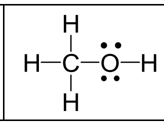
2022 ACES State Chemistry Solution Set

Answer	**Explanation**
1. Answer is D.	Some of the metal particles will still be in the solid state until it becomes completely melted. In this process the temperature will remain constant.
2. Answer is E.	The prefixes such as mono-, di- and such are not used in ionic compounds (whose formula starts with a metal).
3. Answer is C.	The total valence electron (VE) count for the species is 16 (shared and unshared). Structure-I disqualifies due to having 18 VE and nitrogen being surrounded by 10 electrons. Structure-II shows 16 VE but nitrogen can't accommodate 10 electrons due to lack of d-orbitals. Structure-III satisfies all rules and is the correct choice.
4. Answer is E.	$\Delta G = \Delta H - T\Delta S$. In a spontaneous process, $\Delta G < 0$. The described process is endothermic ($\Delta H > 0$). Hence, ΔS must be positive (> 0).
5. Answer is A.	Hydrogen bonding requires a hydrogen atom in the structure to be bonded to either F, N, or O with at least one lone pair of electrons residing on them. Only CH_3OH fulfills those requirements. 
6. Answer is A.	The reaction stoichiometry is: $NaOH(aq) + HC\ell(aq) \rightarrow NaC\ell(aq) + H_2O(\ell)$. $9.88 \times 10^{-3}\ \text{L HCl} \times \frac{0.1775\ \text{mol HCl}}{1\ \text{L HCl}} \times \frac{1\ \text{mol NaOH}}{1\ \text{mol HCl}} = 1.7537 \times 10^{-3}\ \text{mol NaOH};$ $M = \frac{m}{V} = \frac{1.7537 \times 10^{-3}\ \text{mol NaOH}}{58.22 \times 10^{-3}\ \text{L NaOH}} = 0.0301\ \text{M}$
7. Answer is D.	Based on the ideal gas law, different gases at STP (1 atm pressure and 0 °C temperature) and the same volume would all have the same number of moles. Answer D is the correct choice, as the same number of moles would also lead to the same number of molecules.
8. Answer is D.	The nuclear reaction is represented by: ${}^{2}_{1}H + {}^{75}_{33}As \rightarrow {}^{1}_{1}H^{+} + {}^{76}_{33}As$
9. Answer is C.	For this acid, H^+ ion reacts with the anion bromite (BrO_2^-) to generate the name bromous acid.
10. Answer is A.	$q = m \times c \times \Delta T$. For the same mass and same ΔT, $c \propto q$. Therefore, more heat loss will happen when water cools down compared to copper as water has the higher specific heat.
11. Answer is C.	Answer is C. Stronger intermolecular forces contribute to surface tension at a higher degree. In molecular compounds, hydrogen bonding is the strongest force, which is present in choices A and C. The latter contains two H-bonding sites.
12. Answer is B.	Basic anhydrides are metal oxides (which produce base when reacting with water). $BaO(s) + H_2O(\ell) \rightarrow Ba(OH)_2(aq)$
13. Answer is B.	$pH = 14 - pOH = 14.0 - 9.85 = 4.15$; $pH = -\log[H_3O^+]$; $\therefore [H_3O^+] = 10^{-pH}\ M = 10^{-4.15}\ M = 7.1 \times 10^{-5}\ M$.
14. Answer is E.	$PV = nRT = \frac{m}{M}RT$, leading to $m = \frac{M \times P \times V}{R \times T}$ $= \frac{28\frac{g}{mol} \times 0.905\ \text{atm} \times 0.100\ \text{L}}{0.0821\ \text{L.}\frac{\text{atm}}{\text{mol.K}} \times (565+273)\text{K}} = 0.0368\ \text{g CO}$

15. Answer is E.	$E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} J.s) \times (3.00 \times 10^{8} m.s^{-1})}{1.876 \times 10^{-6}.m} = 1.060 \times 10^{-19}$ J (E will become negative due to emission) $E = -2.18 \times 10^{-18} [\frac{1}{n_f^2} - \frac{1}{n_i^2}] \rightarrow -1.060 \times 10^{-19} = -2.18 \times 10^{-18} [\frac{1}{n_f^2} - \frac{1}{4^2}]$ $0.04862 = [\frac{1}{n_f^2} - \frac{1}{4^2}] \rightarrow 0.11112 = [\frac{1}{n_f^2}] \rightarrow 9.00 = n^2_f \rightarrow 3 = n_f$
16. Answer is D.	Isoelectronic configurations occur when two elements and/or ions have the same electronic configurations. Sn^{2+} will not be isoelectronic with krypton.
17. Answer is A.	Exothermic reactions have negative values for ΔH° and heat is viewed as a product. If temperature is decreased, the reaction will shift to the right. Therefore, the pressures of the products would increase. O_2 is a product, so its pressure will increase.
18. Answer is B.	$\Delta T = i K_f \underline{m}$ 6.1 °C = (1) (30. °C kg mol^{-1}) (***x*** / 2.50 kg) 6.1 °C = (1) (12. °C mol^{-1}) (***x***) leading to x = 0.51 mol 0.51 mol × 80.1 g/mol = 41 g
19. Answer is C.	$P_{H_2O} = P_{total} - P_{H_2}$ = (0.076 − 0.021) atm = 0.055 atm The equilibrium constant expression can be written, remembering that solids and pure liquids are ignored. $K_p = (P_{H_2O})/(P_{H_2}) = K_p$ = (0.055 atm)/(0.021 atm) = 2.6
20. Answer is B.	For radius comparisons, anions are larger than their neutral atoms and cations are smaller than their neutral atoms. That makes **II** and **III** incorrect. Rb^+ is not larger than Rb and Cℓ is not larger than $Cℓ^-$.
21. Answer is D.	The copper ion in CuS is Cu^{2+}. As a result, it will have 27 electrons. The two electrons lost will be the single 4s electron and one of the 3d electrons, making the correct configuration $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$.
22. Answer is C.	575 mL solution x $\frac{1.06 \text{ g solution}}{1 \text{ mL solution}}$ = 609.5 g Mass of water = mass of solution – mass of NaCℓ = 609.5 – 98.6 = 510.9 Mass % = $\frac{\text{mass of water}}{\text{total mass of solution}}$ x 100 = $\frac{510.9}{609.5}$ x 100 = 83.8 %
23. Answer is A.	Osmotic pressure (π) = *M*RT T = 25 + 273 = 298 K π = 8.44 torr x $\frac{1 \text{ atm}}{760 \text{ mmHg}}$ = 0.0111 atm 0.0111 = $\frac{\text{moles}}{0.150 \text{ L}}$ x 0.08206 x 298 → moles = 6.812 x 10^{-5} moles molar mass = $\frac{\text{grams}}{\text{moles}} = \frac{0.0152 \text{ g}}{6.812 \times 10^{-5} \text{ mole}}$ = 223 g/mol
24. Answer is E.	Nonmetals become <u>less</u> reactive going down a column.

25. Answer is B.	One needs to consider that calcium hydroxide is $Ca(OH)_2$. Therefore, it would require two moles of HCℓ to completely react. 0.020 L $Ca(OH)_2$ x $\frac{0.0500 \text{ mole } Ca(OH)_2}{1 \text{ L } Ca(OH)_2}$ x $\frac{2 \text{ moles HCl}}{1 \text{ mole } Ca(OH)_2}$ x $\frac{1 \text{ L HCl}}{0.0100 \text{ mole HCl}}$ = 0.020 L or 20.0 mL
26. Answer is A.	A homogenous solution would form when the solute and solvent are nearly miscible. The pair of compounds must have nearly identical intermolecular forces to be miscible. Identical intermolecular forces are found in C_6H_{14} and C_5H_{12}.
27. Answer is D.	Low energy radiation would be long wavelength radiation. So the correct order from long to short wavelength would be: microwave > infrared > visible > X-ray
28. Answer is B.	The volume of the rock is 0.011 mL (12.461 – 12.450 = 0.011) which has only 2 significant figures. Thus, the density can only have 2 significant figures.
29. Answer is E.	Since the instrument is in good working order we can assume it provides consistent measurements, suggesting it is precise. However, without proper calibration the values are likely inaccurate.
30. Answer is C.	J. J. Thomson's experiment with the cathode ray tube established a mass-to-charge ratio for electrons. Robert Millikan's oil drop experiments determined that an electron has a specific charge. Multiplying these two results provides a mass for the electron.
31. Answer is E.	Assuming 1 gram of carbon in both compounds, ethane would have 0.252 grams of hydrogen ($\frac{6 \text{ mol Hx}1.00794 \text{ g/mol}}{2 \text{ mol Cx}12.0107 \text{ g/mol}}$) and propane would have 0.224 grams of hydrogen ($\frac{8 \text{ mol Hx}1.00794 \text{ g/mol}}{3 \text{ mol Cx}12.0107 \text{ g/mol}}$). Dividing these results ($\frac{0.252}{0.224}$) gives 1.125 which when multiplied by 8 gives the whole number ratio 9:8.
32. Answer is D.	Since 33.37% of this compound is carbon and sulfur, and those two elements contribute a molar mass of 76.14 g/mol, the compound must have a total molar mass of 228.17 (76.14/0.3337 = 228.2. The missing molar mass is (228.17 – 76.14 = 152.02 must be due to the 8 atoms of element [*X*]. Thus, the atomic mass of [*X*] must be $\frac{152.02}{8}$ = 19.00, which is fluorine.
33. Answer is B.	Assuming a sample of 100.0 grams, there would be 3.33 moles carbon ($\frac{40.0 \text{ g}}{12.01 \text{ g/mol}}$), 10.0 moles hydrogen ($\frac{10.1 \text{ g}}{1.01 \text{ g/mol}}$), 1.66 moles nitrogen ($\frac{23.3 \text{ g}}{14.01 \text{ g/mol}}$), and 1.66 moles oxygen ($\frac{26.6 \text{ g}}{16.0 \text{ g/mol}}$). Dividing all these values by 1.66 yields an empirical formula of C_2H_6NO, with a molar mass of ~60 g/mol. Since the compound's actual molar mass is ~180 g/mol ($\frac{10.0 \text{ g}}{0.0555 \text{ mol}}$), its chemical formula must be $C_6H_{18}N_3O_3$.
34. Answer is A.	This buffer will initially have 0.01 mole of both acetic acid and the acetate ion (0.050 L x 0.200 mol/L), which means pKa = pH = 4.74 The addition of NaOH will force the dissociation of 0.00075 moles (0.500 M x 0.00150 L) of the acid into conjugate base. This will reduce the acid to 0.00925 mole (0.01 - 0.00075) and increase the acetate concentration to 0.01075 mole (0.01 + 0.00075). Using Henderson-Hasselbalch with these new concentrations yields a pH of 4.81 pH = (4.74 + log[$\frac{0.01075 \text{ mol } A^-}{0.00925 \text{ mol HA}}$]).

35. Answer is D.	The dissociation equation for aluminum hydroxide can be written as $K_{sp} = [A\ell^{3+}] \times [OH^-]^3$. Setting the aluminum ion concentration to $\boldsymbol{X}$ yields the following equation: $1.26 \times 10^{-33} = \boldsymbol{X} \times (3\boldsymbol{X})^3 = 27\boldsymbol{X}^4$. Solving for $\boldsymbol{X}$ ($\sqrt[4]{\frac{1.26\text{x}10^{-33}}{27}}$) gives. 2.61×10^{-9} M.
36. Answer is A.	The data provided suggests first order kinetics since the concentration of the reactant is cut in half with each ten-minute time period. The integrated rate law which yields a linear plot for first order kinetics is ℓn[A] vs t.
37. Answer is B.	The overall rate will be determined by the second step since it is the slow one (rate = $k_2[NOBr_2][NO]$). We don't have concentrations for the intermediates, so we cannot have intermediates in the final rate law. Therefore, we must use the assumption that the fast reaction is in equilibrium between the forward and reverse reactions ($Rate_1 = Rate_{-1}$, so $k_1[NO][Br_2] = k_{-1}[NOBr_2]$). Solving this for the intermediate gives $[NOBr_2] = \frac{k_1}{k_{-1}}[NO][Br_2]$ .Substituting this into the slow reaction's rate law gives rate= $k_2 \frac{k_1}{k_{-1}}= [NO][Br_2][NO] = k[NO]^2[Br_2]$
38. Answer is E.	The principal quantum number (n) can be any positive, non-zero integer. The angular momentum quantum number (ℓ) can be any value from 0 to n-1. The magnetic quantum number (m_ℓ) can be any value from –ℓ to + ℓ. In addition, the spin quantum number (m_s) can be either +½ or –½.
39. Answer is C.	In the Schrödinger equation, $\hat{H}$ is the Hamiltonian operator, which when it operates on ψ (the wave function) yields the total energy (E) of an electron. The most commonly accepted interpretation for the wave function is that is represents a complex probability amplitude for the electrons wave properties.
40. Answer is C.	Balancing this equation in basic solution yields the following balanced half reactions: oxidation half reaction is $2\ OH^- + H_2O + CN^- \rightarrow CNO^- + 2\ H^+ + 2\ OH^- + 2\ e^-$ and the reduction half reaction is $3\ e^- + 4\ OH^- + 4\ H^+ + MnO_4^- \rightarrow MnO_2 + 2\ H_2O + 4\ OH^-$. Simplifying and combining the two equations yields the following balanced equation: $H_2O + 3\ CN^- + 2\ MnO_4^- \rightarrow 3\ CNO^- + 2\ MnO_2 + 2\ OH^-$.