Annotated Solution
2010 USNCO Local Exam

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1. Let us use the equation for density to determine the volume.

$$d = \frac{m}{V}$$

$$V = \frac{m}{d}$$

Now, we can substitute $m = 30.0$ g and $d = 0.7914$ $\frac{\text{g}}{\text{mL}}$, we get

$$V = \frac{30.0}{0.7914} = \boxed{37.9 \text{ mL}}$$

Thus, the correct answer is $\boxed{D}$.

2. This question relies on your knowledge of flame test colors. $\boxed{\text{Copper}}$ is blue-green, sodium is yellow, strontium is red, and zinc is colorless. The answer is $\boxed{A}$.

3. The key fact to understand is that in basic solutions, phenolphtalein turns pink. Thus, we need to find a basic compound in order to create the pink solution. Both NaCl and LiBr are neutral salts, while NH_4NO_3 is weakly acidic due to the presence of $NH_4{}^+$, conjugate acid of the weak base NH_3. Thus, the correct answer is $\boxed{KC_2H_3O_2}$, or $\boxed{B}$. This works due to the presence of a neutral ion (K^+) and the weak base ($C_2H_3O_2{}^-$, conjugate base of the weak acetic acid $HC_2H_3O_2$).

4. Ionic solids like NaCl are are often soluble in water, but not in nonpolar solvents such as oil. Network solids and metallic solids such as diamond and titanium are generally not soluble in either solvent. A $\boxed{\text{molecular solid}}$, such as $\boxed{C}$, can be nonpolar (such as solid saturated fats) and therefore soluble in oil.

5. $\boxed{\text{Overheating the hydrate}}$ will cause the removal of some of the $CuSO_4$, which will cause the mass percent of H_2O to appear bigger. The option that fits this analysis is $\boxed{A}$.

6. We need to find an anion that precipitates selectively with silver, but not magnesium or strontium.

- Na^+ does not interact with any of the three cations.
- $MgCl_2$ and $SrCl_2$ are both soluble in water, but AgCl is not.
- OH^- precipitates with both magnesium and silver.
- $SO_4{}^{2-}$ salts of all three metals are insoluble except for Mg^{2+}
- $PO_4{}^{3-}$ salts of all three metals are insoluble.

Thus, the reagent that will most selectively precipitate the Ag^+ is the $\boxed{0.20 \text{ M NaCl}}$, or $\boxed{A}$.

7. We need to balance the S, so we can add a coefficient of 3 to the SO_2.

$$As_2S_3 + O_2 \longrightarrow As_2O_3 + 3\,SO_2$$

Now to balance the oxygens, we have 9 O on the products side, and 2 O on the reactants side. Thus, the reaction is

$$As_2S_3 + \frac{9}{2}O_2 \longrightarrow As_2O_3 + 3\,SO_2$$

However, to eliminate the fractional coefficient, we multiply by 2 throughout the equation.

$$2\,As_2S_3 + 9\,O_2 \longrightarrow 2\,As_2O_3 + 6\,SO_2$$

Thus, the coefficient on the O_2 is $\boxed{9}$, or $\boxed{D}$.

8. We are already given the molar masses, so we need to determine the number of N in each compound. For Compound A, we have

$$\frac{14.0}{33.0} \times 100\% = 42.4\%$$
$$\frac{28.0}{64.1} \times 100\% = 43.7\%$$
$$\frac{28.0}{76.0} \times 100\% = 36.8\%$$
$$\frac{28.0}{78.1} \times 100\% = 35.9\%$$

Thus, the correct answer is $\boxed{NH_4NO_2}$, or $\boxed{B}$.

9. We can use dimensional analysis with Avogadro's number.

$$0.025 \text{ mol} \times \frac{6.02 \times 10^{23} \text{ atoms}}{\text{mol}} \times \frac{(54-24) \text{ neutrons}}{\text{atom}} = \boxed{4.5 \times 10^{23} \text{ neutrons}}$$

Thus, the correct answer is $\boxed{C}$.

10. $MgCl_2$ is a typical ionic compound which dissolves in water. The dissociation of magnesium chloride with water is as follows. The term "hydrated" just means that each ion is surrounded by water molecules, represented by "aq" in the equation above)

$$MgCl_2(s) \longrightarrow \boxed{Mg^{2+}(aq) + 2\,Cl^-(aq)}$$

This reaction corresponds to answer $\boxed{B}$.

11. This is a stoichiometry problem, in which we want the mass of the ethanol formed from a given amount of glucose.

$$15.5 \text{ kg } C_6H_{12}O_6 \times \frac{1 \text{ mol } C_6H_{12}O_6}{180 \text{ g } C_6H_{12}O_6} \times \frac{2 \text{ mol } C_2H_5OH}{1 \text{ mol } C_6H_{12}O_6} \times \frac{46.1 \text{ g } C_2H_5OH}{1 \text{ mol } C_2H_5OH} = \boxed{7.93 \text{ kg}}$$

Thus, the correct answer is $\boxed{D}$.

12. We can solve this with dimensional analysis.

$$\frac{5.00}{100} \times \frac{1 \text{ mol}}{60.0 \text{ g}} \times \frac{1.00 \text{ g}}{\text{mL}} \times \frac{1000 \text{ mL}}{\text{L}} = \boxed{0.833 \text{ M}}$$

Thus, the answer is $\boxed{A}$.

13. We can use the combined gas law to solve this question, which is below.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

We are given that $V_1 = 2.00$, $T_1 = 20 + 273 = 293$ K, and $T_2 = 10 + 273 = 283$ K. Now, we can substitute to solve for V_2.

$$\frac{(745)(2.00)}{293} = \frac{(700)(V_2)}{283}$$

Solving, we get $V_2 = \boxed{2.06 \text{ L}}$, or $\boxed{C}$.

14. Only two elements are liquid in their standard state, which are bromine and mercury. Mercury's family (Group 12) is not an option; it has no gases, anyways. That leaves us with the halogens. Fluorine and chlorine are gases and iodine is a solid. Thus, the answer is $\boxed{\text{halogens}}$, or $\boxed{D}$. The trends of the boiling points and melting points of halogens can be further explained by the intermolecular forces.

15. We can use Graham's Law of Diffusion to get the following relation.

$$\frac{R_1}{R_2} = \sqrt{\frac{M_2}{M_1}}$$

We are given that $R_2 = \frac{1}{3}R_1$, and we know the molar mass of O_2 is $M_1 = 32$ g/mol. Substituting, we get

$$\frac{1}{\frac{1}{3}} = \sqrt{\frac{M_2}{32}}$$

$$3 = \sqrt{\frac{M_2}{32}}$$

$$M_2 = 9 \times 32 = 288$$

Thus, the correct answer is $\boxed{C_5F_{12}}$, or $\boxed{D}$.

16. Let us compare the molar masses of H_2O, N_2, O_2. The molecular mass of H_2O is 18 g/mol, N_2 is 28 g/mol, and O_2 is 32 g/mol. The equation for molar mass M in terms of density d is

$$M = \frac{dRT}{P}$$

This can be derived from $PV = nRT$. We see that the $\boxed{\text{molar mass of } H_2O \text{ is less}}$ than the other compounds, and thus will have a smaller density. Thus, the correct explanation is $\boxed{C}$.

17. Melting refers to the phase transition from solid to liquid, and sublimation to the transition from solid to gas. We additionally know that A represents the solid state, B represents the liquid state, and C represents the gas state based on the pressure and temperature of each area. Thus, $\boxed{\text{A} \rightarrow \text{B}}$ corresponds to melting, and the answer is $\boxed{A}$.

18. The definition of the supercritical fluid in a phase diagram is when the liquid and gas phases are indistinguishable, which is the area above critical temperature and critical pressure. So the critical temperature is also the $\boxed{\text{maximum temperature at which liquid water can exist}}$, as water will be either gas or supercritical fluid under a higher temperature. This description is most accurately depicted in answer choice $\boxed{C}$. Sketching a phase diagram to label each phase is a good way to solve problems like this.

19. Heat is needed for phase transitions where the molecules are excited. Endothermic reactions or processes, such as fusion (melting), vaporization (boiling), and sublimation, require heat. Exothermic reactions or processes, such as freezing, $\boxed{\text{condensation}}$, and deposition, release heat. Thus, the correct is $\boxed{A}$.

20. Reshuffle the reactions to get the desired final reaction. We see that the last reaction must remain the same to keep the $1\,N_2O_4$. However, let us double the first two reactions to eliminate the fractional coefficients.

$$N_2 + O_2 \longrightarrow 2\,NO$$

$$N_2 + 2\,O_2 \longrightarrow 2\,NO_2$$

$$2\,NO_2 \longrightarrow N_2O_4$$

However, seeing the final reaction, there is no N_2 present, so we need to reverse the first reaction to eliminate N_2.

$$2\,NO \longrightarrow N_2 + O_2$$

$$N_2 + 2\,O_2 \longrightarrow 2\,NO_2$$

$$2\,NO_2 \longrightarrow N_2O_4$$

Hess' Law allows us to calculate ΔH° for the final reaction:

$$\Delta H^\circ = 2(-1)(90.4) + 2(33.8) - 58.0 = \boxed{-171.2\ \frac{\text{kJ}}{\text{mol}}}$$

This is $\boxed{A}$.

21. The heat of a reaction can be calculated with:

$$\Delta H^\circ_{\text{rxn}} = \Delta H^\circ_{\text{f}}(\text{prod}) - \Delta H^\circ_{\text{f}}(\text{reac})$$

To calculate the sum of enthalpy of formation for products, we have the following.

$$\Delta H^\circ_{\text{f}}(\text{prod}) = -1675.7 + 2(12.4)\ \text{kJ/mol}$$

To calculate the sum of enthalpy of formation for reactants, we have the following. Note that the standard enthalpy of formation of Al, as with all standard elements, is 0.

$$\Delta H^\circ_{\text{f}}(\text{reac}) = -825.5 + 0 = -825.5\ \text{kJ/mol}$$

$$\Delta H^\circ_{\text{rxn}} = -1675.7 + 2(12.4) - (-825.5) = -825.4\ \text{kJ/mol}$$

$\Delta H^\circ_{\text{rxn}}$ is 'per mole', so we need to find the number of moles of reactant.

$$5.00\ \text{g}\ Fe_2O_3 \times \frac{1\ \text{mol}\ Fe_2CO_3}{159.68\ \text{g}\ Fe_2CO_3} \times \frac{-825\ \text{kJ}}{1\ \text{mol}\ Fe_2O_3} = \boxed{-25.8\ \text{kJ}}$$

Thus, the answer is $\boxed{A}$.

22. By just looking for the phases of the reactants and products, we can determine how the entropy changes, as the trend of molar entropy in general is $S_{\text{m}}(\text{gas}) >> S_{\text{m}}(\text{liquid}) > S_{\text{m}}(\text{solid})$. For Option A, there is no significant change in entropy because there is no phase change or change in number of moles. For Options C and D, there is a decrease in entropy, with a transition from gas to aqueous in Option C, and liquid to solid in Option D. The correct answer is the reaction below, or $\boxed{B}$, because there is a transition from solid to gas.

$$\boxed{CaCO_3(s) \rightarrow CaO(s) + CO_2(g)}$$

23. In order for a reaction to be spontaneous, $\Delta G < 0$. We know $\Delta G = \Delta H - T\Delta S$. At low temperatures, the ΔH term dominates; thus $\boxed{\Delta H \text{ must be negative}}$. At high temperatures, the $T\Delta S$ term dominates; T is in Kelvin and must always be positive in order to make $\Delta G > 0$, so $\boxed{\Delta S \text{ must be negative}}$. Thus, the correct answer is confirmed to be $\boxed{C}$.

24. The most stable elemental form of each element in their standard states have a value of 0 for standard free energy of formation, so we need to determine the answer choice that is not in standard state or not the most stable elemental form. We see that $\boxed{O_3}$ is not the most stable elemental form of oxygen, as O_2 is the standard state of oxygen. Thus, the answer is $\boxed{D}$.

25. Both temperature and concentration are factors that can increase the rate of the reaction. In addition, increasing the size of the solid particles will decrease the rate, as the surface area is smaller and less particles are exposed. Thus, the only non contributing factor is $\boxed{\text{volume of the container}}$, or $\boxed{B}$. This is because the reaction involves a solution reacting with a solid, so change in volume of the container doesn't affect the surface area of the solid nor the concentration of the solution.

26. We can do dimensional analysis to determine the rate of NH_3.

$$\frac{1.2 \times 10^{-3} \text{ mol } H_2}{\text{min}} \times \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} = \boxed{8.0 \times 10^{-4} \ \frac{\text{mol } NH_3}{\text{min}}}$$

Thus, the correct answer is $\boxed{D}$.

27. With an energy profile diagram (energy versus reaction progress) sketched, we can easily find that the relationship between the enthalpy change and the activation energy of forward and reverse reaction.

$$\Delta H = E_\text{a}(\text{f}) - E_\text{a}(\text{r})$$

where $E_\text{a}(\text{f}) = 140$ kJ is the forward rate activation energy, and $E_\text{a}(\text{r})$ is the reverse rate activation energy. We are given that $\Delta H = 100$ kJ, so we can just substitute to solve for $E_\text{a}(\text{r})$.

$$140 \text{ kJ} = E_\text{a}(\text{r}) + 100 \text{ kJ}$$

$$E_\text{a}(r) = \boxed{40 \text{ kJ}}$$

Thus, the correct answer is $\boxed{A}$.

28. First we can use the first-order half-life equation and solve for k.

$$t_{\frac{1}{2}} = \frac{\ln(2)}{k}$$

$$34.0 \text{ s} = \frac{\ln(2)}{k}$$

$$k = \frac{\ln 2}{34.0} \text{ s}^{-1}$$

Now, to solve for the time when $[\text{A}] = \frac{1}{8}[\text{A}_0]$, we can substitute our value of k into the first-order integrated rate law.

$$\ln[\text{A}] = -kt + \ln[\text{A}]_0$$

$$kt = \ln[\text{A}]_0 - \ln[\text{A}] = \ln\left(\frac{[\text{A}]_0}{[\text{A}]}\right) = \ln 8$$

$$t = \frac{\ln 8}{k} = \frac{34.0 \ln 8}{\ln 2} = 34.0 \times \log_2 8 = 34.0 \times 3 = \boxed{102 \text{ s}}$$

Thus, the answer is $\boxed{C}$. Alternatively, we can simply recognize that a "one-eighth life" is three half-lives because $(\frac{1}{2})^3 = \frac{1}{8}$.

29. The definition of an intermediate is a substance that is formed in one step, and consumed in a later step. The substance that fits this definition is $\boxed{C_3H_7{}^+}$, or $\boxed{B}$, which is produced in Step 1 and consumed in Step 2.

30. First we must determine the rate law. From experiment 1 to experiment 2, $[\text{I}^-]$ was divided by 2 and the rate was divided by 2 (thus the amount of time was multiplied by 2). Therefore, the reaction is first order in I^-. From experiment 1 to experiment 3, $[S_2O_8{}^{2-}]$ was divided by 4 and the rate was divided by 4. Therefore, the reaction is first order in $S_2O_8{}^{2-}$.

Finally, from reaction 3 to reaction 4, we first multiply the rate by 2 because $[\text{I}^-]$ was multiplied by 2. Then we divide the rate by 4 because $[S_2O_8{}^{2-}]$ was divided by 4. So far we have divided the rate by 2. Since the time is inversely proportional to rate, we multiply the time by 2. Therefore, the correct answer is $\boxed{C}$.

$$T_4 = T_3 \cdot 2 = 156 \times 2 = \boxed{312 \text{ sec}}$$

31. Note that S(s) will not count in calculating the equilibrium expression, as it is not aqueous or gaseous. (Its concentration is constant.) Therefore, the correct answer is $\boxed{D}$.

$$K_c = \boxed{\frac{[SO_3]^2}{[O_2]^3}}$$

32. Let us account for both an increase and decrease in volume. When the volume is increased, pressure decreases. The equilibrium state will shift to favor the side of the reaction with more moles of gases (thus increasing pressure). Similarly, a decrease in volume will shift the equilibrium state to favor the reaction with fewer moles. Looking at all of the answer choices, only the reaction below has more moles on the reactants than the products, and will therefore increase in reactant moles with a volume increase.

$$\boxed{N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)}$$

Thus, the correct answer is $\boxed{D}$.

33. First, let us write the reaction involving HCl and NaOH.

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(s) + H_2O(l)$$

Now, let us calculate the moles of HCl and moles of NaOH.

$$140.\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times \frac{0.107\ \text{mol HCl}}{\text{L}} = 0.0150\ \text{mol HCl}$$

$$200.\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times \frac{0.0657\ \text{mol NaOH}}{\text{L}} = 0.0131\ \text{mol NaOH}$$

Now to calculate [HCl] after the reaction, we can derive the following result.

$$[\text{HCl}] = \frac{(0.0150\ \text{mol} - 0.0131\ \text{mol})}{140. + 200. + 160.\ \text{mL}} \times \frac{1000\ \text{mL}}{1\ \text{L}} = 3.68 \times 10^{-3}\ \text{M}$$

This is equal to $[H_3O^+]$, so we can determine the pH by taking the antilog.

$$\text{pH} = -\log_{10}[H_3O^+] = -\log_{10}(3.68 \times 10^{-3}) = \boxed{2.43}$$

Thus, the answer is $\boxed{C}$.

34. Let us use the formula for percent ionization below to solve this question.

$$\%\ \text{ionization} = \frac{[COOH^-]}{[HCOOH]} \times 100\%$$

Now, let us write the reaction to represent this reaction.

$$HCOOH \rightleftharpoons H^+ + HCOO^-$$

Now, let us calculate the acid dissociation constant.

$$K_a = \frac{[H^+][HCOO^-]}{[HCOOH]}$$

From the reaction, we know that $[H^+] = [HCOO^-] = x$, for some value x. We are given the values of initial concentration of HCOOH = 0.10 M, and $K_a = 1.8 \times 10^{-4}$. Solving for x, we get

$$1.8 \times 10^{-4} = \frac{x^2}{0.10 - x}$$

Assume that the percent of ionization is less than 5%. $0.10 - x$ can be simplified to 0.10. (This is the 5% rule: if the percent of ionization is greater than 5%, we'll have to redo the calculation without crossing out x.)

$$x = 0.0042$$

We can now substitute into the percent ionization formula, and get

$$\% \text{ ionization} = \frac{0.0042}{0.10} \times 100\% = \boxed{4.2\%}$$

Thus, the correct answer is $\boxed{A}$. Moreover, 4.2% is less than 5%, which confirms the validity of the simplification.

35. Let us write the equilibrium reaction to determine K_a.

$$\text{HF} \rightleftharpoons \text{H}^+ + \text{F}^-$$

Solving for K_a, we get

$$K_\text{a} = \frac{[\text{H}^+][\text{F}^-]}{[\text{HF}]}$$

We are given that $K_\text{a} = 7.2 \times 10^{-4}$, $[\text{F}^-] = 0.40$, and $[\text{HF}] = 0.20$. Thus, we can substitute to solve for $[\text{H}^+]$.

$$7.2 \times 10^{-4} = \frac{0.40[\text{H}^+]}{0.20}$$

$$[\text{H}^+] = 3.6 \times 10^{-4} \text{ M}$$

Now taking the antilog of $[\text{H}^+]$, this will give us the pH.

$$-\log_{10}([\text{H}^+]) = \boxed{3.44}$$

Thus, the correct answer is $\boxed{D}$.

36. First, let us write the reaction to solve for K_sp.

$$\text{MgCO}_3\text{(s)} \rightleftharpoons \text{Mg}^{2+}\text{(aq)} + {\text{CO}_3}^{2-}\text{(aq)}$$

We know that $[\text{Mg}^{2+}] = [{\text{CO}_3}^{2-}] = S$, for some value S. Writing the expression for $K_\text{sp} = 4.0 \times 10^{-5}$, we get

$$K_\text{sp} = [\text{Mg}^{2+}][{\text{CO}_3}^{2-}]$$

$$4.0 \times 10^{-5} = S^2$$

$$S = 6.3 \times 10^{-3} \text{ M}$$

To solve for the volume that was evaporated, we can subtract the remaining from the total.

$$V = 500.\text{ mL} - 120.\text{ mL} = 380.\text{ mL}$$

Now, we can calculate the mass of the solid via dimensional analysis.

$$6.3 \times 10^{-3} \ \frac{\text{mol MgCO}_3}{1 \text{ L}} \times 0.380 \text{ L} \times \frac{84.3141 \text{ g MgCO}_3}{1 \text{ mol MgCO}_3} = \boxed{0.20 \text{ g MgCO}_3}$$

Thus, the correct answer is $\boxed{C}$.

37. If we check what elements displace the others, we can determine what metals are more reactive via the activity series. In Equation 1, Y displaces X, so Y > X. In Equation 2, Z displaces X, so Z > X. In Equation 3, however, Z does not displace Y, so Z < Y. Thus, with all of this information, we have

$$\boxed{\text{X} < \text{Z} < \text{Y}}$$

Thus, the correct answer is $\boxed{B}$.

38. To increase the voltage in a galvanic cell (i.e., drive the reaction towards the products), we can either increase the concentration of reactants, or decrease the concentration of products. The answer choice that corresponds to this is $\boxed{\text{increasing the } [\text{H}^+]}$, or $\boxed{C}$.

39. In NO_3^-, the oxidation state of nitrogen is +5. In NO, the oxidation state of nitrogen is +2. Therefore, we have $5 - 2 = \boxed{\text{3 electrons are gained}}$, and the answer is $\boxed{A}$.

40. By looking at the reaction, $\boxed{Cl^-}$ is the reducing agent because it is oxidized to Cl_2, and $\boxed{ClO_3^-}$ is the oxidizing agent because it is reduced to Cl_2. Thus, the answer is $\boxed{B}$.

41. To get the $Co(s)$ on the left side, we need to reverse the second reaction. Additionally, in order to get the 2 Ag^+, we need to double the first reaction, but this will not change the standard potential. Thus, the total voltage was

$$0.80 \text{ V} - (-0.28 \text{ V}) = \boxed{1.08 \text{ V}}$$

Thus, the correct answer is $\boxed{C}$.

42. We can use Faraday's Law to get the mass of the metal, m, which is stated below.

$$m = \frac{M}{n} \times \frac{It}{F}$$

In this equation, we have that n is the number of electrons transferred for each metal atom. From the metal deposit that we want, we can write the reaction

$$\text{Cu(s)} \longrightarrow \text{Cu}^{2+}\text{(aq)} + 2\,\text{e}^-$$

We are given that $I = 10.0$ A, $F = 96500 \ \frac{\text{C}}{\text{mol}}$, $t = 30.6$ s, $M = 63.54$ g/mol, and $n = 2$. Substituting, we get

$$m = \frac{63.54}{2} \times \frac{10.0 \times 30.6}{96500}$$

$$m = \boxed{0.101 \text{ g}}$$

Thus, the correct answer is $\boxed{A}$.

43. The wavelength formula proves that the $\boxed{\text{product of the frequency and the wavelength is equal to a constant}}$, or the speed of light in a vacuum: $\boxed{A}$.

$$c = \lambda f$$

Photon energy increases with *decreasing* wavelength. Amplitude (intensity) indicates how many photons are in a beam of light, not its wavelength. Green light is earlier on the ROYGBIV spectrum and is thus lower frequency than blue light.

44. This question tests knowledge about early experiments to characterize the atom. Rutherford shot positively charged alpha particles at gold foil, expecting them to all pass through albeit with some small angle of deflection. At the time, the reigning atomic model was the "plum pudding model", with electrons uniformly distributed through a positive proton cloud. Surprisingly, while most alpha particles passed through atoms with no issue, a few were sharply deflected. This indicated the existence of a small and densely positive $\boxed{\text{nucleus}}$, or $\boxed{D}$.

45. Ionization energy increases as you travel from left to right*, but decreases while going down a group. Thus, the element closest to the top right will have the highest ionization energy. The answer choice that is closest is $\boxed{\text{Cl}}$, or $\boxed{B}$. Note that Group 13 and 16 are exceptions to this trend due to the relative smaller electron-electron repulsion related to their electron configuration.

46. Atomic radius increases from right to left. Additionally, cations have a smaller atomic radius than isoelectronic anions. Among cations, size decreases with increasing positive charge, and among anions, size increases with increasing negative charge due to increasing electron repulsion. Understanding these trends, we can rank the species below.

$$Li^+ < He < F < Li < F^- < O^{2-}$$

Looking at the pairs in the answer choices, we see that $\boxed{Li^+ \text{ and } O^{2-}}$ have the greatest radii difference. Thus, the correct answer is $\boxed{C}$.

47. First, let us write the standard electron configuration for Co.

$$\text{Co} \ : \ [\text{Ar}]4\text{s}^2 3\text{d}^7$$

Removing 3 electrons results in the following configuration:

$$\text{Co} \ : \ [\text{Ar}]3\text{d}^6$$

This is because the electrons in the s orbital are removed first, and then one electron in the d orbital. Thus, by placing the first 5 electrons, and then placing the last electron, we have $\boxed{4}$ unpaired electrons, or $\boxed{C}$.

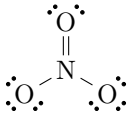
48. As and Ge are both semi-metals, so they will not have a high electrical conductivity. P is a non metal, so it will have a low electrical conductivity. Thus, the only option that works is $\boxed{\text{Sn}}$, or $\boxed{D}$. This makes sense because Sn is a metal, and metals are good electrical conductors.

49. O has 6 valence electrons, and S has 6 valence electrons, with the $2-$ charge. Thus, the total number of valence electrons is as follows, and the correct answer is $\boxed{D}$.

$$1(6) + 5(6) + 2 = \boxed{38}$$

50. Bond strength is inversely proportional to the bond length. H-F has the shortest bond of the answer choices, which necessarily implies that it is the strongest. Thus, the correct answer is $\boxed{\text{HF}}$, or $\boxed{B}$.

51. First we must draw the structure.



We see that the molecule is trigonal planar. Because the molecule is planar, the bond angles will sum up to $360°$. Because of resonance, all three bonds will have the same length and the same angle.

$$3\theta = 360°$$

$$\theta = \boxed{120°}$$

Thus, the correct answer is $\boxed{A}$.

52. Drawing the Lewis structures for all of the options will reveal that the individual bond dipoles do not cancel out in NCl_3 and PCl_3 due to the presence of lone pairs, and in CHCl_3 is polar due to the molecule being asymmetrical. However, $\boxed{\text{BCl}_3}$, or $\boxed{A}$, adopts a trigonal planar structure and is nonpolar. Note that the center boron atom is electron deficient, but this is common for boron.

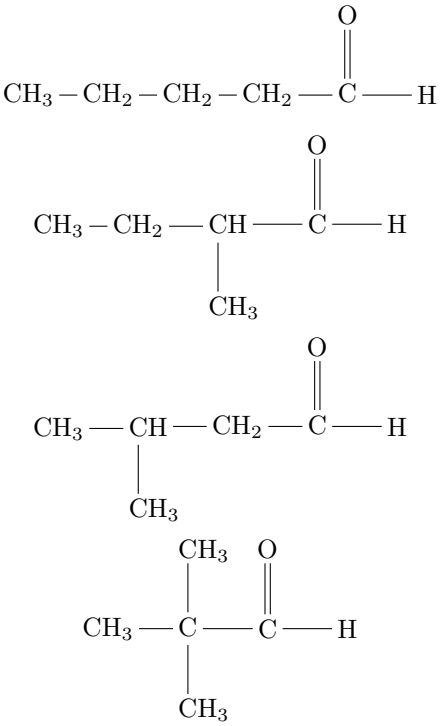
53. Boiling point increases with the strength of the intermolecular forces. CH_4 has the lowest boiling point as it is the only one without hydrogen bonds, therefore, we can eliminate B and C. Regarding A and D, we need to compare the hydrogen bond strength in H_2O and HF, each water molecule can form two hydrogen bonds averagely, while each HF molecule can only form one hydrogen bond, therefore, water has a higher boiling point than HF. The reason that NH_3 has a significantly lower boiling point is because of the smaller difference in electronegativity of H and N. Thus, the correct ordering is $\boxed{D}$, or the ordering as follows.

$$\boxed{\text{CH}_4 < \text{NH}_3 < \text{HF} < \text{H}_2\text{O}}$$

54. Lattice energy is described by Coulomb's law, increasing with the product of ionic charges and decreasing with ionic radii. NaCl and KBr both have ions with a charge of $1+$ and $1-$, while MgO and SrS have ions with charges of $2+$ and $2-$. MgO will have a smaller ionic radius than SrS due to the less electron layers of Mg and O. Thus, the correct answer is $\boxed{\text{MgO}}$, or $\boxed{B}$.

55. It seems natural to view the bottom right line as part of the main carbon chain. Instead, let the long zig-zag from the bottom left to the top right be the main carbon chain as it is the longest. Then we see there are 6 points on the chain, so we are dealing with some form of hexane. Then we see a branch coming out of the third point from the top right, so we have a 3-methyl group. Thus the answer is $\boxed{\text{3-methylhexane}}$, or $\boxed{C}$.

56. $C_5H_{10}O$ has many different isomers, $\boxed{4}$ of which are aldehydes. We must draw all possible aldehydes to answer this question. As aldehyde group can only be on the terminal position, a systematic strategy is to decrease the number of the carbons on the main chain (the longest carbon chain with the **-**CHO group) and to add the remaining carbon(s) as branch(es). Thus, the correct answer is $\boxed{C}$.



57. Decolorization of bromine from yellow-orange to colorless occurs when Br_2 is added across a double or triple bond. Both of the answer choices B and C (cyclohexane and hexane) are both completely saturated, and bromine cannot add to them. A, benzene, is aromatic, and thus does not undergo electrophilic addition with bromine (in order to remain the aromatic system). This leaves us with, or $\boxed{\text{1-hexene}}$, or $\boxed{D}$, producing 1,2-dibromohexane.

58. The combination of a $\boxed{\text{carboxylic acid and an alcohol}}$ will create an ester through esterification. Thus, the correct answer is $\boxed{A}$.

59. The $-SH$ groups can be oxidized to form $S-S$ bridges between different areas of a polymer (eg: proteins). The process of adding sulfur to strengthen rubber is known as vulcanization. The answer is $\boxed{\text{S}}$, or $\boxed{D}$.

60. When a fat is unsaturated, it $\boxed{\text{contains carbon-carbon double bonds}}$ (or triple bonds). When the fat is saturated with hydrogen, the carbon must lose these double bonds in order to form single bonds with hydrogen. Thus, the answer is $\boxed{B}$. We know A and D are incorrect because both types of fat are common in many foods of animal origin: saturated are common in meat and unsaturated are common in fish.