Chemistry

1. What is the number of hydrogen molecules, H_2, in 12 grams of H_2 (gas)?

A. 6.02×10^{23}
B. 1.0×10^{23}
C. 3.6×10^{23}
D. 3.6×10^{24}
E. 5.0×10^{22}

(D) There are 6 mols of hydrogen in 12 g H_2; 6 mols H_2 = 12 g (1 mol H_2 / 2 g H_2). Avogadro's number and the mols give the molecule count. (6 mols H_2)(6.02×10^{23} molecules H_2 / mol) = 3.6×10^{24}

2. How many mols of sulfuric acid will be formed when 24 mols of sulfur react according to the following pair of reactions? These following equations summarize how acid rain is formed in the atmosphere.

$$2\ S\ (s) + 3\ O_2\ (g) \rightarrow 2\ SO_3\ (g)$$
$$SO_3\ (g) + H_2O\ (l) \rightarrow H_2SO_4\ (aq)$$

A. 24
B. 48
C. 12
D. 6
E. 3

(C) The mol ratio is 1 mol H_2SO_4 / 2 mol S. This gives mols H_2SO_4 = 24 mols S (1 mol H_2SO_4 / 2 mol S).

3. How many moles of CO_2 will be formed when 120 grams of carbon are burned according to the following equation?

$$C(s) + O_2\ (g) \rightarrow CO_2\ (g)$$

A. 120
B. 152
C. 130
D. 10
E. 5

(D) The balanced equation gives a ratio of 1 mole CO_2 / 1 mole C. The molar mass of carbon is 1 mole C = 12 g C. This gives moles CO_2 = 120 g C (1 mole C / 12 g C) (1 mole CO_2 / 1 mole C) = 10 moles CO_2.

4. Which of the following compounds has the greatest percent hydrogen by mass?

A. HF
B. HCl
C. HBr
D. HAt
E. HI

(A) The molar mass is smallest for HF. Hydrogen contributes more to the molar mass than in the other formulas.

5. Which of the following sets of coefficients is needed to balance this equation for the incomplete combustion of methane?

$$CH_4(g) + O_2(g) \rightarrow CO(g) + H_2O(g)$$

A. 1, 2, 1, 1
B. 2, 3, 2, 2
C. 2, 3, 2, 4
D. 1, 3, 1, 4
E. 2, 3, 2, 3

(C) The balanced equation requires 2 molecules of methane. This immediately dictates 2 CO and 4 H_2O. The oxygen molecules are adjusted by using a multiplier of 3.

6. What is the new volume in liters for 34.0 L of $SO_2(g)$ initially at 17°C and 750 torr when the new temperature increases to17°C and the pressure decreases to 375 torr?

A. 68.0 L
B. 17.0 L
C. 34.0 L
D. 8.5 L
E. L

(A) This is an example of Boyle's law: $P_2V_2 = P_1V_1$, $V_2 = V_1 [P_1 / P_2] = 34.0$ L [750 torr /375 torr] = 68.0 L.

7. Which of the following gases will have the highest density?

A. $H_2(g)$
B. HI(g)
C. HCl(g)
D. HF(g)
E. HBr(g)

(B) The density for HI is highest. The sequence of HF, HCl, HBr, HI has increasingly heavier halogen atoms. The H_2 is one of the smallest mass atoms in the periodic table with correspondingly low densities.

8. A gas mixture has the following gases and partial pressures. N_2 = 120 torr; H_2 = 300 torr; O_2 = 80 torr. What is the mole fraction of nitrogen in this mixture?

A. 0.12
B. 0.06
C. 0.48
D. 0.96
E. 0.24

(E) Mole fractions are determined using Dalton's law of partial pressures. The ratio of partial pressure to total pressure ratio equals the mole fraction, χ. $\chi = P_{artial} / T_{otal}$ = 120 torr / 500 torr = 0.24.

9. Which of the following molecules has a tetrahedral shape?

A. ammonia, NH_3
B. carbon monoxide, CO
C. carbon dioxide, CO_2
D. silane, SiH_4
E. water, H_2O

(D) A tetrahedral-shaped molecule must have four atoms attached to the central atom. Silane is tetrahedral.

10. What will happen to the pressure of an ideal gas in a sealed steel container when it is heated from 200°C to 400°C?

A. The pressure will increase by a factor of two.
B. The pressure will be cut in half.
C. The pressure will increase by a factor of 673/473.
D. The pressure will decrease by a factor of 473/673.
E. The pressure will remain the same.

(C) Gay-Lussac's law $P_2/T_2 = P_1/T_1$ is the relation used. $P_2 = P_1(T_2/T_1) = P_1$ (673 Kelvin / 473 Kelvin)

11. Which of the following molecules is the most polar?

A. HF
B. SO_3
C. HI
D. H_2
E. CO_2

(A) The polarity of the molecule depends on electronegativity differences between atoms and the molecular shape. Fluorine has the highest electronegativity of all elements. Molecules like CO_2 and SO_3 have polar bonds, but symmetry cancels out the polarity.

12. Which of the following molecules has a molar mass of 78 grams?

A. H_2
B. C_2H_2
C. SO_3
D. CH_2Cl_2
E. C_6H_6

(E) Add the atomic masses for all atoms in the formula. MM = $6 \times 12.0 + 6 \times 1.0 = 78$.

13. Which of the following metals is the most reactive with water?

A. silver
B. calcium
C. sodium
D. potassium
E. gold

(D) Group 1A elements are the most reactive metals. Potassium is in Group 1A. The reactivity with water increases going down the group.

14. Which of the following elements has the electron configuration $1s^2\ 2s^2\ 2p^5$?

- **A.** hydrogen
- **B.** carbon
- **C.** lithium
- **D.** fluorine
- **E.** neon

(D) Fluorine has 9 electrons: $1s^2\ 2s^2\ 2p^5$.

15. Which of the following elements has exactly six valence electrons?

- **A.** carbon with atomic number 6
- **B.** nitrogen with atomic number 7
- **C.** oxygen with atomic number 8
- **D.** fluorine with atomic number 9
- **E.** neon with atomic number 10

(C) Oxygen has 8 electrons: $1s^2\ 2s^2\ 2p^4$. There are six electrons in the $n = 2$ outer shell.

16. Which one of these elements has the highest density in the following set?

- **A.** C
- **B.** Si
- **C.** Ge
- **D.** Sn
- **E.** Pb

(E) These are Group 4A elements. The density increases down the group.

17. Which of the following elements is a rare gas or noble gas?

- **A.** neon
- **B.** oxygen
- **C.** chlorine
- **D.** nitrogen
- **E.** hydrogen

(A) Neon, Ne, is in Group 8A. These are the rare or noble gases.

18. When the following weak acids are neutralized to form a sodium salt, which of the sodium salts will hydrolyze to give the highest pH?

- **A.** chlorous acid, $HClO_2$ $K_a = 1.1 \times 10^{-2}$
- **B.** acetic acid, $HC_2H_3O_2$ $K_a = 1.8 \times 10^{-5}$
- **C.** hydrocyanic acid, HCN $K_a = 4.0 \times 10^{-10}$
- **D.** formic acid, HCOOH $K_a = 6.0 \times 10^{-7}$
- **E.** nitrous acid, HNO_2 $K_a = 4.5 \times 10^{-3}$

(C) Hydrocyanic acid forms NaCN. The weakest acid of this set will yield the most basic solution with the biggest $K_b = K_w / K_a = (1.0 \times 10^{-14})/(4.0 \times 10^{-10}) = 2.5 \times 10^{-5}$ This is about the same base strength as aqueous ammonia.

19. A spontaneous reaction will always have a negative value for which property?

A. internal energy
B. enthalpy
C. entropy
D. reaction speed
E. free energy

(E) Free energy is always negative for a spontaneous process: $\triangle G = \triangle H - T\triangle S$. The enthalpy change, $\triangle H$, can be positive where the $T\triangle S$ term can offset it.

20. Which of the following will have a negative enthalpy change?

A. breaking a hydrogen bond
B. breaking a carbon-carbon single bond
C. breaking a carbon-carbon double bond
D. forming a hydrogen-hydrogen single bond in H_2
E. forming a sodium ion from a sodium atom

(D) All bond breaking processes are endothermic. All bond formation processes are exotyhermic with a negative enthalpy change.

21. How many electrons are there in a +2 cation formed from uranium-235 with Z = 92?

A. 90
B. 92
C. 235
D. 233
E. 94

(A) Uranium has atomic number 92. There will be 90 electrons remaining in a uranium +2 cation.

22. Which of the following systems has the lowest entropy?

A. sodium metal, Na(s)
B. hydrogen gas, H_2(g)
C. liquid mercury, Hg(l)
D. neon gas, Ne(g)
E. salt water, NaCl(aq)

(A) Sodium metal is the most organized of the materials listed.

23. Which of the following reactions requires the least energy?

A. dissociation of O_2 molecules
B. dissociation of F_2 molecules
C. dissociation of Cl_2 molecules
D. dissociation of Br_2 molecules
E. dissociation of N_2 molecules

(B) Fluorine is the most reactive of the Group 7A elements. This reactivity is partly due to the weakest single bond.

24. Which of the following is true of nonmetals?

A. high density
B. usually poor conductors of electricity
C. usually good conductors of electricity
D. usually form positive ions
E. typically solids at room temperature

(B) Nonmetals are typically poor conductors of electricity and heat. They usually form anions. Metals are typically solids.

25. For the reaction, 2 NO_2F (g) $\leftarrow \rightarrow$ N_2O_4 (g) + F_2 (g), at some given set of conditions, we find that at equilibrium the concentrations are $[NO_2F]=0.1$, $[N_2O_4]=0.2$ and $[F_2]=0.3$. What is the value of the equilibrium constant for this reaction at these conditions?

A. 1.67
B. 0.167
C. 6.
D. 0.6
E. 0.00167

(C) The equilibrium expression is from = reactants / products = $[N_2O_4]\,[F_2]/\,[NO_2F]^2 = [0.2]\,[0.3]/\,[0.1]^2 = 6$.

26. How many neutrons are in the nucleus of a U-238 isotope of uranium with atomic number 92?

A. 238
B. 146
C. 92
D. 328
E. 148

(B) The number of neutrons equals the mass number, A, (238) minus Z, the atomic number, (92). Neutrons = A – Z = 238 – 92 = 146.

27. Which of the following best describes the electronic configuration $1s^2 2s^2 2p^5 3s^2$?

A. forbidden state
B. excited state
C. triplet state
D. unknown state
E. ground state

(B) This is an excited state in which an electron is excited from the 2p orbital to a 3s orbital.

28. Where is silver being produced in the following reaction $Cu|Cu^{+2}||Ag^{+}|Ag$?

A. anode
B. cathode
C. salt bridge
D. voltmeter
E. ampmeter

(B) Silver ions are reduced at the cathode from Ag^{+}|to Ag atoms. The formalism shows the species involved in the anode half reaction first (Cu and Cu^{+2}), then a symbol for a salt bridge (||), and finally the species reacting in the cathode half reaction (Ag^{+} and Ag).

29. What is the role of aluminum chloride in the reaction?

$$NH_3 + AlCl_3 \rightarrow NH_3AlCl_3$$

A. Lewis acid
B. Lewis base
C. Brønsted-Lowry base
D. Brønsted-Lowry acid
E. Arrhenius base

(A) Aluminum chloride is a Lewis acid. Aluminum is electron deficient. It can accept an electron pair from ammonia.

30. What state of matter has the characteristics of definite shape and volume?

A. liquid
B. solid
C. plasma
D. gas
E. ether

(B) Solids have definite shape and volume.

31. Which of the following would give a Normal concentration of 0.4 N for a molar concentration of 0.2 M concentration?

A. all of these
B. HCl(aq)
C. H_2SO_4(aq)
D. H_3PO_4(aq)
E. NH_3(aq)

(C) Sulfuric acid can produce two equivalents of protons per formula unit. Normality = 0.2 M × 2 equivalents / mol.

32. Which of the following types of radiation is the most dangerous?

A. beta
B. gamma
C. alpha
D. neutrons
E. ultraviolet

(B) Gamma radiation has the highest energy and is the most penetrating. Beta particles can be stopped by a sheet of aluminum. Alpha radiation can be stopped by a layer of paper.

33. What is the maximum number of electrons that can "fit" in a sigma bonding molecular orbital?

A. 2
B. 1
C. 3
D. 4
E. 6

(A) Sigma bonding molecular orbitals can each hold a maximum of two electrons. This makes up a single bond.

34. What is the oxidizing agent in the following redox reaction?

$$2\ H^{+}\ (aq) + 2\ Fe^{+2}\ (aq) + NO_3\ (aq) \rightarrow 2\ Fe^{+3}\ (aq) + NO_2^{-}\ (aq) + H_2O\ (l)$$

A. iron II ion
B. nitrate ion
C. iron III ion
D. hydronium ion
E. nitrite ion

(B) Nitrogen in nitrate ion is reduced from +5 to +3 in nitrite ion.

35. What does malleability relate to when describing iron?

A. a physical property
B. a chemical property
C. a measurement
D. a chemical change
E. an exact number

(B) The ease of hammering a material into sheets is described as *malleability.*

36. When the Soviet nuclear power plant at Chernobyl went through a meltdown, radioactive strontium was released. Which of the following body organs is the most likely place for strontium to accumulate?

A. liver
B. heart
C. spleen
D. bone
E. lungs

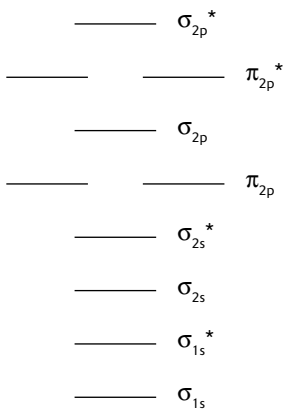
(D) Strontium is in Group 2A just like calcium. Strontium is incorporated in bone in the same fashion as calcium.

37. The relation $t_{1/2} = (1 / ak[A]_o)$ predicts the half life for a second order decomposition reaction. The half-life time is 0.01 seconds when the initial concentration is 2.00 M for $[A]_o$. What is the value for ak? The general form for the reaction is a A $\rightarrow$ product.

A. 0.02 $M^{-1}sec^{-1}$
B. 500 $M^{-1}sec^{-1}$
C. 0.2 $M^{-1}sec^{-1}$
D. 50 $M^{-1}sec^{-1}$
E. 200 $M^{-1}sec^{-1}$

(D) Solve the half-life equation for ak: ak = (1 / $t_{1/2}$ $[A]_o$) = (1 / (0.01) [2.00]) = 1 / 0.02 = 50 $M^{-1}sec^{-1}$.

38. Which of the following molecules has the strongest oxygen-oxygen bond based on the molecular orbital energy diagram?



A. O_2^+
B. O_2
C. O_2^{-2}
D. O_2^{+2}
E. O_2^{-1}

(D) There are 16 electrons in the O_2 molecule. The bond order for the O_2^{+2} cation is 3. The other structures have more anti-bonding electrons that yield a lower bond order.

39. Calcium hydroxide, $Ca(OH)_2$, forms a saturated solution with $[Ca^{+2}]$ = 0.01 M. What is the solubility product for calcium hydroxide?

A. 2×10^{-4}
B. 1×10^{-4}
C. 4×10^{-6}
D. 8×10^{-6}
E. 2×10^{-6}

(C) Calcium hydroxide has the formula $Ca(OH)_2$. The solubility product expression is $K_{sp}=[Ca^{+2}][OH^-]^2$. If the concentration of calcium is 0.01, though, the concentration of hydroxide will be 0.02 because of the stoichiometric ratio, 2 hydroxides /1 calcium. Thus, $K_{sp} = [0.01][0.02]^2 = 4 \times 10^{-6}$.

40. Which of the following acid-base theories is the only one that can be applied to non-aqueous systems?

A. Lewis
B. Arrhenius
C. Brønsted-Lowry
D. Dalton
E. Boyle

(A) The Lewis model is an electron pair acceptor. Dalton and Boyle never proposed acid-base models. Arrhenius and Brønsted-Lowry models involve proton (hydronium ion) ion transfer.

41. When a radioactive nucleus emits an alpha particle, the daughter nucleus will have a mass number that is

A. lower by 2 mass units.
B. higher by 4 mass units.
C. lower by 4 mass units.
D. higher by 2 mass units.
E. unchanged.

(C) An alpha particle has a mass number of 4 units. The daughter nucleus will have a mass number lower by 4 units.

42. Which of the following is a decomposition reaction?

A. $CH_4(g) + O_2(g) \rightarrow CO(g) + H_2O(g)$
B. $C_6H_{10}(g) + H_2(g) \rightarrow C_6H_{12}(g)$
C. $C_6H_{12}(g) + Cl_2(g) \rightarrow C_6H_{10}Cl_2(g) + 2\,HCl(g)$
D. $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(aq)$
E. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

(E) Decomposition reactions involve a single reactant that forms multiple products.

43. Which of the following salts will form a neutral aqueous solution?

A. NaF
B. NaCN
C. $NaHSO_3$
D. NaCl
E. NaOH

(D) Sodium chloride is the salt formed by the reaction of a strong acid and a strong base. This type of salt forms a neutral solution.

44. Which of the following liquids has the fewest number of ions in solution?

A. 0.1 M NaCl
B. 0.1 M $CaCl_2$
C. 0.1 M $FeCl_3$
D. pure water
E. rain water

(D) Pure water has the fewest number of dissolved ions. Rain water contains ions formed when atmospheric gases dissolve in the rain drops.

45. What is the correct IUPAC name for $FePO_4$?

A. Iron (III) Phosphate
B. Iron (II) Phosphate
C. Iron (I) Phosphate
D. Iron Phosphate
E. Iron (III) Phosphite

(A) The ions in $FePO_4$ are iron (III), Fe^{+3}, and phosphate, PO_4^{-3}. The charge on the metal ion is written as a Roman numeral in the name of the compound.

46. If you neutralize the following solutions, which one will require the largest volume 0.10 N NaOH?

A. 300 mL of 0.20 N HCl
B. 30 mL of 1.00 N HCl
C. 3 mL of 1.00 N HCl
D. 2.00 L of 0.06 N HNO_3
E. 3.00 L of 1.00 N HCl

(E) The 3.00 liters of 1.00 N HCl contains the greatest number of equivalents of acid and require the largest volume of base to neutralize the acid. Equivalents of acid = normality × liters of solution.

47. What type of atomic nucleus will form when ^{205}Pb with Z = 82 undergoes alpha decay?

A. ^{204}Bi
B. ^{205}Bi
C. ^{201}Hg
D. ^{203}Hg
E. ^{201}Pb

(C) The daughter nucleus will have a mass number of 201 and an atomic number of 80. This matches mercury-201.

48. What is the reason for the term "a" in the Van der Waal's equation for gases, $(P + a\, n^2/V^2)(V - nb) = nRT$?

A. to correct for errors introduced by using temperature scales other than Kelvin
B. to correct for colligative properties of mixtures of gases
C. to correct for the volume occupied by real gas particles
D. to account for intermolecular forces that are present in real gases
E. to account for entropy differences due to molecular structure

(D) Real gas pressures are lower than the value needed to make PV = nRT. The *a* term is added to the pressure to account for intermolecular forces that produce a lower observed pressure.

49. For the reaction $2\ NO_2\ (g) \leftarrow \rightarrow N_2O_4\ (g)$, what is the reaction quotient if $[NO_2] = 0.1$ and $[N_2O_4] = 1.0$?

A. 0.1
B. 10
C. 100
D. 0.01
E. 1000

(D) The reaction quotient $Q = [N_2O_4] / [NO_2]^2 = 1.0 / 0.1^2 = 100$. This is not the equilibrium constant because the reaction is not at equilibrium.

50. If it were to dissociate completely, how many ions (total) would be produced by $Ca_3(PO_4)_2$?

A. 3
B. 13
C. 4
D. 5
E. 16

(D) The salt forms three Ca^{+2} and two PO^{-3}_4 ions for a total of 5 ions.

51. Which of the following functional groups will yield the most partial positive carbon in the β position to the functional group?

A. aldehyde
B. alcohol
C. alkene
D. amine
E. alkyl halide

(A) An aldehyde has a double-bonded oxygen in a carbonyl group, and with oxygen's strong electronegativity, the O atom draws electrons from nearby beta carbons (the inductive effect).

52. Formaldehyde has the formula CH_2O. How many pi bonds would be present in this compound according to Lewis structures?

A. 0
B. 1
C. 3
D. 2
E. ½

(A) An aldehyde has a double-bonded oxygen in a carbonyl group. A double-bond has one pi bond and one sigma bond.

53. Which of the following will lead to the formation of a free radical in an organic reaction?

A. hydrolysis
B. rearrangement
C. heterolytic cleavage
D. homolytic cleavage
E. dehydration

(D) Homolytic cleavage means that a single bond is split with one electron going to each of the atoms involved in the bond. This leaves an unpaired electron on each fragment producing two free radicals.

54. How many pi bonds are in a triple bond?

A. 4
B. 2
C. 1
D. 3
E. 0

(B) A single bond consists of a sigma bond, a double-bond consists of one sigma and one pi bond, and a triple bond consists of one sigma and two pi bonds. Pi bonds are electron rich and important in organic reactions involving electrophilic agents that attack the electron rich and weaker pi bonds.

55. Of the following free radicals, which will be the most stable?

A. methyl carbon
B. primary carbon
C. tertiary carbon
D. secondary carbon
E. hydrogen atom

(C) The more carbons and branched the free radical, the more stable the free radical will be. Radicals that have resonance possibilities are more stable.

56. The dehydration reaction of a carboxylic acid with an alcohol yields what functional group?

A. acid anhydride
B. ether
C. amide
D. ester
E. alkene

(D) Esters are formed when RCOOH and R'OH react to eliminate water and form RCOOR'.

57. In the infra-red spectrum of an alcohol, the hydroxide functional group usually is shown how?

A. a broad strong peak at 3200-3550 cm^{-1}
B. a sharp peak at 1630-1780 cm^{-1}
C. a medium peak at 2220-2260 cm^{-1}
D. a medium-strong peak at 2853-2962 cm^{-1}
E. a narrow strong band in the range 1200-800 cm^{-1}

(A) The broad strong hydroxyl (OH) band in an IR spectrum at 3200–3550 cm^{-1} is one of the most easily recognized functional groups in infra-red spectroscopy. A band at 1630–1780 cm^{-1} is a carbonyl; a band at 2220–2260 cm^{-1} is a nitrile; and a common band at 2853–2962 cm^{-1} is due to stretching the C–H bond.

58. Which of the following is a meta director for aromatic electrophilic substitution?

A. $–CO_2H$
B. $–NH_2$
C. –OH
D. –X
E. $–CH_2CH_3$

(A) Meta directors help stabilize a positive charge on the benzene meta position and withdraw electrons from the ortho and para positions. A meta director typically has an atom with a relative positive charge or withdraws electrons from the aromatic ring.

59. Which of the following functional groups contains the most highly oxidized carbon atom?

A. alkene
B. ketone
C. alcohol
D. alkyne
E. alkane

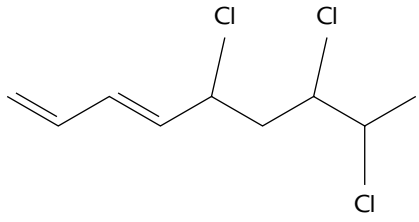
(B) The order of oxidation is alkyne, alkene, alkane, alcohol, ketone or aldehyde, carboxylic acid, carbon dioxide.

60. Which part of an organic compound is likely to give a peak at 30 AMU on a mass spectrograph?

A. CH_2O^+
B. OH^+
C. CH_3^+
D. $C_6H_5^+$
E. CH_2^+

(A) A mass spectrograph breaks molecules into positively charged parts by impacting the molecules with high energy electrons. This creates positively charged species that are transient fragments (such as the hydroxide cation). Separation of these pieces is based simply on mass to charge ratios. The masses of the pieces are determined just like you would any molecule. The abundance of a fragment is related to its stability and the strength of the bonds broken to make it.

61. What will be the most likely product in the dehydrochlorination of 5,7,9-trichloro-1,3-nonadiene (shown below)?



A. 7,9-dichloror-1,3,5-nonatriene
B. 5,9-dichloro-1,3,6-nonatriene
C. 5,9-dichloro-1,3,5-nonatriene
D. 5,7-dichloro-1,3,8-nonatriene
E. 5,7-dichloro-1,3,6,8-nonatetraene

(A) The significance of this compound is the conjugated diene; this can help stabilize (through resonance) the cation formed in the loss of the chlorine at the 5 position. Because the cation will be stabilized, we are likely to lose that chlorine fastest, further propagating the conjugated pi system.

62. Which of the following does not contain a carbonyl group?

A. ketones
B. aldehydes
C. alkynes
D. carboxcylic acid anhydrides
E. esters

(C) Alkynes are hydrocarbons with a triple bond., RC:::CR'. There are no carbonyl groups in alkynes.

63. Which of the following functional groups have an infrared spectrum with an intense band at 1630–1780 cm^{-1}?

A. alkenes
B. alcohol
C. alkanes
D. ketones
E. alkyl halides

(D) Ketones contain a carbonyl group that has a strong absorption band in the range 1630–1780 cm^{-1}.

64. What type of isomer will rotate plane polarized light?

A. Enantiomer
B. Diastereomer
C. Constitutional
D. Hydration
E. Cis-trans

(A) Enantimers are mirror images of one another.

65. What type of amine will be the most alkaline?

A. primary
B. secondary
C. tertiary
D. quaternary
E. protonated

(C) The more substituted the amine the more alkaline; 1°< 2°< 3°. However, quaternary amines cannot be alkaline because no lone pair electrons are on the nitrogen in the amine.

66. "Reducing sugars" contain a carbonyl that can be further oxidized (without oxidizing completely to carbon dioxide). What functional group would reducing sugars have?

A. carboxylic acid
B. aldehyde
C. alcohol
D. ketone
E. ester

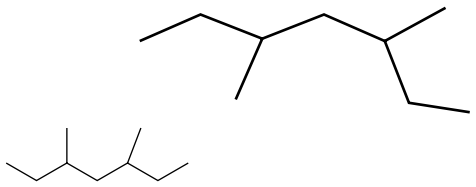
(B) Aldehydes can be oxidized to a carboxylic acid. Alcohols have no carbonyl (C=O) group. Carboxylic acids are oxidized as far as possible short of carbon dioxide. Ketones cannot be further oxidized.

67. Which of the following is the reaction mechanism of an organic decomposition caused by the presence of another substance to get the reaction started?

A. S_N1
B. E1
C. S_N2
D. E2
E. hydrogenation

(D) Decomposition is an elimination (for example the dehydration of alcohols to form alkenes). E2 involves a second species to facilitate the reaction.

68. What is the correct name for the compound in the figure?



A. 2-ethyl-4-methyl hexane
B. 2-ethyl-5-methyl hexane
C. 5-ethyl-3-methyl hexane
D. 3,5-dimethyl heptane
E. 3,5,6-trimethyl pentane

(D) The name is determined by the longest continuous carbon chain, in this case, seven carbons (heptane).

69. Which of the following types of carbon atoms will form the most stable carbocation intermediate?

A. primary
B. secondary
C. tertiary
D. quaternary
E. methyl

(C) The more carbons on the carbocation, the more stable the carbocation. A quaternary carbocation cannot exist.

70. Which of the following DOES NOT contain at least one sp^2 hybridized carbon atom?

A. formaldehyde
B. acetone
C. ethylene
D. acetic acid
E. methane

(E) Carbonyl carbon atoms are sp^2 hybridized. Alkenes have sp^2 hybridized carbons. Alkanes like methane only have sp^3 hybridized carbons.

71. Which of the following types of molecular orbitals is populated with the most energetic electrons?

A. LUMO
B. HOMO
C. sigma bonds
D. pi bonds
E. sigma antibonding

(B) ”HOMO” is the “highest occupied molecular orbital”. “LUMO” means “lowest unoccupied molecular orbital.”

72. What is the most stable conformation of cyclohexane?

A. chair
B. boat
C. twist
D. conformational
E. planar

(A) In the chair conformation, the atoms are as far apart from each other as possible, and as close to the angle of tetrahedral atoms, as possible.

73. Which of the following groups is a meta director in electrophilic aromatic substitution?

A. –OH
B. $–NH_2$
C. $–CH_3$
D. $–NO_2$
E. $–CH_2CH_3$

(D) The nitro group withdraws electrons from the ortho and para positions, making them less susceptible to electrophilic attack.

74. Which of the following contains a chiral carbon atom?

A. CH_4
B. CH_3CH_3
C. $CH_3CH_2CHClCH_3$
D. C_6H_6
E. CH_2Br_2

(C) A chiral carbon atom must have four different groups bonded to it.

75. Which of the following has a skeleton of eight carbon atoms?

A. pentane
B. butane
C. hexane
D. heptane
E. octane

(E) An octane has eight carbon atoms in the longest chain.

76. In the nomenclature of alkenes, what means the two higher priority groups of four different groups are on the same side of the double bond?

A. cis
B. trans
C. E
D. Z
E. ortho

(D) The labels cis and trans apply to two of the same type of group on the two different carbons at the ends of a double bond in an alkene.

77. Which of the following is the formula for propanoic acid?

A. CH_3COOH
B. CH_3CH_2COOH
C. $CH_3CH_2CH_2COOH$
D. C_6H_5COOH
E. $HCOOH$

(B) The acid name is based on the number of carbons in the "skeleton" including the carbon in the carboxyl group.

78. Which of the following contains an sp^3 hybridized oxygen atom and no sp^2 hybridized oxygen?

A. CO_2
B. CH_3COOCH_3
C. CH_3OCH_3
D. CH_3COCH_3
E. CH_3CH_2CHO

(C) Ethers have an oxygen in the same hybridization state as exists in water. The ether has alkyl groups in place of the hydrogen atoms in water.

79. The Huckel $4n + 2$ rule predicts that which of the following will be aromatic?

A. cyclopropenyl cation, $C_3H_3^+$
B. cyclopentadienyl anion, $C_5H_5^-$
C. benzene, C_6H_6
D. tropylium cation, $C_7H_7^+$
E. all of these

(E) The rule applies to planar pi systems where *n* can have integer values from 0 to 5. The examples given all are planar with sp^2 hybridization at all the carbon atoms.

80. Acid hydrolysis of esters will yield which of the following pairs of compounds?

A. ether and an alcohol
B. ether and ketone
C. carboxylic acid and alcohol
D. carboxylic acid and water
E. carboxylic acid and an amine

(C) Esters are formed from alcohols and carboxylic acids. Acid hydrolysis reverses the reaction.

81. The Tollen's test deposits a silver mirror on the clean glass wall of a test tube. What functional group is oxidized in the reaction?

A. ketones
B. alcohols
C. carboxylic acids
D. ethers
E. aldehydes

(E) The RCHO group is oxidized to a carboxylic acid. Ketones and carboxylic acids cannot be oxidized further. Alcohols and ethers are not oxidized so easily.

82. The reaction of a carboxylic acid with an alcohol will produce which of the following types of compounds?

A. ether
B. ester
C. amide
D. water
E. amino acid

(B) The alcohol R'OH and acid RCOOH will form an ester, RCOOR'.

83. Friedel-Crafts alkylation of aromatics requires a Lewis acid. What carbon cation is formed when $AlCl_3$ and CH_3CH_2Cl are used in the reaction with benzene?

A. $CH_3CH_2^+$
B. $CH_3CH_2Cl^+$
C. $C_6H_6^+$
D. $C_6H_5^+$
E. CH_3^+

(A) The alkylhalide, CH_3CH_2Cl, is converted to a carbon cation by the loss of Cl^- (halide) to the aluminum chloride.

84. What type of compound has two or more internal chiral carbons that cancel out the rotation of light?

A. meso
B. chiral
C. racemic
D. enantiomer
E. tautomer

(A) In a meso compound, there is always a plane of symmetry. A racemic mixture will also show no plane polarized light rotation, but this is because it is a mixture of equal amounts of two enantiomers.

85. Which of the following would not make a good leaving group?

A. iodide
B. hydroxide
C. halides
D. chloride
E. methyl

(E) A good leaving group would be stable in an ionic form in water; methyl does not form a stable cation or anion.

86. What functional group is represented by the formula RCH_2OOCH_2R?

A. ethers
B. acid anhydrides
C. peroxides
D. esters
E. carboxylic acids

(C) The structure has a single bond between two oxygen atoms. This is a peroxide analogous to H_2O_2.

87. Which of the following is expected to have the most acidic hydrogen atoms?

- **A.** terminal alkenes
- **B.** terminal alkynes
- **C.** alkanes
- **D.** non-terminal alkenes
- **E.** aromatics

(B) Terminal alkynes are the most acidic. The triple-bond pi electron system in alkynes can stabilize the anion.

88. What kind of isomer has a non-superimposeable mirror image?

- **A.** enantiomer
- **B.** cis-trans isomer
- **C.** achiral compound
- **D.** constitutional isomer
- **E.** diastereoisomers

(A) Enantiomers by definition are compounds whose mirror image is nonsuperimposeable. Diastereoisomers are not mirror images of one another. A constitutional isomer is not the mirror image of its isomers. This is not a stereoisomer.

89. What type of reaction mechanism produces a chiral center if the reactant begins with a chiral center?

- **A.** S_N1
- **B.** E2
- **C.** S_N2
- **D.** E1
- **E.** dehydration

(C) Elimination reactions produce pi bonds, which cannot be connected to a chiral center. In S_N1 reactions, the chiral center is destroyed in the intermediate.

90. What type of spectroscopy destroys the sample in the analysis?

- **A.** MS
- **B.** NMR
- **C.** FT-IR
- **D.** UV-Vis
- **E.** Polarimetry

(A) Mass spectrometers routinely destroy the sample. A high energy electron beam is used to break up the sample molecules and produce cation fragments. The other methods are nondestructive.

91. Which of the following is the type of reaction that follows the Saytzeff rule?

- **A.** dehydration of alcohols
- **B.** esterification
- **C.** reduction of aldehydes
- **D.** oxidation of aldehydes
- **E.** electrophilic attack of aromatic compounds

(A) The Saytzeff rule applies to the dehydration and dehalogenation reactions. The rule says that an H atom is preferentially removed from 3o . 2o . 1o. This can be described as "the poor get poorer". The more Rs on a carbon, the more likely it will lose an H atom. The more Rs on the C=C group, the more stable the alkene.

92. Which of the following compounds is the least polar?

A. cis-1,2-dichloroethylene
B. trans-1,2-dichloroethylene
C. 1,1-dichloroethylene
D. 1,1-dibromoethylene
E. 1,1-difluoroethylene

(B) The trans isomer of dichloroethylene is the least polar. The C-Cl bond moments are equal but are in opposite directions. They cancel one another.

93. Ultraviolet spectroscopy depends on molecules absorbing light to excite electrons from a low-energy molecular orbital to a higher one. These electrons are in σ bonds, π bonds and unshared electrons, *n*, in non-bonding MOs. Which of the following types of compounds cannot have an excitation from a π to a π^* molecular orbital?

A. aldehydes
B. ketones
C. alkanes
D. esters
E. aromatics

(C) Alkanes only have single bonds. There are no molecular orbitals in alkanes so there can be no excitation from a π_to a π^* MO.

94. Proton magnetic resonance is used to identify different types of protons because the magnetic field surrounding a particular H atom depends on any external field and the bonding environment of the H in the molecule. The "chemical shift, δ" is used to identify H atoms in different functional groups and bonding environments. Which of the following has the smallest chemical shift?

A. CH_3CH_3
B. CH_4
C. $(CH_3)_4Si$
D. C_6H_6
E. C_3H_3

(D) The reference for chemical shift values is TMS, tetramethylsilane, $(CH_3)_4Si$. The zero of the chemical shift scale is determined by the signal produced by the H's in TMS.

95. Proton magnetic resonance is useful to determine structures, partly because of spin-spin coupling. The groups of peaks clustered around a chemical shift result from this effect. The spectrum for $CH^a_3CH^bCl_2$ has two chemical shifts. What are the multiplets expected for the types of H atoms, H^a? and H^b?

A. H^a singlet and H^b, doublet
B. H^a singlet and H^b singlet
C. H^a quartet and H^b doublet
D. H^a doublet and H^b quartet
E. H^a triplet and H^b singlet

(D) The $n + 1$ rule predicts the number of "lines" that a resonance is split into by neighboring H atoms. The H^a resonance is subject to two different magnetic fields, $n + 1 = 1 + 1 = 2$, exerted by the one H^b atom. The H^b resonance is split into a quartet by four magnetic fields, $n + 1 = 3 + 1 = 4$, produced by the three H^a atoms.

96. Electromagnetic energy is related to wavelength. Which of the following wavelength ranges matches the visible spectrum?

- **A.** 100–200 nm
- **B.** 200–350 nm
- **C.** 350–700 nm
- **D.** 1–300 μm
- **E.** 1 m

(C) The visible spectrum approximately matches the range 350–700 nm. The far uv matches 100–200 nm. Near uv matches 200–350–nm. Infrared matches 1–300 μm. Electron spin (ESR) and nuclear magnetic resonance match radio waves in the range cm to meters.

97. Which of the following has the greatest stability resulting from delocalization.

- **A.** cyclohexane
- **B.** cyclohexene
- **C.** 1,4-cyclohexadiene
- **D.** benzene
- **E.** 1,3-cyclohexadiene

(D) Benzene has the greatest delocalization energy for this set. The six electrons in the conjugated pi system are stabilized more than pi electrons in three isolated double bonds by 150.7 kJ/mol.

98. The reaction between sodium amide and acetylene yields which of the following compounds?

- **A.** HC:::CNa
- **B.** NaC:::CNa
- **C.** $HC:::CNH_2$
- **D.** $NH_2C:::CNH_2$
- **E.** CH_3CH_3C

(A) The acetylenic hydrogen is acidic. It will react with the amide anion, NH_2^- to form ammonia. The acetylide anion, $HC:::C^-$, forms a salt with sodium ion.

99. Which of the following is the only functional group that is alkaline?

- **A.** alcohol
- **B.** amine
- **C.** amide
- **D.** alkyne
- **E.** alkane

(B) Amines are alkaline. Amides are acidic in spite of the presence of the nitrogen. Resonance makes amides slightly acidic.

100. A Claisen Rearrangement will produce which of the following types of compounds?

A. amine derivative
B. phenol derivative
C. carboxylic acid derivative
D. alkyne derivative
E. halide derivatives

(B) The Claisen Rearrangement tends to cause phenyl-ethers to internally rearrange to form o-substituted phenols.