Recitation Worksheet Twelve

Name: | UGA ID:

Textbook:
Chemistry & Chemical Reactivity
by John C. Kotz, Paul M. Treichel, John R. Townsend, David Treichel
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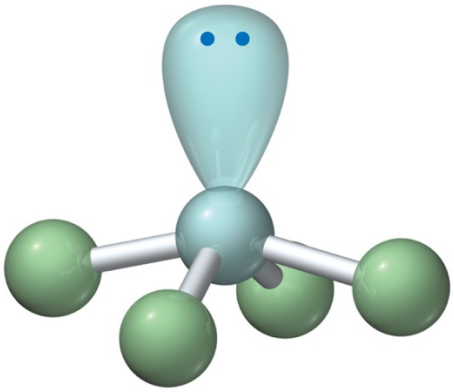
Instructions:

- This recitation worksheet covers Ch. 8.8-8.10, 9.1.
- Please enter your first and last name as it appears on the eLC roster (do not use a nickname that is not reflected in eLC).
- Your UGA myID is a combination of letters and numbers (example: Dr. Seivert's MyID is mds73312). **Do not use your 81x number**.
- Your completed worksheet has to be submitted to **Gradescope**. You have multiple options for submission:
  - You may use an app to annotate the worksheet by placing your answers in the answer boxes and showing your work when appropriate. Afterward, submit the worksheet to Gradescope. You will not need to upload anything to eLC.
  - You may print out the worksheet, write your answers in the answer boxes, and show your work on it when appropriate. Afterward, convert the worksheet to a PDF and submit to Gradescope. You will not need to upload anything to eLC.
  - If you do not have access to a printer, you may type your answers directly into the worksheet PDF and then submit it to Gradescope. Write your work on separate sheets of paper, convert them to a PDF, and upload to the appropriate dropbox on eLC.
  - There is a Gradescope app available for both iOS and Android devices that allows you to scan and submit your printed work, or you can submit your fillable PDF directly.
- The following criteria **must** be met to be eligible for full credit:
  - You must make sure the pages are in the correct order and have the same layout as the original worksheet when submitting to Gradescope regardless of your submission type.
  - Answers must be written in the corresponding answer boxes.
  - You must show your work when appropriate.
- This worksheet is due no later than **9:00 AM on the Saturday of the recitation week.**
- A periodic table and formula sheet are attached to the end of this worksheet. Please keep these attached to your worksheet in the correct order when submitting to Gradescope.

1. Consider a hypothetical molecule, MX_4, which has a square planar molecular geometry. How many lone pairs are on the central atom “M” of this molecule? The terminal atoms “X” have three lone pairs each. Answer by using an integer (e.g. 0, 1, etc.).

2. Which of the following statements below are **true** regarding the molecule below which is illustrated **incorrectly**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

Hint: the molecular geometry shown below is not a standard geometry you have learned.



A. The correct molecular geometry should be square planar
B. The correct electron geometry should be square planar
C. The correct molecular geometry should be seesaw
D. The correct electron geometry should be seesaw
E. The lone pair should be in the axial position
F. The lone pair should be in the equatorial position
G. The lone pair may be in the axial or equatorial position because electron pair repulsions are minimized in either case

Use the following options below to answer **ALL** parts of questions 3 and 4. Please also be sure to **include this page in your Gradescope submission**.

Electron/molecular geometries

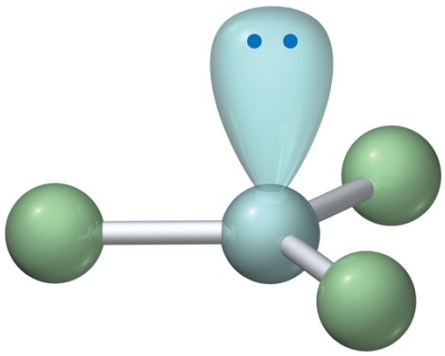
A. Linear
B. Trigonal planar
C. Tetrahedral
D. Trigonal bipyramidal
E. Octahedral
F. Bent
G. Seesaw
H. T-shaped
I. Square pyramidal
J. Square planar
K. Trigonal pyramidal

Bond angles

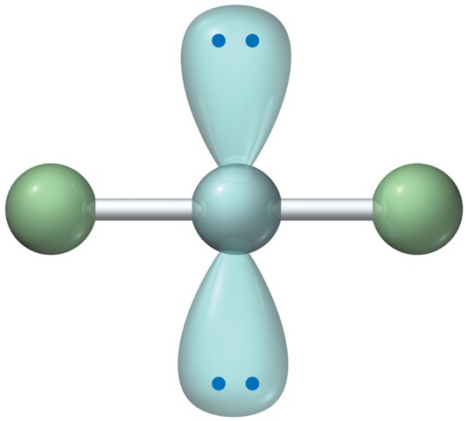
A. 90°
B. <109.5°
C. 109.5°
D. <120°
E. 120°
F. 180°

3. Consider the molecules below all of which are illustrated **incorrectly**. Determine the correct molecular geometry for each and provide the **<u>corresponding letters</u>** in the boxes below using the options on page 3.

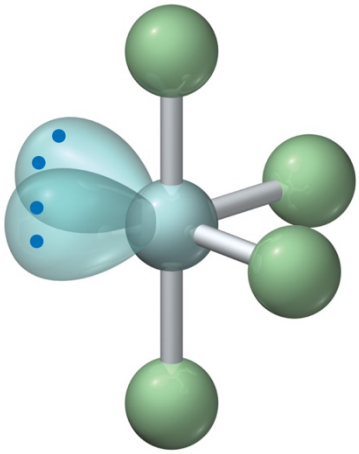
I. ☐



II. ☐



III. ☐



4. Determine the electron and molecular geometries of the molecules or ions below, then determine the bond angle(s). Write the **corresponding letters** in the boxes below using the options on page 3.

	Molecule or Ion	Electron Geometry?	Molecular Geometry?	Bond Angle(s)?
I	Sulfur difluoride			
II	BF_2^-			
III	ICl_3			
IV	BrF_5			
V	TeF_4			

5. In the alternate universe of Flatland, everything is in two dimensions. What is the bond angle in a molecule that has five bonding groups and zero lone pairs? Report your answer in **standard notation** and **two significant figures**.

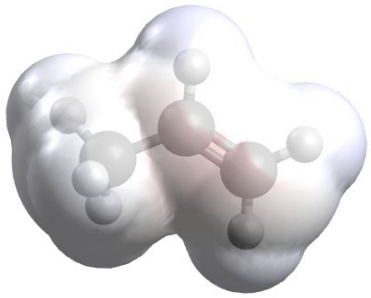
[ ] degrees

6. Which statement(s) is/are **true** about molecular polarity?

[ ]

A. Molecules are always nonpolar if all of the terminal atoms are identical
B. T-shaped molecules are always polar
C. Linear molecules are always nonpolar
D. More than one of the above are true
E. None of the above are true

7. The following electrostatic potential map has very little to no color difference. It shows a _____ molecule.



[ ]

A. Polar
B. Nonpolar
C. Ionic
D. Stoichiometric

8. Label the following molecules as (P) polar or (NP) nonpolar. Write the **corresponding letters** in the boxes below.

I. CH_3COOH ☐

II. SF_4 ☐

III. SCl_6 ☐

IV. SCl_5Br ☐

V. AsH_3 ☐

9. Which of the following molecules is predicted to have a net dipole moment? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. CF_4
B. SO_3
C. NH_3
D. H_2O
E. CO_2

10. Based on electronegativity trends in the periodic table, predict which of these compounds will have the greatest % ionic character in its bonds.

A. H_2O
B. CaO
C. RbF
D. HCl

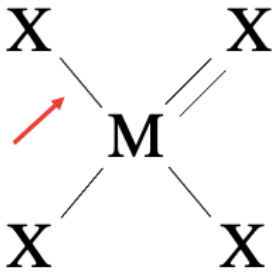
11. Arrange the bonds in order of *decreasing* bond length.

A. C=N > C–N > C–P
B. C–N > C–P > C=N
C. C–P > C–N > C=N
D. C=N > C–P > C–N

12. Which of the following would be the *strongest* bond based on the relationship between bond length and strength?

A. C-C
B. C=C
C. C-N
D. C=N
E. C-O
F. C=O

13. One of the equivalent, best resonance structures of a hypothetical molecule, MX_4, is provided below. What is the bond order for the M-X bond pointed out by the red arrow in this molecule?



A. 1
B. 1.25
C. 1.5
D. 2
E. The bond order rapidly switches from being either 1 or 2
F. There is not enough information to determine this

14. Which of the following statements is **true**?

A. Energy is required to break bonds
B. Energy is released from breaking bonds
C. Energy is not exchanged from breaking bonds
D. Whether energy is required for or released by breaking bonds depends on the exact bond broken

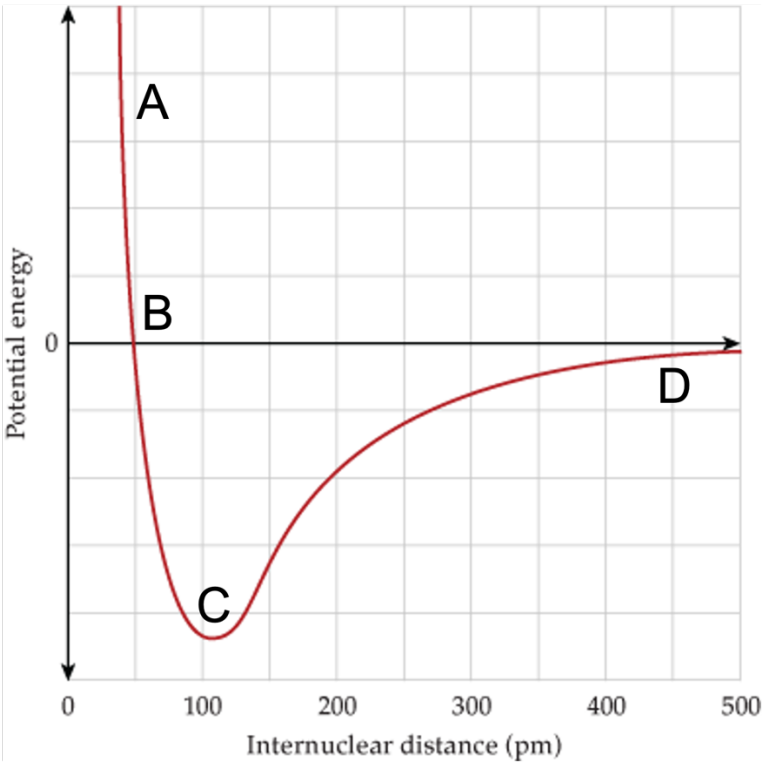
15. Using the table of average bond energies below, the ΔH for the reaction is _____ kJ/mol. Report your answer in **standard notation** and **two significant figures**.

kJ/mol

$$C_2H_4 + HCN \rightarrow CH_3CH_2CN$$

Bonds	C-C	C=C	C≡C	C-H	C=N	C≡N
Energies (kJ/mol)	348	614	839	413	615	891

Answer questions 16-18 using the potential energy diagram for the methane molecule (CH_4) below.



16. At which point in the graph is the methane molecule most stable?

A. Around Point A because it is at the highest potential energy
B. Around Point B because it is at a zero potential energy
C. Around Point C because it is at the lowest potential energy
D. Around Point D because it is at the farthest internuclear distance

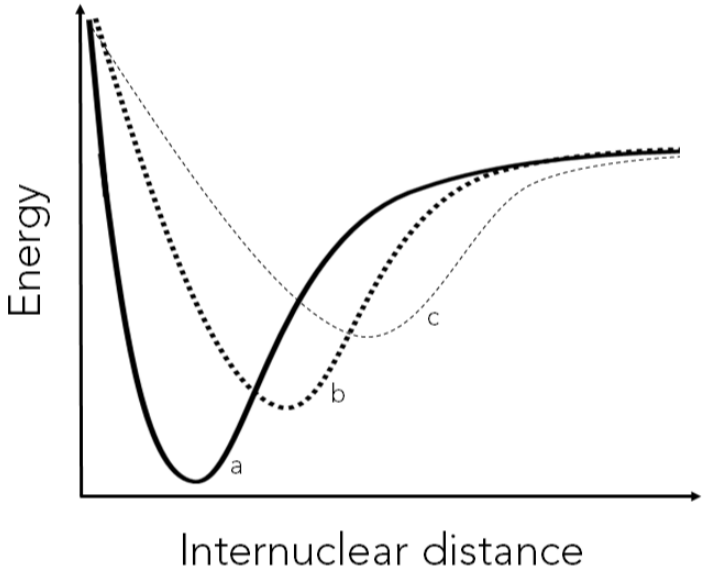
17. At which point in the graph are the proton-proton repulsions and electron-electron repulsions most prevalent?

A. Around Point A because it is at the highest potential energy
B. Around Point B because it is at a zero potential energy
C. Around Point C because it is at the lowest potential energy
D. Around Point D because it is at the farthest internuclear distance

18. At which point in the graph are the proton-proton repulsions and electron-electron repulsions most negligible?

A. Around Point A because it is at the highest potential energy
B. Around Point B because it is at a zero potential energy
C. Around Point C because it is at the lowest potential energy
D. Around Point D because it is at the farthest internuclear distance

19. Consider the following bond energy diagram below.



Which of the following are **false**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. The curve “a” represents the longest bond.
B. The curve “a” represents the strongest bond.
C. The curve “b” represents the shortest bond.
D. The curve “b” represents the weakest bond.
E. The curve “c” represents the longest bond.
F. The curve “c” represents the strongest bond.

20. What is **true** of hybridization and hybrid orbitals? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. Non-hybrid orbitals could not form the bond angles predicted in VSEPR
B. sp^2 hybrid orbitals are formed from the mixing of one s and two p orbitals
C. Hybrid orbitals retain the same shapes as the original orbitals
D. Pi bonds do not involve hybrid orbitals
E. An sp orbital is degenerate with the two remaining p orbitals

21. What is **false** about bonding according to Valence Bond Theory?

A. Bonds are formed by the overlap of atomic orbitals
B. Orbitals hybridize to achieve a favorable geometry
C. Orbitals hybridize to create degenerate orbitals they can use for bonding
D. Two different types of covalent bonds can be formed: sigma and pi
E. None of the above are false

22. What is **true** about a pi bond? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. They are formed by the head-to-head overlap of p orbitals
B. They are formed by the side-to-side overlap of p orbitals
C. They are stronger than sigma bonds
D. They do not involve hybrid orbitals
E. They are the first type of bonds to form between atoms

23. Determine whether the hybridization around the central atoms on the following molecules below are (A) sp, (B) sp^2, (C) sp^3, (D) sp^3d, or (E) sp^3d^2. Write the **corresponding letters** in the boxes below.

I. XeF_4 ☐

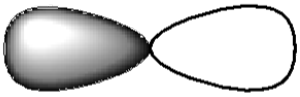
II. CO_3^{2-} ☐

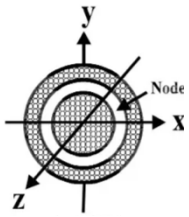
III. CO ☐

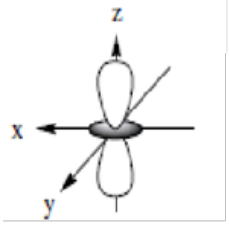
IV. NF_3 ☐

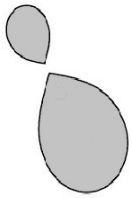
V. IF_3 ☐

24. Which of the following is a hybrid orbital?

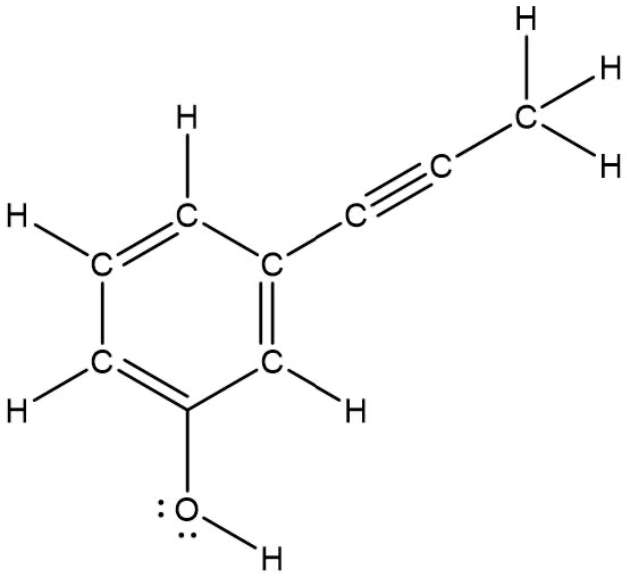
A. 

C. 

B. 

D. 

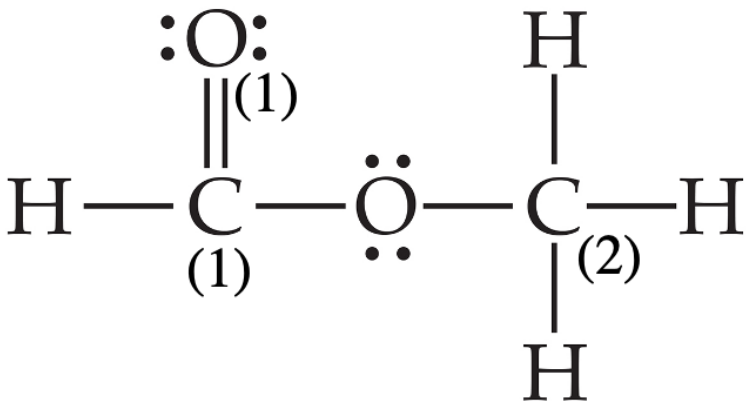
25. How many sigma and pi bonds are in the molecule below? Answer by using integers (e.g. 0, 1, etc.).



I. Sigma:

II. Pi:

Answer questions 26-30 using the Lewis structure provided below.



26. What is the bond angle around the C(1) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

27. What is the hybridization around the C(1) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

28. What is the bond angle around the C(2) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

29. What is the hybridization around the C(2) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

30. What is the hybridization around the O(1) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

31. Carbon uses _____ orbitals in the bond between carbon and sulfur in CCl_2S. Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. s
B. p
C. sp
D. sp^2
E. sp^3
F. sp^3d
G. sp^3d^2

Extra Practice Questions: these questions will not be graded.

1. Which of the following molecules would have a trigonal planar *electron* geometry? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. O_3
B. NH_3
C. BH_3
D. SCl_2
E. ClF_3
F. None of the above

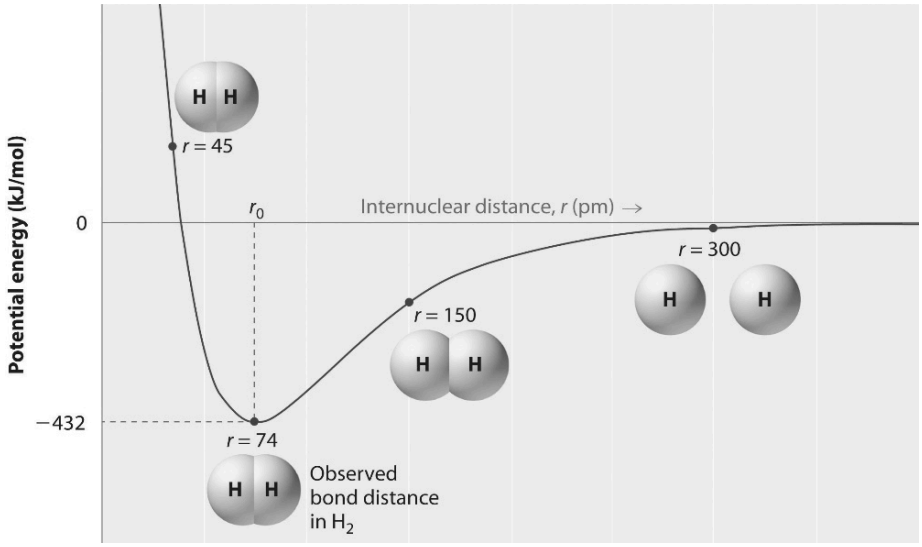
2. What is the expected bond angle in the sulfite ion, SO_3^{2-}?

A. 90°
B. <109.5°
C. 109.5°
D. <120°
E. 120°
F. 180°

3. What is **true** about the trigonal bipyramidal electron geometry and associated molecular shapes?

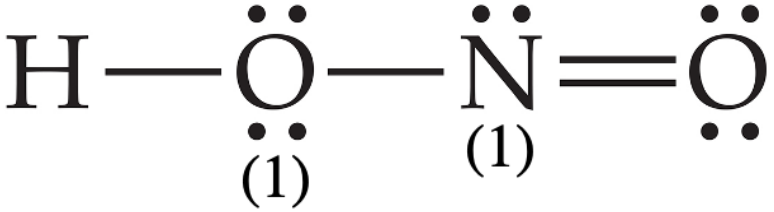
A. Lone pairs occupy the equatorial position to minimize electron repulsion
B. Lone pairs occupy the axial position to minimize electron repulsion
C. Lone pairs are equally likely to occupy either an axial or equatorial position
D. Three lone pairs will occupy both axial and one equatorial position, resulting in a bent molecular shape
E. One lone pair will result in a trigonal pyramidal molecular shape

4. Why does the energy of a bond increase when the hydrogen atoms in the bond energy diagram below are at 45 pm distance vs 74 pm? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).



A. The electron-electron repulsion has increased
B. The nuclei-nuclei repulsion has increased
C. The nuclei-electron repulsion has increased
D. The nuclei-electron attraction has increased
E. The electron-electron attraction has increased
F. The nuclei-nuclei attraction has increased

Answer questions 5-8 using the Lewis structure provided below.



5. What is the bond angle around the O(1) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

6. What is the hybridization around the O(1) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

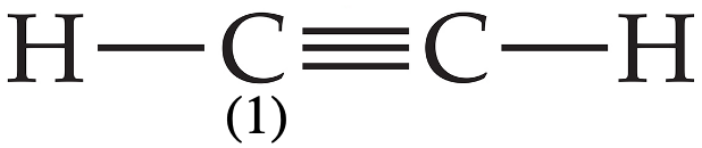
7. What is the bond angle around the N(1) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

8. What is the hybridization around the N(1) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

Answer questions 9-10 using the Lewis structure provided below.



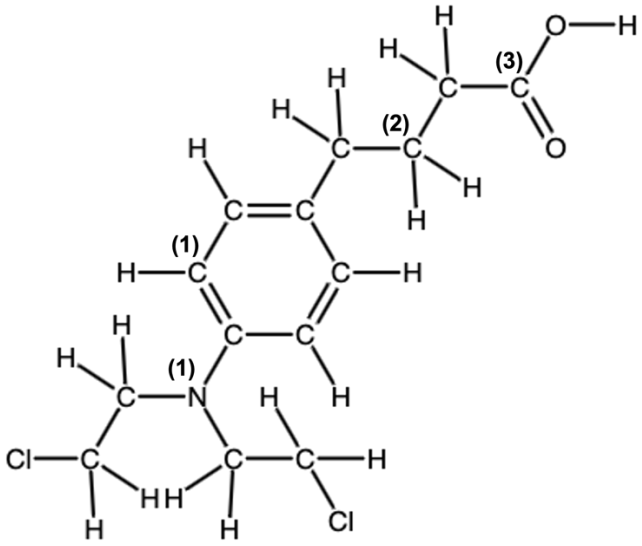
9. What is the bond angle around the C(1) atom?

☐	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

10. What is the hybridization around the C(1) atom?

☐	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

The Lewis structure of Chlorambucil, a common chemotherapy drug used for leukemia and various lymphomas, is provided below. Answer questions 11-19 using the Lewis structure provided below (note: lone pairs have been omitted).



11. What is the bond angle around the N(1) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

12. What is the bond angle around the C(1) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

13. What is the bond angle around the C(2) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

14. What is the bond angle around the C(3) atom?

	A. 90°	D. <120°
	B. <109.5°	E. 120°
	C. 109.5°	F. 180°

15. What is the hybridization around the N(1) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

16. What is the hybridization around the C(1) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

17. What is the hybridization around the C(2) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

18. What is the hybridization around the C(3) atom?

	A. sp	D. sp^3d
	B. sp^2	E. sp^3d^2
	C. sp^3	F. None of the above

19. What orbitals are involved in the bonding of the COOH group? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

	A. s
	B. p
	C. sp
	D. sp^2
	E. sp^3
	F. sp^3d
	G. sp^3d^2

20. Which of the following is **true** about the Lewis structure for KrF_2? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. The electron-pair geometry is trigonal bipyramidal
B. The molecular geometry is trigonal bipyramidal
C. There are two lone pairs in the axial position and one lone pair in the equatorial position
D. The angle between the two fluorine atoms is 180°
E. The hybridization of Kr is sp

21. A scientist collects an electrostatic potential map for a molecule in which they note a negligible difference in color throughout. Which of the following molecules below could this map belong to?

A. PH_3
B. SBr_6
C. IF_5
D. COS (carbon is central)
E. More than one of the above
F. None of the above

22. List the following bonds in order of *increasing* bond length.

A. N-O < N=O < N-P
B. N=O < N-O < N-P
C. N-P < N=O < N-O
D. N-P < N-O < N=O

23. Predict the enthalpy of reaction for the combustion of methane, given the following average bond energies:

$$CH_4\ (g) + 2\ O_2\ (g) \rightarrow CO_2\ (g) + 2\ H_2O\ (g)$$

Bond	Bond Energy (kJ/mol)
H-H	432
C-H	413
C-O	358
C=O	799
O=O	495
O-O	146
O-H	467

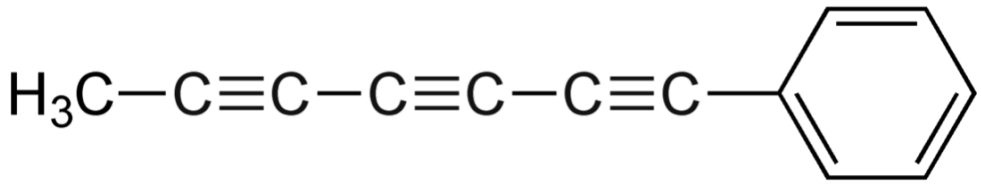
Report your answer in **standard notation** and **three significant figures**.

kJ/mol

24. What orbitals participate in the bonding of HCCH? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A. s
B. p
C. sp
D. sp^2
E. sp^3
F. sp^3d
G. sp^3d^2

25. How many pi bonds are in the molecule below? Answer by using an integer (e.g. 0, 1, etc.).



Periodic Table of the Elements

1												13	14	15	16	17	18
1 H 1.01	2																2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc [97]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
37 Cs 132.91	56 Ba 137.33		72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra [226]		104 Rf [267]	105 Db [268]	106 Sg [269]	107 Bh [270]	108 Hs [269]	109 Mt [277]	110 Ds [281]	111 Rg [282]	112 Cn [285]	113 Nh [286]	114 Fl [290]	115 Mc [290]	116 Lv [293]	117 Ts [294]	118 Og [294]

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
89 Ac [227]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]

Formula Sheet

Length
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy
1 joule = 1 kg·m^2/s^2
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure
1 pascal = 1 N/m^3 = 1 kg/m·s^2
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in^2
1 bar = 1×10^5 Pa (exactly)

Temperature
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

Mass
1 kg = 2.205 lbs

Volume
1 mL = 1 cm^3 = 1 cc

Constants
c = 2.998×10^8 m/sec
h = 6.626×10^{-34} J·sec
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: 9.109 x 10^{-31} kg
Mass of a proton: 1.673 x 10^{-27} kg
RH = 2.18 x 10^{-18} J
Specific heat of water = 4.184 J/g·K
Avogadro's number: 6.022×10^{23}
F = 96485 J/(V·mol e$^-$)
$K_w = 1.0 \times 10^{-14}$ at 25 °C
$k_b = 1.381 \times 10^{-23}$ J/K

Equations
$(P + a(n^2/V^2))\cdot(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT

$$KE = \frac{3}{2}RT$$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ of\ effusion\ A}{Rate\ of\ effusion\ B} = \sqrt{\frac{MW_B}{MW_A}}$$

$$\Delta E = -2.18 \times 10^{-18} J(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$C_g = kP_g$
$P_{solution} = P_{solvent}\ X_{solvent}$
$P_{solution} = \sum P_j = \sum P_j X_j$
$\pi = MRTi$

Thermodynamic and Electrochemistry

$S = k_b \times \ln(W)$
$\Delta S = q_{rev}/T$
$\Delta G = \Delta G° + RT \cdot \ln Q$
$R = 8.314$ J/mol.K
$\Delta G° = -RT \cdot \ln K$
$\Delta G = -nFE_{cell}$
$E°_{cell} = RT/nF \ln K$
$E°_{cell} = (0.0257/n) \ln K = (0.0592/n) \log K$
$E_{cell} = E°_{cell} - (RT/nF) \ln Q$
$E_{cell} = E°_{cell} - (0.0257/n) \ln Q$
Electrolysis: Q (total charge) = I × t = n × F

Integrated Rate Laws & half-life

$$\ln\frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$ln\frac{k_2}{k_1} = -\frac{E_a}{R}(\frac{1}{T_2} - \frac{1}{T_1})$$

Equilibrium and Acid / Base

$K_P = K_c \times (RT)^{\Delta n}$

$$ln\ \frac{K_2}{K_1} = \frac{\Delta H^\circ_{rxn}}{R}\ (\frac{1}{T_1} - \frac{1}{T_2})$$