1. Given the following data, calculate the standard enthalpy of formation of tungsten carbide, WC.

\[ \text{2W(s) + 3O}_2(g) \rightarrow \text{2WO}_3(s); \quad \Delta H^\circ_{\text{rxn}} = -1685.8 \text{ kJ} \]

\[ \text{C(graphite) + O}_2(g) \rightarrow \text{CO}_2(g); \quad \Delta H^\circ_{\text{rxn}} = -393.5 \text{ kJ} \]

\[ \text{2WC(s) + 5O}_2(g) \rightarrow \text{2WO}_3(s) + 2\text{CO}_2(g); \quad \Delta H^\circ_{\text{rxn}} = -2391.8 \text{ kJ} \]

A) -40.5 kJ/mol  
B) -84.3 kJ/mol  
C) -120 kJ/mol  
D) +84.3 kJ/mol  
E) -54.3 kJ/mol

2. A 625 g piece of iron is removed from an oven and put into an insulated pot containing 525 g of water. The temperature of the water increases from 24.0 to 31.0 °C. The specific heat capacity of iron is 0.45 J g\(^{-1}\) °C\(^{-1}\). What is the temperature of the oven?

A) 86 °C  
B) 95 °C  
C) 74 °C  
D) 63 °C  
E) 72 °C

3. A gas expands from a volume of 21.3 L to 26.3 L against a pressure of 735 mmHg. Calculate the work, in joules. (1 L.atm = 101.3 J; 1 atm = 760 mmHg)

A) -4.9 x 10^2 J  
B) -4.8 kJ  
C) -2.5 x 10^3 J  
D) -1.6 x 10^2 J  
E) -7.5 x 10^4 J
4. Determine the standard enthalpy change for the following reaction:

\[ 2\text{Cl}_2(g) + 2\text{H}_2\text{O}(l) \rightarrow 4\text{HCl}(g) + \text{O}_2(g) \]

The standard enthalpies of formation for \( \text{H}_2\text{O}(l) \) and \( \text{HCl}(g) \) are -285.8 kJ/mol and -92.31 kJ/mol, respectively.

A) 202.4 kJ  
B) 354.5 kJ  
C) 4572 kJ  
D) 168.3 kJ  
E) 907.2 kJ

5. Which term is not correctly matched?

A) state function / property that depends on how the process takes place  
B) heat measured at constant volume / change in internal energy  
C) exothermic / energy is released  
D) universe / system plus surroundings  
E) endothermic / energy is absorbed

6. Which of the following statements is (are) true?

I. An excited atom can return to its ground state by absorbing electromagnetic radiation.
II. An electron in the \( n = 4 \) state in the hydrogen atom can go to the \( n = 2 \) state emitting electromagnetic radiation at the appropriate frequency.
III. The frequency and wavelength of electromagnetic radiation are inversely proportional to each other.

A) II and III only  
B) I and III only  
C) I and II only  
D) All of them  
E) I only

7. How many \( f \) orbitals are allowed for \( n = 6 \)?

A) 7  
B) 2  
C) 14  
D) 5  
E) 3
8. An electron in the ground state of the hydrogen atom moves at an average speed of \(5 \times 10^6\) m/s. If the speed is known to an uncertainty of 20\%, what is the minimum uncertainty in its position? The mass of an electron is \(9.1094 \times 10^{-31}\) kg.

A) \(6 \times 10^{-11}\) m  
B) \(9 \times 10^{-9}\) m  
C) \(8 \times 10^{-10}\) m  
D) \(7 \times 10^{-8}\) m  
E) \(1 \times 10^{-10}\) m

9. A proton has a mass of \(1.67 \times 10^{-27}\) kg. If the proton has wavelength of \(3.97 \times 10^{-10}\) m. What is its velocity as determined by the de Broglie equation?

A) \(1.00 \times 10^3\) m/s.  
B) \(1.59 \times 10^6\) m/s.  
C) 899 m/s.  
D) 108 m/s.  
E) 605 m/s

10. Which one of the following correctly arranges electron affinity (EA) in increasing order from smallest to highest:

A) Sr < Rb < Sb < Sn < Te  
B) Rb < Sr < Sn < Sb < Te  
C) Rb < Sr < Sb < Sn < Te  
D) Sr < Rb < Sn < Sb < Te  
E) Te < Sb < Sn < Sr < Rb

11. Which of the following statements is/are false?

I. The effective nuclear charge experienced by an electron in an outer shell is more than the actual nuclear charge.

II. For the representative elements, \(Z_{\text{eff}}\) increases within the same period from left to right.

III. For the representative elements, the general trend is that the first ionization energy decrease within the same period from left to right.

A) I and III only  
B) I and II only  
C) II only  
D) II and III only  
E) All of them are true
12. An electron cannot have the quantum numbers \( n = \underline{\hspace{1cm}} \), \( l = \underline{\hspace{1cm}} \), \( m_l = \underline{\hspace{1cm}} \).
   A) 3, 2, 3  
   B) 6, 1, 0  
   C) 3, 2, -2  
   D) 1, 0, 0  
   E) 3, 2, 1

13. Which one of the following is the correct electron configuration of \( \text{Pb}^{2+} \)?
   A) \([\text{Xe}] 4f^{14} 5d^{10} 6s^2\)
   B) \([\text{Xe}] 4f^{14} 5d^{10} 6p^2\)
   C) \([\text{Xe}] 4f^{14} 5d^8 6s^2 6p^2\)
   D) \([\text{Xe}] 4f^{14} 5d^{10} 6s^1 6p^1\)
   E) \([\text{Xe}] 4f^{12} 5d^{10} 6s^2 6p^2\)

14. Which of these pairs consists of isoelectronic species?
   A) \(\text{Co}^{3+}\) and \(\text{Fe}^{2+}\)
   B) \(\text{Br}^-\) and \(\Gamma^-\)
   C) \(\text{Cr}^{3+}\) and \(\text{Mn}^{2+}\)
   D) \(\text{Cl}^-\) and \(\text{Na}^+\)
   E) \(\Gamma^-\) and \(\text{Kr}\)

15. Which pair of ions exhibits the greatest attractive force between them?
   A) \(\text{Ca}^{2+}\) and \(\text{O}^{2-}\)
   B) \(\text{K}^+\) and \(\text{S}^{2-}\)
   C) \(\text{K}^+\) and \(\text{Cl}^-\)
   D) \(\text{Na}^+\) and \(\Gamma^-\)
   E) \(\text{Ca}^{2+}\) and \(\Gamma^-\)
16. Hydrazine, N\textsubscript{2}H\textsubscript{4}, contains a N-N single bond and 4 N-H bonds, and is synthesized by the reaction: \( \text{N}_2(\text{g}) + 2\text{H}_2(\text{g}) \rightarrow \text{N}_2\text{H}_4(\text{g}) \). Use the following bond energies to estimate \( \Delta H \) in kJ/mol for this reaction.

<table>
<thead>
<tr>
<th>Bond</th>
<th>H–H</th>
<th>N–H</th>
<th>N–N</th>
<th>N≡N</th>
<th>N≡N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond Energies (kJ/mol)</td>
<td>436</td>
<td>389</td>
<td>159</td>
<td>418</td>
<td>941</td>
</tr>
</tbody>
</table>

A) 98  
B) 425  
C) −597  
D) 778  
E) −425

17. In which one of the following species the central atom is NOT surrounded by 8 valence electrons?

A) ClF\textsubscript{3}  
B) NO\textsubscript{3}\textsuperscript{−}  
C) SO\textsubscript{2}  
D) PBr\textsubscript{3}  
E) O\textsubscript{3}

18. What are the formal charges on carbon, oxygen and chlorine in the COCl\textsubscript{2} molecule?

NOTE: C is the central atom, and both Cl and O are bound to C.

A) Carbon is 0  
B) Carbon is +4  
C) Carbon is +2  
D) Carbon is 0  
E) Carbon is -1  
Oxygen is 0  
Oxygen is -2  
Oxygen is 0  
Oxygen is -2  
each Chlorine is 0  
each Chlorine is -1  
each Chlorine is -1  
each Chlorine is +1  
each Chlorine is 0

19. The dipole moment of chlorine monofluoride, ClF(g), is 0.880 D. The bond length of the molecule is 1.63 Å. What is the partial charge on the fluorine atom, in units of electronic charge \( (e^-) \)?

\[ 1 \text{ D} = 3.336 \times 10^{-30} \text{ C.m}; \quad 1e^- = 1.6022 \times 10^{-19} \text{ C}; \quad 1 \text{ Å} = 1 \times 10^{-10} \text{ m} \]

A) −0.112 \( e^- \)  
B) +0.112 \( e^- \)  
C) −0.339 \( e^- \)  
D) −0.890 \( e^- \)  
E) +0.339 \( e^- \)
20. Which pair of atoms would form the most ionic bond?
   A) Rb and Cl
   B) Be and S
   C) Ca and Br
   D) Al and Ge
   E) P and F
Answer Key

1. A
2. A
3. A
4. A
5. A
6. A
7. A
8. A
9. A
10. A
11. A
12. A
13. A
14. A
15. A
16. A
17. A
18. A
19. A
20. A