NESACS Avery A. Ashdown High School Chemistry Examination Contest

Confidential

Identification Sheet

Test Number__________________________

Full Name___________________________________________________________________________
(Print) Last Name                                      First Name    Middle Initial

Home Address_________________________________________________________________________

Home Town, State & Zip______________________________________________________________

High School__________________________________________________________________________

Name of Local Newspaper____________________________________________________________

Name of Chemistry Teacher___________________________________________________________

Year of Graduation _________________________ Home Phone_______________________________

e-mail_______________________________________________________________________________

Number of Years of Chemistry (including this year)_______________________________________

Circle:

Have you taken the Ashdown exam in a previous year? Yes    No

If so, were you a prize winner? Yes    No

If you qualify, will you take the next Olympiad exam? Yes    No
(Must be U.S. Citizen or Green Card holder)
Rules for the Examination

• There are 85 questions, and the exam will last 100 minutes.

• Absolutely **NO** cell phones, beepers or electronic messaging devices may be used in the test room. Any such devices that are used will be interpreted as cheating, and the user will be disqualified.

• **NO** cell phones, iPads or other devices which can communicate with the internet or with others may be used. Use of such devices will be interpreted as cheating and the user will be disqualified.

• When the proctor announced that time is up, you must **immediately** stop and turn in your bubble sheet.

• If you bring any books, papers, backpacks, etc. into the test room, deposit them against a wall.

• The only items allowed within your reach during the test are calculators, the exam, the bubble sheet, pencils, and erasers.

• ANY kind of calculator may be used as long as it is **only** a calculator. If you are using a graphing calculator, clear its memory **now**.

• ANY talking between students once the exam has begun will be interpreted as cheating, and all parties will be disqualified.

• Once the examination begins, you will not be allowed to leave the room.

• Students must remain seated during the exam. Once a student stands up, their exam must be turned in without any modifications.

• Nassiff’s Test Taking Skill App: Cycle through the exam. Some questions are easier than others and the easy ones are scattered throughout. Do the easy stuff first and don’t get stuck on the hard ones. Time is not your friend!
DIRECTIONS

• Put your name, school, and test number on the bubble sheet, as follows;

  NAME__Your_Name__
  SUBJECT__School___
  PERIOD_______DATE_____Test_Number____

• When you have selected your answer to each question, blacken the corresponding space on the answer sheet using a soft, #2 pencil. Make a heavy, full mark, but no stray marks. If you decide to change an answer, erase the unwanted mark very carefully.

• There is only one correct answer to each question. Any questions for which more than one response has been blackened will not be counted.

• Your score is based solely on the number of questions you answer correctly. It is to your advantage to answer every question.

• When you are told to start the exam, you may tear off sheets 1, 2, and 3, the periodic table.

• After the test is over and the proctors have collected the bubble sheets, you may take this exam home with you.

• Answers will be posted in the registration area after the examination.

• Prize winners and qualifiers will be notified within 3 days or sooner.

• If you wish to continue as a qualifier for the U.S. Chemistry Olympiad, make sure you have filled out the official form.

• After the exam and after you have examined the answer key and if you feel that the answer key is incorrect, you have 72 hours to contact me for an appeal. My email is: nassifi@bpsk12.org
  Your appeal must include your justification.

• Good luck!
1. The name of the carbon allotrope shown to the right is:
   A. charcoal
   B. diamond
   C. Bucky ball
   D. graphite

2. An atom with more electrons than protons is called:
   A. an anion
   B. a cation
   C. a molecule
   D. an isotope

3. Symbol to the right that represents the primary professional organization for chemists is:
   A. American Cancer Society
   B. Army Community Service
   C. Australian Cinematographers Society
   D. American Chemical Society

4. Discovered by French chemist Barnard Courtois in 1811 from seaweed ash, this element’s name comes from the Greek word for violet, which happens to be the color of its gas. It turns blue in starch.
   A. selenium
   B. bromine
   C. iodine
   D. phosphorus

5. The chemical substance sometimes referred to as the “universal solvent” is:
   A. ethyl alcohol
   B. water
   C. benzene
   D. hydrochloric acid

6. A common laboratory reaction performed in a high school laboratory is dissolving of copper metal in concentrated nitric acid, resulting in a blue beautiful solution of copper (II) nitrate. Balance the equation below to the smallest whole number coefficients and select the answer.

   \[
   \text{Cu(s)} + \text{HNO}_3(aq) \rightarrow \text{Cu(NO}_3)_2(aq) + \text{NO}_2(g) + \text{H}_2\text{O}(l)
   \]

   A. 15
   B. 20
   C. 30
   D. 40

7. Which of the following will be found on a Material Safety Data Sheet (MSDS)?
   A. Health hazards
   B. Precautions for Safe Handling and Use
   C. Fire and Explosion Hazard Data
   D. All of the above
8. The ion that will produce pale/apple green color in a flame test is:

A. K⁺  
B. Cu²⁺  
C. Cl⁻  
D. Ba²⁺

9. Teachers just love it when students request the proper equipment when doing a laboratory. To impress your teacher, you ask for the item to the right as a(n):

A. test tube holder  
B. Erlenmeyer flask holder  
C. hot glass holder  
D. thingamajig to hold hot glassware

10. The element that has a melting point of 842 °C, a density of 1.55 grams/cm³, an electronegativity of 1.00, an atomic radius of 197 pm, an electron affinity of 2.37 kJ/mole and a first ionization energy of 590 kJ/mole is

A. Si  
B. Ca  
C. I  
D. B

11. The mass measured in grams by the balance to the left with the correct number of significant figures is:

A. 373 g  
B. 373.3 g  
C. 373.35 g  
D. 373.350 g

12. Which sample has the most N atoms: N₀ = 6.02 x 10²³, N = 14.0, H = 1.01, O = 16.0, C = 12.0, and Ca = 40.1

A. 1.00 x 10²³ molecules of nitroglycerine, C₃H₅N₃O₉  
B. 0.400 moles of urea, CH₄N₂O  
C. 34.5 grams of NO₂  
D. 49.4 grams of Ca₃N₂

13. The equation for the standard heat of formation, ΔH°_f, for Fe(OH)₃(s) is:

A. 2 Fe(s) + 6 H₂O(g) → 2 Fe(OH)₃(s) + 3 H₂(g)  
B. Fe³⁺ (aq) + 3OH⁻ (aq) → Fe(OH)₃(s)  
C. Fe(s) + 3/2 H₂(g) + 3/2 O₂(g) → Fe(OH)₃(s)  
D. 2 Fe(s) + 3 H₂(g) + 3 O₂(g) → 2 Fe(OH)₃(s)

14. The electron geometry, molecular geometry, and hybridization for IF₄⁻ are:

<table>
<thead>
<tr>
<th>Electron geometry</th>
<th>Molecular geometry</th>
<th>Hybridization</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. tetrahedral</td>
<td>tetrahedral</td>
<td>sp³</td>
</tr>
<tr>
<td>B. trigonal pyramidal</td>
<td>seesaw</td>
<td>dsp²</td>
</tr>
<tr>
<td>C. trigonal pyramidal</td>
<td>square pyramid</td>
<td>dsp²</td>
</tr>
<tr>
<td>D. octahedral</td>
<td>square planar</td>
<td>d²sp³</td>
</tr>
</tbody>
</table>
15. You have won the Ashdown lottery and get a 45-foot semi-trailer full of $1 bills. Assuming you can pack the trailer with dollar bills with no loss of volume, how much did you win? 1 foot = 12 inches, 1 inch = 2.54 cm

A. $4.80 million
B. $12.2 million
C. $78.6 million
D. $624 million

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Trailer</th>
<th>Dollar Bill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>44 ft. 1½ in.</td>
<td>15.60 cm.</td>
</tr>
<tr>
<td>Width</td>
<td>93.0 in.</td>
<td>6.629 cm.</td>
</tr>
<tr>
<td>Height</td>
<td>110 in.</td>
<td>0.01092 cm.</td>
</tr>
</tbody>
</table>

16. Use the data to the right to find the formula for Al₂(SO₄)₃·xH₂O. Al₂(SO₄)₃ = 342.15 g/mole, H₂O = 18.01 g/mole

A. Al₂(SO₄)₃·3H₂O
B. Al₂(SO₄)₃·6H₂O
C. Al₂(SO₄)₃·12H₂O
D. Al₂(SO₄)₃·18H₂O

<table>
<thead>
<tr>
<th>Mass of hydrate</th>
<th>3.332 grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of anhydride</td>
<td>1.711 grams</td>
</tr>
</tbody>
</table>

17. The empirical formula for an unknown compound composed of 19.15% potassium, 47.04% carbon, 2.47% hydrogen and 31.33% oxygen is: K = 39.1, O = 16.0, C = 12.0, H = 1.01

A. KC₂H₃O₂
B. K₂C₆H₅O₄
C. KC₆H₅O₃
D. KC₈H₅O₄

18. A current of 15.0 amperes is applied to aqueous solution Al(NO₃)₃ for 2.00 hours. The grams of Al metal plated are: (1 Faraday = 96,500 coulombs/mole, Al = 27.0 g/mole)

A. 0.00 g
B. 8.04 g
C. 10.1 g
D. 30.2 g

19. A sample of P-32 decays 5.0% daily. The half-life of P-32 is:

A. 4.32 days
B. 13.5 days
C. 28.0 days
D. 324 days

20. The correct number of names in the table to the right for the given formulas is:

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

<table>
<thead>
<tr>
<th>Formula</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>K₂O</td>
<td>dipotassium monoxide</td>
</tr>
<tr>
<td>C₄H₁₀</td>
<td>propane</td>
</tr>
<tr>
<td>CuSO₄</td>
<td>copper carbonate</td>
</tr>
<tr>
<td>HOCl</td>
<td>hydrochloric acid</td>
</tr>
</tbody>
</table>
Use the following figures below to answer questions 21-24. Chemistry teachers love to give demos that excite students, and chemistry students observe many memorable reactions when doing labs. Identify the following four laboratories involving Zn and Cu from the images below:

A.  
B.  
C.  
D.  

22. Cu metal in 6M nitric acid.
23. Zn in 3M hydrochloric acid.
24. Zn metal in 1M copper sulfate.

Use the following balanced equation to answer questions 25-27.

Tetrachloroethane, C₂Cl₄, often called perchloroethylene (perc), is a colorless liquid used in dry cleaning and can be made by the following balanced reaction:

\[
8 \text{C}_2\text{H}_4\text{Cl}_2(l) + 6 \text{Cl}_2(g) + 7 \text{O}_2(g) \rightarrow 4 \text{C}_2\text{HCl}_3(l) + 4 \text{C}_2\text{Cl}_4(l) + 14 \text{H}_2\text{O}(l)
\]

In an experiment involving this reaction, 50.0 grams of C₂H₄Cl₂ reacted with 36.0 grams of Cl₂ and 16.0 g of O₂.

25. Assuming a theoretical yield, the grams of C₂Cl₄ formed are:
   A. 41.9 g
   B. 42.1 g
   C. 47.4 g
   D. 56.1 g

26. Assuming a theoretical yield, the amount of excess reactant s remaining after the reaction is:
   A. 11.0 g left
   B. 27.3 g left
   C. 54.6 g left
   D. 61.1 g left

27. The student only obtained 17.5 grams of C₂Cl₄. Thus, the % yield was:
   A. 31.2%
   B. 36.9%
   C. 41.6%
   D. 41.8%
28. Which of the following is not evidence for the “big bang” theory is:

A. Red shift spectra of galaxies.
B. The abundance of helium in the universe.
C. Cosmic microwave background radiation.
D. All of the above are evidence for the “big bang” theory.

29. In order to change the orbital shown in A to the orbital shown in B, an electron would have to

A. reverse its spin.
B. absorb energy.
C. emit energy.
D. be removed from the atom.

Use the following for questions 30-33. A 1.00 mole sample of CO₂, molar mass of 44.01 g/mole, occupies 0.200 liters at 27 °C. R =0.08206 L • atm/ mole • K.

30. Using the ideal gas law, the pressure of the CO₂ is:

A. 11.1 atm
B. 112 atm
C. 123 atm
D. 542 atm

31. The actual pressure of CO₂ using van der Waals equation, shown to the right, is: For CO₂, a = 3.592 atm L²/mole² and b = 0.04267 L/mole

A. 52.6 atm
B. 66.7 atm
C. 89.9 atm
D. 156 atm

32. From the ideal gas law, the pressure of the CO₂ at 0.0500 L is 492 atm. Use the van der Waals equation and the constants found in #31 and calculate the pressure at 0.0500 L.

A. 265 atm
B. 1170 atm
C. 1620 atm
D. 1920 atm

33. The van der Waal’s equation accounts for deviations of gases from ideal behavior. Examine the following statements about the two parameters, a and b, used in this equation and select all the true statements.

I. Parameter a accounts for weak attractive forces between the molecules.
II. Parameter b accounts for the sizes of the molecules.
III. The higher pressure from ideal predicted at 0.0500 L is mostly due to its large value of a.

A. III is true.
B. II and III are true.
C. I and II are true.
D. I, II, and III are true.
34. If you do not understand a direction or part of a lab procedure, you should

A. figure it out as you do the lab.
B. try several methods until something works.
C. skip it and go on to the next part.
D. ask the teacher before proceeding.

35. For the overall reaction: \( 4 \text{HBr} + \text{O}_2 \rightarrow 2 \text{H}_2\text{O} + 2 \text{Br}_2 \)
The following mechanism to the right was proposed.
The equation for step 2 is:

A. \( \text{HBr} + \text{HOOBr} \rightarrow \text{HOBr} + \text{H}_2\text{O} + \text{Br}_2 \)
B. \( 2 \text{HBr} + 3 \text{HOBr} \rightarrow \text{HOOBr} + \text{H}_2\text{O} + \text{Br}_2 \)
C. \( 2 \text{HBr} + \text{HOOBr} + \text{HOBr} \rightarrow 3 \text{H}_2\text{O} + 2 \text{Br}_2 \)
D. \( 2 \text{HBr} + \text{HOOBr} \rightarrow \text{HOBr} + \text{H}_2\text{O} + \text{Br}_2 \)

36. Which statement concerning the autoionization of water is false?

\[ 2 \text{H}_2\text{O}(l) \rightleftharpoons \text{H}_3\text{O}^+(aq) + \text{OH}^-(aq) \]

A. This is an acid base reaction according to the Bronsted-Lowry theory
B. Water is amphiprotic.
C. \( \text{H}_3\text{O}^+ \) and \( \text{OH}^- \) are a conjugate acid-base pair.
D. A \( \text{H}_2\text{O} \) molecule may react as an acid by donating a proton.

37. Which of the following signs should be prominently displayed in a chemistry laboratory?

- Eye Protection Required in this area at all times.

I. II. III. IV.

A. I only
B. I and II only
C. I, II, and III only
D. All should be prominently displayed

38. Classify the 0.01 M aqueous solutions shown below as acidic, basic, or neutral and select the correct option.

\[
\begin{array}{cccccc}
\text{CH}_3\text{OH} & \text{NH}_4\text{NO}_3 & \text{NaF} & \text{Al}_3(\text{SO}_4)_2 & \text{Na}_2\text{SO}_4 \\
\hline
\text{Acidic} & \text{Basic} & \text{Neutral} \\
A. & 2 & 1 & 2 \\
B. & 1 & 3 & 1 \\
C. & 2 & 2 & 1 \\
D. & 1 & 2 & 2
\end{array}
\]
Use the following for questions 39 and 40. 1-Propanol has the following vapor pressures: Clausius-Clapeyron Equation with $R = 8.314 \text{ J/mole} \cdot \text{K}$ is:

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

39. The enthalpy of vaporization, $\Delta H_{vap}$, is:

A. 5320 J  
B. 19.4 kJ  
C. 44.2 kJ  
D. 48.2 kJ

40. The total entropy change, $\Delta S$, when 100 g of 1-propanol (60.09 g/mole) is vaporized at the boiling point is:

A. 120 J  
B. 199 J  
C. 461 J  
D. 767 J

Use the following for questions 41 and 42. The apparatus shown to the right consists of three bulbs connected by stopcocks. The contents of the bulbs are shown in the table below.

41. What is the pressure inside the system when the stopcocks are opened? Assume that the lines connecting the bulbs have zero volume and that the temperature remains constant.

A. 0.669 atm  
B. 0.956 atm  
C. 1.45 atm  
D. 1.50 atm

42. The mole fraction of $H_2$ is:

A. 0.153  
B. 0.223  
C. 0.332  
D. 0.376

43. The phase diagram for compound X is shown to the right. If you had a bottle of compound X in your book bag, what state would it be in?

A. solid  
B. liquid  
C. gas  
D. solid and gas

44. The correct answer for the calculation below with values that are obtained from scientific measurement is:

$$3.969 - 1.800 + 8.26 \times 10^{-3}$$

A. 2.178  
B. 2.177  
C. 2.1773  
D. 2.17726
Use the following for questions 45-48 for the reaction: \[ 2 \text{CO}(g) + \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) \]

\[ R = 8.314 \text{ J/mole K} \]

45. \( \Delta G^\circ \) for the reaction is:

A. -257 kJ  
B. -514 kJ  
C. -1010 kJ  
D. -1060 kJ

46. \( \Delta S^\circ \) for the reaction:

A. 0.17 J  
B. -95 J  
C. -174 J  
D. 1720 J

47. The equilibrium constant at 100 °C is:

A. 3.5 x 10^{-68}  
B. 2.9 x 10^{67}  
C. 9.6 x 10^{71}  
D. 1.3 x 10^{90}

48. \( \Delta G \) at 0 °C when the partial pressures of \( P_{\text{CO}_2} = 1.00 \text{ atm} \), and \( P_{\text{O}_2} = P_{\text{CO}} = 5.00 \text{ atm} \):

A. -521 kJ  
B. -525 kJ  
C. -529 kJ  
D. 1020 kJ

49. The number of the following compounds that are soluble in water are:

CuSO₄  |  PbBr₂  |  CaSO₄  |  (NH₄)₂CO₃  |  LiOH

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

50. What is the empirical formula of the unit cell shown to the right? The light spheres are M and dark spheres are X.

A. MX  
B. MX₂  
C. M₂X₃  
D. MX₃
51. From the reaction below and the table to the right, the average N-H bond energy is:

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2 \text{NH}_3(g) \]

A. 229 kJ/mole  
B. 272 kJ/mole  
C. 359 kJ/mole  
D. 390 kJ/mole

52. A sample contains both KBr and KI in unknown quantities. If a 5.00 gram sample contains 1.50 grams of potassium, what are the percentages by mass of KBr and KI in the sample?  
K = 39.10, Br = 79.90, I = 126.90

A. 30.0% KBr, 70.0% KI  
B. 58.2% KBr, 41.8% KI  
C. 69.3% KBr, 30.7% KI  
D. 78.0% KBr, 22.0% KI

53. Which of the following is optically active, has a molecular formula of C7H16 and has the correct IUPAC name?

A. 2-methylhexane  
B. 3-methylhexane  
C. 2-ethylpentane  
D. 3-methylheptane

54. The potential for the reaction below is

\[ \text{I}_2(s) + 2\text{e}^- \rightarrow 2\text{I}^- \]

A. 0 V  
B. 0.085 V  
C. 1.070 V  
D. 1.155 V

55. The equilibrium constant for the above reaction is

A. 2.05  
B. 17.8  
C. 27.3  
D. 747

56. The solubility in g/L of I2(s) in water, \( \text{I}_2(s) \rightleftharpoons \text{I}_2(aq) \), is:  
I = 126.9 g/mole

A. 0.17 g/L  
B. 0.34 g/L  
C. 4.64 g/L  
D. 9.3 g/L
Use the following for questions 57-60. A sample of $\text{N}_2\text{O}_4(g)$ undergoes a temperature-dependent equilibrium to form $\text{NO}_2(g)$ as shown in the reaction below. An evacuated reaction bulb was filled with argon gas in the conditions shown in the table. Assume the gases are ideal. $\text{Ar} = 39.948 \text{ g/mole}$, $R = 0.08206 \text{ L atm/mole K}$, $K = 8.314 \text{ J K}^{-1} \text{ mole}^{-1}$, $\text{N}_2\text{O}_4 = 92.011 \text{ g/mole}$, $\text{NO}_2 = 46.0055 \text{ g/mole}$

$$\text{N}_2\text{O}_4(g) \rightleftharpoons 2 \text{NO}_2(g)$$

57. What is the volume of the flask?
A. $1.922 \times 10^{-2} \text{ L}$
B. $0.2816 \text{ L}$
C. $0.4602 \text{ L}$
D. $0.7678 \text{ L}$

58. The bulb was evacuated, filled with $\text{N}_2\text{O}_4$, and allowed to reach equilibrium at $57.0 \degree \text{C}$ and $1.000 \text{ atm}$. The bulb had a mass of $99.50500 \text{ g}$. The average molar mass of the equilibrium gas mixture is
A. 35.66
B. 46.06
C. 51.74
D. 58.28

59. The value of the equilibrium, $K_p$, at $57 \degree \text{C}$ is
A. 0.491
B. 1.11
C. 2.02
D. 3.23

60. $K_p$ at $-23 \degree \text{C}$ is $2.50 \times 10^{-3}$. The value of $\Delta H^\circ$ for this reaction is
A. 0.704 $\text{kJ}$
B. 48.5 $\text{kJ}$
C. 57.4 $\text{kJ}$
D. 70.1 $\text{kJ}$

61. The Mars Rover brought back a “mystery metal” that it crystallizes in a face centered cubic lattice with cell edge $a = 508.42 \text{ pm}$ and its density is $11.724 \text{ g/cm}^3$. 1 pm = $10^{-12} \text{ m}$ What is the metal? $N_o = 6.022 \times 10^{23}$
A. Fe
B. Os
C. Pb
D. Th

62. According to the Heisenberg Uncertainty Principle, $\Delta p \Delta x \geq \frac{\hbar}{4\pi}$, if the uncertainty in the speed of an electron is $3.5 \times 10^3 \text{ m/s}$, the uncertainty in its position in meters is at least:

$m_{\text{electron}} = 9.11 \times 10^{-31} \text{ kg}$, $h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
A. $1.5 \times 10^{38} \text{ m}$
B. $1.7 \times 10^{-8} \text{ m}$
C. $6.6 \times 10^{-8} \text{ m}$
D. $0.20 \text{ m}$
63. The first ionization energy of beryllium is more than that of boron because:

A. Beryllium has filled s-orbital.
B. Beryllium has filled a half-filled s-orbital.
C. Boron atom is smaller in size than the beryllium atom.
D. Boron is more electronegative than beryllium.

Use the following for questions 64 and 65. Due to the recent snowstorms and because of your acumen in science, you were asked to determine the kilograms of rock salt (NaCl) needed to melt the ice on the school’s sidewalks and outside waiting areas so that you and your fellow classmates may be safe as you walk to your car or bus. It is estimated that the school’s side walks and outside areas are 50.0 m x 10.0 m and the ice is 5.0 mm thick. The density of ice is 0.934 g/cm$^3$.

64. Approximately how many kg of ice are there?

A. 2.35 kg
B. 2340 kg
C. 2500 kg
D. 23500 kg

65. It was requested that ice solution be -5.00 °C. $K_f$ for water is 1.86 °C/m. How many kg of NaCl are required? The molar mass of NaCl is 58.44 g/mole.

A. 183 kg
B. 196 kg
C. 366 kg
D. 392 kg

66. In an empty flask, COCl$_2$(g) is introduced at 1.0 atm pressure where it dissociates according to the reaction below until equilibrium is reached:

$$2\text{COCl}_2(\text{g}) \rightleftharpoons \text{C}_\text{graphite} + \text{CO}_2(\text{g}) + 2\text{Cl}_2(\text{g})$$

If x represents the partial pressure of CO$_2$(g) at equilibrium, the value of $K_p$ is

A. $\frac{x \cdot (2x)^2}{(1.0 - 2x)^2}$
B. $\frac{2x^2}{(1.0 - 2x)^2}$
C. $\frac{x(2x)^2}{(1.0 - 2x)^2}$
D. $\frac{x(2x)^2}{(1.0 - x)^2}$
67. The reaction, \(2A + 2B \rightarrow C + D\), proceeds by the following proposed mechanism:

<table>
<thead>
<tr>
<th>Step</th>
<th>Reaction</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>(2A \rightleftharpoons A_2)</td>
<td>equilibrium</td>
</tr>
<tr>
<td>Step 2</td>
<td>(A_2 + B \rightarrow X + C)</td>
<td>rate determining</td>
</tr>
<tr>
<td>Step 3</td>
<td>(X + B \rightarrow D)</td>
<td>rapid</td>
</tr>
</tbody>
</table>

The rate equation for the reaction is

A. \(\text{rate} = k[A][B]\)

B. \(\text{rate} = k[A]^2[B]^2\)

C. \(\text{rate} = k\frac{[A]^2[B]}{[C][D]}\)

D. \(\text{rate} = k[A]^2[B]\)

68. The following molar absorptivities, \(\varepsilon_o\) in \(\text{M}^{-1}\text{cm}^{-1}\), pertaining to the analysis of compounds A and B at 272 nm and 327 nm, are shown to the right. A mixture of A and B in a 1.00 cm cell had an absorption of 0.960 at 272 nm and 0.560 at 327 nm. The concentrations of A and B are:

A. \([A] = 4.42 \times 10^{-5} \text{ M}, [B] = 5.97 \times 10^{-5} \text{ M}\)

B. \([A] = 4.34 \times 10^{-5} \text{ M}, [B] = 6.10 \times 10^{-5} \text{ M}\)

C. \([A] = 3.23 \times 10^{-5} \text{ M}, [B] = 4.55 \times 10^{-5} \text{ M}\)

D. \([A] = 1.41 \times 10^{-4} \text{ M}, [B] = 2.70 \times 10^{-6} \text{ M}\)

Use the following for questions 69 and 70. Solution A contains 0.0500 M HF. Solution B contains 0.0500 M ammonia. \(K_a(\text{HF}) = 6.8 \times 10^{-4}, K_b(\text{NH}_3) = 1.8 \times 10^{-5}, K_w = 1.0 \times 10^{-14}\)

69. What is the equilibrium constant, \(K\), for the reaction when the two solutions are mixed?

\[\text{HF}(aq) + \text{NH}_3(aq) \rightleftharpoons \text{F}^- (aq) + \text{NH}_4^+(aq)\]

A. \(3.9 \times 10^{-15}\)

B. \(1.2 \times 10^8\)

C. 39.0

D. \(1.2 \times 10^6\)

70. What is the pH of a solution that has 20.0 mL of 0.0500 M HF mixed with 15.0 mL of 0.0500 M NH\(_3\)?

A. 2.69

B. 3.65

C. 4.28

D. 5.23

71. This compound to the right has the following functional groups:

A. ketone, alkene, carboxylic acid, ester

B. alkyne, ester, carboxylic acid, aldehyde

C. carboxylic acid, alkene, ketone, ester

D. ester, aldehyde, carboxylic acid, alkene
72. From the half reactions in the table, the solubility product, $K_{sp}$, for $\text{Mg(OH)}_2$ is:

$$E = E^o - \frac{0.05916}{n} \log Q$$

A. $7.0 \times 10^{-12}$  
B. $7.5 \times 10^{-9}$  
C. $1.3 \times 10^{-6}$  
D. $1.4 \times 10^{-5}$

73. A mixture contains only cyclohexane, $\text{C}_6\text{H}_{12}$ (84.16 g/mole) and oxirane, $\text{C}_2\text{H}_4\text{O}$ (44.05 g/mole). When 7.300 mg was analyzed by combustion analysis, 22.000 mg of CO$_2$ (44.01 g/mole) were produced. The % by weight of oxirane is

A. 10.8%  
B. 18.2%  
C. 21.5%  
D. 40.1%

74. Approximately how many grams of potassium acid phthalate, $\text{KHP}$ (204.233 g/mole), should be weighed into a flask to standardize $\sim 0.10$ M NaOH if you wish to titrate $\sim 35$ mL of the base for the titration?

A. 0.06 g  
B. 0.66 g  
C. 0.71 g  
D. 0.83 g

75. Which of the following is false?

A. Valence bond (VB) theory and molecular orbital (MO) theory are as two different views of the same thing.  
B. Molecular orbitals are generally more delocalized than hybridized atomic orbitals.  
C. One of the shortcomings of the VB theory is the inability to account for paramagnetism in the O$_2$ molecule.  
D. One of the shortcomings of the MO theory is the inability to account for the triple bond in the N$_2$ molecule.

76. A compound with a molar mass of 292.16 g/mole was dissolved in a 5.00-mL volumetric flask. A 1.00-mL aliquot was pipette into a 10.00-mL volumetric flask and diluted to the mark. The absorbance measured at 340 nm was 0.429 in a 1.000 cm cuvette. Molar absorptivity for this compound at 340 nm is $\varepsilon_{340} = 6130$ M$^{-1}$cm$^{-1}$. How many milligrams of the compound were used to make the 5.00-mL solution

A. 0.700 mg  
B. 1.02 mg  
C. 1.40 mg  
D. 2.04 mg

77. The resonance structure that gives the most accurate representation of the SCN$^-$ anion is one which

A. the formal charge of S is -1, the formal charge of C is +2, and the formal charge of N is -2.  
B. the formal charge of S is -1, the formal charge of C is 0, and the formal charge of N is 0.  
C. the formal charge of S is 0, the formal charge of C is 0, and the formal charge of N is -1.  
D. the formal charge of S is +1, the formal charge of C is 0, and the formal charge of N is -2.
78. At 25 °C, the activation energy, $E_a$, for the decomposition of H$_2$O$_2$ is 75.3 kJ/mole. In the presence of the iodide ion catalyst, $E_a = 56.5$ kJ/mole. However, when catalyzed by the blood enzyme, catalase, $E_a = 8.40$ kJ/mol. If 1.0 seconds is required to collect 100 mL of oxygen when catalase is present, how long would it take to collect 100 mL of oxygen when iodide is used as a catalyst? $R = 8.314$ J/mole·K

A. 3.3 minutes  
B. 6.7 days  
C. 8.6 years  
D. 1.0 million years

79. If a 0.10 M solution of a base has a pH = 9.71, what is the $K_b$ for the base? $pK_w = 14.00$

$$B + H_2O \rightleftharpoons BH^+ + OH^-$$

A. $2.8 \times 10^{-18}$  
B. $5.0 \times 10^{-10}$  
C. $2.6 \times 10^{-8}$  
D. $5.0 \times 10^{-5}$

80. The planet Aragonose, composed mainly of the mineral aragonite (CaCO$_3$) (picture to the right) has an atmosphere containing CH$_4$ and CO$_2$, each at a pressure of 0.20 atm. The oceans are saturated with aragonite and have a pH of 6.5. Given the equilibria below, calculate how many grams of Ca per liter are in Aragonose sea water. Ca = 40.08 g/mole

Hint: Reverse the first reaction and see what adds up!

A. 0.11 g  
B. 0.17 g  
C. 0.39 g  
D. 3.62 g

$\text{CaCO}_3(s, \text{aragonite}) \rightleftharpoons \text{Ca}^{2+}(aq) + \text{CO}_3^{2-}(aq)$  
$K_{sp} = 6.0 \times 10^{-9}$

$\text{CO}_2(g) \rightleftharpoons \text{CO}_2(aq)$  
$K_{CO_2} = 3.4 \times 10^{-2}$

$\text{CO}_2(aq) + \text{H}_2\text{O(l)} \rightleftharpoons \text{HCO}_3^-(aq) + \text{H}^+(aq)$  
$K_{1} = 4.4 \times 10^{-7}$

$\text{HCO}_3^-(aq) \rightleftharpoons \text{H}^+(aq) + \text{CO}_3^{2-}(aq)$  
$K_{2} = 4.7 \times 10^{-11}$

Use the following for questions 81 and 82.

81. The energy produced in the fusion of 1.00 gram of hydrogen in the following reaction is: 1 amu = 1.6605 x $10^{-24}$ g, c = 2.998 x $10^{8}$ m/s, $N_o$ = 6.0223 x $10^{23}$

$$4^1_1\text{H} \rightarrow ^4_2\text{He} + 2^0_1\text{e}$$

A. 6.20 x $10^8$ kJ  
B. 2.48 x $10^8$ kJ  
C. 6.90 x $10^8$ kJ  
D. 2.48 x $10^9$ kJ

82. The enthalpy of combustion of propane (44.0 g/mole) gas is -2220 kJ/mole. How many kilograms of propane will be needed to produce the same amount of heat?

A. 1.23 x $10^4$ kg  
B. 4.91 x $10^4$ kg  
C. 4.91 x $10^7$ kg  
D. 1.23 x $10^{10}$ kg
83. A fluoride ion selective electrode is calibrated over a range of 0.10 to 10.0 ppm and found to have an intercept of 230 mV and a slope of -56.3 mV. A water sample containing an unknown F⁻ is analyzed by taking a 10.0 mL sample of water, a buffer, and diluting it to 250.0 mL in a volumetric flask. Using the calibrated electrode, the resulting solution measured 330 mV. What is the concentration of the fluoride in the original water sample?  
Hint: \( E = m \log [F^-] + b \)  
A. 0.017 ppm  
B. 0.42 ppm  
C. 0.94 ppm  
D. 2.35 ppm

84. The Mg²⁺ and Ca²⁺ ions in hard water hinder soaps and detergents. Water softeners which use Na₂CO₃ are used to remove these ions. Suppose that hard water used to do laundry contains 75 ppm CaCO₃ and 55 ppm MgCO₃ by mass. What mass of Na₂CO₃ must be used to remove 90.0% of these ions from 10.0 L of laundry water?  
Hint: ppm = mg/L  
\[ \text{Molar Mass (g/mole)} \]  
\[ \begin{array}{|c|c|} \hline \text{Mg} & 24.30 \\ \text{MgCO₃} & 84.31 \\ \text{Ca} & 40.08 \\ \text{CaCO₃} & 100.09 \\ \text{Ksp} & \begin{array}{c} \text{MgCO₃} \ 6.82 \times 10^{-6} \\ \text{CaCO₃} \ 6.00 \times 10^{-9} \end{array} \\ \hline \end{array} \]  
A. 15.9 g  
B. 31.8 g  
C. 51.6 g  
D. 111 g

85. Chemists learn early on that “like dissolves like.”  
Select the bear below that fits “like dissolves like.”  
A. Black Bear  
B. Polar Bear  
C. Grizzly Bear  
D. Panda Bear

A.  
B.  
C.  
D.