2019 Academic Challenge Sectional Chemistry Solution Set

Answer	Explanation
1. Answer is B.	Answer is self-explanatory
2. Answer is A.	The associated ions are Mg^{2+} and NO_2^{-}.
3. Answer is C.	The species contains 22 valence electrons. Xe is able to go beyond octet by using the vacant d-orbitals to accommodate the lone pairs.
4. Answer is A.	$\Delta t = 125\ ^oC - 25\ ^oC = 100\ ^oC$ $q = mc_p\Delta t \quad \therefore c_p = \frac{q}{m \text{ x } \Delta t} = \frac{59.3 \text{ x } 10^3 \text{ J}}{150.0 \text{ g x } 100\ ^oC} = 3.95 \text{ J/g . } ^oC$
5. Answer is E.	For six electron groups, the inner atom's orbital mixing involves one from s, three from p, and two from d orbitals respectively.
6. Answer is D.	Boiling point depends on the imposed pressure. In liquids lower external pressure results in lower boiling point.
7. Answer is C.	The associated ions are Ba^{2+} and PO_4^{3-}.
8. Answer is E.	Entropy increases with increasing number of electrons and atomic size.
9. Answer is B.	The nitrogen atoms in #1, #2, and #3 have a lone pair of electrons and are bonded to at least one hydrogen atom, thus capable of hydrogen bonding.
10. Answer is E.	For aqueous systems, $K_w = [H^+] \text{ x } [OH^-] = x^2$ $\therefore x = [OH^-] = \sqrt{K_w} = \sqrt{1.47 \text{ x } 10^{-14}} = 1.21 \text{ x } 10^{-7}\ \underline{M}$
11. Answer is C.	It is an aldehyde with six carbon atoms in the continuous chain.
12. Answer is D.	The species can both accept and donate proton. $HPO_4^{2-}(aq) \rightarrow H^+(aq) + PO_4^{3-}(aq)$ $HPO_4^{2-}(aq) + H^+(aq) \rightarrow H_2PO_4^{-}(aq)$
13. Answer is D.	Answer is D. $PV = nRT = \frac{m}{M}RT$ $\therefore \mathcal{M} = \frac{mRT}{PV} = \frac{0.465 \text{ g x } 0.0821 \text{ L . atm /(mol . K) x } 298 \text{ K}}{1.22 \text{ atm x } 0.245 \text{ L}} = 38.1 \text{ g/mol}$
14. Answer is B.	The emission of beta particle results in the next higher element in this process.
15. Answer is D.	$D = \frac{m}{V} = \frac{10.782 \text{ g}}{13.72 \text{ mL}} = 0.78586 \frac{g}{mL} = 7.859 \text{ x } 10^{-1} \frac{g}{mL} \text{(four sig. fig.)}$
16. Answer is A.	Oxygen has 8 protons, a gain of 2 electrons will result in 10 electrons.
17. Answer is B.	mass % N = $\frac{\text{mass of all N−atoms}}{\text{mass of } PtCl_2(NH_3)_2} \text{ x } 100 = \frac{2 \text{ x } 14.01 \text{ amu}}{300.06 \text{amu}} \text{ x } 100 = 9.34\%$
18. Answer is C.	The pair contains metal and nonmetal which can form cation and anion.
19. Answer is A.	Convert all mass into one single unit, i.e. to kg, and compare. A) $2.5 \text{ x } 10^1$ kg = 25 kg B) $2.5 \text{ x } 10^{-2}$ mg = $2.5 \text{ x } 10^{-8}$ kg ($1 \text{ x } 10^6$ mg = 1 kg) C) $2.5 \text{ x } 10^{15}$ pg = 2.5 kg ($1 \text{ x } 10^{15}$ pg = 1 kg) D) $2.5 \text{ x } 10^9$ fg = $2.5 \text{ x } 10^{-9}$ kg ($1 \text{ x } 10^{18}$ fg = 1 kg) E) $2.5 \text{ x } 10^{10}$ ng = $2.5 \text{ x } 10^{-2}$ kg ($1 \text{ x } 10^{12}$ ng = 1 kg)

20. Answer is C.	| | Mn | O | mass, g: Mn 72, O 28 molar mass (g/mol): Mn 55, O 16 mol: Mn 1.31, O 1.75 ratio to fewest mol: Mn 1, O 1.34 whole number ratio: Mn 3, O 4 Simplest formula = Mn_3O_4
21. Answer is B.	Henderson-Hasselbach equation: pH = pK_a + log$\frac{[\text{conjugate base}]}{[\text{acid}]}$. pH = pK_a when [Conjugate base] = [acid]. pK_a of $NH_3/NH_4C\ell$: $pK_a = –\log K_a = –\log 5.6 \times 10^{-10} = 9.25$ which falls between 9.2 and 9.3.
22. Answer is E.	overall rate = k $[A]^m[B]^n$ Order with respect to reactant A, use equations 3 and 1 $\frac{\text{rate}_3}{\text{rate}_1} = \frac{k\,[0.819]^m\,[0.763]^n}{k\,[0.273]^m\,[0.763]^n}$ $\frac{25.47 \text{ M/s}}{2.83 \text{ M/s}} = \frac{[0.819]^m}{[0.273]^m}$ $9 = 3^m$ leading to $m = 2$ Order with respect to reactant B, use equations 2 and 1 $\frac{\text{rate}_3}{\text{rate}_1} = \frac{k\,[0.273]^m\,[1.526]^n}{k\,[0.273]^m\,[0.763]^n}$ $\frac{2.83 \text{ M/s}}{2.83 \text{ M/s}} = \frac{[1.526]^n}{[0.763]^n}$ $1 = 2^n$ leading to $n = 0$ Therefore, the overall rate = k $[A]^2$
23. Answer is B.	de Broglie wavelength equation, $\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\text{ m}^2\text{.kg/s}}{0.0060\text{ kg} \times 331\text{ m/s}} = 3.3 \times 10^{-34}$ m
24. Answer is A.	The quote is the statement of the Pauli Exclusion principle.
25. Answer is D.	Oxidation occurs at the anode, thus the answer is $Zn \rightarrow Zn^{2+} + 2e^-$
26. Answer is C.	Order with respect to NH_4^+: $\frac{\text{rate}_2}{\text{rate}_1} = \frac{k\,[0.0200]^m\,[0.200]^n}{k\,[0.0100]^m\,[0.200]^n}$ $\frac{6.4 \times 10^{-3}\text{ M/s}}{3.2 \times 10^{-3}\text{ M/s}} = \frac{[0.0200]^m}{[0.0100]^m}$ $2 = 2^m$ leading to m = +1
27. Answer is E.	Cell notation convention: anodic half reaction |salt bridge| cathodic half reaction. Pt (inert to the reaction) is serving as an electrode at the anode and silver metal is at the cathode.
28. Answer is B.	Solve the problem using the stoichiometric ratios provided in the balanced equation: $0.024\text{ L Fe}^{3+} \times \frac{0.200\text{ mol Fe}^{3+}}{1\text{ L}} \times \frac{1\text{ mol SO}_3^{2-}}{2\text{ mol Fe}^{3+}} \times \frac{1\text{ L SO}_3^{2-}}{0.100\text{ mol SO}_3^{2-}}$ 0.024 L (24.0 mL)
29. Answer is C.	The 2d sublevel does not exist, making choice ‘c’ as the correct answer.
30. Answer is A.	Expanded volume would cause a shift to the left (more moles of gas on that side); therefore, NO_2 is the darker substance. Higher temperature also causes a shift to left (darker substance). As a result, the reaction must be exothermic. Heat is a product.

31. Answer is E.	Calcium fluoride is CaF_2 (*s*): $CaF_2 (s) \leftrightarrow Ca^{2+} (aq) + 2 F^- (aq)$ $K_{sp} = [Ca^{2+}][F^-]^2$ Solve for the fluoride concentration. $4.0 \times 10^{-11} = [2.0 \times 10^{-3}][F^-]^2 \quad \therefore [F^-] = \sqrt{\frac{4.00 \text{ x } 10^{-11}}{2.00 \text{ x } 10^{-3}}} = 1.4 \text{ x } 10^{-4} \text{ M}$
32. Answer is A.	Selenium has 4 valence electrons in the 4*p* sublevel. Due to Hund's rule, two of these four electrons will be unpaired in the orbital diagram. $[Ar]4s^2 3d^{10} 4p^4$
33. Answer is D.	Using stoichiometric rations, determine the theoretical yield. $17 \text{ kg NH}_3 \text{ x } \frac{1 \text{ kmol NH}_3}{17 \text{ kg NH}_3} \text{ x } \frac{1 \text{ kmol (NH}_4)_2\text{SO}_4}{2 \text{ kmol NH}_3} \text{ x } \frac{132 \text{ kg (NH}_4)_2\text{SO}_4}{1 \text{ kmol (NH}_4)_2\text{SO}_4} = 66 \text{ kg}$ $200 (\frac{49}{100}) \text{ kg H}_2\text{SO}_4 \text{ x } \frac{1 \text{ kmolH}_2\text{SO}_4}{98 \text{ kg H}_2\text{SO}_4} \text{ x } \frac{1 \text{ kmol (NH}_4)_2\text{SO}_4}{1 \text{ kmol H}_2\text{SO}_4} \text{ x } \frac{132 \text{ kg (NH}_4)_2\text{SO}_4}{1 \text{ kmol (NH}_4)_2\text{SO}_4}$ $= 132 \text{ kg}$
34. Answer is C.	Oxide has a 2- charge; therefore, X_2O_3 would indicate that the metal (X) would have a 3+ charge. The formula of the chloride should be $XC\ell_3$ since chloride has a 1- charge.
35. Answer is A.	Use Planck's constant and the speed of light to solve for energy. $E = \frac{hc}{\lambda} = \frac{6.626 \text{ x } 10^{-34} \text{ J} \cdot \text{s x } 3.00 \text{ x } 10^8 \text{ m/s}}{9.38 \text{ x } 10^{-8} \text{ m}} = 2.12 \text{ x } 10^{-18} \text{ J}$
36. Answer is B.	Find the ratio of water to stock solution needed: $\frac{60 \text{ g NaOH}}{0.300 \text{ L NaOH}} \text{ x } \frac{1 \text{ mol NaOH}}{40 \text{ g NaOH}} = 5.0 \text{ M NaOH}$ $M_1V_1 = M_2V_2 \quad \therefore \left(5.0 \frac{\text{mol}}{\text{L}}\right)(0.300 \text{ L}) = \left(1 \frac{\text{mol}}{\text{L}}\right)(V_2) \quad \therefore V_2 = 1.5 \text{ L}$ One would need 1.2 L water and 0.300 L of stock solution. Ratio of water to stock solution is 1.2 L/0.30L = 4. Answer 'B' is the same ratio.
37. Answer is E.	Mass of solution = 200 g $200(0.95) = 190 \text{ g of ethanol x } \frac{1 \text{ mole}}{46.08 \text{ g}} = 4.12 \text{ mole ethanol}$ $200\text{g} - 190 \text{ g} = 10 \text{ g water x } \frac{1 \text{ mole}}{18.02 \text{ g}} = 0.555 \text{ mole water}$ $X = \frac{\text{mole water}}{(\text{mole water} + \text{mole ethanol})} = \frac{0.555}{(0.555 + 4.12)} = 0.12$
38. Answer is D.	Based on the given ionization energies, element X would have two valence electrons. So, the best choice would be X^{2+}.
39. Answer is D.	Use the equation $\Delta T_f = k_f \times m$. $m = \frac{\text{mole ethanol}}{\text{kg water}} = \frac{800 \text{ g x } \frac{1 \text{ mole}}{46.08 \text{ g}}}{8.0 \text{ kg}} = 2.17\ m$ $\Delta T_f = 1.86\ ^0 \text{C}/m(2.17\ m) = 4.0\ ^0 \text{C}$.
40. Answer is E.	Energy is emitted when electrons transition from higher to lower energy levels. The highest energy emission would be between the closet two energy levels. Quantization of energy levels indicates that they get closer together at higher levels. Therefore, n = 3 to n = 2 would be the highest energy emission.