ON YOUR SCANTRON:
✓ BUBBLE IN YOUR 7 DIGIT PERM (Leaving the last three digits blank)
✓ BUBBLE IN THE VERSION:
✓ WRITE YOUR NAME

AT THE END, HAND IN ONLY THE SCANTRON.

INFORMATION

\[ \Delta T = K_b \text{ m}_{\text{solute}} \]
\[ \Delta T = K_f \text{ m}_{\text{solute}} \]
\[ \Pi = \text{MRT} \]
\[ P_{\text{soln}} = X_{\text{solvent}} P_{\text{solvent}} \]
\[ P_{\text{TOTAL}} = P_A + P_B \]
\[ X_A = (n_A + n_B)/n_A \]
\[ P = k_{H}X \]
\[ \ln(P_{\text{vap}}) = - (\Delta H_{\text{vap}}/R)(1/T) + C \]
\[ Q_{\text{heating}} = S_{\text{sp.heat}} \text{ Mass } \Delta T \]
\[ Q_{\text{phase change}} = \Delta H (\# \text{ Mols}) \]
\[ \lambda \nu = c \]
\[ E = h\nu \]
\[ n \lambda = 2 d \sin \theta \]
\[ h = 6.626 \times 10^{-34} \text{ J s} \]
\[ c = 3.0 \times 10^8 \text{ m/s} \]
\[ R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1} \]
\[ 1.0 \text{ atm} = 760 \text{ Torr} \]
1. Which of the following sets of quantum numbers describes a 3d electron:

<table>
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<tr>
<th></th>
<th>n</th>
<th>l</th>
<th>m_l</th>
<th>m_s</th>
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<td>0</td>
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<tr>
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<td>0</td>
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<tr>
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<td>(E)</td>
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<td>1</td>
<td>0</td>
<td>-½</td>
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</table>

2. Which of the following atoms is the most electronegative:

(A) K  
(B) F  
(C) Mg  
(D) C  
(E) Cs

3. Which of the following statements is correct:

(A) A double bond is composed of two σ bonds  
(B) A triple bond is composed of three π bonds  
(C) Multiple bonds are stronger than single bonds  
(D) Single bonds are stronger than multiple bonds  
(E) Single bonds are shorter than multiple bonds

4. Given this graph, what is the boiling point of carbon tetrachloride?

(A) 0 °C  
(B) 20 °C  
(C) 77 °C  
(D) 95 °C  
(E) 100 °C
5. Which of the following molecules has the shortest carbon-oxygen bond length:

(A) CH₃OH  
(B) CO  
(C) CO₂  
(D) CO₃²⁻  
(E) They are all equal

6-7. Predict the molecular structure and the angle closest to the bond angles for SF₆

<table>
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<th>7: bond angle</th>
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<tbody>
<tr>
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<td>(A) 90°</td>
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<td>(B) square planar</td>
<td>(B) 107°</td>
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<td>(C) tetrahedral</td>
<td>(C) 45°C</td>
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<tr>
<td>(D) trigonal planar</td>
<td>(D) 120°</td>
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<tr>
<td>(E) octahedral</td>
<td>(E) 180°</td>
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</table>

8. In which of the following processes will energy by released (in the form of heat)?

(A) sublimation  
(B) melting  
(C) vaporization  
(D) condensation  
(E) none of these

For questions 9-14 consider phenylalanine, pictured here:

9. What type of molecule is this?

(A) amino acid  
(B) ester  
(C) coordination complex  
(D) salt  
(E) diatomic
10. In this diagram all carbon atoms and most hydrogen atoms are omitted. What is the molecular formula of this molecule?

(A) H₃NO₂  
(B) C₆H₃NO₂  
(C) C₆H₆NO₂  
(D) C₉H₁₁NO₂  
(E) C₉H₁₁NO₁₁

11. What is the hybridization of the carbon atom labeled α?

(A) sp³  
(B) it is not hybridized  
(C) sp  
(D) d²sp³  
(E) sp²

12. What is the hybridization of the carbon atoms that form the six membered ring?

(A) sp³  
(B) it is not hybridized  
(C) sp  
(D) pd  
(E) sp²

13. How many electrons are involved in π bonding?

(A) 0  
(B) 2  
(C) 4  
(D) 6  
(E) 8

14. What is the approximate C-O-H angle between the 2 bonds of the oxygen atom indicated in the figure?

(A) 180°  
(B) 90°  
(C) 120°  
(D) 0°  
(E) 109°
Question 15 -17 refer to the following complex: \([\text{Co(NH}_3\text{)}_6]\text{Cl}_3

15. What is the geometry?

(A) linear  
(B) trigonal planar  
(C) tetrahedral  
(D) trigonal bipyramidal  
(E) octahedral

16. What is the name?

(A) hexaaminocobalt(VI)chloride  
(B) teraminocobalt(III)chloride  
(C) hexaaminocobalt(III)chloride  
(D) tetrachlorocobalt(III)amine  
(E) hexaaminocobalt(II)chloride

17. How many \(d\) electrons does it have?

(A) 3  
(B) 4  
(C) 5  
(D) 6  
(E) 7

18. Which of the following is paramagnetic:

(A) \(\text{C}_2\)  
(B) \(\text{N}_2\)  
(C) \(\text{F}_2\)  
(D) \(\text{O}_2\)  
(E) \(\text{H}_2\)

19. \(\text{CO}_2\) is a greenhouse gas because it absorbs heat radiation from the earth. It has the following Lewis structure ::O=C=O:: Which is a true statement:

(A) \(\text{CO}_2\) has a measurable permanent dipole  
(B) \(\text{CO}_2\) has no measurable permanent dipole but it can have a dynamic dipole (from a bending vibration)  
(C) \(\text{CO}_2\) never has any dipole (and so it never absorbs IR radiation)  
(D) all of the above  
(E) none of the above
20. A 10 g sample of a large biomolecule was dissolved in 100 g of carbon tetrachloride (boiling-point constant 5 °C·kg/mol). The boiling point of this solution was determined to increase by 1 °C. What is the molar mass of the biomolecule?

(A) 10 g/mol  
(B) 100 g/mol  
(C) 200 g/mol  
(D) 500 g/mol  
(E) 1000 g/mol

21. Which has the most polar bond?

(A) H-Cl  
(B) O-O  
(C) H-I  
(D) H-H  
(E) All the same

22. Suppose in each atomic orbital there could be not 2 but 3 electrons. Which would be the first rare gas instead of He?

(A) H  
(B) He  
(C) Li  
(D) Be  
(E) Ne

23. A solution contains 46 g of ethanol (C₂H₅OH), 32 g of methanol (CH₃OH) and 54 g of water. What is the mole fraction of the water?

(A) 0.32  
(B) 0.46  
(C) 0.6  
(D) 1  
(E) 2

24. Which of the following has the highest boiling point?

(A) H₃C-O-CH₃ (dimethyl ether)  
(B) C₄H₁₀ (butane)  
(C) CO₂  
(D) CH₄ (methane)  
(E) HO-CH₃ (methanol)
25. How many geometrical and linkage isomers of Co(NH₃)₄(NO₂)₂ appear in the figure below?

(A) 1  
(B) 2  
(C) 3  
(D) 4  
(E) 5

26. A salt AₓBᵧ, when dissolved in water dissociates completely as follows: AₓBᵧ → xA + yB. Dissolving 1 mol of a AₓBᵧ, in 1 liter of water (Kf = 1.86 °C kg/mol) lowers the freezing point to - 5.58 °C. Which of the following can represent its empirical formula?

(A) AB  
(B) A₂B  
(C) A₃B  
(D) A₂B₃  
(E) A₂B₂

27. When a vapor condenses which of the following is a true statement?

(A) The gibbs free energy, ΔG increases  
(B) The entropy, ΔS, decreases  
(C) The entropy, ΔS increases  
(D) The enthalpy, ΔH increases  
(E) None of the above
28. How many resonant structures are there for CO$_3^{2-}$

(A) 0
(B) 1
(C) 2
(D) 3
(E) 4

29. The unit cell in a certain lattice of atoms X and Y consists of a cube formed by an X at each corner of the cube, a Y at the center of the cube and a Y at the center of each face. The empirical formula of the compound is:

(A) XY$_4$.
(B) X$_5$Y$_6$.
(C) X$_5$Y$_3$.
(D) XY.
(E) X$_2$Y$_2$.

30-31. What are the bond angles for the following molecules:

<table>
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<th>30. $\text{SeO}_2$</th>
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<tr>
<td>(E)</td>
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<td>$360^\circ$</td>
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</table>

32. Which of the following is paramagnetic?

(A) $[\text{CoF}_6]^{3-}$ (strong field)
(B) $[\text{Co(NH}_3)_6]^{3+}$ (strong field)
(C) $[\text{Zn(H}_2\text{O}_6]^{2+}$
(D) $[\text{Co(F)}_6]^{3+}$ (weak field)
(E) none of these

33. The color of a transition metal complex results from

(A) bending vibrations.
(B) stretching vibrations.
(C) transition of an electron between d orbitals.
(D) transition of an electron between an s and a p orbital.
(E) nuclear magnetic resonance.
34. Consider the following amino acids:

<table>
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<td>H</td>
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<tr>
<td>alanine</td>
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<td>CH₃</td>
</tr>
<tr>
<td>cysteine</td>
<td>Cys</td>
<td>CH₂SH</td>
</tr>
</tbody>
</table>

Which of these amino acids are optically active (have stereoisomers)?

(A) Gly and Ala  
(B) Ala and Cys  
(C) Gly and Cys  
(D) All three of these amino acids  
(E) none of these amino acids  

35. How much energy does it take to boil 18 grams of water, starting at 25 °C  
(Specific heat capacity $S_{\text{water}} = 4.46$ J/g °C and $\Delta H_{\text{vap}} = 40.7$ kJ/mol)?

(A) 44.9 J  
(B) 46730 J  
(C) 10⁹ J  
(D) 18 x 10⁶ J  
(E) 46.73 J  

36. Which are arranged in order of increasing intermolecular forces?

(A) CsBr < CO < CH₃OH < I₂ < Cl₂  
(B) CO < Cl₂ < I₂ < CH₃OH < CsBr  
(C) I₂ < Cl₂ < CO < CH₃OH < CsBr  
(D) Cl₂ < I₂ < CO < CsBr < CH₃OH  
(E) Cl₂ < I₂ < CO < CH₃OH < CsBr  

37. Which of the following have bond order 0.5:

(A) $\text{H}_2^-$, $\text{H}_2$, and $\text{H}_2^+$  
(B) $\text{H}_2^-$, $\text{H}_2^+$, and $\text{He}_2^+$  
(C) $\text{H}_2$ and $\text{He}_2$  
(D) $\text{B}_2$ and $\text{Li}_2$  
(E) $\text{O}_2$
38. A 0.1 molar solution of NaCl at 244 °K has an osmotic pressure of:

(A) 0.5 atm  
(B) 1 atm  
(C) 760 atm  
(D) 4 atm  
(E) 7 atm

39. How many isomers of C₅H₁₂ are there?

(A) 1  
(B) 2  
(C) 3  
(D) 4  
(E) 5

40. For propene in which one hydrogen is replaced by a chlorine atom (C₃H₅Cl), how many possible isomers are there?

(A) 1  
(B) 2  
(C) 3  
(D) 4  
(E) 5

41. Smaller intermolecular forces in a liquid lead to

(A) Higher vapor pressure  
(B) smaller viscosity  
(C) lower boiling point  
(D) (b) and (c)  
(E) all of the above

42. The configuration \((\sigma_{2s})^2(\sigma_{2s}^*)^2(\sigma_{2p})^2(\pi_{2p})^4(\pi_{2p}^*)^4\) is the molecular orbital description for the valence shell ground state of

(A) Li²⁺  
(B) N₂⁻  
(C) O₂  
(D) O₂⁻  
(E) C₂
43. In a diffraction experiment with 1 nm X-rays the first order (n=1) diffraction angle is 30°. What is the distance between the atoms that produce the diffraction?

(A) 0.1 nm  
(B) 0.5 nm  
(C) 1 nm  
(D) 5 nm  
(E) 10 nm

44. Which of the following could be the boiling point of water on Mount Everest?

(A) 0 °C  
(B) 90 °C  
(C) 100 °C  
(D) 105 °C  
(E) 200 °C

45. In ethene, C₂H₄ the valence orbitals of the carbon atoms are hybridized as follows:

(A) not hybridized  
(B) sp  
(C) sp²  
(D) sp³  
(E) dsp

46. The sequence of amino acids in a polypeptide chain determines which type of protein structure?

(A) primary structure  
(B) secondary structure  
(C) tertiary structure  
(D) quaternary structure  
(E) globular structure

47. Which of the compounds below is an example of an ionic solid?

(A) diamond  
(B) SiO₂  
(C) graphite  
(D) CaCO₃  
(E) C₂₅H₅₂
48. At a given temperature, the vapor pressure of heptane is 100 torr and the vapor pressure of octane is 40 torr. Assuming ideal behavior, what is the vapor pressure of a solution that contains three times as many moles of heptane as octane?

(A) 140 torr  
(B) 100 torr  
(C) 85 torr  
(D) 75 torr  
(E) 45 torr

49. Consider the following codons: CUA codes for Leu, AGC codes for Ser, and AAG codes for Phe. What tripeptide is coded for by the following DNA sequence: TTCGATTCG?

(A) Phe-Leu-Ser  
(B) Leu-Phe-Ser  
(C) Leu-Ser-Phe  
(D) Ser-Phe-Leu  
(E) Phe-Ser-Leu

50. A perfume bottle lists the following ingredients: methylphenylpropanal, propanol, methyl-butanone, water. The perfume contains molecules of the following types:

(A) alcohol  
(B) aldehyde  
(C) ketone  
(D) all of the above  
(E) none of the above

**BONUS:** Oxygen is transported between the heart and lungs of mammals which type of molecule?

(A) hemoglobin  
(B) myoglobin  
(C) chlorophyll  
(D) cytochrome  
(E) prophyrin

*Don’t forget: perm number – name - version*

*Have a great summer!*
The Periodic Table of the Elements

<table>
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