Annotated Solution
2001 USNCO National Exam Part I

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1 Solutions

1. Amphoteric hydroxides are very helpful to remember. The most common are hydroxides of Zn and Al and others include Sn, Pb, and Be. These hydroxides can act as an acid by combining with hydroxide ions to form complexes (e.g. $Al(OH)_3 + OH^- \longrightarrow Al(OH)_4{}^-$) and can act as bases when neutralizing acid (e.g. $Al(OH)_3 + H^+ \longrightarrow Al(OH)_2{}^+ + H_2O$). Therefore, the answer is $\boxed{\text{C. } I \text{ and } III \text{ only}}$.$Ba(OH)_2$ is a typical strong base.

2. Since the hydrogen in CaH_2 has a negative charge as suggested by the name of hydride, it will react with the positively charged hydrogen in water to form H_2. Also, due to the fact that the reaction involves excess water, CaO cannot be formed since it will react with water to form $Ca(OH_2)$. Therefore, the answer is $\boxed{\text{D. } Ca(OH)_2 \text{ and } H_2}$.

3. Since this mixture is close to ideal, Raoult's Law states that the boiling point will be $\boxed{\text{B. between 69 and 98 °C}}$. Please be aware that an ideal solution is a solution in which the interaction between molecules of the components does not differ from the interactions between the molecules of each component.

4. $\boxed{\text{B. Silicon}}$ forms a network structure analogous to diamond, resulting in a very high melting point.

5. The carbon in $H_2C_2O_4$ has an oxidization state of +3. Therefore, it can be *readily* oxidized to a state of +4 in CO_2 and reduced to a state of +2 in CO when it decomposes as $H_2C_2O_4 \xrightarrow{\text{heat}} H_2O + CO + CO_2$. $KMnO_4$ is a typical strong oxidizing agent with a +7 Mn, which can be easily reduced, but hard to be oxidized. All other compounds cannot be either easily reduced or oxidized due to the relative stable oxidation number of each element. Therefore, the answer is $\boxed{\text{D. } H_2C_2O_4}$

6. The number of mols of magnesium hydroxide required is $\frac{.125 \times .136}{2} = .00850$ mol. This equates to $.00850 \times 58.33 = \boxed{\text{B. 0.496 g}}$

7. This depicts a $\boxed{\text{C. refluxing}}$ apparatus. The cool water is put into the apparatus which condenses the reactants when it evaporates.

8. The ratio of the mass of ammonia to platinum in the compound is $\frac{17.0 \times 2}{195} = .175$. Therefore, the answer is $.100 \times .175 = \boxed{\text{C. 0.0175 g}}$

9. The gasses will combine in a 1 : 3 ratio as suggested by the balanced equation $N_2 + 3\,H_2 \longrightarrow 2\,NH_3$. Therefore, .06 L of N_2 will react with .18 L of H_2, so there will be $0.10 - 0.06 = \boxed{\text{D. 0.04 L } N_2}$ left over.

10.

$$\frac{12.0\text{ mol}}{1\text{ L}} \times \frac{36.5\text{ g}}{1\text{ mol}} = \frac{438\text{ g HCl}}{1\text{ L}} \times \frac{100\text{ g solution}}{36\text{ g HCl}} = \frac{1220\text{ g solution}}{1\text{ L}} = \boxed{\text{A. 1.22 g/mL}}$$

11. The theoretical yield is $1.00 \times \frac{180.15}{138.12} = 1.30$ g so the percent yield is $\frac{0.85}{1.30} = \boxed{\text{A. 65\%}}$

12. Since solid CO_2 is more dense than the liquid, we would need to increase both pressure and temperature to achieve a liquid state. However, C is incorrect since it would lead to supercritical conditions. Therefore, the answer is $\boxed{\text{A.}}$

13. Vapor pressure does not depend on volume, so the answer is $\boxed{\text{B. 17.54 mmHg}}$

14. Using ideal gas law, we have

$$\frac{n}{V} = \frac{P}{RT} = .0398\text{ mol/L} = \boxed{\text{C. 1.75 g/L}}$$

15. Since the ratio of masses is inversely proportional to the ratio of the velocity squared (from the formula $KE = \frac{1}{2}mv^2$) we know the mass of the unknown gas is 4 times that of methane, or $\boxed{\text{D. 64 g/mol}}$

16. Using the formula $KE = \frac{1}{2}mv^2$, doubling of energy results in a $\sqrt{2} = 1.41$ increase in velocity, so the answer is $\boxed{\text{B.}}$

17. Since arsenic has one more valence electron than silicon, it is more negative and therefore $\boxed{\text{A. } n\text{-type}}$

18. Let x be the desired bond dissociation energy. Given the reaction $N_2 + O_2 \longrightarrow 2\,NO$ with $\Delta H = 90$ kJ/mol, we have the equation $941 + 499 - 2x = 180$ which gives $x = \boxed{\text{A. 630 kJ/mol}}$

19. Since there are 2 mols of water, $6.01 \times 2 = 12$ kJ will be required to melt the ice. An additional $4.18 \times 25 \times 36 = 4$ kJ will be required to heat the melted water to room temperature. Summing gives $\boxed{\text{B. 16 kJ}}$

20. Using the equation $\Delta G = \Delta H - T\Delta S$ and the given information that $\Delta G < 0 < \Delta H$, we can deduce that $\boxed{\text{D. } \Delta S > 0}$ or else the left side is negative while the right is positive.

21. Using the equation $\Delta G = \Delta H - T\Delta S$, we see that the conditions are satisfied when ΔS is most negative. Therefore, the answer is $\boxed{\text{C. } \Delta S = -50}$

22. The first law of thermodynamics states $\Delta U = Q - W$. It is given that $Q = -220$ kJ and $W = 10$ kJ, so $\Delta U = \boxed{\text{D. -230 kJ}}$

23. The desired reaction can be written as the sum of twice the reverse of the first reaction with three times the second reaction. Summing them up, we get $\Delta H = -2(234.1) + 3(-393.5) = \boxed{\text{C. 1648.7 kJ}}$

24. From $\Delta G = -RTlnK$, a large positive value for ΔG corresponds to a $\boxed{\text{A. Small positive } K}$

25. Location 1 is a reaction intermediate since it is at a local minimum that is not the reactants or products. Location 2 is an activated complex since it is a local maximum. Thus the answer is $\boxed{\text{B.}}$

26. There will be $\frac{730}{242}$ half lives, so the percent remaining is $(.5)^{\frac{730}{242}} = \boxed{\text{C. 12.5\%}}$

27. Mechanism **I** is consistent since it has a rate law of Rate=k[NO_2][O_3]. Mechanism **II** is also consistent since it has a rate law of Rate=k[NO_2][O]=k[NO_2]$\frac{[O_3]}{[O_2]}$. $\boxed{\text{C. Both \textbf{I} and \textbf{II}}}$ satisfy the rate law.

28. Apply the formula

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$
$$\ln(2) = \frac{E_a}{8.314}\left(\frac{1}{300} - \frac{1}{310}\right)$$
$$E_a = \boxed{\text{C. 53.6 kJ/mol}}$$

29. From the first trial to the second, [A] was doubled while the rate stayed the same, so the order in [A] must be 0. From the first trial to the third, [B] was tripled while the rate was increased 9 fold, so the order in [B] must be 2. Therefore, the rate law is $\boxed{\text{D. rate}=k[B]^2}$

30. From the Arrhenius equation, the reaction rate with the greatest activation energy fluctuates most with temperature. Since the activation energy is represented by the height of the initial hump, $\boxed{\text{B. Reaction \textbf{I} reversed}}$ has the highest activation energy.

31. Reversing and halving a reaction is equivalent to taking the square rook of the reciprocal of its rate constant. Therefore, the answer is $\frac{1}{\sqrt{80}} = \boxed{\text{B. 0.112}}$

32. $K_c = \frac{K_p}{(RT)^{\Delta n}} = \boxed{\text{A. } \frac{K_p}{(RT)^2}}$

33. Assuming minimal dissociation, $K_a = \frac{[H^+][HCOO^-]}{[HCOOH]} = \frac{[H^+](.050)}{.10} = 1.7 \times 10^{-4} \implies [H^+] = \boxed{\text{B. } 3.4 \times 10^{-4} M}$

34. It is a good idea to memorize the strong acids. The strong acids listed is $\boxed{\text{A. \textbf{I} only}}$

35. $\boxed{\text{C.}}$ has the closest pH to 9. Its pH can be computed with $\sqrt{k_1 k_2}$. All other pH can be calculated as single equilibria, none of which are as close to 9.

36. Letting $x = [OH^-]$, we have $k_s p = \frac{x^3}{2} = 6.0 \times 10^{-12} \implies x = 2.29 \times 10^{-4}$. Then, pH$= 14 + \log(x) = \boxed{\text{B. 10.36}}$

37. This is a disproportion reaction where P_4 acts as both the oxidizing and reducing agent, so the answer is $\boxed{\text{D. } P_4 \text{ and } P_4}$

38. When combining, the aluminum will reduce the copper, with an electric potential of $1.66 + 0.34 = \boxed{\text{B. 2.00 V}}$

39. $\boxed{\text{B. \textbf{II} Only}}$ will vary with pH. This is due to the fact that the species have a different number of oxygen molecules, so when balancing the oxidization reduction reaction, H^+ molecules will be needed, making the reaction vary with pH. For example, when balencing the reaction for **II**, we will get $AmO_2^{2+} + 4H^+ + 2e^- \longrightarrow Am^{4+} + 2H_2O$ which varies with pH.

40. C. and D. will both have no effect on the potential since they both involve solids. $\boxed{\text{A.}}$ will have greater effect than B. since $[Ag^+]$ has a coefficient of 2, giving it a larger effect on Q in the Nernst equation.

41. Apply the formula $E = \frac{RT}{nF}\ln K \implies 0.15 = \frac{8.314 \times 298}{10 \times 96500}\ln K \implies K = \boxed{\text{A. } 2.4 \times 10^{25}}$

42. We know that 2 mol of H_2 will be produced for each mol of O_2. Therefore, the mass

ratio should be 1 : 8, so the answer is C. 8.00 g

43. The shielding effect most impacts the C. Radius since higher shielding results in larger radius and vice versa.

44. Ni^{2+} has a d^8 orbital, which from Hund's rule has B. 2 unpaired electrons.

45. Generally, ionization energies increase going left to right across the periodic table. However, N has a half filled p orbital, giving it an uncharacteristically large ionization energy. Thus, the correct order is D. C, O, N

46. These two electrons represent a filled $2s$ orbital. The next orbital to be filled is $2p$, which is represented by B. $n = 2$, $l = 1$

47. The question is asking which element will exhibit the photoelectric effect with the least energy. The photoelectric effect is observed when electrons are emitted when light hits a certain material. Therefore, we want the element that requires the least energy to remove an electron, or the lowest first ionization energy. This is B. Rb

48. C has allotropes such as diamond and graphite. O has allotropes such as O_2 and O_3. S is best known for rhombic sulfur and monoclinic sulfur. Thus, the answer is C. Kr

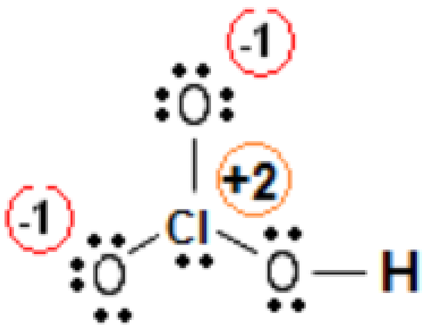
49. There are 4 pi bonds (one for each double bond and two for each triple bond) so the answer is D. We can also verify it has 11 sigma bonds.

50. A. is correct since it changes from trigonal planar to tetrahedral.

51. From coulumb's law, the lattice energy is maximum when charges are greatest and radius is smallest. out of all the options, C. MgO has the largest charge (2) and the smallest radius.

52. A covalent bond involves electrons being shared by more than one nucleus, so the answer is A.

53.



Drawing the Lewis diagram with only single bonds, we can see the formal charge in the Cl atom is D. 2+

54. A compound is not adequately represented by a valence bond model if it has resonance due to the delocalization of electrons. B. **II** Only has a Lewis structure with resonance.

55. C. is the answer since the compound represents a ketone, not an ether.

56. The Cl atom can either replace the H on the $-CH_3$ group of toulene, or in the o, m, p positions, giving D. 4 different molecules.

57. Since CH_3COOH is an acid, it is the most acidic. Thus, the answer is D. For verification, C_6H_5OH is the second most acidic since the structure is resonance stabilized.

58. Esterification reactions require an acidic catalyst, so the answer is B. **II** only

59. A carbocation has a positive charge, so it will be attracted to negative charges. That makes it A. electrophilic

60. A racemic mixture has an equal amount of D. enantiomers