

INDIANA SECTION of the AMERICAN CHEMICAL SOCIETY

High School Scholarship Exam

April 13, 2002



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.

1. Which of the following are physical changes?
- I. vaporization of water
 - II. melting of ice
 - III. combustion of methane
 - IV. digestion of a protein
 - V. sublimation of carbon dioxide
 - VI. dissolution of sugar in water
- a) I, II, V, VI
 - b) III, IV
 - c) I, II
 - d) III, IV, V, VI
 - e) I, II, VI
2. Which of the following is a pure substance?
- a) lemonade
 - b) tap water
 - c) bronze
 - d) carbon dioxide
 - e) air
3. Consider a mixture of sand in salt water. This mixture could be separated into its three components (sand, salt, and water) by first _____ the mixture and then _____ the mixture.
- a) distilling, distilling
 - b) distilling, filtering
 - c) filtering, distilling
 - d) shaking, distilling
 - e) stirring, filtering
4. Which of the following is the smallest mass?
- a) 25 kg
 - b) 2.5×10^{-2} Mg
 - c) 2.5×10^{10} pg
 - d) 2.5×10^{14} fg
 - e) 2.5×10^{10} ng
5. An object will sink in a liquid if the density of the object is greater than that of the liquid. What volume must an object have if its mass is 9.83 g for it to sink in liquid mercury (density = 13.6 g/cm^3)?
- a) greater than 0.723 cm^3
 - b) less than 0.723 cm^3
 - c) greater than 1.38 cm^3
 - d) less than 1.38 cm^3
 - e) greater than 0.134 cm^3

6. A laboratory technician analyzed a standard known to contain 135 ppm lead. The following results were obtained. Which one of the following is true concerning this data set?

<u>Trial</u>	<u>ppm Lead</u>
1	169
2	114
3	142
4	115

- a) the data set is both precise and accurate
b) the data set is neither precise nor accurate
c) the data set is accurate but not precise
d) the data set is precise but not accurate
7. You need to add exactly 25.00 mL of reagent X to your reaction mixture. Which of the following would be the most accurate glassware for this transfer?
- a) 50-mL beaker
b) 50-mL pipet
c) 25-mL graduated cylinder
d) 25-mL pipet
e) 50-mL Erlenmeyer
8. Which of the following numbers has the greatest number of significant figures?
- a) 0.000302
b) 100.0
c) 0.105
d) 100
9. One molecule of a compound has a mass of 1.463×10^{-22} g. It has a composition by mass of 54.5 % C, 9.15 % H, and 36.3 % O. What is the formula of this compound?
- a) $C_4H_8O_2$
b) C_2H_4O
c) $C_5H_{12}O$
d) $C_3H_4O_3$
10. How many electrons, protons, and neutrons are in the ion ${}^{197}_{79}\text{Au}^{3+}$?
- a) 3, 79, 197
b) 82, 79, 118
c) 79, 79, 197
d) 76, 79, 118
e) 194, 79, 79

11. Consider the supplied periodic table. The elements in groups IA, IIA, and VIIA are called, respectively:
- alkali metals, alkaline earth metals, halogens
 - alkaline earth metals, alkali metals, halogens
 - transition metals, chalcogens, halogens
 - active metals, active (II) metals, halogens
 - alkali metals, alkaline earth metals, noble gases
12. The empirical formula of a compound made up of molecules containing 12 carbon atoms, 14 hydrogen atoms, and 6 oxygen atoms is:
- $C_{12}H_{14}O_6$
 - $C_{24}H_{28}O_{12}$
 - $C_6H_7O_3$
 - C_2H_4O
13. What is the formula for the compound formed between strontium ions and nitride ions?
- SrN
 - Sr_3N_2
 - SrN_2
 - Sr_2N_3
 - Sr_2N
14. Which of the following ions has a -1 charge?
- ammonium
 - sulfate
 - carbonate
 - monohydrogen phosphate
 - cyanide
15. What is the charge on the arsenate ion, AsO_4^x ?
- 3-
 - 2-
 - 1-
 - 1+
 - 2+

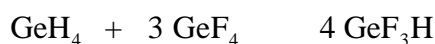
16. The correct name for the compound SiCl_4 is:
- silicon chloride
 - silicon tetrachlorine
 - silicon chlorine
 - silicon (IV) chloride
 - silicon tetrachloride
17. What is the coefficient of O_2 when the following equation is correctly balanced?
- $$\text{C}_3\text{H}_8\text{O}_3 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$
- 1
 - 2
 - 3
 - 5
 - 7
18. What is the formula weight in amu of $(\text{NH}_4)_3\text{PO}_4$?
- 149.1
 - 144.1
 - 133.1
 - 113.0
19. How many grams of sodium ions are needed to prepare 50.0 g of Na_2CO_3 ?
- 10.8
 - 21.7
 - 23.0
 - 46.0
20. Each molecule of water is made from _____ hydrogen atoms. One mole of water is made from _____ hydrogen atoms.
- two . . . 1.20×10^{24}
 - two . . . 6.02×10^{23}
 - 6.02×10^{23} . . . 1.20×10^{24}
 - 1.20×10^{24} . . . two
 - 6.02×10^{23} . . . two
21. Calculate the number of chlorine atoms present in 15.0 mL of methylene chloride (CH_2Cl_2). The density of methylene chloride is 1.32 g/mL.
- 1.40×10^{23}
 - 1.61×10^{23}
 - 2.81×10^{23}
 - 8.05×10^{22}
 - 2.81×10^{24}

22. Ethanol burns according to the following equation:



What mass of carbon dioxide can be formed by complete combustion of 10.0 grams of ethanol in excess oxygen?

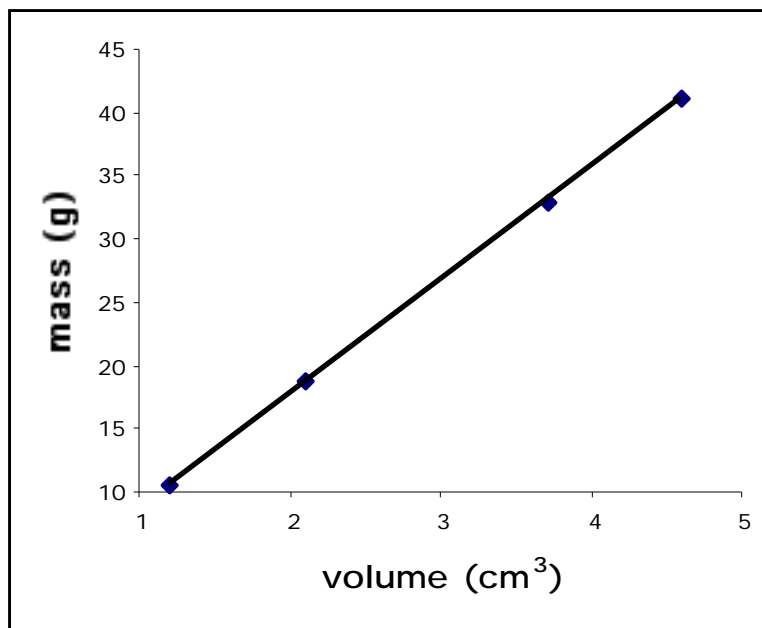
- a) 19.1 g
b) 9.57 g
c) 20.9 g
d) 10.0 g
23. How many moles of GeF_4 are needed to form 8.00 moles of GeF_3H according to the reaction if the product is obtained in 92.6 % yield?



- a) 5.56 mol
b) 6.48 mol
c) 6.00 mol
d) 9.85 mol
e) 11.5 mol
24. A 25.0-g sample of aluminum is reacted with 50.0 g of hydrogen chloride to produce aluminum chloride and hydrogen as shown below. After the reaction is complete, what mass of excess reactant will remain? $2 \text{Al (s)} + 6 \text{HCl (g)} \rightarrow 2 \text{AlCl}_3 \text{(g)} + 3 \text{H}_2 \text{(g)}$
- a) 12.3 g Al
b) 12.7 g Al
c) 16.7 g Al
d) 25.0 g HCl
e) 36.5 g HCl
25. An element M forms both a dichloride MCl_2 and a tetrachloride MCl_4 . Treatment of 15.00 g of MCl_2 with excess chlorine forms 20.61 g of MCl_4 . Identify M.
- a) Os
b) Pb
c) Pt
d) Sn
e) Lr
26. Two solutions are mixed: 50.0 mL of 0.10 M K_3PO_4 (aq) and 25.0 mL of 0.20 M KNO_3 . Calculate the concentration of potassium ion in the resulting mixture.
- a) 0.010 M
b) 0.020 M
c) 0.13 M
d) 0.15 M
e) 0.27 M

27. How many milliliters of 0.510 M NiCl_2 must be measured out to obtain 1.00 g of NiCl_2 ?
- a) 3.85 mL
 - b) 15.1 mL
 - c) 20.8 mL
 - d) 151 mL

28. In lab you measure the mass and the volume of each of four solid copper metal samples. In your data analysis, you plot the mass as a function of volume for the samples as shown below. The slope of the best fit line through the data points approximates:

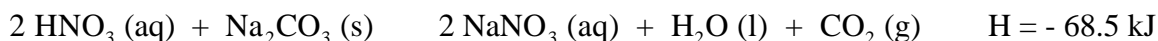


- a) the molar mass of copper
 - b) the density of copper
 - c) the volume of copper
 - d) the mass of copper
29. Gases consist mostly of
- a) electron clouds
 - b) atomic nuclei
 - c) empty space
 - d) ions
30. A tank containing both HF and HBr gases developed a leak. Which gas will effuse faster and by what factor?
- a) HF, 2
 - b) HF, 4
 - c) HBr, 2
 - d) HBr, 4
 - e) They will effuse at the same rate

31. A certain metal oxide, M_2O , was decomposed into its constituent elements, a solid metal M and gaseous O_2 , according to the following balanced equation:
- $$2 M_2O (s) \rightarrow 4 M (s) + O_2 (g)$$
- If 1.42 g of the metal oxide produced 68.6 mL of O_2 (g) at STP, what is the identity of the metal M ?
- Pa
 - Ag
 - U
 - At
 - Fr
32. An unweighed quantity of O_2 and 0.66 g of helium and are mixed in a flask at room temperature. The partial pressure of helium in the flask is 55 torr, and the partial pressure of O_2 is 125 torr. What is the mass of the oxygen in the container?
- 1.5 g
 - 2.3 g
 - 6.0 g
 - 12 g
 - 24 g
33. Treatment of Zn with aqueous HCl produced $ZnCl_2(aq)$ and hydrogen gas. The H_2 (g) produced by the reaction was collected by displacement of water in an inverted test tube held in a dish of water. After the reaction was complete, the test tube was adjusted so that the water level in the test tube was at the same height as the water level in the dish. Which of the following is true about the gas collected?
- The pressure of the H_2 collected is greater than the atmospheric pressure.
 - The pressure of the H_2 collected is less than the atmospheric pressure.
 - The pressure of the H_2 collected equals the atmospheric pressure.
 - There is no pressure of H_2 because it was collected in a vacuum.
34. Consider a 1.0-L vessel of fixed volume containing neon gas at STP. What effect does doubling the number of moles of neon in the vessel have on the following?
- average kinetic energy
 - average velocity
 - frequency of collisions of gas molecules with the walls of the container
- decrease, decrease, increase
 - increase, remain the same, increase
 - remain the same, remain the same, increase
 - remain the same, decrease, remain the same
 - increase, increase, increase

35. Consider a mixture of two gases, A and B, confined to a closed vessel of fixed volume. A quantity of a third gas, C, is added to the same vessel at the same temperature. How does the addition of gas C affect the following?
- I. the partial pressure of gas A
 - II. the total pressure in the vessel
 - III. the mole fraction of gas B
- a) decrease, increase, increase
 - b) increase, remain the same, increase
 - c) remain the same, remain the same, increase
 - d) remain the same, increase, decrease
 - e) decrease, increase, remain the same
36. A 15.0-g sample of nickel metal is heated to 100.0 °C and dropped into 55.0 g of water, initially at 23.0 °C in an insulated container. Assuming that all the heat lost by the nickel is absorbed by the water, calculate the final temperature of the nickel and water. The specific heat of nickel is 0.444 J/g•°C and the specific heat of water is 4.18 J/g•°C.
- a) 78.4 °C
 - b) 61.5 °C
 - c) 34.5 °C
 - d) 27.6 °C
 - e) 25.2 °C
37. A sample of an oxide of manganese of unknown empirical formula and of mass 10.00 g gave only 8.77 g of pure manganese(II,III) oxide, Mn_3O_4 (s), and oxygen gas when heated to a constant mass. What is the empirical formula of the original oxide of manganese? Assume complete decomposition of the original oxide of manganese.
- a) MnO
 - b) MnO_2
 - c) Mn_2O_3
 - d) Mn_2O_7
38. Use the average bond enthalpy values provided below to calculate the enthalpy change for the following reaction: $\text{N}_2 + 3 \text{H}_2 \rightarrow 2 \text{NH}_3$
- | <u>average bond enthalpies in kJ/mol</u> | | | | | | | |
|--|-----|------|-----|------|-----|-----|-----|
| C-H | 413 | N-H | 391 | H-H | 436 | N=N | 418 |
| C-C | 348 | N-N | 163 | H-F | 567 | N N | 941 |
| C-N | 293 | N-O | 201 | H-Cl | 431 | C=C | 614 |
| C-O | 358 | N-Br | 243 | H-O | 463 | C=N | 615 |
- a) + 204 kJ
 - b) - 204 kJ
 - c) + 97 kJ
 - d) - 97 kJ
 - e) - 574 kJ

39. On Easter Sunday, April 3, 1983, nitric acid was spilled from a tank car near downtown Denver, CO. The spill was neutralized with sodium carbonate:



Approximately 7.6×10^4 L of nitric acid was spilled. Assume that the acid was an aqueous solution containing 70 % HNO_3 by mass with a density of 1.42 g/cm^3 . How much heat was evolved in the neutralization reaction?

- a) 4.1×10^7 kJ
b) 8.3×10^7 kJ
c) 5.8×10^7 kJ
d) 8.3×10^{10} kJ
e) 4.1×10^8 kJ
40. How many electrons in the ground state zinc atom have $m_l = -1$ as one of their quantum numbers?
- a) 2
b) 4
c) 6
d) 8
e) 10
41. What ground state element with its 1st, 2nd, 3rd, and 4th shells completely filled has the lowest atomic number?
- a) Cd
b) Kr
c) Lr
d) Lu
e) Zn
42. Arrange the following in order of increasing radius: Mn^{2+} , Mn^{3+} , Fe^{3+} , Mn
- a) Mn, Mn^{2+} , Mn^{3+} , Fe^{3+}
b) Mn^{2+} , Mn^{3+} , Fe^{3+} , Mn
c) Mn, Fe^{3+} , Mn^{2+} , Mn^{3+}
d) Fe^{3+} , Mn^{3+} , Mn^{2+} , Mn
e) Mn^{3+} , Fe^{3+} , Mn^{2+} , Mn
43. In general, an anion is _____ its corresponding atom while a cation is _____ its corresponding atom.
- a) smaller than . . . larger than
b) larger than . . . smaller than
c) larger than . . . the same size as
d) the same size as . . . the same size as
e) the same size as . . . smaller than

44. Arrange the following ions in order of increasing ionization energy: O^{2-} , F , Na^+ , Mg^{2+}
- O^{2-} , F , Na^+ , Mg^{2+}
 - Mg^{2+} , Na^+ , F , O^{2-}
 - F , O^{2-} , Mg^{2+} , Na^+
 - Na^+ , Mg^{2+} , O^{2-} , F
45. The ionization energy of gold is 8.90×10^2 kJ/mole. What is the maximum wavelength of light that is capable of ionizing a gold atom in the gas phase?
- 135 nm
 - 806 nm
 - 327 nm
 - 196 nm
46. Based on the positions of the elements on the periodic table, rank the following bonds in order of increasing polarity: P-P, P-N, P-O, P-F
- P-F, P-N, P-O, P-P
 - P-F, P-O, P-N, P-P
 - P-P, P-F, P-O, P-N
 - P-P, P-N, P-O, P-F
 - P-P, P-O, P-N, P-F
47. Third row and larger elements often exceed the octet rule when forming molecular compounds because:
- large elements have "free floating" electrons that can bond in several places
 - they have larger p orbitals that can hold more electrons
 - their valence electrons are so close to the nucleus
 - they can use their d orbitals for bonding
48. In which of the following does the central atom have a sp^3d hybrid orbital set?
- NH_4^+
 - XeF_4
 - PCl_4^-
 - SF_6
 - IF_5
49. Which of the following have a net dipole moment?
- | | | | |
|------------|--------------|-----------------|--|
| I. BF_3 | II. NO_3^- | III. CH_2Cl_2 | |
| IV. CO_2 | V. PCl_3 | | |
- II, III, IV
 - III, V
 - I, II, IV
 - II, III, V
 - III, IV, V

50. Compounds like CCl_2F_2 are known as chlorofluorocarbons, or CFCs. These compounds were once widely used as refrigerants but are now being replaced by compounds that are believed to be less harmful to the environment. The heat of vaporization of CCl_2F_2 is 289 J/g . What mass of this substance must evaporate in order to freeze 100.0 g of water initially at $18.0 \text{ }^\circ\text{C}$? The heat of fusion of water is 334 J/g ; the specific heat of water is $4.18 \text{ J/g}\cdot^\circ\text{C}$.

- a) 142 g
- b) 116 g
- c) 100 g
- d) 409 g
- e) 86.5 g

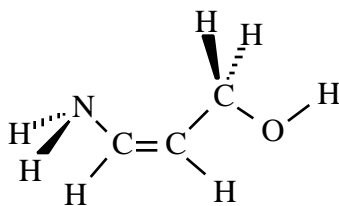
51. Sodium thiosulfate hydrate, $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, is commonly used as a photographic fixer. You are an amateur photographer in addition to a chemist, and decide to determine the exact stoichiometry of the sodium thiosulfate hydrate in your dark room. You heat a known mass of the hydrate in a crucible to remove the water of hydration then reweigh the anhydrous $\text{Na}_2\text{S}_2\text{O}_3$. You do three trials and collect the following data.

	mass of $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$ (g)	mass of anhydrous $\text{Na}_2\text{S}_2\text{O}_3$ (g)
Trial # 1	4.96	3.17
Trial # 2	7.44	4.72
Trial # 3	9.92	6.34

What is the value of x in the formula $\text{Na}_2\text{S}_2\text{O}_3 \cdot x\text{H}_2\text{O}$?

- a) 1
- b) 3
- c) 5
- d) 7
- e) 9

52. How many sigma () bonds, pi () bonds, and nonbonding pairs of valence electrons are in the molecule shown below?



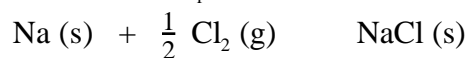
- a) 10 bonds, 1 pi bond, 3 nonbonding pairs
- b) 11 bonds, 1 pi bond, 3 nonbonding pairs
- c) 11 bonds, 1 pi bond, 2 nonbonding pairs
- d) 10 bonds, 2 pi bonds, 0 nonbonding pairs
- e) 10 bonds, 2 pi bonds, 3 nonbonding pairs

53. What is the oxidation number of chlorine in the chlorite ion, ClO_2^- ?
- 1
 - 0
 - +1
 - +3
 - +5
54. In the following reaction, what species is reduced?
 $\text{FeBr}_2(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{ZnBr}_2(\text{aq}) + \text{Fe}(\text{s})$
- Zn
 - Zn^{2+}
 - Fe
 - Fe^{2+}
 - Fe^{3+}
55. Which of the following is a weak electrolyte?
- $\text{HCl}(\text{aq})$
 - $\text{NaOH}(\text{aq})$
 - $\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$
 - $\text{NaCl}(\text{aq})$
56. Write the balanced net ionic equation for the reaction that occurs when the following are mixed.
 $\text{AgC}_2\text{H}_3\text{O}_2(\text{aq}) + \text{K}_3\text{PO}_4(\text{aq})$
- $\text{Ag}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Ag}_3\text{PO}_4(\text{s})$
 - $3\text{Ag}^+(\text{aq}) + \text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Ag}_3\text{PO}_4(\text{s})$
 - $3\text{K}^+(\text{aq}) + 3\text{C}_2\text{H}_3\text{O}_2^-(\text{aq}) \rightarrow 3\text{KC}_2\text{H}_3\text{O}_2(\text{s})$
 - $\text{K}^+(\text{aq}) + \text{C}_2\text{H}_3\text{O}_2^-(\text{aq}) \rightarrow \text{KC}_2\text{H}_3\text{O}_2(\text{s})$
 - there is no net ionic equation; all species are soluble spectator ions
57. Balance the following redox reaction that occurs in acidic solution. What is the coefficient of CH_2O in the balanced equation?
 $\text{CH}_3\text{OH}(\text{aq}) + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) \rightarrow \text{CH}_2\text{O}(\text{aq}) + \text{Cr}^{3+}(\text{aq})$
- 1
 - 3
 - 6
 - 7
 - 9

58. A certain alkane was found to contain 82.8 % C by mass. What is the proper molecular formula of the alkane?
- C_2H_5
 - C_3H_8
 - C_4H_{10}
 - C_8H_{20}
 - C_4H_8
59. Which of the following would have the lowest vapor pressure at 25 °C ?
- F_2
 - Cl_2
 - Br_2
 - I_2
60. Which of the following must be true for a substance whose triple point occurs at 222 K and 3.93 atm?
- A solid sample of this substance at 1 atm will melt rather than sublime when subjected to standard temperature and pressure.
 - This substance is a liquid at standard temperature and pressure.
 - This substance will have a critical point of 233 K and 2.93 atm.
 - A solid sample of this substance at 1 atm will sublime rather than melt when subjected to standard temperature and pressure.
 - This substance will not have a critical point.
61. Vanadium crystallizes to afford a body-centered cubic unit cell, which has atoms at the center and corners of a cube. The length of the edge of the unit cell is found by X-ray diffraction to be 3.05×10^{-10} m. Calculate the density of vanadium from the information given.
- 5.96 g/cm³
 - 11.9 g/cm³
 - 2.68 g/cm³
 - 6.67 g/cm³
62. Which of the following contains an ester functional group?
- $CH_3-\overset{\overset{O}{\parallel}}{C}-H$
 - $CH_3-\overset{\overset{O}{\parallel}}{C}-OH$
 - $CH_3-\overset{\overset{O}{\parallel}}{C}-CH_2-CH_3$
 - $CH_3-O-CH_2-CH_3$
 - $CH_3-\overset{\overset{O}{\parallel}}{C}-O-CH_3$

63. Which of the following has (have) delocalized bonding?
- I. CO_2 III. C_2H_4
II. CO_3^{2-} IV. C_6H_6
- a) I only
b) II only
c) IV only
d) III and IV
e) II and IV
64. In general, as you go across a period from left to right on the periodic table the atomic radius _____, the energy of the electron affinity becomes more _____, and the first ionization energy _____.
- a) decreases, positive, increases
b) decreases, negative, decreases
c) increases, positive, increases
d) decreases, negative, increases
e) increases, negative, increases
65. Which of the following properties of a liquid is NOT affected by an increase in intermolecular forces?
- a) viscosity
b) molecular weight
c) heat of vaporization
d) boiling point
e) volatility
66. Rank the following in order of increasing melting point: C_6H_{14} , CO_2 , Mg, MgO .
- a) C_6H_{14} , CO_2 , Mg, MgO
b) CO_2 , Mg, MgO, C_6H_{14}
c) CO_2 , C_6H_{14} , Mg, MgO
d) CO_2 , C_6H_{14} , MgO, Mg
e) MgO, Mg, C_6H_{14} , CO_2
67. In which compound would you expect hydrogen to have an oxidation number of -1 ?
- a) H_2
b) NaH
c) CH_4
d) NH_3
e) HCl

68. Use the following data to estimate H_f° for sodium chloride.



Lattice Energy	- 786 kJ/mol
Ionization Energy for Na	495 kJ/mol
Electron Affinity of Cl	- 349 kJ/mol
Bond Energy of Cl_2	239 kJ/mol
Enthalpy of sublimation for Na	109 kJ/mol

- a) - 292 kJ/mol
b) - 412 kJ/mol
c) + 292 kJ/mol
d) + 1160 kJ/mol
e) - 1980 kJ/mol
69. A 1.0 gram sample of KOH (s) was dissolved in 1.5 L of water. What is the pH of the resulting solution?
- a) 1.00
b) 1.93
c) 12.07
d) 12.25
e) 13.00
70. Sodium carbonate, Na_2CO_3 , can be used to neutralize nitric acid. The neutralization reaction proceeds as follows:
- $$\text{Na}_2\text{CO}_3 + 2 \text{HNO}_3 \rightarrow 2 \text{NaNO}_3 + \text{H}_2\text{O} + \text{CO}_2$$
- In the process of neutralizing some acid solution generated in lab, you add 2.5 grams of solid Na_2CO_3 to a beaker containing 2.00 L of 0.025 M aqueous nitric acid. What is the approximate pH of the resulting solution? Assume no volume change occurs upon addition of the Na_2CO_3 to the nitric acid solution.
- a) 1.33
b) 1.63
c) 2.55
d) 2.85
e) 7.00
71. When a saturated salt solution is in contact with the solid salt
- a) the rate of crystallization > the rate of dissolution
b) the rate of dissolution > the rate of crystallization
c) seed crystal addition may cause massive crystallization
d) the rate of crystallization = the rate of dissolution
e) addition of more water causes massive crystallization

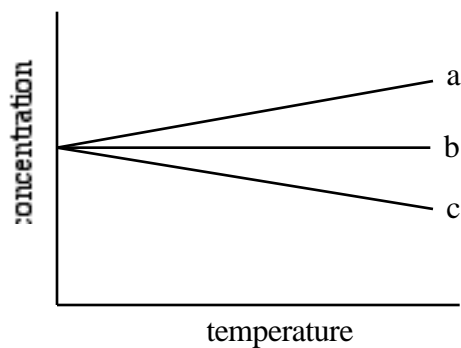
72. Consider a pure, crystalline substance being heated from absolute zero to some very high temperature. Which one of the following processes produces the greatest increase in the entropy (i. e. largest ΔS) of the substance per a unit energy input?

- a) heating the solid
- b) melting the solid
- c) heating the liquid
- d) boiling the liquid
- e) heating the gas

73. A solution is prepared by dissolving 59.4 g of CaCl_2 in 290. g of water. The density of the resulting solution is 1.15 g/mL. Calculate the concentration (in molarity) of Cl^- in the solution described above. Assume that the calcium chloride is completely dissociated into ions.

- a) 1.76 M
- b) 3.52 M
- c) 1.84 M
- d) 3.69 M
- e) 1.33 M

74. Which of the following lines best describes the solubility of a gas in a liquid?



- a) a
- b) b
- c) c
- d) none of the above

75. What is the mass percent of nitrogen in ammonium nitrate, NH_4NO_3 ?

- a) 14.0 %
- b) 17.5 %
- c) 28.0 %
- d) 35.0 %
- e) 70.0 %

76. When a non-volatile solute is added to a volatile solvent, the solution vapor pressure _____, the boiling point _____, and the freezing point _____.
- decreases, decreases, decreases
 - increases, remains the same, increases
 - remains the same, increases, decreases
 - increases, increases, decreases
 - decreases, increases, decreases
77. When argon is placed in a container of neon, the argon spontaneously disperses throughout the neon. Why?
- the dispersion of argon atoms produces an increase in disorder
 - there are large attractive forces between argon and neon atoms
 - hydrogen bonding occurs
 - the gases absorb heat energy from the surroundings upon mixing
 - solvent-solute interactions promote mixing
78. Wool, hair, and fingernails are made of fibrous proteins known as α -keratins. α -Keratins are composed almost entirely of α -helices, a structure in which single protein chains are coiled in a spiral with a right-handed twist. What type of bonding holds the protein chain in the shape of an α -helix?
- intramolecular hydrogen bonding
 - intermolecular hydrogen bonding
 - disulfide linkages
 - covalent bonds
 - β -pleated sheet
79. In the reaction $2 \text{NO}_2 \rightarrow 2 \text{NO} + \text{O}_2$ at 300°C , $[\text{NO}_2]$ decreases from 0.010 M to 0.0065 M in 100 seconds. What is the average rate of appearance of O_2 for this period in M/s ?
- 1.8×10^{-5}
 - 3.5×10^{-5}
 - 6.5×10^{-5}
 - 7.0×10^{-5}
 - 1.3×10^{-4}
80. A catalyst increases the reaction rate by
- increasing the energy of the reactants
 - increasing the heat of reaction
 - lowering the activation energy of the reaction
 - decreasing the energy of the products
 - increasing the value of the equilibrium constant

81. Use the information below to determine the overall order of the reaction: $A + B \rightarrow P$

<u>Trial</u>	<u>[A], M</u>	<u>[B], M</u>	<u>Initial Rate (M/s)</u>
1	0.273	0.763	2.83
2	0.273	1.526	5.66
3	0.819	0.763	25.47

- a) 0
b) 1
c) 2
d) 3
e) 4
82. Blood is buffered by the carbonic acid-bicarbonate buffer system to a pH of about 7.4. The equilibrium expression for the buffer system is: $H_2O + CO_2 \rightleftharpoons H^+ + HCO_3^-$
When people panic, cry, or have a high fever, they often begin to hyperventilate. Hyperventilation is abnormally fast or deep respiration, which results in the loss of carbon dioxide from the blood. What happens to the pH of the blood when this occurs?
- a) The pH of the blood increases
b) The pH of the blood decreases
c) The pH of the blood remains the same because it is buffered
d) There is not enough information given to answer the question.
83. The hypothetical compound HZ is a weak acid. An aqueous solution prepared by dissolving 0.020 moles of HZ in 1.0 liter of solution has a pH of 4.93 at 25 °C. What is the K_a for HZ?
- a) 1.2×10^{-3}
b) 5.9×10^{-4}
c) 1.2×10^{-5}
d) 1.2×10^{-8}
e) 6.9×10^{-9}
84. A 0.1 M aqueous solution of which of the following would have a pH of 7.0 ?
- a) Na_2S
b) KF
c) $NaNO_3$
d) NH_4Cl
e) $Fe(NO_3)_3$

85. A saturated aqueous solution of a lead(II) halide, PbX_2 , has a freezing point of -0.058°C . Approximate the K_{sp} of PbX_2 . The molal freezing point depression constant for water is $1.86^\circ\text{C}/m$.

- a) 3.1×10^{-2}
- b) 3.0×10^{-5}
- c) 9.7×10^{-4}
- d) 4.5×10^{-6}
- e) 1.2×10^{-6}

86. The following reactions:

$$2 \text{Ce}^{4+} + 2 \text{I}^- \rightleftharpoons \text{I}_2 + 2 \text{Ce}^{3+}$$

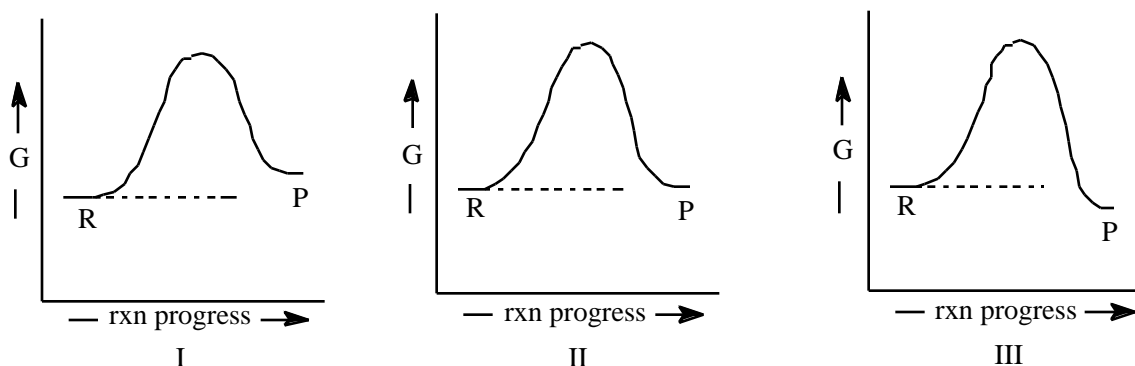
$$\text{Cu}^{2+} + 4 \text{NH}_3 \rightleftharpoons [\text{Cu}(\text{NH}_3)_4]^{2+}$$

$$\text{Pb}^{2+} + 2 \text{I}^- \rightleftharpoons \text{PbI}_2$$

are examples of:

- a) acid-base reactions
- b) redox reactions
- c) precipitation, acid-base, and redox reactions, respectively
- d) redox, acid-base, and precipitation reactions, respectively
- e) precipitation, redox, and acid-base reactions, respectively

87. Which of the following reaction energy diagrams best describes a reaction that has an equilibrium constant K equal to one?

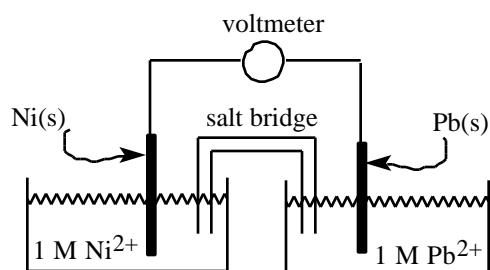


- a) I only
- b) II only
- c) III only
- d) I and III
- e) none of the above

88. Dissolving ammonium chloride in water lowers the temperature of the solution. For this dissolving process

- a) ΔH is negative and ΔS is negative
- b) ΔH is positive and ΔS is negative
- c) ΔH is negative and ΔS is positive
- d) ΔH is positive and ΔS is positive

89. Consider the voltaic cell shown below. The standard reduction potentials in volts for Pb^{2+} and Ni^{2+} are -0.13 and -0.28 respectively. The _____ electrode is the electrode where the reduction will occur and it is called the _____.



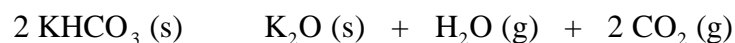
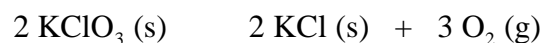
- a) Pb, cathode
b) Pb, anode
c) Ni, cathode
d) Ni, anode
90. The element indium can be obtained by electrolysis of a molten halide of the element. The passage of a 3.20 A current for 40.0 minutes results in formation of 4.57 g of In. What is the oxidation state of indium in the halide melt?
- a) +1
b) +2
c) +3
d) +4
91. Radon-222 decays to a stable nucleus by a series of three alpha emissions and two beta emissions. What is the stable nucleus that is formed?
- a) Pb-210
b) Pt-210
c) Po-210
d) Pb-212
e) Rn-217
92. Which of the following is NOT an elemental form of carbon?
- a) quartz
b) diamond
c) graphite
d) buckminsterfullerene
93. Which of the following is NOT considered to be a strong acid?
- a) HCl
b) HClO_4
c) HNO_3
d) HBr
e) H_3PO_4

94. The synthetic radioisotope technetium-99, which decays by beta emission, is the most widely used isotope in nuclear medicine. The following data were collected on a sample of ^{99}Tc .

<u>Disintegrations per minute</u>	<u>Time (hr)</u>
180	0
130	2.5
104	5.0
77	7.5
59	10.0
46	12.5
24	17.5

Determine the approximate value of the half-life of ^{99}Tc from these data.

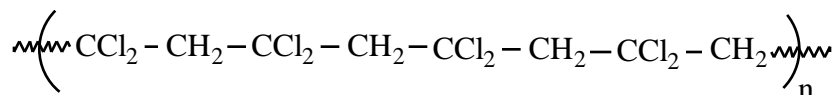
- a) 5.0 hr
 b) 6.2 hr
 c) 8.8 hr
 d) 17.5 hr
 e) 24.0 hr
95. A mixture containing KClO_3 , K_2CO_3 , KHCO_3 , and KCl was heated, producing CO_2 , O_2 , and H_2O gases according to the following equations:



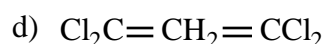
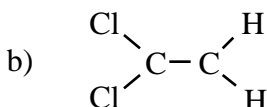
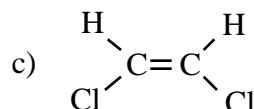
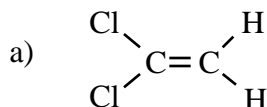
If 100.0 g of the mixture produces 1.80 g of H_2O , 13.20 g of CO_2 , and 4.00 g of O_2 , what is the percent by mass of KCl in the original mixture? Assume complete decomposition of the mixture.

- a) 6.22 %
 b) 10.2 %
 c) 18.3 %
 d) 56.0 %
 e) 74.6 %
96. How many moles of $\text{Fe}(\text{OH})_2$ [$K_{\text{sp}} = 1.8 \times 10^{-15}$] will dissolve in one liter of water buffered at $\text{pH} = 12.00$?
- a) 1.5×10^{-16} moles
 b) 1.8×10^{-15} moles
 c) 1.8×10^{-11} moles
 d) 7.67×10^{-6} moles
 e) 1.8×10^{-3} moles

97. Poly(vinylidene chloride) is an addition polymer of the structure shown below.



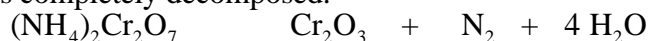
Materials containing this polymer are sold by Dow Brands under the name *Saran Wrap*. What is the structure of the monomer used to make the above polymer?



98. Two elements, X and Y, combine to form two different binary compounds. In the first compound, 6.00 g of X combines with 1.74 g of Y. In the second compound, 12.0 g of X combines with 6.95 g of Y. If the formula of the first compound is XY_2 , what is the empirical formula of the second compound?

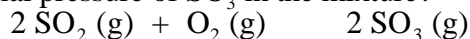
- a) XY
 b) X_4Y
 c) XY_3
 d) X_2Y
 e) XY_4

99. When ammonium dichromate, $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$, decomposes, the only products are Cr_2O_3 , N_2 , and H_2O as shown below. Calculate the mass percent of H_2O in the product mixture when $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ is completely decomposed.



- a) 7.56 %
 b) 9.09 %
 c) 28.6 %
 d) 40.0 %
 e) 66.7 %

100. At 900 K the following reaction has $K_p = 0.345$. In an equilibrium mixture of the three gases, the partial pressures of SO_2 and O_2 are 0.215 atm and 0.679 atm respectively. What is the equilibrium partial pressure of SO_3 in the mixture?



- a) 0.0504 atm
 b) 0.104 atm
 c) 0.0108 atm
 d) 0.302 atm
 e) 0.0910 atm

INDIANA SECTION of the AMERICAN CHEMICAL SOCIETY

High School Scholarship Exam Answer Key

April 13, 2002



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