CHEM 131 Final Exam Review Worksheet

Based on problems from the ACS Exam Review booklet, published ACS Chemistry Olympiad Exams, OpenStax Chemistry, and other sources. Note: The final exam may cover topics not included on this list or in the practice problems.

Part I

Introduction to Chemistry

Scientific Method

Measurements
- *significant figures*
- *percent yield*
- *percent error*

Atoms
- *isotopes*
  - *atomic number*
  - *mass number*
  - *symbol*
  - *protons, neutrons, electrons*
- *average atomic mass*
  - *from isotopes*

Molecules
- *percent composition*
- *counting atoms/molecules*

Concentration
- *molarity*
- *molality*
- *percent by mass (w/w)%*
- *percent by mass-volume (w/v)%*
- *percent by volume (v/v)%*

Chemical Reactions
- *balancing*
  - *listing coefficients*
  - *summing coefficients*
- *classification*

Stoichiometry
- *g → mol → percent yield*
- *molarity → mol → percent yield*
- *actual vs. percent yield*
- *titrations*

Part II

Gas Laws
- *standard conditions (STP)*
- $PV = nRT$
- $R = 0.082057\ L{\cdot}atm/mol{\cdot}K$
- $R = 8.3145\ J/mol{\cdot}K$

Enthalpy
- *calorimetry*
- $q = mc_p\Delta T$

Hess's Law
- *standard conditions,* $\Delta H°$
- $\Delta H_{rxn} = \Delta H_1 + \Delta H_2 + \ldots$
- $\Delta H = \sum \Delta H_{f\ products} - \sum \Delta H_{f\ reactants}$
  - *products − reactants*
- $\Delta H_{bonds} = \sum \Delta H_{broken} - \sum \Delta H_{formed}$
  - *bonds broken – formed*

Part III

Intermolecular Forces
- *dispersion*
- *dipole-dipole*
  - *hydrogen bonds*
  - *donors vs. acceptors*
- *induced-dipole*
- *like-dissolves-like*

Colligative Properties
- *vapor pressure lowering*
  - $\Delta P_{solvent} = X_{solute}\ P°_{solvent}$
  - $P_{solvent} = X_{solvent}\ P°_{solvent}$
- *boiling point elevation*
  - $\Delta T_b = iK_b m$
- *freezing point depression*
  - $\Delta T_f = iK_f m$
- *osmotic pressure*
  - $\prod = iMRT$

Part IV

The Structure of the Atom

Energy
- $E = h\nu = hc/\lambda$
- $c = \lambda\nu$
- $h = 6.6260693 \times 10^{-34}\ J{\cdot}s$
- $c = 2.99792458 \times 10^{8}\ m/s$

The Bohr Model

$$\frac{1}{\lambda} = R_h\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\Delta E = k\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Quantum Numbers
- *n: principal*
- *ℓ: angular momentum*
- *$m_ℓ$: magnetic*
- *m_s: spin*

Electron Configuration
- *atoms vs. ions*

Periodic Trends
- *Z_{eff}: effective nuclear charge*
- *atomic size*
- *ionic size*
- *electronegativity*
- *electron affinity*

Bonding Models
- *Lewis structures*
  - *valence electrons*
  - *resonance structures*
  - *formal charges*
  - *VSEPR and geometry*
  - *polarity*
- *Valence Bond Theory*
  - *hybrid atomic orbitals*
  - *multiple bonds (π and σ)*
  - *bond angles*

Part I

1. What is the correct reading of the buret shown?

(A) 30.20 mL **(B)** 30.25 mL
(C) 30.30 mL **(D)** 31.75 mL

2. Which of the following is the best name for TiO_2?

(A) titanium oxide **(B)** titanium dioxide
(C) titanium(IV) dioxide **(D)** titanium(IV) oxide

3. Which of the following is the formula for barium phosphate?

(A) $BaPO_4$ **(B)** Ba_3PO_4
(C) $Ba_3(PO_4)_2$ **(D)** $Ba(PO_4)_3$

4. Which of the following is the best name for Mo_3N_2?

(A) molybdenum(II) nitrite **(B)** molybdenum(III) nitride
(C) molybdenum nitride **(D)** molybdenum(II) nitride

5. Which of the following is the best name for MnS_2?

(A) magnesium sulfide **(B)** manganese (IV) sulfide
(C) manganese disulfide **(D)** magnesium(IV) sulfide

6. Europium has two stable isotopes, ^{151}Eu and ^{153}Eu. ^{151}Eu has a mass of 150.9199 amu and ^{153}Eu has a mass of 152.9212 amu. What are the abundances of ^{151}Eu and ^{153}Eu?

	^{151}Eu	^{153}Eu
(A)	32.75%	67.25%
(B)	47.81%	52.19%
(C)	75.31%	24.69%
(D)	39.92%	60.08%

7. Which of the following is the correct symbol for an ion containing 30 neutrons, 18 electrons, and an overall charge of +6?

(A) $^{54}_{24}Cr^{6+}$ **(B)** $^{60}_{30}Zn^{6+}$ **(C)** $^{48}_{18}Ar^{6+}$ **(D)** $^{78}_{48}Nd^{6+}$

8. What is the concentration of chloride ions in a solution formed by mixing 150.0 mL of 1.50 M NaCl with 250.0 mL if 0.750 M $MgCl_2$?

(A) 0.563 M **(B)** 1.03 M **(C)** 1.50 M **(D)** 2.25 M

9. In which of the following substances is chlorine in the lowest oxidation state?

(A) Cl_2 **(B)** KCl **(C)** KClO **(D)** $KClO_4$

10. The formula for terbium phosphate is $TbPO_4$. What is the formula for terbium sulfate?

(A) Tb_2SO_4 **(B)** $TbSO_4$ **(C)** $Tb_2(SO_4)_3$ **(D)** $Tb(SO_4)_2$

11. A mixture is prepared by adding 50.0 mL of 0.200 M NaOH to 75.0 mL of 0.100 M NaOH. What is the $[OH^-]$ in the mixture?

(A) 0.0600 M **(B)** 0.0800 M
(C) 0.140 M **(D)** 0.233 M

12. A compound with 69.41% C, 4.16% H, and 26.42% O has a molar mass of 230-250 g/mol. What is its molecular formula?

(A) $C_{13}H_9O_4$ **(B)** $C_{14}H_{10}O_4$
(C) $C_{13}H_6O_4$ **(D)** $C_{15}H_{14}O_3$

13. What is the coefficient for oxygen gas when the reaction for the combustion of propane, C_3H_8, is balanced?

(A) 1 **(B)** 3 **(C)** 5 **(D)** 9

14. Boron carbide, B_4C, is made by the high temperature reaction of boron oxide with graphite, yielding carbon monoxide as a by-product.

__ B_2O_3 + __ C → __ B_4C + __ CO

What is the sum of the smallest whole number coefficients for reactants and products in the balanced equation?

(A) 9 **(B)** 10 **(C)** 15 **(D)** 16

15. What is the sum of the smallest whole number coefficients used to balance the following reaction?

___ $CaCl_2(aq)$ + ___ $K_3PO_4(aq)$ → ___ $Ca_3(PO_4)_2(s)$ + ___ KCl(aq)

(A) 1, 1, 3, 6 **(B)** 3, 2, 1, 6 **(C)** 3, 3, 2, 6 **(D)** 3, 2, 1, 3

16. What is the oxidation number of technetium in $NaTcO_4$?

(A) +2 **(B)** +4 **(C)** +7 **(D)** +8

17. What is the oxidation number for carbon in methanol, CH_3OH?

(A) −2 **(B)** +2 **(C)** +4 **(D)** −4

Classify the following reactions by using the labels given below.

(A) synthesis

(B) decomposition

(C) double displacement

(D) single replacement

(E) combustion

18. $2\ C_2H_6(g) + 7\ O_2(g) \rightarrow 4\ CO_2(g) + 6\ H_2O(g)$

19. Sodium hydroxide is mixed with hydrochloric acid.

20. $P_4(s) + 10\ Cl_2(g) \rightarrow 4\ PCl_5(\ell)$

21. Lead nitrate reacts with potassium sulfate in aqueous solution.

22. $Zn(NO_3)_2(aq) + Cu(s) \rightarrow Zn(s) + Cu(NO_3)_2(aq)$

23. $Ag_2CO_3(aq) \rightarrow Ag(s) + CO_2(g) + O_2(g)$

24. Aluminum reacts with sulfur to form aluminum sulfide. If 27.00 g of Al react with 95.70 g of Te, what is the theoretical yield of aluminum telluride in grams?

(A) 109.2 g **(B)** 218.5 g **(C)** 70.6 g **(D)** 38.6 g

25. In a combustion reaction, benzene, C_6H_6, reacts with oxygen gas to form CO_2 and H_2O. How much oxygen gas is required for the complete combustion of 1.0 mol C_6H_6?

(A) 6.0 mol **(B)** 7.5 mol **(C)** 9.0 mol **(D)** 12 mol

26. Barium chloride reacts with sodium sulfate according to the following equation:

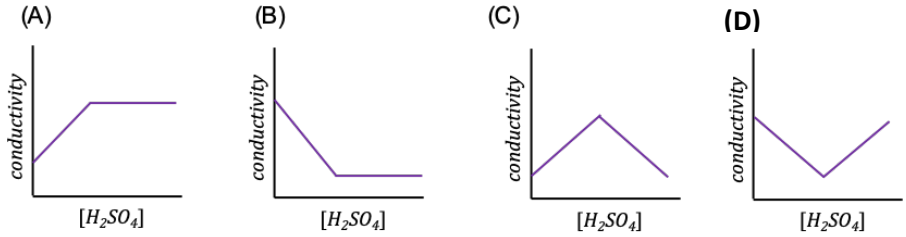
$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2\ NaCl(aq)$

A student mixes a solution containing 10.0 g $BaCl_2$ with a solution containing 10.0 g Na_2SO_4 and obtains 12.0 g $BaSO_4$. What is the percent yield for this reaction?

(A) 60.0% **(B)** 73.1% **(C)** 93.3%

(D) The isolated product is most likely wet, since the yield would otherwise be greater than 100%.

27. Which of the following graphs would best represent the changes when 0.10 M barium hydroxide is titrated with 0.10 M sulfuric acid?



28. In order to determine the concentration of a sodium hydroxide solution, titrations were performed with a standardized 0.200 M HCl solution. Phenolphthalein was used as the indicator.

Trial	Vol HCl	Vol NaOH	[NaOH] calculated
1	21.43	19.26	0.223
2	18.57	16.73	0.222
3	22.20	21.14	0.210

Which explanation best accounts for the lower calculated concentration for NaOH in Trial 3?

(A) Some of the neutralized solution from Trial 2 was left in the flask for Trial 3.
(B) The number of drops of phenolphthalein was doubled in Trial 3.
(C) 0.250 M for [HCl] was accidentally used in the [NaOH] calculation.
(D) A few drops of NaOH spilled on the benchtop during Trial 3.

29. What mass of $NaHCO_3$ (84.0 g/mol) is required to completely neutralize 25.0 mL of 0.125 M H_2SO_4?

(A) 0.131 g **(B)** 0.262 g **(C)** 0.525 g **(D)** 1.05 g

Part II

30. A sample of 54.0 g of methanol, CH_3OH, is heated from 25.0 °C to 35.0 °C. How much heat is required? The specific heat capacity for methanol is 2.48 J g^{-1} K^{-1}.

(A) 0.0049 J **(B)** 0.0747 J **(C)** 1340 J **(D)** 4690 J

31. A sample of NaOH(s) was added to water in a constant pressure calorimeter. The temperature was monitored as the NaOH dissolved. The data are given below. Determine the heat released during the solution process. The specific heat for the solution is 4.18 J $g^{-1} \cdot °C^{-1}$.

Mass of H_2O	100.00 g
Mass of NaOH(s)	10.00 g
Initial temperature of water	24.0 °C
Final temperature of solution	48.2 °C

(A) 1.01 x 10^3 J **(B)** 2.66 x 10^3 J
(C) 1.01 x 10^4 J **(D)** 1.11 x 10^4 J

32. For the reaction:

$3\ H_2(g) + N_2(g) \rightarrow 2\ NH_3(g)$ $\Delta H° = -97$ kJ/mol

The H_2 and N_2 bond energies are 436 and 941 kJ/mol, respectively. What is the bond energy for a single N−H bond in kJ/mol?

(A) 246 **(B)** 359 **(C)** 391 **(D)** 782

33. Given the standard enthalpy changes for the reactions below, calculate the standard enthalpy change for the reaction:

$$P_4O_6(s) + 2\ O_2(g) \rightarrow P_4O_{10}(s)$$

$P_4(s) + 3\ O_2(g) \rightarrow P_4O_6(s)$ $\Delta H° = -1640$ kJ/mol
$P_4(s) + 5\ O_2(g) \rightarrow P_4O_{10}(s)$ $\Delta H° = -2940$ kJ/mol

(A) −4.58 x 10^3 kJ **(B)** −1.30 x 10^3 kJ
(C) 1.79 kJ **(D)** 4.82 x 10^6 kJ

34. Choose the reaction(s) for which the heat of formation is equal to the heat of reaction.

I. $\frac{1}{2}\ N_2(g) + O_2(g) \rightarrow NO_2(g)$ $\Delta H° > 0$
II. $SO_2(g) + \frac{1}{2}\ O_2(g) \rightarrow SO_3(g)$ $\Delta H° < 0$

(A) I only **(B)** II only
(C) Both I and II **(D)** Neither I nor II

35. The combustion of 2-propanol (M = 60.0 g/mol) occurs according to the reaction:

$2\ CH_3CHOHCH_3(\ell) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(\ell)$

	$CH_3CHOHCH_3(\ell)$	$CO_2(g)$	$H_2O(\ell)$
ΔH_f°(kJ/mol)	−318.2	−393.5	−285.8

What is q for the combustion of 15.0 g of 2-propanol?

(A) -5.01×10^2 kJ **(B)** -1.00×10^3 kJ
(C) -2.01×10^3 kJ **(D)** -4.01×10^3 kJ

36. What is $\Delta H°$ for the reaction shown?

$2\ H_2S(g) + 3\ O_2(g) \rightarrow 2\ H_2O(\ell) + 2\ SO_2(g)$

ΔH_f° for $H_2S(g) = -20.15$ kJ/mol
ΔH_f° for $H_2O(\ell) = -285.8$ kJ/mol
ΔH_f° for $SO_2\ (g) = -296.4$ kJ/mol

(A) −19.4 kJ/mol **(B)** −347.7 kJ/mol
(C) −562.1 kJ/mol **(D)** −1124.1 kJ/mol

37. A sample of neon gas is held at 25.0 °C and 1.0 atm in a cylinder with a movable piston. Under these conditions, the gas occupies 5.0 L. What volume does the gas occupy at 12.5 °C and 1.0 atm?

(A) 2.5 L **(B)** 4.8 L **(C)** 5.2 L **(D)** 10 L

38. Which of the following is/are true for gases?

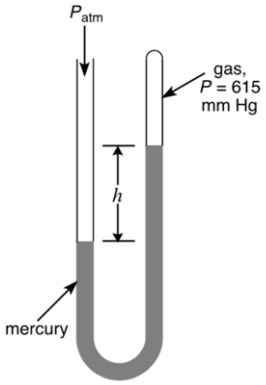
1. The amount of a gas in moles in inversely proportional to its volume at constant temperature and pressure.
2. The pressure of a gas is inversely proportional to its temperature at constant volume and amount in moles.
3. The volume of a gas is directly proportional to its temperature at constant pressure and amount in moles.

(A) 1 only **(B)** 2 only
(C) 3 only **(D)** 1 and 3 **(E)** 2 and 3

39. Under what conditions does the behavior of real gases deviate most from that predicted by the ideal gas law?

(A) low P, low T **(B)** high P, low T
(C) low P, high T **(D)** high P, high T

40. A gas with P = 615 mmHg is contained in the U-tube as shown. If h = 65 mm, what is the atmospheric pressure?



(A) 550 mmHg **(B)** 615 mmHg
(C) 680 mmHg **(D)** 760 mmHg

41. What volume would a 16.0 g sample of oxygen gas occupy at standard temperature and pressure?

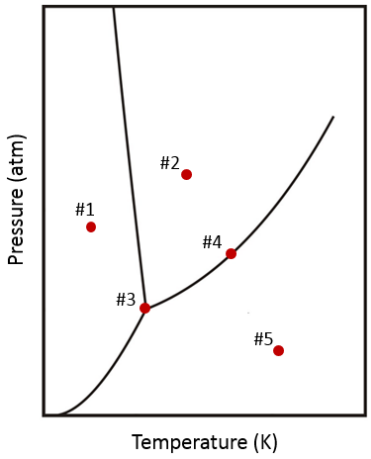
(A) 5.60 L **(B)** 11.2 L **(C)** 12.2 L **(D)** 24.4 L

42. Into both ends of a meter-long glass tube, samples of gas are introduced simultaneously. One end receives HCl gas while the other end receives NH_3 gas. When the gases meet in the tube, a reaction occurs and solid ammonium chloride forms. Where in the tube does $NH_4Cl(s)$ form?

(A) At the center of the tube.
(B) Closer to the end where the HCl was introduced.
(C) Closer to the end where the NH_3 was introduced.
(D) Uniformly in all positions in the tube.

Part III

43. Which statement concerning the phase diagram is ***incorrect***?



(A) Only solid exists at point #1.
(B) At point #3, all three phases (solid, liquid, and gas) are in equilibrium.
(C) Solid and liquid are in equilibrium at point #4.
(D) At point #5, only gas is present.

44. The lattice energy of MgO is much larger than that of LiF. What contributes most to this difference?

(A) Mg^{2+} is a smaller ion than Li^{+}, and O^{2-} is a smaller ion than F^{-}.
(B) F is more electronegative than O, and Li is more electropositive than Mg.
(C) MgO contains doubly charged ions, while LiF contains singly charged ions.
(D) MgO contains more electrons than LiF.

45. Pure samples of which of the following exhibit hydrogen bonding?

I. CH_3OH II. CH_3NO_2 III. CH_3CN

(A) I only **(B)** I and II only
(C) II and III only **(D)** I, II, and III

46. Which physical property decreases with an increase in intermolecular forces?

(A) boiling point **(B)** vapor pressure
(C) enthalpy of vaporization **(D)** viscosity

47. Which molecule has a dipole moment of zero?

(A) CO **(B)** CO_2 **(C)** CH_2O **(D)** CH_3OH

48. Which of the following compounds would have the highest vapor pressure?

(A) $CH_3CH_2CH_3$ **(B)** $CH_3CH_2CH_2OH$
(C) CH_3OOCH_3 **(D)** CH_3CH_2COOH

49. What is the principal energetic factor in the lack of miscibility between $C_6H_{14}(\ell)$ and $H_2O(\ell)$?

(A) The strength of intermolecular forces of attraction between $C_6H_{14}(\ell)$ molecules
(B) The strength of intermolecular forces of attraction between $H_2O(\ell)$ molecules
(C) The difference between the molecular weights of the molecules
(D) The difference in electronegativity between carbon and hydrogen

50. The value of which concentration unit for a solution changes with temperature?

(A) molarity **(B)** molality
(C) mole fraction **(D)** mass percentage

51. A student wishes to determine the molar mass of a pure solid organic compound. Which measurement would be most useful?

(A) melting point of the solid
(B) heat of combustion of the solid
(C) freezing point depression of the solid dissolved in pure benzene
(D) solubility in pure benzene

52. Which aqueous solution exhibits the largest freezing point depression?

(A) 1.0 m KBr **(B)** 0.75 m $C_6H_{12}O_6$
(C) 0.5 m $MgCl_2$ **(D)** 0.25 m $Ga_2(SO_4)_3$

53. How would the freezing point depression of a 0.05 m $CaCl_2$ solution compare with that of an NaCl solution? The freezing point depression would be:

(A) less than that for 0.10 m NaCl solution.
(B) between that for a 0.10 m NaCl and a 0.20 m NaCl solution.
(C) between that for a 0.20 m NaCl and a 0.30 m NaCl solution.
(D) greater than that of a 0.30 m NaCl solution.

54. Interferon is a water-soluble protein. A solution prepared by dissolving 15.0 mg of interferon in 2.50 mL of H_2O exhibits an osmotic pressure of 5.80 mmHg at 25 °C. What is the molar mass of interferon?

(A) 1.92×10^4 g/mol **(B)** 1.92×10^7 g/mol
(C) 1.95×10^6 g/mol **(D)** 1.61×10^3 g/mol

Part IV

55. The wavelength of one of the spectral lines of helium is 492 nm. What is the energy of a photon at this wavelength?

(A) 3.26×10^{-40} J **(B)** 3.26×10^{-31} J
(C) 4.04×10^{-28} J **(D)** 4.04×10^{-19} J

56. Which of the following statements is ***incorrect***?

(A) It is not possible to know the exact location and energy of an electron at the same time.
(B) Electrons have both wave-like and particle-like properties.
(C) The behavior of electrons around an atom can be described by circular orbits around the nucleus.
(D) Quantum numbers define the orbitals available to an electron.

57. In the ground-state phosphorus atom, how many electrons have the quantum numbers $n = 3$, $\ell = 1$, and $m_\ell = -1$?

(A) 0 **(B)** 1 **(C)** 2 **(D)** 3

58. For a hydrogen atom, which change in principal quantum number would correspond to emission of a photon with the longest wavelength?

(A) $n = 4 \rightarrow n = 1$ **(B)** $n = 5 \rightarrow n = 2$
(C) $n = 1 \rightarrow n = 5$ **(D)** $n = 2 \rightarrow n = 4$

59. Which of the following gas phase ions has the largest number of unpaired electrons in its ground state?

(A) Cr^{3+} **(B)** Co^{3+} **(C)** Ni^{2+} **(D)** Cu^{2+}

60. A sulfur atom in its ground state has the electron configuration:

$$1s^2\,2s^2\,2p^6\,3s^2\,3p^4$$

How many orbitals are occupied by at least one electron?

(A) 3 **(B)** 5 **(C)** 8 **(D)** 9

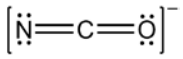
61. Rank the elements Si, P, Ar, and Na in order of increasing atomic size.

(A) Na < P < Si < Ar **(B)** Ar < P < Si < Na
(C) Na < Si < P < Ar **(D)** Ar < Si < P < Na

62. Of the atoms listed, which has the largest third ionization energy?

(A) Ca **(B)** Al **(C)** Mg **(D)** Si

63. Consider the Lewis structure below. What are the formal charges on the atoms?



	N	C	O
(A)	−1	0	0
(B)	−1	+1	−1
(C)	0	0	−1
(D)	−1	−1	+1

64. Arrange the following species in order of decreasing C−O bond length.

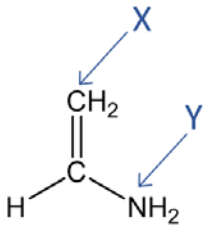
CO_3^{2-} CO CO_2

(A) CO_3^{2-}, CO, CO_2 **(B)** CO_2, CO, CO_3^{2-}
(C) CO, CO_3^{2-}, CO_2 **(D)** CO_3^{2-}, CO_2, CO

65. What is the formal charge on the oxygen atom in carbon monoxide?

(A) 0 **(B)** +1 **(C)** −1 **(D)** −2

66. The structure of vinylamine is shown below. What geometry is exhibited by each of the marked atoms?



	Geometry at X	Geometry at Y
(A)	trigonal planar	trigonal planar
(B)	trigonal planar	trigonal pyramidal
(C)	trigonal pyramidal	trigonal planar
(D)	trigonal pyramidal	trigonal pyramidal

67. How many σ and π bonds are in 1,3-butadiene, CH_2=CH−CH=CH_2?

(A) 7 σ and 2 π **(B)** 2 σ and 7 π
(C) 9 σ and 2 π **(D)** 2 σ and 9 π

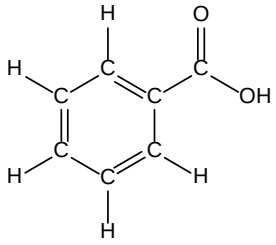
68. What is the geometry of SF_4?

(A) tetrahedral **(B)** see-saw
(C) square planar **(D)** trigonal pyramidal

69. For the two species listed, which have the same shape?

(A) CO_2 and SO_2 **(B)** CCl_4 and $SiCl_4$
(C) C_2H_6 and B_2H_6 **(D)** NO_3^- and PO_3^{3-}

70. How many σ bonds are present in the molecule below?



(A) 4 **(B)** 10 **(C)** 14 (D) 15 **(E)** 19

Determine the hybridization of each atom marked in the molecule below.

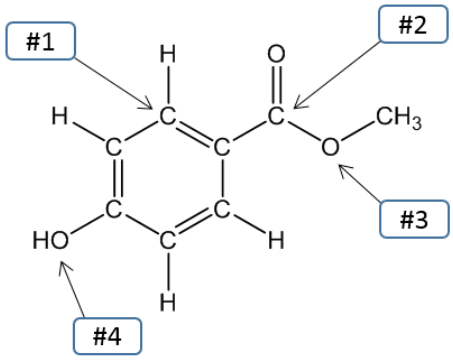
(A) sp (B) sp^2 (C) sp^3 (D) sp^3d (E) sp^3d^2

_____ **71.** atom #1

_____ **72.** atom #2

_____ **73.** atom #3

_____ **74.** atom #4



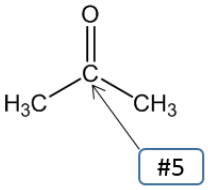
Determine the geometry of each atom marked in the molecules below.

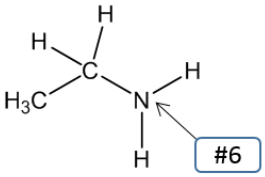
(A) linear (B) bent (C) trigonal pyramidal (D) trigonal planar (E) tetrahedral

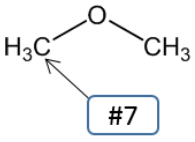
_____ **75.** atom #5

_____ **76.** atom #6

_____ **77.** atom #7







78. Of the three molecules shown (for Problems #75-77), which will form hydrogen bonds?

(A) The molecule with the carbon marked #5.
(B) The molecule with the nitrogen marked #6.
(C) The molecule with the carbon marked #7.
(D) Impossible to tell without further information.