DO NOT DETACH FROM BOOK.

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)

Material in the following table may be useful in answering the questions in this section of the examination.

Note: For all questions involving solutions and/or chemical equations, assume that the system is in pure water and at room temperature unless otherwise stated.

Part A (75 questions, 54 minutes)

Directions: Each set of lettered choices below refers to the numbered questions or statements immediately following it. Select the one lettered choice that best answers each question or 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

(A) Heisenberg uncertainty principle
(B) Pauli exclusion principle
(C) Hund's rule (principle of maximum multiplicity)
(D) Shielding effect
(E) Wave nature of matter

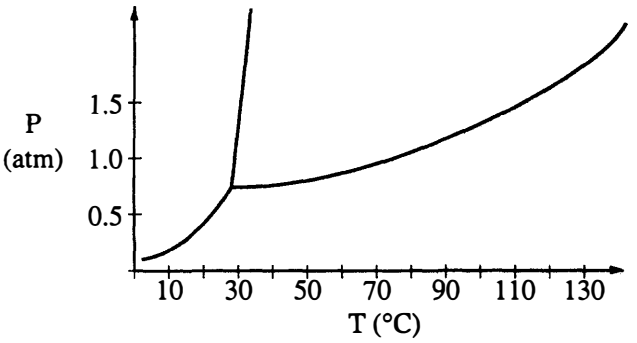
1. Can be used to predict that a gaseous carbon atom in its ground state is paramagnetic

2. Explains the experimental phenomenon of electron diffraction

3. Indicates that an atomic orbital can hold no more than two electrons

4. Predicts that it is impossible to determine simultaneously the exact position and the exact velocity of an electron

Questions 5-7 refer to the phase diagram below of a pure substance.



(A) Sublimation
(B) Condensation
(C) Solvation
(D) Fusion
(E) Freezing

5. If the temperature increases from 10° C to 60° C at a constant pressure of 0.4 atmosphere, which of the processes occurs?

6. If the temperature decreases from 110° C to 40° C at a constant pressure of 1.1 atmospheres, which of the processes occurs?

7. If the pressure increases from 0.5 to 1.5 atmospheres at a constant temperature of 50° C, which of the processes occurs?

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Questions 8-10 refer to the following diatomic species.

(A) Li_2
(B) B_2
(C) N_2
(D) O_2
(E) F_2

8. Has the largest bond-dissociation energy

9. Has a bond order of 2

10. Contains 1 sigma (σ) and 2 pi (π) bonds

Questions 11-13

(A) Pb
(B) Ca
(C) Zn
(D) As
(E) Na

11. Utilized as a coating to protect Fe from corrosion

12. Is added to silicon to enhance its properties as a semiconductor

13. Utilized as a shield from sources of radiation

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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.

14. Which of the following is lower for a 1.0-molar aqueous solution of any solute than it is for pure water?

    (A) pH
    (B) Vapor pressure
    (C) Freezing point
    (D) Electrical conductivity
    (E) Absorption of visible light

15. In a molecule in which the central atom exhibits sp^3d^2 hybrid orbitals, the electron pairs are directed toward the corners of

    (A) a tetrahedron
    (B) a square-based pyramid
    (C) a trigonal bipyramid
    (D) a square
    (E) an octahedron

16. Commercial vinegar was titrated with NaOH solution to determine the content of acetic acid, $HC_2H_3O_2$. For 20.0 milliliters of the vinegar, 26.7 milliliters of 0.600-molar NaOH solution was required. What was the concentration of acetic acid in the vinegar if no other acid was present?

    (A) 1.60 *M*
    (B) 0.800 *M*
    (C) 0.600 *M*
    (D) 0.450 *M*
    (E) 0.200 *M*

17. Relatively slow rates of chemical reaction are associated with which of the following?

    (A) The presence of a catalyst
    (B) High temperature
    (C) High concentration of reactants
    (D) Strong bonds in reactant molecules
    (E) Low activation energy

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18. $2\ H_2O + 4\ MnO_4^- + 3\ ClO_2^- \rightarrow 4\ MnO_2 + 3\ ClO_4^- + 4\ OH^-$

Which species acts as an oxidizing agent in the reaction represented above?

(A) H_2O
(B) ClO_4^-
(C) ClO_2^-
(D) MnO_2
(E) MnO_4^-

19. In which of the following compounds is the mass ratio of chromium to oxygen closest to 1.62 to 1.00 ?

(A) CrO_3
(B) CrO_2
(C) CrO
(D) Cr_2O
(E) Cr_2O_3

20. $\ldots Ag^+ + \ldots AsH_3(g) + \ldots OH^- \rightarrow \ldots Ag(s) + \ldots H_3AsO_3(aq) + \ldots H_2O$

When the equation above is balanced with lowest whole-number coefficients, the coefficient for OH^- is

(A) 2
(B) 4
(C) 5
(D) 6
(E) 7

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21. Correct statements about alpha particles include which of the following?

I. They have a mass number of 4 and a charge of +2.
II. They are more penetrating than beta particles.
III. They are helium nuclei.

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

22. $HSO_4^- + H_2O \rightleftharpoons H_3O^+ + SO_4^{2-}$

In the equilibrium represented above, the species that act as bases include which of the following?

I. HSO_4^-
II. H_2O
III. SO_4^{2-}

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

23. Step 1: $Ce^{4+} + Mn^{2+} \rightarrow Ce^{3+} + Mn^{3+}$

Step 2: $Ce^{4+} + Mn^{3+} \rightarrow Ce^{3+} + Mn^{4+}$

Step 3: $Mn^{4+} + Tl^{+} \rightarrow Tl^{3+} + Mn^{2+}$

The proposed steps for a catalyzed reaction between Ce^{4+} and Tl^{+} are represented above. The products of the overall catalyzed reaction are

(A) Ce^{4+} and Tl^{+}
(B) Ce^{3+} and Tl^{3+}
(C) Ce^{3+} and Mn^{3+}
(D) Ce^{3+} and Mn^{4+}
(E) Tl^{3+} and Mn^{2+}

24. A sample of 0.0100 mole of oxygen gas is confined at 37° C and 0.216 atmosphere. What would be the pressure of this sample at 15° C and the same volume?

(A) 0.0876 atm
(B) 0.175 atm
(C) 0.201 atm
(D) 0.233 atm
(E) 0.533 atm

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25. $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(\ell)$ $\quad \Delta H^\circ = -286$ kJ

$2\ Na(s) + \frac{1}{2} O_2(g) \rightarrow Na_2O(s)$ $\quad \Delta H^\circ = -414$ kJ

$Na(s) + \frac{1}{2} O_2(g) + \frac{1}{2} H_2(g) \rightarrow NaOH(s)$ $\quad \Delta H^\circ = -425$ kJ

Based on the information above, what is the standard enthalpy change for the following reaction?

$$Na_2O(s) + H_2O(\ell) \rightarrow 2\ NaOH(s)$$

(A) −1,125 kJ
(B) −978 kJ
(C) −722 kJ
(D) −150 kJ
(E) +275 kJ

26. Which of the following actions would be likely to change the boiling point of a sample of a pure liquid in an open container?

I. Placing it in a smaller container
II. Increasing the number of moles of the liquid in the container
III. Moving the container and liquid to a higher altitude

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

27. Which of the following sets of quantum numbers (n, l, m_ℓ, m_s) best describes the valence electron of highest energy in a ground-state gallium atom (atomic number 31) ?

(A) $4, 0, 0, \frac{1}{2}$

(B) $4, 0, 1, \frac{1}{2}$

(C) $4, 1, 1, \frac{1}{2}$

(D) $4, 1, 2, \frac{1}{2}$

(E) $4, 2, 0, \frac{1}{2}$

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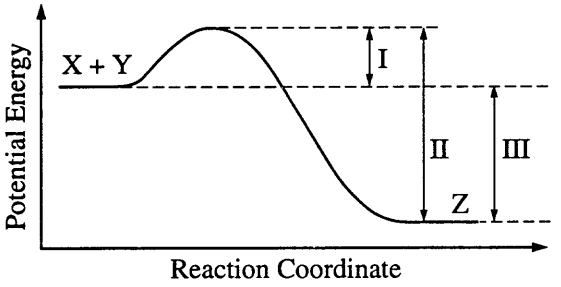
28. Given that a solution is 5 percent sucrose by mass, what additional information is necessary to calculate the molarity of the solution?

I. The density of water
II. The density of the solution
III. The molar mass of sucrose

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

29. When an aqueous solution of NaOH is added to an aqueous solution of potassium dichromate, $K_2Cr_2O_7$, the dichromate ion is converted to

(A) CrO_4^{2-}
(B) CrO_2^-
(C) Cr^{3+}
(D) $Cr_2O_3(s)$
(E) $Cr(OH)_3(s)$



30. The energy diagram for the reaction $X + Y \rightarrow Z$ is shown above. The addition of a catalyst to this reaction would cause a change in which of the indicated energy differences?

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

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31. $H_2C_2O_4 + 2\ H_2O \rightleftarrows 2\ H_3O^+ + C_2O_4^{2-}$

Oxalic acid, $H_2C_2O_4$, is a diprotic acid with $K_1 = 5.36 \times 10^{-2}$ and $K_2 = 5.3 \times 10^{-5}$. For the reaction above, what is the equilibrium constant?

(A) 5.36×10^{-2}
(B) 5.3×10^{-5}
(C) 2.8×10^{-6}
(D) 1.9×10^{-10}
(E) 1.9×10^{-13}

32. CH_3CH_2OH boils at 78° C and CH_3OCH_3 boils at −24° C, although both compounds have the same composition. This difference in boiling points may be attributed to a difference in

(A) molecular mass
(B) density
(C) specific heat
(D) hydrogen bonding
(E) heat of combustion

33. A hydrocarbon gas with an empirical formula CH_2 has a density of 1.88 grams per liter at 0° C and 1.00 atmosphere. A possible formula for the hydrocarbon is

(A) CH_2
(B) C_2H_4
(C) C_3H_6
(D) C_4H_8
(E) C_5H_{10}

34. $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}CH_3$ (*X*) $CH_3\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}OH$ (*Y*) $HO\text{-}CH_2\text{-}CH_2\text{-}CH_2\text{-}OH$ (*Z*)

Based on concepts of polarity and hydrogen bonding, which of the following sequences correctly lists the compounds above in the order of their increasing solubility in water?

(A) $Z < Y < X$
(B) $Y < Z < X$
(C) $Y < X < Z$
(D) $X < Z < Y$
(E) $X < Y < Z$

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35. For which of the following processes would ΔS have a negative value?

I. $2\ Fe_2O_3(s) \rightarrow 4\ Fe(s) + 3\ O_2(g)$

II. $Mg^{2+} + 2\ OH^- \rightarrow Mg(OH)_2(s)$

III. $H_2(g) + C_2H_4(g) \rightarrow C_2H_6(g)$

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

36. $$Zn(s) + Cu^{2+} \rightleftharpoons Zn^{2+} + Cu(s)$$

An electrolytic cell based on the reaction represented above was constructed from zinc and copper half-cells. The observed voltage was found to be 1.00 volt instead of the standard cell potential, E^0, of 1.10 volts. Which of the following could correctly account for this observation?

(A) The copper electrode was larger than the zinc electrode.
(B) The Zn^{2+} electrolyte was $Zn(NO_3)_2$, while the Cu^{2+} electrolyte was $CuSO_4$.
(C) The Zn^{2+} solution was more concentrated than the Cu^{2+} solution.
(D) The solutions in the half-cells had different volumes.
(E) The salt bridge contained KCl as the electrolyte.

37. A sample of 3.30 grams of an ideal gas at 150.0°C and 1.25 atmospheres pressure has a volume of 2.00 liters. What is the molar mass of the gas? The gas constant, R, is 0.0821 (L · atm)/(mol · K).

(A) 0.0218 gram/mole
(B) 16.2 grams/mole
(C) 37.0 grams/mole
(D) 45.8 grams/mole
(E) 71.6 grams/mole

38. Concentrations of colored substances are commonly measured by means of a spectrophotometer. Which of the following would ensure that correct values are obtained for the measured absorbance?

I. There must be enough sample in the tube to cover the entire light path.
II. The instrument must be periodically reset using a standard.
III. The solution must be saturated.

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

39. Samples of F_2 gas and Xe gas are mixed in a container of fixed volume. The initial partial pressure of the F_2 gas is 8.0 atmospheres and that of the Xe gas is 1.7 atmospheres. When all of the Xe gas reacted, forming a solid compound, the pressure of the unreacted F_2 gas was 4.6 atmospheres. The temperature remained constant. What is the formula of the compound?

(A) XeF
(B) XeF_3
(C) XeF_4
(D) XeF_6
(E) XeF_8

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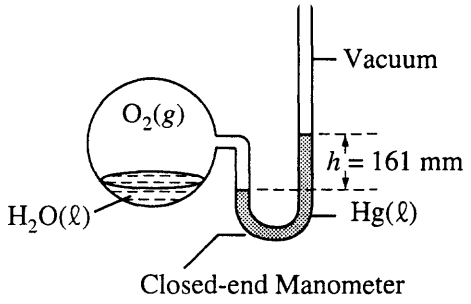

40. The system shown above is at equilibrium at 28° C. At this temperature, the vapor pressure of water is 28 millimeters of mercury. The partial pressure of $O_2(g)$ in the system is

(A) 28 mm Hg
(B) 56 mm Hg
(C) 133 mm Hg
(D) 161 mm Hg
(E) 189 mm Hg

41. A strip of metallic scandium, Sc, is placed in a beaker containing concentrated nitric acid. A brown gas rapidly forms, the scandium disappears, and the resulting liquid is brown-yellow but becomes colorless when warmed. These observations best support which of the following statements?

(A) Nitric acid is a strong acid.
(B) In solution scandium nitrate is yellow and scandium chloride is colorless.
(C) Nitric acid reacts with metals to form hydrogen.
(D) Scandium reacts with nitric acid to form a brown gas.
(E) Scandium and nitric acid react in mole proportions of 1 to 3.

42.

Mass of an empty container	3.0 grams
Mass of the container plus the solid sample	25.0 grams
Volume of the solid sample	11.0 cubic centimeters

The data above were gathered in order to determine the density of an unknown solid. The density of the sample should be reported as

(A) 0.5 g/cm^3
(B) 0.50 g/cm^3
(C) 2.0 g/cm^3
(D) 2.00 g/cm^3
(E) 2.27 g/cm^3

43. Which of the following pairs of compounds are isomers?

(A) $CH_3—CH_2—CH_2—CH_3$ and $CH_3—\underset{\displaystyle CH_3}{\underset{|}{CH}}—CH_3$

(B) $CH_3—\underset{\displaystyle CH_3}{\underset{|}{CH}}—CH_3$ and $CH_3—\underset{\displaystyle CH_3}{\underset{|}{C}}=CH_2$

(C) $CH_3—O—CH_3$ and $CH_3—\overset{\displaystyle O}{\overset{\|}{C}}—CH_3$

(D) $CH_3—OH$ and $CH_3—CH_2—OH$

(E) CH_4 and $CH_2=CH_2$

44. Which of the following solutions has the lowest freezing point?

(A) 0.20 *m* $C_6H_{12}O_6$, glucose
(B) 0.20 *m* NH_4Br
(C) 0.20 *m* $ZnSO_4$
(D) 0.20 *m* $KMnO_4$
(E) 0.20 *m* $MgCl_2$

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45. A sample of an ideal gas is cooled from 50.0° C to 25.0° C in a sealed container of constant volume. Which of the following values for the gas will decrease?

I. The average molecular mass of the gas
II. The average distance between the molecules
III. The average speed of the molecules

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

46. Which of the following solids dissolves in water to form a colorless solution?

(A) $CrCl_3$
(B) $FeCl_3$
(C) $CoCl_2$
(D) $CuCl_2$
(E) $ZnCl_2$

47. Which of the following has the lowest conductivity?

(A) 0.1 *M* $CuSO_4$
(B) 0.1 *M* KOH
(C) 0.1 *M* $BaCl_2$
(D) 0.1 *M* HF
(E) 0.1 *M* HNO_3

48. $PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g) + \text{energy}$

Some PCl_3 and Cl_2 are mixed in a container at 200° C and the system reaches equilibrium according to the equation above. Which of the following causes an increase in the number of moles of PCl_5 present at equilibrium?

I. Decreasing the volume of the container
II. Raising the temperature
III. Adding a mole of He gas at constant volume

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

49. The isomerization of cyclopropane to propylene is a first-order process with a half-life of 19 minutes at 500° C. The time it takes for the partial pressure of cyclopropane to decrease from 1.0 atmosphere to 0.125 atmosphere at 500° C is closest to

(A) 38 minutes
(B) 57 minutes
(C) 76 minutes
(D) 152 minutes
(E) 190 minutes

50. Which of the following acids can be oxidized to form a stronger acid?

(A) H_3PO_4
(B) HNO_3
(C) H_2CO_3
(D) H_3BO_3
(E) H_2SO_3

51. $4\ HCl(g) + O_2(g) \rightleftarrows 2\ Cl_2(g) + 2\ H_2O(g)$

Equal numbers of moles of HCl and O_2 in a closed system are allowed to reach equilibrium as represented by the equation above. Which of the following must be true at equilibrium?

I. [HCl] must be less than $[Cl_2]$.
II. $[O_2]$ must be greater than [HCl].
III. $[Cl_2]$ must equal $[H_2O]$.

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

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52. When dilute nitric acid was added to a solution of one of the following chemicals, a gas was evolved. This gas turned a drop of limewater, $Ca(OH)_2$, cloudy, due to the formation of a white precipitate. The chemical was

(A) household ammonia, NH_3
(B) baking soda, $NaHCO_3$
(C) table salt, NaCl
(D) epsom salts, $MgSO_4 \cdot 7H_2O$
(E) bleach, 5% NaOCl

53. If 87 grams of K_2SO_4 (molar mass 174 grams) is dissolved in enough water to make 250 milliliters of solution, what are the concentrations of the potassium and the sulfate ions?

	$[K^+]$	$[SO_4^{2-}]$
(A)	0.020 *M*	0.020 *M*
(B)	1.0 *M*	2.0 *M*
(C)	2.0 *M*	1.0 *M*
(D)	2.0 *M*	2.0 *M*
(E)	4.0 *M*	2.0 *M*

54. All of the following statements concerning the characteristics of the halogens are true EXCEPT:

(A) The first ionization energies (potentials) decrease as the atomic numbers of the halogens increase.
(B) Fluorine is the best oxidizing agent.
(C) Fluorine atoms have the smallest radii.
(D) Iodine liberates free bromine from a solution of bromide ion.
(E) Fluorine is the most electronegative of the halogens.

55. What volume of 0.150-molar HCl is required to neutralize 25.0 milliliters of 0.120-molar $Ba(OH)_2$?

(A) 20.0 mL
(B) 30.0 mL
(C) 40.0 mL
(D) 60.0 mL
(E) 80.0 mL

56. It is suggested that SO_2 (molar mass 64 grams), which contributes to acid rain, could be removed from a stream of waste gases by bubbling the gases through 0.25-molar KOH, thereby producing K_2SO_3. What is the maximum mass of SO_2 that could be removed by 1,000. liters of the KOH solution?

(A) 4.0 kg
(B) 8.0 kg
(C) 16 kg
(D) 20. kg
(E) 40. kg

57. Molecules that have planar configurations include which of the following?

I. BCl_3
II. $CHCl_3$
III. NCl_3

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

58. $$N_2(g) + 3\ H_2(g) \rightarrow 2\ NH_3(g)$$

The reaction indicated above is thermodynamically spontaneous at 298 K, but becomes nonspontaneous at higher temperatures. Which of the following is true at 298 K ?

(A) ΔG, ΔH, and ΔS are all positive.
(B) ΔG, ΔH, and ΔS are all negative.
(C) ΔG and ΔH are negative, but ΔS is positive.
(D) ΔG and ΔS are negative, but ΔH is positive.
(E) ΔG and ΔH are positive, but ΔS is negative.

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59. When a 1.00-gram sample of limestone was dissolved in acid, 0.38 gram of CO_2 was generated. If the rock contained no carbonate other than $CaCO_3$, what was the percent of $CaCO_3$ by mass in the limestone?

(A) 17%
(B) 51%
(C) 64%
(D) 86%
(E) 100%

60. $$I_2(g) + 3\ Cl_2(g) \rightarrow 2\ ICl_3(g)$$

According to the data in the table below, what is the value of $\Delta H°$ for the reaction represented above?

Bond	Average Bond Energy (kilojoules/mole)
I—I	149
Cl—Cl	239
I—Cl	208

(A) −860 kJ
(B) −382 kJ
(C) +180 kJ
(D) +450 kJ
(E) +1,248 kJ

61. A 1-molar solution of which of the following salts has the highest pH ?

(A) $NaNO_3$
(B) Na_2CO_3
(C) NH_4Cl
(D) $NaHSO_4$
(E) Na_2SO_4

62. The electron-dot structure (Lewis structure) for which of the following molecules would have two unshared pairs of electrons on the central atom?

(A) H_2S
(B) NH_3
(C) CH_4
(D) HCN
(E) CO_2

63. What is the maximum mass of copper that could be plated out by electrolyzing aqueous $CuCl_2$ for 16.0 hours at a constant current of 3.00 amperes? (1 faraday = 96,500 coulombs)

(A) 28 grams
(B) 57 grams
(C) 64 grams
(D) 114 grams
(E) 128 grams

64. At 25° C, a sample of NH_3 (molar mass 17 grams) effuses at the rate of 0.050 mole per minute. Under the same conditions, which of the following gases effuses at approximately one-half that rate?

(A) O_2 (molar mass 32 grams)
(B) He (molar mass 4.0 grams)
(C) CO_2 (molar mass 44 grams)
(D) Cl_2 (molar mass 71 grams)
(E) CH_4 (molar mass 16 grams)

65. Barium sulfate is LEAST soluble in a 0.01-molar solution of which of the following?

(A) $Al_2(SO_4)_3$
(B) $(NH_4)_2SO_4$
(C) Na_2SO_4
(D) NH_3
(E) $BaCl_2$

66. What is the pH of a 1.0×10^{-2}-molar solution of HCN ? (For HCN, $K_a = 4.0 \times 10^{-10}$.)

(A) 10
(B) Between 7 and 10
(C) 7
(D) Between 4 and 7
(E) 4

GO ON TO THE NEXT PAGE

67. Substances X and Y that were in a solution were separated in the laboratory using the technique of fractional crystallization. This fractional crystallization is possible because substances X and Y have different

(A) boiling points
(B) melting points
(C) densities
(D) crystal colors
(E) solubilities

68. Which of the following molecules has a dipole moment of zero?

(A) C_6H_6 (benzene)
(B) NO
(C) SO_2
(D) NH_3
(E) H_2S

69. Correct procedures for a titration include which of the following?

I. Draining a pipet by touching the tip to the side of the container used for the titration
II. Rinsing the buret with distilled water just before filling it with the liquid to be titrated
III. Swirling the solution frequently during the titration

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

70. To determine the molar mass of a solid monoprotic acid, a student titrated a weighed sample of the acid with standardized aqueous NaOH. Which of the following could explain why the student obtained a molar mass that was too large?

I. Failure to rinse all acid from the weighing paper into the titration vessel
II. Addition of more water than was needed to dissolve the acid
III. Addition of some base beyond the equivalence point

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

71. $\ldots Fe(OH)_2 + \ldots O_2 + \ldots H_2O \rightarrow \ldots Fe(OH)_3$

If 1 mole of O_2 oxidizes $Fe(OH)_2$ according to the reaction represented above, how many moles of $Fe(OH)_3$ can be formed?

(A) 2
(B) 3
(C) 4
(D) 5
(E) 6

GO ON TO THE NEXT PAGE

72. The nuclide $^{249}_{96}Cm$ is radioactive and decays by the loss of one beta (β^-) particle. The product nuclide is

(A) $^{245}_{94}Pu$

(B) $^{245}_{95}Am$

(C) $^{248}_{96}Cm$

(D) $^{250}_{96}Cm$

(E) $^{249}_{97}Bk$

73. $$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$$

When 0.40 mole of SO_2 and 0.60 mole of O_2 are placed in an evacuated 1.00-liter flask, the reaction represented above occurs. After the reactants and the product reach equilibrium and the initial temperature is restored, the flask is found to contain 0.30 mole of SO_3. Based on these results, the equilibrium constant, K_c, for the reaction is

(A) 20.
(B) 10.
(C) 6.7
(D) 2.0
(E) 1.2

74. A solution of calcium hypochlorite, a common additive to swimming-pool water, is

(A) basic because of the hydrolysis of the OCl^- ion
(B) basic because $Ca(OH)_2$ is a weak and insoluble base
(C) neutral if the concentration is kept below 0.1 molar
(D) acidic because of the hydrolysis of the Ca^{2+} ions
(E) acidic because the acid HOCl is formed

75. A direct-current power supply of low voltage (less than 10 volts) has lost the markings that indicate which output terminal is positive and which is negative. A chemist suggests that the power supply terminals be connected to a pair of platinum electrodes that dip into 0.1-molar KI solution. Which of the following correctly identifies the polarities of the power supply terminals?

(A) A gas will be evolved only at the positive electrode.
(B) A gas will be evolved only at the negative electrode.
(C) A brown color will appear in the solution near the negative electrode.
(D) A metal will be deposited on the positive electrode.
(E) None of the methods above will identify the polarities of the power supply terminals.

STOP

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.

Chapter III

Answers (AP Chemistry 1994)

■ SECTION I: MULTIPLE-CHOICE

Listed below are the correct answers to the multiple-choice questions and the percentage of candidates who attempted each question and answered it correctly. As a general rule, candidates who correctly answered an individual question in this section also achieved a higher mean score on the test as a whole than candidates who did not answer that question correctly. An answer sheet gridded with the correct responses appears on the next page.

Section I Answer Key and Percent Answering Correctly

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

AP* Chemistry: 1994 Released Multiple Choice Exam
Answer Section

OTHER

1. ANS:

   C

   Paramagnetic is code for the presence of “unpaired electrons”. The unpaired electrons allow for temporary magnetization of substances.

   Hund's rule (principle of maximum multiplicity) states that when there is a choice of occupation of orbitals of the same energy, the electrons occupy those orbitals so as to maximize the number of electrons with parallel spin (which minimizes electron-electron repulsions).

   DIF: Hard TOP: Atomic Theory MSC: 1999 #1
   NOT: 32% answered correctly
2. ANS:

   E

   Electrons are particles that can behave as waves. The wave nature of matter deals with the fact that electromagnetic radiation, including light, was once thought to be entirely wavelike, but was found to have certain characteristics of particulate matter. That was extrapolated to photons and subatomic particles.

   DIF: Hard TOP: Atomic Theory MSC: 1994 #2
   NOT: 38% answered correctly
3. ANS:

   B

   Pauli exclusion principle states that no two electrons in an atom can have the same quantum numbers. This requires that electrons within the same orbital have opposite spins.

   DIF: Medium TOP: Atomic Theory MSC: 1994 #3
   NOT: 44% answered correctly
4. ANS:

   A

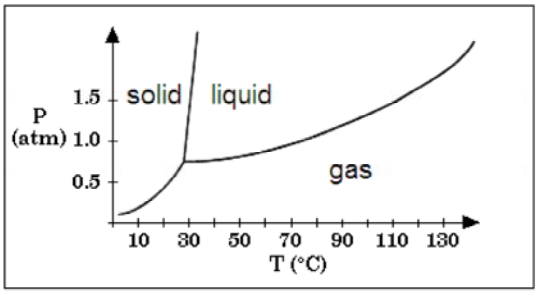
   Heisenberg uncertainty principle is the idea that the exact position and momentum of a particle cannot be precisely determined at the same time. Only the probability of its location at a certain time can be predicted.

   DIF: Easy TOP: Atomic Theory MSC: 1994 #4
   NOT: 82% answered correctly

5. ANS:

   A

   Hopefully, you were able to fill in the missing labels and figure out that the transition at 0.4 atm is from solid to gas which is sublimation.

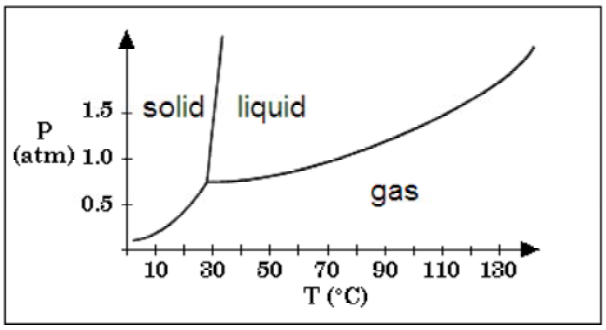


   DIF: Easy TOP: States of Matter MSC: 1994 #5
   NOT: 73% answered correctly

6. ANS:

   B

   At a pressure of 1.1 atm, the substance condenses from gas to liquid over the stated temperature range. As the molecules are cooled, they slow down which enhances the effect of their attractive IMFs.

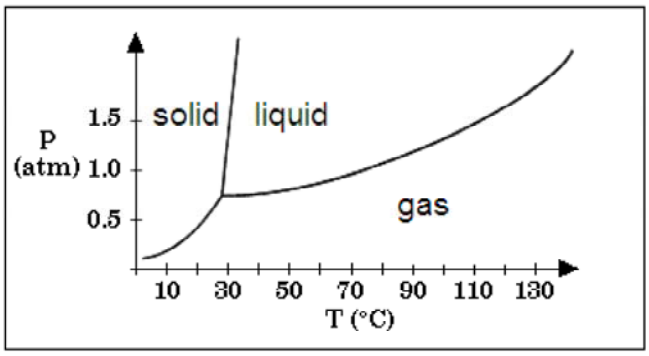


   DIF: Easy TOP: States of Matter MSC: 1994 #6
   NOT: 74% answered correctly

7. ANS:

   B

   Condensation occurs as the pressure is increased at 50°C. The added pressure forces gas molecules together which enhances their IMFs and they are brought closer together.



   DIF: Easy TOP: States of Matter MSC: 1994 #7
   NOT: 66% answered correctly

8. ANS:

   C

   Li_2 and B_2 are not usually found in nature. Diatomic halogens are singly bound, oxygen has a double bond, and nitrogen has a triple bond. Therefore it requires the most energy to break the triple bond of nitrogen.

   DIF: Hard TOP: Bonding & Molecular Structure MSC: 1994 #8
   NOT: 21% answered correctly

9. ANS:

   D

   A bond order of 2 is code for “has a double bond”, so that would be oxygen.

   Li_2 and B_2 are not usually found in nature. Diatomic halogens are singly bound, oxygen has a double bond, and nitrogen has a triple bond. Therefore it requires the most energy to break the triple bond of nitrogen.

   DIF: Medium TOP: Bonding & Molecular Structure MSC: 1994 #9
   NOT: 47% answered correctly

10. ANS:

    C

    Every single bond as well as one of the bonds of a multiple bond is sigma. It’s the 2nd and/or 3rd bond of a multiple bond that is/are the pi bond(s). Therefore nitrogen has 3 bonds, one sigma and two pi. Oxygen has one sigma and one pi and all the other listed only have single, sigma bonds.

    DIF: Medium TOP: Bonding & Molecular Structure MSC: 1994 #10
    NOT: 57% answered correctly

11. ANS:

C

Iron corrodes easily and is a prime component of steel. Coating iron with zinc stops the corrosion. The process is called galvanizing. Zinc is a more active metal, so any oxidation that occurs dissolves zinc rather than iron. The zinc oxide coating that forms provides further protection.

Both Alcatraz and the Statue of Liberty have suffered substantial damage as a result of this corrosion. The process was developed in 1742 but took quite a while to become an industry standard.

DIF: Medium TOP: Descriptive MSC: 1994 #11 NOT: 52% answered correctly

12. ANS:

D

Semiconductor materials are insulators at absolute zero temperature that conduct electricity in a limited way at room temperature. The defining property of a semiconductor material is that it can be doped with impurities that alter its electronic properties in a controllable way. Common metals used for doping are Ga, Ge, In, and As. These metals make semiconductor disposal a health concern.

DIF: Hard TOP: Descriptive MSC: 1994 #12 NOT: 21% answered correctly

13. ANS:

A

Alpha particles are essentially a helium nucleus and can be stopped with clothing or a sheet of paper. Beta are smaller and are essentially an electron (can be positively charged and called a positron) and require thin sheets of metal or plastic to stop them. Gamma radiation is a wave with no mass and no charge and much more difficult to stop! It takes thick sheets of lead or concrete to stop them.

It's why you wear a lead apron to have a dental X-ray, although X-rays are NOT gamma radiation, a thin sheet of lead effectively stops them.

DIF: Easy TOP: Descriptive MSC: 1994 #13 NOT: 78% answered correctly

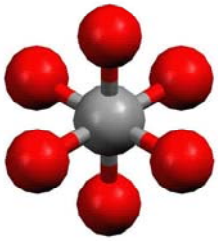
MULTIPLE CHOICE

14. ANS: C
Adding a solute, whether molecular or ionic lowers the freezing point of an aqueous solution.

DIF: Medium TOP: Solutions MSC: 1994 #14 NOT: 46% answered correctly

15. ANS: E

If the central atom exhibits sp^3d^2 hybridization, that's 6 sites of electron density (*spppdd*--6 "letters", 6 sites) so the molecular geometry is that of an octahedron.



DIF: Medium TOP: Bonding & Molecular Structure MSC: 1994 #15
NOT: 59% answered correctly

16. ANS: B

Expect easy math! Since NaOH and the monoprotic acid $HC_2H_3O_2$ are involved you can use the shortcut formula for neutralization and solve for M_a.

$$M_a V_a = M_b V_b$$

$$\therefore M_a = \frac{M_b V_b}{V_a} = \frac{32 \times 0.5}{20} = \frac{16}{20} = \frac{8}{10} = 0.8\,M$$

DIF: Easy TOP: Acid-Base MSC: 1994 #16 NOT: 69% answered correctly

17. ANS: D

The rate of a chemical reaction depends on many factors, but most importantly molecules or atoms must collide with effective geometry and sufficient energy to break bonds.

The presence of a catalyst would speed up a reaction, not slow it down. High temperature would increase the speed of the molecules making their collisions more energetic, thus speeding up the reaction. High concentrations make for more frequent collisions, thus speeding up the formation of products. Low activation energy makes reactions faster, not slower.

DIF: Easy TOP: Kinetics MSC: 1994 Q#17 NOT: 82% answered correctly

18. ANS: E

An oxidizing agent is itself reduced and it must be a reactant. Therefore, the permanganate ion is the oxidizing agent. The chlorite ion is the reducing agent since it is oxidized.

DIF: Easy TOP: Chemical Reactions MSC: 1994 Q#18
NOT: 62% answered correctly

19. ANS: B

The molar mass of Cr is 52 g/mol. For CrO_3 the ratio is 52:48, which is closer to 1:1. For CrO_2, the ratio is 52:32 which is our winner!

For CrO the ratio is 52 : 16 which is about 4:1, for Cr_2O the ratio is 104: 16 which is way off and for Cr_2O_3 the ratio is 104: 48 which is closer to 2:1.

DIF: Easy TOP: Stoichiometry MSC: 1994 #19
NOT: 83% answered correctly

20. ANS: D

It's easiest to remove the water and OH^- from the original equation and balance each half-reaction in acidic media, then neutralize any excess H^+ ions and finally, cancel any waters.

Red: $6(Ag^+ + e^- \rightarrow Ag^0)$

Ox: $AsH_3 + 3\,H_2O \rightarrow H_3AsO_3 + 6H^+ + 6\,e^-$

Sum: $6\,Ag^+ + AsH_3 + 3\,H_2O \rightarrow H_3AsO_3 + 6\,H^+ + 6\,Ag^0$ in *acidic* solution, so neutralize!

$+ 6\,OH^-$ $+ 6\,OH^-$ (add 6 hydroxides to EACH side)

Forming 6 waters on the right ($6\,H^+ + 6\,OH^- = 6$ waters)

Therefore, 3 waters on left cancel leaving 3 waters on the right)

Final: $6\,Ag^+ + AsH_3 + + 6\,OH^- \rightarrow H_3AsO_3 + 3\,H_2O + 6\,Ag^0$

DIF: Medium TOP: Chemical Reactions MSC: 1994 Q#20
NOT: 58% answered correctly

21. ANS: D

Alpha particles are a helium nucleus, ${}_2^4\text{He}$ or ${}_2^4\alpha$, and are the largest of the nuclear particles, thus easiest to shield.

Beta particles are equivalent to an electron and gamma waves are not particulate in nature.

DIF: Medium TOP: Nuclear MSC: 1994 #21 NOT: 58% answered correctly

22. ANS: E

Bases "accept" a hydrogen ion [or donate an electron pair--Lewis], so in the forward reaction, H_2O reacts to produce H_3O^+. In the reverse reaction, SO_4^{2-} reacts to form HSO_4^-.

DIF: Medium TOP: Acid-Base MSC: 1994 #22 NOT: 62% answered correctly

23. ANS: B

Cross off catalysts and intermediates and sum the steps.

Step 1: $Ce^{4+} + \cancel{Mn^{2+}} \rightarrow Ce^{3+} + \cancel{Mn^{3+}}$

Step 2: $Ce^{4+} + \cancel{Mn^{3+}} \rightarrow Ce^{3+} + \cancel{Mn^{4+}}$

Step 3: $\cancel{Mn^{4+}} + Tl^+ \rightarrow Tl^{3+} + \cancel{Mn^{2+}}$

Overall Reaction: $2\,Ce^{4+} + Tl^+ \rightarrow Tl^{3+} + 2\,Ce^{3+}$

DIF: Easy TOP: Kinetics MSC: 1994 Q#23 NOT: 71% answered correctly

24. ANS: C

Expect easy math! Volume is held constant, so use Gay-Lussac's Law to solve for P_2.

$P_1T_2 = P_2T_1$

$$P_2 = \frac{P_1T_2}{T_1} = \frac{(0.80\text{ atm})(300\text{ K})}{400\text{ K}} = 0.80\left(\frac{3}{4}\right) = 0.60\text{ atm}$$

DIF: Easy TOP: Gas Laws MSC: 1994 #24 NOT: 76% answered correctly

25. ANS: D

You should recognize each of the three reactions as formation reactions. Thus, Hess's Law is applied and $\Delta H°= 2z – [x + y]$ which is equivalent to answer (D) once the negative sign is distributed across the terms within the bracket.

DIF: Medium TOP: Thermochemistry MSC: 1994 #25
NOT: 63% answered correctly

26. ANS: C

It's an open container, so you can't change the pressure easily. Changing the volume of the open container or the amount of liquid in the open container will not affect the boiling point, it will just affect the time it takes to boil.

Changing altitude will affect the boiling point. A substance boils when its vapor pressure is equal to the atmospheric pressure. Higher altitudes have lower atmospheric pressures, so as heat energy is added to the system, the vapor pressure of the pure liquid will equal the atmospheric pressure at a lower temperature.

DIF: Medium TOP: States of Matter MSC: 1994 #26
NOT: 61% answered correctly

27. ANS: C

Gallium has a valence electron configuration of $4s^2 4p^1$. So it is the 4*p* electron that has the highest energy. For that electron, $n = 4$, $\ell = 1$, thus $m_\ell = 1$ (or –1, but not both!) and m_s can be either a +½ or a –½.

DIF: Medium TOP: Atomic Theory MSC: 1994 #27
NOT: 48% answered correctly

28. ANS: E

$M = \dfrac{\text{moles of solute}}{\text{liters of solution}}$, so the molar mass of sucrose is needed in order to calculate the number of moles of solute. If we have mass percent, then we can figure the mass of the entire solution, but we need the density to obtain the volume of the solution. While the density of the solution may be close to water, it isn't exactly the same as that of pure water.

DIF: Medium TOP: Solutions MSC: 1994 #28 NOT: 58% answered correctly

29. ANS: A

There just a series of "stuff" to memorize to get redox reactions correct. These are summarized in your net ionic equation notes. In basic media, dichromate ion is oxidized to chromate ion while in acid media, dichromate is oxidized to Cr^{3+} ion.

DIF: Hard TOP: Chemical Reactions MSC: 1994 Q#29
NOT: 36% answered correctly

30. ANS: D

A catalyst lowers the activation energy [top of the "hump"] thus it lowers any measurement that includes that portion of the graph, so I and II are affected by the presence of a catalyst.

DIF: Medium TOP: Thermodynamics MSC: 1994 #30
NOT: 55% answered correctly

31. ANS: C

$H_2C_2O_4$, $+ H_2O \leftrightarrows H_3O^+ + HC_2O_4^-$ $\quad K_1 = 5 \times 10^{-2}$

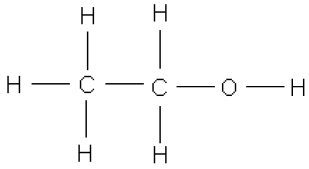
$HC_2O_4^- + H_2O \leftrightarrows H_3O^+ + C_2O_4^{2-}$ $\quad K_2 = 5 \times 10^{-5}$

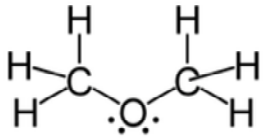
The reaction given is the sum of these two reactions. When summing reactions, their *K* values are *multiplied*. So the quotient is 25×10^{-7} or 2.5×10^{-6}.

DIF: Hard TOP: Equilibrium MSC: 1994 #31 NOT: 39% answered correctly

32. ANS: D

Structural isomers have the same number of atoms, but a different arrangement of those atoms. The VP, BP, MP and ΔH_{vap} all depend on IMFs. Examine the structure of the two isomers: ethanol (2 lone pairs missing from O in the diagram) vs. dimethylether





Since ethanol has *a* hydrogen atom (as opposed to all of them!) bound to a "highly electronegative" atom (F, N or O--in this case O), it can exhibit hydrogen bonding which is a special case of dipole-dipole IMFs. Dimethylether has no hydrogens bound to a highly electronegative atom, thus it cannot hydrogen bond and its only IMF is the much weaker induced dipole-induced dipole force (also called London dispersion forces). Dispersion forces are much weaker, so dimethylether has a much lower VP, BP, MP and ΔH_{vap} since less energy is required to separate molecules since they are less attracted to each other than those of ethanol.

DIF: Easy TOP: IMFs MSC: 1994 #32 NOT: 77% answered correctly

33. ANS: C

Expect easy math and estimate!

A gas's density at STP is calculated using this formula : $density = \dfrac{MM}{22.4\ \mathrm{L/mol}}$ so, MM = ($density$ × 22.4 L/mol) = (about 2 g/L × 22.4 L/mol) = about 45ish g/mol, so C_3H_6 is the best answer choice.

DIF: Medium TOP: Stoichiometry MSC: 1994 #33
NOT: 52% answered correctly

34. ANS: E

The pure hydrocarbon butane *X*, is the least polar, thus has the lowest solubility in water. The presence of an –OH group on butanol *Y*, makes it more soluble than butane, but less soluble than the 1,3-propanediol *Z*, that contains two –OH groups. Aren't you glad you don't have to name all of them?

DIF: Hard TOP: IMFs MSC: 1994 #34 NOT: 39% answered correctly

35. ANS: D

A negative ΔS value implies a decrease in disorder, therefore a more ordered product or set of products is/are formed. Look for reactions that produce more condensed states and/or fewer moles of product.

I. 2 moles solid $\rightarrow$ 4 moles solid...therefore, more disorder... + 3 moles gas...again, more disorder

II. 3 moles of ions $\rightarrow$ 1 mole of solid...far more ordered

III. 2 moles of gas $\rightarrow$ 1 mole of gas...more ordered even though all are gases

DIF: Medium TOP: Thermodynamics MSC: 1994 Q#35
NOT: 54% answered correctly

36. ANS: C

The Nernst equation is:

$E = E^0 - \frac{0.0592}{n} \log Q$ AND

$Q = \frac{\left[\mathrm{Zn}^{2+}\right]}{\left[\mathrm{Cu}^{2+}\right]}$

The voltage decreased which means the term subtracted in the Nernst equation was positive, so the log of Q was positive, therefore the Q expression must have been a number greater than 1.0 which indicates that the concentration of the zinc solution was greater than the concentration of the copper(II) solution.

DIF: Medium TOP: Electrochemistry MSC: 1994 Q#36
NOT: 46% answered correctly

37. ANS: D

$PV = nRT \therefore n = \frac{PV}{RT} = \frac{g}{MM} \therefore \frac{MM}{g} = \frac{RT}{PV} \therefore MM = \frac{gRT}{PV} = \frac{[(3.0)(0.08)(400)]}{[(1.0)(1.5)]}$

DIF: Easy TOP: Gas Laws MSC: 1994 #37 NOT: 81% answered correctly

38. ANS: C

If you have not used a spectrophotometer or a virtual spectrophotometer, you are at a disadvantage on this laboratory question. The instrument will report accurate values of absorbance or transmittance if the cuvette is clean (void of fingerprints), there is enough sample in the cuvette to cover the light path, the machine is properly calibrated with a blank containing pure solvent, and zeroed periodically. It is also imperative that the wavelength be set properly.

DIF: Medium TOP: Lab MSC: 1994 #38 NOT: 41% answered correctly

39. ANS: C
Expect easy math!

Rxn:	F_2 +	Xe →	Xe_xF_y
Initial:	8.0 atm	1.7 atm	0
After:	4.6 atm*	0	

So 3.4 atm of F_2 reacted AND 1.7 atm of the Xe reacted which is a 2 F_2 : 1 Xe ratio which is equivalent to a 4 F : 1 Xe ratio or XeF_4

DIF: Hard TOP: Gas Laws MSC: 1994 #39 NOT: 38% answered correctly

40. ANS: C
The pressure of the wet oxygen (O_2 + H_2O vapor) is equal to 161 mm Hg. So, the pressure of just the oxygen is (161 – 28) mm Hg = 133 mm Hg

DIF: Easy TOP: Gas Laws MSC: 1994 #40 NOT: 67% answered correctly

41. ANS: D
Answer (A) is weak--its true, but nothing presented in the scenario leads you to that conclusion. Answer (B) where did the chloride part come from? Not valid. Answer (C) hydrogen gas is not brown. Not valid. Answer (E) no evidence of a 1:3 mole ratio was observed.

Nitric acid is the "oxidizing acid" and readily dissolves most metals. If the metal is a transition metal with unpaired *d*-electrons, the remaining ionic solution is often colored. The brown gas is NO_2 and is highly toxic and quite choking. If you've never heard the account of Ira Remsen's (discovered saccharin) encounter with a penny, you should! Check out this link: http://www.eagan.k12.mn.us/fletcher/acn/flash/nitric_copper.html

DIF: Medium TOP: Lab MSC: 1994 #41 NOT: 58% answered correctly

42. ANS: D
Expect easy math! This question is also about sig. figs. A simple subtraction yields a mass value of 22.0 grams (respect least number of decimal places for sig. figs. in addition and subtraction) and the volume is given, so the density is "two" g/cm^3. Since both the mass number and the volume number have 3 SF, the answer of "two" should also have 3 SF.

DIF: Hard TOP: Lab MSC: 1994 #42 NOT: 39% answered correctly

43. ANS: A
Structural isomers have the same number of atoms, but a different arrangement of those atoms. Count the Cs, Os and Hs in each compound. Also note that isomers can have different properties.

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1994 #43
NOT: 55% answered correctly

44. ANS: E
The freezing point depression is calculated using the formula $\Delta T_f = K_f m i$, where i is the van't Hoff factor (1st chemist to ever win a Nobel prize, 1901) and indicates the number of moles of charged particles in solution. Since all the solutions have the same concentration, the value of i becomes most important. Glucose has an i of 1, NH_4Br has an i of 2, $ZnSO_4$ has an i of 2, $KMnO_4$ has an i of 2, and $MgCl_2$ has an i of 3.

DIF: Hard TOP: Solutions MSC: 1994 #44 NOT: 31% answered correctly

45. ANS: C
When a gas cools at constant volume, the KE_{ave} (velocity) and the pressure decrease. The molecular mass is the molar mass that certainly won't change. The distance between the gas molecules won't change since the gas still expands to fill its container.

DIF: Medium TOP: Gas Laws MSC: 1994 #45 NOT: 44% answered correctly

46. ANS: E
All chlorides are soluble *except* silver, mercury and lead--so all the solids listed are soluble. Solutions of metal ions with *unpaired d*-electrons have color. Zinc is $4s^2\ 3d^{10}$ thus colorless in solution. Solutions of Cr^{3+} are violet, Fe^{3+} are a dull orange, Co^{2+} are purple and Cu^{2+} are blue (Cu^{+} are green).

DIF: Medium TOP: Descriptive MSC: 1994 #46 NOT: 46% answered correctly

47. ANS: D
Electrolytes are solutions that contain charged and mobile ions. The more charged ions present (either concentration or variety), the better the conduction. Since all of these solutions are 0.1 *M*, the solution that conducts best is $BaCl_2$, and the one that conducts least is HF since it is a weak acid and does not dissociate much into H^+ and Cl^- ions.

DIF: Hard TOP: Solutions MSC: 1994 #47 NOT: 38% answered correctly

48. ANS: A
PCl_5 is a product, so removing energy (cooling) or adding more of either reactant would cause more product to form. Since there are 2 moles of gas on the left vs. 1 mole on the right, increasing the pressure (decreasing the volume increases the pressure) will also produce more product. Adding an inert gas has no effect on the equilibrium.

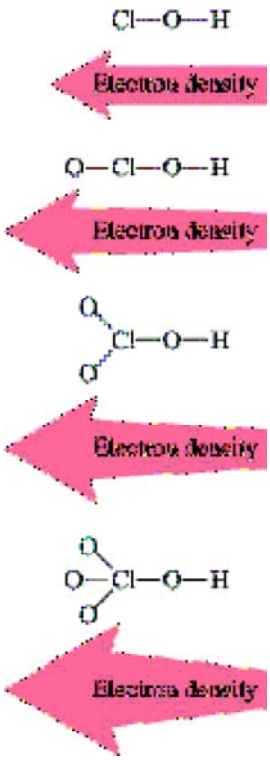
DIF: Hard TOP: Equilibrium MSC: 1994 #48 NOT: 35% answered correctly

49. ANS: B
Resist the urge to use the kinetics math with this one. It's much faster to just think about how many half-lives are needed to get the job done and how much time that takes. It will also be faster if you round 19 minutes to 20 minutes.

$1.0 \xrightarrow{20\,\text{min}} 0.5 \xrightarrow{20\,\text{min}} 0.25 \xrightarrow{20\,\text{min}} 0.125$, so about 60 minutes.

DIF: Medium TOP: Kinetics MSC: 1994 #49 NOT: 49% answered correctly

50. ANS: E
Oxidized, in this case, literally means “add an oxygen”. The trend is “the more oxygen present in an oxyacid, the stronger the acid”, but that’s not an *explanation*. Note that the H that is to be ionized is bonded to an oxygen which is highly electronegative. IF you add even more oxygens, they reside opposite the oxygen, so that the O–H bond becomes even more polarized and it requires less and less energy to remove the hydrogen, making the acids stronger and stronger. So, H_2SO_3 can be oxidized to form H_2SO_4.



DIF: Medium TOP: Acid-Base MSC: 1994 #50 NOT: 58% answered correctly

51. ANS: D
A quick RICE table will help:

R	$4\ HCl(g) + O_2(g) \leftrightarrows 2\ Cl_2(g) + 2\ H_2O(g)$			
I	equal # of moles		0	0
C	$-4x$	$-x$	$+2x$	$+2x$
E				

Notice:
We don’t have enough information to determine whether I is true or not.
We do know that 4 times as many moles of HCl react compared to oxygen and they started out equal, so $[O_2]$ must be greater than [HCl], so II is true. Since both Cl_2 and H_2O have the same coefficient thus $2x$ moles will be formed of each, III is also true.

DIF: Hard TOP: Equilibrium MSC: 1994 #51 NOT: 29% answered correctly

52. ANS: B
When acid is added to ammonia, ammonium nitrate forms and is very soluble and would not form a ppt with $Ca(OH)_2$.
When acid is added to sodium bicarbonate, carbonic acid forms which decomposes to carbon dioxide (bubbles produced) and water. If the resulting solution is mixed with $Ca(OH)_2$, a precipitate of $CaCO_3$ would form.
When acid is added to table salt, no gas is formed.
When acid is added to epsom salts, no gas is formed.
When acid is added to bleach, chlorine gas (green) is formed (a really bad idea!), but when $Ca(OH)_2$ is added, no precipitate forms since $CaCl_2$ is soluble.

DIF: Hard TOP: Lab MSC: 1994 #52 NOT: 29% answered correctly

53. ANS: E
Expect easy math! 87 g is ½ of a mole and it is dissolved in ¼ of a liter, so the original concentration is 2.0 *M*. Since 2 K^+ ions are in solution...double that to 4.0 *M* for potassium while sulfate remains 2.0 *M*.

DIF: Medium TOP: Solutions MSC: 1994 #53 NOT: 55% answered correctly

54. ANS: D
The halogens sit on the periodic table in their own activity series. F being the most active (Go, figure!) First ionization energies decrease down any family on the periodic table--the valence electrons are farther from the nucleus, thus less tightly held. F is most active and most likely to be reduced (oxidizing agents are themselves reduced). F is the smallest and the most electronegative of the family. F is the most electronegative element, period!

DIF: Medium TOP: Atomic Theory MSC: 1994 #54
NOT: 43% answered correctly

55. ANS: C
Expect easy math! But, be careful since $Ba(OH)_2$ releases 2 OH^- ions. You can use the shortcut formula for neutralization and solve for V_a BUT, the amount of base should be doubled since each $Ba(OH)_2$ releases 2** OH^- ions.

$$M_a V_a = M_b V_b$$

$$\therefore V_a = \frac{M_b V_b}{M_a} = \frac{2^{**}(25 \times 0.12)}{0.15} = 50\left(\frac{4}{5}\right) = \frac{200}{5} = 40\,\text{mL}$$

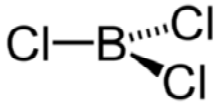
DIF: Hard TOP: Acid-Base MSC: 1994 #55 NOT: 35% answered correctly

56. ANS: B
You must write a *balanced* equation (water is the other product) and calculate the moles of KOH. Remember that molarity × liters = moles. No limiting reactant, but not as friendly math.

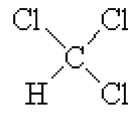
MM: (64 g/mol)				
SO_2	+ 2 KOH	→	+ K_2SO_3	+ H_2O
mole:mole 1	2		1	1
# moles If "2" = 250 mol, what's "1" equal? 125 mol, so convert to grams (125 mol)(64) = 8000 g or 8.0 kg	=(1,000 L)(0.25mol/L) = 250 mol			

DIF: Hard TOP: Stoichiometry MSC: 1994 #56
NOT: 35% answered correctly

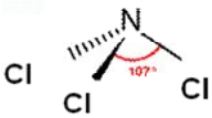
57. ANS: A
Draw the dang Lewis structures!



Boron trichloride



Chloroform



NCl_3
Trichloramine

trigonal planar tetrahedral the lone pair is not drawn here, trigonal pyramidal

DIF: Medium TOP: Bonding & Molecular Structure MSC: 1994 #57
NOT: 46% answered correctly

58. ANS: B
They told us the reaction is spontaneous at 298 K, so we know ΔG is negative.

If spontaneity changes with changing temperature, then go directly to $\Delta G = \Delta H - T\Delta S$. For the reaction to be spontaneous, ΔG must be negative so, ΔG is switching signs or becoming positive as the $T\Delta S$ term is increasing with increasing temperatures.

Examine the reaction, 4 moles of gas are converted to 2 moles of gas, a more ordered state, so we know that ΔS is negative, AND we know that T must be a positive term since it is a Kelvin temperature. That means the $T\Delta S$ term is a **negative** term, so when it is subtracted, it becomes a positive term...increasing the temperature increases the magnitude of the positive term which "overtakes" the negative ΔH term.

How do we know the ΔH term is negative? If it were positive, and we subtract the negative $T\Delta S$ term, we would *always* have a $+\Delta G$ and the reaction would *never* be spontaneous.

DIF: Hard TOP: Thermodynamics MSC: 1994 #58
NOT: 29% answered correctly

59. ANS: D
Expect easy math! The molar mass of calcium carbonate is a favorite among chemistry teachers since it equals 100 g/mol making percent comp questions easy. Think about the rxn:
$CaCO_3$ + acid $\rightarrow CO_2$ (all the carbon came from this carbonate, so moles CO_2 = moles $CaCO_3$)

$$\frac{0.44\,\text{g}\,CO_2}{44\,\text{g/mol}} = 0.01\,\text{mol}\ CO_2 \therefore\ 0.01\,\text{mol}\ CaCO_3 \therefore\ (0.01\,\text{mol C})\left(100\,\text{g/mol}\right) = 1.00\,\text{g}\,CaCO_3$$

So, percent composition of the limestone is $\frac{1.00\,\text{g}\,CaCO_3}{1.25\,\text{g limestone}} \times 100\% = 80\%$

DIF: Hard MSC: 1994 #59 NOT: 29% answered correctly

60. ANS: B
Energy is required to break bonds (cost), in other words, energy is absorbed. Energy is released (payoff) when bonds form.

Cost: 150 + 3(250 estimated) = 900 kJ/mol *absorbed*
Payoff: 2(3 I–Cl bonds) = 6 (200 estimated) = 1200 kJ/mol *released*

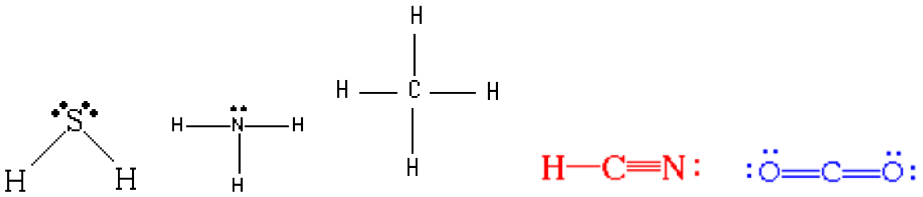
Result? More energy was released than absorbed, resulting in a *negative* (energy left the system) value for $\Delta H°$ *greater than* 300 kJ/mol, since we rounded down both times.

DIF: Medium TOP: Thermochemistry MSC: 1994 #60
NOT: 47% answered correctly

61. ANS: B
"Highest pH" indicates most basic. These are all salts, so recall that salts are produced when a acid reacts with a base. So, ask yourself, "Which acid reacted with which base?" If both are strong, the salt is neutral as in the case of $NaNO_3$, $NaHSO_4$, and Na_2SO_4. Na_2CO_3 is a basic salt since NaOH (strong base) reacted with carbonic acid (weak acid), strong wins...the salt is basic with a high pH. NH_4Cl is an acidic salt with a lower pH since a weak base reacted with a strong acid to form the ammonium chloride salt.

DIF: Hard TOP: Acid-Base MSC: 1994 #61 NOT: 21% answered correctly

62. ANS: A
Draw the dang Lewis structures!



DIF: Medium TOP: Bonding & Molecular Structure MSC: 1994 #62
NOT: 64% answered correctly

63. ANS: B
This is a giant dimensional analysis moment. Glance at the answers if you don't know where to start...they all begin with 16, so start with 16 hours. Remember that an amp is the rate of flow of charge and is equivalent to coulombs/sec:

$$16\,h \times \left(\frac{3600\,s}{h}\right) \times \left(\frac{3.0\,c}{s}\right) \times \left(\frac{63.55\,g\,Cu}{1\,mol\,Cu}\right) \times \left(\frac{1\,mol\,e^-}{96,500\,c}\right) \times \left(\frac{1\,mol\,Cu}{2\,mol\,e^-}\right)$$

DIF: Hard TOP: Electrochemistry MSC: 1994 #63
NOT: 24% answered correctly

64. ANS: D
Graham's Law of diffusion: reason that if a second molecule diffuses at half the rate of ammonia, then it is the heavy molecule and ammonia is the light one. Also half of ammonia's rate is 0.025.

$$\frac{\text{rate of light}}{\text{rate of heavy}} = \sqrt{\frac{MM_{heavy}}{MM_{light}}}$$

$$\frac{0.050}{0.025} = 2 = \sqrt{\frac{x}{17}} \text{ now, square both sides; } 4 = \frac{x}{17} \quad \therefore x = \text{ a bit less than } 80$$

DIF: Hard TOP: Gas Laws MSC: 1994 #64 NOT: 23% answered correctly

65. ANS: A
Peruse the answers...see any common ions? Yep, this is common ion effect, so think in terms of equilibrium. $BaSO_4(s) \leftrightarrows Ba^{2+} + SO_4^{2-}$ So adding either ion shifts the equilibrium LEFT meaning barium sulfate is less soluble. Aluminum sulfate releases 3 sulfate ions in solution, which is three times more sulfate than the other salts release!

DIF: Hard TOP: Equilibrium MSC: 1994 #65 NOT: 21% answered correctly

66. ANS: D
It's easy math, but a bit time consuming...
$HCN \leftrightarrows H^+ + CN^-$

$$K_a = \frac{[H^+][CN^-]}{[HCN]} = \frac{x^2}{0.01} = 4 \times 10^{-10}$$

$$\therefore x^2 = 4 \times 10^{-12} \ \therefore x = [H^+] = 2 \times 10^{-6}$$

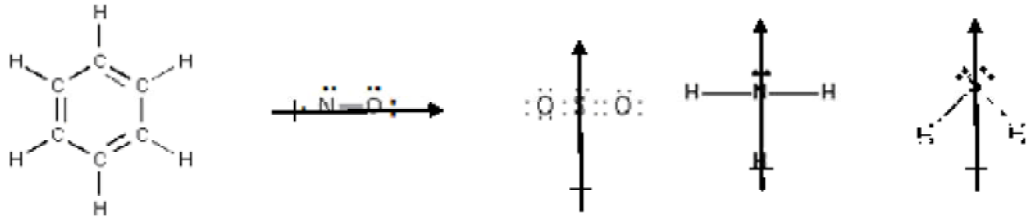
$$pH = -\log 2 \times 10^{-6} \text{ which is about 6ish}$$

DIF: Medium TOP: Acid-Base MSC: 1994 #66 NOT: 64% answered correctly

67. ANS: E
Fractional crystallization is a method of refining substances based on differences in solubility. If two or more substances are dissolved in a solvent, they will crystallize out of solution (precipitate) at different rates.

DIF: Hard TOP: Lab MSC: 1994 #67 NOT: 25% answered correctly

68. ANS: A
If you know benzene is a ring structure with alternating single and double bonds and extremely symmetrical and nonpolar, then it is the obvious choice. If not, then draw the dang Lewis structures and contemplate the dipole moments:



DIF: Medium TOP: Bonding & Molecular Structure MSC: 1994 #68
NOT: 41% answered correctly

69. ANS: C
Water adheres to glass more strongly that it itself, so the final drop will "jump" to the glass and can be washed down without changing the number of moles of the solution delivered from the pipette. If you rise the buret with water, it will "wet" the glass (water molecules cling to the glass) and those water molecules will dilute the solution placed into the buret. Mixing is always a good idea!

DIF: Hard TOP: Lab MSC: 1994 #69 NOT: 34% answered correctly

70. ANS: A

Don't lose sight of the big idea: moles acid = moles base at the equivalent point. If the student didn't transfer all the solid acid into the vessel, then fewer moles are actually present than recorded.

$MM = \frac{\text{g of acid}}{\text{mol of acid}}$, less base will be required, thus the number of moles of acid used in the calculation will be less which results in a larger denominator and a smaller overall number for the calculated *MM*.

Adding water to dissolve the acid will not affect the number of moles of acid present. Addition of base beyond the equivalence point will make the moles of base data point too large which, will make the calculated *MM* too small.

DIF: Hard TOP: Lab MSC: 1994 #70 NOT: 15% answered correctly

71. ANS: C

Red: $O_2 + 2\ H^+ + 4\ e^- \rightarrow 2\ OH^-$

Ox: $4(Fe^{2+} \rightarrow Fe^{3+} + e^-)$

Sum: $4\ Fe^{2+} + O_2 + 2\ H^+ \rightarrow 4\ Fe^{3+} + 2\ OH^-$ (I can quit there since balancing in basic won't affect the number of moles of Fe ions...for each mole of oxygen, there are 4 moles of iron hydroxides involved.)

DIF: Hard TOP: Chemical Reactions MSC: 1994 Q#71
NOT: 33% answered correctly

72. ANS: E

This is a transmutation reaction. It is essential to know that an alpha particle is akin to a helium nucleus, ${}^{4}_{2}\text{He}$, and that a beta particle is akin to an electron shot out of the nucleus, ${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$ (recall that a neutron consists of a proton plus an electron and a bit of binding energy--when the electron is emitted, there is one less neutron but one more proton). If you know that the rest is simple math since the law of conservation of mass must be obeyed.

${}^{249}_{96}\text{Cm} \rightarrow {}^{0}_{-1}\beta + {}^{?}_{?}X$

So, ${}^{?}_{?}X$ must be equal to ${}^{(249)}_{(96-(-1)}X = {}^{249}_{97}X$, so the element *X* has a mass of 249 and an atomic number of 97 which is Bk.

DIF: Medium TOP: Nuclear MSC: 1994 #72 NOT: 53% answered correctly

73. ANS: A

Note that you were told the equilibrium amount of SO_3. Use it to work out the entire equilibrium line of the RICE table.

R $2\ SO_2(g) + O_2(g) \leftrightarrows 2\ SO_3(g)$

I 0.40 0.60 0

C $-2x$ $-x$ $+2x$

E *0.10 *0.45 0.30 *so, $2x = 0.30$, so $x = 0.15$

$$K = \frac{[SO_3]^2}{[O_2][SO_2]^2} = \frac{[0.30]^2}{[0.45][0.10]^2}$$

DIF: Hard TOP: Equilibrium MSC: 1994 #73 NOT: 24% answered correctly

74. ANS: A

Calcium hypochlorite is a salt, therefore ask yourself which acid reacted with which base AND are those strong or weak? CaOH is a strong base (so, Ca^{2+} is a spectator --"strong -spectator--get it? both start with an "s") while hypochlorous acid is a weak acid, strong wins and the salt is basic as a result. A neutral salt results when a strong acid reacts with a strong base. The acid HOCl does form, but it is weak and doesn't release hydrogen ions.

The hydrolysis reaction of calcium hypochlorite is : $OCl^- + HOH \rightarrow HOCl + OH^-$

DIF: Hard MSC: 1994 #74 NOT: 34% answered correctly

75. ANS: B

"Direct power supply" is code for a battery. Placing a direct power supply or any power supply into a circuit creates an electrolytic cell. EPA is now relevant ("electrolytic positive anode") as well as AN OX and RED CAT. Contemplate the oxidation and reduction half-reactions: Recall that *alkali* metals are NEVER reduced...if they were, the metal would be formed and an explosion would be imminent! Rather, water is reduced in *alkali* media.

Red: $2\ H_2O \rightarrow 2OH^- + H_2(g) + 4\ e^-$

Ox: $2\ I^- + 2\ e^- \rightarrow I_2(s)$; since iodine is insoluble in water

Reduction occurs at the cathode [RED CAT] which is *negative* in an electrolytic cell, [EPA--positive anode] so oxygen gas is evolved at the cathode or negative terminal.

DIF: Hard TOP: Electrochemistry MSC: 1994 Q#75
NOT: 16% answered correctly