Constants: \( h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s} \), \( c = 3.00 \times 10^8 \text{ m/s} \), \( N_A = 6.02 \times 10^{23} \text{ mol}^{-1} \)

Conversion Factors:

Molar Masses: \( \text{CH}_3\text{OH} - 32 \), \( \text{Cl}_2 - 71 \).
MULTIPLE CHOICE (Circle the ONE correct answer)

1. From the following thermochemical equations,
   \[ 2 \text{H}_2\text{O}(g) \rightarrow 2 \text{H}_2(g) + \text{O}_2(g) \quad \Delta H = +484 \text{ kJ} \]
   \[ 2 \text{O}_3(g) \rightarrow 3 \text{O}_2(g) \quad \Delta H = +286 \text{ kJ} \]
   \[ \Delta H \text{ for the reaction, } 3 \text{H}_2(g) + \text{O}_3(g) \rightarrow 3 \text{H}_2\text{O}(g), \] is
   (A) -583 kJ            (B) -341 kJ            (C) +583 kJ            (D) +869 kJ

2. \( \Delta H \) for the combustion (reaction with \( \text{O}_2 \)) of 2 (two) moles of propane, \( \text{C}_3\text{H}_8 \), to form \( \text{CO}_2 \) and \( \text{H}_2\text{O} \) is -4446 kJ. From this information and the enthalpies of formation of \( \text{CO}_2 \) (-394 kJ/mol), and \( \text{H}_2\text{O} \) (-286 kJ/mol), what is the Enthalpy of Formation of propane?
   (A) +103 kJ/mol              (B) -206 kJ/mol                (C) -103 kJ/mol
   (D) Additional data is required

3. The Fuel Value of methanol, \( \text{CH}_3\text{OH} \), is 23 kJ/g. Therefore, \( \Delta H \) for combusting 4 (four) moles of methanol in \( \text{O}_2 \) is approximately:
   (A) -2940 kJ              (B) +92 kJ              (C) -2200 kJ
   (D) +2940 kJ

4. The \( \text{O}=\text{O} \) Bond Strength (aka Bond Enthalpy) in \( \text{O}_2 \) is 495 kJ/mol. What is the frequency of light with just enough energy to break an \( \text{O}=\text{O} \) bond?
   (A) 7.5x10^{38} \text{ s}^{-1}         (B) 1.2x10^{18} \text{ s}^{-1}         (C) 240 nm         (D) 1.2x10^{15} \text{ s}^{-1}

5. A laser with a wavelength of 460 nm is emitting energy at a rate of 0.10 J/s. Approximately how many photons of radiation will have been emitted in 30 minutes?
   (A) 2.8x10^{20}             (B) 4.2x10^{20}             (C) 2.6x10^{22}             (D) 9.5x10^{20}

6. Which of the following sets of quantum numbers is/are NOT allowed for an electron in a hydrogen atom?
   (1) \( n = 4, \ell = 3, m_l = -3, m_s = -\frac{1}{2} \)      (2) \( n = 3, \ell = 3, m_l = 0, m_s = +\frac{1}{2} \)
   (3) \( n = 5, \ell = 1, m_l = -1, m_s = -\frac{1}{2} \)      (4) \( n = 3, \ell = -2, m_l = 0, m_s = -\frac{1}{2} \)
   (A) 2 & 3            (B) 1 & 2 & 4            (C) 2 & 4            (D) 3 & 4

7. What is the total number of electrons that can be contained in the third shell \((n = 3)\) of an atom?
   (A) 16            (B) 9            (C) 32            (D) 18
8. The complete electron configuration of the Cr$^{3+}$ ion is:
(A) $1s^22s^22p^63s^23p^64s^23d^7$  
(B) $1s^22s^22p^63s^23p^64s^23d^1$  
(C) $1s^22s^22p^63s^23p^63d^3$  
(D) $1s^22s^22p^63s^23p^63d^3$

9. Of the four atoms, S, P, Si, and Mg, ____ has the least unpaired electrons and ____ has the most unpaired electrons.
(A) Mg, Si  
(B) Mg, P  
(C) Na, Si  
(D) Na, P

10. Rank the following atoms in order of decreasing First Ionization Energy?
Ca, Sr, Rb, Ge
(A) Rb > Sr > Ca > Ge  
(B) Ge > Ca > Sr > Rb  
(C) Rb > Ge > Ca > Sr  
(D) Ge > Ca > Rb > Sr

11. Of the four atoms, Sb, Pb, Cl, Se, ____ has the largest radius and ____ has the largest First Ionization Energy.
(A) Pb, Cl  
(B) Sb, Cl  
(C) Pb, Se  
(D) Cl, Pb

12. Which atom would have a sixth ionization energy very much greater than the fifth ionization energy?
(A) P  
(B) Al  
(C) S  
(D) Si

13. The Electron Affinity of an atom is defined as the energy change for which one of the following processes?
(A) $M \rightarrow M^+ + e^-$  
(B) $X \rightarrow X^+ + e^-$  
(C) $X + e^- \rightarrow X^-$  
(D) $X^+ + e^- \rightarrow X$

14. The total number of lone pairs of electrons in the PS$^{-1}$ ion is/are:
(A) 0  
(B) 2  
(C) 3  
(D) 4

15. What is the Sb-O bond order in the SbO$_2$$^{+1}$ ion?
(A) 1.0  
(B) 1.50  
(C) 2.0  
(D) 3.0

16. The number of lone pairs of electrons around the central atom in XeBr$_3$$^{-1}$ ion is:
(A) 1  
(B) 3  
(C) 2  
(D) 4

17. In the AsP$\equiv$S molecule (Lewis Structure on right), the formal charges on P and S are:
(A) P: +1, S: -1  
(B) P: -1, S: +1  
(C) P: 0, S: -1  
(D) P: 0, S: +1
18. Which of the following molecules do not obey the octet rule? NO₂, GeBr₄, TeCl₃⁻¹
   (A) NO₂ & GeBr₄           (B) NO₂             (C) TeCl₃⁻¹             (D) NO₂ & TeCl₃⁻¹

19. For the transition metal complex, Fe(CO)ₙ(CH₃)₂, use the 18 electron rule to determine n, the number of CO ligands in the complex.

   Note: The CO ligand contributes two (2) electrons to the metal and the CH₃ ligand contributes one (1) electron to the metal.

   (A) n = 2           (B) n = 4           (C) n = 5           (D) n = 3

20. In the molecule with the condensed structural formula, CH₃CBrNH, the carbon-nitrogen bond order is _____ and the number of lone pairs (i.e. non-bonding pairs) of electrons on the nitrogen atom is _____.

   (A) 1 , 1           (B) 2 , 2           (C) 2 , 1           (D) 1 , 2

21. What are the C-N and C-O Bond Orders in the ion with the condensed structural formula, CH₃CH(CN)C(O)O⁻¹?

   (A) 3 , 1.5           (B) 3 , 2           (C) 3 , 1           (D) 2 , 1.5

Two (2) Problems: #1 directly below on this page

1. Write the Condensed Electron Configuration of Polonium (Po, Z = 84).

2. Consider the photodissociation of Chlorine (Cl₂) in the upper atmosphere:
   Cl₂(g) + hν → 2 Cl(g).

   A sample of Cl₂(g) is irradiated with light having a wavelength of 345 nm from a 60 Watt (W = J/s) lamp. Assuming that 100% of the photons are absorbed, how many hours will it take to decompose 142 grams of Cl₂(g)?
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Constants:
\[ h = 6.63 \times 10^{-34} \text{ Js} \]
\[ c = 3.00 \times 10^8 \text{ m/s} \]
\[ N_A = 6.02 \times 10^{23} \text{ mol}^{-1} \]

Conversion Factors:

Molar Masses:
\[ \text{CH}_3\text{OH} - 32. \quad \text{Cl}_2 - 71. \]
MULTIPLE CHOICE (Circle the ONE correct answer)

1. The Fuel Value of methanol, CH₃OH, is 23 kJ/g. Therefore, ∆H for combusting 4 (four) moles of methanol in O₂ is approximately:
   (A) +2940 kJ  (B) +92 kJ  (C) -2200 kJ  (D) -2940 kJ

2. ∆H for the combustion (reaction with O₂) of 2 (two) moles of propane, C₃H₈, to form CO₂ and H₂O is -4446. kJ. From this information and the enthalpies of formation of CO₂ (-394 kJ/mol), and H₂O (-286 kJ/mol), what is the Enthalpy of Formation of propane?
   (A) -103 kJ/mol  (B) -206 kJ/mol  (C) +103 kJ/mol  (D) Additional data is required

3. From the following thermochemical equations,
   
   \[ 2 \text{H}_2\text{O}(g) \rightarrow 2 \text{H}_2(g) + \text{O}_2(g) \quad \Delta H = +484 \text{ kJ} \]
   
   \[ 2 \text{O}_3(g) \rightarrow 3 \text{O}_2(g) \quad \Delta H = +286 \text{ kJ} \]

   ∆H for the reaction, 3 H₂(g) + O₃(g) → 3 H₂O(g), is
   (A) +583 kJ  (B) -341 kJ  (C) -583 kJ  (D) +869 kJ

4. The O=O Bond Strength (aka Bond Enthalpy) in O₂ is 495 kJ/mol. What is the frequency of light with just enough energy to break an O=O bond?
   (A) 7.5x10³⁸ s⁻¹  (B) 1.2x10¹⁵ s⁻¹  (C) 240 nm  (D) 1.2x10¹⁸ s⁻¹

5. What is the total number of electrons that can be contained in the third shell (n = 3) of an atom?
   (A) 18  (B) 16  (C) 32  (D) 9

6. A laser with a wavelength of 460 nm is emitting energy at a rate of 0.10 J/s. Approximately how many photons of radiation will have been emitted in 30 minutes?
   (A) 4.2x10²⁰  (B) 2.8x10²⁰  (C) 2.6x10²²  (D) 9.5x10²⁰

7. Which of the following sets of quantum numbers is/are NOT allowed for an electron in a hydrogen atom?
   (1) n = 4, ℓ = 3, mᵢ = -3, mₛ = -½  (2) n = 3, ℓ = 3, mᵢ = 0, mₛ = +½
   (3) n = 5, ℓ = 1, mᵢ = -1, mₛ = -½  (4) n = 3, ℓ = -2, mᵢ = 0, mₛ = -½
   (A) 2 & 3  (B) 1 & 2 & 4  (C) 3 & 4  (D) 2 & 4
8. Rank the following atoms in order of decreasing First Ionization Energy? Ca, Sr, Rb, Ge
   (A) Rb > Sr > Ca > Ge           (B) Ge > Ca > Rb > Sr
   (C) Rb > Ge > Ca > Sr           (D) Ge > Ca > Sr > Rb

9. Of the four atoms, Sb, Pb, Cl, Se, ____ has the largest radius and ____ has the largest First Ionization Energy.
   (A) Cl, Pb             (B) Sb, Cl          (C) Pb, Cl            (D) Pb, Se

10. Of the four atoms, S, P, Si, and Mg, ____ has the least unpaired electrons and ____ has the most unpaired electrons.
    (A) Mg, Si               (B) Na, P             (C) Na, Si             (D) Mg, P

11. The complete electron configuration of the Cr\(^{3+}\) ion is:
    (A) 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)4s\(^2\)3d\(^7\)             (B) 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)4s\(^2\)3d\(^1\)
    (C) 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)3d\(^3\)             (D) 1s\(^2\)2s\(^2\)2p\(^6\)3s\(^2\)3p\(^6\)4p\(^3\)

12. Which atom would have a sixth ionization energy very much greater than the fifth ionization energy?
    (A) Si                 (B) Al                (C) S                (D) P

13. The Electron Affinity of an atom is defined as the energy change for which one of the following processes?
    (A) M \(\rightarrow\) M\(^+\) + e\(^-\)                (B) X \(\rightarrow\) X\(^+\) + e\(^-\)
    (C) X\(^+\) + e\(^-\) \(\rightarrow\) X             (D) X + e\(^-\) \(\rightarrow\) X\(^-\)

14. What is the Sb-O bond order in the SbO\(^{2+}\) ion?
    (A) 1.0                (B) 2.0               (C) 1.50             (D) 3.0

15. The total number of lone pairs of electrons in the PS\(^{-1}\) ion is/are:
    (A) 4                   (B) 0                 (C) 3                (D) 2

16. The number of lone pairs of electrons around the central atom in XeBr\(^{3-}\) ion is:
    (A) 1                   (B) 2                 (C) 3                (D) 4

17. In the AsPS molecule (Lewis Structure on right), the formal charges on P and S are:
    \[\text{As} \equiv P \equiv S: \]
    (A) P: 0, S: -1         (B) P: -1, S: +1   (C) P: +1, S: -1       (D) P: 0, S: +1
18. For the transition metal complex, Fe(CO)$_n$(CH$_3$)$_2$, use the 18 electron rule to determine $n$, the number of CO ligands in the complex.

**Note:** The CO ligand contributes two (2) electrons to the metal and the CH$_3$ ligand contributes one (1) electron to the metal.

(A) $n = 2$  
(B) $n = 4$  
(C) $n = 5$  
(D) $n = 3$

19. Which of the following molecules do **not** obey the octet rule? NO$_2$, GeBr$_4$, TeCl$_3$\(^{-1}\)

(A) NO$_2$ & TeCl$_3$\(^{-1}\)  
(B) NO$_2$  
(C) TeCl$_3$\(^{-1}\)  
(D) NO$_2$ & GeBr$_4$

20. What are the C-N and C-O Bond Orders in the ion with the condensed structural formula, CH$_3$CH(CN)C(O)O\(^{-1}\) ?

(A) 2 , 1.5  
(B) 3 , 2  
(C) 3 , 1.5  
(D) 3 , 1

21. In the molecule with the condensed structural formula, CH$_3$CBrNH, the carbon-nitrogen bond order is _____ and the number of lone pairs (i.e. non-bonding pairs) of electrons on the nitrogen atom is _____.

(A) 1 , 1  
(B) 2 , 2  
(C) 2 , 1  
(D) 1 , 2

Two (2) Problems: #1 directly below on this page

(4) 1. Write the **Condensed Electron Configuration** of Polonium (Po, Z = 84).

(12) 2. Consider the photodissociation of Chlorine (Cl$_2$) in the upper atmosphere: Cl$_2$(g) + h$\nu$ \rightarrow 2 Cl(g).

A sample of Cl$_2$(g) is irradiated with light having a wavelength of 345 nm from a 65 Watt (W = J/s) lamp. Assuming that 100% of the photons are absorbed, how many **hours** will it take to decompose 142 grams of Cl$_2$(g) ?