Academic Challenge 2012 Sectional Chemistry Exam Solution Set

1. C. 15.25 g Mg (1 mol Mg/24.3g)(1 mol dypingite/5 mol Mg)(485.65 g/1 mol dypingite) = 60.95 g

2. D. (89.9043)*(.05146)+(90.9053)*(0.1123)+(91.9046)*(0.1711)+(93.9061)*(0.1740)+(95.9082)*(0.280) = 91.23 = Zr

3. D. (0.02597 L)(3.52 mol sugar/L)+ (0.05589 L)(6.85 mol sugar/L) = 0.474 mol sugar. Divide by the total volume 0.474mol/.08186L = 5.79M

4. E. CaF_2 dissolves to give Ca^{2+}(aq) and F^-(aq). The fluoride anion is a weak base and will therefore react with HCl causing a decrease in fluoride ion concentration. As per Le Chatelier's principle this will then drive the solubility reaction (CaF_2(s) $\rightarrow$ Ca^{2+}(aq) + $2F^-$(aq)) to the right

5. A. In (A) the correct representation of the SO_3 molecules is used as well as the correct consideration of limiting reagents. Option (C) involves the creation of some oxygen atoms. Options (B) and (D) show the coefficient on the SO_3 as representing the 2 SO_3 molecules are actually bound together and not that it is the lowest whole number ratio.

6. B. First calculate the theoretical mass of PCl_5 produced:
   = 61.3 g Cl_2[1 mol Cl_2/70.91 g Cl_2][1 mol PCl_5/1mol Cl_2][208.2 g PCl_5/1 mol PCl_5]
   = 180.0 g
   Theoretical yield = [119.3 / 180.0] x100 = 66.3%

7. D. The oxidation numbers of the reactants and products do not change, so it cannot be a redox reaction.

8. D. Use PV=nRT to solve for moles.
   (1 atm)(1 L) = n(0.0821)(300 K)
   n= 0.0406 mol

   MW = 1.79 g / 0.0406 mol = 44.1. This corresponds to D (C_3H_8).

9. D. The graph for D should show an upward (positive) linear slope for Boyle's Law.

10. E. Only E is a constitutional isomer. All the others are conformers.

11. C. Bond formation is an exothermic process.

12. D. In this temperature range, water will boil so the entropy change will be the greatest.

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13. D. The value of A changes by 32 which would take 8 alpha particles. The net change in Z is 10 therefore 6 beta particles are needed to balance.

14. A. 1.000g x (1 mol O/16.00 g O) = 0.06250 mol O
mol M = 0.06250 mol O x (1 mol M/3 mol O) = 0.02083 mol M
molar mass M = 1.083 g/0.02083 mol M = 51.99 g/mol (Cr)

15. D. Given that the photons have energy greater than the threshold frequency they will be able to remove electrons. Einstein explained that each photon removes one electron.

16. A. 28 is the number of electrons that would be found in n levels 1,2, and 3.

17. C. The answer is C.

18. C. Hydrogen cannot hybridize.

19. B. Calculate hours = $1x10^3$ kg Na[1000g/1 kg][1mol Na/22.99g Na] [1 mol e/1mol Na][96485 C/1mole][1 s/$3.00x10^4$ C][1min/60s][1hr/60 min.] = 38.9 hours.

20. B. In examining trials 1 and 3, the rate doubles when [B] doubles, therefore the reaction is first order in B. In examining trials 1 and 2, when [A] doubles, the rate increases by a factor of 4. Therefore the reaction is second order in A.

21. B. The units of the rate constant indicate a 4^{th} order reaction. The sum of the exponents in the rate law must equal the order. The reaction must be 2^{nd} order in H^+.

22. D. A weak base would have a relatively low pH before any acid is added and should have a pH that is less than 7 at the equivalence point. As it is being titrated with a strong acid the final pH will be very low.

23. C. The i value for $Cu(NO_3)_2$ is 3 and is 2 for NaBr. In equimolal solutions, there will be more ions present in the $Cu(NO_3)_2$ solution, which will both lower the vapor pressure further according to Raoult's Law and decrease the freezing point more than NaBr.

24. C. Vapor is only dependent on temperature, not the volume of liquid present.

25. E. The greater the IM forces the lower the vapor pressure. Therefore Cl_2, with only Van derWaals forces will have the highest vapor pressure (and is, in fact, a gas at room temperature)

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26. C. Use the integrated first-order rate law.
$\ln 0.0120 = \ln (0.0200) - (1.06\text{x}10^{-3}\ \text{min}^{-1})\ t$
t = 481 min

27. C. Solve for molarity of N_2O_4 first and do an ICE table.

	$N_2O_4(g) \longleftrightarrow$	$2NO_2(g)$	$K = 4.0 \times 10^{-7}$
I	0.20 M	0	
C	-x	+2x	
E	0.20-x	2x	

$K = 4.0\text{x}10^{-7} = (2x)^2 / 0.20 - x$. Solve for x. $x=1.4\text{x}10^{-4}$ M
Therefore $[NO_2] = 2(1.4\text{x}10^{-4})$

28. C. ΔH = sum of the B.E. of the reactants – sum of the B.E. of the products.

x = [(1mol(945 kJ/mol) + (3 mol)(432 kJ/mol)] – [(6 mol)(391 kJ/mol)]

29. C. According to periodic trends for the alkali and alkali earth metals (which generally form cations), the answer is C. For an element to favorably form a cation it must cost little energy to form (low ionization energy) and be unfavorable to form the anion (positive, or just slightly negative electron affinities)

30. B. The one with the lowest molecular weight will have the highest number of molecules in a 1 g sample.

31. B. M = [20.2g HCl/100g soln][1.096g soln/1mL soln][[1mol HCl/36.45g HCl][1000 mL/1L] = 6.07 M

32. C. Mol of base = 0.0009 mol. Mol of acid = 0.0018 mol. There is a 1:2 ratio from base to acid. Since it takes twice as many moles of acid to titrate the base, there must be two OH^- ions for each mole of base.

33. A. SeF_4 is VSEPR shape AX_4E, which has a molecular shape of see-saw. This is a trigonal bipyramidal electronic geometry but due to the lone pair on the central atom a see-saw molecular shape.

34. D. The one with the highest temperature has the highest average kinetic energy.

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35. A. The answer is A according to periodic trends. (size decreases up and to the right on the periodic table) Remember that cations cause a decrease in size and anions an increase relative to their parent atoms.
36. D. Use Hess' Law. Switch the first equation and therefore change the sign to -67.7 kJ and then add to 9.7 kJ, as the second equation remains in the order provided.

37. D. Do a Q test first. $Q = (2)^3(6) / (5)^3 = 0.384$. Q > K, so the equilibrium will shift to the left.

38. C. If the volume is reduced, the equilibrium will shift to the side that has fewer moles of gas. The reactant side has 3 moles and the product side has 4.

39. E. Only E contains a polyatomic ion. There are covalent bonds between C and N in the polyatomic ion and there is an ionic bond between Na^+ and CN^-.

40. B. Only statement II is true. (note that the lone pairs on oxygen have not been drawn but must be included to correctly determine the validity of statement IV)