MATERIAL IN THE FOLLOWING TABLE MAY BE USEFUL IN ANSWERING THE QUESTIONS IN THIS SECTION OF THE EXAMINATION.

PERIODIC TABLE OF THE ELEMENTS

1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 16.00	9 F 19.00	10 Ne 20.179
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.938	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.91	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 *La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.2	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.02	89 †Ac 227.03	104 Unq (261)	105 Unp (262)	106 Unh (263)	107 Uns (262)	108 Uno (265)	109 Une (266)									

*Lanthanide Series:	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
†Actinide Series:	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

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CHEMISTRY

SECTION I

Time — 54 minutes

NO CALCULATORS MAY BE USED WITH SECTION I.

Note: For all questions, assume that the temperature is 298 K, the pressure is 1.00 atmosphere, and solutions are aqueous unless otherwise specified.

Throughout the test the following symbols have the definitions specified unless otherwise noted.

T = temperature	M = molar
P = pressure	m = molal
V = volume	L, mL = liter(s), milliliter(s)
S = entropy	g = gram(s)
H = enthalpy	nm = nanometer(s)
G = free energy	atm = atmosphere(s)
R = molar gas constant	J, kJ = joule(s), kilojoule(s)
n = number of moles	V = volt(s)
	mol = mole(s)

Part A

Directions: Each set of lettered choices below refers to the numbered statements immediately following it. Select the one lettered choice that best fits each statement and then fill in the corresponding oval on the answer sheet. A choice may be used once, more than once, or not at all in each set.

Questions 1-4 refer to the following types of energy.

(A) Activation energy
(B) Free energy
(C) Ionization energy
(D) Kinetic energy
(E) Lattice energy

1. The energy required to convert a ground-state atom in the gas phase to a gaseous positive ion

2. The energy change that occurs in the conversion of an ionic solid to widely separated gaseous ions

3. The energy in a chemical or physical change that is available to do useful work

4. The energy required to form the transition state in a chemical reaction

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Questions 5-8 refer to atoms for which the occupied atomic orbitals are shown below.

(A) $1s$____ $2s$ ↑__

(B) $1s$ ↑↓ $2s$ ↑↓

(C) $1s$ ↑↓ $2s$ ↑↓ $2p$ ↑ ↑ ____

(D) $1s$ ↑↓ $2s$ ↑↓ $2p$ ↑↓ ↑↓ ↑↓

(E) [Ar] $4s$ ↑↓ $3d$ ↑↓ ↑ ↑ ↑ ↑

5. Represents an atom that is chemically unreactive

6. Represents an atom in an excited state

7. Represents an atom that has four valence electrons

8. Represents an atom of a transition metal

Questions 9-12 refer to aqueous solutions containing 1:1 mole ratios of the following pairs of substances. Assume all concentrations are 1 *M*.

(A) NH_3 and NH_4Cl

(B) H_3PO_4 and NaH_2PO_4

(C) HCl and NaCl

(D) NaOH and NH_3

(E) NH_3 and $HC_2H_3O_2$ (acetic acid)

9. The solution with the lowest pH

10. The most nearly neutral solution

11. A buffer at a pH > 8

12. A buffer at a pH < 6

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Questions 13-16 refer to the following descriptions of bonding in different types of solids.

(A) Lattice of positive and negative ions held together by electrostatic forces
(B) Closely packed lattice with delocalized electrons throughout
(C) Strong single covalent bonds with weak intermolecular forces
(D) Strong multiple covalent bonds (including π-bonds) with weak intermolecular forces
(E) Macromolecules held together with strong polar bonds

13. Cesium chloride, $CsCl(s)$

14. Gold, $Au(s)$

15. Carbon dioxide, $CO_2(s)$

16. Methane, $CH_4(s)$

Questions 17-18 refer to the following elements.

(A) Lithium
(B) Nickel
(C) Bromine
(D) Uranium
(E) Fluorine

17. Is a gas in its standard state at 298 K

18. Reacts with water to form a strong base

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Part B

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

19. Which of the following best describes the role of the spark from the spark plug in an automobile engine?

(A) The spark decreases the energy of activation for the slow step.
(B) The spark increases the concentration of the volatile reactant.
(C) The spark supplies some of the energy of activation for the combustion reaction.
(D) The spark provides a more favorable activated complex for the combustion reaction.
(E) The spark provides the heat of vaporization for the volatile hydrocarbon.

20. What mass of Au is produced when 0.0500 mol of Au_2S_3 is reduced completely with excess H_2 ?

(A) 9.85 g
(B) 19.7 g
(C) 24.5 g
(D) 39.4 g
(E) 48.9 g

21. When a solution of sodium chloride is vaporized in a flame, the color of the flame is

(A) blue
(B) yellow
(C) green
(D) violet
(E) white

22. Of the following reactions, which involves the largest decrease in entropy?

(A) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

(B) $2\ CO(g) + O_2(g) \rightarrow 2\ CO_2(g)$

(C) $Pb(NO_3)_2(s) + 2\ KI(s) \rightarrow PbI_2(s) + 2\ KNO_3(s)$

(D) $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$

(E) $4\ La(s) + 3\ O_2(g) \rightarrow 2\ La_2O_3(s)$

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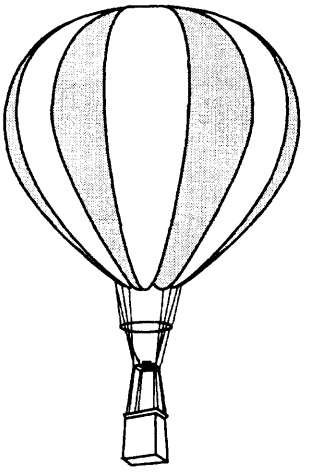

23. A hot-air balloon, shown above, rises. Which of the following is the best explanation for this observation?

(A) The pressure on the walls of the balloon increases with increasing temperature.
(B) The difference in temperature between the air inside and outside the balloon produces convection currents.
(C) The cooler air outside the balloon pushes in on the walls of the balloon.
(D) The rate of diffusion of cooler air is less than that of warmer air.
(E) The air density inside the balloon is less than that of the surrounding air.

24. The safest and most effective emergency procedure to treat an acid splash on skin is to do which of the following immediately?

(A) Dry the affected area with paper towels
(B) Sprinkle the affected area with powdered $Na_2SO_4(s)$
(C) Flush the affected area with water and then with a dilute NaOH solution
(D) Flush the affected area with water and then with a dilute $NaHCO_3$ solution
(E) Flush the affected area with water and then with a dilute vinegar solution

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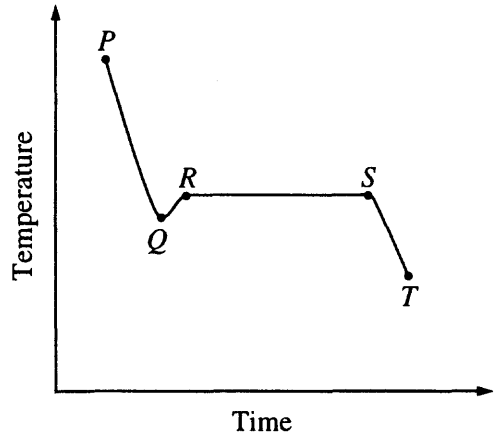

25. The cooling curve for a pure substance as it changes from a liquid to a solid is shown above. The solid and the liquid coexist at

(A) point Q only
(B) point R only
(C) all points on the curve between Q and S
(D) all points on the curve between R and T
(E) no point on the curve

$$\ldots C_{10}H_{12}O_4S(s) + \ldots O_2(g) \rightarrow \ldots CO_2(g) + \ldots SO_2(g) + \ldots H_2O(g)$$

26. When the equation above is balanced and all coefficients are reduced to their lowest whole-number terms, the coefficient for $O_2(g)$ is

(A) 6
(B) 7
(C) 12
(D) 14
(E) 28

27. Appropriate uses of a visible-light spectrophotometer include which of the following?

I. Determining the concentration of a solution of $Cu(NO_3)_2$
II. Measuring the conductivity of a solution of $KMnO_4$
III. Determining which ions are present in a solution that may contain Na^+, Mg^{2+}, Al^{3+}

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

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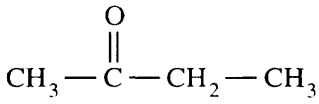
28. The melting point of MgO is higher than that of NaF. Explanations for this observation include which of the following?

I. Mg^{2+} is more positively charged than Na^{+}.
II. O^{2-} is more negatively charged than F^{-}.
III. The O^{2-} ion is smaller than the F^{-} ion.

(A) II only
(B) I and II only
(C) I and III only
(D) II and III only
(E) I, II, and III



29. The organic compound represented above is an example of

(A) an organic acid
(B) an alcohol
(C) an ether
(D) an aldehyde
(E) a ketone

$$H_2Se(g) + 4\ O_2F_2(g) \rightarrow SeF_6(g) + 2\ HF(g) + 4\ O_2(g)$$

30. Which of the following is true regarding the reaction represented above?

(A) The oxidation number of O does not change.
(B) The oxidation number of H changes from -1 to $+1$.
(C) The oxidation number of F changes from $+1$ to -1.
(D) The oxidation number of Se changes from -2 to $+6$.
(E) It is a disproportionation reaction for F.

31. If the temperature of an aqueous solution of NaCl is increased from 20°C to 90°C, which of the following statements is true?

(A) The density of the solution remains unchanged.
(B) The molarity of the solution remains unchanged.
(C) The molality of the solution remains unchanged.
(D) The mole fraction of solute decreases.
(E) The mole fraction of solute increases.

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32. Types of hybridization exhibited by the C atoms in propene, CH_3CHCH_2, include which of the following?

I. sp
II. sp^2
III. sp^3

(A) I only
(B) III only
(C) I and II only
(D) II and III only
(E) I, II, and III

33. A 1.0 L sample of an aqueous solution contains 0.10 mol of NaCl and 0.10 mol of $CaCl_2$. What is the minimum number of moles of $AgNO_3$ that must be added to the solution in order to precipitate all of the Cl^- as $AgCl(s)$? (Assume that AgCl is insoluble.)

(A) 0.10 mol
(B) 0.20 mol
(C) 0.30 mol
(D) 0.40 mol
(E) 0.60 mol

Questions 34-35 refer to an electrolytic cell that involves the following half-reaction.

$$AlF_6^{3-} + 3\ e^- \rightarrow Al + 6\ F^-$$

34. Which of the following occurs in the reaction?

(A) AlF_6^{3-} is reduced at the cathode.
(B) Al is oxidized at the anode.
(C) Aluminum is converted from the −3 oxidation state to the 0 oxidation state.
(D) F^- acts as a reducing agent.
(E) F^- is reduced at the cathode.

35. A steady current of 10 amperes is passed through an aluminum-production cell for 15 minutes. Which of the following is the correct expression for calculating the number of grams of aluminum produced? (1 faraday = 96,500 coulombs)

(A) $\frac{(10)\,(15)\,(96,500)}{(27)\,(60)}$ g

(B) $\frac{(10)\,(15)\,(27)}{(60)\,(96,500)}$ g

(C) $\frac{(10)\,(15)\,(60)\,(27)}{(96,500)\,(3)}$ g

(D) $\frac{(96,500)\,(27)}{(10)\,(15)\,(60)\,(3)}$ g

(E) $\frac{(27)\,(3)}{(96,500)\,(10)\,(15)\,(60)}$ g

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Experiment	Initial [NO] (mol L^{-1})	Initial [O_2] (mol L^{-1})	Initial Rate of Formation of NO_2 (mol $L^{-1}s^{-1}$)
1	0.10	0.10	2.5×10^{-4}
2	0.20	0.10	5.0×10^{-4}
3	0.20	0.40	8.0×10^{-3}

36. The initial-rate data in the table above were obtained for the reaction represented below. What is the experimental rate law for the reaction?

$$2\ NO(g) + O_2(g) \rightarrow NO_2(g)$$

(A) Rate $= k[NO][O_2]$

(B) Rate $= k[NO][O_2]^2$

(C) Rate $= k[NO]^2[O_2]$

(D) Rate $= k[NO]^2[O_2]^2$

(E) Rate $= k\dfrac{[NO]}{[O_2]}$

Ionization Energies for element X (kJ mol^{-1})				
First	Second	Third	Fourth	Fifth
580	1,815	2,740	11,600	14,800

37. The ionization energies for element X are listed in the table above. On the basis of the data, element X is most likely to be

(A) Na
(B) Mg
(C) Al
(D) Si
(E) P

38. A molecule or an ion is classified as a Lewis acid if it

(A) accepts a proton from water
(B) accepts a pair of electrons to form a bond
(C) donates a pair of electrons to form a bond
(D) donates a proton to water
(E) has resonance Lewis electron-dot structures

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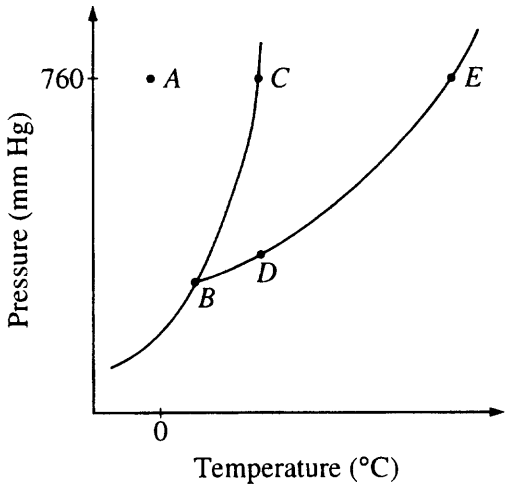

39. The phase diagram for a pure substance is shown above. Which point on the diagram corresponds to the equilibrium between the solid and liquid phases at the normal melting point?

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

40. Of the following molecules, which has the largest dipole moment?

(A) CO
(B) CO_2
(C) O_2
(D) HF
(E) F_2

$$2\ SO_3(g) \rightleftarrows 2\ SO_2(g) + O_2(g)$$

41. After the equilibrium represented above is established, some pure $O_2(g)$ is injected into the reaction vessel at constant temperature. After equilibrium is reestablished, which of the following has a lower value compared to its value at the original equilibrium?

(A) K_{eq} for the reaction
(B) The total pressure in the reaction vessel
(C) The amount of $SO_3(g)$ in the reaction vessel
(D) The amount of $O_2(g)$ in the reaction vessel
(E) The amount of $SO_2(g)$ in the reaction vessel

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$$\ldots Li_3N(s) + \ldots H_2O(l) \rightarrow \ldots Li^+(aq) + \ldots OH^-(aq) + \ldots NH_3(g)$$

42. When the equation above is balanced and all coefficients reduced to lowest whole-number terms, the coefficient for $OH^-(aq)$ is

(A) 1
(B) 2
(C) 3
(D) 4
(E) 6

43. A sample of 61.8 g of H_3BO_3, a weak acid, is dissolved in 1,000 g of water to make a 1.0-molal solution. Which of the following would be the best procedure to determine the molarity of the solution? (Assume no additional information is available.)

(A) Titration of the solution with standard acid
(B) Measurement of the pH with a pH meter
(C) Determination of the boiling point of the solution
(D) Measurement of the total volume of the solution
(E) Measurement of the specific heat of the solution

44. A rigid metal tank contains oxygen gas. Which of the following applies to the gas in the tank when additional oxygen is added at constant temperature?

(A) The volume of the gas increases.
(B) The pressure of the gas decreases.
(C) The average speed of the gas molecules remains the same.
(D) The total number of gas molecules remains the same.
(E) The average distance between the gas molecules increases.

45. What is the $H^+(aq)$ concentration in 0.05 M $HCN(aq)$? (The K_a for HCN is 5.0×10^{-10}.)

(A) 2.5×10^{-11} M
(B) 2.5×10^{-10} M
(C) 5.0×10^{-10} M
(D) 5.0×10^{-6} M
(E) 5.0×10^{-4} M

46. Which of the following occurs when excess concentrated $NH_3(aq)$ is mixed thoroughly with 0.1 M $Cu(NO_3)_2(aq)$?

(A) A dark red precipitate forms and settles out.
(B) Separate layers of immiscible liquids form with a blue layer on top.
(C) The color of the solution turns from light blue to dark blue.
(D) Bubbles of ammonia gas form.
(E) The pH of the solution decreases.

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47. When hafnium metal is heated in an atmosphere of chlorine gas, the product of the reaction is found to contain 62.2 percent Hf by mass and 37.4 percent Cl by mass. What is the empirical formula for this compound?

(A) HfCl
(B) $HfCl_2$
(C) $HfCl_3$
(D) $HfCl_4$
(E) Hf_2Cl_3

48. If 87.5 percent of a sample of pure ^{131}I decays in 24 days, what is the half-life of ^{131}I ?

(A) 6 days
(B) 8 days
(C) 12 days
(D) 14 days
(E) 21 days

49. Which of the following techniques is most appropriate for the recovery of solid KNO_3 from an aqueous solution of KNO_3 ?

(A) Paper chromatography
(B) Filtration
(C) Titration
(D) Electrolysis
(E) Evaporation to dryness

50. In the periodic table, as the atomic number increases from 11 to 17, what happens to the atomic radius?

(A) It remains constant.
(B) It increases only.
(C) It increases, then decreases.
(D) It decreases only.
(E) It decreases, then increases.

51. Which of the following is a correct interpretation of the results of Rutherford's experiments in which gold atoms were bombarded with alpha particles?

(A) Atoms have equal numbers of positive and negative charges.
(B) Electrons in atoms are arranged in shells.
(C) Neutrons are at the center of an atom.
(D) Neutrons and protons in atoms have nearly equal mass.
(E) The positive charge of an atom is concentrated in a small region.

52. Under which of the following sets of conditions could the most $O_2(g)$ be dissolved in $H_2O(l)$?

	Pressure of $O_2(g)$ Above $H_2O(l)$ (atm)	Temperature of $H_2O(l)$ (°C)
(A)	5.0	80
(B)	5.0	20
(C)	1.0	80
(D)	1.0	20
(E)	0.5	20

$$W(g) + X(g) \rightarrow Y(g) + Z(g)$$

53. Gases W and X react in a closed, rigid vessel to form gases Y and Z according to the equation above. The initial pressure of $W(g)$ is 1.20 atm and that of $X(g)$ is 1.60 atm. No $Y(g)$ or $Z(g)$ is initially present. The experiment is carried out at constant temperature. What is the partial pressure of $Z(g)$ when the partial pressure of $W(g)$ has decreased to 1.0 atm?

(A) 0.20 atm
(B) 0.40 atm
(C) 1.0 atm
(D) 1.2 atm
(E) 1.4 atm

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$$2\ NO(g) + O_2(g) \rightleftarrows 2\ NO_2(g) \qquad \Delta H < 0$$

54. Which of the following changes alone would cause a decrease in the value of K_{eq} for the reaction represented above?

(A) Decreasing the temperature
(B) Increasing the temperature
(C) Decreasing the volume of the reaction vessel
(D) Increasing the volume of the reaction vessel
(E) Adding a catalyst

$$10\ HI + 2\ KMnO_4 + 3\ H_2SO_4 \rightarrow 5\ I_2 + 2\ MnSO_4 + K_2SO_4 + 8\ H_2O$$

55. According to the balanced equation above, how many moles of HI would be necessary to produce 2.5 mol of I_2, starting with 4.0 mol of $KMnO_4$ and 3.0 mol of H_2SO_4 ?

(A) 20.
(B) 10.
(C) 8.0
(D) 5.0
(E) 2.5

56. A yellow precipitate forms when 0.5 *M* NaI(*aq*) is added to a 0.5 *M* solution of which of the following ions?

(A) $Pb^{2+}(aq)$
(B) $Zn^{2+}(aq)$
(C) $CrO_4^{2-}(aq)$
(D) $SO_4^{2-}(aq)$
(E) $OH^-(aq)$

$$M(s) + 3\ Ag^+(aq) \rightarrow 3\ Ag(s) + M^{3+}(aq) \qquad E^\circ = +\ 2.46\ V$$
$$Ag^+(aq) + e^- \rightarrow Ag(s) \qquad E^\circ = +\ 0.80\ V$$

57. According to the information above, what is the standard reduction potential for the half-reaction $M^{3+}(aq) + 3\ e^- \rightarrow M(s)$?

(A) −1.66 V
(B) −0.06 V
(C) 0.06 V
(D) 1.66 V
(E) 3.26 V

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58. On a mountaintop, it is observed that water boils at 90°C, not at 100°C as at sea level. This phenomenon occurs because on the mountaintop the

(A) equilibrium water vapor pressure is higher due to the higher atmospheric pressure
(B) equilibrium water vapor pressure is lower due to the higher atmospheric pressure
(C) equilibrium water vapor pressure equals the atmospheric pressure at a lower temperature
(D) water molecules have a higher average kinetic energy due to the lower atmospheric pressure
(E) water contains a greater concentration of dissolved gases

59. A 40.0 mL sample of 0.25 *M* KOH is added to 60.0 mL of 0.15 *M* $Ba(OH)_2$. What is the molar concentration of $OH^-(aq)$ in the resulting solution? (Assume that the volumes are additive.)

(A) 0.10 *M*
(B) 0.19 *M*
(C) 0.28 *M*
(D) 0.40 *M*
(E) 0.55 *M*

$$NH_4NO_3(s) \rightarrow N_2O(g) + 2\ H_2O(g)$$

60. A 0.03 mol sample of $NH_4NO_3(s)$ is placed in a 1 L evacuated flask, which is then sealed and heated. The $NH_4NO_3(s)$ decomposes completely according to the balanced equation above. The total pressure in the flask measured at 400 K is closest to which of the following? (The value of the gas constant, *R*, is 0.082 L atm mol^{-1} K^{-1}.)

(A) 3 atm
(B) 1 atm
(C) 0.5 atm
(D) 0.1 atm
(E) 0.03 atm

$$C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(g)$$

61. For the reaction of ethylene represented above, ΔH is −1,323 kJ. What is the value of ΔH if the combustion produced liquid water $H_2O(l)$, rather than water vapor $H_2O(g)$? (ΔH for the phase change $H_2O(g) \rightarrow H_2O(l)$ is −44 kJ mol^{-1}.)

(A) −1,235 kJ
(B) −1,279 kJ
(C) −1,323 kJ
(D) −1,367 kJ
(E) −1,411 kJ

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$$HC_2H_3O_2(aq) + CN^-(aq) \rightleftarrows HCN(aq) + C_2H_3O_2^-(aq)$$

62. The reaction represented above has an equilibrium constant equal to 3.7×10^4. Which of the following can be concluded from this information?

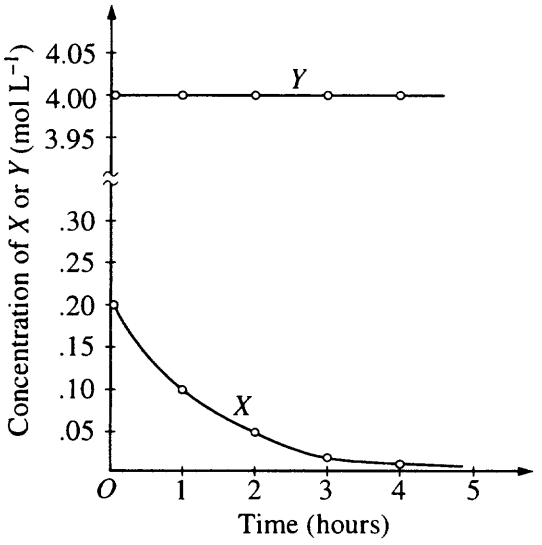
(A) $CN^-(aq)$ is a stronger base than $C_2H_3O_2^-(aq)$.

(B) $HCN(aq)$ is a stronger acid than $HC_2H_3O_2(aq)$.

(C) The conjugate base of $CN^-(aq)$ is $C_2H_3O_2^-(aq)$.

(D) The equilibrium constant will increase with an increase in temperature.

(E) The pH of a solution containing equimolar amounts of $CN^-(aq)$ and $HC_2H_3O_2(aq)$ is 7.0.



63. The graph above shows the results of a study of the reaction of X with a large excess of Y to yield Z. The concentrations of X and Y were measured over a period of time. According to the results, which of the following can be concluded about the rate law for the reaction under the conditions studied?

(A) It is zero order in $[X]$.
(B) It is first order in $[X]$.
(C) It is second order in $[X]$.
(D) It is first order in $[Y]$.
(E) The overall order of the reaction is 2.

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64. Equal numbers of moles of He(g), Ar(g), and Ne(g) are placed in a glass vessel at room temperature. If the vessel has a pinhole-sized leak, which of the following will be true regarding the relative values of the partial pressures of the gases remaining in the vessel after some of the gas mixture has effused?

(A) $P_{He} < P_{Ne} < P_{Ar}$
(B) $P_{He} < P_{Ar} < P_{Ne}$
(C) $P_{Ne} < P_{Ar} < P_{He}$
(D) $P_{Ar} < P_{He} < P_{Ne}$
(E) $P_{He} = P_{Ar} = P_{Ne}$

65. Which of the following compounds is NOT appreciably soluble in water but is soluble in dilute hydrochloric acid?

(A) $Mg(OH)_2(s)$
(B) $(NH_4)_2CO_3(s)$
(C) $CuSO_4(s)$
(D) $(NH_4)_2SO_4(s)$
(E) $Sr(NO_3)_2(s)$

66. When solid ammonium chloride, $NH_4Cl(s)$, is added to water at 25°C, it dissolves and the temperature of the solution decreases. Which of the following is true for the values of ΔH and ΔS for the dissolving process?

	ΔH	ΔS
(A)	Positive	Positive
(B)	Positive	Negative
(C)	Positive	Equal to zero
(D)	Negative	Positive
(E)	Negative	Negative

67. What is the molar solubility in water of Ag_2CrO_4 ?
(The K_{sp} for Ag_2CrO_4 is 8×10^{-12}.)

(A) $8 \times 10^{-12}\ M$
(B) $2 \times 10^{-12}\ M$
(C) $\sqrt{4 \times 10^{-12}}\ M$
(D) $\sqrt[3]{4 \times 10^{-12}}\ M$
(E) $\sqrt[3]{2 \times 10^{-12}}\ M$

GO ON TO THE NEXT PAGE

68. In which of the following processes are covalent bonds broken?

(A) $I_2(s) \rightarrow I_2(g)$
(B) $CO_2(s) \rightarrow CO_2(g)$
(C) $NaCl(s) \rightarrow NaCl(l)$
(D) $C(\text{diamond}) \rightarrow C(g)$
(E) $Fe(s) \rightarrow Fe(l)$

69. What is the final concentration of barium ions, $[Ba^{2+}]$, in solution when 100. mL of 0.10 *M* $BaCl_2(aq)$ is mixed with 100. mL of 0.050 *M* $H_2SO_4(aq)$?

(A) 0.00 *M*
(B) 0.012 *M*
(C) 0.025 *M*
(D) 0.075 *M*
(E) 0.10 *M*

70. When 100 mL of 1.0 *M* Na_3PO_4 is mixed with 100 mL of 1.0 *M* $AgNO_3$, a yellow precipitate forms and $[Ag^+]$ becomes negligibly small. Which of the following is a correct listing of the ions remaining in solution in order of increasing concentration?

(A) $[PO_4^{3-}] < [NO_3^-] < [Na^+]$
(B) $[PO_4^{3-}] < [Na^+] < [NO_3^-]$
(C) $[NO_3^-] < [PO_4^{3-}] < [Na^+]$
(D) $[Na^+] < [NO_3^-] < [PO_4^{3-}]$
(E) $[Na^+] < [PO_4^{3-}] < [NO_3^-]$

71. In a qualitative analysis for the presence of Pb^{2+}, Fe^{2+}, and Cu^{2+} ions in aqueous solution, which of the following will allow the separation of Pb^{2+} from the other ions at room temperature?

(A) Adding dilute $Na_2S(aq)$ solution
(B) Adding dilute $HCl(aq)$ solution
(C) Adding dilute $NaOH(aq)$ solution
(D) Adding dilute $NH_3(aq)$ solution
(E) Adding dilute $HNO_3(aq)$ solution

72. After completing an experiment to determine gravimetrically the percentage of water in a hydrate, a student reported a value of 38 percent. The correct value for the percentage of water in the hydrate is 51 percent. Which of the following is the most likely explanation for this difference?

(A) Strong initial heating caused some of the hydrate sample to spatter out of the crucible.
(B) The dehydrated sample absorbed moisture after heating.
(C) The amount of the hydrate sample used was too small.
(D) The crucible was not heated to constant mass before use.
(E) Excess heating caused the dehydrated sample to decompose.

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73. The volume of distilled water that should be added to 10.0 mL of 6.00 *M* HCl(*aq*) in order to prepare a 0.500 *M* HCl(*aq*) solution is approximately

(A) 50.0 mL
(B) 60.0 mL
(C) 100. mL
(D) 110. mL
(E) 120. mL

74. Which of the following gases deviates most from ideal behavior?

(A) SO_2

(B) Ne

(C) CH_4

(D) N_2

(E) H_2

75. Which of the following pairs of liquids forms the solution that is most ideal (most closely follows Raoult's law) ?

(A) $C_8H_{18}(l)$ and $H_2O(l)$

(B) $CH_3CH_2CH_2OH(l)$ and $H_2O(l)$

(C) $CH_3CH_2CH_2OH(l)$ and $C_8H_{18}(l)$

(D) $C_6H_{14}(l)$ and $C_8H_{18}(l)$

(E) $H_2SO_4(l)$ and $H_2O(l)$

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS SECTION.
DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions and the percentage of AP candidates who answered each question correctly.

Section I Answer Key and Percent Answering Correctly

Item No.	Correct Answer	Percent Correct by Grade 5	4	3	2	1	Total Percent Correct
1	C	96	90	79	65	45	74
2	E	82	66	48	34	19	48
3	B	66	54	42	33	24	42
4	A	93	85	76	63	48	71
5	D	94	90	82	69	40	75
6	A	98	94	86	73	42	78
7	C	83	70	58	45	22	55
8	E	99	96	91	81	55	83
9	C	82	67	56	42	26	52
10	E	76	56	42	26	12	41
11	A	70	46	28	15	11	33
12	B	69	47	33	22	14	35
13	A	94	81	63	45	27	60
14	B	94	84	69	52	33	64
15	D	94	86	72	52	29	65
16	C	92	82	67	49	23	61
17	E	87	82	75	67	49	70
18	A	87	81	75	61	35	67
19	C	85	77	73	68	62	73
20	B	87	77	61	39	23	55
21	B	46	36	31	26	21	33
22	E	94	89	77	62	30	68
23	E	80	73	69	63	55	67
24	D	39	24	18	13	10	20
25	C	81	69	59	48	35	57
26	C	83	78	77	73	61	74
27	A	31	19	15	11	6	16
28	B	74	66	56	45	33	53
29	E	45	32	26	19	13	26
30	D	93	88	83	72	43	75
31	C	38	26	19	14	11	21
32	D	73	54	37	23	15	38
33	C	93	78	58	36	19	54
34	A	73	54	44	29	16	42
35	C	80	63	43	29	17	43
36	B	90	75	58	34	15	52
37	C	65	49	34	20	13	35
38	B	68	48	39	25	20	38
39	C	95	89	80	64	34	71
40	D	86	71	57	39	26	54
41	E	92	85	75	55	28	65
42	C	85	77	74	67	56	71
43	D	80	72	63	55	39	60
44	C	86	73	60	41	22	54
45	D	79	58	41	21	12	40
46	C	37	24	20	15	16	22
47	C	80	66	52	36	20	50
48	B	74	58	43	29	18	42
49	E	78	63	55	45	32	53
50	D	80	73	68	57	36	62
51	E	86	76	64	51	29	59
52	B	58	42	31	20	14	31
53	A	80	61	46	32	20	46
54	B	66	47	35	22	15	35
55	D	93	82	74	63	46	69
56	A	60	43	29	21	14	32
57	A	72	56	46	35	21	44
58	C	75	55	38	23	14	39
59	C	59	41	25	13	15	28
60	A	53	26	13	11	11	22
61	E	62	43	31	19	9	31
62	A	74	45	25	12	10	31
63	B	64	46	32	21	17	34
64	A	87	80	68	57	40	65
65	A	59	41	32	26	20	35
66	A	68	44	29	13	9	31
67	E	65	38	18	9	6	25
68	D	81	65	52	40	34	54
69	C	62	35	24	19	21	31
70	A	73	48	27	16	12	34
71	B	63	40	28	18	18	32
72	B	45	27	21	18	18	25
73	D	58	43	30	23	18	33
74	A	85	66	50	31	16	48
75	D	57	37	26	20	20	33

AP* Chemistry: 1999 Released Multiple Choice Exam
Answer Section

OTHER

1. ANS:
   C

   This is the definition for ionization energy. Be sure and state "gas phase" in the free response if you are asked about ionization energy.

   DIF: Easy TOP: Periodicity MSC: 1999 #1 NOT: 74% answered correctly
2. ANS:
   E

   This energy overcomes the electrostatic attractions between closely spaced oppositely charged ions. You can also link this to melting points, boiling points, etc.

   DIF: Medium TOP: Periodicity MSC: 1999 #2 NOT: 48% answered correctly
3. ANS:
   B

   The classic definition for Gibbs' free energy, ΔG.

   DIF: Medium TOP: Thermodynamics MSC: 1999 #3
   NOT: 42% answered correctly
4. ANS:
   A

   The classic definition for activation energy. Remember that it can be decreased by the addition of a catalyst. Why? The catalyst provides a surface for more effective collisions.

   DIF: Easy TOP: Thermodynamics MSC: 1999 #4
   NOT: 71% answered correctly
5. ANS:
   D

   The classic ns^2np^6 noble gas configuration.

   DIF: Easy TOP: Atomic Structure MSC: 1999 #5
   NOT: 75% answered correctly

6. ANS:
A

If only one electron is present, the ground state orbital notation should correspond to $1s^1$. This atom is excited since its electron resides in a higher energy level.

DIF: Easy TOP: Atomic Structure MSC: 1999 #6
NOT: 78% answered correctly

7. ANS:
C

Remember valence sublevels have the same (and largest) value of the principle quantum number, *n*. So, the orbital notation showing 4 electrons with $n = 2$ is:

2*s* ⇅ 2*p* ↑ ↑

DIF: Medium TOP: Atomic Structure MSC: 1999 #7
NOT: 55% answered correctly

8. ANS:
E

By definition, the ground state electron configuration of a transition metal contains *d*-electrons. Note that this element will also be paramagnetic since it contains some unpaired *d*-electrons and it will form colored aqueous solutions.

DIF: Easy TOP: Atomic Structure MSC: 1999 #8
NOT: 83% answered correctly

9. ANS:
C
Lowest pH means most acidic. This is the only pair that contains a strong acid.

NH_3 and NH_4Cl → weak *base* + soluble salt containing conjugate acid ∴ a *basic* buffer is formed

H_3PO_4 and NaH_2PO_4 → weak *acid* + soluble salt containing conjugate base ∴ an *acidic* buffer is formed

HCl and NaCl → strong *acid* + neutral soluble salt ∴ no buffer is formed, but the result is very acidic (low pH)

NaOH and NH_3→ strong *base* + weak *base* ∴ no buffer is formed, but the result is very basic (high pH)

NH_3 and $HC_2H_3O_2$ (acetic acid) → weak *base* + weak *acid* ∴ a buffer is formed since the salts of both the base and the acid are in solution

DIF: Medium TOP: Acid-Base MSC: 1999 #9 NOT: 52% answered correctly

10. ANS:
E
Since the K_a and K_b of acetic acid and ammonia are both 1.8×10^{-5}, this solution is closest to neutral.

NH_3 and NH_4Cl → weak *base* + soluble salt containing conjugate acid ∴ a *basic* buffer is formed

H_3PO_4 and NaH_2PO_4 → weak *acid* + soluble salt containing conjugate base ∴ an *acidic* buffer is formed

HCl and NaCl → strong *acid* + neutral soluble salt ∴ no buffer is formed, but the result is very acidic (low pH)

NaOH and NH_3→ strong *base* + weak *base* ∴ no buffer is formed, but the result is very basic (high pH)

NH_3 and $HC_2H_3O_2$ (acetic acid) → weak *base* + weak *acid* ∴ a buffer is formed since the salts of both the base and the acid are in solution

DIF: Medium MSC: 1999 #10 NOT: 41% answered correctly

11. ANS:
A

Looking for a basic buffer, so look for a solution containing a weak base and its salt.

NH_3 and NH_4Cl → weak *base* + soluble salt containing conjugate acid ∴ a *basic* buffer is formed

H_3PO_4 and NaH_2PO_4 → weak *acid* + soluble salt containing conjugate base ∴ an *acidic* buffer is formed

HCl and NaCl → strong *acid* + neutral soluble salt ∴ no buffer is formed, but the result is very acidic (low pH)

NaOH and NH_3→ strong *base* + weak *base* ∴ no buffer is formed, but the result is very basic (high pH)

NH_3 and $HC_2H_3O_2$ (acetic acid) → weak *base* + weak *acid* ∴ a buffer is formed since the salts of both the base and the acid are in solution

DIF: Hard MSC: 1999 #11 NOT: 33% answered correctly

12. ANS:
B

Looking for an acidic buffer, so look for a solution containing a weak acid and its salt.

NH_3 and NH_4Cl → weak *base* + soluble salt containing conjugate acid ∴ a *basic* buffer is formed

H_3PO_4 and NaH_2PO_4 → weak *acid* + soluble salt containing conjugate base ∴ an *acidic* buffer is formed

HCl and NaCl → strong *acid* + neutral soluble salt ∴ no buffer is formed, but the result is very acidic (low pH)

NaOH and NH_3→ strong *base* + weak *base* ∴ no buffer is formed, but the result is very basic (high pH)

NH_3 and $HC_2H_3O_2$ (acetic acid) → weak *base* + weak *acid* ∴ a buffer is formed since the salts of both the base and the acid are in solution

DIF: Hard MSC: 1999 #12 NOT: 35% answered correctly

13. ANS:
A

A) Implies a solid of ionic character, so look for combinations of metal and nonmetal (from opposite sides of the periodic table--high melting points)
B) Implies a solid metal since "delocalized electrons" is a major hammer hitting you over the head--and the hammer is made of METAL
C) Implies a solid of covalent character, so look for combinations of nonmetal with nonmetal (near each other on the periodic table--low melting points)
D) Implies a solid combination from the elements CNOPS (pronounce "seenops", rhymes with cyclops) since those are the only elements capable of forming multiple covalent bonds (including π bonds).
E) Implies a huge molecule like a polymer, protein, starch, etc.

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1999 #13
NOT: 60% answered correctly

14. ANS:
B

A) Implies a solid of ionic character, so look for combinations of metal and nonmetal (from opposite sides of the periodic table--high melting points)
B) Implies a solid metal since "delocalized electrons" is a major hammer hitting you over the head--and the hammer is made of METAL
C) Implies a solid of covalent character, so look for combinations of nonmetal with nonmetal (near each other on the periodic table--low melting points)
D) Implies a solid combination from the elements CNOPS (pronounce "seenops", rhymes with cyclops) since those are the only elements capable of forming multiple covalent bonds (including π bonds).
E) Implies a huge molecule like a polymer, protein, starch, etc.

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1999 #14
NOT: 64% answered correctly

15. ANS:
D

A) Implies a solid of ionic character, so look for combinations of metal and nonmetal (from opposite sides of the periodic table--high melting points)
B) Implies a solid metal since “delocalized electrons” is a major hammer hitting you over the head--and the hammer is made of METAL
C) Implies a solid of covalent character, so look for combinations of nonmetal with nonmetal (near each other on the periodic table--low melting points)
D) Implies a solid combination from the elements CNOPS (pronounce “seenops”, rhymes with cyclops) since those are the only elements capable of forming multiple covalent bonds (including π bonds).
E) Implies a huge molecule like a polymer, protein, starch, etc.

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1999 #15
NOT: 65% answered correctly

16. ANS:
C

A) Implies a solid of ionic character, so look for combinations of metal and nonmetal (from opposite sides of the periodic table--high melting points)
B) Implies a solid metal since “delocalized electrons” is a major hammer hitting you over the head--and the hammer is made of METAL
C) Implies a solid of covalent character, so look for combinations of nonmetal with nonmetal (near each other on the periodic table--low melting points)
D) Implies a solid combination from the elements CNOPS (pronounce “seenops”, rhymes with cyclops) since those are the only elements capable of forming multiple covalent bonds (including π bonds).
E) Implies a huge molecule like a polymer, protein, starch, etc.

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1999 #16
NOT: 61% answered correctly

17. ANS:
E

Fluorine gas is a yellow irritating toxic flammable gas and a powerful oxidizing agent.

Fluorine is the smallest of the halogens, therefore it has the least number of electrons and is least polarizable. That means it has the weakest IMFs among its family which is why fluorine and chlorine (also small) are gases, bromine is a liquid and iodine is a gas at room temperature.

DIF: Easy TOP: Periodicity MSC: 1999 #17 NOT: 70% answered correctly

18. ANS:
A

The IA and IIA (with some solubility issues--Be and Mg are not considered very soluble) metal hydroxides and oxides form strong bases in solution.

DIF: Easy TOP: Periodicity MSC: 1999 #18 NOT: 67% answered correctly

MULTIPLE CHOICE

19. ANS: C
The combustion of octane [primary component of gasoline] is thermodynamically spontaneous. The spark supplies energy that contributes to the acquisition of the activation energy for the reaction. Temperature also plays a role since it factors into molecular motion. The spark is an electric spark.

The spark is not a catalyst and cannot decrease the activation energy.
The spark does not vaporize, thus cannot increase the concentration of the volatile reactant.
The spark is not a reactant and thus cannot combine with other reactants to form an activated complex.
The spark does not provide the heat of vaporization for the volatile hydrocarbon. Heat of vaporization relates to evaporation, not combustion.

DIF: Easy TOP: Kinetics MSC: 1999 #19 NOT: 73% answered correctly

20. ANS: B
You were only given one starting amount (and it says *excess* hydrogen), so you have *not* entered the "land of limiting reactant". Whew! You were given the number of moles of reactant, but must calculate the mass of the product which will require that *you* supply a balanced equation.

$Au_2S_3 + H_2 \rightarrow Au + H_xS_y$

If 0.0500 moles of Au_2S_3 completely reacts (not a limiting reactant), then 0.100 moles of Au was formed. The *MM* of Au is 197, so 1/10 mole × 197 g/mol = 19.7 g

DIF: Medium TOP: Stoichiometry MSC: 1999 #20
NOT: 55% answered correctly

21. ANS: B
It is the sodium that is making the color in the flame. When the sodium electrons in the are excited, they jump to higher energy levels. As the electrons fall back down, and leave the excited state, energy is re-emitted, the wavelength of which refers to the discrete lines of the emission spectrum. The only way to see the entire spectrum is to view the flame test through a diffraction grating. Otherwise, you get a general, qualitative result as shown below.
Go to: http://en.wikipedia.org/wiki/Flame_test for a chart of which metals produce which colors.

DIF: Hard TOP: Lab MSC: 1999 #21 NOT: 33% answered correctly

22. ANS: E
In other words, which reaction system becomes more ordered as the reaction proceeds?

Look for formation of the more condensed states (preferably solids). The reaction in (C) forms three moles of solid from three moles of solid while the reaction in E forms only two moles of solid from four moles of solid and three moles of gas, bringing much more order to the system.

DIF: Easy TOP: Thermodynamics MSC: 1999 #22
NOT: 68% answered correctly

23. ANS: E
A helium balloon floats because it contains a gas that is lighter than the surrounding air. An air-filled balloon floats because the hot air inside the balloon is less dense than the surrounding air. As the air is warmed, the distances between gas particles increase causing the gas to be less dense.

Remember, heat does not rise! Heat travels from hot to cold, not "up". Saying "heat" rises is a misnomer. What we should say is that warmed air expands and is less dense [again, due to increased distance between particles], thus it floats and carries thermal energy with it.

DIF: Easy TOP: Gas Laws MSC: 1999 #23 NOT: 67% answered correctly

24. ANS: D
Obviously, flushing the area is the first step. Since acid is the splash culprit, it would be best to follow with a *weak base* wash as well to neutralize any residual acid on the skin.

DIF: Hard TOP: Lab MSC: 1999 #24 NOT: 20% answered correctly

25. ANS: C
P to *Q* shows the liquid cooling to a supercooled state. Most likely the liquid was not stirred during the cooling. Once it is stirred, or a seed crystal is added, the temperature rises as the heat of crystallization is released (points *Q* to *R*) and the freezing point is reached. Note that the temperature (KE_{ave}) remains constant throughout the freezing process from points *R* to *S*.
So, solid must be present from points *Q* to *S*.

DIF: Medium TOP: States of Matter MSC: 1999 #25
NOT: 57% answered correctly

26. ANS: C
The correctly balanced equation is:

$$10\ C_{10}H_{12}O_4S(s) + 12\ O_2(g) \rightarrow 10\ CO_2(g) + SO_2(g) + 6\ H_2O(g)$$

Note that when compounds containing nonmetals are combusted, that oxides of the nonmetals form.

DIF: Easy TOP: Chemical Reactions MSC: 1999 #26
NOT: 74% answered correctly

27. ANS: A
A visible-light spectrophotometer is used for measuring absorbance or transmittance of light in a *colored* solution at a certain wavelength. I. Solutions containing ions of transition metals with *unpaired d*-electrons are colored. Those containing Cu^{2+} are blue. II. We use a conductivity apparatus or conductivity probe to measure the conductivity of a solution. III. The ions listed are not transition metals with unpaired *d*-electrons, thus solutions containing these ions are colorless.

DIF: Hard TOP: Lab MSC: 1999 #27 NOT: 16% answered correctly

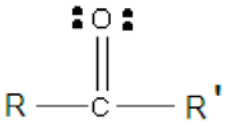
28. ANS: B
When asked about melting points, (or FP, BP, vapor pressure, etc.) your thought process should run something like this: Is this compound covalent (nonmetal-nonmetal) or ionic (metal-nonmetal)? If it is covalent, think IMFs and consider polarizability of the molecule due to how many overall electrons are present. The more electrons present, the larger the electron cloud, the more polarizable it is.
If it is ionic, think in terms of Coulomb's Law and do the math!

$F = \frac{q_1 q_2}{d^2}$; For MgO, $F = \frac{(+2)(-2)}{d^2}$ and for NaF, $F = \frac{(+1)(-1)}{d^2}$

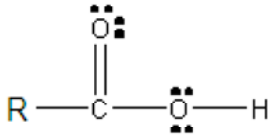
The "players" in these molecules are neighbors, so their ionic radii *d* is about the same. It's the difference in charges that greatly increase the attractive Coulombic-force between the ions in the crystal. You can clearly see that the Coulombic-force attraction ions in the MgO crystal is about 4 times greater than those attracting ions in the NaF crystal, so MgO will have a much higher melting point.

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1999 #28
NOT: 53% answered correctly

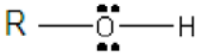
29. ANS: E
Occasionally, you get to celebrate your memorization skills. All of these answer choices are basic examples of organic functional groups. The "R" can be simple like an H atom or a more complex group. If two R groups differ, we use R and R´ to designate that they are different. The compound given contains a ketone functional group and two different R groups, the one on the left is a methyl and the one on the right is an ethyl.



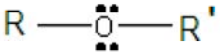
Here are the others:



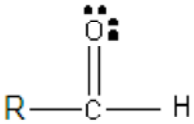
an organic acid



an alcohol



an ether



an aldehyde

DIF: Hard TOP: Descriptive MSC: 1999 #29 NOT: 26% answered correctly

30. ANS: D
The oxidation number for each atom is given above its symbol in the equation below:

+1,–2 +1 ,–1 +6,–1 +1,–1 0
$H_2Se(g) + 4\ O_2F_2(g) \rightarrow SeF_6(g) + 2\ HF(g) + 4\ O_2(g)$

The oxidation number of O does change from +1 [very weird for oxygen] to 0.
The oxidation number of hydrogen does NOT change since neither a metal hydride nor H_2 is present.
The oxidation number of F does not change, it is –1 in all compounds given.
A disproportionation reaction is one in which the same element is BOTH oxidized and reduced which is not the case here. Se is oxidized while O is reduced.

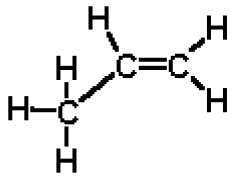
DIF: Easy TOP: Chemical Reactions MSC: 1999 #30
NOT: 75% answered correctly

31. ANS: C
An increase in temperature causes an expansion of solution volume. So, any term that contains *V* as a variable is going to change. So, the only terms that are temperature independent are molality and mole fraction since they depend on mass alone rather than mass and volume.

$D = \frac{m}{V}$ $M = \frac{\#\,mol}{V_{sol'n}}$ $m = \frac{\#\,mol}{\text{kg solvent}}$ $\chi = \frac{moles\ A}{moles_{total}}$

DIF: Hard TOP: Solutions MSC: 1999 #31 NOT: 21% answered correctly

32. ANS: D
Draw the dang Lewis structure! Count the number of "sites" around each carbon. The carbon pictured left has 4 sites, so it is sp^3 hybridized (4 sites, 4 letters, think: *sppp*), the two remaining carbons each have 3 sites of electron density, so they are both sp^2 hybridized (3 sites, 3 letters, think: *spp*). NEVER use the "letter" simplification , *spp*¸when answering a free-response--condense it to sp^2!



DIF: Hard TOP: Bonding & Molecular Structure MSC: 1999 #32
NOT: 38% answered correctly

33. ANS: C
Expect easy math! How much chloride ion is already present?

0.10 mol of NaCl yields 0.10 mol Cl^-
0.10 mol of $CaCl_2$ yields 0.20 mol Cl^-
For a total of 0.30 moles of Cl^-, so you need the same amount of Ag^+ since there is one silver ion for each chloride ion.

DIF: Medium TOP: Stoichiometry MSC: 1999 #33
NOT: 54% answered correctly

34. ANS: A
Aluminum is being reduced from a +3 state to the elemental state where its oxidation state is zero. Reduction does occur at the cathode (RED CAT). Oxidation occurs at the anode (AN OX), but aluminum is being reduced. F^- is being neither oxidized nor reduced, so it is neither an oxidizing agent nor a reducing agent.

DIF: Medium TOP: Electrochemistry MSC: 1999 #34
NOT: 42% answered correctly

35. ANS: C
Begin by calculating the number of coulombs produced: #coulombs = It; where time is in seconds. Also remember an ampere is equal to 1c/s.

$$\#\text{coulombs} = \text{It} = \left(10\,\frac{\text{coulombs}}{\text{s}}\right)\left(15\,\text{min}\times\frac{60\,\text{s}}{\text{min}}\right)$$

Then, # coulombs can be converted to moles of electrons, moles of Al and finally grams of Al using the following:

$$\left(\frac{10\times15\times60}{1}\,\text{coulombs}\right)\times\left(\frac{1\,\text{mol}\,e^-}{96{,}500\,\text{coulombs}}\right)\left(\frac{1\,\text{mol Al}}{3\,\text{mol}\,e^-}\right)\left(\frac{27\,\text{g}}{1\,\text{mol Al}}\right)$$

DIF: Medium TOP: Electrochemistry MSC: 1999 #35
NOT: 43% answered correctly

36. ANS: B
Experiments 1 and 2 hold $[O_2]$ constant and double [NO], the rate doubles, therefore the reaction is 1st order in NO. Experiments 2 and 3 hold [NO] constant and quadruple $[O_2]$, the rate increases by a factor of 16 which is [quad or 4]^2, therefore the reaction is 2nd order in O_2.

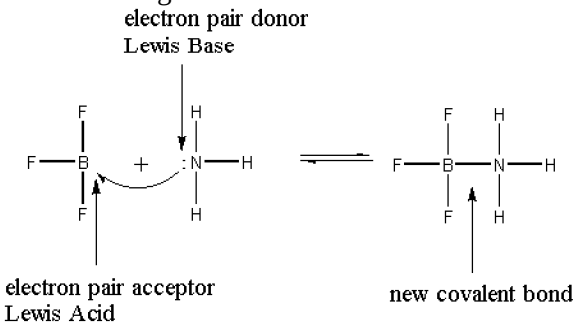
The rate law expression is rate = $k[NO]\,[O_2]^2$

DIF: Medium TOP: Kinetics MSC: 1999 #36 NOT: 52% answered correctly

37. ANS: C
There is a HUGE jump in ionization energy from the 3rd to the 4th. Such an increase indicates that the core has been disrupted meaning the entire valence was removed at the 3rd ionization, so this element most likely makes a +3 ion and is Al.

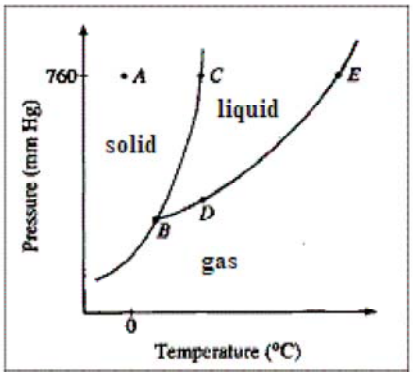
DIF: Hard TOP: Periodicity MSC: 1999 #37 NOT: 35% answered correctly

38. ANS: B
Lewis acids accept (appreciate the alliteration "acids accept") an electron pair and form a coordinate covalent bond. The classic example is ammonia reacting with boron trifluoride.



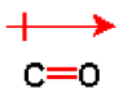
DIF: Hard TOP: Acid-Base MSC: 1999 #38 NOT: 38% answered correctly

39. ANS: C
The "normal" melting point (or boiling point or any other phase change) occurs at 1 atm or 760 mm Hg. Also remember that each of the lines represents an equilibrium line where both phases exist. The usual phase labels were left off to test if you knew them!

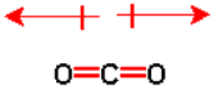


DIF: Easy TOP: States of Matter MSC: 1999 #39
NOT: 71% answered correctly

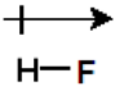
40. ANS: D
You should know that oxygen and fluorine, the diatomic molecules have zero dipole moment since they are linear and cancel each other out. Draw the Lewis structures of the others and contemplate their dipole moments:



has a dipole moment as shown



dipole moments cancel



has the greatest dipole moment since F is much more electroneg ative

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1999 #40
NOT: 54% answered correctly

41. ANS: E
Adding a reactant or a product causes a shift *away* from the addition. Adding O_2 to the vessel causes more reactant to form (shift left, shift toward reactant). K_{eq} for the reaction would not change since it is the ratio of products to reactants and is a constant at constant temperature. The total pressure will not change since 3 moles of gas is shifted to 2 moles of gas.

DIF: Medium TOP: Equilibrium MSC: 1999 #41 NOT: 65% answered correctly

42. ANS: C
Not a redox equation, although it looks like it could be. Nothing is neither oxidized nor reduced. The balanced equation is:

$$Li_3N(s) + 3\ H_2O(l) \rightarrow Li^+(aq) + 3\ OH^-(aq) + NH_3(g)$$

DIF: Easy TOP: Chemical Reactions MSC: 1999 #42
NOT: 71% answered correctly

43. ANS: D

$M = \dfrac{\#\,mol}{V_{sol'n}}$ $m = \dfrac{\#\,mol}{\text{kg solvent}}$ the only variable you are missing is the volume of the solution.

DIF: Medium TOP: Solutions MSC: 1999 #43 NOT: 60% answered correctly

44. ANS: C

Rigid is code for constant volume. The pressure would increase. Since the temperature is held constant the average KE of the molecules remains the same and since their mass remains constant (only oxygen in the tank), their velocity also remains constant. If you added oxygen to the tank you increased the number of molecules within the tank, so the average distance between the molecules decreases (more crowded).

DIF: Medium TOP: Gas Laws MSC: 1999 #44 NOT: 54% answered correctly

45. ANS: D

Expect easy math!

$HCN \leftrightarrows H^+ + CN^-$

$$K_a = \frac{[H^+][CN^-]}{[HCN]} = \frac{x^2}{0.05} = 5.0 \times 10^{-10}$$

$$\therefore\ x^2 = 0.25 \times 10^{-10}\ \ \therefore\ x = [H^+] = \sqrt{0.25 \times 10^{-10}} = 0.5 \times 10^{-5} = 5 \times 10^{-6}$$

DIF: Medium TOP: Acid-Base MSC: 1999 #45 NOT: 40% answered correctly

46. ANS: C

If you have not performed this reaction or seen it as a demonstration, you are at a disadvantage for this question. Here's the reaction:

$Cu^{2+}(aq) + 4\ NH_3(aq) \rightarrow Cu(NH_3)_4^{2+}(aq)$

The tetraamminecopper(II) complex ion is a deep blue in solution and is shown on the right compared to copper(II) nitrate on the left in the picture below.

DIF: Hard TOP: Lab MSC: 1999 #46 NOT: 22% answered correctly

47. ANS: C
Expect easy math and estimate!

$$\frac{62.2\,\text{g}}{178.5\,\frac{\text{g}}{\text{mol}}} \approx 3\,\text{moles Hf} \qquad \text{and} \qquad \frac{37.4\,\text{g}}{35.5\,\frac{\text{g}}{\text{mol}}} \approx 1\,\text{mole Cl, so } HfCl_3$$

DIF: Medium TOP: Stoichiometry MSC: 1999 #47
NOT: 50% answered correctly

48. ANS: B
Start with 100% and realize that if 87.5% decays, then 12.5% remains!
$100 \xrightarrow{1} 50 \xrightarrow{2} 25 \xrightarrow{3} 12.5$, so it takes 3 half-lives to decay to 12.5%, so each half-life is 24/3 or 8 days.

DIF: Medium TOP: Nuclear MSC: 1999 #48 NOT: 42% answered correctly

49. ANS: E
Paper chromatography works nicely to separate dyes or pigments in solution. Filtration is used to separate a solid precipitate from a solution. Titration is used to determine the concentration of an known quantity unknown acid or base with a known quantity of acid or base of known concentration. Electrolysis is using an electric current to separate metals from molten ores or related compounds, convert water into hydrogen and oxygen gas, or plate metals. Since KNO_3 is such a soluble salt, evaporating away the water is the most appropriate.

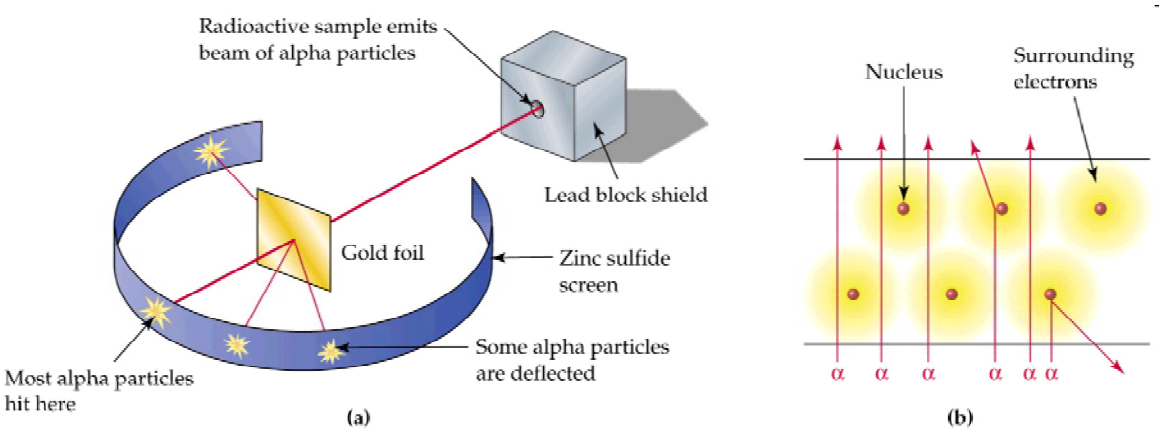
DIF: Medium TOP: Lab MSC: 1999 #49 NOT: 53% answered correctly

50. ANS: D
The trend is that atomic radii generally decrease as you go across the periodic table since the effective nuclear charge increases. When answering a question like this in the free-response section be sure to talk about *why*. Discuss effective nuclear charge and attractive forces, just stating the trend will earn you no points since it is an observation rather than an explanation!

DIF: Medium TOP: Periodicity MSC: 1999 #50 NOT: 62% answered correctly

51. ANS: E
Hans Geiger (as in the counter) and Earnest Marsden actually performed the experiments since they were graduate students of Earnest Rutherford at the time. (Not a typo--Earnest was a popular name.) He made them repeat it several times since he couldn't believe the results. Rutherford said of the alpha particles that made a direct hit and bounced straight back, "It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

Also, here's a great animation with explanation:
http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/ruther14.swf



DIF: Medium TOP: Atomic Structure MSC: 1999 #51
NOT: 59% answered correctly

52. ANS: B
Gases, especially oxygen, are more soluble in water at high pressures and low temperatures. Think about aquariums, if they get too warm, the fish suffocate and die. The highest pressure listed is 5.0 atm and the lowest temperature is 20°C.

DIF: Hard TOP: Solutions MSC: 1999 #52 NOT: 31% answered correctly

53. ANS: A
A quick RICE table will help (even though this is not shown as an equilibrium):

	$W(g)$	+	$X(g)$	→	$Y(g)$	+	$Z(g)$
R							
I	1.20 atm		1.60 atm		0		0
C	$-x$		$-x$		$+x$		$+x$
E	1.00 atm						

So, $-x$ must equal –0.20 atm, thus $+x$ must equal +0.20 atm

DIF: Medium TOP: Stoichiometry MSC: 1999 #53
NOT: 46% answered correctly

54. ANS: B

$\Delta H < 0$; thus it is a negative value, therefore the reaction is exothermic, so think of the reaction as:

$$2\ NO(g) + O_2(g) \leftrightharpoons 2\ NO_2(g) + heat$$

Thus, adding heat (increasing the temperature) shifts the reaction to the left (reactants favored) decreasing the value of $K_{eq.}$

DIF: Hard TOP: Equilibrium MSC: 1999 #54 NOT: 35% answered correctly

55. ANS: D

The "trick" to getting this one correct is to recognize that you have entered the "land of limiting reagent"! You were given the number of moles of *three* reactants. Determine the limiting reagent. Start by using I_2 since it is the smallest starting amount coupled with the highest coefficient.

If 5 = 2.5 mol, then 10 = 5.0 mol. Calculate ***subsequent moles*** (if 10 = 5 mol, then 1 = 1/2 mol, so 2 = 1.0 mol and 3 = 1.5 mol) from that limiting amount of moles using the mole:mole.

10 HI	2 $KMnO_4$	3 H_2SO_4	$\rightarrow$	5 I_2	2 $MnSO_4$	K_2SO_4	8 H_2O
? mol	4.0 mol	3.0 mol		2.5 mol			
5.0 mol	***1.0 mol***, so plenty is available	***1.5 mol***, so plenty is available		***limit!***			

DIF: Easy TOP: Stoichiometry MSC: 1999 #55
NOT: 69% answered correctly

56. ANS: A

A solubility rule moment. Salts containing Group I elements are soluble (Li^+, Na^+, K^+, Cs^+, Rb^+), so the I^- ion is the precipitation culprit! That realization eliminates the negative ions from the possible answer choices, leaving PbI_2 or ZnI_2 as the only possible choices. Salts containing Cl^-, Br^-, I^- are generally soluble. Important *exceptions* to this rule are halide salts of Ag^+, Pb^{2+}, and $(Hg_2)^{2+}$. PbI_2 is indeed yellow!

DIF: Hard TOP: Lab MSC: 1999 #56 NOT: 32% answered correctly

57. ANS: A

The balanced redox reaction is given first, that means the cell potential is E°_{cell} = +2.46 V. Also, it is clear that silver is reduced and its reduction potential is also given. M is therefore oxidized, so solve for the oxidation half-reaction AND DON'T FORGET TO CHANGE ITS SIGN since you are asked for M's reduction potential.

$E^\circ_{cell} = E^\circ_{reduction} + E^\circ_{oxidation}$

The values are given, but you had to figure out the situation! E°_{cell} = +2.46 V and $E^\circ_{reduction}$ = + 0.80 V

$\therefore E^\circ_{oxidation} = E^\circ_{cell} - E^\circ_{reduction}$ = (+2.46 V) – (+0.80 V) = +1.66 V so M's *reduction* potential is –1.66 V

DIF: Medium TOP: Electrochemistry MSC: 1999 #57
NOT: 44% answered correctly

58. ANS: C

On mountaintops, the atmospheric pressure is less. The "pull" of gravity originates at the center of earth and acts on the gases in the atmosphere. The further away from the source of our gravitational pull, the less tightly the atmospheric gases are held, the lower the density of air, thus the lower the atmospheric pressure. Water boils when its vapor pressure is equal to atmospheric pressure. If the atmospheric pressure is less, less thermal energy must be added to a sample of water to raise its VP to a (lesser) atmospheric pressure. Since the water is actually boiling at a lower temperature, food must be boiled longer to compensate!

DIF: Hard TOP: States of Matter MSC: 1999 #58
NOT: 39% answered correctly

59. ANS: C

Expect easy math! Calculate the *total* number of moles of OH^- and simply divide by the total volume.

$M = \dfrac{\text{moles}}{V_{liters}} \;\therefore\; moles = M \times L$

(0.04 L)(0.25 *M*) = 0.01 moles of OH^- from KOH
(0.06 L)(0.15 *M*)(2 OH^- ions per mole $Ba(OH)_2$ = 0.018 moles of OH^- from $Ba(OH)_2$
Total volume = 100 mL or 0.10 L

$\therefore\; M = \dfrac{\text{moles}}{V_{liters}} = \dfrac{(0.028\,\text{mol})}{0.10\,\text{L}} = 0.28\,M$

DIF: Hard TOP: Solutions MSC: 1999 #59 NOT: 28% answered correctly

60. ANS: A

Expect easy math! Use 8/100 for R and since the answer choices are so far apart...estimate!

$NH_4NO_3(s) \rightarrow N_2O(g) + 2\,H_2O(g)$

0.03 mol solid $\therefore \rightarrow$ (0.03 mol + 0.06 mol) gas, so there is a total of 0.09 mol of gas in the 1 L flask

$PV = nRT \;\therefore\; P = \dfrac{nRT}{V} = \dfrac{(0.09)(\frac{8}{100})(400)}{1} = (0.09)(32) \approx \dfrac{1}{10}(32) \approx 3\,\text{atm}$

DIF: Hard TOP: Gas Laws MSC: 1999 #60 NOT: 22% answered correctly

61. ANS: E
Realize this is a combustion reaction and heat energy is lost. Vaporization is an endothermic process and *requires* energy. That means some of the energy lost by the combustion system is subsequently reused by the system to vaporize water if $H_2O(g)$ is formed. This lowers the total energy yield.

As a result, more total energy is lost from the combustion reaction that produces *liquid* water compared to gaseous water. So, expect that this reaction would yield $2(-44\ \text{kJ mol}^{-1})$ more energy if liquid water is formed rather than water vapor. Both answers D and E yield more energy, but D didn't factor in that two moles of water are involved.

DIF: Hard TOP: Thermochemistry MSC: 1999 #61
NOT: 31% answered correctly

62. ANS: A
Write out the equilibrium expression and think about that tiny value for K_a.

$K_a = \dfrac{[\text{HCN}][\text{C}_2\text{H}_3\text{O}_2^-]}{[\text{HC}_2\text{H}_3\text{O}_2][\text{CN}^-]} = 3.7 \times 10^{-4}$ which is much less than one, so the denominator is a larger term, therefore reactants are favored, meaning acetic acid is a stronger acid than hydrocyanic acid AND cyanide ion is a stronger base than acetate ion. Answer (E) is only true if the acid base mixture is of equimolar solutions of a strong acid and strong base are mixed.

DIF: Hard TOP: Acid-Base MSC: 1999 #62 NOT: 31% answered correctly

63. ANS: B
It's a concentration vs. time graph which means you must deal with integrated rate law. Ah, note that one of the reactants *Y*, has a massive concentration compared to *X*. That is called "swamping" and is a technique used to determine the order of the nonswamped reactant. IF the graph for reactant *X* were a straight line with a negative slope, then we'd know it was zero order. Alas, the *X* line is a curve, so it is not zero order, it is either first or second order, but at least answer (A) is eliminated.

What if the data were in a table?

[*X*] from graph	[*Y*] from graph	We know the rate is changing since the *X* line is a curve, so the rate is dependent upon decreasing [*X*] *and* independent of the concentration of *Y*, thus the order of *Y* is zero--too bad that's not an answer choice! But at least answer (D) is eliminated.
0.20	4.0	
0.10	4.0	
0.05	4.0	

Recall that $rate = k[X]^m[Y]^n$, and we just determined *Y* is zero order, so its exponent is zero and its value in the rate law expression is 1! So, our rate law expression simplifies to $rate = k[X]^m$. Thus, if (C) were correct, then (E) would also be correct and that can't be, so these choices are eliminated. Answer (B) is all that is left.

DIF: Hard TOP: Kinetics MSC: 1999 #63 NOT: 34% answered correctly

64. ANS: A
Light gas molecules move faster than heavy ones. So, He moved out quickest, with Ne in second place and Ar dragging up the rear. That left more Ar in the container to exert a greater pressure (more molecules colliding with the container) with Ne being in the middle and He having the fewest molecules remaining, thus exerting the least pressure. So, P_{He} is less than P_{Ne} which is less than P_{Ar}.

DIF: Medium TOP: Gas Laws MSC: 1999 #64 NOT: 65% answered correctly

65. ANS: A
Do the *not soluble in water* part first: scratch the ammonium compounds as well as the nitrate since all of both are always soluble in water. That leaves magnesium hydroxide and copper sulfate. Most sulfate salts are soluble. Important exceptions to this rule include $BaSO_4$, $PbSO_4$, Ag_2SO_4 and $SrSO_4$, so that leaves only magnesium hydroxide insoluble in water. No need to stress over the "soluble in dilute acid" part. It was a nice clue, that may have led you straight to the only hydroxide.

It is important to note that hydroxides of IA and IIA metals are generally strong bases, but the "little IIA guys", Be and Mg are not very soluble, so they are often classified as weak and written undissociated on the net ionic reaction question.

DIF: Hard TOP: Chemical Reactions MSC: 1999 #65
NOT: 35% answered correctly

66. ANS: A
If a solid dissolves, chaos abounds, thus disorder increases ($+\Delta S$). If the temperature of the system decreases, heat from the surroundings is being *added* to the system ($+\Delta H$).

DIF: Hard TOP: Thermodynamics MSC: 1999 #66
NOT: 31% answered correctly

67. ANS: E
$Ag_2CrO_4 \rightleftarrows 2\ Ag^+ + CrO_4^{2-}$

The molar solubility is the concentration in moles/L of the salt that dissolves so it is equal to x and equal to $[CrO_4^{2-}]$.

Therefore, $K_{sp} = [Ag^+]^2[CrO_4^{2-}] = [2x]^2[x] = 4x^3 = 8 \times 10^{-12}$

$$\therefore x^3 = \frac{8 \times 10^{-12}}{4} = 2 \times 10^{-12}$$

$$\therefore x = \sqrt[3]{2 \times 10^{-12}}\ M$$

$$= 4 \times 10^{-12}$$

DIF: Hard TOP: Equilibrium MSC: 1999 #67 NOT: 25% answered correctly

68. ANS: D

$I_2(s) \rightarrow I_2(g)$--phase change; energy added to overcome dispersion IMFs in molecular solid

$CO_2(s) \rightarrow CO_2(g)$--phase change; solid carbon dioxide is not a network covalent solid nor an ionic crystal, energy added to overcome dispersion IMFs in a molecular solid

NaCl(s) → NaCl(l)--phase change; energy added to overcome lattice energy and melt ionic crystal

C(diamond) → C(g)--phase change; BUT diamond and graphite are network covalent solids, meaning *four* covalent bonds exist between the carbons of diamond, that's why it is so hard!

Fe(s) → Fe(l)--phase change; energy added to overcome attractions between charged iron ions and delocalized electrons

DIF: Medium TOP: States of Matter MSC: 1999 #68
NOT: 54% answered correctly

69. ANS: C

Expect easy math!

Net ionic reaction: $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Calculate the *total* number of moles of Ba^{2+} and simply divide by the total volume.

$M = \frac{\text{moles}}{V_{liters}} \ \therefore \ moles = M \times L$

(0.10 L)(0.10 *M*) = 0.01 moles of Ba^{2+} from $BaCl_2$
(0.10 L)(0.05 *M*) = 0.005 moles of SO_4^{2-} from H_2SO_4 which limits the amount of precipitate formed!

So, there is 0.005 unreacted Ba^{2+} in solution.

Total volume = 200 mL or 0.20 L $\therefore \ M = \frac{\text{moles}}{V_{liters}} = \frac{(0.005\,\text{mol})}{0.200\,\text{L}} = 0.025\,M$

DIF: Hard TOP: Solutions MSC: 1999 #69 NOT: 31% answered correctly

70. ANS: A

It's all about understanding your solubility rules! Who does Ag precipitate with? Phosphate, so it's concentration will be the smallest listed...only answers A & B are reasonable. Equal volumes and equal molarities mean equal number of moles (moles = $M \times V_{\text{liters}}$), so Na outnumbers nitrate by 3 to 1, it should be in greatest concentration and listed last. The correct *increasing* concentration order is phosphate ion, nitrate ion, and sodium ion.

DIF: Hard TOP: Chemical Reactions MSC: 1999 #70
NOT: 34% answered correctly

71. ANS: B
There is value in memorizing and applying your solubility rules as well as understanding the question. Separation will be achieved by precipitate formation accompanied by subsequent filtering. In other words, you are trying to cull lead ion from the herd of ions given. Pb^{2+} ion is *not* soluble with halides (while halides of other metals *are* soluble) so, go for the halide.

You could make a ppt. of PbS_2, but that wouldn't separate it from the others since iron(II) and copper(II) sulfides would also form.
You could make a ppt. of $Pb(OH)_2$, but that wouldn't separate it from the others either since iron(II) and copper(II) hydroxides would also form.
Lead(II) ion doesn't even precipitate with ammonia.
Lead(II) ion would form lead(II) nitrate with nitric acid (the oxidizing acid), which is soluble.

DIF: Hard TOP: Lab MSC: 1989 #71 NOT: 32% answered correctly

72. ANS: B
Your initial thoughts should be:
1) Either the sample was still "wet", not enough water was driven out OR
2) The mass of the hydrate was recorded as too large to begin with OR
3) There was a lot of humidity in the laboratory and the solid reabsorbed water.

Initially spattering would carry away the *hydrate* implying its waters of hydration are still intact, so it isn't just water that splattered out. The amount of the hydrate sample used is irrelevant. Not heating the crucible to constant mass before use leaves water in the pores of the porcelain. The water trapped would be counted as waters of hydration and make the percent reported too high, rather than too low. It is not likely that excess heating would cause the dehydrated sample to decompose since the anhydrous compound is most likely ionic with an extremely high melting point and even higher amounts of heat would be needed for decomposition to occur.

DIF: Hard TOP: Lab MSC: 1999 #72 NOT: 25% answered correctly

73. ANS: D
Two molarities, both HCl...dilution! $M_1V_1 = M_2V_2$.
$V_2 = \dfrac{(6.00\,M)(10.0\,\text{mL})}{0.500\,M} = 60 \div \dfrac{1}{2}$ (or 60×2)
which is 120 mL of TOTAL volume, so add 50.0 mL since 10.0 mL was already in the container. You *had* to suspect something when "added" was underlined!

DIF: Hard TOP: Solutions MSC: 1989 #73 NOT: 33% answered correctly

74. ANS: A
Deviations occur due to molecular volume (larger molecules have more mass as well) and attractive forces. The more electrons present, the more polarizable a molecule, thus the greater the London dispersion (induced dipole-induced dipole) attractive forces become. SO_2 has a higher molecular mass, more electrons and is more polarizable than the other answer choices.

DIF: Medium TOP: Gas Laws MSC: 1999 #74 NOT: 48% answered correctly

75. ANS: D

It's all about IMFs. Deviations from ideal behavior occur when IMFs enter the scenario. So, you are looking for nonpolar-nonpolar combinations.

A) $C_8H_{18}(l)$ and $H_2O(l)$--polar solvent means lots of attractions even with octane
B) $CH_3CH_2CH_2OH(l)$ and $H_2O(l)$--even more attractions with a polar alcohol
C) $CH_3CH_2CH_2OH(l)$ and $C_8H_{18}(l)$--better, while the alcohol is polar, octane isn't
D) $C_6H_{14}(l)$ and $C_8H_{18}(l)$--best, both very nonpolar
E) $H_2SO_4(l)$ and $H_2O(l)$--polar solvent with a very strong acid--not ideal at all!

DIF: Hard TOP: Solutions MSC: 1999 #75 NOT: 33% answered correctly