_s = \frac{1}{2}$	4s
Electron X	$n = 3$	$L = 2$	$m_l = 1$	$m_s = \frac{1}{2}$	3d
Electron Y	$n = 3$	$L = 2$	$m_l = -2$	$m_s = -\frac{1}{2}$	3d
Electron Z	$n = 3$	$L = 1$	$m_l = 1$	$m_s = -\frac{1}{2}$	3p

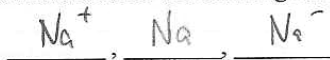
On the lines below, write the letters of these four electrons, arranging them in order of increasing energy. If two electrons have the same energy, indicate that by circling both electrons. If an electron does not exist, do not add it to the list.

Z, W, X, Y

sequence 4  
 switch 2 -2 3  
 no circle -2  
 reverse -2

17. (16 pts) For the following, the answer because "that's the trend" will receive no credit; you must explain why the trend is the way it is, if applicable.

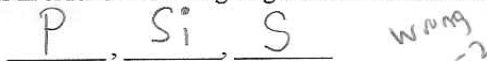
a. (4 pts) Put these ions and atoms in order of increasing radius: Na Na<sup>+</sup> Na<sup>-</sup>



(4 pts) Explain your reasoning here, in 2-3 sentences, using principles of atomic structure.

- more e<sup>-</sup> means more e<sup>-</sup>-e<sup>-</sup> repulsions
- ~~extra electron in new shell~~

b. (4 pts) Put these elements in order of increasing magnitude of electron affinity: Si P S



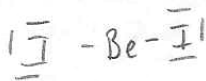
(4 pts) Explain your reasoning here, in 2-3 sentences, using principles of atomic structure.

- P has 1 1 1, and adding one e<sup>-</sup> would be destabilizing
- EA inc → b/c of inc eff. nuclear charge (more p<sup>+</sup> and similar shielding)

18. (8 pts) Draw the correct Lewis structures for the following compounds.

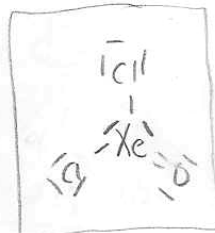
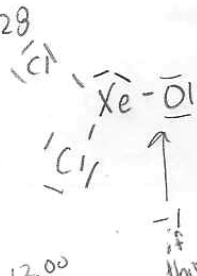
a. BeI<sub>2</sub>

2+14=16



b. XeOCl<sub>2</sub>

8+6+14=28



19. (5 pts) After placing a 50-g sample of water in a cup in the microwave, you remove it and determine that its temperature is 85.0°C. Since this is too hot for you to drink, you add 12-g of cool water (14.0°C) from the sink. What is the final temperature of the combined sample of water? (Given: c<sub>water</sub> = 4.18 J/g°C)

q<sub>hot water</sub> = q<sub>cool water</sub>

-q = q

-m<sub>h</sub>c<sub>h</sub>ΔT = m<sub>c</sub>c<sub>c</sub>ΔT

-50 · 4.18 (T<sub>f</sub> - 85.0) = 12 (4.18) (T<sub>f</sub> - 14.0)

-50 T<sub>f</sub> + 4250 = 12 T<sub>f</sub> - 168

4418 = 62 T<sub>f</sub>

T<sub>f</sub> = 71.26°C

MC: ( \_\_\_\_\_ - \_\_\_\_\_ / 4)(2.5 pts each) = \_\_\_\_\_ FR: \_\_\_\_\_ / 37 Overall: \_\_\_\_\_ / 75

**SECTION I: Multiple Choice (2.5 pts each):** Choose the option that is the best answer or completes each question or statement. Write your answers in the blanks provided and erase mistakes completely. In this section, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly.

1. Adding heat to a system:

- a. Decreases the internal energy of the system
- b. Represents a positive change in enthalpy
- c. Increases the work on a system
- d. Increases the volume
- e. Causes a change in state

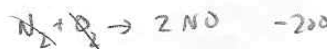
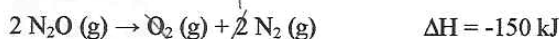
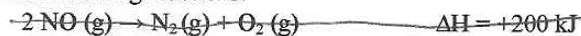
Ans: b

2. Which of the following is a state function?

- I. Enthalpy
  - II. Temperature
  - III. Work
- a. I only
  - b. II only
  - c. III only
  - d. I and II only
  - e. II and III only

Ans: d

3. Given the following reactions:



The enthalpy of reaction for  $2 \text{N}_2\text{O}(\text{g}) \rightarrow 2 \text{NO}(\text{g}) + \text{N}_2(\text{g})$  is:

- a. -50 kJ
- b. 50 kJ
- c. -350 kJ
- d. 350 kJ
- e. Cannot be determined from the given information.

Ans: c

4. The electromagnetic process associated with an electron transition from  $n = 4$  to  $n = 2$  is associated with:

- I. Balmer series
  - II. Brackett series
  - III. Far infrared light
- a. I only
  - b. III only
  - c. I and II only
  - d. I and III only
  - e. II and III only

Ans: a

5. Energy transitions in which a ground state electron "moves" to  $n = 2$  describes:
- Aufbau principle
  - Energy absorption
  - Energy release
  - Hund's rule
  - Cannot be determined from the given information
- Ans: e
6. The angular momentum quantum number describes the:
- Essential "shape" of the electron's distribution *plot e*
  - Orbital of the electron
  - Shell number of the electron
  - Spatial orientation of the electron's distribution *plot*
  - Spin of an electron
- Ans: a
7. What is a permissible set of quantum numbers for the highest energy electron of a ground state nickel  $2+$  ion?
- 1, 0, 0
  - 3, 1, -1 *3d*
  - 3, 2, 0
  - 4, 1, -1
  - 4, ~~2~~, ~~1~~  
0 0
- Ans: c
8. Which of the following would have the greatest first ionization energy?
- As
  - P
  - S
  - Se
  - Si
- Ans: b
9. Which series is ranked in order ~~from~~ of increasing atomic radius?
- Br, As, Ca, K
  - Ca, K, Br, As
  - As, Br, Ca, K
  - K, Ca, As, Br
  - Br, K, Ca, As
- Ans: a
10. An aqueous solution of an unknown salt is colorless. The flame test of the solution displays a characteristic green color. The unknown is most likely to contain cations of:
- Ba
  - Ca
  - K
  - Li
  - Ne
- Ans: a
11. The compound with the smallest lattice energy is:
- Calcium fluoride
  - Magnesium chloride
  - Calcium fluoride *chloride*
  - Magnesium chloride *fluoride*
  - Cannot be determined from the given information.
- Ans: c

12. Which of the following atoms or ions is smallest in size?

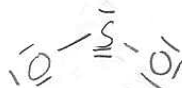
- a. K
- b.  $K^{1-}$
- c.  $K^{1+}$
- d.  $K^{2-}$
- e.  $K^{2+}$

Ans: e

13. What is the total number of resonance structures for the  $SO_2^{2-}$  compound?

- a. 1
- b. 2
- c. 3
- d. 4
- e. There are no resonance structures

$6 + 12 + 12 = 20$



Ans: e

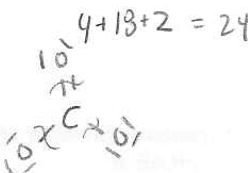
14. Which of the following series ranks the compounds in order of decreasing bond strength?

- a.  $N_2, O_2, F_2$
- b.  $F_2, O_2, N_2$
- c.  $F_2, N_2, O_2$
- d.  $N_2, F_2, O_2$
- e.  $O_2, N_2, F_2$

Ans: a

15. In  $CO_3^{2-}$ , carbon has a formal charge of:

- a. -2
- b. -1
- c. 0
- d. 1
- e. 2



Ans: c

**SECTION II: Free Response (37 pts)**

16. (8 pts) The quantum numbers listed below represent four different electrons in the same atom. Note that a "capital L" is used instead of the normal "lowercase l" for one of the quantum numbers, to distinguish it from the "number one."

Electron W	$n = 3$	$L = 2$	$m_l = 1$	$m_s = \frac{1}{2}$	3d	
Electron X	$n = 4$	$L = 2$	$m_l = -2$	$m_s = -\frac{1}{2}$	4d	
Electron Y	$n = 4$	$L = 0$	$m_l = 0$	$m_s = \frac{1}{2}$	4s	
Electron Z	$n = 3$	$L = 3$	$m_l = 1$	$m_s = -\frac{1}{2}$	3f	

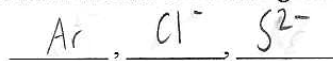
On the lines below, write the letters of these four electrons, arranging them in order of decreasing average distance from the nucleus. If two electrons have the same energy, indicate that by circling both electrons. If an electron does not exist, do not add it to the list.

~~W X Y Z~~  
~~W X Y Z~~  
X W Y =

switch -2  
 circle -2  
 rev -3  
 no blk -2  
 YW\*

17. (16 pts) For the following, the answer because "that's the trend" will receive no credit; you must explain why the trend is the way it is, if applicable.

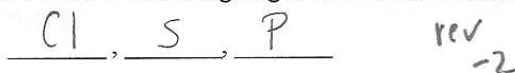
b. (4 pts) Put these ions and atoms in order of increasing radius:  $S^{2-}$   $Cl^-$   $Ar$   $S^{2-}$   $Cl^-$   $Ar$  rev  
-2



(4 pts) Explain your reasoning here, in 2-3 sentences, using principles of atomic structure.

• isoelectronic  
• lowest ENC means lowest pull on  $e^-$  so largest

c. (4 pts) Put these elements in order of decreasing magnitude of electron affinity: P S Cl

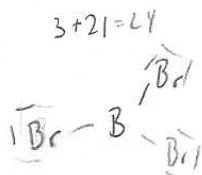


(4 pts) Explain your reasoning here, in 2-3 sentences, using principles of atomic structure.

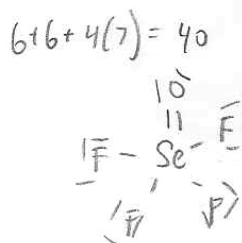
• EA dec ← w/ dec ENC (no exceptions in these series)

18. (8 pts) Draw the correct Lewis structures for the following compounds.

d.  $BBr_3$



b.  $SeOF_4$



19. (5 pts) After placing a 25-g sample of water in a cup in the microwave, you remove it and determine that its temperature is  $75.0^\circ C$ . Since this is too hot for you to drink, you add 12-g of cool water from the sink. If the final temperature of the combined sample of water is  $10.0^\circ C$ , what is the temperature of the water from the sink? (Given:  $c_{water} = 4.18 J/g^\circ C$ )

$-q_{Hot H_2O} = q_{cool H_2O}$  ↑ +10.0

$$-m \Delta T = m \Delta T$$

$$-25.00(4.18)(10.00 - 75.00) = 12.00(4.18)(10.00 - T_i)$$

$$1625 = 120.72 - 12T_i$$

$$T_i = 135.6$$

$$150.5 = -12T_i$$

$$T_i = -12.5^\circ C$$

impossible



MC: ( \_\_\_\_\_ - \_\_\_\_\_ / 4)(2.5 pts each) = \_\_\_\_\_      FR: \_\_\_\_\_ / 37      Overall: \_\_\_\_\_ / 75

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1. Removing heat from a system:
- ~~a.~~ Decreases the internal energy of the system
  - ~~b.~~ Represents a positive change in enthalpy
  - ~~c.~~ Increases the work on a system
  - ~~d.~~ Increases the volume
  - ~~e.~~ Causes a change in state

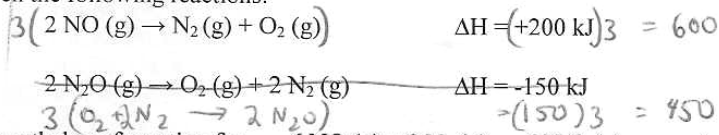
Ans: a

2. Which of the following is a state function?
- ~~I.~~ Work
  - II. Internal energy
  - III. Enthalpy

- a. I only
- b. II only
- c. III only
- d. I and II only
- e. II and III only

Ans: e

3. Given the following reactions:



The enthalpy of reaction for  $6 \text{ NO (g)} + 3 \text{ N}_2 \text{ (g)} \rightarrow 6 \text{ N}_2\text{O (g)}$  is:

- a. -150 kJ
- b. 150 kJ
- c. -1050 kJ
- d. 1050 kJ
- e. Cannot be determined from the given information.

Ans: d

4. The electromagnetic process associated with an electron transition from  $n = 4$  to  $n = 1$  is associated with:

- ~~I.~~ Balmer series
- II. Lyman series
- ~~III.~~ Far infrared light

- a. I only
- b. II only
- c. I and II only
- d. I and III only
- e. II and III only

Ans: b

5. Energy transitions in which an excited state electron "moves" to  $n = 1$  describes:
- a. Aufbau principle
  - b. Energy absorption
  - c. Energy release
  - d. Hund's rule
  - e. Cannot be determined from the given information
- Ans: c
6. The magnetic quantum number describes the:
- a. Essential "shape" of the electron's distribution plot
  - b. Orbital of the electron
  - c. Shell number of the electron
  - d. Valence of the electron
  - e. Spin of an electron
- Ans: a
7. What is a permissible set of quantum numbers for the highest energy electron of a ground state silver  $1+$  ion?
- a. 1, 0, 0
  - b. 3, 1, -1
  - c. 3, 2, 0
  - d. 4, 1, -1
  - e. 4, 2, -1
- Ans: e
8. Which of the following would have the greatest first ionization energy?
- a. As
  - b. N
  - c. P
  - d. S
  - e. Se
- Ans: b
9. Which series is ranked in order of decreasing atomic radius?
- a. Br, As, Ca, K
  - b. Ca, K, Br, As
  - c. As, Br, Ca, K
  - d. K, Ca, As, Br
  - e. Br, K, Ca, As
- Ans: d
10. An aqueous solution of an unknown salt is colorless. The flame test of the solution displays a characteristic lilac color. The unknown is most likely to contain cations of:
- a. Ba
  - b. Ca
  - c. K
  - d. Li
  - e. Ne
- Ans: c
11. The compound with the largest lattice energy is:
- a. Calcium fluoride
  - b. Magnesium chloride
  - c. Calcium chloride
  - d. Magnesium fluoride
  - e. Cannot be determined from the given information.
- Ans: d

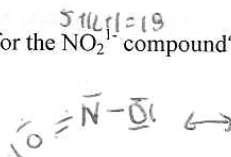
12. Which of the following atoms or ions is largest in size?

- a. K
- b.  $K^{1-}$
- c.  $K^{1+}$
- d.  $K^{2-}$**
- e.  $K^{2+}$

Ans: d

13. What is the total number of resonance structures for the  $NO_2^-$  compound?

- a. 1
- b. 2
- c. 3
- d. 4
- e. There are no resonance structures



Ans: b

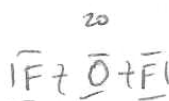
14. Which of the following series ranks the compounds in order of increasing bond strength?

- a.  $N_2, O_2, F_2$
- b.  $F_2, O_2, N_2$
- c.  $F_2, N_2, O_2$
- d.  $N_2, F_2, O_2$
- e.  $O_2, N_2, F_2$

Ans: b

15. In  $OF_2$ , oxygen has a formal charge of:

- a. -2
- b. -1
- c. 0
- d. 1
- e. 2



Ans: c

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Electron W       $n = 4$     $L = 1$     $m_l = 1$     $m_s = \frac{1}{2}$

4p

Electron X       $n = 3$     $L = 2$     $m_l = -2$     $m_s = -\frac{1}{2}$

3d

Electron Y       $n = 3$     $L = 2$     $m_l = 0$     $m_s = \frac{1}{2}$

3d

Electron Z       $n = 4$     $L = 3$     $m_l = 1$     $m_s = -\frac{1}{2}$

4f

4p, 3d, 3d

On the lines below, write the letters of these four electrons, arranging them in order of decreasing energy. If two electrons have the same energy, indicate that by circling both electrons. If an electron does not exist, do not add it to the list.

Z, W, X, Y

16 pts) For the following, the answer because "that's the trend" will receive no credit; you must explain why the trend is the way it is, if applicable.

a. (4 pts) Put these ions and atoms in order of first ionization energy:  $S^{2-}$   $Cl^{-}$   $Ar$   
 $16+$   $17+$   $18+$

$S^{2-}$ ,  $Cl^{-}$ ,  $Ar$

(4 pts) Explain your reasoning here, in 2-3 sentences, using principles of atomic structure.

- all isoelectronic

-  $Ar$  has most protons, so most difficult to remove  $e^{-}$

b. (4 pts) Put these elements in order of "increasing" (becoming more negative) electron affinity:  $C, N, F$

$N$ ,  $C$ ,  $F$

(4 pts) Explain your reasoning here, in 2-3 sentences, using principles of atomic structure.

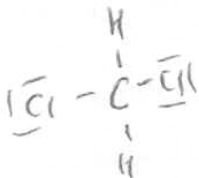
$C$  ↑ ↑ — → more stable if gains  $e^{-}$  (half-filled)

$N$  ↑ ↑ ↑ → less stable if " "

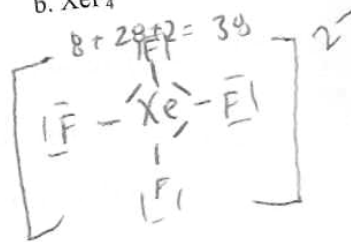
$F$  ↑ ↑ ↑ → most stable if gains  $e^{-}$  (filled subshell)

18. (8 pts) Draw the correct Lewis structures for the following compounds.

e.  $CH_2Cl_2$



b.  $XeF_4^{2-}$



19. (5 pts) After placing a 15.00-g sample of water in a cup in the microwave, you remove it and determine that its temperature is 65.00 °C. Since this is too hot for you to drink, you add 2.00-g of cool water from the sink. If the final temperature of the combined sample of water is 60.00 °C, what is the temperature of the water from the sink? (Given:  $c_{water} = 4.18 \text{ J/g}^\circ\text{C}$ )

$q = -q$

$$2(4.18)(60 - T) = 15(4.18)(60 - 65)$$

$$120 - 2T = 175$$

$$T = +22.5^\circ\text{C}$$

~~$m_1 \Delta T = -m_2 \Delta T$~~   
 ~~$(2)(4.18)(60 - T) = -15(4.18)(T - 65)$~~   
 ~~$120 - 2T = -15T + 975$~~   
 ~~$12T = 1045$~~   
 ~~$T = 87.08$~~