INSTRUCTIONS ---

This examination has two parts. The first part is in multiple choice format; the questions are in this Exam Booklet and the answers should be placed on the "Test Scoring Answer Sheet" which must be turned in and will be machine graded.

The second part requires your responding to questions in the Exam Booklet by writing answers into the spaces provided. The Exam Booklet must be handed in and will be returned to you with a grade.

On the Test Scoring Answer Sheet, using a soft pencil, enter the following data (in the appropriate places): your name, instructor's name, your student (Social Security) number, course number (30022101) and the test number (01); darken the appropriate bubbles under the entries, making dark black marks which fill the bubbles.

You may use a set of molecular models and the tables provided, but no other aids, during the exam.

Answer all questions. The questions on Part I are worth 2.5 points each.

You have 90 minutes. Good luck!
1. Today, organic chemistry is the study of

(a) the element carbon.  (b) the compounds of carbon.  (c) compounds that are found in nature.  (d) compounds that contain carbon and are found in nature.

2. At one time it was believed that living systems contained a "vital force" which enabled them to synthesize complex carbon containing compounds from "inorganic" sources of carbon. An experiment performed in 1828 ended the vital force theory. This experiment was performed by ________ and involved ________.

(a) Baron Jons Jakob Berzelius ... chanting while heating carbon dioxide under pressure.
(b) Friedrich Wöhler ... synthesizing urea from ammonium cyanate.
(c) Genghis Khan ... burning yak dung for heat and then analyzing the ashes.
(d) Friedrich Flintstone ... setting up a microbrewery in his backyard in which he used yeast to convert complex carbohydrates into a passable beer containing ethyl alcohol.
(e) Bogus question! The vital force theory has lost none of its force and is as vital as ever. Long live the vital force!

3. The ability of carbon to form a virtually limitless number of compounds — a property not shared with other elements, with the possible exception of silicon — is most closely related to which of the following properties of carbon.

(a) Its four valence electrons. (b) Its electronegativity of ~ 2.5 Pauling units. (c) Its ability to form sp³ hybrid orbitals. (d) Its ability to form bonds to itself and certain other elements without limit, resulting in large covalent structures.

**Now for some real questions.**

4. The smallest (fewest carbons) alkanes which are constitutional isomers of each other have ___ carbon atoms.

(a) 2,  (b) 3,  (c) 4,  (d) 5,  (e) 6

5. It has been calculated that there are 366,319 possible constitutional isomers of eicosane, C₂₀H₄₂. However, leaving out considerations of time, it would be impossible to synthesize all of the structures which could be drawn. The reason for this impossibility is

(a) torsional strain. (b) carbon-carbon σ-bond instability. (c) steric hinderance.
(d) angle strain. (e) there is not enough carbon in the universe to make even a small sample of each of the isomers. (f) Bogus question! There is no fundamental reason why a group of demented individuals could not spend their lifetimes attempting and accomplishing this feat.

6. Which of the following pairs of elements would \textit{covalently} bond with each other?


Answers: (a) I-V, (b) I-IV, (c) I-III, (d) I-II, (e) I, (f) None of the previous answers is correct.

7. Atoms are held together by covalent bonds because

(a) one atom develops a positive charge and the other a negative charge, and the opposite charges attract each other.
(b) the electrons in the bonds are negatively charged and are located between the positively charged nuclei; both nuclei are attracted to the electrons between them.
(c) in forming the bond one of the electrons flipped its spin and became a positron (an electron with a + charge); this positron is attracted to the negatively charged electron which came from the other atom with its spin unflipped. Since one atom "owns" the positron and the other "owns" the electron they are bonded together by the attraction between the positron and electron.
(d) these bonds are based on Velcro®.
(e) None of the above answers bears even a remote resemblance to the truth.

8. Which formula would you use to calculate the formal charge associated with an atom in a Lewis structure?

(a) Formal charge = core charge - electron ownership.
(b) Formal charge = core charge + electron ownership.
(c) Formal charge = core charge x electron ownership.
(d) Formal charge = core charge/electron ownership.
(e) Formal charge = valence shell occupancy - electron ownership.
(f) Formal charge = valence shell occupancy + electron ownership.
(g) Formal charge = valence shell occupancy x electron ownership.
(h) Formal charge = valence shell occupancy/electron ownership.
9. Since a given skeleton structure does not always lead to a unique Lewis structure, the simple Lewis model has been modified to include the concept of

(a) constitutional isomerism. (b) stereoisomerism. (c) resonance. (d) valence isomerism. (e) equilibrium.

10. In those instances where it is used in drawing Lewis structures, the concept of resonance is employed to accurately represent

(a) the 3-dimensional structure of the molecule which is being represented.
(b) the atomic connectivity (ie which atoms are joined together) in the molecule which is being represented.
(c) the electronic structure of the molecule which is being represented.
(d) the molecular vibrations of the molecule which is being represented.
(e) None of the above answers is correct.

11. To determine the relative contributions of resonance structures to the hybrid (which we intend to accurately represent the molecule) we can use the three rules below. Rank these rules in order of decreasing importance (most important first).

I: Structures with fewer bonds or those with atoms having a valence shell occupancy of fewer than 8 electrons contribute less than those with a greater number of bonds or a valence shell occupancy of 8 (or more).

II: The greater the charge separation, the less important the structure.

III: Where formal charges are involved, structures in which + charge resides on electropositive elements, and negative charge on electronegative elements, are favored over those where the opposite obtains.

(a) I>II>III, (b) III>II>I, (c) II>I>III, (d) II>III>I, (e) I>III>II, (f) III>I>II

12. Which of the three resonance structures
shown is the most important (ie makes the largest contribution)?
[The carbons are numbered for purposes of identification in question #13.]

(a) I, (b) II, (c) III,
(d) None of the previous answers is correct; they all contribute equally.

13. Consider the resonance structures shown in question #12. Should another structure be
drawn to complete the hybrid? If so, would one of the carbons have a -1 formal charge?
(a) The resonance picture is complete; no additional structure should be drawn.
(b) The resonance picture is incomplete; another structure should be drawn but no
carbon would have a -1 formal charge.
(c) The resonance picture is incomplete; another structure should be drawn in which
carbon-1 has a -1 formal charge.
(d) The resonance picture is incomplete; another structure should be drawn in which
carbon-3 has a -1 formal charge.
(e) The resonance picture is incomplete; another structure should be drawn in which
carbon-5 has a -1 formal charge.
(f) The resonance picture is incomplete; another structure should be drawn in which
carbon-6 has a -1 formal charge.

14. Acrylonitrile is used to make acrylic
polymers eg Lucite® and acrylic yarn for
sweaters, etc. Select the answer from
the table in the figure which correctly
identifies the geometry of the three
carbons and nitrogen in acrylonitrile.

(f) None of the answers (a) - (e) is
correct.

15. Consider the methyl acetylene molecule. Which of the following
statements is a correct assessment of the bonding of carbon #2
to the other two carbons?

(f) None of the answers (a) - (e) is
correct.
(a) C-2 forms three \( \sigma \)-bonds to C-1, using three of its sp\(^3\) hybrid atomic orbitals, and one \( \sigma \)-bond to C-3, using the remaining sp\(^3\) hybrid atomic orbital.

(b) C-2 forms two \( \sigma \)-bonds to C-1, using two of its sp\(^2\) hybrid atomic orbitals, and one \( \pi \)-bond to C-1, using its p atomic orbital, and one \( \sigma \)-bond to C-3, using the remaining sp\(^2\) hybrid atomic orbital.

(c) C-2 forms two \( \pi \)-bonds to C-1, using two of its sp\(^2\) hybrid atomic orbitals, and one \( \sigma \)-bond to C-1, using its p atomic orbital, and one \( \sigma \)-bond to C-3, using the remaining sp\(^2\) hybrid atomic orbital.

(d) C-2 forms two \( \pi \)-bonds to C-1, using two of its p atomic orbitals, and one \( \sigma \)-bond to C-1, using one of its sp hybrid atomic orbitals, and one \( \sigma \)-bond to C-3, using the remaining sp hybrid atomic orbital.

(e) C-2 forms two \( \pi \)-bonds to C-1, using both of its sp hybrid atomic orbitals, and one \( \sigma \)-bond to C-1, using one of its p atomic orbitals, and one \( \sigma \)-bond to C-3, using the remaining p atomic orbital.

16. Consider the acid-base equilibrium shown to the right. Select the answer below which correctly labels the participants as stronger acid (SA), stronger base (SB), weaker acid (WA), and weaker base (WB).

(a) I: SA, II: SB, III: WB, IV: WA,  
(b) I: SA, II: SB, III: WA, IV: WB,  
(c) I: SB, II: SA, III: WB, IV: WA,  
(d) I: WA, II: WB, III: SB, IV: SA,  
(e) I: WB, II: WA, III: SA, IV: SB.

17. Rank the following species in order of decreasing acidity (most acidic first) (pK\(_\text{a}\)s are shown in parenthesis).
I: HBr (−8), II: H₃O⁺ (−1.74), III: HF (3.17), IV: HCN (9.22), V: NH₃ (33).
(a) I>II>III>IV>V, (b) V>IV>III>II>I, (c) II>IV>I>III>V, (d) II>III>I>IV>V,
(e) None of the above answers is correct.

18. Rank the following species in order of decreasing basicity (most basic first).

(a) I>II>III>IV>V, (b) V>IV>III>II>I, (c) II>IV>I>III>V, (d) II>III>I>IV>V,
(e) None of the above answers is correct.

19. When basis orbitals (the electron orbitals one starts with) mix or interact to form new orbitals,

(a) the new orbitals must all be of the same energy.
(b) each of the new orbitals has the same energy as one of the basis orbitals.
(c) there will be the same number of new orbitals as there were basis orbitals.
(d) the new orbitals can hold more than two electrons each.
(e) the new orbitals will all be p orbitals.

20. Which of the following orbital types would have approximately this shape?

(1) s, (II) p, (III) π, (IV) sp, (V) sp², (VI) sp³

(a) I, (b) II, (c) III, (d) IV, (e) II & III, (f) IV-VI

DIRECTIONS: Questions 21 - 23 are of the type where a statement is followed by an explanation: <Statement> because <Reason>. For each of these questions select the correct response from those immediately following:

(a) Both the statement and reason are correct and the reason justifies or explains the statement.
(b) Both the statement and reason are correct but the reason does not justify or explain the statement.
(c) The statement is false but the reason is true (although it does not apply to the statement).
(d) The statement is true but the reason is false.
(e) Both the statement and reason are false.
21. Methane is tetrahedral because the electrons in the C-H bonds have negative charges, and thus the bonds repel each other resulting in a structure in which they are as far away from each other as is possible for four bonds radiating from one atom.

22. Carbon forms an ionic bond with chlorine because atoms that have electronegativities greater than 1.7 form ionic bonds with each other.

23. Carbon does not usually form stable compounds with more than four bonds because carbon cannot accommodate more than 8 electrons in its valence shell.

24. When two hybrid atomic orbitals on different atoms approach each other head-on and join to form molecular orbitals, the electrons associated with the atomic orbitals usually wind up in ___ molecular orbitals.

(a) σ, (b) σ*, (c) π, (d) π*, (e) χ, (f) χ*

25. When two p atomic orbitals on adjacent atoms join each other sideways in parallel fashion to form molecular orbitals, the electrons associated with the p orbitals usually wind up in ___ molecular orbitals.

(a) σ, (b) σ*, (c) π, (d) π*, (e) χ, (f) χ*

26. How many structural (constitutional) isomers are possible for C₃H₆Cl₂? [Hint: Draw all the possibilities, then count them.]

(a) 2, (b) 3, (c) 4, (d) 5, (e) 6

27. Rank the following compounds in terms of decreasing acidity (most acidic first). [The most acidic proton(s) in each compound is(are) shown in bold face italic.]

(I) CH₃OH, (II) CH₃NH₂, (III) CH₃SH, (IV) CH₃Cl

(a) II > I > III > IV, (b) IV > III > I > II, (c) IV > I > III > II, (d) IV > II > I > III, (e) IV > III > I > II, (f) III > I > II > IV, (g) None of the above is correct.
28. If one mixes acetic acid (pK_a = 4.7), CH_3COOH, with water (pK_a = 15.7) in hopes of forming acetate ion, CH_3COO^-, and hydronium ion (pK_a = 1.74), H_3O^+, what will be the outcome?

(a) No reaction will take place.  
(b) Reaction will occur, but only a small amount of product will be formed.  
(c) Reaction will occur, and most of the reactants will be converted to product.  
(d) The reaction will go to completion.  
(e) No prediction can be made from the information given.

29. (CH_3)_2CH- is known as the _____ group.

(a) propyl, (b) isopropyl, (c) neopropyl, (d) butyl, (e) isobutyl

30. Which figure correctly indicates the direction of the dipole moment for dichloromethane?

![Dipole Moment Figures]

(a) (b) (c) (d)

31. Which of the following compounds is a Lewis acid but is not a Brønsted-Lowry acid?

(a) CH_3-OH, (b) AlCl_3, (c) H_2O, (d) CH_3-CH_2-N^+H_3

32. Which of the following compounds have a carbonyl group?

(a) H_2C=CH_2, (b) CH_3-OH, (c) CH_3-O-CH_3, (d) (CH_3)_2C=O, (e) CH_3-C≡N
33. Select the answer which correctly identifies the class (primary, secondary, tertiary, quarternary) of each of the indicated carbon atoms, A through D.

![Diagram of molecules with carbon atoms labeled A, B, C, D.]

<table>
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<tr>
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<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tr>
<td>(a)</td>
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<td>30</td>
<td>40</td>
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<td>(b)</td>
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34. Select the IUPAC name for the compound in question #33.

(a) 2,2,5-trimethylheptane, (b) 4-ethyl-1,1,4-tetramethylbutane, (c) 1-ethyl-1,4,4-tetramethylbutane, (d) 1,1,4-tetramethylhexane, (e) None of the above answers is correct.

35. Gasoline is a mixture of compounds. But if you were to substitute a single compound for gasoline as a fuel for your car, which of the following would be the best choice?

(a) \( \text{CH}_3(\text{CH}_2)_5\text{CH}_3 \)  
(b) \( \text{CH}_3\text{CCH}_2\text{CHCH}_3 \)  
(c) \( \text{CH}_3\text{CH}_4\text{CH}_3 \)  
(d) \( \text{CH}_3(\text{CH}_2)_5\text{CH}(\text{CH}_2)_4\text{CH}_3(\text{CH}_2)_3\text{CH}_3 \)
Name________________________

Directions for Part II --- Answer the questions in the space provided. If there is insufficient space continue your answer on the back of the sheet but clearly indicate on the front of the sheet that you have done this.

1. Use the $\delta^+/\delta^-$ convention to indicate the direction of expected polarity for each of the bonds indicated.

   $\text{H}_3\text{C}-\text{Br} \quad \text{H}_3\text{C}-\text{NH}_2 \quad \text{H}_3\text{C}-\text{MgBr} \quad \text{H}_3\text{C}-\text{OH}$

2. (a) Convert the following structures into skeletal drawings.

   ![Structure 1](image1.png) ![Structure 2](image2.png)

   (b) Convert these skeletal drawings into Lewis structures that show all carbons, hydrogens, bonds and unshared electrons.

   ![Lewis Structure 1](image3.png) ![Lewis Structure 2](image4.png)

3. Draw structures for these compounds.
   (a) 4-isopropyl-3-methylheptane,

   (b) trans-1,3-dibromocyclopentane

Part I (88) ________
Part II---
1. (4) ________
2. (8) ________
3. (4) ________
Total (104)________