Each of the 65 multiple choice questions counts 1.2 point. Give the letter of the correct answer.

1. What is the term for the ability of an atom in a chemical bond to attract a shared electron pair?
   (a) bond moment  
   (b) dipole moment  
   (c) electronegativity  
   (d) surface tension  
   (e) viscosity

2. Which species violates the octet rule?
   (a) NH₃  
   (b) PF₃  
   (c) NO₂⁻  
   (d) all of the above  
   (e) none of the above

3. How many pairs of nonbonding electrons are shown in the Lewis electron dot formula of the nitrite ion, NO₂⁻?
   (a) 3  
   (b) 6  
   (c) 8  
   (d) 9  
   (e) none of the above

4. What is the Formal Charge on the nitrogen atom in the nitrite ion?
   (a) 0  
   (b) +1  
   (c) +2  
   (d) -1  
   (e) -2

5. Which of the following is held together by ionic bonds?
   (a) CO₂  
   (b) Fe₂O₃  
   (c) P₂O₅  
   (d) SO₂  
   (e) XeO₄

6. How many valence electrons are in an chlorine atom and an chloride ion?
   (a) 6 and 8, respectively  
   (b) 7 and 7, respectively  
   (c) 7 and 8, respectively  
   (d) 8 and 7, respectively  
   (e) none of the above

7. Which of the following bonds is very polar, but not ionic?
   (a) Li-F.  
   (b) C-O.  
   (c) I-Br.  
   (d) Cu-O.  
   (e) none of the above

8. List the molecules BeH₂, BH₃, NH₃, and OH₂ in order of increasing bond angle:
   (a) OH₂ < NH₃ < BH₃ < BeH₂  
   (b) NH₃ < OH₂ < BeH₂ < BH₃  
   (c) OH₂ < BeH₂ < BH₃ < NH₃  
   (d) OH₂ < BeH₂ < NH₃ < BH₃  
   (e) BH₃ < NH₃ < OH₂ < BeH₂
9. Molecular orbitals can be considered to be formed by the “overlap” of atomic orbitals. Which one of the overlap sketches below best describes H-Br bond in HBr?

(a) A 
(b) B 
(c) C 
(d) D 
(e) E

10. According to the general trends in the periodic table, which of the following is the most electronegative element?

(a) B  
(b) C  
(c) N  
(d) O  
(e) P

11. A graph representing the relationship between energy and the distance between a hydrogen and bromine atom is shown at the right. Which statement is true about the HBr molecule?

(a) bond energy is B and bond length is A.  
(b) bond energy is A and bond length is B.  
(c) bond energy is B and bond length is D.  
(d) bond energy is C and bond length is A.  
(e) bond energy is C and bond length is D.

12. What is the molecular shape of an ammonia, NH₃, molecule?

(a) bent (angular)  
(b) linear  
(c) trigonal pyramidal  
(d) trigonal planar  
(e) none of the above

13. What is the molecular shape of a methane, CH₄, molecule?

(a) bent (angular)  
(b) linear  
(c) tetrahedral  
(d) trigonal pyramidal  
(e) none of the above

14. Water beads up on a freshly waxed automobile. This phenomenon is an example of:

(a) Cohesive forces being weaker than adhesive forces.  
(b) Adhesive forces being stronger than cohesive forces.  
(c) Cohesive forces being stronger than adhesive forces.  
(d) Both a and b.  
(e) none of the above

15. What is the term for the temperature at which the vapor pressure of a liquid is equal to the atmospheric pressure?

(a) absolute zero  
(b) boiling point  
(c) critical point  
(d) vapor point  
(e) none of the above
16. What is the strongest intermolecular force in dimethyl ether, \( \text{CH}_3\text{-O-CH}_3 \)?
   (a) ion-ion attraction       (d) hydrogen bond
   (b) dipole-dipole attraction (e) metallic bond
   (c) dispersion force

17. What is the term for an attraction between two molecules with temporary dipoles?
   (a) covalent bond            (d) hydrogen bond
   (b) dipole force             (e) intermolecular bond
   (c) dispersion force

18. What is the term for the heat required to convert a solid to a liquid at its melting point?
   (a) heat of crystallization   (d) specific heat
   (b) heat of fusion           (e) none of the above
   (c) heat of vaporization

19. What is the term for an attraction between molecules that contain a hydrogen atom bonded to a highly electronegative atom such as oxygen or nitrogen?
   (a) dipole force             (d) intermolecular bond
   (b) dispersion force         (e) polar covalent bond
   (c) hydrogen bond

20. The best description of the CO bond in formaldehyde \( \text{H}_2\text{C}=\text{O} \), is:
   (a) two sigma bonds         (d) a sigma and two pi bonds
   (b) two pi bonds            (e) a delta bond and a pi bond
   (c) a sigma and a pi bond

21. What is the term for the tendency of a liquid to form spherical droplets?
   (a) dipole attraction       (d) surface tension
   (b) dispersion forces       (e) viscosity
   (c) intermolecular attraction

22. What is the common term for the pressure exerted by vapor molecules above a liquid in a closed container when the rates of evaporation and condensation are equal?
   (a) atmospheric pressure    (d) vapor pressure
   (b) equilibrium pressure    (e) none of the above
   (c) gas pressure

23. The best description of the CN bond in HCN is:
   (a) a sigma bond            (d) a sigma bond and two pi bonds
   (b) a pi bond               (e) three pi bonds
   (c) a sigma bond and a pi bond

24. If the molecules in a liquid have a strong attraction for each other, which of the following properties has a relatively low value?
   (a) boiling point           (d) viscosity
   (b) surface tension         (e) all of the above
   (c) vapor pressure

25. What is the strongest intermolecular force in a liquid having molecules with H-O bonds?
   (a) covalent bonds          (d) hydrogen bonds
   (b) dipole forces           (e) none of the above
   (c) dispersion forces
26. Which of the following properties is a general characteristic of liquids?
(a) liquids have a variable shape and fixed volume 
(b) liquids flow readily 
(c) liquids do not compress or expand significantly 
(d) a substance is much more dense as a liquid than a gas 
(e) all of the above

27. Which of the following properties is a general characteristic of liquids?
(a) liquids have a fixed shape and variable volume 
(b) liquids compress and expand significantly 
(c) a substance is much less dense as a liquid than a gas 
(d) liquids that are soluble form heterogeneous mixtures 
(e) none of the above

28. Consider the five pictures below. Which is the most realistic representation of liquified Kr?
(a) A  
(b) B  
(c) C  
(d) D  
(e) E

29. Which of the following is true of the intermolecular attraction in liquids?
(a) Nonpolar molecules can be attracted by dispersion forces. 
(b) Polar molecules can be attracted by temporary dipole forces. 
(c) Polar molecules can be attracted by permanent dipole forces. 
(d) Polar molecules can be attracted by hydrogen bonds. 
(e) all of the above

30. Which of the following properties is a general characteristic of solids?
(a) solids have a rigid shape and fixed volume 
(b) solids can have crystalline or noncrystalline structures 
(c) solids do not compress or expand significantly 
(d) a substance is usually more dense as a solid than a liquid 
(e) all of the above

31. Which of the following is not an example of a molecular crystalline solid?
(a) halite, NaCl  
(b) iodine, I₂  
(c) phosphorus, P₄  
(d) sucrose, C₁₂H₂₂O₁₁  
(e) urea, CO (NH₂)₂

32. Which of the following explains why ice floats in water?
(a) Molecules in ice are closer together. 
(b) The unit cell of ice has holes in it. 
(c) Ice has a smaller specific heat than water. 
(d) all of the above 
(e) none of the above
33. Which of the following properties of water would you predict to be unusually high?
(a) melting point  (d) heat of vaporization
(b) boiling point  (e) all of the above
(c) heat of fusion

34. Which of the following explains why a needle can float on water?
(a) The density of the water is greater than the needle.
(b) The molar mass of the water is greater than the needle.
(c) The surface tension of the water supports the needle.
(d) The vapor pressure of the water supports the needle.
(e) The viscosity of the water supports the needle.

35. List the three compounds below in order of increasing boiling point:

\[ \text{A} \quad \begin{array}{c}
\text{B} \\
\text{C}
\end{array} \quad \text{B} \quad \begin{array}{c}
\text{C} \\
\text{B}
\end{array} \quad \text{C} \quad \begin{array}{c}
\text{O} \quad \begin{array}{c}
\text{CH}_3 \\
\text{CH}_3
\end{array}
\end{array} \]

(a) A, B, C  (d) B, C, A
(b) A, C, B  (e) C, B, A
(c) B, A, C

36. Which of the following types of crystalline solids is hard and brittle, has a high melting point, and conducts electricity only when melted?
(a) ionic  (d) all of the above
(b) molecular  (e) none of the above
(c) metallic

37. Which of the following types of crystalline solids is malleable, ductile, and a conductor of electricity?
(a) ionic  (d) all of the above
(b) molecular  (e) none of the above
(c) metallic

38. Which of the following types of crystalline solids has a low melting point, is generally insoluble in water, and is a nonconductor of electricity?
(a) ionic  (d) all of the above
(b) molecular  (e) none of the above
(c) metallic

39. What is the term that refers to two liquids that are not soluble in one another and separate into two layers?
(a) immiscible  (d) Tyndall effect
(b) equal vapor pressure  (e) none of the above
(c) miscible

40. A crystalline solid and an amorphous solid are different because:
(a) they have different densities
(b) they have different structures
(c) a crystalline solid has a unit cell
(d) the amorphous solid solidified more rapidly
(e) all of the above
41. What is the term for the general principle that solubility is greatest when the polarity of the solute is similar to that of the solvent?
(a) like dissolves like rule  
(b) polarity principle  
(c) solute principle  
(d) solution principle  
(e) solvent principle

42. What is the term for a solution that contains the maximum amount of solute that will dissolve at a given temperature at equilibrium?
(a) colloid  
(b) concentrated  
(c) saturated  
(d) solubility  
(e) supersaturated

43. Which statement is correct about the cooling curve at the right?
(a) A is cooling of the solid  
(b) B is freezing of the liquid  
(c) After D, solid starts to form below the freezing point  
(d) F is freezing of the liquid  
(e) E is boiling of the liquid

44. What is the term for a solution that contains more solute than is ordinarily soluble at a given temperature?
(a) colloid  
(b) concentrated  
(c) saturated  
(d) supersaturated  
(e) unsaturated

45. Which of the following liquids is miscible with water.
(a) chloroform, CHCl₃  
(b) cyclohexane, C₆H₁₂  
(c) glycerin, C₃H₅(OH)₃  
(d) pentane, C₅H₁₂  
(e) toluene, C₆H₅CH₃

46. At the right are four molecular orbital diagrams with filled orbitals in black. The correct statement is:
(a) A is an insulator and D is a conductor  
(b) A is an insulator and C is an n-type semiconductor  
(c) D is an insulator and B is an n-type semiconductor  
(d) D is an insulator and C is an n-type semiconductor  
(e) None of the above

47. Which substances whose MO diagrams are above would be colorless?
(a) only A  
(b) only B  
(c) only B and C  
(d) only C  
(e) only D

48. Which element should be added in a very small amount to silicon to give MO diagram B?
(a) arsenic  
(b) carbon  
(c) gallium  
(d) all of the above would work  
(e) none of the above would work

49. Give the following bond energies (H-H = 435; H-I = 295; I-I = 150 kJ/mol), the change in energy for the reaction of one mole of hydrogen with one mole of iodine, H₂ + I₂ → 2HI, is:
(a) -290 kJ  
(b) -5 kJ  
(c) +290 kJ  
(d) +880 kJ  
(e) none of the above
50. At the right are two molecular orbital diagrams for simple diatomic molecules of Period 2 elements. The correct statement is:

(a) orbital C is a sigma bonding orbital
(b) orbital M is a sigma bonding orbital
(c) orbitals J are pi bonding orbitals
(d) orbital I is a pi antibonding orbital
(e) none of the above

51. Consult the MO diagrams for simple diatomics. The correct statement is:

(a) no more than four electrons can be in orbital M
(b) orbitals B and K have the same general shape
(c) orbital L is a sigma bonding orbital formed from two s orbitals
(d) the first excited state of H2 has one electron in orbital G and one in orbital H
(e) orbitals M, N, O, and P are bonding and orbitals I, J, K, and L are antibonding

52. The molecule which has the highest paramagnetism is:

(a) B2
(b) C2
(c) F2

53. According to Molecular Orbital Theory, the Bond Order of the C2 molecule is:

(a) 0
(b) 1
(c) 2

54. According to Molecular Orbital Theory, the Bond Order of the N2 molecule is:

(a) 0
(b) 1
(c) 2

55. The molecular orbitals in the sketch below with the same symmetry as MO C are (+ indicates location of the nuclei):

(a) A and B
(b) A and D
(c) B and D

56. The antibonding molecular orbitals in the sketch above are:

(a) A and B
(b) A, B, and D
(c) A and D

(d) B, C, and E
(e) C, D, and E
57. The orbital geometry at the right is called:
(a) octahedral  (d) trigonal bipyramidal
(b) pentagonal  (e) trigonal planar
(c) tetrahedral

58. Which molecule(s), XeF₂, ClF₃, XeF₄, and ClF₅, have the same orbital geometries as that shown in Question 57?
(a) only XeF₂  (d) XeF₄ and ClF₅
(b) XeF₂ and ClF₃  (e) only ClF₅
(c) ClF₃ and XeF₄

59. Which of the following molecules are polar? BeH₂, BH₃, and NH₃
(a) BeH₂ only  (d) none are polar
(b) BH₃ only  (e) all are polar
(c) NH₃ only

60. Which of the following molecules are polar? CF₄, SF₄, and XeF₄
(a) CF₄ only  (d) CF₄ and SF₄
(b) SF₄ only  (e) CF₄ and XeF₄
(c) XeF₄ only

61. Which of the following molecules are polar? CO₂, NO₂, and SO₂
(a) CO₂ only  (d) CO₂ and NO₂
(b) NO₂ only  (e) NO₂ and SO₂
(c) SO₂ only

62. Which of the following molecules are polar? ClF₃, SF₄, BrF₅,
(a) ClF₃ only  (d) none are polar
(b) SF₄ only  (e) all are polar
(c) BrF₅ only

63. Which of the following alkenes are polar?
(a) first
(b) second
(c) both
(d) neither

64. Which of the following benzenes are polar?
(a) first
(b) second
(c) both
(d) neither

65. Two allotropes of carbon are graphite and diamond. Bonding in graphite is delocalized while the bonding in diamond is not. The correct statement is:
(a) Graphite conducts electricity and pure diamond is colored.
(b) Pure graphite is colorless but impure graphite is colored.
(c) Both graphite and diamond are good electrical conductors.
(d) Both graphite and diamond are poor electrical conductors.
(e) None of the statements are correct.
66. (24%) Give Lewis electron dot structures, three dimensional sketches, the hybridization of the central atom, AND the approximate values of all bond angles in:

a. NH₃

b. NH₄⁺

c. CO₂

d. SO₂

e. ClF₃

f. XeF₄