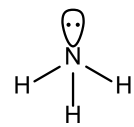
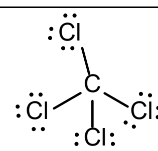
2024 ACES Regional Chemistry Solution Set

Answer	Explanation
1. Answer is A.	It has 3 significant figures while all others have 2 significant figures.
2. Answer is E.	Carbon always has 6 protons no matter what. Isotopes vary in the number of neutrons. Carbon-12 has 6 protons and 6 neutrons (giving it a mass number of 12). Thus, an isotope of carbon-12 is “E”, with 6 protons and 8 neutrons (giving it a mass number of 14 for carbon-14).
3. Answer is A.	In order to float in water, the density of the object must be less than the density of water. D = m/V produces for object-I: 50.0 g / 60.8 mL = 0.822 g/mL. This one will float. All others produce densities higher than water’s density.
4. Answer is D.	Each mol of water contains 2 mol H-atom. $25.0\ g\ H_2O \times \frac{1\ mol\ H_2O}{18\ g\ H_2O} = 1.39\ mol\ H_2O \times \frac{2\ mol\ H}{1\ mol\ H_2O} = 2.78\ mol\ H$
5. Answer is C.	Answer is C. The correct name should be aluminum oxide (the III is not needed).
6. Answer is B.	Answer is B. The Lewis structure of NH_3 shows 3 bonding pairs and one nonbonding pair around the central atom N. This is very close to the ideal situation such as CH_4 (4 bonding pairs around the central atom C) producing 109.5° angle according to VSEPR theory. 
7. Answer is E.	Adding 4.21 + 97.46 gives 101.67. In addition and subtraction, the lowest decimal place is to be reported, thus, the answer will have 5 significant figures.
8. Answer is E.	The most stable ion for oxygen is O^{2-} which has 8 protons and 10 electrons.
9. Answer is D.	The chemical equation describing this process is $KNO_3(aq) + NaCl(aq) \rightarrow KCl(aq) + NaNO_3(aq)$ But these aqueous solutions consist of ions, so no chemical reaction takes place.
10. Answer is A.	The corresponding formulas with molar masses are: A) Fe_2O_3 = 159.7 g/mol, B) FeO = 71.85 g/mol, C) $Fe(OH)_2$ = 89.87 g/mol D) $Fe(OH)_3$ = 106.87 g/mol, E) $FeSO_4$ = 151.92 g/mol
11. Answer is A.	All formulas contain polar bonds, however, the bond polarities in CCl_4 cancel out due to the shape. 
12. Answer is B.	Least precise is in bold. $\frac{85.\mathbf{3}-21.48\mathbf{9}}{0.005\mathbf{9}} = \frac{63.\mathbf{8}11}{0.005\mathbf{9}}$ Two significant figure is the highest reliable precision in this calculation.
13. Answer is C.	The formula is FeO with molar mass of 55.8 + 16.0 = 71.8 g/mol.
14. Answer is C.	Saturated hydrocarbons, e.g., alkanes contain all single bonds, aromatic hydrocarbons contain the benzene ring (no triple bonds), alkenes contain at least one double bond, but no triple bonds.
15. Answer is B.	Use the following setup for the calculation $BaF_2(s) \rightleftharpoons Ba^{2+}(aq) + 2F^-(aq)$ 0.0122 X $K_{sp} = 1.7 \times 10^{-6} = [Ba^{2+}][F^-]^2 = [0.0122][x]^2$ $1.39 \times 10^{-4} = x^2$ leading to $x = 0.012\ M$
16. Answer is C.	Carbon tetrachloride is nonpolar. C_4H_{10} is the only nonpolar answer choice.

17. Answer is D.	Using the copper half reaction, identify that 6 e^- are required: 3 Cu → 3 Cu^{2+} + 6 e^- $\Delta G^o = -nFE^o = (-6 \text{ mol})(9.6485 \times 10^4 \text{ J} \cdot \text{mol}^{-1} \cdot \text{V}^{-1})(+1.34 \text{ V}) = -7.76 \times 10^5 \text{ J}$ $-7.76 \times 10^5 \text{ J} \times \frac{1 \text{ kJ}}{1000 \text{ J}} = -776 \text{ kJ}$
18. Answer is D.	Convert wavelength to meters: 550 nm x $\frac{1 \text{ m}}{10^9 \text{ nm}}$ = 5.5×10^{-7} m $c = \lambda v \rightarrow 3.00 \times 10^8 \frac{\text{m}}{\text{s}} = 5.50 \times 10^{-7} \text{ m}(v)$ $\nu = 5.45 \times 10^{14} \text{ Hz} \times \frac{1 \text{ MHz}}{10^6 \text{ Hz}} = 5.45 \times 10^8 \text{ MHz} = 5.5 \times 10^8 \text{ MHz}$
19. Answer is C.	Core electrons are closest to the nucleus; therefore, they would be more efficient at screening the nuclear charge.
20. Answer is A.	Based on the rules of quantum, mechanics, the spin quantum number, m_s, is only allowed to be +½ or –½. This makes 4, 3, 0, 0 impossible.
21. Answer is B.	Changing reaction 1 to reaction 2: double coefficients, which requires raising *K* to the second power then reverse, which requires taking the reciprocal of *K*. Therefore, the equilibrium constant for reaction 2 would be $1/K^2$ 1. $SO_2(g)$ + ½ $O_2(g)$ ⇌ $SO_3(g)$ *K* 2. 2 $SO_3(g)$ ⇌ 2$SO_2(g)$ + $O_2(g)$ (reverse and multiply by 2)
22. Answer is B.	First, calculate the theoretical yield using $\% \text{ yield} = \frac{\text{actual}}{\text{theoretical}} \times 100$ $89.1 = \frac{3.50}{\text{theoretical}} \times 100$ → theoretical = 3.93 moles GeF_3H Then calculate the moles of GeF_4 $3.93 \text{ mol g } GeF_3H \times \frac{3 \text{ mol } GeF_4}{4 \text{ mol } GeF_3H} = 2.95 \text{ mole } GeF_4$
23. Answer is A.	Mass % = $\frac{\text{mass solute}}{\text{mass solution}} \times 100 = \frac{27.7 \text{ g}}{(27.7 \text{ g} + 375 \text{ g})} \times 100 = 6.88$ %
24. Answer is E.	The Pauli exclusion principle states that no two electrons in an atom can have the same set of four quantum numbers. The two parallel spin electrons in the 2s level for choice E would have the same set of four quantum numbers; therefore, this is a violation.
25. Answer is A.	There are three orbitals in the p-sublevel. Each orbital differs based on the orientation in 3D space. The x in p_x designates the axis of alignment for the orbital.
26. Answer is D.	Each row of the periodic table introduces a new valence shell; therefore, the quantum number for the valence electrons will increase. This causes a subsequent increase in radius.
27. Answer is E.	Combustion is the reaction with oxygen to produce CO_2 and H_2O. So, $C_4H_8O_2$ + __O_2 → __CO_2 + __H_2O Correctly balancing would result in five O_2 molecules.
28. Answer is B.	$3.549 \text{ moles atoms} \times \frac{1 \text{ mole } CO_2}{3 \text{ moles atoms}} \times \frac{44.01 \text{ g } CO_2}{1 \text{ mole } CO_2} = 52.06 \text{ g}$

29. Answer is E.	Since one mole of each compound is used to make the solution, the compound with the highest Van't Hoff factor would have the greatest effect on the freezing point. Li_3PO_4 has a Van't Hoff factor of 4, which is the highest of the possible choices.
30. Answer is D.	Quantized energy levels get closer together (lower energy) as the principal quantum number increases. As a result, n = 4 to n = 3 is a lower energy transition than n = 3 to n = 2. Lower energy transitions have both lower frequencies and higher wavelengths.
31. Answer is C.	Reduction can be defined as the loss of oxygen. Cr is losing oxygen going from left to right; therefore, it is the element being reduced.
32. Answer is E.	Based on the balanced chemical equation: $\frac{-\Delta[I^-]}{3\Delta T} = \frac{-\Delta[S_2O_8^{2-}]}{\Delta T}$ leading to $\frac{-(0.037-0.072)}{3(1200)} = \frac{-\Delta[S_2O_8^{2-}]}{1200}$ Therefore, $-\Delta[S_2O_8^{2-}] = -0.012\ M = [S_2O_8^{2-}]_f - 0.050\ M$ Therefore, $[S_2O_8^{2-}]_f = 0.038\ M$
33. Answer is D.	In an exothermic reaction, heat is released. Thus, A and B are incorrect. Because heat would be required to reverse the reaction, we can consider the products more stable (lower in energy) than the reactants.
34. Answer is C.	Methane is a non-polar molecule, so only London dispersion forces are present.
35. Answer is D.	Since NaOH completely dissociates into Na^+ and OH^-, the $[OH^-] = 0.0200\ M$. Using $pOH = -\log[OH^-]$, the pOH = 1.70. Therefore, the pH = 14.00 – 1.70 = 12.30.
36. Answer is B.	Answer is B. Manipulation of gas law, PV = nRT leads to $P = \frac{nRT}{V} = \frac{1.80\text{ mol x }0.0821\frac{L.atm}{mol.K}\text{ x }305\text{ K)}}{2.92\text{ L}} = 15.4\text{ atm}$
37. Answer is B.	MRI stands for magnetic resonance imaging, commonly used in hospitals.
38. Answer is C.	The mathematical relationship, $q = mC_p\Delta T$ leads to $q \propto C_p$ for the same mass and ΔT. Since the specific heat of water is greater than that of copper, more heat will be released by the water as it cools.
39. Answer is A.	Reacting with water carbon dioxide forms carbonic acid. $H_2O(\ell) + CO_2(g) \rightarrow H_2CO_3(aq)$
40. Answer is E.	In this problem P = 745 mmHg = 0.9803 atm, T = 28 °C + 273 = 301 K, and V = 248 mL = 0.248 L. Use of PV = nRT and mole (n) = gram mass ÷ molar mass will lead to Molar mass = $\frac{\text{mass x R x T}}{\text{P x V}} = \frac{0.433\text{ g x }0.0821\frac{L.atm}{mol.K}\text{ x }301\text{ K}}{0.9803\text{ atm x }0.248\text{ L}}$ = 44.01 g/mol