

Annotated Solution

2013 USNCO Local Exam

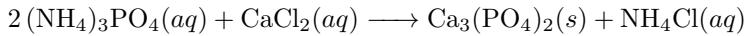
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1. We can treat the ions as separate entities in order to balance this equation. Let us start by writing the unbalanced reaction.



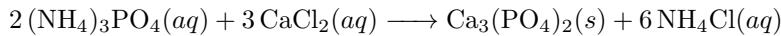
There are 2 PO_4^{3-} ions on the products side, but 1 PO_4^{3-} on the reactants side. So, we add a coefficient of 2 to $(\text{NH}_4)_3\text{PO}_4$.



There is 1 NH_4^+ ion on the products side, but 6 NH_4^+ on the reactants side. So, we add a coefficient of 6 to NH_4Cl .



There are now 6 Cl^- ions on the products side, while there are only 2 Cl^- ions on the reactants side. Thus, we add a coefficient of 3 to CaCl_2 .



The reaction is now balanced. Adding the coefficients, we get $6 + 3 + 2 + 1 = \boxed{12}$, or \boxed{D} .

2. Both molarity (mol/L) and density (mass/volume) require the volume of the solution, so it will be impossible to solve without knowing density of the solution. Molality, which has units in terms of $\frac{\text{mol solute}}{\text{kg solvent}}$, does not require volume. Thus, the answer is $\boxed{\text{II only}}$, or \boxed{B} .

3. We can do dimensional analysis using Avogadro's constant to yield \boxed{C} as our answer.

$$4.5 \times 10^{23} \text{ O atoms} \times \frac{1 \text{ mol O}}{6.02 \times 10^{23} \text{ O atoms}} \times \frac{1 \text{ mol CrO}_3}{3 \text{ mol O}} \times \frac{100.0 \text{ g}}{\text{mol CrO}_3} = \boxed{25.0 \text{ g}}$$

4. Sn can form both Sn(II) and Sn(IV) ions; we can't differentiate between A and B. We thus need to calculate the ratio of the elements.

$$18.5 \text{ g} \times \frac{1 \text{ mol}}{118.7 \text{ g}} = 0.156 \text{ mol Sn}$$

$$10.0 \text{ g} \times \frac{1 \text{ mol}}{32.07 \text{ g}} = 0.313 \text{ mol S}$$

Because $0.313 : 0.156 \approx 2 : 1$, there are two sulfur atoms for each tin atom. Thus, the formula for the compound is $\boxed{\text{SnS}_2}$, and the answer is \boxed{B} .

5. The moles of NaOH in the two solutions before mixing is equal to the moles of NaOH in the combined solution:

$$M_1V_1 + M_2V_2 = M_3V_3$$

We are given initial molarities and volumes and can add the volumes to get our final volume (0.125 L). Plug in these numbers to solve for the final molarity (M_3).

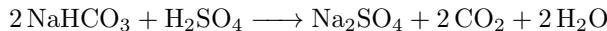
$$(0.200)(0.0500) + (0.100)(0.0750) = M_3(0.1250)$$

$$M_3 = 0.140 \text{ M}$$

$$[\text{OH}^-] = 0.140 \times \frac{1 \text{ mol OH}^-}{\text{mol NaOH}} = \boxed{0.140 \text{ M OH}^-}$$

Thus, the answer is **C**.

6. First, write a balanced reaction for the neutralization of H₂SO₄ with NaHCO₃.



Using dimensional analysis to determine the grams of NaHCO₃ yields **C**.

$$(0.125 \text{ M H}_2\text{SO}_4) \cdot (0.0250 \text{ L}) \cdot \frac{2 \text{ mol NaHCO}_3}{1 \text{ mol H}_2\text{SO}_4} \cdot \frac{84.0 \text{ g NaHCO}_3}{\text{mol NaHCO}_3} = \boxed{0.525 \text{ g NaHCO}_3}$$

7. Decantation separates liquid (supernatant) from solid (precipitate) by carefully pouring off the liquid. Distillation uses differing boiling points to separate two liquid substances. Filtration runs solutions through fine holes so that a solid can be removed or collected. **Hydration**, or **D**, is the process of adding water and does nothing to separate liquids from solids.

8. The reported density varies greatly from the experimental value. Therefore, the accuracy is low. However, the precision of the results is high because all of the results are very close to each other. Thus, the results can be described as **low accuracy and high precision**, or **B**.

9. This question tests the understanding of chlorides and sulfides. Metal chlorides, except for those of Pb²⁺, Hg₂²⁺, and Ag⁺, are soluble. Metal sulfides are mostly insoluble, except for those of Na⁺, and K⁺. **Pb²⁺**, or **D**, is insoluble in both cases.

10. First, A is a weak acid, which dissociates with a very small degree, as indicated by the K_a value. While B, C, and D are strong electrolytes, which fully dissociate into ions. More ions means higher conductivity. Thus, **HC₂H₃O₂(aq)**, or **A**, has the lowest electrical conductivity.

11. The Clausius-Clapeyron equation describes the phase transition between liquid and gas:

$$\ln P_{\text{vap}} = \frac{-\Delta H}{R} \left(\frac{1}{T} \right) + C$$

We can clearly see that P_{vap} increases with T but not linearly, so we can eliminate both C and D. Rewriting the equation as follow:

$$\ln \frac{P_2}{P_1} = \frac{-\Delta H}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) = \frac{-\Delta H}{R} \left(\frac{T_1 - T_2}{T_1 T_2} \right) = \frac{\Delta H}{R} \left(\frac{T_2 - T_1}{T_1 T_2} \right)$$

So when T is lower, P_{vap} increases faster. Thus, only **A** depicts an exponential function.

12. Let us write the equation that is being used to calculate the molarity of NaOH. The moles of HCl must equal the moles of NaOH at the equivalence point:

$$M_{\text{HCl}} \times V_{\text{HCl}} = M_{\text{NaOH}} \times V_{\text{NaOH}}$$

Solving for M_{NaOH} , we derive the following relationship between volumes and molarity:

$$\frac{M_{\text{HCl}} \times V_{\text{HCl}}}{V_{\text{NaOH}}} = M_{\text{NaOH}}$$

Our molarity is too low. In A, leftover neutralized solution won't affect the result as it just adds some neutral solution to trial 3; B asks about phenolphthalein, which is an indicator. More drops of indicator may cause the end point to show earlier if NaOH(aq) is added dropwisely to HCl(aq), which needs less volume of NaOH to titrate, thus increasing the molarity. C assumes a higher concentration of HCl, which would increase the molarity of NaOH. In **D**, the correct answer, **some NaOH is lost**, and thus the molarity is low.

13. We can use the combined gas law to solve this problem:

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

We are told that $P_1 = 1.20$ atm, $P_2 = 3.60$ atm, $V_1 = 0.500$ L, $T_1 = 25 + 273 = 298$ K, and $T_2 = 348$ K, and asked to solve for V_2 .

$$\frac{(1.20 \text{ atm})(0.500 \text{ L})}{298 \text{ K}} = \frac{(3.60 \text{ atm})(V_2)}{348 \text{ K}}$$

We get $V_2 = \boxed{0.195 \text{ L}}$, or \boxed{B} .

14. We are given the total pressure, and we can calculate the mol fractions of the elements individually.

$$\chi(\text{N}_2) = 0.700$$

$$\chi(\text{O}_2) = 1 - 0.700 = 0.300$$

Now that we have the total pressures, we can calculate the partial pressure of the O_2 . Note that pressure is directly proportional to the number of moles from $PV = nRT$.

$$P(\text{O}_2) = 0.300 \times P_t = 0.300 \times 1.42 \text{ atm} = \boxed{0.426 \text{ atm}}$$

Thus, the answer is \boxed{B} .

15. Boiling point increases with increasing intermolecular forces. B, C, and D all contain polar C–O bonds, allowing for dipole-dipole interactions, C has even stronger hydrogen bonds. The only nonpolar molecule is $\boxed{\text{CH}_3\text{CH}_2\text{CH}_3}$, or A, which only has London Dispersion Forces. One more fact to point out is that all four molecules have similar molar mass, which indicates comparable London Dispersion Forces. Thus, \boxed{A} has the lowest boiling point.

16. A critical point is the point on a phase diagram at which $\boxed{\text{liquid and gas are indistinguishable}}$, or \boxed{B}

17. Molecules mix with substances containing similar intermolecular forces, as quoted by "like dissolves like"; mixtures that separate into layers are composed of substances with opposite polarities, which is also called immiscible. Of the given choices, ethanol and methanol (A) are both polar and capable of hydrogen bonding. In the answer, \boxed{B} , $\boxed{\text{carbon tetrachloride}}$ is non-polar, while $\boxed{\text{methanol}}$ is polar. Hexane and pentane (C) are both nonpolar, as are carbon tetrachloride and hexane (D).

18. Density is equal to mass/volume. The unit cell containing the fewest number of atoms will be the least dense. Body-centered cubic (A) unit cells contain 2 atoms. Face-centered cubic (B) and hexagonal [closest packed] unit cells contain 4 and 2 atoms, respectively. $\boxed{\text{Simple cubic}}$ unit cells, or \boxed{D} , contain only 1 atom, and thus will have the lowest density. Note that the volume of each unit cell of the hexagonal lattice is smaller than that of face-centered cubic one.

19. Conservation of energy dictates that the energy lost by the NaOH is equal to the energy gained by the H_2O . Thus, we can use $q = mC \times \Delta T$ to solve for the energy. (Note that m is the sum of the masses of NaOH and H_2O , since they are now combined and both must be heated.)

$$q = (100.00 + 10.00 \text{ g}) \times \left(4.18 \frac{\text{J}}{\text{g } ^\circ\text{C}} \right) \times (48.2 - 24.0 \text{ }^\circ\text{C}) = 11127 \text{ J} = \boxed{1.11 \times 10^4 \text{ J}}$$

Thus, the answer is \boxed{D} .

20. Heats of formation refer to enthalpy values for the formation of 1 mol of molecules from their constituent elements in their standard states. For instance, oxygen is present as diatomic oxygen (O_2), not ozone (O_3), in its standard state. Heat of reaction can be calculated by subtracting reactant enthalpies from product enthalpies. In order for heat of formation to equal heat of reaction, all reactants must be elements in their standard states. This eliminates Option 2, and the answer is \boxed{A} , or \boxed{I} .

21. We can calculate ΔH_f° by subtracting the reactants' enthalpies from the products' enthalpies. All we have to do substitute, since we have all of the values, leading us to **[A]**.

$$\Delta H_{\text{rxn}}^\circ = \Delta H_f(\text{prod}) - \Delta H_f(\text{reac})$$

$$\Delta H_{\text{rxn}}^\circ = (-95.4) - 2 \times (92.3) - (-74.6)$$

$$\Delta H_{\text{rxn}}^\circ = \boxed{-205 \frac{\text{kJ}}{\text{mol}}}$$

22. We can do dimensional analysis to determine the molar enthalpy.

$$-296.6 \text{ kJ} \times \frac{46.02 \text{ g}}{1 \text{ mol}} \times \frac{1}{10.00 \text{ g}} = \boxed{-1366 \frac{\text{kJ}}{\text{mol}}}$$

Thus, the correct answer is **[B]**.

23. Increasing entropy corresponds to randomness and increasing disorder. Liquids and solids are both comparably ordered, so there is little entropy gained or lost between them. It is conversions to or from gases that impact entropy the most; look for an answer choice where the moles of gases increases from reactant to product. In all the other answer choices, the amount of gas either decreases or stays the same. Thus, the correct reaction is as follows, and the correct answer is **[C]**.



24. For these types of questions, remember the following four cases at standard state.

- If $\Delta S^\circ > 0$ and $\Delta H^\circ < 0$ (exothermic), then a reaction is *always* spontaneous.
- If $\Delta S^\circ < 0$ and $\Delta H^\circ > 0$ (endothermic), then a reaction is *never* spontaneous.
- If $\Delta S^\circ > 0$ and $\Delta H^\circ > 0$, then a reaction is spontaneous only at high temperatures.
- If $\Delta S^\circ < 0$ and $\Delta H^\circ < 0$, then a reaction is spontaneous only at low temperatures.

You can also get the same conclusion by analyzing the sign of ΔG° with the equation $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$. In the given reaction, the moles of gases increase from reactants to products, and so $\Delta S^\circ > 0$. Combined with a positive heat of reaction, we can conclude that the reaction is **spontaneous at high temperatures**, or **[B]**.

25. We can just use dimensional analysis to determine the rate of consumption of B.

$$\frac{2.0 \text{ mol A}}{\text{L} \times \text{s}} \times \frac{3 \text{ mol B}}{2 \text{ mol A}} = \boxed{\frac{3.0 \text{ M B}}{\text{s}}}$$

Thus, the answer is **[D]**.

26. Rate always has units of concentration/time. This is a second order reaction, so we can write:

$$\text{rate} = k[\text{A}]^2 = \text{M s}^{-1}$$

Since concentration [A] is in units of M, we can solve for the rate constant *k*.

$$k(\text{M})^2 = \text{M s}^{-1}$$

$$k = \boxed{\text{M}^{-1}\text{s}^{-1}}$$

Thus, the answer is **[B]**.

27. We can use the integrated first order rate law as follows.

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

$$[A] = [A]_0 e^{-kt}$$

In order to find k , we can use the time of $t = 120$ hr, $[A] = 250 \text{ min}^{-1}$, and $[A]_0 = 2000 \text{ min}^{-1}$.

$$250 \text{ min}^{-1} = 2000 \text{ min}^{-1} \times e^{(-k \times 120 \text{ hr})}$$

Dividing, we get

$$\frac{1}{8} = e^{-120k \text{ hr}}$$

Taking the natural log and using log rules, we get

$$-3 \ln 2 = -120k \text{ hr}$$

$$k = \frac{\ln 2}{40 \text{ hr}}$$

Now in order to determine the half-life, we need to substitute $[A] = 0.5[A]_0$, and solve for $t_{1/2}$.

$$\frac{1}{2} = e^{t_{1/2} \times -\frac{\ln 2}{40 \text{ hr}}}$$

Taking the natural log, we get

$$-\ln(2) = -\frac{t_{1/2} \times \ln 2}{40 \text{ hr}}$$

Solving for t , we get $t_{1/2} = \boxed{40 \text{ hr}}$, or \boxed{C} .

28. Similar to the philosophy that a chain is only as strong as its weakest link, the **slowest** step is what determines the overall rate of the reaction. Thus, the answer is \boxed{D} .

29. A homogeneous catalyst is defined as a catalyst that is in the same phase as the reactants. Check the phases of the catalysts in each answer choice. For Option I, there is a solid catalyzing with gas reactants. In this case, Pt would be a heterogeneous catalyst. Options **II and III** both feature catalysts and reactants in the same phase, leading us to \boxed{D} .

30. The activation energy of a reverse reaction is defined as the amount of energy needed to take the products of the forward reaction to the transition state. Seeing that the products have an energy of 60 kJ, and the transition state is at ≈ 85 kJ, we can subtract these to get the reverse reaction's activation energy:

$$85 \text{ kJ} - 60 \text{ kJ} = \boxed{25 \text{ kJ}}$$

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

31. Solids and liquids have constant concentrations, and so they are not included in equilibrium expressions. The only molecule that will account for when determining the equilibrium expression is the O₂ as follows.

$$K = \boxed{[\text{O}_2]}$$

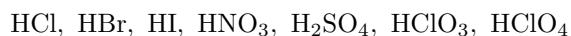
Thus, the answer is \boxed{D} .

32. Determine which process, in the answer choices, actually shifts equilibrium.

For Choice A, decreasing the temperature will shift the reaction towards the right (where heat is produced) to balance the loss in heat. In Choice C, adding an inert gas will not shift equilibrium, as there is no change in partial pressures. In Choice D, the addition of products changes such that $Q_c > K_c$, causing a shift towards the reactants.

Decreasing the container volume will increase pressure, which favors the side with fewer moles of gases (products). Thus, the correct answer is \boxed{B} .

33. For future reference, remember the 7 strong acids



HI is the only strong acid among the given options. The other acids, HF and HNO₂, are weak acids. Thus, the correct options are **I and III**, or **D**.

34. A conjugate acid is a base that has accepted a proton, and a conjugate base is an acid that has donated a proton. The conjugate base of HCO₃⁻ will donate a proton (H⁺), and then become **CO₃²⁻**, or **D**.

35. We must find the molar solubility of each salt (s), instead of directly comparing the K_{sp} values.

$$[\text{Ag}^+][\text{Cl}^-] = (s)(s) = s^2 = K_{\text{sp}}$$

$$\text{AgCl} : [\text{Ag}^+] = s = \sqrt{K_{\text{sp}}} = 1.3 \times 10^{-5} \text{ M}$$

$$[\text{Ag}^+]^2[\text{CrO}_4^{2-}] = (2s)^2(s) = 4s^3 = K_{\text{sp}}$$

$$\text{Ag}_2\text{CrO}_4 : [\text{Ag}^+] = 2s = 2 \times \sqrt[3]{\frac{K_{\text{sp}}}{4}} = 1.3 \times 10^{-4} \text{ M}$$

$$[\text{Ag}^+]^3[\text{PO}_4^{3-}] = (3s)^3(s) = 27s^4 = K_{\text{sp}}$$

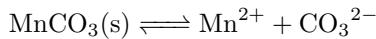
$$\text{Ag}_3\text{PO}_4 : [\text{Ag}^+] = 3s = 3 \times \sqrt[4]{\frac{K_{\text{sp}}}{27}} = 4.8 \times 10^{-5} \text{ M}$$

$$[\text{Ag}^+]^2[\text{S}^{2-}] = (2s)^2(s) = 4s^3 = K_{\text{sp}}$$

$$\text{Ag}_2\text{S} : [\text{Ag}^+] = 2s = 2 \times \sqrt[3]{\frac{K_{\text{sp}}}{4}} = 2.3 \times 10^{-15} \text{ M}$$

We see that the salt with the highest [Ag⁺] is **Ag₂CrO₄**, or **B**.

36. First, determine the concentration of MnCO₃. Each mole of MnCO₃ dissociates into one mole of Mn²⁺ and CO₃²⁻ each (both with concentrations *x*), which are necessary for finding K_{sp} .



$$x = [\text{MnCO}_3] = 5.44 \times 10^{-5} \text{ g MnCO}_3 \times \frac{1 \text{ mol MnCO}_3}{114.95 \text{ g MnCO}_3} \times \frac{1}{0.100 \text{ L}} = 4.7 \times 10^{-6} \text{ M MnCO}_3$$

To calculate K_{sp} , we can use the equation below

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

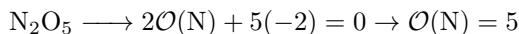
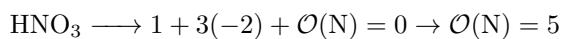
$$K_{\text{sp}} = x^2 = (4.7 \times 10^{-6})^2 = \boxed{2.2 \times 10^{-11}}$$

Thus, the answer is **C**.

37. Oxidation happens at anodes, and reduction at cathodes. The more active metal has a smaller standard reduction potential, and will serve as the anode. From the first statement, we know that $E_A^\circ > E_B^\circ$. From the second statement, we know that $E_C^\circ > E_B^\circ$. From the third statement, we know that $E_C^\circ > E_A^\circ$. Given these three statements, we can identify the correct ordering as follows, and that the correct answer is **C**.

$$\boxed{\text{C} > \text{A} > \text{B}}$$

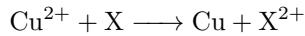
38. The easiest way to solve this problem is just check all molecules to determine the oxidation number of N. O has an oxidation state of -2 in each of these molecules, and H an oxidation state of +1. For Option 1, we have the following, where $\mathcal{O}(n)$ denotes the oxidation state of the element.



Thus, the two molecules in which N has the same oxidation number are **HNO₃ and N₂O₅**, or **A**.

39. An oxidizing agent oxidizes the others and is reduced in the process. A reducing agent reduces the others and is oxidized. Pb, oxidized from Pb(0) to Pb(II) in PbSO_4 , serves as the reducing agent. $\boxed{\text{PbO}_2}$, reduced from Pb(IV) to Pb(II) in PbSO_4 , is the oxidizing agent. Thus, the answer is \boxed{B} .

40. As the copper half-cell is the cathode, Cu^{2+} is reduced. The general equation for this reaction is



X is acting as an anode and being oxidized.

$$E_{\text{cell}}^{\circ} = E_{\text{Cu}^{2+}/\text{Cu}}^{\circ} - E_{\text{X}^{2+}/\text{X}}^{\circ}$$

$$0.47 \text{ V} = 0.34 \text{ V} - E_{\text{X}^{2+}/\text{X}}^{\circ}$$

$$E_{\text{X}^{2+}/\text{X}}^{\circ} = \boxed{-0.13 \text{ V}}$$

The answer is \boxed{B} . Note that since all reagents are at standard concentration, or 1.0 M, we have no need for the Nernst Equation here.

41. This type of electrochemistry question is a Le Chatelier's Principle problem in disguise. An increase in voltage is associated with an increase in product concentration. Now, let us analyze the four answer choices.

- A: an increase in reactants pushes the reaction towards the right.
- B: an increase in products pushes the reaction towards the left.
- C: a decrease in reactants pushes the reaction towards the left.
- D: reducing electrode size decreases surface area and thus rate of reaction (kinetics), but has no effect on equilibrium (thermodynamics).

Therefore, $\boxed{\text{increasing } [\text{Sn}^{2+}]}$ is the only option increases product concentration and voltage, and the answer is \boxed{A} .

42. First, we will select the half-reactions that are most likely to happen.

In terms of reduction at the cathode, water (-0.80 V) competes with K^+ (-2.92 V). Water has a less negative reduction potential, so Reaction 3 happens at the cathode with formation of hydrogen gas and hydroxide ions. In electrochemistry, a more negative potential means the species with higher oxidation number is harder to gain electrons as electrons flow from lower potential to higher potential.

In terms of oxidation at the anode, water (-1.23 V) competes with Br^- (-1.07 V). Br^- has a less negative **reduction** potential, so Reaction 2 happens at the anode, and brown diatomic bromine is formed. We may interpret the conclusion in a similar way, a less positive **reduction** potential means the species with a lower oxidation is easier to lose electrons.

Now, let's look at the answer choices. Solid metal is not formed at either reaction, so A is out. $\boxed{\text{Bubbles forming}}$ correspond to gas formation; this lines up with the formation of hydrogen at the cathode. As an indicator, phenolphthalein $\boxed{\text{turns pink}}$ in the presence of a base, corresponding with formation of OH^- at the cathode. C would be correct if we were talking about the anode, but no bromine is formed at the **cathode**. D is half right, but phenolphthalein would only remain clear if no OH^- were formed. Thus, the correct answer is \boxed{B} .

43. $\boxed{\text{Ernest Rutherford}}$ 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 tiny and densely positive nucleus. Thus, the correct answer is \boxed{D} .

Bohr proposed the concept of quantized energy levels for electrons, deBroglie concocted the deBroglie equation which concludes that all matter has wave properties including electrons, and Millikan measured the elementary electric charge by using the oil drop experiment.

44. Every energy level has a *s* subshell, so A is valid. All energy levels with $n \geq 2$ have *p* subshells, so B is valid. Only energy levels with $n \geq 4$ have *f* subshells, so $[3f]$, or $[C]$, is invalid. All energy levels with $n \geq 3$ have *d* subshells, so D is valid.

45. Atomic number, or the number of protons, determines the identity of the element. From a periodic table, we can see that Mn has 25 protons. Atomic weight, 55, is the sum of protons and neutrons; there must be 30 neutrons. The +2 charge indicates that there are two more protons than electrons. Thus, the correct answer is $\boxed{\text{Row A}}$, or \boxed{A} .

46. Potassium's characteristic color is $\boxed{\text{violet}}$, so the answer is \boxed{D} . Some useful flame test colors to memorize are the Group 1 - 3 elements.

47. Electronegativity increases from left to right, and decreases from top to bottom. Among the third row elements (Na, P, Cl), Cl is most electronegative. Between the halogens, Cl is more electronegative than Br. Thus, the correct element is $\boxed{\text{Cl}}$, and the answer is \boxed{C} .

48. If you can't remember which elements are metalloids, eliminate every pair that contains a metal or nonmetal. A contains transition *metals*, C contains common metals tin and lead, and D contains nonmetal bromine. Only \boxed{B} contains two metalloids, which are $\boxed{\text{Ge and As}}$ and are located near the zigzag boundary of typical metals and non-metals on the periodic table.

49. The Si–O bonds are $\boxed{\text{polar covalent}}$ due to the difference in electronegativity between the two elements. Thus, the answer is \boxed{D} .

50. First, bond strength is generally proportional to the bond order, the number of bonds in between atoms. All four options are double bonds. Another factor to affect the bond strength is the bond length. As we know, atomic radius decreases across a period, due to increasing effective nuclear charge. The smallest atom out of C, N, O, and S is O. Smaller atomic radius allows for less bond distance. Because shorter bonds have stronger interactions, the strongest bond is the $\boxed{\text{C=O}}$ bond, or \boxed{C} .

51. Let us define the answer choices given.

- Geometric isomers refer to *cis-trans* isomers
- Enantiomers are mirror images of each other.
- $\boxed{\text{Resonance forms}}$ are alternative Lewis structures of the same molecule, where electrons and pi bonds are shuffled around the molecule.
- Structural isomers are where atoms are bonded in different ways

Thus, \boxed{C} best describes the relation between the two species.

52. Draw the Lewis structures. We see that BF_3 is trigonal planar (120°). CF_4 is tetrahedral (109.5°) NF_3 is trigonal pyramidal (around 107.5° , since the lone pair on the nitrogen pushes the fluorine atoms closer to each other). OF_2 has two lone pairs and is bent (around 104.5° , since there are two lone pairs on the oxygen, pushing down the fluorines even more. Thus, the correct compound is $\boxed{\text{OF}_2}$, and the answer is \boxed{D} .

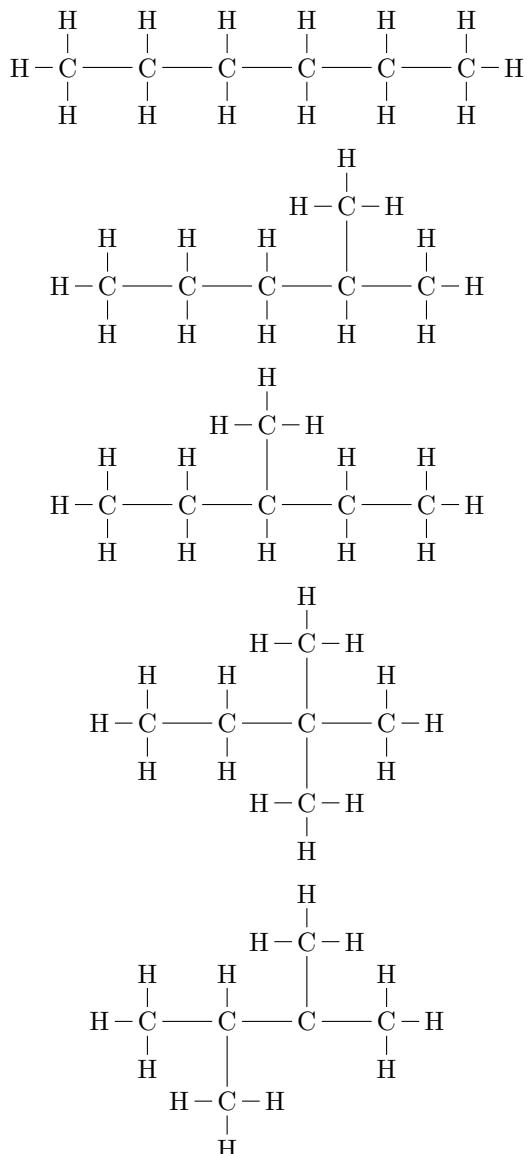
53. A Lewis dot structure of SOCl_2 shows that it is surrounded by three atoms and one lone pair. The electronic structure is tetrahedral. Upon removing one electron domain (for the lone pair), the resulting geometry is $\boxed{\text{trigonal pyramidal}}$, or \boxed{D} .

54. Drawing a Lewis structure will help us identify the types of bonds, and in turn, the number of σ and π bonds.



We have 1 triple bond, which counts as 1 σ bond and 2 π bonds. The two other single bonds count as 1 σ bond each. The total amount of σ and π bonds is $\boxed{3 \sigma \text{ and } 2 \pi}$ bonds, or \boxed{D} .

55. For this problem, we must draw all the isomers.

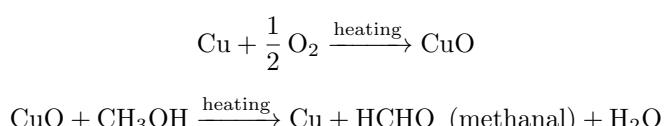


If rotating a structure gets you another structure, then the two structures are identical. We count distinct isomers. Thus, the answer is .

56. Polymers can be sorted into two categories, depending on their mode of formation. Condensation polymers, often featuring two or more kinds of monomers, are formed via loss of smaller molecules such as water. This includes nylon, proteins, starch, and polyester. Addition polymers, are formed as monomers are added to each other with no byproducts. Most poly-alkenes are addition polymers. The answer here is polyethylene, or B.

57. The keyword here hot copper metal, which is a *mild oxidant*. Methanol, as a primary alcohol, can be oxidized to methanal, an aldehyde, and then to acetic acid, a carboxylic acid. A strong oxidant will oxidize it all the way to acetic acid, whereas a mild oxidant will stop at methanal, or **D**.

The oxidation mechanism here is as follows. Moreover, we can see that the hot copper metal is actually the catalyst of the reaction, while oxygen gas is the actual oxidant. You can expect the color of the copper metal changes from copper red to black (color of CuO) and then turns back to copper red again.



58. Let us analyze the answer choices.

- A: Benzene (C_6H_6) is one of the most famous aromatic hydrocarbons.
- B: It does not exist in two isomeric forms. Two possible structures can be drawn, but these are resonance structures.
- C: It is reticent towards addition reactions, but it is capable of undergoing substitution reactions.
- D: There are three different ways (*ortho*, *meta*, and *para*) to place two chlorine substituents around the ring, in $C_6H_4Cl_2$ by replacing hydrogen with chlorine.

However, benzene does not exist in two isomeric forms. Thus, only **B** is false.

59. Peptides are formed from amino acids, each of which has an amino group ($-NH_2$) and a carboxyl group ($-COOH$). Phosphorus is not present in amino acids, so the answer is **D**.

60. Other than vitamin **C**, which is water-soluble due to its polarity and multiple hydroxyl groups, all the listed vitamins are fat-soluble. The answer is **C**.