

INDIANA SECTION of the AMERICAN CHEMICAL SOCIETY

High School Scholarship Exam

April 12, 2003



1. The exam contains 100 questions. You have 2 hours and 30 minutes to complete the exam.
2. Choose the single *best* answer for each question and darken the corresponding letter on your answer sheet. The score is based on the number of correct answers- there is no penalty for incorrect guesses.
3. Scientific calculators are permitted. Graphing calculators, and/or those with stored programs and information are not allowed.
4. You may write on this exam. The exam does not need to be returned.
5. Use of significant digits and correct units may be considered in the choice of the best answer.
6. A periodic table and a sheet of selected formulas are also provided.

Section I. Measurement and Calculation in Science

- Density is equal to the mass of a material divided by its volume. What must be plotted on the Y-axis such that the slope of a line relating mass and volume will be equivalent to density?
 - inverse mass
 - mass
 - inverse volume
 - volume
 - density
- A rectangle has the measured width 4.230 m and length 12.7 m. The number representing the perimeter will have ___ significant figures and the number expressing the area will have ___ significant figures.
 - 4, 3
 - 3, 4
 - 3, 3
 - 5, 4
 - 4, 5
- A freighter carries a cargo of 2.25×10^8 kg uranium hexafluoride. The total cargo was contained in 30 drums, each having a volume of 1.62×10^6 L. What is the density of uranium hexafluoride in g/mL?
 - 1.39
 - 4.63
 - 13.9
 - 46.3
 - 41.7
- In a precipitation reaction, 4.90 grams of product were theoretically predicted, but 5.12 grams of material were obtained after the reaction. What is the apparent percent yield of this reaction?
 - 104 %
 - 95.7 %
 - 4.30 %
 - 4.49 %
 - 4.90 %

5. A monolayer of oleic acid of mass 3.20×10^{-6} g has an area of 20.0 cm^2 . If the density of oleic acid is 0.895 g/mL , what is the length of the oleic acid molecule?
- $2.86 \times 10^{-6} \text{ cm}$
 - $3.58 \times 10^{-6} \text{ cm}$
 - $5.59 \times 10^{-6} \text{ cm}$
 - $1.79 \times 10^{-7} \text{ cm}$
 - $1.43 \times 10^{-7} \text{ cm}$
6. A British Thermal Unit (BTU) is defined as the energy required to raise one pound of pure water one degree Fahrenheit. A calorie is defined as the energy required to raise one gram of water one degree Celsius. Recall that one Fahrenheit degree is $5/9$ the size of a Celsius degree, and that there are 454 grams in one pound, how many calories represent a BTU?
- 817
 - 252
 - 1.22×10^{-3}
 - 3.96×10^{-3}
 - Cannot be determined from given information
7. The density of mercury at $25.0 \text{ }^\circ\text{C}$ has been carefully measured and found to be 13.60 g/mL . Values obtained by a student in a freshman lab are 13.4, 13.0, 13.7 and 13.2 g/mL . What is the percent error of the average student value?
- 13.325 %
 - 2.022 %
 - 2.02 %
 - 2.064 %
 - 2.06 %
8. The calibration points for the linear Reaumur scale are the usual melting point of ice and boiling point of water, which are assigned the values $0 \text{ }^\circ\text{R}$ and $80 \text{ }^\circ\text{R}$, respectively. The normal body temperature of humans is $37 \text{ }^\circ\text{C}$. What is this temperature in $^\circ\text{R}$?
- 37.0
 - 28.0
 - 29.0
 - 29.6
 - None of the above

Section II Chemical Composition and Stoichiometry

9. What is the mass in nanograms of one million molecules of uranium hexafluoride?
- 3.520×10^2
 - 5.85×10^{-16}
 - 5.85×10^{-7}
 - 5.85×10^{-10}
 - 5.85×10^0
10. One atom of an element has a mass of 9.123×10^{-23} grams. Identify the element.
- Mn
 - Si
 - He
 - Os
 - Cannot be determined from given information
11. List the following in the order of increasing percent by mass of oxygen:
NO, N₂O₄, N₂O, NO₂, NO₃⁻.
- N₂O, NO, NO₂ = N₂O₄, NO₃⁻
 - NO₃⁻, N₂O₄ = NO₂, NO, N₂O
 - N₂O = NO, NO₂, NO₃⁻, N₂O₄
 - N₂O₄, NO₃⁻, NO₂, N₂O, NO
 - NO₃⁻, NO, N₂O, NO₂, N₂O₄
12. The compound named ammonium permanganate would have which of the following formulae?
- NH₄MnO₄
 - NH₃MnO₄
 - (NH₄)₂MnO₄
 - (NH₃)₂MnO₄
 - NH₄MnO₅
13. In a chemical reaction $2A + B \rightarrow C$, in which there are no reactants left over after reaction is complete, the mass of C
- is equal to the mass of A plus the mass of B
 - is equal to twice the moles of A divided by the moles of B
 - is equal to the sum of moles of A plus the moles of B
 - is less than the sum of twice the moles of A plus the moles of B
 - is equal to the moles of C

14. In the lab, 260. mL of 1.20 M calcium nitrate solution is mixed with 315 mL of 2.00 M potassium sulfate solution. Which of the following is *false*?
- Calcium sulfate will precipitate from solution
 - The remaining solution will contain 0.553 M sulfate ion
 - The remaining solution will contain 0.624 M nitrate ion
 - 0.312 moles of calcium sulfate will precipitate
 - The remaining solution will contain 0.318 moles of sulfate ion.
15. The thermite reaction involves the reduction of iron (III) oxide to metallic iron for welding. The reducing agent is aluminum metal and is converted to aluminum oxide. What mass, in grams, of aluminum metal is needed to produce 100.0 g of metallic iron?
- 96.62
 - 48.31
 - 24.15
 - 20.70
 - 41.40
16. A white unknown powder is sent to a laboratory for analysis. It is the product of a reaction between materials containing only nitrogen, carbon, hydrogen and oxygen. It is found to contain 4.58 % by mass hydrogen, 40.92 % by mass carbon and 54.50 % by mass oxygen. The apparatus used to determine percent by mass nitrogen is currently being repaired and no data can be obtained. What is the empirical formula of the material?
- Cannot be determined from given information
 - $C_6H_8O_6$
 - $C_3H_4O_3N_2$
 - $C_4H_4O_4N$
 - $C_3H_4O_3$
17. A metal reacts in the presence of bromine to produce MBr_3 . If 6.00 g of the metal react with an excess of bromine to form 59.31 grams MBr_3 , what is the formula of the compound?
- $ScBr_3$
 - $FeBr_3$
 - $CaBr_3$
 - $AlBr_3$
 - IBr_3

18. A 1.500 g sample of a mixture containing only Cu_2O and CuO was treated with hydrogen to produce 1.252 g of pure copper metal. What was the percent by mass of Cu_2O in the original sample?
- a) 59.93 %
 - b) 66.85 %
 - c) 33.15 %
 - d) 40.07 %
 - e) Cannot be determined from given information

Section III Atomic Theory, Periodicity and Bonding

19. Which of the following is **true**?
- a) An individual atom is a solid, liquid or gas depending on the element.
 - b) An individual atom is a charged species
 - c) An individual atom is very dense material composed of protons and neutrons
 - d) An individual atom has the same number of electrons as its atomic number
 - e) An individual atom is a hard sphere and doesn't interact with the surroundings
20. Which of the following is **true** for electromagnetic radiation?
- a) Higher energy radiation has longer wavelengths
 - b) Radio waves are of higher energy than X rays
 - c) Visible wavelengths are of higher energy than infrared radiation
 - d) Microwaves are more similar to gamma rays than radio waves
 - e) Most of the radiation spectrum is visible to the human eye
21. Which of the following is **false** about an orbital in a polyelectronic atom?
- a) It is a representation of the probable positions for a set of electrons
 - b) It is a mathematical result of the quantum mechanical treatment for electrons in an atom
 - c) It has an associated energy dependent on values of both n and l quantum numbers
 - d) It has a general shape and direction associated with the quantum numbers l and m_l
 - e) It is a hard shell composed of electrons around the nucleus
22. Which of the following sets of quantum numbers is *not* allowed in the hydrogen atom?

	n	l	m_l
a)	2	1	-1
b)	1	1	0
c)	8	7	-6
d)	2	0	0
e)	3	2	2

23. A certain atom has the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2 (5s^0) 4d^1$. The atom is
- Yttrium
 - Y^{4+}
 - An excited state of As
 - An excited state of Y
 - This electron configuration is not possible
24. Copper (I) chloride is used to make a blue color in fireworks. When it reacts, it emits light at 450 nm. What is the energy of a mole of photons of this light in units of J?
- 4.17×10^{-19}
 - 2.66×10^5
 - 1.88×10^{-16}
 - 1.13×10^8
 - Cannot be determined from given information
25. What is the electron configuration for the most stable ion formed by Zn?
- $1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^{10}$
 - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$
 - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^9$
 - $1s^2 2s^2 2p^6 3s^0 3p^6 4s^2 3d^{10}$
 - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 5s^1$
26. Which of the following is *false*?
- Halogen atoms have seven valence electrons
 - Alkali metal atoms have one valence electron
 - Alkaline earth metal atoms have two valence electrons
 - Hydrogen has an octet of electrons
 - Helium is a noble gas
27. What is the most likely compound to be formed between lithium and nitrogen?
- LiN
 - Li_3N
 - Li_2N
 - LiN_3
 - No compound can be formed

28. The chemical equation that represents the process associated with the ionization energy for bromine is
- $\text{Br}_{2(g)} + e^- \rightarrow \text{Br}_{2(g)}^-$
 - $\text{Br}_{(g)} \rightarrow \text{Br}_{(g)}^+ + e^-$
 - $\text{Br}_{(g)} + e^- \rightarrow \text{Br}_{(g)}^-$
 - $\text{Br}_{(g)}^+ + e^- \rightarrow \text{Br}_{(g)}$
 - $\text{Br}_{2(l)} \rightarrow \text{Br}_2^+ + e^-$
29. Which of the following is **false** about electron affinity values?
- They are sometimes negative, meaning the process is exothermic
 - They refer to the loss of an electron from an atom in the gas phase
 - They are the most favorable (exothermic) for the most electronegative elements
 - They cannot be directly measured for some elements
 - They can be used in Hess' law calculations like other thermodynamic properties
30. Hydrogen has an intermediate electronegativity value equivalent in magnitude to that of phosphorous. Which of the following bonds is expected to be the most polar?
- F-H
 - O-H
 - N-H
 - C-H
 - P-H
31. Which of the following statements is (are) **false**?
- The hexagonal closest packed structure is ABABAB....
 - A body-centered cubic unit cell has 4 atoms per unit cell
 - Atoms in a simple cubic structure are as closely packed as possible.
 - Atoms in a solid consisting of only one element would have six nearest neighbors if the crystal structure was a simple cubic array.
- I
 - II
 - II, III
 - I, IV
 - II, III, IV
32. Using Lewis structures, predict which of the following would have the shortest C-O distance.
- CO
 - CO₂
 - CO₃²⁻
 - H₃C-OH
 - All are predicted to have about the same C-O distance

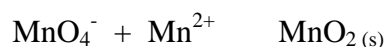
33. Which of the following is a polar molecule, as predicted by VSEPR theory? (Lewis structures and molecular geometry)
- a) I_3^-
 - b) SeF_6
 - c) CO_3^{2-}
 - d) XeF_4
 - e) PF_3

Section IV Gases Liquids and Solids

34. In the theory of gases, atoms or molecules of gases are described as being small spheres at large distances to one another, interacting only upon collision. What is in the space between these spheres?
- a) air
 - b) dust particles
 - c) vacuum
 - d) nitrogen and oxygen gas
 - e) subatomic particles
35. Helium balloons float to the ceiling because
- a) The pressure in the balloon is less than atmospheric pressure
 - b) Helium molecules in the balloon are much larger than the molecules of air outside.
 - c) Helium is a noble gas and doesn't interact with air molecules
 - d) The temperature inside the balloon is always higher than the surrounding air
 - e) The gas inside the balloon weighs less than the air it displaces
36. The ideal gas law is accurate for
- a) most real gases at pressures above 10 atmospheres
 - b) most real gases at pressures below about 1 atmosphere
 - c) gases that strongly interact with one another
 - d) monatomic gases at high pressures only
 - e) diatomic gases at high pressures only
37. A soap bubble is blown with methane (CH_4) from a laboratory gas jet at STP. If the bubble is lit with a match and the combustion of methane forms 1.32×10^{-5} mole H_2O , what was the original volume of this bubble in mL?
- a) 0.0821
 - b) 0.296
 - c) 0.741
 - d) 1.48
 - e) 0.148

38. A small piece of dry ice (solid CO_2) with a mass of 2.00 g is placed in an air-filled but otherwise empty 4.00 L flask and the flask is tightly closed with a stopper. If atmospheric pressure is 1.03 atm and the temperature is 35 °C, what will be the final pressure in the flask?
- a) 0.287 atm
 - b) 1.32 atm
 - c) 1.03 atm
 - d) 0.144 atm
 - e) 1.17 atm
39. A child is chewing bubble gum and blows an award-winning bubble. The bubble is 1.23 L in volume and is at body temperature (37 °C) and saturated with water vapor (vapor pressure of water at 37 °C is 47.10 torr). If the bubble is found to contain 4.55×10^{-2} moles of dry gas, what is the atmospheric pressure?
- a) 47.10 torr
 - b) 0.879 atm
 - c) 0.941 atm
 - d) 9.41 atm
 - e) 1.00 atm
40. Helium leaks from a child's latex party balloon overnight through the process of effusion through the latex membrane. If the balloon volume is reduced by 25 % in the course of 12 hours, what will be the volume reduction under identical circumstances if the balloon is filled with Kr?
- a) 5.5 %
 - b) 55 %
 - c) 33 %
 - d) 4.5 %
 - e) Cannot be determined from given information
41. In the Van Der Waals equation, $P = nRT/(V-nb) - a(n/V)^2$, the empirical correction factor b refers to the
- a) correction due to attraction of the particles to one another
 - b) correction to the volume due to the volume excluded by the particles (size)
 - c) correction to the temperature due to heating in collisions
 - d) correction due to an inaccurate count of the number of moles
 - e) correction factor due to relativistic considerations

42. In an acid-base reaction, which is **false**?
- a) Water is formed from Brønsted acids and Brønsted bases
 - b) A conjugate acid is formed from the base
 - c) A conjugate base is formed from the base
 - d) A precipitate is sometimes formed
 - e) The hydrogen ion concentration of the initial solutions are changed
43. Which of the following is **true**?
- a) It is possible for a material to be highly soluble and be a strong electrolyte
 - b) It is possible for a strong acid to be a weak electrolyte
 - c) It is possible for a strong base to have a strong conjugate acid
 - d) A saturated solution of a non-electrolyte will permit electrical current to flow freely
 - e) For most solids, solubility decreases with increasing temperature
44. A 0.500 g sample of an organic acid ($C_6H_8O_7$) requires 37.2 mL of a 0.210 M NaOH solution to be fully neutralized. How many acidic hydrogens are present per molecule of this acid?
- a) 1
 - b) 2
 - c) 3
 - d) 0.5
 - e) Cannot be determined from the given information
45. Permanganate and manganese(II) can react to form MnO_2 in acidic solution.



This reaction is not balanced, as shown. What mass of potassium permanganate must be added to a solution to precipitate 0.250 L of a 0.764 M solution of Mn^{2+} ?

- a) 30.2
- b) 0.191
- c) 15.1
- d) 1.91
- e) 20.1

46. You wish to make 1.000 L of a solution that is 1.000×10^{-4} M in potassium dihydrogen phosphate. Because of limitations in available glassware, you must make this by diluting 25.00 mL of a 1.000 M stock solution to 1.000 L and then diluting 25.00 mL of this solution to make the final solution. How much potassium dihydrogen phosphate should you weigh out into the flask to make this first stock solution?
- a) 218 g
 - b) 21.8 g
 - c) 0.544 g
 - d) 5.44 g
 - e) 136.1 g
47. When an iron bar rusts
- a) there is no change in mass of the bar because of the law of conservation of mass
 - b) the mass of the bar increases, but if you scrape off all the rust, the mass of the bar will be unchanged
 - c) the mass of the bar decreases as the iron is oxidized to form rust
 - d) the mass of the bar increases, but if you scrape off the rust, the mass of the bar will be decreased
 - e) the mass of the bar will change in an unpredictable way.
48. Ionic compounds show all of the following properties *except*
- a) They have high lattice energies
 - b) As solids, they are poor conductors of electricity
 - c) They have relatively high melting points and boiling points
 - d) They are very soluble in nonpolar solvents
 - e) They tend to be very brittle materials, cracking and crumbling under stress
49. Silver crystallizes as a cubic closest packed structure, which is also called face centered cubic. If the atomic radius of a silver atom is 144 pm, what is the density of silver metal in g/cm^3 ?
- a) 5.52
 - b) 10.6
 - c) 7.81
 - d) 13.5
 - e) 3.59

50. Supercritical carbon dioxide is used to decaffeinate coffee. Which of the following is true?
- a) The critical point in a phase diagram is the pressure and temperature at which solid, liquid and gas are in equilibrium
 - b) Above the critical point, only the solid phase exists
 - c) Supercritical fluids are neither liquids nor vapors but some other 'fluid' state
 - d) Supercritical fluids are all explosive
 - e) The critical point in a phase diagram is where the solid and liquid coexist

Section 5 Thermodynamics and Equilibrium

51. Which of the following *do not* fit the definition of a state function?
- a) Molar enthalpy of a chemical reaction
 - b) Work of expansion against a constant pressure
 - c) Elevation of an object above sea level
 - d) Molar volume of an ideal gas
 - e) The total free energy of a closed system
52. Standard enthalpies of formation of compounds
- a) Are defined as zero
 - b) Refer to formation of the compound from the atoms of the elements
 - c) Involve formation of the compounds from the elements in standard states
 - d) Are always negative (exothermic)
 - e) Always refer to one gram of the compound
53. When potassium metal is placed in water, hydrogen gas is formed and the solution becomes strongly basic. What is the value of ΔH° for this reaction per mole of potassium metal? ($\Delta H^\circ_f(\text{KOH}_{(\text{aq})}) = -481 \text{ kJ/mol}$, $\Delta H^\circ_f(\text{H}_2\text{O}_{(\text{l})}) = -286 \text{ kJ/mol}$)
- a) -195 kJ
 - b) -390 kJ
 - c) -780 kJ
 - d) +390 kJ
 - e) -39.0 kJ
54. What is the work of expansion performed by one mole of an ideal gas as it expands from 1.00 L to 65.0 L against a constant pressure of 12.0 atmospheres?
- a) 780 L atm
 - b) 768 L atm
 - c) 50 L atm
 - d) 5.4 L atm
 - e) Cannot be determined from information given

55. For the reaction $\text{S}_{(s)} + \text{O}_{2(g)} \rightarrow \text{SO}_{2(g)}$ $\Delta H = -296 \text{ kJ/mol}$. How much heat can be produced if 1.00 kg of solid sulfur is burned in 500. L of pure oxygen at 2.00 atm and 27.0 °C?
- $1.20 \times 10^4 \text{ kJ}$
 - $9.23 \times 10^3 \text{ kJ}$
 600. kJ
 - $2.12 \times 10^4 \text{ kJ}$
 - Cannot be determined from information given
56. Which one of the following statements is *false*?
- The change in internal energy for a process is equal to the amount of heat (q) absorbed at constant volume
 - The change in enthalpy, ΔH , for a process is equal to the amount of heat (q) absorbed at constant pressure
 - A bomb calorimeter measures directly changes in enthalpy, ΔH .
 - If the value of q (heat) measured at constant pressure is negative, the process is exothermic
 - The freezing of water is an example of an exothermic process.
57. In a constant pressure calorimeter, the formation of one mole of Fe_2O_3 from iron filings and oxygen gas held at 1.00 atm caused an increase in temperature of the water surrounding the calorimeter to be raised by 28.7°C. If the heat capacity of water is $4.18 \text{ kJ K}^{-1} \text{ kg}^{-1}$ and ΔH_f° of Fe_2O_3 is -826 kJ/mol , what mass of water was used?
- 6.89 kg
 - 2.87 kg
 - 3.50 kg
 - 1.00 kg
 - Cannot be determined from information given
58. A cup of cold water is added to a bathtub full of hot water. The final temperature can be calculated
- by adding the temperatures of the two samples if they are first converted to Kelvin
 - by converting the initial temperatures of the two samples to Celsius and adding their values
 - by adding the temperatures of the two samples in Kelvin and dividing the result by 2.
 - by determining the volumes of the two samples of water using density values, then adding the volumes
 - by setting heat lost by hot water equal to the heat gained by the cold water knowing that the final temperature of both samples will be the same.

59. The specific heat capacity of silver is $0.240 \text{ J/g } ^\circ\text{C}$. A bar of silver of mass $100. \text{ g}$ is heated to $45.00 \text{ } ^\circ\text{C}$. The bar is placed in an expandable chamber with one mole of a nonreactive ideal gas. As the heat from the silver is transferred to the gas, the chamber expands against a constant external pressure of 1.00 atm . If the final temperature of the silver and the gas is $4.00 \text{ } ^\circ\text{C}$, what is the final volume of the gas? Assume the bar of silver adds negligible volume.
- 22.7 L
 - 22.4 L
 - 26.1 L
 - 11.3 L
 - Cannot be determined from information given
60. At what temperature will a reaction become spontaneous if ΔH for the reaction is $+75 \text{ kJ}$ and ΔS is -10.5 J/K ?
- 7100 K
 - 7100 C
 - 0.710 K
 - The reaction is never spontaneous
 - The reaction is spontaneous at all temperatures
61. The melting point of tungsten is $3407 \text{ } ^\circ\text{C}$. The enthalpy of fusion has been found to be 35.2 kJ/mol . What is the entropy of fusion?
- $35.2 \text{ J mol}^{-1} \text{ K}^{-1}$
 - $10.3 \text{ J mol}^{-1} \text{ K}^{-1}$
 - $9.57 \text{ J mol}^{-1} \text{ K}^{-1}$
 - $4.27 \text{ J mol}^{-1} \text{ K}^{-1}$
 - Cannot be determined from information given
62. The value of the equilibrium constant of a reaction is dependent upon which of the following?
- The concentration of products only expressed in molarity
 - The concentration of the reactants and products expressed in molality
 - The total pressures of gaseous reactants and products only
 - The temperature of the system and the Gibbs free energy of the reaction
 - The number of moles of each reactant or product in the initial system.

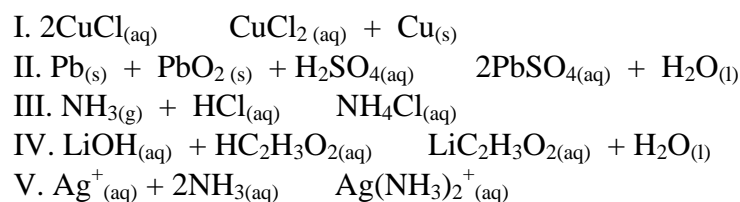
63. One mole of a gaseous reactant, A, is placed in an empty one liter container. At equilibrium, 11 % of this gas is found to have dissociated according to the reaction $A \rightleftharpoons B + C$. What is the value of the equilibrium constant?
- a) $K = 1.3 \times 10^{-1}$
 - b) $K = 1.2 \times 10^{-2}$
 - c) $K = 1.4 \times 10^{-2}$
 - d) $K = 1.3 \times 10^{-2}$
 - e) $K = 1.2 \times 10^{-1}$
64. If the value of K, the equilibrium constant based on concentrations, for the reaction $N_{2(g)} + 3 H_{2(g)} \rightleftharpoons 2 NH_{3(g)}$ is 6.0×10^{-2} at 770 K, what is the value of the equilibrium constant based on pressures, K_p , at this temperature?
- a) 240
 - b) 3.8
 - c) 1.5×10^{-5}
 - d) 9.5×10^{-4}
 - e) Cannot be determined from information given
65. For the reaction $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$, which of the following changes will shift the equilibrium to the left (toward reactants) if H_{rxn} is -92.9 kJ?
- I. Increasing the temperature
 - II. Increasing the volume
 - III. Removing NH_3
 - IV. Removing H_2
- a) All of the above
 - b) II and IV
 - c) I and II
 - d) I and III
 - e) I, II and IV
66. If $K_p = 1.16$ at 800 °C for the reaction $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$, what percent of a 1.00 g sample placed in a 5.00 L container will react to reach equilibrium at this temperature?
- a) 0 %
 - b) 6.58 %
 - c) 65%
 - d) 100%
 - e) Cannot be determined from information given.

67. The autoionization of water at 40 °C has an equilibrium constant value of 2.92×10^{-14} . What is the value of ΔG° for this reaction at 40 °C?
- +81.1 kJ
 - 81.1 kJ
 - 801 J
 - 801 J
 - Cannot be determined from information given
68. Consider the enthalpy and entropy associated with the dissociation of diatomic hydrogen gas: $\text{H}_{2(g)} \rightleftharpoons 2\text{H}_{(g)}$. One would expect that this reaction
- cannot be determined from information given
 - will be spontaneous at high temperatures
 - will be spontaneous only at low temperatures
 - will not be spontaneous at any temperature
 - will be spontaneous at all temperatures
69. A 2.0 L flask is filled with 1.2 mol of gas A and 0.60 mol of gas C. These react according to the equation $2\text{A} \rightleftharpoons \text{B} + 3\text{C}$. After equilibrium is reached, the concentration of B is found to be 0.20 mol/L. What is the value of the equilibrium constant?
- 9.0×10^{-1}
 - 11
 - 1.2
 - 3.6
 - 6.3
70. What is the pH of an aqueous solution that is 1.34×10^{-12} M in KOH at 25 °C?
- 11.9
 - 2.13
 - 7.00
 - 11.9
 - Cannot be determined from information given
71. The K_{sp} of BaF_2 is 2.4×10^{-5} . When 10 mL of 0.010 M NaF is mixed with 15 mL of 0.0075 M $\text{Ba}(\text{NO}_3)_2$, will a precipitate form?
- Yes because $Q = 1.8 \times 10^{-5}$ and since this is less than K_{sp} , a precipitate will form
 - No because $Q = 1.8 \times 10^{-5}$ and since this is less than K_{sp} , a precipitate will not form
 - Yes because $Q = 7.2 \times 10^{-8}$ and since this is more than K_{sp} , a precipitate will not form
 - No because $Q = 7.2 \times 10^{-8}$ and since this is less than K_{sp} , a precipitate will not form
 - Cannot be determined from information given.

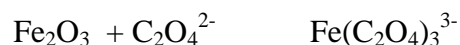
72. When heat is added to proteins, the hydrogen bonding in the secondary structure breaks apart. What are the algebraic signs of ΔH and ΔS for the denaturation process?
- both ΔH and ΔS are positive
 - both ΔH and ΔS are negative
 - ΔH is positive and ΔS is negative
 - ΔH is negative and ΔS is positive
 - ΔH is positive and ΔS is zero

Section 6 Electron Transfer Processes

73. Which of the following are oxidation-reduction reactions?



- All of the above
 - II and IV
 - II, IV and V
 - I, II and V
 - I and II
74. When the following reaction is balanced under acidic conditions in aqueous solution, the coefficient of H^+ is found to be what number?



- H^+ does not take part in this reaction
 - 12
 - 6
 - 2
 - 9
75. The following unbalanced redox reaction occurs in basic solution.



How many moles of MnO_4^- are required to produce one mole of CO_3^{2-} ?

- 2
- 3
- 6
- 1/3
- 1/6

76. How many electrons are transferred in the following redox reaction?

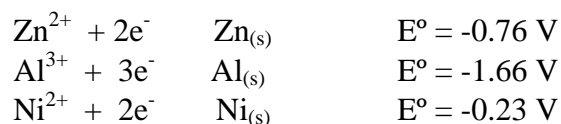


- a) 12
- b) 5
- c) 2
- d) 10
- e) 15

77. Which of the following species cannot function as an oxidizing agent?

- a) $\text{S}_{(s)}$
- b) $\text{NO}_3^-_{(aq)}$
- c) $\text{Cr}_2\text{O}_7^{2-}_{(aq)}$
- d) $\text{I}^-_{(aq)}$
- e) $\text{MnO}_4^-_{(aq)}$

78. Which metal, Al or Ni, could reduce Zn^{2+} to $\text{Zn}_{(s)}$ if placed in an aqueous solution of Zn^{2+} ?

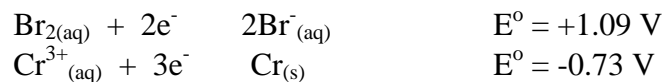


- a) Al
- b) Ni
- c) Both Al and Ni would work
- d) Neither Al nor Ni would work
- e) Cannot be determined from information given

79. If the standard half cell potential of the reduction of Cu^{2+} to Cu metal is + 0.34 V and the standard half cell potential of the reduction of Al^{3+} to Al metal is – 1.66 V, what, if anything will happen when copper(II) nitrate solution is shipped in aluminum cans?

- a) nothing can be predicted from the information given
- b) no reaction will occur
- c) copper will plate out on the inside of the containers
- d) aluminum will plate out on the inside of the containers
- e) the concentration of aluminum ions in the solution will decrease

80. The following three questions refer to this cell. A galvanic cell is constructed in which one solution contains 0.50 M Br₂ and 0.10 M Br⁻ and the other contains 0.20 M Cr³⁺. The standard reduction potential are



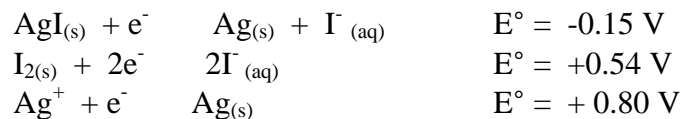
What is E° for this cell?

- a) 0.36 V
b) 4.75 V
c) 4.40 V
d) 1.79 V
e) 1.82 V
81. For the cell described in the problem above, what is the value of E for this cell at 25 °C?
- a) 2.21 V
b) 1.76 V
c) 2.12 V
d) 1.88 V
e) 0.59 V
82. For the cell described in the problem above, which of the following statements is *false*?
- a) This is a galvanic cell
b) Electrons flow from the electrode in the bromine/bromide solution to the electrode in the chromium ion solution
c) Reduction occurs in the bromine/bromide solution
d) The cell is not at standard conditions
e) Electrons flow from the electrode in the chromium ion solution to the electrode in the bromine/bromide solution.
83. A fuel cell has the following net reaction in which one mole of alcohol can yield 1320 kJ at a maximum. What is theoretical maximum voltage of this cell?



- a) 0.760 V
b) 1.14 V
c) 2.01 V
d) 2.28 V
e) 13.2 V

84. Calculate the solubility product constant of silver iodide at 25 °C given the following data:



- a) 2.9×10^{-3}
- b) 1.9×10^{-4}
- c) 2.1×10^{-12}
- d) 8.5×10^{-17}
- e) 2.4×10^{-24}

Section 7 Kinetics

85. The rate of a chemical reaction in aqueous solution is affected by all of the following *except*
- a) the temperature of the reaction mixture
 - b) the orientation of the collisions between reacting species
 - c) the frequency of the collisions between reacting species
 - d) the presence of a catalyst
 - e) the size of the container, other factors being constant
86. Which of the following statements is *false*?
- a) The rate law cannot be deduced from examination of the overall balanced equation for a reaction
 - b) The activation energy of a reaction depends on the difference in total internal energies between products and reactants (E) for the reaction
 - c) The presence of a homogeneous or heterogeneous catalyst alters the activation energy of the reaction
 - d) Orientation of the reactants during a collision may be important to the rate of reaction
 - e) A second order rate law suggests a rate-determining step involving collision of two species.
87. If the units on a rate constant are given as $\text{L}^2 \text{mol}^{-2} \text{s}^{-1}$, the reaction under consideration must be
- a) overall first order
 - b) overall second order
 - c) overall third order
 - d) overall a non-integral order
 - e) The order of the reaction cannot be determined from the information given

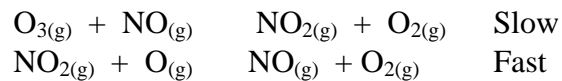
88. The following rate data were obtained by experiment

<u>[A]₀ (mol/L)</u>	<u>[B]₀ (mol/L)</u>	<u>Initial Rate (μmol/L s)</u>
2.21	1.00	0.619
4.42	1.00	1.24
4.42	3.00	3.71

What is the form of the differential rate law?

- a) first order in [A] and zeroth order in [B]
 - b) first order in both [A] and [B]
 - c) second order in both [A] and [B]
 - d) second order in [A] and first order in [B]
 - e) zeroth order in [A] and second order in [B]
89. For the reaction described in Problem 88 above, what would be the initial rate for an experiment with $[A]_0 = 3.36 \text{ mol/L}$ and $[B]_0 = 2.40 \text{ mol/L}$?
- a) 2.26 mol/L
 - b) 5.42 mol/L
 - c) 0.619 mol/L
 - d) 3.71 mol/L
 - e) Cannot be determined from information given
90. The rate constant for a reaction at 40.0 °C is exactly three times that at 20.0 °C. What is the Arrhenius energy of activation for this reaction?
- a) 3.00 kJ/mol
 - b) 366 kJ/mol
 - c) 41.9 kJ/mol
 - d) 3.20 kJ/mol
 - e) None of the above
91. For the reaction $aA \rightarrow bB$, at a particular temperature, when $[A]_0 = 2.00 \times 10^{-3} \text{ M}$, a plot of $\ln[A]$ versus time data yields a straight line of slope $-2.97 \times 10^{-3} \text{ min}^{-1}$. How much time is required for the concentration of A to be reduced to $2.5 \times 10^{-4} \text{ M}$?
- a) 700 min
 - b) 700 sec
 - c) 2700 sec
 - d) 270 sec
 - e) Cannot be determined from information given

92. One proposed mechanism for the destruction of ozone has these two elementary steps



For the overall reaction, which of these species can be considered catalysts?

- a) $\text{O}(\text{g})$
- b) $\text{NO}(\text{g})$
- c) $\text{NO}_2(\text{g})$
- d) $\text{NO}(\text{g})$ and $\text{NO}_2(\text{g})$
- e) $\text{O}_3(\text{g})$ and $\text{NO}(\text{g})$

Section 8 Organic and Nuclear Chemistry

93. Electron capture transforms ^{40}K into what nuclide?

- a) ^{40}Ca
- b) ^{40}Ar
- c) ^4He
- d) $^{40}\text{K}^-$
- e) ^{39}Ca

94. Which of the following processes increases the atomic number by 1?

- a) gamma-ray production
- b) electron capture
- c) beta-particle production
- d) positron production
- e) alpha-particle production

95. If neutron capture of uranium-238 is followed by two successive beta decays, what is the final product?

- a) ^{239}Pu
- b) ^{235}Ra
- c) ^{235}U
- d) ^{238}Pu
- e) ^{239}Np

96. A certain type of nucleus decays via first-order kinetics with a rate constant of $1.0 \times 10^{-3} \text{ h}^{-1}$. If a sample contains 5.0×10^9 radioactive nuclides of this type, what is the time required for 77 % of these nuclides to decompose?
- a) $2.6 \times 10^2 \text{ h}$
 - b) $6.8 \times 10^{-4} \text{ h}$
 - c) $1.5 \times 10^3 \text{ h}$
 - d) $2.1 \times 10^3 \text{ h}$
 - e) $7.7 \times 10^{-4} \text{ h}$
97. The compound $\text{H}_2\text{CCHCH}_2\text{N}(\text{CH}_3)_2$ is
- a) an alkyne with a secondary amine
 - b) an alkene with a primary amine
 - c) an alkene with a tertiary amine
 - d) an alkyne with a tertiary amine
 - e) none of these
98. Which of these functional groups lacks an sp^2 hybridized carbon center?
- a) aldehyde
 - b) ketone
 - c) alcohol
 - d) alkene
 - e) amide
99. How many geometric isomers can be drawn for the following compound:
- $$\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}=\text{C}(\text{CH}_3)_2$$
- a) 2
 - b) 3
 - c) 4
 - d) 5
 - e) 6
100. Which of the following yields a primary alcohol upon reduction?
- a) a ketone
 - b) an alkene
 - c) an amine
 - d) an aldehyde
 - e) an ether

END OF EXAMINATION

INDIANA SECTION of the AMERICAN CHEMICAL SOCIETY

High School Scholarship Exam Answer Key

April 12, 2003



1. B	21. E	41. B	61. C	81. D
2. C	22. B	42. C	62. D	82. B
3. B	23. C	43. A	63. C	83. B
4. A	24. B	44. C	64. C	84. D
5. D	25. A	45. E	65. E	85. E
6. B	26. D	46. B	66. D	86. B
7. C	27. B	47. D	67. A	87. C
8. D	28. B	48. D	68. B	88. B
9. C	29. B	49. B	69. D	89. A
10. A	30. A	50. C	70. C	90. C
11. A	31. C	51. B	71. D	91. A
12. A	32. A	52. C	72. A	92. B
13. A	33. E	53. A	73. E	93. B
14. C	34. C	54. B	74. C	94. C
15. B	35. E	55. B	75. D	95. A
16. E	36. B	56. C	76. D	96. C
17. D	37. E	57. A	77. D	97. C
18. D	38. B	58. E	78. A	98. C
19. D	39. E	59. A	79. C	99. A
20. C	40. A	60. D	80. E	100. D