SHOW ALL CALCULATIONS & USE PROPER SIGNIFICANT FIGURES AND UNITS

Avogadro’s number, \(N_A = 6.02 \times 10^{23}\)  
Planck’s constant, \(h = 6.626 \times 10^{-34}\) J s  
DeBroglie wavelength, \(\lambda = h / mv\)  
Speed of light, \(c = \lambda \nu = 3.00 \times 10^8\) m/s  
Photon energy, \(E_n = n h \nu\)  
Hydrogen energy, \(E_n = -R_H / n^2\)  
Rydberg constant, \(R_H = 2.181 \times 10^{-18}\) J  
Heat transfer, \(q = m C \Delta T\)

Multiple Choice Questions: Circle the single best answer. No penalty for guessing.

1. What is the formal charge on the central N atom in \(\text{N}_2\text{O}\)? (5 points)
   A) -3  
   B) 0  
   C) +1  
   D) +3  
   E) +5

2. What is the approximate shape of a \(3d_{xy}\) orbital? (5 points)
   A) spherical  
   B) circular  
   C) dumb-bell  
   D) 4-leaf clover  
   E) cubic

3. Which of the following atoms or ions has the \(1s^2 2s^2 2p^1\) electron configuration? (5 points)
   A) \(\text{C}^+\)  
   B) \(\text{Al}\)  
   C) \(\text{Ga}\)  
   D) \(\text{B}^+\)  
   E) \(\text{Si}^+\)

4. Which of the following has the greatest number of significant digits as written? (5 points)
   A) 0.0021  
   B) 0.1021  
   C) 0.210  
   D) 1.0021  
   E) 2000

5. Calculate the number of grams of oxygen, \(\text{O}_2\), that can react with 2.5 g of aluminum, \(\text{Al}\), to produce \(\text{Al}_2\text{O}_3\). (5 points)
   \(4 \text{Al} + 3 \text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3\)
   A) 1.9 g  
   B) 2.2 g  
   C) 2.5 g  
   D) 3.0 g  
   E) 4.0 g

6. What is the heat required to raise the temperature of 100.0 g of water from 25.0 °C to 30.0 °C \((C_{\text{H}_2\text{O}} = 4.184 \text{ J/g °C})\)? (5 points)
   A) -2090 J  
   B) 2090 J  
   C) -418 J  
   D) 418 J  
   E) 5 J

7. How many possible values are there for the \(l\) quantum number if \(n = 4\)? (5 points)
   A) 0  
   B) 1  
   C) 2  
   D) 3  
   E) 4
8. Which ion has the smallest radius in the first ionized state? (5 points)
   A) Li⁺    B) Mg⁺    C) Be⁺    D) Ag⁺    E) Xe⁺

9. What symbol corresponds to an ion or atom with 13 electrons, 14 protons, and 16 neutrons? (5 points)
   A) ³⁰S³⁺    B) ³⁰N⁺    C) ¹⁴Si    D) ¹⁴N⁺    E) ³⁰Si⁺

10. Which cation forms soluble salts regardless of the anion present? (5 points)
    A) Fe³⁺    B) Rb⁺    C) Ca²⁺    D) Ag⁺    E) Sr²⁺

11. Which molecule has carbon in a state of sp² hybridization? (5 points)
    A) CH₄    B) CO₂    C) CO    D) CH₃Cl    E) H₂CO

12. Which of the following compounds has the smallest lattice energy? (5 points)
    A) CaS    B) SrS    C) RbI    D) RbF    E) LiF

13. Write the formula or name of the following compounds (as appropriate) and circle the solubility. (16 points)
    MgSO₄ ___________________________  soluble/insoluble
    NH₄ClO ___________________________  soluble/insoluble
    ___________________________ titanium (IV) chloride  soluble/insoluble
    ___________________________ strontium nitrite  soluble/insoluble

14. Which atom, sulfur (S) or phosphorus (P), has the larger first ionization energy? Explain using electron configuration and effective charge arguments. (10 points)
15. A 12.34 g sample of pure gaseous hydrocarbon (a molecule made of only C and H) with molecular weight 26.037 amu was burned in excess oxygen to generate 41.71 g of CO\textsubscript{2} and 8.54 g of H\textsubscript{2}O and 609 kJ of heat.

A) Calculate the molecular formula of the hydrocarbon. (10 points)

B) Calculate $\Delta H_{f}$ for this compound. (15 points, $\Delta H_{f} = -393$ kJ/mol and $-242$ kJ/mol for CO\textsubscript{2} and H\textsubscript{2}O respectively.)

16. How much NH\textsubscript{4}MgPO\textsubscript{4}•6H\textsubscript{2}O precipitate would be formed if 2.512 g of K\textsubscript{2}HPO\textsubscript{4} was reacted with excess NH\textsubscript{3} and MgSO\textsubscript{4}? (10 points)
17. Balance the following two equations and write out a final net ionic equations. (12 points)

\[ \text{____ Pb(NO}_3\text{)}_2 \text{ (aq) + ____ Na}_2\text{SO}_4 \text{ (aq) } \rightarrow \text{_________ + _________} \]

\[ \text{____ NH}_4\text{ClO}_2 \text{ (aq) + ____ Sr(NO}_3\text{)}_2 \text{ (aq) } \rightarrow \text{_________ + _________} \]

18. Explain how the atomic orbitals of O atoms are involved in creating the bond(s) in \( \text{O}_2 \). Describe both the \( \pi \) and \( \sigma \) parts separately as appropriate. (8 points)

19. Write the ground state electron configuration for Li, Ge\(^{2+}\) and Co\(^{2+}\). (9 points)

20. Calculate the De Broglie wavelength of an electron (\( m_e = 9.501 \times 10^{-31} \text{ kg} \)) moving at a speed of \( 2.5 \times 10^3 \text{ m/s} \). (10 points)
21. Draw the Lewis dot structure (showing resonance structures if appropriate) for $\text{PO}_4^{3-}$, indicating formal charges on each atom in each structure. (10 points)

22. The $\Delta H$ for the following reaction is $+55.2 \text{ kJ mol}^{-1}$. Calculate the mass of $\text{H}_2\text{O}$ gas which may be produced if excess ammonium carbonate is heated by $350.0 \text{ kJ}$ of energy (assume constant temperature and all heat is used to drive the reaction). (15 points)

$\text{(NH}_4\text{)}_2\text{CO}_3 (s) \rightarrow 2 \text{NH}_3 (g) + \text{CO}_2 (g) + \text{H}_2\text{O} (g)$

23. A piece of aluminum foil measuring 12.0 m by 15.5 m has a mass of 51.75 g. Aluminum has a density of 2.70 g/cm$^3$. What thickness is the aluminum foil in millimeters? (15 points)