Practice Test 1 Answers

AP® CHEMISTRY
2001 SCORING GUIDELINES

Question 1

(10 points)

(a) (i) $AgCl(s) \rightarrow Ag^{+}(aq) + Cl^{-}(aq)$ — *1 point*

- Correct charges needed to earn credit.
- Phases not necessary to earn credit.

(ii) $\frac{8.9 \times 10^{-5}\ g}{143.32\ g/mol} = 6.2 \times 10^{-7}$ mol (in 100 mL) — *1 point*

$(6.2 \times 10^{-7}$ mol/100 mL) (1,000 mL/1.000 L) = $\mathbf{6.2 \times 10^{-6}}$ **mol/L** — *1 point*

Note: The first point is earned for the correct number of moles; the second point is earned for the conversion from moles to molarity.

(iii) $K_{sp} = [Ag^{+}][Cl^{-}] = (6.2 \times 10^{-6})^2 = \mathbf{3.8 \times 10^{-11}}$ — *1 point*

Note: Students earn one point for squaring their result for molarity in (a) (ii).

(b) (i) n_{Cl^-} = (0.060 L) (0.040 mol/L) = 0.0024 mol — *1 point*

$[Cl^{-}]$ = (0.0024 mol)/(0.120 L) = 0.020 mol/L = **0.020 *M***

$n_{Pb^{2+}}$ = (0.060 L) (0.030 mol/L) = 0.0018 mol

$[Pb^{2+}]$ = (0.0018 mol)/(0.120 L) = 0.015 mol/L = **0.015 *M***

$Q = [Pb^{2+}][Cl^{-}]^2 = (0.015)(0.020)^2 = \mathbf{6.0 \times 10^{-6}}$ — *1 point*

$Q < K_{sp}$, therefore no precipitate forms — *1 point*

Note: One point is earned for calculating the correct molarities; one point is earned for calculating Q; one point is earned for determining whether or not a precipitate will form.

(ii) $[Pb^{2+}] = \frac{K_{sp}}{[Cl^{-}]^2} = \frac{1.6 \times 10^{-5}}{(0.25)^2} = \mathbf{2.6 \times 10^{-4}\ \mathit{M}}$ — *1 point*

Question 1 (cont.)

(iii) for AgCl solution: $[Cl^-] = \dfrac{K_{sp}^{AgCl}}{[Ag^+]} = \dfrac{1.8 \times 10^{-10}}{0.120} = \mathbf{1.5 \times 10^{-9}}\ M$ — *1 point*

for $PbCl_2$ solution: $[Cl^-] = \sqrt{\dfrac{K_{sp}^{PbCl_2}}{[Pb^{2+}]}} = \sqrt{\dfrac{1.6 \times 10^{-5}}{0.150}} = \mathbf{1.0 \times 10^{-2}}\ M$

The $[Cl^-]$ will reach a concentration of $1.5 \times 10^{-9}\ M$ before it reaches a concentration of $1.0 \times 10^{-2}\ M$, (or $1.5 \times 10^{-9} << 1.0 \times 10^{-2}$), therefore AgCl(*s*) will precipitate first. — *1 point*

Note: One point is earned for calculating $[Cl^-]$ in saturated solutions with the appropriate Ag^+ and Pb^{2+} concentrations; one point is earned for concluding which salt will precipitate first, based on the student's calculations.

Question 2

(10 points)

(a) $\dfrac{73.1\ g}{30.01\ g/mol} = \mathbf{2.44\ mol\ NO}$ — *1 point*

$2.44\ mol\ NO \times \dfrac{114.1\ kJ}{2\ mol\ NO} = \mathbf{139\ kJ\ released}$ — *1 point*

Note: The first point is earned for calculating the number of moles of NO involved; the second point is earned for the correct answer with the correct units.

(b) (i) $K = e^{-\Delta G/RT} = e^{(70{,}400\ J)/(8.314\ J\ mol^{-1}\ K^{-1})(298\ K)} = e^{28.4} = \mathbf{2.2 \times 10^{12}}$ — *2 points*

Note: The first point is earned for using correct (and consistent) values of $\Delta G°$, R, and T; the second point is earned for the correct equation and appropriate math. No penalty if student starts with the equation $\Delta G = -RT \ln K$ and follows through correctly.

(ii) $\Delta G° = \Delta H° - T\Delta S°$ — *1 point*

As the temperature increases, $T\Delta S°$ will decrease ($\Delta S°$ is negative), $-T\Delta S°$ will increase, therefore $\Delta G°$ will become less negative. — *1 point*

Note: The first point is earned for using $\Delta G° = \Delta H° - T\Delta S°$, and the second point is earned for the discussion and the correct conclusion. Students should focus on the sign of the $\Delta S°$ term. One point can be earned for a response discussing spontaneity with reference to $\Delta H°$, although this is not entirely correct because K is temperature-dependent. (Since $\Delta H°$ is negative, increasing the temperature sends the reaction to the left, therefore the reaction is less spontaneous, therefore $\Delta G°$ must be getting more positive.)

(c) $\Delta S_{rxn} = \Delta S_f^{products} - \Delta S_f^{reactants} = 2(S^{NO_2}) - [2(S^{NO}) + S^{O_2}]$ — *1 point*

$-146.5\ J\ K^{-1} = 2(240.1)\ J\ K^{-1} - [2(210.8)\ J\ K^{-1} + S^{O_2}]$

$S^{O_2} = \mathbf{205.1\ J\ K^{-1}}$ = standard molar entropy of O_2 — *1 point*

Note: The first point is earned for correctly using the equation $\Delta S_{rxn} = \Delta S_f^{products} - \Delta S_f^{reactants}$ with the correct coefficients from the reaction equation. (All four terms must be in the correct position in the equation.) The second point is earned for calculating the correct answer.

Question 2 (cont.)

(d) ΔH_{rxn} = enthalpy of bonds broken − enthalpy of bonds formed

ΔH_{rxn} = [2(N≡O) + O=O] − 4[N=O] — *1 point*

−114.1 kJ = [2(607) + 495] kJ − 4 moles [N=O]

N=O bond energy = 456 kJ mol^{-1} — *1 point*

- One point can be earned if the student does problem correctly except for indicating that only two N=O bonds form.
- One point can be earned if the initial equation is reversed, but the rest of the problem is done correctly.

Question 3

(10 points)

(a) (0.325 g/2.00 g) × 100% = **16.2%** — *1 point*

(b) $\frac{1.200\text{ g } H_2O}{18.02\text{ g/mol}}$ = 0.06659 mol H_2O

(0.06659 mol H_2O) (2 mol H /mol H_2O) = 0.1332 mol H
(0.1332 mol H)(1.008 g/mol H) = **0.1343 g H** — *1 point*

$n_{CO_2} = \frac{PV}{RT} = \frac{(750/760)\text{ atm} \times 3.72\text{ L}}{(0.0821\text{ L atm mol}^{-1}\text{ K}^{-1})(298\text{ K})}$ = **0.150 mol CO_2** — *1 point*

(0.150 mol CO_2)(1 mol C /mol CO_2) = 0.150 mol C
(0.150 mol C) (12.0 g/mol) = **1.80 g C** — *1 point*

grams of oxygen = 3.00 g − (1.80 g + 0.133 g) = **1.07 g O** — *1 point*

Note: The first point is earned for getting the correct mass of H ; the second point is earned for using the Ideal Gas Law and substituting consistent values of *P*, *V*, *R*, and *T*. The third point is earned for converting moles of CO_2 to moles of C and then grams of C. If the number of moles of CO_2 is calculated incorrectly, but that incorrect value is used correctly, the third point is earned. The fourth point is earned for using the values of H and C to get the mass of oxygen by difference. If one (or both) of the previously determined values is incorrect, but the student uses those incorrect values correctly, the fourth point is still earned.

(c) moles OH = (0.08843 L) (0.102 mol/L) = 0.00902 mol OH , — *1 point*

therefore, 0.00902 mol H neutralized, therefore 0.00902 mole acid

molar mass = $\frac{1.625\text{ g}}{0.00902\text{ mol}}$ = 180. g/mol — *1 point*

Note: The first point is earned for setting up the calculation to determine the number of moles of OH^- used in the titration; the second point is earned for using the number of moles of OH^- correctly to get the molar mass. If the number of moles of OH^- is incorrectly calculated, credit can be earned for this step if the student uses the incorrect value correctly.

Question 3 (cont.)

(d) (i) The pK_a is equal to the pH halfway to the equivalence point. *1 point*

At 10.00 mL of added NaOH, pH = 3.44, therefore pK_a = 3.44

$K_a = 10^{-3.44} = 3.6 \times 10^{-4}$

- Other paths to the correct answer include using the initial data point and the acid equilibrium value, or using the Henderson-Hasselbalch equation

(ii) Beyond the end point, there is excess OH^-, and the $[OH^-]$ determines the pH. *1 point*

Moles of excess OH^- = (0.00500 L) (0.100 mol/L) = 5.00×10^{-4} mol OH^-

$$[OH^-] = \frac{5.00 \times 10^{-4} \text{ mol } OH^-}{0.04000 \text{ L}} = 1.25 \times 10^{-2}\ M\ OH^-$$

pOH = 1.90

pH = **12.10** *1 point*

Note: The first point is earned for recognizing that the pH past the end point is determined by the amount of excess OH^- ions; the second point is earned for the calculations and the final answer.

Question 4

(15 points)

Students choose five of the eight reactions. Only the answers in the boxes are graded (unless clearly marked otherwise). Each correct answer earns 3 points: 1 point for reactants and 2 points for products. Reactants must be completely correct to earn the reactant point. All products must be correct to earn both product points; one of the two products correct earns 1 product point. Equations need not be balanced nor phases indicated (and no penalty if present but incorrect). Any spectator ions on the reactant side nullify the 1 possible reactant point, but if they appear again on the product side, there is no product-point penalty. Ion charges must be correct.

(a) $SO_2 + H_2O \rightarrow H^+ + HSO_3^-$
(*or* $SO_2 + H_2O \rightarrow H_3O^+ + HSO_3^-$, *or* $SO_2 + H_2O \rightarrow H_2SO_3$)

- 1 product point earned for "$H^+ + SO_3^{2-}$"

(b) $Fe^{3+} + SCN^- \rightarrow [Fe(SCN)]^{2+}$ (*or* $[Fe(SCN)(H_2O)_5]^{2+}$ *or* $[Fe(SCN)(H_2O)_5]^{2+}$)

- Credit can be earned for any number of coordinated SCN ions from 1 through 6.
- For full credit, charges must be correct (square brackets not required).
- 1 product point earned if only product error is wrong charge.

(c) $Cu + Ag^+ \rightarrow Cu^{2+} + Ag$

- 1 product point earned for "$Cu^+ + Ag$"

(d) $C_2H_5COOH + OH^- \rightarrow C_2H_5COO^- + H_2O$

- Other correct formulas for propanoic acid, including structural formulas, are also accepted.

(e) $Fe^{2+} + Cr_2O_7^{2-} + H^+ \rightarrow Fe^{3+} + Cr^{3+} + H_2O$

- 2 product points but no reactant point earned for "$Fe^{2+} + Cr_2O_7^{2-} \rightarrow Fe^{3+} + Cr^{3+}$"

(f) $Cl_2 + Br^- \rightarrow Cl^- + Br_2$

(g) $Sr^{2+} + SO_4^{2-} \rightarrow SrSO_4$

(h) $MgCO_3 \rightarrow MgO + CO_2$

- 1 product point earned for "$Mg + CO_2$"

Question 5

(10 points)

In each part, one point is earned for the correct solution or solutions, and one point is earned for the correct explanation (in parts a, b, and e), precipitate (in part c), or product (in part d).

(a) $Pb(NO_3)_2$ (Solution 1) — *1 point*

$Pb(NO_3)_2$ has the largest value of i, the van't Hoff factor, so the solution has the highest number of solute particles (it dissociates into the most particles). — *1 point*

- Student must address the relative number of particles.

(b) $KC_2H_3O_2$ (Solution 5) — *1 point*

The acetate ion is the conjugate base of a weak acid, so it is a weak base (*or* $KC_2H_3O_2$ is the salt of a strong base and a weak acid, so the solution is basic). — *1 point*

(c) $Pb(NO_3)_2$ and NaCl (Solutions 1 and 2) — *1 point*

$PbCl_2$ would precipitate — *1 point*

- Points can also be earned for $KMnO_4$ plus one of the other solutions (with the precipitation of MnO_2).
- Points can also be earned for $KMnO_4$ plus $Pb(NO_3)_2$ (with the precipitation of PbO_2, or MnO_2).

(d) $KMnO_4$ (Solution 3) — *1 point*

The product of the oxidation is Cl_2 — *1 point*

(e) C_2H_5OH (Solution 4) — *1 point*

Ethanol is the only nonelectrolyte given. It does not readily dissociate into ions, so it would not produce charged species that would conduct a current. — *1 point*

- One point can also be earned for explanations using i, the van't Hoff factor.

Question 6

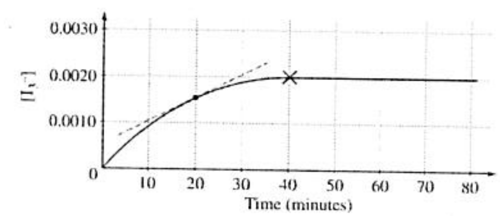
(10 points)

(a) The reaction is an oxidation-reduction (redox) reaction. — *1 point*

To go from I^- to I_3^-, the iodine has to be oxidized, so credit is earned for the formula of any reasonable oxidizing agent (e.g., F_2, Co^{3+}, O_2, MnO_4^-) — *1 point*

(b) (i) One point is earned for an "X" drawn on the curve at a point corresponding to approximately 37-42 minutes (see graph below). This is where the curve levels off. — *1 point*

(ii) The instantaneous rate of the reaction at 20 minutes is the slope of the line tangent to the curve at 20 minutes. (See the graph below.) — *1 point*



- No credit is earned if the student confuses "rate" with "rate constant".

(b) Keep the initial concentration of $S_2O_8^{2-}$ constant, change the initial concentration of I^- by a known amount, and see what effect this change has on the measured rate of the reaction. This procedure should be repeated, but this time keeping the concentration of I^- constant and changing the concentration of $S_2O_8^{2-}$. — *2 points*

Note: Points are earned for a method that involves controlling one reactant concentration and varying the other while comparing the reaction rates.

- No credit is earned if student confuses product and reactant concentrations.

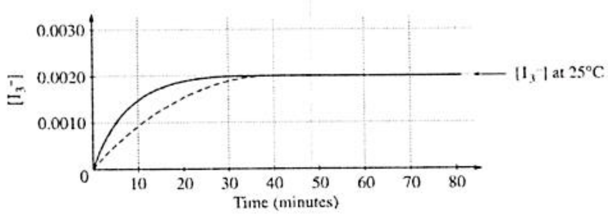
Question 6 (cont.)

(d) The general rate law expression is: rate = $k[I^-]^x[S_2O_8^{2-}]^y$ — *1 point*

The values of x and y can be determined by the experiments described in (c) above. These values can then be put into the equation with the rate and concentrations at a particular time in a particular trial, and the equation can then be solved for k. — *1 point*

- No credit is earned if student confuses rate law with equilibrium expression.
- No credit is earned if student uses reverse reaction expression.

(e) On the graph, a curve is drawn that starts at the origin, rises more quickly than the original curve, and levels off at $[I_3^-]$ = 0.0020 M. (See example drawn on the graph below.) — *2 points*



Note: One point is earned if the curve starts at the origin and rises more quickly than the original curve; the other point is earned if the curve levels off at the same $[I_3^-]$ as the original curve.

Question 7

(8 points)

(a) • The anode is the electrode on the right (Zn is the anode) — *1 point*

- Point is also earned if the student points to the Zn cell in the diagram.

The half-reaction is $Zn \rightarrow Zn^{2+} + 2e$ — *1 point*

(b) $Zn + Ni^{2+} \rightarrow Zn^{2+} + Ni$ — *1 point*

E°_{cell} = (−0.25 V) − (−0.76 V) = **0.51 V** — *1 point*

- Some work must be shown to support the answer.

(c) E_{cell} would decrease — *1 point*

Since Ni^{2+} is a reactant, a decrease in its concentration decreases the driving force for the forward reaction — *1 point*

or

$$E_{cell} = E^\circ - \frac{RT}{n\mathfrak{F}} \ln Q, \text{ where } Q = \frac{[Zn^{2+}]}{[Ni^{2+}]}$$

Decreasing the $[Ni^{2+}]$ would increase the value of Q, so a larger number would be subtracted from E°, thus decreasing the value of E_{cell}.

(d) $K > 1$ — *1 point*

E° is positive, so $K > 1$ — *1 point*

Note: The student's score in part (d) is based on the sign of E°_{cell} calculated in part (b).

Note on Overall Question: If in part (a) a student incorrectly identifies Ni as being oxidized, partial credit is earned if subsequent parts are followed through consistently.

Question 8

(8 points)

For each part, the student earns credit by indicating what kind of bonding and/or intermolecular forces are present, and giving some information about their relative strengths. The student can earn one point for giving the correct type of bonding and/or intermolecular forces present in <u>both</u> of the species in any part.

(a) NH_3 has hydrogen bonding between molecules (***or*** dipole-dipole interactions between molecules), and CH_4 has London dispersion forces. The intermolecular forces in NH_3 are stronger than those in CH_4. — *2 points*

- No credit earned for only a discussion of lone pairs of electrons.
- No credit earned for saying only that NH_3 is polar and CH_4 is nonpolar (with no more discussion).

(b) C_2H_6 and C_6H_{14} both have London dispersion forces. The forces in C_6H_{14} are stronger because the molecule is larger and more polarizable. — *2 points*

- Credit is earned for other accurate explanations of London dispersion forces.
- No credit is earned for saying only that C_6H_{14} is heavier or has more mass.

(c) Si is a network covalent solid (***or*** a macromolecule) with strong covalent bonds between atoms. Cl_2 has discrete molecules with weak London dispersion forces between the molecules. Therefore, more energy is required to break the stronger bonds of Si than the weak intermolecular forces of Cl_2. — *2 points*

- No credit is earned for saying only that Si forms a lattice.

(d) MgO and NaF are both ionic solids (***or*** ions are listed to indicate this). The +2 and −2 charges in MgO result in a greater attraction between ions than the +1 and −1 charges in NaF (***or*** according to Coulomb's Law, the attraction between +2 ions and −2 ions is greater than that between +1 ions and −1 ions, ***or*** student shows calculations using Coulomb's Law). — *2 points*

- Credit is earned also for stating that the lattice energy of MgO is greater than the lattice energy of NaF.
- No credit is earned for only a discussion of electronegativity.
- Since the sizes are about the same, no credit is earned for only a size argument.

MC Practice Test 1 Answers.

1. (D)

Answer (A) is not true as they do not tend to have more protons than neutrons. Answer (B) is incorrect: plenty of stable nuclei undergo reactions with the addition of external energy. Answer (C) is incorrect: over time unstable nuclei eventually spontaneously change to stable nuclei, which is the goal of a radioactive unstable nucleus. Answer (E) is incorrect because a nucleus can be heavier simply because it has a lot of protons and neutrons. It does not need to have more neutrons than protons to be heavy. Answer (D) is correct: the lighter a nucleus is, the more similar the number of protons and neutrons.

2. (B)

As K_a increases, the strength of an acid increases. Rank the K_a's given from smallest to greatest and that will point you to the correct answer.

3. (D)

You want to look for a metal/nonmetal pairing here; i.e., ionic bonds. KCl is the only ionic bond in the bunch. All the others contain covalent bonds.

4. (D)

Answer choice (D) is wrong: the atomic numbers and mass numbers on the left do not add up to the same as the atomic and mass numbers on the right.

5. (A)

$$[OH^-][H^+] = K_w$$
$$[OH^-] = 0.00200$$
$$\frac{K_w}{0.00200} = [H^+]$$

6. (D)

Balancing redox reactions can be confusing. You need to break this original equation into two half-reactions:

Oxidation Reaction: $Fe^{2+} \rightarrow Fe^{3+} + e^-$
Reduction Reaction: $ClO_3^- \rightarrow Cl^-$

The reduction reaction is incomplete, and in order to balance it you must add oxygen to the right side of the equation. The way you do this is by adding three H_2O molecules. But now there are six hydrogen molecules on the right and none on the left. You counter this by adding six protons to the left side, giving you:

Reduction Reaction: $6H^+ + ClO_3^- \rightarrow Cl^- + 3H_2O$

Lastly, you need to balance the charge on both sides. There is a total charge of +5 on the left and −1 on the right. This means you need to add six electrons to the left side to give the balanced equation of:

Reduction Reaction: $6e^- + 6H^+ + ClO_3^- \rightarrow Cl^- + 3H_2O$

When completing the balancing of the reaction, you need to multiply the oxidation reaction by six so that the electrons will cancel out, giving you a final balanced reaction of:

$$6\,Fe^{2+} + 6H^+ + ClO_3^- \rightarrow Cl^- + 3H_2O + 6\,Fe^{3+}$$

7. (C)

The van der Waals equation corrects for volume and the effect of intermolecular forces. Answer choice (C) sums this up nicely.

8. (C)

The molecule oxygen tetrafluoride, OF_4, has 34 electrons that need to be placed around the molecule. Oxygen is the central atom and is single bonded to each of the four fluorine atoms. The maximum possible number of electrons that can be drawn with this structure is 32. This structure is not possible.

9. (B)

The kinetic molecular theory consists of the following postulates:

- The molecules of a gas have volumes that are negligible compared to the volume of the gas itself. [Answer choice (E)]
- The molecules of a gas are in a continuous, rapid, and random state of motion. [Answer choice (A)]
- The gas temperature determines the average kinetic energy of the gas molecules. [Answer choice (D)]
- Gas molecules collide in perfectly elastic collisions and with the walls of their container, and do not lose energy in the process. [Answer choice (C)]

10. (D)

A catalyst increases the rate of reaction by lowering the activation energy. This will result in a change in the rate constant.

11. (C)

When the graph of $\frac{1}{[A]}$ versus time produces a straight line, then the reaction is a second order reaction with the following rate reaction: rate = $k[A]^2$.

12. (D)

The only answer choice on this list that does not accurately describe ionic substances is (D): that they deform when they are struck. The other four answer choices accurately described ionic compounds.

13. (B)

Answer choice (B), helium, is thought of as a "near" ideal gas. It exhibits the relationships expected of an ideal gas between pressure and temperature and volume and temperature.

14. (B)

This is a good fact to know for the AP chemistry exam. $\Delta H = Q$ when pressure is held constant.

15. (A)

Metals are located on the left of the Periodic Table, nonmetals on the right. Electronegativity increases as you move from left to right on the table. It can therefore be concluded that answer choice (A) is incorrect because metals exhibit *lower* electronegativities than nonmetals.

16. (B)

This question involves ideal gas law equations:

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{(750)(40)}{(298)} = \frac{(765)(50)}{T_2}$$

$$T_2 = \frac{(765)(50)(298)}{(750)(40)}$$

17. (E)

This question tests your understanding of Rutherford's scattering experiments and their demonstration of the nuclear model of the atom.

18. (C)

Looking at the Periodic Table, the elements not found in nature made in nuclear reactions that involve the 5*f* orbitals are known as the actinides.

19. (C)

Roman numeral I is incorrect. It does not properly account for the fact that to balance the equation you need to multiply the top equation by two. This allows you to eliminate answer choices (A) and (D). Roman numeral II is incorrect: a negative overall E° represents a nonspontaneous reaction. This allows you to eliminate answers (B) and (E). This leaves you with just answer choice (C)—and Roman numeral III is indeed a correct statement.

20. (C) $K_p = K_c(RT)^{\Delta n}$. Rearrange the equation to solve for K_c: $K_c = (K_p) \div ((RT)^{\Delta n})$. R is the molar gas constant of 0.0821. T is the temperature in Kelvin of 499K. Δn is calculated by adding the moles on the right and subtracting the moles on the left, which would be –1. Now just plug the numbers in to the equation for K_c:

$$K_c = \frac{1.36}{[(0.0821)(499)]^{-1}}$$

21. (E)

The third law of thermodynamics says that the entropy at zero Kelvin (absolute zero) for a perfectly arranged crystalline material is zero.

22. (A)

The ionic radius increase from right to left across the table and from top to bottom. Because Li is above Na, K, Rb, and Cs in Group 1 of the Periodic Table, it must have the smallest ionic radius.

23. (E)

This problem again tests your knowledge of the van der Waals equation that accounts for molecular volume and intermolecular force. Roman numerals II and III are correct.

24. (A)

This question tests your understanding of acid and base equivalents. H_2SO_4 has 2 equivalents per mole and KOH has 1. You must first calculate how many equivalents of OH^- there must be by calculating how many moles of KOH there were. 1 L of 0.10M KOH would be 0.10 moles of KOH, which would be 0.10 equivalents. To completely neutralize this base you need 0.10 equivalents of H^+. Since H_2SO_4 has 2 equivalents per mole, this would be only 0.05 moles of H_2SO_4, which would make it $\frac{0.050 \text{ moles}}{0.05\text{L}} = 1.0\text{M}$.

25. (A)

An intensive property is one that independent of the quantity of substance present. The only example of such is answer choice (A), pressure.

26. (B)

When trying to determine which of these salts will produce the most basic aqueous solution, remember that you will be adding the salt into water. Answer choice (B) is correct because when water reacts with $KC_2H_3O_2$, it will form KOH, a strong base, and $HC_2H_3O_2$, a weak acid. Thus, it will produce a solution that is more basic than acidic. Answer choice (A) will produce $Al(OH)_3$, a weak base, and HCN, a weak acid. Answer choice (C) will produce $Fe(OH)_3$, a weak base, and HCl, a strong acid. Answer choice (D) will produce KOH, a strong base, and HCl, a strong acid. Answer choice (E) will produce $Pb(OH)_2$, a weak base, and $HC_2H_3O_2$, a weak acid.

27. (D)

For this problem you must first calculate how many moles there are in 0.2 g of hydrogen gas (H_2). Then you must convert this to molecules using Avogadro's number.

28. (E)

Just think about this one logically. Of the five devices listed, the beaker has the least accuracy simply because its units of measurement provide the largest room for error. Using a beaker, you can not measure out a volume as precisely as you might be able to with any of the other four listed in this question.

29. (E)

For a spontaneous reaction, the equilibrium constant, K, is known to be greater than 1.

30. (B)

An amphoteric substance is one that can be both an acid and a base. ZnO is the only one on the list that fits this description.

31. (C)

This problem involves the equation $q = c_p m \Delta T$.

$$250 \text{ Joules} = 50(c)(10)$$
$$250 = 500c$$
$$c = 0.5 \text{ J/g} \cdot \text{K}$$

32. (C)

A molecule that has 5 bonded pairs and 1 nonbonded pair of electrons has square-pyramidal geometry.

33. (C)

First you need to calculate how many moles of barium nitrate you would need to prepare 250 mL of a 0.100 M solution. Then you need to calculate how many grams would be in that many moles. Answer choice (C) shows the proper calculation.

$$\text{Molarity} = \frac{\text{moles solute}}{\text{liters solution}}$$

$$0.100 = \frac{\text{moles solute}}{0.250 \text{ liters solution}} = .025 \text{ moles solute}$$

$$0.025 \text{ moles solute} \times \frac{199.34 \text{ grams}}{1 \text{ mole}} = 4.98 \text{ grams}$$

34. (D)

Oxygen's oxidation number is always −2 except with peroxides. The four oxygen atoms give a combined −8, and in order for the entire compound to have a −1 oxidation number, the chloride must be +7.

35. (C)

Since we are told that it is a neutral atom, we can add together the superscripts to determine the atomic number of the element. There are 11 electrons in the neutral atom, which means we are looking at sodium. This atom will lose one electron to form a cation with a +1 charge.

36. (B)

An alpha particle is a helium atom: ${}^{4}_{2}He$. The decay reaction will look as follows:

$$ {}^{226}_{88}Ra \rightarrow {}^{4}_{2}He + {}^{222}_{86}Rn $$

You must make sure that the atomic numbers and mass number totals on the left and right are equal when you are finished.

37. (E)

The Rydberg equation is used to predict wavelength and can give the frequency of a series of lines in the hydrogen spectrum.

38. (D)

The reaction does not necessarily need to proceed slowly so that the endpoint is readily observable. Quick reactions can result in successful titration procedures. The other four answer choices are indeed necessary for a reaction to be used in a titration.

39. (E)

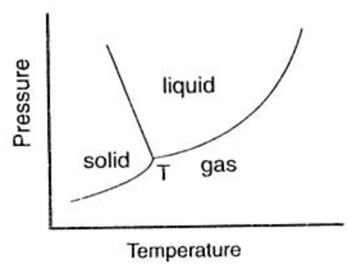
NO_2^+ has 16 total electrons. The compound consists of a central nitrogen double bonded to two oxygen atoms in a linear configuration.

40. (D)

Roman numeral I is a true statement: $\Delta G = 0$ represents a system in equilibrium. This allows you to eliminate answer choices (B) and (C). Roman numeral II contains a correct equation and Roman numeral III is an incorrect statement. Therefore answer choice (D) is correct I and II only.

41. (D)

A phase diagram plots temperature on the x-axis versus pressure on the y-axis.



As you can see by looking at the chart, the pressure at the triple point, T, is the lowest pressure at which the liquid phase exists. All other points for the liquid section have a higher pressure than the triple point pressure. Answer (D) is correct. By looking at the chart you can prove to yourself why answers (A), (B), (C), and (E) are incorrect.

42. (D)

NH_4^+ has 4 bonded pairs and 0 nonbonded electron pairs, giving it a tetrahedral geometry.

43. (C)

Roman numeral I is true which allows you to eliminate answer choice (D). Roman numeral II is incorrect, and Roman numeral III is correct, leaving you with answer choice (C).

44. (B)

Answer choice (B) is an excellent definition of LeChâtelier's principle. You need to be familiar with this principle and how to apply it for the AP Chemistry exam.

45. (E)

All three of these statements about carbon-containing compounds are true.

46. (B)

The charge and the size of the radius of the ions play an important role in measuring the strength of a bond. The different sized radii and the changing charge will affect the strength with which the two ions pull towards each other. Changing temperature does not affect the strength of the bond.

47. (A)

Electronegativity increases as you go up the Periodic Table and as you move from left to right. Lithium is higher up the table than Na, K, Rb, and Cs, and is therefore the most electronegative of those choices.

48. (A)

The formula for acetic acid is CH_3COOH. This means that there are 2 moles of carbon in each mole of the trichloroacetic acid. To solve this problem you need to first calculate how many moles of trichloroacetic acid there are in 27.3 grams. You can then use Avogadro's number to figure out how many carbon atoms there are.

$$2\left(\frac{27.3 \text{ g}}{163.5 \text{ g/mol}}\right) = \text{moles of C}$$

$$2\left(\frac{27.3 \text{ g}}{163.5 \text{ g/mol}}\right)(6.02 \times 10^{23} \text{ atoms/mole}) = \text{atoms of C}$$

49. (A)

This question makes sure that you know that the Bohr model of the atom only works for the hydrogen atom. That is what you should take from this question.

50. (E)

The question wants to know which answer choice is NOT true. Answer choice (A) is true, because Fe^{3+} is adding an electron, it is being reduced. Answer choice (B) is true because the oxidation state is changing from +3 to +2. Answer choice (C) is true because the species being reduced is also known as the oxidizing agent. Answer choice (D) is true and answer choice (E) is false: Fe^{3+} and Fe^{2+} are cations.

51. (B)

This question uses the formula $Q = mc\Delta T = (100)(4.18)(5 - 25)$

52. (D)

Increasing the temperature of a reaction will definitely increase the kinetic energy of the molecules. Kinetic energy is the energy of motion and it is directly proportional to temperature. As temperature rises, so does the kinetic energy of a system.

53. (E)

Some argue that glass is a liquid and not a solid. How could this be? How could glass be solid to the touch if it is a liquid? An important characteristic of liquids that comes into play here is viscosity, which is resistance to flow. Usually, viscosity will increase when a liquid is cooled and when a liquid is cooled to a temperature lower than its freezing point, it changes into the solid form. But this is not always the case. Supercooling can occur, which allows the substance to remain in the liquid phase even though it is below its freezing point. As this is happening, if the viscosity grows to be large enough, the substance may never solidify and instead may form what is known as an amorphous solid. The molecules of an amorphous solid have a chaotic arrangement compared to most normal solids, but they are cohesive enough to give substances such as glass the appearance and some characteristics of a solid. Because of this, glass is often thought of in terms of being a very viscous fluid.

54. (C)

$$NH_4^+ + H_2O \rightleftharpoons H_3O^+ + NH_3$$

$$K_a = \frac{[H_3O^+][NH_3]}{[NH_4^+]}$$

Since the molar ratio of H_3O^+: NH_3Cl^- is 1:1, you can write the K_a expression as:

$$K_a = \frac{[X]^2}{[NH_4^+]}$$

You can then estimate the concentration of H_3O^+ by rearranging the equation and solving.

$$[NH_4^+]K_a = ([X])^2$$

$$\sqrt{[NH_4^+]K_a} = [X] = \sqrt{[1.0M](5.6 \times 10^{-10})} = 2.4 \times 10^{-5} = [H_3O^+]$$

$$pH = -\log[H_3O^+] = -\log[2.4 \times 10^{-5}] = 4.62 \approx 5.00$$

55. (C)

In general the trend is for electronegativity to increase as you go from left to right across the table and from bottom to top. The reason (C) is the best answer to this question is because it contains the only pair of elements that are from different "sections" of the table. Boron is a metalloid and aluminum is a metal, causing the electronegativities to be further apart than the other pairs.

56. (E)

Sodium carbonate, Na_2CO_3, is a basic compound that produces a basic solution when dissolved in water.

57. (B)

This question involves the Henderson-Hasselbalch equation:

$pH = pKa + \log\frac{[A^-]}{[HA]}$ We can set the pH = 7, and in fact it is easier to solve this problem with the pH in the log form: $-\log[1 \times 10^{-7}] = -\log[4.3 \times 10^{-7}] + \log\frac{[A^-]}{[HA]}$

Rearranging the above equation leaves you with:

$$\log[4.3] = +\log\frac{[A^-]}{[HA]}$$

$$4.3 = \frac{[A^-]}{[HA]}$$

58. (C)

Hydrogen bonding is common among alcohols, amines, and carboxylic acids. Answer choice (C), CH_3NH_2, is the only compound of that type among the answer choices.

59. (D)

If B is doubled with A remaining constant, the rate doubles. This means that B is a first order reactant. If A is tripled with B constant, the rate increases by nine-fold. This means that A is a second order reactant.

60. (A)

An oxidizing agent causes the other element involved in the reaction to be oxidized. This means that the oxidizing agent gets reduced. Remember that if an atom loses electrons it is oxidized, if it gains electrons it is reduced.

61. (E)

A p-type semiconductor is formed by adding Group 13 atoms to silicon, and that an n-type semiconductor is formed by adding Group 15 atoms to silicon. This adds an extra electron to the crystal lattice, which moves freely throughout the lattice, i.e., a nonbonded electron. Therefore Roman numerals I and III are true statements. Roman numeral II is false because doping *increases* conductivity. Therefore choice (E) is the correct answer.

62. (A)

This question uses the equation $\lambda\nu = c$. λ = wavelength; ν = frequency; c = speed of light = 3 $\times$ 10^8 m/s.

$$(3 \times 10^{-5}\text{m})\ \nu = 3 \times 10^8 \text{ m/s}$$
$$\nu = 1 \times 10^{13}$$

63. (B)

A Lewis acid is known to be an electron acceptor. The only answer among the five choices here that has room to add electrons is BF_3.

64. (A)

CH_3F has the shortest carbon-halogen bond because fluorine is the most active of the halogens and pulls the electron more strongly than any of the other halogens.

65. (C)

All of the answer choices are true except for (C)—entropy *is* a state function under all conditions.

66. (E)

Solvation is not a process used to separate mixtures. In fact it is the process of binding a solute to one or more molecules of a solvent.

67. (A)

The Pauli exclusion principle states that two electrons of an atom cannot have the exact same quantum numbers.

68. (B)

Based on the equation $\ln K = \ln A - \frac{Ea}{RT}$; you can tell that the natural logarithm of the rate constant would be inversely proportional to the temperature.

69. (D)

In this problem you want to look for nonmetal/metal pairs. Answer choice (D) is the only ionic compound in the bunch.

70. (B)

The structure of HN_3 is most likely:

$$H-\overset{+}{N}\equiv\overset{+}{N}-\ddot{\underset{\cdot\cdot}{N}}:^{2-}$$

When two atoms are joined by a triple bond, the bond order is 3. When there is a single bond between two atoms, the bond order is 1. The bond order for the first bond in this structure is 1, and the bond order for the second bond in this structure is 3.

71. (E)

NO_2 has 17 electrons total and thus will have an unpaired electron when drawn.

72. (D)

Xenon tends to form compounds that disobey the octet rule and can bond up to 6 halogens. XeF_4 has 4 bonded pairs and 2 nonbonded pairs and thus has a square planer configuration.

73. (B)

C_2H_2 is an alkyne—it has a triple bond. It has two carbons triple bonded to each other, each bonding to an atom of hydrogen on the other side. The triple bond is composed of one sigma bond and two pi bonds.

74. (D)

When trying to solve this problem, try to use a good example, like this one:

$$HA + H_2O \rightleftharpoons H_3O^+ + A^-$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

$$1.0 \times 10^{-10} = \frac{[X][X]}{0.01}$$

$$X^2 = 1.0 \times 10^{-12}$$

$$X^2 = [H_3O^+] = 1.0 \times 10^{-6}$$

75. (B)

This answer choice goes against the third law of thermodynamics, which states that the entropy of a perfect crystal is taken to be 0 at 0K, not 298K.