1. Which of the functional groups are present in the following structure?

A. amine and ether
B. carboxylic acid and ketone
C. amine, aldehyde, and carboxylic acid
D. amine, ketone, and aldehyde
E. ether, aldehyde, and ketone

2. What is the approximate bond angle (a) in this molecular structure?

A. 90°
B. 109.5°
C. 120°
D. 180°
E. 60°

3. In which of the following molecules is the central atom surrounded by four electron domains?

I CO₂  II SO₃  III CHCl₃  IV SeF₂

A. only choice I
B. only choice II
C. choices I and II
D. choices III and IV
E. choices I, II and III

4. What is the molecular weight of a gas if 3.5 g of the gas occupies 2.1 L at STP?

A. 41 g/mol
B. 5.5 x 10³ g/mol
C. 37 g/mol
D. 4.6 x 10² g/mol
E. 2.7 x 10⁻² g/mol
5. What species is oxidized in the following chemical reaction?

   \[ \text{Cu (s)} + 2\text{AgNO}_3(\text{aq}) \rightarrow 2\text{Ag (s)} + \text{Cu(NO}_3)_2(\text{aq}) \]

   A. \( \text{Cu (s)} \)
   B. \( \text{Ag}^+ (\text{aq}) \)
   C. \( \text{Ag (s)} \)
   D. \( \text{Cu}^{2+} (\text{aq}) \)
   E. \( \text{NO}_3^- (\text{aq}) \)

6. What is the standard enthalpy of formation of one mole of strontium carbonate, \( \text{SrCO}_3(\text{s}) \)?

   \[ \text{Sr (s)} + \frac{1}{2} \text{O}_2(\text{g}) \rightarrow \text{SrO (s)} \quad \Delta H^\circ = -592 \text{ kJ} \]
   \[ \text{SrCO}_3(\text{s}) \rightarrow \text{SrO (s)} + \text{CO}_2(\text{g}) \quad \Delta H^\circ = +234 \text{ kJ} \]
   \[ \text{C (graphite)} + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) \quad \Delta H^\circ = -394 \text{ kJ} \]

   A. -1812 kJ
   B. -1220 kJ
   C. -752 kJ
   D. +36 kJ
   E. +752 kJ

7. For the molecule, pick the choice with the correct hybridization for carbon atoms 1, 2 and 3.

   ![Molecule Diagram]

   A. \( \text{sp} \quad \text{sp}^2 \quad \text{sp}^3 \)
   B. \( \text{sp}^2 \quad \text{sp} \quad \text{sp}^3 \)
   C. \( \text{sp}^2 \quad \text{sp}^2 \quad \text{sp}^3 \)
   D. \( \text{sp}^2 \quad \text{sp} \quad \text{sp}^3 \)
   E. \( \text{sp} \quad \text{sp} \quad \text{sp}^2 \)

8. The \( \text{C–Cl} \) bond dissociation energy in \( \text{CF}_3\text{Cl} \) is 339 kJ/mol. What is the maximum wavelength of photons that can rupture this bond?

   A. 45 nm
   B. 353 nm
   C. 137 nm
   D. 275 nm
   E. 742 nm
9. Using the bond energy data tabulated below, estimate the enthalpy of formation (per mole) of NH₃ (g).

<table>
<thead>
<tr>
<th>Bond</th>
<th>Average bond energy (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N≡N (N₂)</td>
<td>941</td>
</tr>
<tr>
<td>H–H</td>
<td>436</td>
</tr>
<tr>
<td>N–H</td>
<td>391</td>
</tr>
</tbody>
</table>

The correct answer is closest to

A. −422 kJ/mol  
B. −49 kJ/mol  
C. 49 kJ/mol  
D. 204 kJ/mol  
E. 422 kJ/mol

10. Given the following reaction at equilibrium at 300.0 K:

\[ \text{NH₄HS (s)} \rightleftharpoons \text{NH}_₃ (g) + \text{H}_₂\text{S (g)} \]

What is the value of K_p if the partial pressures of NH₃ and H₂S are P_{NH₃} = P_{H₂S} = 0.111 atm?

A. \(1.23 \times 10^{-2}\)  
B. \(4.99 \times 10^{-4}\)  
C. \(1.11 \times 10^{-1}\)  
D. \(8.12 \times 10^{-2}\)  
E. Not enough information is given to calculate K_p

11. K_c for the reaction below equals 125 at a particular temperature.

\[ \text{F}_₂(g) + \text{Cl}_₂(g) \rightleftharpoons 2 \text{FCl(g)} \]

What is the value of K_c for the reaction given below?

\[ \frac{1}{2} \text{F}_₂(g) + \frac{1}{2} \text{Cl}_₂(g) \rightleftharpoons \text{FCl(g)} \]

A. K_c = 0.0894  
B. K_c = 11.2  
C. K_c = 0.0160  
D. K_c = 62.5  
E. K_c = 125

12. A student measures the following in the process of collecting nitrogen gas by water displacement at STP:

- Vapor pressure of water at 0 °C: 4.58 mm Hg
- Volume of gas collected: 100 mL

Assuming ideal gas behavior, which of the following is the number of moles of N₂ the student collected?

A. 0.00444 moles N₂  
B. 0.00429 moles N₂  
C. 0.00393 moles N₂  
D. 3.85 \times 10^{-3} moles N₂  
E. 2.68 \times 10^{-5} moles N₂
13. Which of the following compounds can have a geometrical isomer?

\[ \text{I} \quad \text{II} \quad \text{III} \]

\[
\begin{align*}
\text{I} & : & \text{H} & \text{C} & \equiv & \text{C} & \equiv & \text{H} \\
\text{II} & : & \text{H} & \text{C} & \equiv & \text{C} & \equiv & \text{H} \\
\text{III} & : & \text{H} & \text{C} & \equiv & \text{C} & \equiv & \text{H} \\
\end{align*}
\]

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

14. Which of the following ions has the electron configuration [Ar] 3d^6?

\[ \text{I} \quad \text{II} \quad \text{III} \]

\[
\begin{align*}
\text{I} & : & \text{Ni}^{2+} \\
\text{II} & : & \text{Co}^{3+} \\
\text{III} & : & \text{Fe}^{2+} \\
\end{align*}
\]

A. I only  
B. II only  
C. III only  
D. II and III  
E. I, II, and III

15. For which one of the following equations is \( \Delta H^\circ_{\text{rxn}} \) equal to \( \Delta H^\circ_{\text{f}} \) for the product?

A. \( \text{N}_2 (g) + 2\text{F}_2 (g) \rightarrow \text{N}_2\text{F}_4 (g) \)  
B. \( \text{CH}_4 (g) + 2\text{Cl}_2 (g) \rightarrow \text{CH}_2\text{Cl}_2 (l) + 2\text{HCl} (g) \)  
C. \( \text{N}_2 (g) + \text{O}_3 (g) \rightarrow \text{N}_2\text{O}_3 (g) \)  
D. \( 2\text{CO} (g) + \text{O}_2(g) \rightarrow 2\text{CO}_2 (g) \)  
E. \( \text{C} (\text{diamond}) + 2\text{Cl}_2 (g) \rightarrow \text{CCl}_4 (l) \)

16. What is the concentration of HCl if 17.5 mL are needed to neutralize 29.6 mL of 0.250 M Ca(OH)_2?

A. 0.157 M  
B. 0.314 M  
C. 0.423 M  
D. 0.846 M  
E. 1.69 M
17. Consider the following reaction:

\[ 6 \text{CO}_2(\text{g}) + 6 \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{C}_6\text{H}_{12}\text{O}_6(\text{s}) + 6 \text{O}_2(\text{g}) \quad \Delta H^\circ = 2816 \text{ kJ} \]

Which one of the following statements about this equilibrium is false?

A. Decreasing the total pressure by increasing the volume at constant temperature will have no effect on the equilibrium.
B. Increasing the CO\(_2\) pressure will cause the reaction to shift to the right.
C. Increasing the temperature will cause the reaction to shift to the right.
D. Removing some of the C\(_6\)H\(_{12}\)O\(_6\) will shift the reaction to the right.
E. Adding catalyst will have no effect on equilibrium.

18. Which of the following equilibriums is least affected by a change in the volume of the system?

A. \(2 \text{C}(\text{s}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{CO}(\text{g})\)
B. \(\text{H}_2(\text{g}) + \text{S}(\text{l}) \rightleftharpoons \text{H}_2\text{S}(\text{g})\)
C. \(2 \text{NO}_2(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g})\)
D. \(\text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{O}(\text{g})\)
E. \(2 \text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2 \text{NOCl}(\text{g})\)

19. Which of the following has the highest melting point?

A. LiCl
B. NaBr
C. MgO
D. SrS
E. KI

20. Rank the C-O bond lengths in the following molecules, from shortest to longest.

A. CO = CO \(_2\) < CO \(_3\)\(^-\)
B. CO\(_2\) < CO < CO\(_3\)\(^-\)
C. CO\(_3\)\(^-\) < CO \(_2\) < CO
D. CO < CO\(_2\) = CO\(_3\)\(^-\)
E. CO < CO\(_2\) < CO\(_3\)\(^-\)

21. Which of the following has the largest second ionization energy?

A. Mg
B. Na
C. Ga
D. Ge
E. S
22. Assuming Bohr model behavior, what is the longest wavelength of light that can be used to ionize a hydrogen atom in its ground state?
   A. 328 nm
   B. 555 nm
   C. 91.2 nm
   D. 912 nm
   E. 906 nm

23. Which one of these molecules has the strongest intermolecular forces?
   A. CH₃Br
   B. CH₃Cl
   C. CHCl₃
   D. CH₃I
   E. CH₃F

24. Caffeine (C₈H₁₀N₄O₂) is a stimulant found in coffee and tea. If a solution of caffeine in chloroform (CHCl₃) as a solvent has a concentration of 0.0750 m, calculate percent caffeine by mass.
   A. 4.19%
   B. 7.78%
   C. 3.20%
   D. 1.44%
   E. 0.59%

25. How would the solubility of CO₂ gas in aqueous solution be affected by increasing the partial pressure of CO₂ above the solution at constant T?
   A. The solubility of the CO₂ gas would increase.
   B. The solubility of the CO₂ gas would decrease.
   C. It would have no effect on the solubility of the CO₂ gas.
   D. Need the total pressure to answer.
   E. Need the temperature of the solution to answer.
26. The plot shows the distribution of speeds of different gases at the same temperature. If each of these gases was in a 1 L box at STP, which one would have the greatest density?

![Graph showing distribution of speeds of gases]

A. A
B. B
C. C
D. They would all have the same density.
E. It is impossible to tell from this information.

27. When Na₂S (aq) and ZnSO₄ (aq) are mixed and a reaction occurs, what are the spectator ions?

A. Na⁺ (aq) and Zn²⁺ (aq)
B. S²⁻ (aq) and Zn³⁺ (aq)
C. Zn²⁺ (aq) and SO₄²⁻ (aq)
D. Na⁺ (aq) and S²⁻ (aq)
E. Na⁺ (aq) and SO₄²⁻ (aq)

28. One mole of aluminum and one mole of manganese oxide are placed in a reaction vessel, and the following reaction occurs

\[ 2 \text{Al (s)} + 3 \text{MnO (s)} \rightarrow \text{Al₂O₃ (s)} + 3 \text{Mn (s)} \]

Which of the following statements is true?

A. 1.0 mole of Mn will be produced.
B. 2.0 mole of Al₂O₃ will be produced.
C. 1.0 mole of Al will be left over.
D. 2.0 mole of MnO will be left over.
E. Al is the limiting reactant.

29. Rank these systems in order of increasing electrostatic potential energy.

I. an electron that is 2.8 nm from a +2 charge
II. an electron that is 2.8 nm from a -2 charge
III. an electron that is 2.8 nm from a proton

A. I < III < II
B. I = II < III
C. II < III < I
D. I = II = III
E. III < II = I

Go on to the next page
30. Which of the following electron configurations is possible for valence electrons of nitrogen (ground state or excited state)?

A. i only
B. ii only
C. i and ii
D. ii and iii
E. all three are correct

31. Which bond in the following molecule is the most polar?

A. C—H
B. C—Cl
C. C—Br
D. C—O
E. C—F

32. Which of the following organic molecules can be classified as an alkene?

A. i and iv
B. ii only
C. ii and v
D. iii and v
E. ii, iii, and v

33. Which of the following molecules are polar?

A. i only
B. ii only
C. i and ii
D. ii and iii
E. all three are polar
34. Arrange the following in order of decreasing melting point.

\[ \text{CaO} \quad \text{Ar} \quad \text{H}_2\text{O} \]

A. \( \text{CaO} > \text{H}_2\text{O} > \text{Ar} \)
B. \( \text{CaO} > \text{Ar} > \text{H}_2\text{O} \)
C. \( \text{H}_2\text{O} > \text{CaO} > \text{Ar} \)
D. \( \text{H}_2\text{O} > \text{Ar} > \text{CaO} \)
E. \( \text{Ar} > \text{H}_2\text{O} > \text{CaO} \)

35. Which one of the following will have delocalized \( \pi \) bonding?

\[ \text{O} \quad \text{O} \quad \text{H} \quad \text{S} \quad \text{O} \]

\[ \text{O} \quad \text{S} \]

A. i only
B. i and ii
C. i and iii
D. ii and iii
E. all three

36. What is the correct order of the freezing points for the following aqueous solutions starting with the highest?

I. 0.010 m \( \text{BaCl}_2 \)
II. 0.010 m \( \text{C}_6\text{H}_{12}\text{O}_6 \)
III. 0.020 m \( \text{KBr} \)

A. III > II > I
B. III > I > II
C. I > III > II
D. II > I > III
E. I > II > III

37. Detonation of nitroglycerin proceeds as follows:

\[ 4 \text{C}_3\text{H}_5\text{N}_3\text{O}_9 (l) \rightarrow 12 \text{CO}_2 (g) + 6 \text{N}_2 (g) + \text{O}_2 (g) + 10 \text{H}_2\text{O} (g) \]

When \( 5.00 \times 10^{-3} \) L of nitroglycerin (density = 1.592 g/mL) is detonated, how many total moles of gas are produced?

A. 0.138 mole
B. 0.253 mole
C. 0.00460 mole
D. \( 2.53 \times 10^{-4} \) mole
E. \( 6.55 \times 10^{-4} \) mole
38. Rank these compounds in order of increasing viscosity starting with the least viscous.

![Chemical structures]

A. I < II < III
B. II < I < III
C. III < I < II
D. II < III < I
E. III < II < I

39. At a particular temperature, for the reaction below \( K_c = 4 \).

\[
N_2 (g) + O_2 (g) \rightleftharpoons 2 \text{NO} (g)
\]

If we mix 1 mol of \( N_2 \) and 1 mol of \( O_2 \) in a 2 L container what will the concentration of NO be once equilibrium is reached at the given temperature?

A. 0.25 M  
B. 0.33 M  
C. 0.50 M  
D. 0.67 M  
E. 1.0 M

40. When a student mixes 50 mL of 1.0 M HCl and 50 mL of 1.0 M NaOH in a coffee-cup calorimeter, the temperature of the resultant solution increases from 21.0 °C to 27.5 °C. Calculate the enthalpy change for the reaction in kJ per mol of HCl, assuming that the calorimeter loses only a negligible quantity of heat. The total volume of the solution is 100 mL, its density is 1.0 g/mL, and its specific heat is 4.18 J/g-K.

A. 2.7 kJ/mol  
B. −2.7 kJ/mol  
C. 54.4 kJ/mol  
D. −54.4. kJ/mol  
E. −108 kJ/mol

End of Exam
Form A
1. D
2. C
3. D
4. C
5. A
6. B
7. C
8. B
9. B
10. A
11. B
12. A
13. C
14. D
15. A
16. D
17. D
18. B
19. C
20. E
21. B
22. C
23. C
24. D
25. A
26. A
27. E
28. A
29. A
30. D
31. E
32. D
33. D
34. A
35. C
36. D
37. B
38. A
39. C
40. D