SECTION I: MULTIPLE-CHOICE EXPLANATIONS

1. **D** Reactions: Reaction Types *Classification set*

A pH less than 7 means an acidic buffer. This narrows the choices to **C** and **D**. Both of these choices contain an acid and a salt of the acid. An optimum buffer is composed of a weak acid and a salt of the weak acid. This allows for the buffer to resist a significant change in pH by absorbing extra H^+ and/or OH^-. Hydrobromic acid is a strong acid, and bromide ion is a very weak conjugate base. Therefore, acetic acid and sodium acetate would be the only choice.

2. **E** Reactions: Reaction Types *Classification set*

A pH greater than 7 means a basic buffer. An optimum buffer is composed of a weak base and a salt of the weak base. Choice **A** is a mixture of a strong base and a weak base. Only choice **E** contains a weak base and a salt of the weak base.

3. **B** Reactions: Reaction Types *Classification set*

A pH of 7 means a neutral solution. Choice **B** contains a strong acid and a strong base. When mixed, the result is a neutral salt and water since the question stated that the mole-to-mole ratio was 1:1.

4. **A** Reactions: Reaction Types *Classification set*

The highest pH means the most basic solution. Choice **A** contains a strong base and a weak base. When mixed, the pH is determined by the sodium hydroxide, which is a strong base. Choice **E** contains only a weak base. All other choices are either neutral or acidic.

5. **E** Structure of Matter: Chemical Bonding *Classification set*

Both $MgCl_2$ and NaCl are ionic compounds. The difference in melting points is due to the strength of the intramolecular forces that hold the ions together. The attractive force is easily estimated using Coulomb's law, $F = \frac{q_1 q_2}{r^2}$. The difference lies in Mg's charge of $+2$ and Na's charge of only $+1$. Since all of the ions are relatively the same size, the attractive force between the ions is twice as strong for $MgCl_2$.

6. **A** Structure of Matter: Chemical Bonding *Classification set*

Both H_2O and H_2S are covalently bonded compounds. The difference in boiling points is primarily due to the strength of the intermolecular attractive forces that hold the molecules together. Hydrogen bonding, the attraction that hydrogen has for the unshared electron pair on the highly electronegative oxygen atom, is found in the water molecule. Hydrogen sulfide molecules are held together by much weaker dipole forces. The more tightly molecules are held together, the more energy needed to separate them and the higher the boiling point.

7. **B** Structure of Matter: Chemical Bonding *Classification set*

Carbon's electron configuration is $1s^2 2s^2 2p^2$. The four bonding electrons in the carbon atom are found in the *s* and the *p* orbitals. Since these orbitals are of different energy, the four carbon bonds would not be equal according to the VSEPR theory. The valence bond theory assumes that bonding electrons will hybridize to form orbitals of equal energy. In fact, in methane, hybridization leads to four sp^3 hybridized orbitals.

8. **D** Structure of Matter: Chemical Bonding *Classification set*
The VSEPR theory relates shape of molecules to the repulsions and positions of shared and unshared electron pairs. Water obeys the octet rule and has two unshared electron pairs, which together have great repulsive force on the two shared pairs, resulting in the bond angle being reduced from the expected 109.5° to 105°.

9. **E** Structure of Matter: Atomic Theory *Classification set*
The copper +1 ion has lost one electron from the outermost energy level, which is the fourth level. The resulting electron configuration for the copper +1 ion is $1s^22s^22p^63s^23p^63d^{10}$. Recall that copper is an exception to the Aufbau filling and, like all transition metals, loses its *s* electrons before losing its *d* electrons.

10. **B** Structure of Matter: Atomic Theory *Classification set*
The fluoride ion gains one electron to form F^{1-}. The electron configuration for the fluorine atom is $1s^2\ 2s^2\ 2p^5$. By gaining one electron, the fluoride ion becomes isoelectronic with neon, $1s^2\ 2s^2\ 2p^6$. Note that choice **C** is incorrect since there is not a 2*d* sublevel.

11. **B** Structure of Matter: Atomic Theory *Classification set*
Alkali metals lose their outer electron to become +1 ions. This makes all ions of the alkali metals isoelectronic with the noble gas preceding them. A sodium atom has the following electron configuration: $1s^22s^22p^63s^1$. By losing one electron from the highest energy level, the sodium ion becomes isoelectronic with neon.

12. **A** Structure of Matter: Atomic Theory *Classification set*
The halogen family is group VIIA. All of the elements in this family have an s^2p^5 electron configuration ending.

13. **E** Reactions: Reaction Types *Classification set*
A strong oxidizing agent is easily reduced. Nitric acid and potassium permanganate are both good oxidizing agents. However, the only substance listed with color is potassium permanganate. Potassium permanganate is purple in color (with its Mn^{7+}) and easily reduces to lower oxidation states, which are all associated with distinct colors.

14. **A** Reactions: Reaction Types *Classification set*
An oxidizing acid reacts with active metals to produce oxides of that element and not the typical hydrogen gas. Nitric acid and hydrochloric acid are the two acids listed. Nitric acid, HNO_3, reacts with metals that HCl does not necessarily react with to produce nitrogen oxide compounds such as NO_2 and NO.

15. **D** Reactions: Reaction Types *Classification set*
Galvanizing is a common method of corrosion protection. Zinc is used as a coating with metals such as iron. The zinc will oxidize instead of the iron, which is very beneficial to protect the hull of ships and protect against corrosion of pipes.

16. **B** Reactions: Reaction Types *Classification set*
Acid rain is produced from gaseous nonmetal oxides (mainly SO_x and NO_x compounds, fondly referred to as "socks and knocks") reacting to form acids. SO_2 reacts to form acid rain in the following way. First, the sulfur dioxide combines with oxygen in the air:

$$2\,SO_2 + O_2 \rightarrow 2\,SO_3$$

The sulfur trioxide combines with moisture to form the strong acid sulfuric acid, which is typically known as acid rain:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

17. **B** Reactions: Reaction Types *Classification set*

Adding NaCl will cause precipitation of $PbCl_2$, which will decrease the concentration of the lead(II) ions in solution. Using the Nernst equation, $E = E° - \frac{RT}{nF}\ln Q$, where $Q = \frac{[\text{products}]^m}{[\text{reactants}]^n} = \frac{[Zn^{2+}]}{[Pb^{2+}]}$, it is easy to see that as $[Pb^{2+}]$ decreases, Q will become greater than 1 and the ln of Q will become positive. Thus, the overall voltage will decrease.

18. **C** Reactions: Reaction Types *Classification set*

Removing the salt bridge will cause a buildup of ions in each half-cell, the cells will soon establish equilibrium, and the voltage will drop to zero.

19. **A** Reactions: Reaction Types *Classification set*

Adding water to the beaker on the left will decrease the concentration of $[Zn^{2+}]$. Using the Nernst equation, $E = E° - \frac{RT}{nF}\ln Q$, where $Q = \frac{[\text{products}]^m}{[\text{reactants}]^n} = \frac{[Zn^{2+}]}{[Pb^{2+}]}$, it is easy to see that as $[Zn^{2+}]$ decreases, Q will decrease, and thus, the overall voltage will increase.

20. **B** Reactions: Reaction Types *Classification set*

As current flows through a cell, the concentration of the ions forming from oxidation is constantly increasing and the concentration of ions that are reduced is constantly decreasing. The voltage of the cell will continue to decrease over time until it reaches equilibrium, zero.

21. **A** Laboratory: Observations of Chemical Reactions *Multiple choice*

Solubility rules must be memorized! KI is a soluble salt and forms K^+ and I^- ions in solution. The ions of alkali metals do not form precipitates, so this eliminates choices **C**, **D**, and **E**. Iodide ions are soluble with everything except for Ag^+, Pb^{2+}, and Hg_2^{2+}. The net ionic reaction is $Pb^{2+} + 2I^- \rightarrow PbI_2$. PbI_2 is a common precipitate in the lab and has a distinct bright yellow color.

22. **C** Reactions: Equilibrium *Multiple choice*

The negative value for ΔH given means that the reaction is exothermic (energy is given off as a product). If the temperature is decreased, the reaction will shift to the product side to replace the heat. Pressure will have no effect since the same number of moles of gas is present on either side of the equation. Adding an inert gas or adding a catalyst has no effect on the equilibrium position since neither appears in the equilibrium expression—they are neither a reactant nor a product. Allowing hydrogen to escape would decrease the concentration of a reactant and thus shift the equilibrium to the reactant side.

23. **C** Reactions: Reaction Types *EXCEPT*

A Brønsted acid donates a proton while a Brønsted base accepts a proton. The following possibilities exist:

Substance	Accepts a Proton	Donates a Proton
HSO_3^-	H_2SO_3	SO_3^{2-}
HPO_4^{2-}	$H_2PO_4^-$	PO_4^{3-}
NH_4^+	NH_5^{2+}	NH_3
H_2O	H_3O^+	OH^-
HCO_3^-	H_2CO_3	CO_3^{2-}

Nitrogen is not capable of expanding its octet to accommodate five hydrogen atoms.

24. **D** Laboratory: Procedure *Multiple choice*

The only significant discrepancy in the data is between the first and subsequent samples. In a titration, the number of moles of acid must equal the number of moles of base at the equivalence point. Adding more water would just increase the volume of the acid but would not affect the number of moles of acid. Adding more phenolphthalein has no effect. If the sample was titrated beyond the end point or the buret not rinsed with NaOH, the volume of NaOH would appear too large. Not rinsing the pipet with acetic acid introduces the error.

25. **B** Reactions: Thermodynamics *Multiple choice*

The most positive value of ΔS indicates the system with the most disorder as the reaction proceeds from reactants to products. Choice **B** shows 2 moles of gaseous reactant producing 3 moles of gaseous product. All other choices show the formation of solids and/or liquids, which is a decrease in entropy.

26. **A** Structure of Matter: Atomic Theory *Multiple choice*

Moving across the period from Li to Ne, electrons are being added to the same energy level. However, the number of protons is also increasing, which causes a greater effective nuclear charge, allowing for the outer electrons to be held more tightly and thus decreasing the size.

27. **A** States of Matter: Gases *Multiple choice*

$$14\text{g } N_2 \times \frac{1 \text{ mol}}{28\text{g } N_2} = 0.50 \text{ mol } N_2$$

$$22\text{g } CO_2 \times \frac{1 \text{ mol}}{44 \text{ g } CO_2} = 0.50 \text{ mol } CO_2$$

Since both compounds contain the same number of moles at the same temperature and pressure, the volume occupied by each would be the same as would the number of molecules. The density of a gas is reported as grams per liter; nitrogen gas is less dense than carbon dioxide. Average kinetic energy is temperature dependent, and all molecules at the same temperature have the same average kinetic energy. Average speed is inversely proportional to the square root of the molecular weight. In general, lighter molecules will travel faster than heavier molecules at the same temperature, so nitrogen would move more quickly than carbon dioxide.

28. **E** Structure of Matter: Chemical Bonding *Multiple choice*

XeF_4 has an octahedral electronic geometry, which means it has six sites of electron density. The hybridization uses the *s* orbital plus all three *p* orbitals plus two *d* orbitals for a total of six "sites" of electron density. The hybridization of atomic orbitals creates bonding areas or "sites" of equal energy. The following hybridizations are common:

Hybridization	**Electronic Shape**
sp	Linear
sp^2	Trigonal planar
sp^3	Tetrahedral
dsp^3	Trigonal bipyramidal
d^2sp^3	Octahedral

29. **B** Reactions: Kinetics *Multiple choice*

In experiment 1 and 2, [B] is held constant while [A] doubles and the rate doubles. The reaction is first order with respect to A. In experiments 2 and 3, [A] is held constant while [B] is increased five times and the rate increases twenty-five times. Setting this up mathematically makes it easy to see that the reaction is second order with respect to B. $5^n = 25$, so $n = 2$ (or second order).

30. **C** Reactions: Reaction Types *Multiple choice*

In the experiment the flask begins with a weak base. A base has a pH greater than 7, so identifying this narrows the choices to **C**, **D**, and **E**. A weak base typically has a pH less than 12, thus eliminating **D** and **E**.

31. **B** Structure of Matter: Nuclear Chemistry *Multiple choice*

In transmutation reactions, the superscripts and the subscripts on each side must be equal. Total superscripts on the reactant side equals 247. On the product side the coefficient of 2 multiplies to give a total of 2 (one for each of two neutrons) + 129 (for iodine) = 131. Subtract: 247 – 131 = 116, which represents the top number. This narrows the choice to **A** or **B**. Follow the same procedure for the subscript. Total on reactant side = 97. Total on product side = 53. Subtract: 97 – 53 = 44. Ruthenium-44 is the correct choice.

32. **C** Structure of Matter: Chemical Bonding *Multiple choice*

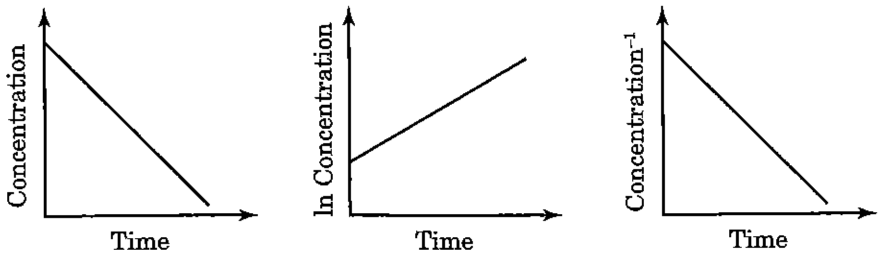
Sketch each Lewis structure to determine the number of unshared electron pairs on the central atom.

(A) (B) (C) (D) (E)

Bromine (**A**) and oxygen (**B**) have no central atom. Methane (**D**) has a molecular geometry that is tetrahedral and has no unshared electron pairs. SO_3 (**E**) has a molecular geometry that is trigonal planar with no unshared electron pairs on the central atom. Ammonia (**C**) has a molecular geometry that is trigonal pyramidal and has one unshared pair of electrons on the central nitrogen atom.

33. **C** Reactions: Kinetics *Multiple choice*

Determining the order of a reaction from experimental data requires graphing. An easy way to remember this is to create a set of graphs in this order with the y-axes being concentration, natural log of concentration, and reciprocal concentration (in alphabetical order by axis name), whichever gives a straight line, corresponds to zero, first, or second order. (Alphabetical order of the y-axis variables yields 0, 1, 2 orders for that reactant.) Time is always on the x-axis.



Zero order
k = negative slope

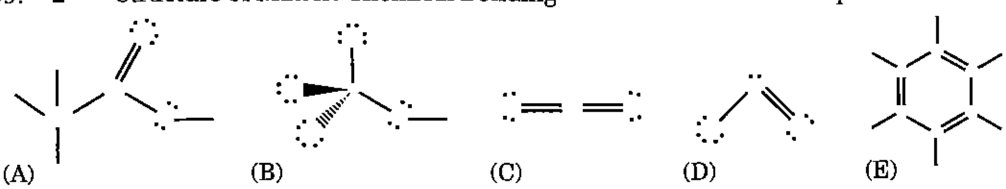
First order
k = negative slope

Second order
k = the slope

34. **C** Reactions: Thermodynamics *Multiple choice*

If the reaction is spontaneous, ΔG is negative, and the second condition of spontaneity is that K_{eq} be greater than 1. When ΔG is positive, the reaction will not occur as written, and when ΔG is zero, the system is at equilibrium.

35. **E** Structure of Matter: Chemical Bonding *Multiple choice*



Pi bonds are present when multiple bonds are present. The structures for each of the choices must be drawn. Chloric acid, $HClO_3$, is the only compound with all single bonds and is easily eliminated. Acetic acid and sulfur dioxide each have one pi bond, and carbon dioxide has two pi bonds. Benzene, C_6H_6, is a ring structure with three double bonds and thus the most pi bonding.

36. **C** States of Matter: Liquids and Solids *Multiple choice*

Potassium, manganese, and uranium are all solid metals at room temperature, whereas chlorine is a yellow-green gas. Bromine is the only liquid in the list.

37. **A** Reactions: Reaction Types *Multiple choice*

Alkali metals react violently with water to produce strong bases. The reaction is

$$2K + 2H_2O \rightarrow 2KOH + H_2.$$

All group IA hydroxides are strong bases. Manganese and uranium are metals but would not react violently with water. Chlorine and bromine are nonmetals and form acids when reacted with water.

38. **E** Reactions: Reaction Types *Multiple choice*

Assign oxidation numbers to each element in the reaction, then analyze. Oxygen changes from 0 to −2. H stays +1. Ag changes from 0 to +1. C is +2 in the cyanide ion. N is −3 in the cyanide ion. If carbon were +4 in the cyanide ion, the charge on the ion would be +1 instead of −1.

39. **B** Reactions: Reaction Types *Multiple choice*

The half-reaction given is written as a reduction since the electrons are on the reactant side. When you analyze oxidation numbers, it is easy to see that gold changes from +3 to 0. This represents a reduction. Reduction always occurs at the cathode. The chloride ion does not change charge in this half-reaction. The reducing agent is not shown here since it is the substance undergoing oxidation.

40. **C** Reactions: Reaction Types *Multiple choice*

The choices give the numerical setup without units. Write in the units and then see what matches numerically. Remember that an amp is equal to a coulomb per second.

$$\frac{2.0\text{ coulomb}}{\text{s}} \times \frac{10\text{ min}}{1} \times \frac{60\text{s}}{1\text{ min}} \times \frac{1\text{ mol e}^-}{96500\text{ coulombs}} \times \frac{1\text{ mol Au}}{3\text{ mol e}^-} \times \frac{197\text{g Au}}{1\text{ mol Au}}$$

41. **E** Structure of Matter: Nuclear Chemistry *Multiple choice*

Half-life is the time that it takes for one-half of a substance to decay. Without a calculator, it is best to set up this problem and work backward for every 5 minutes, the half-life given in the problem:

Amount (g)	Time (min.)
80	45
160	40
320	35
640	30
1,280	25
2,560	20
5,120	15
10,240	10
20,480	5
40,960	0 (This is the original amount at the beginning.)

42. **B** Structure of Matter: Atomic Theory *Multiple choice*

Rutherford knew that the atom was mostly empty space and expected that all of the positively charged alpha particles would be attracted to the sea of electrons and pass straight through the foil. To his surprise, some of the positive particles were deflected and bounced back. This meant that there must be some dense, positive substance within the atom. Many of the answer choices given in this question are true statements but are not significant to Rutherford's experiment. This experiment led to his title "father of nuclear science."

43. **D** Reactions: Thermodynamics *Multiple choice*

The desired equation is

$$6\,C(s) + 3\,H_2(g) \rightarrow C_6H_6(l)$$

The three equations given must be rearranged to give this equation. Remember that for thermodynamic data, whatever is done to the equation is done to the thermodynamic value. If the equation is reversed, change the sign. If the equation is multiplied by some value, multiply the thermodynamic quantity by that same value.

The first equation is reversed and divided by 2:

$$6\,CO_2(g) + H_2O(l) \rightarrow C_6H_6(l) + 7\frac{1}{2}O_2(g) \qquad \Delta G^\circ = +3{,}200.0\text{ kJ}$$

The second equation is multiplied by 6:

$$6C(s) + 6\,O_2(g) \rightarrow 6\,CO_2(g) \qquad \Delta G^\circ = -2{,}400.0\text{ kJ}$$

The third equation is multiplied by 3:

$$3H_2(g) + 1\frac{1}{2}O_2(g) \rightarrow 3\,H_2O(l) \qquad \Delta G^\circ = -750.0\text{ kJ}$$

Adding the equations gives the desired reaction. Add the ΔG° values:

$$3{,}200.0\text{ kJ} + (-3{,}150.\text{ kJ}) = 50.0\text{ kJ}$$

44. **A** Reactions: Kinetics *Multiple choice*

If [Y] doubles and the rate quadruples, with all other factors held constant, then the reaction must be second order with respect to [Y]. $2^n = 4; n = 2$. We do not have enough information about the reaction mechanism to determine if choice **B**, **C**, or **D** is correct. Choice **E** is an incorrect statement.

45. **E** Laboratory: Procedure *I, II, III*

All of the statements are appropriate lab procedures. pH probes must be calibrated in order to give accurate readings. Glass tubing slides easily into a rubber stopper with lubrication but may break if lubrication is not used. Massing an object that is hot will cause the measured mass to be less than the true value because of the convection currents produced when hot air collides with the cold air around the dish.

46. **A** Reactions: Kinetics *EXCEPT*

Catalysts generally speed up the reaction rate by providing alternate pathways that take less energy for reactants to become products. All of the other choices given slow down reaction rates. When the temperature is lowered, molecules collide less often with less force. Increasing the concentration of a product may shift the reaction to favor the reactants. High bond energy and high activation energy both refer to the large amount of energy needed to overcome the activation energy barrier, which is indicative of slower reactions.

47. **D** Reactions: Stoichiometry *EXCEPT*

The net ionic reaction for the precipitation of barium with sulfate is:

$$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$$

The mole ratio of Ba^{2+} to SO_4^{2-} is 1:1. The total moles of barium in the solution will be equal to the total moles of sodium sulfate needed for complete precipitation. Find the total moles of barium in the solution:

$BaCl_2 \rightarrow Ba^{2+} + 2\,Cl^-$; $BaCl_2$ and Ba^{2+} are 1:1, so the total is 0.10 mole Ba^{2+}

$Ba_3(PO_4)_2 \rightarrow 3\,Ba^{2+} + 2\,PO_4^{3-}$; $Ba_3(PO_4)_2$ and Ba^{2+} are 1:3, so 3(0.10) = 0.30 mol Ba^{2+}

The total Ba^{2+} in 1.0 liter of solution is 0.10 mol + 0.30 mol = 0.40 mole. This is the number of moles of Na_2SO_4 needed.

48. **A** Reactions: Equilibrium *Multiple choice*

Products are favored at equilibrium since the given K value is greater than 1. Ammonia, NH_3, and acetate ion, $C_2H_3O_2^-$, both act as bases, but since the reaction proceeds as written, ammonia must be a stronger base. With the same logic, choice **B** is incorrect since acetic acid, $HC_2H_3O_2$, must be the stronger acid—the reaction proceeds in the forward direction. Choice **C** is incorrect since acetate ion is the conjugate base for acetic acid, not for ammonia. Not enough information is given for you to know whether choices **D** and **E** are correct.

49. **C** Reactions: Equilibrium *Multiple choice*

Given the equation 2 A(g) + B(g) ⇔ 2 C(g), the K_c expression is: $K_c = \frac{[C]^2}{[A]^2[B]}$

From the information provided and the stoichiometry, calculate equilibrium concentrations:

2 A	+	B	⇔	2 C
0.60 mol		0.75 mol		0
$-2x$		$-x$		$+2x$
?		?		0.30 mol

Since $2x = 0.30$ and then $x = 0.15$, calculate the concentrations of A and B at equilibrium.

$$[A] = 0.60\text{ mol} - 0.30\text{ mol} = 0.30\text{ mol}$$

$$[B] = 0.75\text{ mol} - 0.15\text{ mol} = 0.60\text{ mol}$$

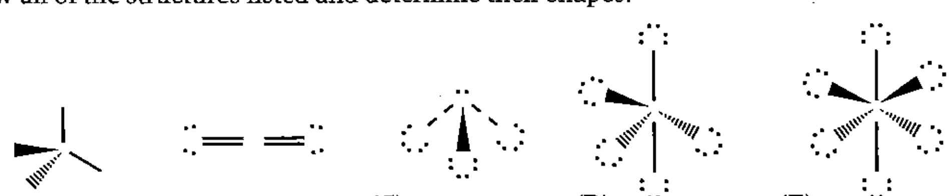
The volume is 1.0 liter, so moles = molarity in this problem. Plug in the values and estimate the answer:

$$K_c = \frac{[0.30]^2}{[0.30]^2[0.60]}$$

The problem simplifies to 1 divided by 0.60, which is the reciprocal of 6/10, so the correct answer is 10/6 ≅ 1.7.

50. **C** Structure of Matter: Chemical Bonding *Multiple choice*

Draw all of the structures listed and determine their shapes.



(A) (B) (C) (D) (E)

Molecule	**Shape**
CH_4	Tetrahedral
SiO_2	Linear
$AsCl_3$	Trigonal pyramidal
$AsCl_5$	Trigonal bipyramidal
SF_6	Octahedral

A square planar molecule has four shared pairs of electrons all in one plane and one unshared pair of electrons above and below the plane.

51. **B** Reactions: Reaction Types *Multiple choice*

$$pH = -\log[H^+] \text{ and } K_a = \frac{[H^+][A^-]}{[HA]}$$

Plugging in values makes the estimation a bit easier

$$6.5 \times 10^{-10} = \frac{[x][x]}{[1.0 \times 10^{-3}]}$$

Cross multiplying gives 6.5 × 10^{-13}; the square root of the exponent would be about –6.5. Log base 10 is the exponent, so the only choice in the range of 6 is choice **B**.

52. **D** States of Matter: Solutions *Multiple choice*

This appears to be a simple dilution problem, solved with $M_1V_1 = M_2V_2$. Plugging in values leads to (6.00 M)(10.0 mL) = (0.100 M)(V_2). V_2 = 600.0 mL, which represents the total volume of the solution. The trick here is that the problem asks for how much water should be added to the 10.0 mL of acid. Subtracting: 600.0 mL – 10.0 mL = 590.0 mL of water needed.

53. **C** Laboratory: Procedure *I, II, III*

A visible-light spectrophotometer is useful for determining the concentration of colored solutions by measuring either the percent transmittance of light passing through a solution or by measuring the absorbance of light by the solution. The absorbance is directly proportional to the concentration according to Beer's law: $A = \varepsilon bc$. All zinc solutions are colorless since all of zinc's d electrons are paired, so choice I is eliminated. Potassium permanganate is colored, but conductivity is not measured by light passing through a substance, so choice II is eliminated. All of the ions listed in the third choice are colored in solution, so determining their concentrations would be possible using a spectrophotometer.

54. **E** Reactions: Reaction Types *Multiple choice*

A Lewis acid is an electron pair acceptor. Fluoride ion and perchlorate ion are both negative and therefore have no affinity for accepting an electron pair. The choice is narrowed to the metal ions listed. The metal with the highest positive charge has the highest affinity for an electron pair, which in this case is the aluminum ion.

55. **E** Reactions: Reaction Types *Multiple choice*

Given that the K_{eq} value is less than 1 indicates the reactants are favored at equilibrium. This indicates the reaction proceeds spontaneously in the reverse direction. The voltage of the cell would be negative, and the ΔG value would be positive.

56. **B** Laboratory: Procedure *Multiple choice*

The net ionic reaction is $SCN^- + Fe^{3+} \Leftrightarrow FeSCN^{2+}$. This complex ion is known to have a distinct brick-red color. A bright yellow color might indicate a precipitate of lead(II) iodide. A solution changing from light blue to dark blue might indicate a complex of copper. Bubbles of nitrogen dioxide usually form from a metal reacting with concentrated nitric acid, and pH decreasing indicates hydrogen ions being produced in solution.

57. **D** Reactions: Reaction Types *Multiple choice*

The desired half-reaction is $X^{3+}(aq) + 3e^- \rightarrow X(s)$. It must be obtained from the two given equations. The equations may be reversed, multiplied, and/or divided before summing them to obtain the desired equation. If the reaction is reversed, the sign on the voltage will reverse. The trick here is that voltages are not a "per mole" quantity and thus are not multiplied or divided by anything.

Equation 1 is reversed:

$$3\,Mg(s) + 2\,X^{3+}(aq) \rightarrow 2\,X(s) + 3\,Mg^{2+}(aq); E = +3.87\text{ V}$$

Equation 2 is multiplied by 3:

$$3\,Mg^{2+}(aq) + 6e^- \rightarrow 3\,Mg(s); E = -2.37\text{ V}$$

Adding these two equations gives

$$2\,X^{3+}(aq) + 6\,e^- \rightarrow 2\,X(s)$$

This equation needs to be divided by 2 to look like the desired equation, but the voltage will just be the addition of the reactions above: $E = 3.87 + (-2.37) = 1.50$ volts.

58. **E** Laboratory: Procedure *Multiple choice*

The easiest way to recover sodium chloride is to evaporate to dryness. Distillation is a separation method for liquids with different boiling points. Filtration works well when particles are suspended in a solution. Electrolysis is useful for obtaining pure forms of elements by running an electric current through either the molten state or a solution. Fractional crystallization is a method for separating multiple solutes contained in a solution. The solution is heated, and the various solutes crystallize at different temperatures as the solution cools.

59. **D** Laboratory: Procedure *I, II, III*

There are two concepts to keep in mind here. First, in any titration moles acid = moles base at the equivalence point. Second, K_a is the acid dissociation constant. Failure to rinse the buret with the NaOH after washing means that water droplets adhering to the walls of the buret will dilute the NaOH solution. More base will be required, and the moles of base reported will be too high, so the moles of acid, HA, reported will also be too high, implying more HA dissociated, so that the acid dissociation constant, K_a, will be reported as too large. Not adding enough water to dissolve the entire solid acid sample will lower the number of acid molecules that dissociate in solution, so less base will be required, and the moles of acid and thus the acid dissociation constant will be reported as too small. The addition of base beyond the equivalence point causes the moles of base reported to be too large; thus the moles of acid reported are also too large, so the acid dissociation constant is reported as too large.

60. **B** Structure of Matter: Atomic Theory *Multiple choice*

The largest jump in ionization energy is between removal of electron number 2 and electron number 3. Large incremental increases in IE usually indicate the removal of an electron from an inner energy level. Write electron configurations for the choices:

Element	**Electron Configuration**
K	[Ar] $4s^1$
Ca	[Ar] $4s^2$
Ga	[Ar] $4s^2 3d^{10} 4p^1$
Ge	[Ar] $4s^2 3d^{10} 4p^2$
As	[Ar] $4s^2 3d^{10} 4p^3$

The largest increase in IE for K would be between the removal of electrons 1 and 2. The largest increase in IE for Ca is between electrons 2 and 3 since the previous principal energy level is broken into. For Ga, Ge, and As, the largest jumps would occur between 3 and 4, 4 and 5, and 5 and 6, respectively.

61. **B** Reactions: Stoichiometry *Multiple choice*

Barium hydroxide is a strong base and would ionize close to 100 percent according to the following equation:

$$Ba(OH)_2 \rightarrow Ba^{2+} + 2\,OH^-$$

There would be relatively zero $Ba(OH)_2$ present in a 0.500 *M* solution. The concentration of Ba^{2+} ions would be 0.500 *M* since the ratio is 1:1 with $Ba(OH)_2$. The concentration of OH^- is 2(0.500) = 1.00 *M* since the ratio is 1:2 with $Ba(OH)_2$. The ion pair $BaOH^+$ does not readily form. Hydronium ions, H_3O^+, would not exist in a strong basic solution.

62. **C** States of matter: Solutions *Multiple choice*

$$MM = \frac{\text{grams}}{\text{mole}}$$

Given this equation, we must know the mass in grams of the substance and the number of moles of the substance. Given the information about the difference in temperature and the boiling point constant, molality could be found using the following equation: $\Delta T_b = K_b \cdot m \cdot i$. Since the unknown substance is molecular and nonvolatile, the i value is 1. Using the molality formula, moles could be calculated if the mass of solvent is known: $m = \frac{\text{mol solute}}{\text{kg slovent}}$. So in addition to the change in boiling point and the boiling point constant, the mass of unknown (solute) used and the mass of solvent used would be necessary to determine the molecular mass.

63. **C** Reactions: Stoichiometry *Multiple choice*

A hydrocarbon is composed of hydrogen and carbon. Assume a 100 percent sample, or 100-gram sample, and simplify the problem. If 20.0 percent, or 20.0 grams, consists of hydrogen, then 80.0 percent, or 80.0 grams, consists of carbon. First convert the grams into moles for each substance:

$$20.0 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 19.88 \text{ mol H}$$

$$80.0 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 6.66 \text{ mol C}$$

Next, divide each of the moles by the smaller number of moles to find subscripts: $\frac{6.66}{6.66} = 1$; $\frac{19.88}{6.66}$ is about 3. The formula is CH_3.

64. **D** Reactions: Reaction Types *Multiple choice*

A solution saturated with silver chloride would appear cloudy and the precipitate would be white. Silver chloride is not very soluble and is thus represented as an insoluble salt. Bubbling ammonia gas into the solution would clear the solution as a soluble complex ion forms. The balanced net ionic reaction would be

$$AgCl + 2\,NH_3 \rightarrow Ag(NH_3)_2^+ + Cl^-$$

65. **E** States of Matter: Solutions *Multiple choice*

Choices **A**, **B**, and **C** are all soluble salts and form ions in solution. Choice **D** is a weak acid and will produce some ions in solution. However, ethanol, C_2H_5OH, is an alcohol. Organic alcohols do not ionize in solution. Be careful not to mistake the alcohol for a base!

66. **B** Reactions: Reaction Types *Multiple choice*

Oxidation of an oxyacid means the addition of more oxygen to the acid as well as a change in oxidation number. In a series of acids, the more oxygen the acid contains, the stronger the acid becomes due to the highly electronegative oxygen atoms pulling on the electrons polarizing the O—H bond. (It is also important to note that the hydrogen that is to be ionized, or removed, is bound to one of the oxygen atoms of the oxyacid.) When HNO_2, a weak acid, is oxidized to HNO_3, a strong acid, the oxidation number of nitrogen changes from +3 to +5, which indicates a loss of electrons, or oxidation.

67. **E** Reactions: Stoichiometry *Multiple choice*

This is a limiting reactant problem. Write a balanced equation first. Notice that everything is in a 1:1 ratio.

$Ba(NO_3)_2$	+	$MgSO_4$	→	$Mg(NO_3)_2$	+	$BaSO_4$
100 mL		100 mL				
0.10 *M*		0.060 *M*				
10.0 mmol		6.00 mmol	$MgSO_4{}^2$ limits the reaction			
–6.00 mmol		–6.00 mmol				
4.00 mmol left		0.00 mmol				

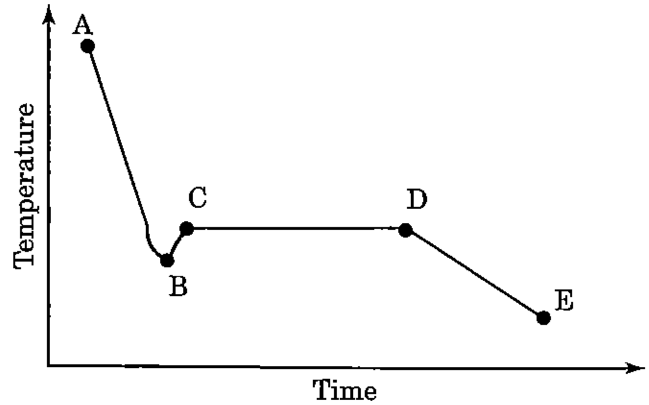
Calculate the number of moles (or millimoles) of given reactants to determine which one is limiting. Just multiply molarity times volume to get millimoles. This is easy to do without a calculator since you're just moving decimals. Determine the limiting reactant—in this case since everything is 1:1, the smaller number limits. Subtract the limiting reactant from the excess reactant to see how many moles are left. Calculate the new molarity of Ba^{2+} ions left by dividing millimoles by total volume.

$$M = \frac{\text{mmol Ba}^{2+}}{\text{total volume of the solution}}$$

$$M = \frac{(4.00)\ \text{mmol Ba}^{2+}}{200\ \text{mL}} = 0.20$$

68. **E** States of Matter: Liquids and Solids *Multiple choice*

In the diagram below, points *A* to *C* represent the liquid phase; points *B* to *C* represent supercooling of the liquid; points *C* to *D* represent melting and freezing; and points *D* to *E* represent the solid phase.



69. **E** States of Matter: Gases *Multiple choice*

In this gas law problem both number of moles and volume are constant. This makes a simple Gay-Lussac law problem. The formula is $\frac{P_1}{T_1} = \frac{P_2}{T_2}$. The temperatures must be converted to Kelvin before solving.

The equation becomes $\frac{2.5\text{ atm}}{400\text{ K}} = \frac{P_2}{300\text{ K}}$. To solve, cross multiply and simplify. $\frac{750}{400}$ is close to the number 2. There is only one answer close to this—1.88 atm.

70. **E** States of Matter: Liquids and Solids *Multiple choice*

"Normal" boiling point is the point at which the liquid and vapor of a substance are in equilibrium at standard atmospheric pressure. In the phase diagram given, when the substance is at 1 atm of pressure, the liquid-vapor equilibrium line does not cross the dashed line of 1 atm, so the boiling point cannot be determined from this graph.

71. **B** States of Matter: Liquids and Solids *Multiple choice*

Only the conditions necessary for sublimation, the change from gas to solid, are provided by the phase diagram. Density determination requires data of mass and volume. Specific heat, latent heat of vaporization, and latent heat of fusion are given by typical heating curves, not phase diagrams.

72. **A** States of Matter: Gases *Multiple choice*

The gaseous state of all substances is less dense than either the solid or the liquid phase of the same material because there are very few particles of gas in a given volume. The slope of the solid-liquid equilibrium line gives qualitative data about the density of the solid in comparison to the liquid. In this example, the slope of the solid-liquid equilibrium line is positive. This is the most common and means that the solid is more dense than the liquid.

73. **B** Reactions: Stoichiometry *Multiple choice*

The first step in solving a stoichiometric problem is to write a balanced equation:

$$Al_2S_3 + 3\,H_2 \rightarrow 2\,Al + 3\,H_2S$$

Notice that the ratio between aluminum sulfide and aluminum is 1:2. This makes the math easy:

$$0.500 \text{ mol } Al_2S_3 \times \frac{2 \text{ mol Al}}{1 \text{ mol } Al_2S_3} \times \frac{27.0 \text{ g Al}}{1 \text{ mol Al}} = 27.0 \text{ g Al}$$

74. **B** Reactions: Stoichiometry *Multiple choice*

$$\% = \frac{\text{mass of } MgCO_3}{\text{total mass of compound}} \times 100$$

The only thing we begin the problem knowing is that the total mass of the compound is 16.8 grams. We must write a balanced equation to see how CO_2 and $MgCO_3$ are related. $MgCO_3 \rightarrow MgO + CO_2$. There is a 1:1 mole relationship between carbon dioxide and magnesium carbonate. The setup might look something like this:

$$4.4 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44 \text{ g } CO_2} \times \frac{1 \text{ mol } MgCO_3}{1 \text{ mol } CO_2} \times \frac{84 \text{ g } MgCO_3}{1 \text{ mol } MgCO_3} = 8.4 \text{ g } MgCO_3$$

Now plug the mass of magnesium carbonate into the first formula to find the percent by mass:

$$\% = \frac{8.4 \ MgCO_3}{16.8 \text{ g total}} \times 100 = 50\%$$

75. **A** Reactions: Reaction Types *Multiple choice*

Given that the two reactants are in 1:1 ratio with each other, the number of Cr atoms in the product must be 2. .1.. Cr + ..1. CrO_4^{2-} + → ...2 $Cr(OH)_3$.