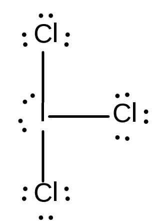
2014 Academic Challenge Regional Chemistry Exam Solution Set

1. D. $3.50 \text{ mol } P_4O_6 * \frac{4 \text{ mol P}}{1 \text{ mol } P_4O_6} * \frac{30.97 \text{ g P}}{1 \text{ mol P}} = 434 \text{ g P}.$

2. A. By Dalton's law of partial pressures, $P_{Total} = P_{oxygen} + P_{nitrogen}$
   1.50 atm = 0.875 atm + $P_{nitrogen}$; $P_{nitrogen}$ = 1.50 atm – 0.875 atm = 0.63 atm

3. C. A tetrahedral electron arrangement indicates four electron groups around the central atom. A V-shape indicates 2 bonding groups attached to the central atom, leaving two lone pairs.

4. C. $\frac{0.400 \text{ g NaCl} * \frac{1 \text{ mol NaCl}}{22.99 \text{ g} + 35.45 \text{ g}}}{0.750 \text{ L}}$ = 9.13×10^{-3} mol/L



5. A. ICl_3 = 7*4 = 28 valence electrons total. This requires 5 electron groups around the central atom, placing the molecule in the trigonal bipyramid electron arrangement, and T-shape.

6. C. An exothermic reaction indicates heat is given off as a product. Low temperature would favor the formation of this product. As well, high pressure favors the side of the reaction with the fewest moles of gas. In this reaction, there are 4 moles of gas on the reactants side and 2 on the products side. Therefore high pressure and low temperature both favor the product side.

7. C. The proper order of operations indicates doing the addition in the numerator first, resulting in 10.0 to the proper number of significant figures (goes by position). Then performing the division, a number with 3 sig. figs. divided by a number with 4 sig. figs. should result in an answer with three sig. figs.

8. B. PV = nRT, $n = \frac{P*V}{R*T} = \frac{1.3 \text{ atm} * 2.4 \text{ L}}{0.08206 \frac{\text{atm}*\text{L}}{\text{mol}*\text{K}} * (273.15 + 20.0)\text{K}}$. n = 0.13 moles

9. D. Electronegativity increases as you move up and to the right on the periodic table. P is both the uppermost and rightmost element of those listed.

10. E. Properly balanced, with only whole number coefficients:

$$2C_3H_7OH_{(g)} + 9O_{2(g)} \rightarrow 6CO_{2(g)} + 8H_2O_{(g)}$$

11. B. $0.1500 \text{ L} * \frac{0.185 \text{ mol NaOH}}{1 \text{ L}} * \frac{40.00 \text{ g NaOH}}{1 \text{ mol NaOH}} = 1.11 \text{ g NaOH needed.}$

12. D. This is the only molecule requiring two π-bonds to complete the structure. O_2, SO, and CH_2O all require 1 π-bond, F_2 requires 0.

13. E. $\frac{2 \text{ mol B}}{1 \text{ mol } B_2H_6} * \frac{10.81 \text{ g B}}{1 \text{ mol B}} + \frac{6 \text{ mol H}}{1 \text{ mol } B_2H_6} * \frac{1.008 \text{ g H}}{1 \text{ mol H}} = 27.67 \frac{\text{g}}{\text{mol } B_2H_6}$

14. E. If converted to grams, A-D all represent 0.0100 g. E is 0.100 g.

15. C. SiO_2 and $NaNO_2$ are named correctly. MgO is magnesium oxide, N_2O_4 is dinitrogen tetroxide (or dinitrogen tetraoxide).

16. E. Iron(III) indicates Fe^{3+} ions, sulfur form S^{2-} ions. To achieve a neutral compound, they must be in the ratio Fe_2S_3.

17. D. The mass of an atom is primarily due to its protons and neutrons, the volume is primarily due to the electron cloud.

18. E. This is the only combination with all three particles paired with the proper charge.

19. D. Uranium atoms have 92 protons. If an atom loses 2 protons, the nucleus will be left with 90 protons, corresponding to the element thorium, Th.

20. A. A reducing agent causes something else to get reduced, getting oxidized itself. It does this by providing electrons to the element being reduced, which is contained in the oxidizing agent.

21. A. These species represent an isoelectronic series, except for Cl^-. The species in the series with the largest radius will be the one with the fewest protons, Se^{2-}. By periodic properties, we know Br^- will be larger than Cl^-, so Cl^- cannot be larger than Se^{2-}.

22. C. $25.0 \text{ g } CO_2 * \frac{1 \text{ mol } CO_2}{44.0 \text{ g } CO_2} * \frac{2 \text{ mol NaOH}}{1 \text{ mol } Co_2} = 1.14 \text{ mol NaOH.}$

23. B. This sample would contain 0.450 mol of chlorine atoms. A & C both contain 0.400 moles of chlorine atoms, D contains 0.250 moles, and E contains 0.300 moles.

24. A. This is a representation of the law of definite composition.

25. E. $K_p = \frac{[P_{HF}]^2}{[P_{H_2}]*[P_{F_2}]} = \frac{2.50^2}{0.500*0.300} = 41.7.$

26. B. A & E contain only ionic bonds, C & D contain only covalent bonds. B contains both.

27. C. $\frac{P_1*V_1}{n_1*T_1} = \frac{P_2*V_2}{n_2*T_2}$. If n and T are constant, this reduces to:

    $P_1*V_1 = P_2*V_2$, or $P_2 = \frac{P_1*V_1}{V_2} = \frac{648 \text{ torr}*4.3 \text{ L}}{6.0 \text{ L}} = 464$ torr.

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28. A. This is the only properly balanced equation using the species specified. B is not balanced, C does not show sulfur dioxide as a product, D does not show carbon dioxide as a product, and E does not show sulfur trioxide as a reactant.

29. B. A decomposition reaction shows a compound being reduced to its elements, or breaking into less complex species. B shows less complex species forming a more complex product. The rest are correctly labeled.

30. A. The magnitude of the freezing point depression depends on the molality of dissolved particles. Solution A will be 0.75 m in dissolved particles, B & C will be 0.25 m, and D will be 0.50 m. A larger magnitude depression indicates a lower freezing point.

31. A. Phosphorus has 3 unpaired electrons; scandium, fluorine, and boron each have 1; calcium has none.

32. D. If a reaction absorbs heat, it is classified as endothermic. Exergonic and endergonic refer to the change in total energy, not just heat energy.

33. D. According to the law of mass conservation, the total mass of species produced must be equal to the total mass of the reactants used. Since 20.0 g of compound A and 16.0 g of compound B were used, 36.0 g of C must have been produced.

34. A. This is the only chemical property listed. The rest are physical properties.

35. E. The electron configuration of a ground state chromium atom is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$. Choice E represents a 4p electron, which is not found in this ground state configuration.

36. C. $0.03985\ \mathrm{L\ KOH} * \frac{0.270\ \mathrm{mol\ KOH}}{1\ \mathrm{L\ KOH}} * \frac{1\ \mathrm{mol\ acid}}{1\ \mathrm{mol\ KOH}} = 0.0108\ \mathrm{mol\ HA}.$ $\frac{0.0108\ \mathrm{mol\ HA}}{0.0850\ \mathrm{L}} = 0.127\ \mathrm{M}.$

37. E. The overall order of a reaction is the sum of the reaction orders with respect to each species. In this case, 2 + 3 = 5.

38. B. STP indicates a pressure of 1 atmosphere and a temperature of 273.15 K (0 ^{o}C). Substituting these values and 0.350 moles into PV = nRT and solving for V yields 7.84 L.

39. B. Choice A includes Cl, choice C uses $AlCl_2$ as the product instead of $AlCl_3$, choice D uses Cl atoms in place of Cl_2, and choice E is not balanced. Only choice B is correct.

40. E. $0.02500\ \mathrm{L\ H_2SO_4} * \frac{0.350\ \mathrm{mol\ H_2SO_4}}{1\ \mathrm{L\ H_2SO_4}} * \frac{2\ \mathrm{mol\ NaOH}}{1\ \mathrm{mol\ H_2SO_4}} * \frac{1\ \mathrm{L\ NaOH}}{0.594\ \mathrm{mol\ NaOH}} = 0.0295\ \mathrm{L\ NaOH} =$ $29.5\ \mathrm{mL\ NaOH}$