1. Which of the following relationships could be correct for the atoms/ions represented?

A. I is Cl and II is Cl⁻.
B. I is Li⁺ and II is F⁻.
C. I is H⁺ and II is H⁻.
D. I is K⁺ and II is Cl⁻.
E. I is Na and II is Na⁺.

2. Arrange the atoms B, C and Al by decreasing first ionization energy.

3. Which of the following electron configurations represents an element with the greatest second ionization energy?

A. ns¹
B. ns²
C. ns² np¹
D. ns² np²
E. ns² np³

4. Which of the following has an electron affinity that is close to zero, making it an exception to the general trend?

A. C
B. Be
C. Li
D. F

5. Which element has the largest difference between the third ionization and the fourth ionization?

A. C
B. Be
C. B
D. F

6. The schematic diagram represents the formation of molecules from atoms. Which statement about the energy change for this process is true?

A. Energy is released
B. Energy is absorbed
C. The energy does not change
D. Cannot tell from the information given

7. The process in Question 6 is represented by which change on the diagram below?

A. Point (a) to point (b).
B. Point (a) to point (c).
C. Point (b) to point (d).
D. Point (b) to point (a).
E. Point (c) to point (a).
F. Point (d) to point (b).
8. In the following drawings, black spheres represent cations and grey spheres represent anions. Which diagram represents $\text{BaSO}_4$?

A.  

B.  

C.  

D.  

9. What is the formula for the simple ionic compound formed by magnesium and iodine?

10. Which of the following is the best representation for the compound formed between iodine (white) and cesium (black)?

A.  

B.  

C.  

D.  

11. The diagrams below are representations of which compounds?

A. I is $\text{N}_2\text{O}_5$ and II is $\text{Ca}_3(\text{PO}_4)_2$.  
B. I is $\text{NaCl}$ and II is $\text{P}_2\text{O}_5$.  
C. I is $\text{Cu}_2\text{CO}_3$ and II is $\text{H}_2\text{O}$.  
D. I is $\text{Al}_2(\text{SO}_4)_3$ and II is $\text{N}_2\text{O}_5$.  
E. I is $\text{P}_2\text{O}_5$ and II is $\text{C}_2\text{H}_2$.

12. Consider three compounds, $\text{NaCl}$, $\text{Cl}_2$ and $\text{HCl}$. Which statement is true?

A. $\text{NaCl}$ is a solid at room temperature, $\text{Cl}_2$ and $\text{HCl}$ are gases.  
B. $\text{Cl}_2$ is a solid at room temperature, $\text{NaCl}$ and $\text{HCl}$ are gases.  
C. $\text{HCl}$ is a solid at room temperature, $\text{NaCl}$ and $\text{HCl}$ are gases.  
D. $\text{NaCl}$ and $\text{HCl}$ are solids at room temperature, $\text{Cl}_2$ is a gas.  
E. $\text{Cl}_2$ and $\text{HCl}$ are solids at room temperature, $\text{NaCl}$ is a gas.

13. Which molecule or compound below contains the most non-polar covalent bond?

A. $\text{Li}_2\text{CO}_3$  
B. $\text{F}_2$  
C. $\text{NaCl}$  
D. $\text{SCl}_6$  
E. $\text{PF}_3$

14. In which case is the bond polarity incorrect?

A. $\delta^+\text{H}–\text{F}\delta^–$  
B. $\delta^+\text{K}–\text{O}\delta^–$  
C. $\delta^+\text{Mg}–\text{H}\delta^–$  
D. $\delta^+\text{Cl}–\text{I}\delta^–$  
E. $\delta^+\text{Si}–\text{S}\delta^–$

15. Place the following elements in increasing order of electronegativity.

Al, Cl, Na, Si

16. Arrange the bonds by increasing polarity:

$\text{S}–\text{S}$, $\text{S}–\text{Br}$, $\text{S}–\text{Cl}$.

17. Which substance has both covalent and ionic bonds?

A. $\text{NH}_2\text{Br}(s)$  
B. $\text{CH}_2\text{Cl}_2(l)$  
C. $\text{KI}(s)$  
D. $\text{SiF}_4(g)$

18. Arrange the following polyatomic ions by increasing negative charge.

$\text{ClO}_4^–$, $\text{PO}_4^–$, $\text{CO}_3^–$. 
19. Which ionic compound in each pair has a smaller lattice energy?  
   Pair I: LiF or NaF  
   Pair II: KF or CaF₂  
   A. LiF and KF  
   B. LiF and CaF₂  
   C. NaF and KF  
   D. NaF and CaF₂  

20. Which of the following solids would have the highest melting point? Which the lowest?  
   A. NaI  
   B. NaF  
   C. MgCl₂  
   D. MgO  

21. The Lewis structure of AsCl₃ has ____ single bonds, ____ double bonds and ____ lone pairs.  

22. Which represents a valid Lewis structure for dinitrogen tetraoxide, N₂O₄?  
   A  
   B  
   C  
   D  

23. Which of the following will have a Lewis structure in which central atom must exceed the octet rule?  
   A. SF₄  
   B. CS₂  
   C. CF₄  
   D. NO₂⁺  
   E. ClF₃  
   F. NO₂⁻  

24. Which of the following ions will exhibit delocalized bonding?  
   NO₂⁻  NO₂⁺  N₃⁻  

25. What is the approximate C—O bond order in the carbonate ion, CO₃²⁻?  

26. Given the following molecule, what are the formal charge on nitrogens a, b and c respectively.  
   H   
   H−C=N=N=N:  
   H  
   a  
   b  
   c  
   A. 0, +1, +1  
   B. 0, -1, +1  
   C. +1, 0, -1  
   D. 0, +1, -1  
   E. 0, 0, 0  

27. Which Lewis structure for the explosive compound, XeO₃, is most appropriate based on formal charges?  
   A  
   B  
   C  
   D  
   E  

28. Arrange the diatomic molecules nitrogen (N₂), oxygen (O₂) and bromine (Br₂) in order of increasing bond strength based on your knowledge of the relative strengths of single, double and triple bonds. (Hint: draw out the molecules.)  

29. The electron pair geometry of XeF₅⁺ molecule is and the molecular shape is _______.  

30. According to VSEPR Model, which one of the following molecules has a tetrahedral molecular geometry?  
   A. NH₃  
   B. CCl₄  
   C. CO₂  
   D. SO₃  
   E. HCN  
   F. SF₄
31. The electron pair (electron domain) geometry of the circled atom in imidazole below is ________ and the molecular shape at this atom is ________.

![Image of imidazole molecule]

32. The H-C-C angle in C₂H₄ is ______

33. According to VSEPR Model, which one of the following molecules would have the smallest bond angle?
   A. CO₂  C. BeCl₂
   B. SO₂  D. HCN

34. Which of the following has the smallest bond angle?
   A. ammonia, NH₃
   B. methane, CH₄
   C. water, H₂O
   D. All three have the same bond angle.

35. What is the hybridization on the circled nitrogen in the structure of imidazole below?

![Image of imidazole molecule]

   A. sp  D. sp³d
   B. sp²  E. sp³d²
   C. sp³

36. What hybridization best describes the central atom if it has the T-shaped molecular geometry

   A. sp²  C. sp³d
   B. sp³  D. sp³d²

37. An atom has two hybrid orbitals arranged in a linear geometry. Which of the following statements is true?
   A. The atom has one p orbital available for pi bonding.
   B. The atom has two p orbitals available for pi bonding.
   C. The atom has no pi orbitals.
   D. The atom has an s orbital available for sigma bonding.

38. Which hybrid orbitals overlap in the formation of the bond in C-C single bond in the molecule below?

![Image of C-C bond]

   A. 1 sp³ orbital and 1 sp orbital
   B. 2 sp³ orbitals
   C. 1 sp³ orbital and 1 sp² orbital
   D. 2 sp orbitals
   E. 1 sp² orbital and 1 sp orbital

39. Thiophenol, C₆H₆S, is a foul smelling, odorless liquid. Its skeleton (lone pair and multiple bonds omitted) is shown below. Based on Valence Bond Theory, what carbon orbital(s) and sulfur orbital(s) overlap to give rise to the C—S bond?

![Image of thiophenol molecule]

   A. C sp orbital overlaps with a S sp orbital
   B. C sp orbital overlaps with a S sp² orbital
   C. C sp² orbital overlaps with a S sp³ orbital
   D. C sp² orbital overlaps with a S sp² orbital.
   E. C sp³ orbital overlaps with a S sp orbital.
   F. C sp³ orbital overlaps with a S sp² orbital.
40. The π bond in ethylene results from the overlap of _____

\[ \text{CH}_2=\text{CH}_2 \]

A. \( \text{sp}^3 \) hybrid orbitals  
B. \( \text{s} \) atomic orbitals  
C. \( \text{sp} \) hybrid orbitals  
D. \( \text{sp}^2 \) hybrid orbitals  
E. \( p \) atomic orbitals

For questions 41-44 below, classify the type of bond that results from each of the orbital overlaps (\( \sigma \), \( \pi \), \( \delta \), \( \lambda \), etc.) represented below.

41.

\[ \sigma \]

42.

\[ \text{sp}^2 \]

43.

\[ p \]

44.

\[ \text{sp}^3 \] and \[ \text{sp}^3 \]

45. Complete the Lewis Structure below, its missing lone pair and multiple bonds. How many sigma (\( \sigma \)) bonds and pi (\( \pi \)) bonds are present in the molecule?

\[
\begin{array}{c}
\text{N} \\
\text{C} \\
\text{C} \\
\text{O} \\
\text{H}
\end{array}
\]

46. According to Molecular Orbital Theory, two separate \( 1s \) orbitals interact to form what molecular orbital(s)?

A. \( \sigma \) only  
B. \( \sigma \) and \( \sigma^* \)  
C. \( \sigma \) and \( \pi \)  
D. \( \pi \) and \( \pi^* \)

47. The carbon-carbon bonding in benzene, \( \text{C}_6\text{H}_6 \), can be best described as consisting of _____

\[
\begin{array}{c}
\text{H} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C} \\
\text{C}
\end{array}
\]

A. 3 sigma bonds and 3 delocalized pi bonds.  
B. 3 sigma bonds and 3 localized pi bonds.  
C. 6 sigma bonds and 3 localized pi bonds.  
D. 6 sigma bonds and 3 delocalized pi bonds.

48. Predict the molecular shape and polarity of the \( \text{SO}_2 \) molecule.

A. linear, polar  
B. linear, nonpolar  
C. bent, polar  
D. bent, nonpolar

49. Which of the following is a polar molecule?

A. \( \text{CS}_2 \)  
B. \( \text{BCl}_3 \)  
C. \( \text{NBr}_3 \)  
D. \( \text{SiF}_4 \)  
E. \( \text{PCl}_5 \)  
F. \( \text{SF}_6 \)

50. The drawing shows two water molecules. Which statement is correct?

\[
\begin{array}{c}
A \\
B
\end{array}
\]

A. A: covalent bond; B: hydrogen bond; B is stronger  
B. A: hydrogen bond; B: covalent bond; A is stronger  
C. A: covalent bond; B: hydrogen bond; A is stronger  
D. A: hydrogen bond; B: covalent bond; B is stronger

51. The molecules in a sample of solid \( \text{SO}_2 \) are attracted to each other by a combination of…

A. London forces and H-bonding  
B. H-bonding and ionic bonding  
C. covalent bonding and dipole-dipole interactions  
D. London forces and dipole-dipole interactions
52. Which of the following has the highest boiling point?

A. \( \text{N}_2 \)  
B. \( \text{H}_2\text{S} \)  
C. \( \text{NH}_3 \)  
D. \( \text{H}_2\text{O} \)  
E. \( \text{SO}_2 \)

53. In each pair, indicate which would be expected to have the higher boiling point?

SF\(_4\) or SF\(_6\)  
NH\(_3\) or PH\(_3\)

A. SF\(_4\) and NH\(_3\)  
B. SF\(_4\) and PH\(_3\)  
C. SF\(_6\) and NH\(_3\)  
D. SF\(_6\) and PH\(_3\)

54. What are all of the intermolecular forces that are responsible for the existence of ice?

A. dipole-dipole and London forces  
B. London forces  
C. dipole-dipole, London forces, and Hydrogen bonding  
D. dipole-dipole and ion-dipole  
E. hydrogen bonding and dipole-dipole

55. Predict which solvent will dissolve more of the given solute.

(I) NaCl in methanol (CH\(_3\)OH) or in propanol (CH\(_3\)CH\(_2\)CH\(_2\)OH)  
(II) Ethylene glycol (HOCH\(_2\)CH\(_2\)OH) in water or in hexane (CH\(_3\)CH\(_2\)CH\(_2\)CH\(_2\)CH\(_3\) )

I  
A. methanol  
B. methanol  
C. propanol  
D. propanol

II  
A. water  
B. hexane  
C. water  
D. hexane

56. Predict which solute is more soluble in the given solvent.

(I) 1,4-butadiol (HOCH\(_2\)CH\(_2\)CH\(_2\)CH\(_2\)OH) or butanol (CH\(_3\)CH\(_2\)CH\(_2\)CH\(_2\)OH) in water  
(II) Chloroform (CHCl\(_3\)) or carbon tetrachloride (CCl\(_4\)) in water

I  
A. 1,4-butadiol  
B. 1,4-butadiol  
C. butanol  
D. butanol

II  
A. chloroform  
B. carbon tetrachloride  
C. chloroform  
D. carbon tetrachloride

57. How many sulfur atoms are in 25.6 g of \( \text{Al}_2(\text{S}_2\text{O}_3)_3 \)?

58. How many grams of aluminum are in 25.6 g of \( \text{Al}_2(\text{S}_2\text{O}_3)_3 \)?

59. \( 7.53 \times 10^{23} \) molecules of an element has a mass of 88.64 g. What is the identity of this molecular element?
## USEFUL INFORMATION:

\[ N_A = 6.0221 \times 10^{23} \]  
\[ 1 \text{ amu} = 1.66054 \times 10^{-24} \text{ g} \]

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**PERIODIC TABLE OF THE ELEMENTS**

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**Electron Geometries and Molecular Shapes from VSEPR (Valence Shell Electron Pair Repulsion Model)**

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