# The 61st Annual
# Merck State Science Day Competition
# May 17, 2011

# CHEMISTRY

**Directions:**
**PLEASE DO NOT OPEN THE EXAM BOOKLET UNTIL DIRECTED.**

Be sure to fill in your name on the answer sheet both by printing it in the correct space, and by filling in the corresponding letter in the provided spaces.

**Use a #2 pencil only**.

Carefully erase any errors, and do not make any extraneous marks on the answer sheet.
Do NOT use *White-Out* on any portion of the answer sheet.

The test has **60 items** that will be scored. You have **90** minutes in which to answer all the questions.

There is only one correct answer per question. Do not spend too much time on any one question. Do the items you find easier first, and then go back to those you find more difficult or time consuming during the time you have remaining. Your individual score will be computed on the basis of the number of correctly answered items. (There is no penalty for guessing.)

In addition to the periodic table, there are several subject-specific items below that you may find useful in answering certain questions. Be sure to read them.

## INFORMATION THAT MAY BE USEFUL IN SOLVING THE PROBLEMS

**Universal gas constant:** **R = 0.0821 atm-liter/(mole-K)**
**R = 8.31 kPa-liter/(mole-K)**

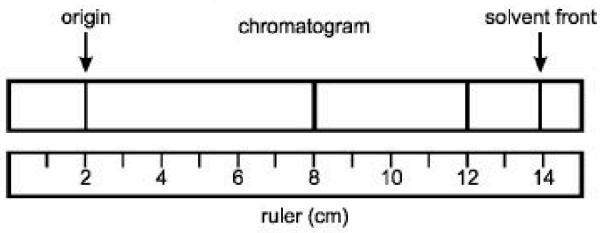
**1 Faraday (ℱ) = 96,500 coulombs/mole**
**= 96,500 joules/volt**
**1 electron volt/atom = 96.5 kilojoules/mole**
**Speed of light in vacuum = 3.00 x $10^{8}$ m/sec**
**Planck's constant, h = 6.63 x $10^{-34}$ joule-sec**
**Boltzmann's constant, k = 1.38 x $10^{-23}$ joule/K**
**Avogadro's number = 6.02 x $10^{23}$ molecules/mole**

**$1dm^3$ = 1 L**
**PV=nRT**
**Specific heat $_{H2O}$ = 4.184 J/g°C**
**1 calorie = 4.184 joules**
**Q = mcΔT**
**$KE_{ave} = ½mv^2$**
**$K_f$ water = -1.86 °C/*m***
**$K_b$ water = 0.51°C/*m***
**STP = 0°C, 101.3 kPa**

**Multiple Choice**

*Identify the letter of the choice that best completes the statement or answers the question and place your selection ON THE ANSWER SHEET.*

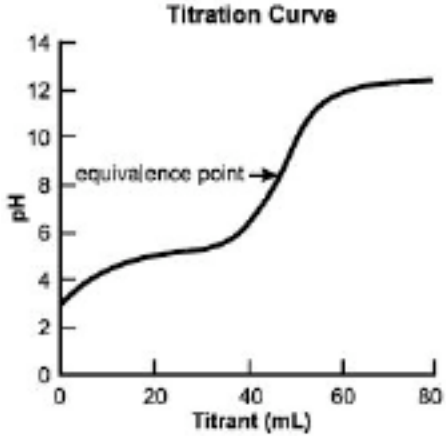
| Chromatography Reference Table | |
|---|---|
| Cation | $R_f$ $\left(\frac{\text{distance of cation}}{\text{distance of solvent}}\right)$ |
| $Ni^{2+}$ | 0.50 |
| $Cu^{2+}$ | 0.58 |
| $Fe^{3+}$ | 0.83 |




**1.** A chemist is using paper chromatography to identify the components of a sample known to contain at least one of the cations shown in the reference table. Given the chromatogram shown above, the unknown consists of:

**A)** $Cu^{2+}$ ions
**B)** $Ni^{2+}$ and $Fe^{3+}$ ions
**C)** $Fe^{3+}$ and $Cu^{2+}$ ions
**D)** $Ni^{2+}$ and $Cu^{2+}$ ions
**E)** $Ni^{2+}$, $Cu^{2+}$, and $Fe^{3+}$ ions

**2.** The graph below depicts the results of a titration experiment. Which conclusion about the titration experiment is best supported by these data?




**A)** The acid being titrated is a poly-protic acid.
**B)** A strong base is being titrated with a weak acid.
**C)** The titrant used in this experiment is a strong acid.
**D)** A weak acid is being titrated with a strong base.
**E)** A weak base is being titrated with a weak acid.

**3.** A chemistry class is planning to use a fume exhaust hood to study the reaction between the elements copper and sulfur. Before beginning the experiment, the teacher will review with the class the proper use of the exhaust hood. Which instruction should be included in this discussion?

**A)** Avoid using Bunsen burners within the fume exhaust hood.
**B)** Turn off the fan while performing the experiment.
**C)** Keep the sash in its lowered position during the experiment.
**D)** Step away from the fume exhaust hood once the reaction has begun.
**E)** Keep all reagent bottles within the fume exhaust hood.

**4.** Which is an example of a chemistry protocol being carried out in a safe manner?

**A)** heating a compound in a test tube over a flame with the test tube opening oriented away from people

**B)** evaporating acetone from a beaker using direct heat from a Bunsen burner

**C)** using a glass stirring rod to assist in pouring a solution of NaClO into a beaker containing HCl

**D)** transferring a beaker containing boiling water directly from a hot plate into an ice bath

**E)** neutralizing an acidic solution of barium chloride before pouring down the drain

**5.** Which technology uses X-rays to visualize an object?

**A)** positron emission tomography (PET scan)

**B)** magnetic resonance imaging (MRI)

**C)** computerized axial tomography (CT scan)

**D)** scanning tunneling microscopy (STM)

**E)** atomic absorption spectroscopy (AA)

**6.** The products of a chemical reaction are solid zinc carbonate and aqueous sodium chloride. Which procedure will achieve the best separation of the mixture into its three components?

**A)** filtering the mixture and then distilling the filtrate

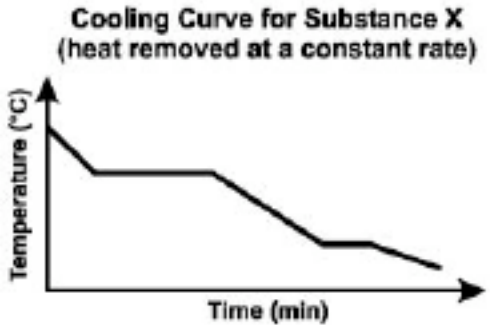
**B)** crystallizing the mixture and then decanting the aqueous portion

**C)** centrifuging the mixture and then crystallizing the supernatant

**D)** distilling the mixture and then centrifuging the distillate

**E)** water displacement of the gas and then evaporating the solution to dryness

**7.** Which statement is supported by the data presented in the cooling curve for substance X at room pressure shown below?




**A)** The heat of vaporization for substance X is greater than its heat of fusion.

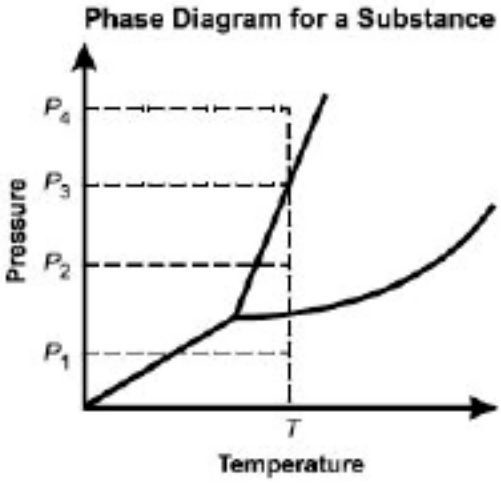
**B)** The specific heat of substance X is greater than its heat of formation.

**C)** The boiling point of substance X is greater than its condensing point.

**D)** The melting point of substance X is greater than its freezing point.

**E)** Substance X will readily sublimate under normal pressure.

**8.** Based on the phase diagram above, which pressure in combination with temperature T would result in the substance being present only as a gas?




**A)** $P_1$
**B)** $P_2$
**C)** $P_3$
**D)** $P_4$
**E)** unable to be determined without knowing the exact temperature and pressure

**9.** A 20.0 L cylinder of oxygen gas is at a temperature of 27.0°C and a pressure of 5.00 atm. What is the density of the oxygen gas in the cylinder?

**A)** 72.0 g/L
**B)** 28.9 g/L
**C)** 6.50 g/L
**D)** 3.25 g/L
**E)** 0.203 g/L

**10.** Which quantum number describes the shape of an orbital?

**A)** the principle quantum number, $n$
**B)** the magnetic quantum number, $m_l$
**C)** the configuration number, $s$, $p$, $d$, or $f$
**D)** the electron spin quantum number, $m_s$
**E)** the angular momentum quantum number, $l$

**11.** ~~How much energy is emitted when an electron in a hydrogen atom transitions from the $n_i = 6$ state to the $n_f = 2$ state?~~ eliminated

~~**A)** $7.27 \times 10^{-19}$ J~~
~~**B)** $6.06 \times 10^{-19}$ J~~
~~**C)** $4.84 \times 10^{-19}$ J~~
~~**D)** $1.36 \times 10^{-19}$ J~~
~~**E)** $6.02 \times 10^{-23}$ J~~

**12.** $^{239}_{94}Pu + {}^{4}_{2}He \rightarrow {}^{242}_{96}Cm + {}^{1}_{0}n$

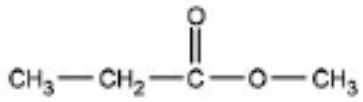
In order to overcome the electrostatic repulsion between alpha particles and the target nucleus, the reaction shown above is carried out using:

**A)** high speeds.
**B)** low temperatures.
**C)** high pressure.
**D)** low volumes.
**E)** low magnetic flux.

**13.** Given that the half-life of strontium-90 is 28.8 years, what mass of Sr-90 will remain in a 50.0 g sample of strontium-90 after 144 years?

**A)** 25.0 g
**B)** 6.25 g
**C)** 3.12 g
**D)** 1.56 g
**E)** 0.391 g

**14.** Which organic functional group does the molecule below contain?



**A)** hydroxyl
**B)** carbonyl
**C)** ether
**D)** ester
**E)** oxy

**15.** The complex ion $[Pt(NH_3)_4]^{2+}$ has a square planar structure. Which substance, in which chloride ions replace ammonia as ligands, can exist as geometric isomers?
**A)** $[PtCl(NH_3)_3]^{1+}$
**B)** $PtCl_2(NH_3)_2$
**C)** $[PtCl_3NH_3]^{1-}$
**D)** $[PtCl_4]^{2-}$
**E)** $[PtCl_4]^{1+}$

**16.** Which molecule has the strongest O—H bond?
**A)** $HClO_4$
**B)** $HClO_2$
**C)** $HClO_3$
**D)** HClO
**E)** $CH_3O$

**17.** In which substance are dipole-dipole forces the primary intermolecular force?
**A)** $PBr_5$
**B)** $CF_4$
**C)** $BeCl_2$
**D)** $NH_3$
**E)** NaCl

**18.** Methanol is considerably more soluble in water than 1-hexanol. Which best explains this difference in solubility?
**A)** Methanol contains fewer hydroxyl groups than 1-hexanol.
**B)** The alkyl group is longer in 1-hexanol than in methanol.
**C)** 1-hexanol is a significantly more polar molecule than methanol.
**D)** The greater number of hydrogen atoms in 1-hexanol increases the amount of hydrogen bonding.
**E)** Methanol has a smaller molar mass than 1-hexanol.

**19.** The reaction shown below is an example of which type of chemical reaction?

$$C_3H_{6(g)} + H_{2(g)} \rightarrow C_3H_{8(g)}$$

**A)** addition
**B)** double displacement
**C)** neutralization
**D)** combustion
**E)** esterification

**20.** Which product is formed when benzene ($C_6H_6$) undergoes a substitution reaction with nitric acid ($HNO_3$)?
**A)** $C_6H_5NO_2$
**B)** $C_6H_7NO_3$
**C)** $CNO_3$
**D)** $H_2CO_3$
**E)** HCN

**21.** What is the pH of a buffer made from 0.25 *M* $NH_3$ and 0.50 *M* $NH_4Cl$ at 25°C?
($K_b$ for $NH_3 = 1.8 \times 10^{-5}$)

**A)** 3.2
**B)** 4.7
**C)** 7.5
**D)** 9.0
**E)** 13

**22.** Nitrite ions ($NO_2^-$) and aluminum (Al) react in a basic environment as shown in the incomplete unbalanced equation below. When this oxidation-reduction reaction is balanced with the lowest set of whole-number coefficients, what is the coefficient for the hydroxide ion ($OH^-$) and on which side of the equation will it appear?

$$NO_2^-(aq) + Al(s) \rightarrow NH_3(aq) + Al(OH)_4^-(aq)$$

**A)** 2, on the product side
**B)** 1, on the product side
**C)** 2, on the reactant side
**D)** 1, on the reactant side
**E)** 1, on the reactant side & 2, on the product side

**23.** A chemist reacts 258 g of $NH_3$ with 425 g of $CO_2$ and produces 298 g $(NH_2)_2CO$ according to the reaction shown below. What is the percent yield for this reaction?

$$2\ NH_3(g) + CO_2(g) \rightarrow (NH_2)_2CO(aq) + H_2O(l)$$

**A)** 16.4%
**B)** 32.8%
**C)** 51.4%
**D)** 65.5%
**E)** 100%

**24.** Why does the reaction rate for the combustion of glucose increase with the addition of $KClO_3$?
**A)** The presence of $KClO_3$ lowers the activation energy of the reaction.
**B)** The decomposition of $KClO_3$ increases the concentration of a combustion reactant.
**C)** The decomposition of $KClO_3$ yields a large quantity of heat.
**D)** The KCl formed from the decomposition of $KClO_3$ is very reactive.
**E)** KCl acts as an intermediate in the reaction mechanism of the combustion.

**25.** The table below shows initial concentrations and reaction rates for the hypothetical reaction

$$A_2 + 2\ B \rightarrow 2\ AB.$$

| Experiment | Initial $[A_2]$ ($M$) | Initial [B] ($M$) | Initial Rate ($M$/s) |
|---|---|---|---|
| 1 | 0.25 | 0.10 | $2.8 \times 10^{-2}$ |
| 2 | 0.25 | 0.30 | $8.3 \times 10^{-2}$ |
| 3 | 0.25 | 0.40 | $1.1 \times 10^{-1}$ |
| 4 | 0.50 | 0.10 | $5.5 \times 10^{-2}$ |
| 5 | 0.75 | 0.30 | $2.5 \times 10^{-1}$ |

Using these data, which is the rate law for this reaction?

**A)** rate = $k[A_2]$
**B)** rate = $k[A_2][B]^2$
**C)** rate = $k[A_2][B]$
**D)** rate = $k[A_2]^3[B]$
**E)** rate = $k[B]$

**26.** Using the data for the decomposition of $H_2O_2$ shown below, what is the reaction rate when $[H_2O_2] = 6.50 \times 10^{-1}$?

| Experiment | Initial $[H_2O_2]$ ($M$) | Initial Rate ($M$/min) |
|---|---|---|
| 1 | $1.50 \times 10^{-2}$ | $1.59 \times 10^{-5}$ |
| 2 | $3.00 \times 10^{-2}$ | $3.18 \times 10^{-5}$ |
| 3 | $4.50 \times 10^{-2}$ | $4.77 \times 10^{-5}$ |
| 4 | $7.50 \times 10^{-2}$ | $7.95 \times 10^{-5}$ |

**A)** $6.36 \times 10^{-5}$ $M$/min
**B)** $6.89 \times 10^{-4}$ $M$/min
**C)** $6.51 \times 10^{-3}$ $M$/min
**D)** $4.60 \times 10^{-2}$ $M$/min
**E)** $6.50 \times 10^{-1}$ $M$/min

**27.** The proposed mechanism for the reaction between $NO_2$ and CO at temperatures less than 600 K is shown below.

**step 1:** $2\ NO_{2(g)} \rightarrow NO_{3(g)} + NO_{(g)}$ (slow)

**step 2:** $NO_{3(g)} + CO_{(g)} \rightarrow NO_{2(g)} + CO_{2(g)}$ (fast)

**overall:** $NO_{2(g)} + CO_{(g)} \rightarrow NO_{(g)} + CO_{2(g)}$

Given this information, which rate law best represents this reaction mechanism?

**A)** rate = $k[CO]$
**B)** rate = $k[NO_2]^2$
**C)** rate = $k[NO_3][CO]$
**D)** rate = $k\sqrt{[NO_2]}$
**E)** rate = $k[NO_2]^2[CO]$

**28.** The proposed mechanism for the reaction between $I^-$ and $OCl^-$ is shown below.

**step 1:** $OCl^-_{(aq)} + H_2O_{(l)} \rightarrow HOCl_{(aq)} + OH^-_{(aq)}$

**step 2:** $I^-_{(aq)} + HOCl_{(aq)} \rightarrow HOI_{(aq)} + Cl^-_{(aq)}$

**step 3:** $HOI_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)} + IO^-_{(aq)}$

**overall:** $I^-_{(aq)} + OCl^-_{(aq)} \rightarrow IO^-_{(aq)} + Cl^-_{(aq)}$

Given the reaction mechanism shown above, how many intermediates are involved in the reaction between $I^-$ and $OCl^-$?

**A)** 0 **B)** 1 **C)** 2 **D)** 3 **E)** 4

**29.** Which best describes what happens to the variables in the equation below as a compound undergoes a phase transition from solid to liquid to gas?

$$S = k \times \log W$$

**A)** The value of $S$ decreases.
**B)** The value of $k$ increases.
**C)** The values of $S$, $k$, and $W$ decrease.
**D)** The value of $W$ increases.
**E)** The value of $W$ decreases only if the enthalpy of the process is exothermic.

**30.** A system undergoes an exothermic process releasing 2.5 kJ of heat. During this process, the system does 0.5 kJ of work. According to the first law of thermodynamics, what is the change in the system's internal energy?

**A)** -3.0 kJ **B)** -2.0 kJ **C)** 0 kJ **D)** 2.0 kJ **E)** 3.0 kJ

**31.** When $1.0 \times 10^2$ g of an unknown metal at 80.0°C is placed in a calorimeter containing $1.0 \times 10^2$ g of water, the temperature of the water rises from 20.0°C to 25.0°C. Given that the specific heat of water is 4.184 J/g•K, what is the specific heat of the metal?

**A)** 0.26 J/g•K
**B)** 0.38 J/g•K
**C)** 1.05 J/g•K
**D)** 1.52 J/g•K
**E)** 1.90 J/g•K

**32.** A constant pressure calorimeter with negligible heat capacity contains 200.0 g of $H_2O$ at 25.00°C. When 12.3 g of $KClO_3$ is dissolved in the $H_2O$, the temperature of the solution in the calorimeter drops to 20.05°C. Assuming the specific heat of the solution is 4.184 J/g•K, what is the heat of solution of $KClO_3$?

**A)** 0.0.0227 kJ/mol
**B)** 0.225 kJ/mol
**C)** 0.377 kJ/mol
**D)** 44.0 kJ/mol
**E)** 168 kJ/mol

**33.** Based on the bond enthalpies and chemical equation shown below, what is the best estimate for the enthalpy of formation for 1 mol of $NF_3$?

| Bond | Bond Enthalpy (kJ/mol) |
|---|---|
| N—N | 159 |
| N=N | 418 |
| N≡N | 941 |
| F—F | 153 |
| N—F | 272 |

$$^1/_2\ N_{2(g)} + {}^3/_2\ F_{2(g)} \rightarrow NF_{3(g)}$$

**A)** –816 kJ/mol
**B)** –507 kJ/mol
**C)** –387 kJ/mol
**D)** –116 kJ/mol
**E)** -40.0 kJ/mol

**34.** Which reaction shown in the table below is spontaneous only at sufficiently high temperatures?

| Reaction | Chemical Equation | $\Delta H°$ (kJ) | $\Delta S$ (J/K) |
|---|---|---|---|
| 1 | $2\ SO_{3(g)} \rightarrow 2\ SO_{2(g)} + O_{2(g)}$ | 198 | 188 |
| 2 | $2\ AsF_{3(l)} \rightarrow 2\ As_{(s)} + 3\ F_{2(g)}$ | –1643 | 316 |
| 3 | $N_2O_{(g)} + 2\ H_2O_{(l)} \rightarrow NH_4NO_{3(s)}$ | 36 | –446 |
| 4 | $4\ Fe_{(s)} + 3\ O_{2(g)} \rightarrow 2\ Fe_2O_{3(s)}$ | –1650 | –549 |

**A)** reaction 1
**B)** reaction 2
**C)** reaction 3
**D)** reaction 4
**E)** reaction 3 & 4

**35.** What mass of silver ion is present in a 500 mL solution of saturated silver acetate, $AgC_2H_3O_2$? ($K_{sp} = 1.9 \times 10^{-3}$)

**A)** $1.9 \times 10^{-3}$ g
**B)** 0.10 g
**C)** 0.21 g
**D)** 2.4 g
**E)** 4.7 g

**36.** The compounds shown in the table below are placed in a sealed flask at 47 °C. Using the given initial partial pressures, what is the value for the reaction quotient ($Q_p$) and how will the reaction proceed from these initial conditions to reach equilibrium?

$$N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$$

$$K_p = 2.79 \times 10^{-5} \text{ at } 472°C$$

| Compound | Initial Partial Pressure (atm) |
|---|---|
| $N_2$ | 3.69 |
| $H_2$ | 11.1 |
| $NH_3$ | 0.415 |

**A)** $Q_p = 1.01 \times 10^{-2}$ and the reaction will shift left.
**B)** $Q_p = 1.01 \times 10^{-2}$ and the reaction will shift right.
**C)** $Q_p = 3.41 \times 10^{-5}$ and the reaction will shift left.
**D)** $Q_p = 3.41 \times 10^{-5}$ and the reaction will shift right.
**E)** $Q_p = K_p$ and is at equilibrium

**37.** Assuming complete dissociation of the solute, what is the freezing point of a solution containing 24.0 g of $SrCl_2$ and 100.0 g of water?

**A)** –2.32°C
**B)** –2.81°C
**C)** –5.62°C
**D)** –8.44°C
**E)** –16.8°C

**38.** Assuming complete dissociation of electrolytes, which solution would have the lowest boiling point?

**A)** 120.0 g of $C_6H_{12}O_6$ in 1.0 L of $H_2O$
**B)** 80.0 g of $ZnSO_4$ in 1.0 L of $H_2O$
**C)** 100.0 g of $C_3H_8O_3$ in 1.0 L of $H_2O$
**D)** 60.0 g of $NH_4Cl$ in 1.0 L of $H_2O$
**E)** 100.0 g of $CH_3OH$ in 1.0 L of $H_2O$

**39.** An elevation in temperature will increase the solubility in water of which compound?

**A)** $CO_2(g)$
**B)** $O_2(g)$
**C)** $Ce_2(SO_4)_3(s)$
**D)** $NH_4Cl(s)$
**E)** $CCl_4(l)$

**40.** Using the standard reduction potentials shown below, which cell is spontaneous at standard conditions?

| Standard Reduction Potentials (1.0 *M* at 25°C) | |
|---|---|
| Half-reaction | E° (V) |
| $Ba^{2+}(aq) + 2\ e^- \rightleftharpoons Ba(s)$ | –2.91 |
| $Na^+(aq) + e^- \rightleftharpoons Na(s)$ | –2.71 |
| $Mn^{2+}(aq) + 2\ e^- \rightleftharpoons Mn(s)$ | –1.18 |
| $Tl^+(aq) + e^- \rightleftharpoons Tl(s)$ | –0.34 |
| $Ag^+(aq) + e^- \rightleftharpoons Ag(s)$ | +0.80 |
| $Au^{3+}(aq) + 3\ e^- \rightleftharpoons Au(s)$ | +1.50 |

**A)** $Mn|Mn^{2+}||Tl^+|Tl$
**B)** $Ag|Ag^+||Mn^{2+}|Mn$
**C)** $Ag|Ag^+||Na^+|Na$
**D)** $Na|Na^+||Ba^{2+}|Ba$
**E)** $Au|Au^{3+}||Ag^+|Ag$

**41.** The following reaction takes place at 25°C.

$$4\ Br^-(aq) + O_2(g) + 4\ H^+(aq) \rightarrow 2\ H_2O(l) + 2Br_2(l)$$

| Standard Reduction Potentials (1.0 *M* at 25°C) | |
|---|---|
| Half-reaction | E° (V) |
| $O_2(g) + 4\ H^+(aq) + 4\ e^- \rightleftharpoons 2\ H_2O(l)$ | +1.23 |
| $Br_2(l) + 2\ e^- \rightleftharpoons 2\ Br^-(aq)$ | +1.08 |

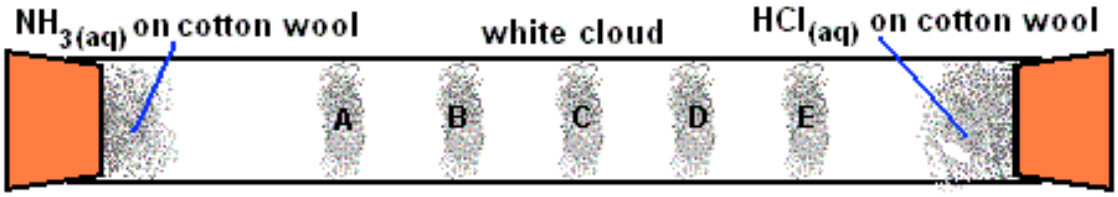
Using the equations and half-reactions shown above, what is the value of the equilibrium constant (*K*) for this chemical reaction?

**A)** $1.1 \times 10^{39}$
**B)** $1.9 \times 10^{20}$
**C)** $1.4 \times 10^{10}$
**D)** 2.31
**E)** $3.5 \times 10^{2}$

**42.** An oxidation-reduction reaction has a negative electrochemical potential at standard conditions. Which is true about the standard free energy change ($\Delta G^\circ$) and equilibrium constant (*K*) for this reaction at 25°C?

**A)** $\Delta G^\circ > 0,\ K < 1$
**B)** $\Delta G^\circ > 0,\ K > 1$
**C)** $\Delta G^\circ < 0,\ K < 1$
**D)** $\Delta G^\circ < 0,\ K > 1$
**E)** $\Delta G^\circ = 0,\ K = 1$

**43.** The acid hydrogen chloride HCl (in water) is placed at one end, and evaporates as HCl gas. Ammonia, (in water solution) is placed at the other end, and gives off ammonia gas, $NH_3$. The two gases diffuse down the tube. Where these gases first meet, they react chemically to make a disk-shaped cloud of dust composed of (the solid) ammonium chloride $NH_4Cl$. Where will they first meet?




**A)** position A
**B)** position B
**C)** position C
**D)** position D
**E)** position E

**44.** Your teacher should have MSDS for you to consult before your lab exercises. What does a MSDS contain?

**A)** compound enthalpies of formation
**B)** lab techniques
**C)** videos of that lab exercise
**D)** safety data information
**E)** Microsoft data spreadsheets

**45.** Which combination of aqueous solutions will produce a precipitate?

**A)** $Ca(NO_3)_2$ and $Na_3PO_4$
**B)** $Li_2CO_3$ and NaOH
**C)** $Cu(NO_3)_2$ and $Na_2SO_4$
**D)** $NH_4NO_3$ and $Na_2S$
**E)** $FeCl_3$ and $Zn(CH_3COO)_2$

**46.** U.S. pennies minted after 1982 consist of a zinc core clad with copper. The zinc will dissolve in HCl if the copper coating is scratched deeply. The reaction is:

$$2\ HCl(aq) + Zn(s) \rightarrow H_2(g) + ZnCl_2(aq)$$

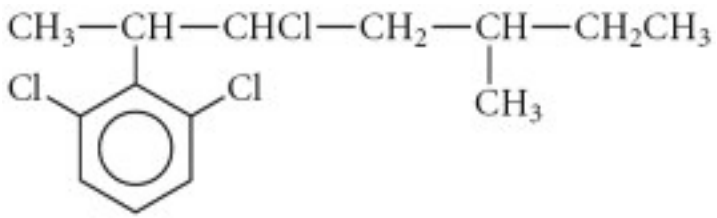
A penny weighs 2.518 g. When scratched and placed in HCl, it produces 900. mL of hydrogen collected over water at 25°C with a total pressure of 794 mm Hg. Assuming all the Zn dissolves, what is the percentage of zinc in the penny? [vapor pressure $H_2O$ @ 25°C = 24 mm Hg, R = 0.0821 atm L $mole^{-1}K^{-1}$]

**A)** 94.1% **B)** 95.4% **C)** 96.8% **D)** 97.8% **E)** 99.8%

**47.** Tartaric acid, a white crystalline organic acid containing only C, H, and O, is found naturally in many plants, such as grapes, bananas, and tamarinds, and is one of the main acids in wine. Its sour taste gives foods, such as Sour Patch Kids, its zing. Combustion analysis of a 1.201 g sample produced 1.408 g of $CO_2$ and 0.432 g of $H_2O$. The empirical formula of tartaric acid is:

**A)** $CH_2O_2$
**B)** $C_2H_3O_3$
**C)** $C_4H_3O_6$
**D)** $C_4H_6O_{11}$
**E)** $(CO_2)_4(H_2O)_3$

**48.** How many chiral carbons in the structure below?

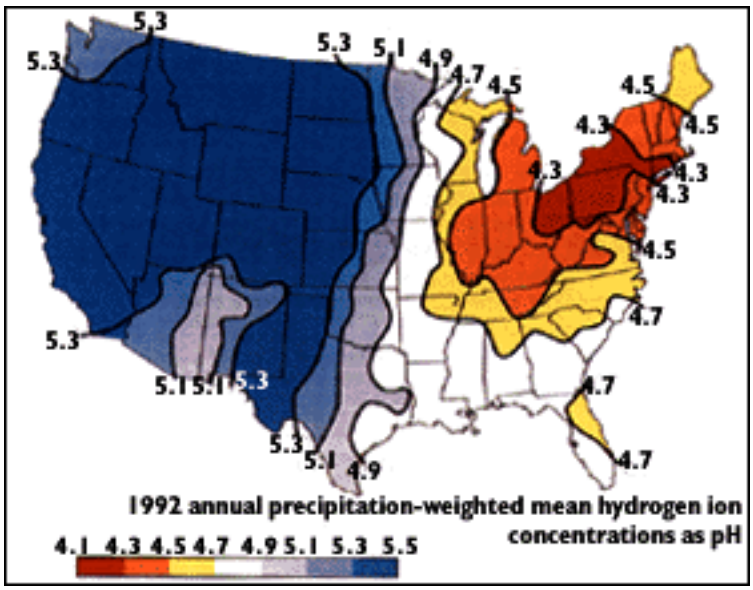


**A)** 0 **B)** 1 **C)** 2 **D)** 3 **E)** 4 or more

**49.** Which statement about acids and bases is **TRUE**?

**A)** A dilute acid is a weak acid.
**B)** A strong acid has a strong conjugate base.
**C)** The conjugate base of a very weak acid is stronger than the conjugate base of a strong acid.
**D)** A weak base is composed of a cation and an anion with a very weak attraction between them.
**E)** A strong acid is composed of a proton and an anion that have a very strong attraction for one another.

**50.** The pH of rain in Southern California is 5.3 whereas in New Jersey it is 4.4. How many times more concentrated is the $[H^+]$ of rain in New Jersey compared to Southern California?




**A)** 0.8 **B)** 0.9 **C)** 1.2 **D)** 8 **E)** 9

**51.** The concentration of a colored substance is determined by measuring the absorbance of its aqueous solution and interpolating from a graph of absorbance versus concentration. Which procedural error will result in a concentration that is too high?

I. Rinsing the cuvette with water just before filling it with the unknown solution
II. Measuring the absorbance of the unknown solution at a wavelength other than its maximum.
III. Using a cuvette for the unknown solution that has air bubbles in the solution.

**A)** I only
**B)** II only
**C)** III only
**D)** I and II only
**E)** II and III only

**52.** In order to be more environmentally friendly, toxic lead has been removed from many consumer products. In the U.S., which product has NOT been changed in order to "get the lead out"?

**A)** pencils
**B)** house paint
**C)** car battery
**D)** gasoline
**E)** shotgun pellets

**Matching** Each choice may be used once, more than once, or not at all.

**#53-56**. All compounds are at the same conditions.

**A)** carbon dioxide, $CO_2$
**B)** nitrous oxide, $N_2O$
**C)** propane, $C_3H_8$
**D)** acetaldehyde, $CH_3CHO$
**E)** none of them

**53.** Is the most polar compound

**54.** Has much more kinetic energy than the others

**55.** Largest heat of combustion.

**~~56. Liquid at room temperature and standard pressure~~** eliminated

**# 57-60** Match the scientist below with the idea, theory, discovery, or invention.

**A)** Fritz Haber
**B)** Charles Hall
**C)** Werner Heisenberg
**D)** Dorothy Hodgkin
**E)** Glenn Seaborg

**57.** Structure of vitamin $B_{12}$

**58.** Synthesis and identification of trans-uranium elements

**59.** Method of converting hydrogen and nitrogen into ammonia

**60.** Economic method of electrolyzing aluminum oxide into aluminum

**Merck State Science Day 2011** **CHEMISTRY**
**Answer Section**

## MULTIPLE CHOICE

1. B
2. D
3. C
4. A
5. C
6. A
7. A
8. ~~B~~ A
9. C
10. E
11. ~~C~~ Eliminated
12. A
13. D
14. D
15. B
16. D
17. D
18. B
19. A
20. A
21. D
22. D
23. D
24. B
25. C
26. B
27. B
28. D
29. D
30. A
31. B
32. D
33. D
34. A
35. D
36. C
37. D
38. E
39. D
40. A
41. C
42. A
43. D
44. D
45. A
46. C
47. B
48. ~~C~~ D
49. C
50. D
51. C
52. C
53. D
54. E
55. C
56. ~~D~~ Eliminated
57. D
58. E
59. A
60. B