AP CHEMISTRY PRACTICE MIDTERM EXAM Name _____

MULTIPLE CHOICE – NO CALCULATOR ALLOWED

Compound	Molar Mass (g/mol)
CaO	56.1
SO_2	64.1
V_2O_3	149.9
$BaSO_4$	233.4

1. According to the information in the table above, a 1.00 g sample of which of the following contains the greatest mass of oxygen?

   (A) CaO (B) SO_2 (C) V_2O_3 (D) $BaSO_4$

2. M^+ is an unknown metal cation with a +1 charge. A student dissolves the iodide of the unknown metal (chemical formula = MI) in enough water to make 100.0 mL of solution. The student then mixes the solution with excess $AgNO_3$ solution, causing silver iodide (AgI) to precipitate. The student collects the precipitate by filtration, dries it, and records the data shown below.
   (The molar mass of silver iodide is 235 g/mol.)

Mass of metal iodide compound, MI	1.66 g
Mass of filter paper	0.901 g
Mass of filter paper plus AgI precipitate	3.251 g

   What is the identity of the metal iodide compound?

   (A) lithium iodide, LiI

   (B) sodium iodide, NaI

   (C) potassium iodide, KI

   (D) rubidium iodide, RbI

3. Complete combustion of a sample of a hydrocarbon in excess oxygen produces equimolar quantities of carbon dioxide and water. Which of the following could be the molecular formula of the compound?

   (A) C_2H_2

   (B) C_2H_6

   (C) C_4H_8

   (D) $C_{10}H_8$

	First	Second	Third	Fourth	Fifth
Ionization Energy (kJ/mol)	801	2,430	3,660	25,000	32,820

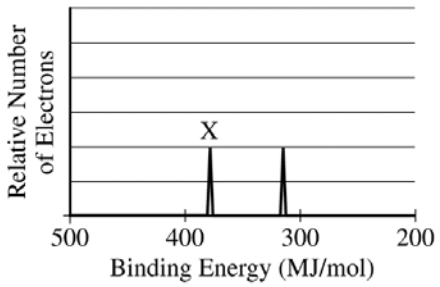
4. The first five ionization energies of a second-period element are listed in the table above. Which of the following correctly identifies the element and best explains the data in the table?

(A) The element is B because it has three valence electrons.

(B) The element is B because it has five core electrons.

(C) The element is N because it has three electrons in the *p* sublevel.

(D) The element is N because it has five valence electrons.



5. The photoelectron spectra of the 1*s* electrons of two isoelectronic species, Ca^{2+} and Ar, are shown above. Which of the following correctly identifies the species associated with peak X and provides a valid justification?

(A) Ar, because it has completely filled energy levels

(B) Ar, because its radius is smaller than the radius of Ca^{2+}

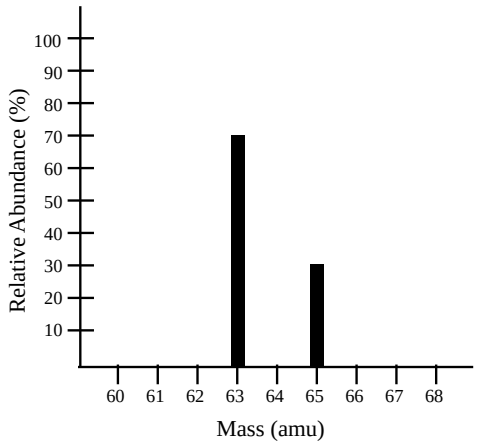
(C) Ca^{2+}, because its average atomic mass is greater than the average atomic mass of Ar

(D) Ca^{2+}, because its nucleus contains two more protons than the nucleus of Ar has

Element	Atomic Radius	First Ionization Energy
Calcium	174 pm	590 kJ/mol
Potassium	?	?

6. Based on periodic trends and the data in the table above, which of the following are the most probable values of the atomic radius and the first ionization energy for potassium?

	Atomic Radius	First Ionization Energy
(A)	144 pm	419 kJ/mol
(B)	144 pm	633 kJ/mol
(C)	196 pm	419 kJ/mol
(D)	196 pm	633 kJ/mol



7. The mass spectrum of element X is presented in the diagram above. Based on this spectrum and information from the periodic table, which of the following statements about element X is most likely to be true?

   (A) Each isotope of element X contains 29 protons.

   (B) ^{65}X has a greater effective nuclear charge than ^{63}X.

   (C) ^{63}X has a higher ionization energy than ^{65}X.

   (D) The average atomic mass of element X is between 64 and 65.

8. In a certain experiment, 1.22 g of benzoic acid, C_6H_5COOH, is dissolved in water and titrated with a solution of NaOH. Benzoic acid is a monoprotic acid. The equivalence point in the titration is reached when 50.0 mL of the base solution is added. (The molar mass of C_6H_5COOH is 122 g/mol.)

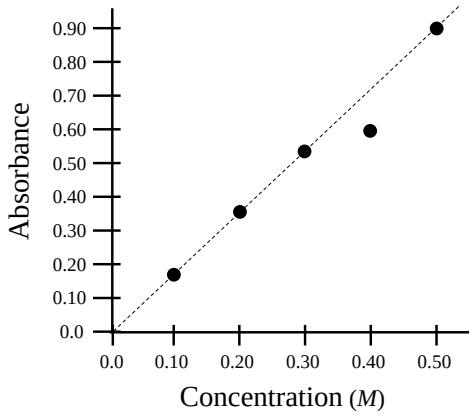
   What is the concentration of the NaOH solution used in this titration experiment?

   (A) 2.00×10^{-4} *M*

   (B) 0.100 *M*

   (C) 0.200 *M*

   (D) 0.500 *M*



9. A student prepared five solutions of $CuSO_4$ with different concentrations, and then filled five cuvettes, each containing one of the solutions. The cuvettes were placed in a spectrophotometer set to the appropriate wavelength for maximum absorbance. The absorbance of each solution was measured and recorded. The student plotted absorbance versus concentration, as shown in the figure above. Which of the following is the most likely explanation for the variance of the data point for the 0.40 *M* $CuSO_4$ solution?

   (A) The cuvette used for the 0.40 *M* solution had scratches on it, causing the light to be scattered.

   (B) The cuvette used for the 0.40 *M* solution had not been wiped clean of fingerprints before it was placed in the spectrophotometer.

   (C) The cuvette into which the 0.40 *M* solution was placed was filled slightly more than the other cuvettes.

   (D) The cuvette into which the 0.40 *M* solution was placed had some water droplets inside.

10. In a certain experiment, 24.0 grams of H_2 reacted with 48.0 grams of O_2 until one of the reactants was completely consumed. What is the theoretical yield of H_2O?

   (A) 27.0 g

   (B) 36.0 g

   (C) 54.0 g

   (D) 72.0 g

Container	Gas	Pressure (atm)	Mass of Gas Sample (g)
1	H_2	2.00	2.02
2	CH_4	2.00	16.0
3	SO_2	1.96	64.1

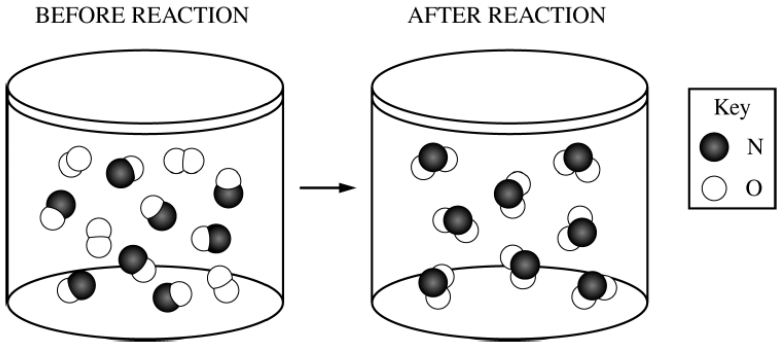
11. The table above contains information about samples of three different gases at 273 K. The samples are in three identical rigid containers numbered 1 through 3. The best explanation for the lower pressure in container 3 is that SO_2 molecules

(A) have a larger average speed than the other two gases

(B) have stronger intermolecular attractions than the other two gases

(C) occupy a larger portion of the container volume than the other two gases

(D) contain π bonds, while the other gases contain only σ bonds.



12. The reaction between NO(g) and O_2(g) to produce NO_2(g) in a rigid reaction vessel is represented in the diagram above. The pressure inside the container is recorded using a pressure gauge. Which of the following statements correctly predicts the change in pressure as the reaction goes to completion at constant temperature, and provides the correct explanation?

(A) The pressure will increase because the product molecules have a greater mass than either of the reactant molecules.

(B) The pressure will decrease because there are fewer molecules of product than of reactants.

(C) The pressure will decrease because the product molecules have a lower average speed than the reactant molecules.

(D) The pressure will not change because the total mass of the product molecules is the same as the total mass of the reactant molecules.

Questions 13 – 14 refer to the following.

$$CH_3OH(g) \rightarrow CO(g) + 2\ H_2(g) \qquad \Delta H^o = +91\ kJ/mol_{rxn}$$

The reaction represented above goes essentially to completion. The reaction takes place in a rigid, insulated vessel that is initially at 600 K.

13. Which of the following describes what happens to the temperature of the contents of the vessel as the reaction occurs and provides the correct justification?

    (A) The temperature must increase, because the molecules move faster as the reaction proceeds.

    (B) The temperature must decrease, because the reaction takes place at a temperature that is higher than room temperature.

    (C) The temperature must decrease, because the reaction is endothermic.

    (D) The temperature does not change, because the vessel is insulated.

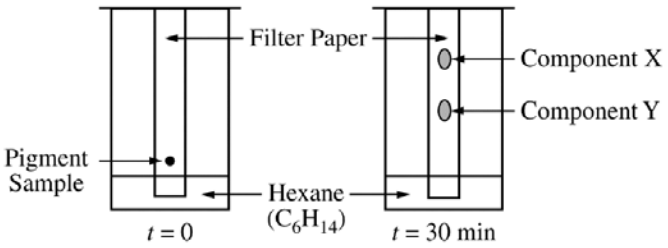
14. A sample of $CH_3OH(g)$ is placed in the previously evacuated vessel with a pressure of 3.0 atm at 600 K. What is the final pressure in the vessel after the reaction is complete and the contents of the vessel are returned to 600 K?

    (A) 1.0 atm

    (B) 3.0 atm

    (C) 6.0 atm

    (D) 9.0 atm



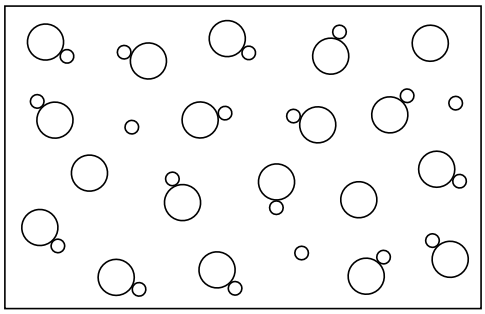
15. In a paper chromatography experiment, a sample of a pigment is separated into two components, X and Y, as shown in the figure above. The surface of the paper is moderately polar. What can be concluded about X and Y based on the experimental results?

    (A) X has a larger molar mass than Y does.

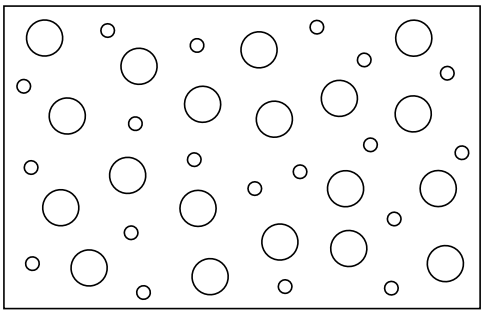
    (B) Y has a larger molar mass than X does.

    (C) X is more polar than Y.

    (D) Y is more polar than X.



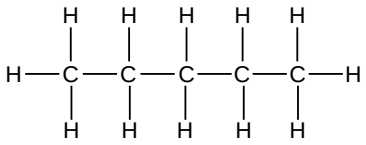
HX(*aq*)



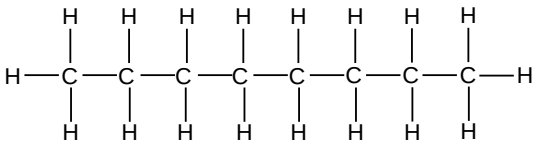
HY(*aq*)

16. The particle diagrams above represent aqueous solutions of acids HX and HY. Water molecules are omitted for clarity. Based on the information in the diagrams above, which of the following best represents the correct net-ionic equation for the reaction between NaOH(*aq*) and each acid?

	Net-Ionic Equation for the Reaction between HX(*aq*) and NaOH(*aq*)	Net-Ionic Equation for the Reaction between HY(*aq*) and NaOH(*aq*)
(A)	$HX(aq) + OH^-(aq) \rightarrow H_2O(l) + X^-(aq)$	$HY(aq) + OH^-(aq) \rightarrow H_2O(l) + Y^-(aq)$
(B)	$HX(aq) + OH^-(aq) \rightarrow H_2O(l) + X^-(aq)$	$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
(C)	$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$	$HY(aq) + OH^-(aq) \rightarrow H_2O(l) + Y^-(aq)$
(D)	$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$	$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$



pentane



octane

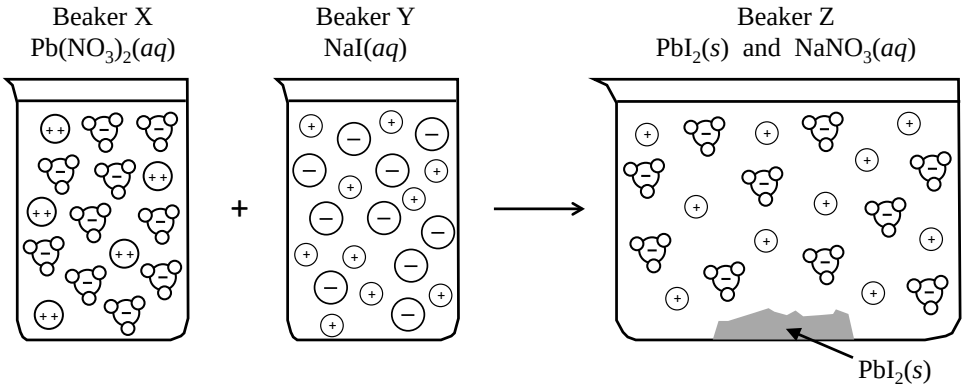
17. A mixture containing equal numbers of moles of pentane and octane was separated using distillation. Based on the diagrams shown above, which of the following identifies the substance that would be initially present in higher concentration in the distillate and correctly explains why that occurs?

(A) pentane, because it has fewer C–C bonds to break

(B) pentane, because it has a shorter carbon chain and weaker London dispersion forces

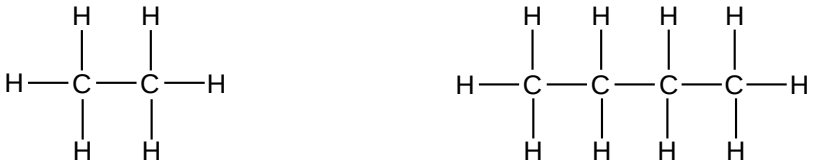
(C) octane, because it has more C–C bonds to break

(D) octane, because it has a longer carbon chain and stronger London dispersion forces



18. Beaker X and beaker Y each contain 1.0 L of solution, as shown above. A student combines the solutions by pouring them into a larger, previously empty beaker Z and observes the formation of a yellow precipitate. Assuming that the volumes are additive, which of the following sets of solutions could be represented by the diagram above?

	Beaker X	Beaker Y	Beaker Z
(A)	1.0 *M* $Pb(NO_3)_2(aq)$	1.0 *M* $NaI(aq)$	2.0 *M* $NaNO_3(aq)$ and $PbI_2(s)$
(B)	1.0 *M* $Pb(NO_3)_2(aq)$	1.0 *M* $NaI(aq)$	1.0 *M* $NaNO_3(aq)$ and $PbI_2(s)$
(C)	1.0 *M* $Pb(NO_3)_2(aq)$	2.0 *M* $NaI(aq)$	2.0 *M* $NaNO_3(aq)$ and $PbI_2(s)$
(D)	1.0 *M* $Pb(NO_3)_2(aq)$	2.0 *M* $NaI(aq)$	1.0 *M* $NaNO_3(aq)$ and $PbI_2(s)$



ethane butane

19. The structural formulas for ethane and butane are shown above. Which compound has the higher boiling point, and why is that compound's boiling point higher?

(A) butane, because it has more hydrogen atoms, resulting in more opportunities to form hydrogen bonds with neighboring molecules

(B) butane, because it has more electrons, resulting in greater polarizability and stronger dispersion forces

(C) ethane, because its molecules are smaller and they can get closer to one another, resulting in stronger coulombic attractions between molecules

(D) ethane, because its molecules have a greater dipole moment and experience stronger dipole-dipole attractions

20. Under which of the following conditions of temperature and pressure will H_2 gas be expected to behave most like an ideal gas?

(A) 50 K and 0.10 atm

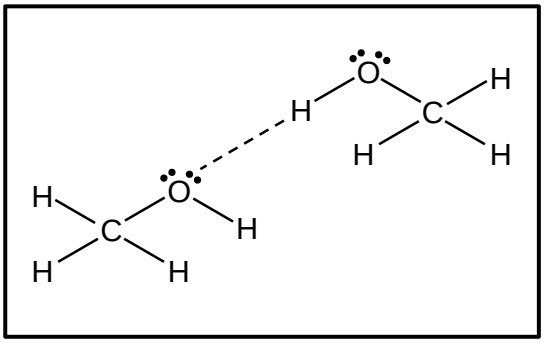
(B) 50 K and 50. atm

(C) 500 K and 0.10 atm

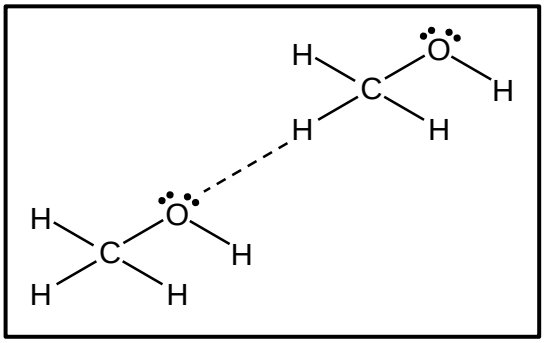
(D) 500 K and 50. atm

21. Which of the following diagrams best illustrates the hydrogen bonding interaction between two molecules of methanol, CH_3OH?

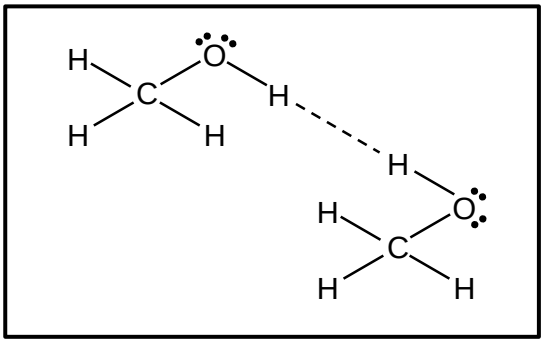
(A)



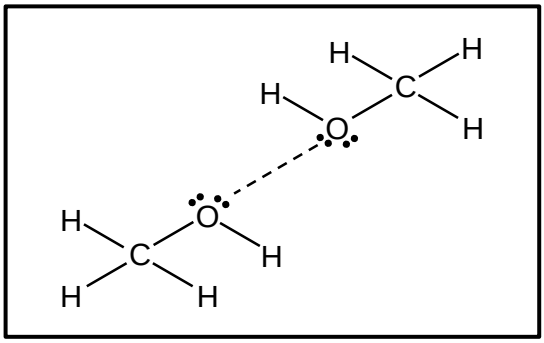
(C)



(B)



(D)



22. The lattice energy of a salt is related to the energy required to separate the ions. For which of the following pairs of ions is the energy that is required to separate the ions largest? (Assume that the distance between the ions in each pair is equal to the sum of the ionic radii.)

(A) Mg^{2+} and O^{2-}

(B) Ba^{2+} and S^{2-}

(C) Na^{+} and F^{-}

(D) K^{+} and Br^{-}

23. Which of the following best helps to explain why the value of ΔH^o for the dissolving of CaF_2 in water is positive?

(A) When $CaF_2(s)$ dissolves in water, the temperature of the solution increases.

(B) When $CaF_2(s)$ dissolves in water, the solution is able to conduct electricity.

(C) Ca^{2+} ions have very strong ion-ion interactions with F^- ions in the crystal lattice.

(D) Ca^{2+} ions have very strong ion-dipole interactions with water molecules in the solution.

	Molar Mass (g/mol)	Boiling Point (^oC)
$CS_2(l)$	76	46.5
$CCl_4(l)$	154	76.7

24. Based on the information in the table above, which liquid, $CS_2(l)$ or $CCl_4(l)$, has the higher equilibrium vapor pressure at 25^{o}C, and why?

(A) $CS_2(l)$, because it has stronger London dispersion forces

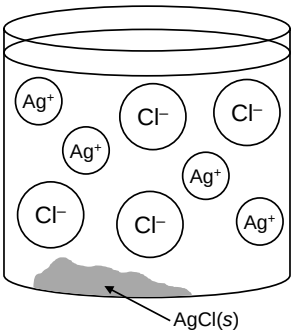
(B) $CS_2(l)$, because it has weaker London dispersion forces

(C) $CCl_4(l)$, because it has stronger London dispersion forces

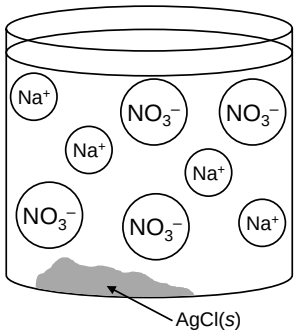
(D) $CCl_4(l)$, because it has weaker London dispersion forces

25. A student mixes 50 mL of 0.10 *M* NaCl with 50 mL of 0.20 *M* $AgNO_3$ to form AgCl(*s*). Which of the diagrams below best represents the ions that are present in significant concentrations in the solution after the reaction is complete?

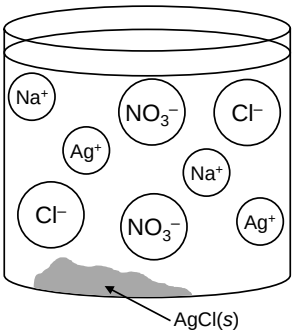
(A)



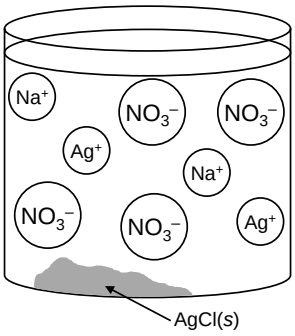
(B)



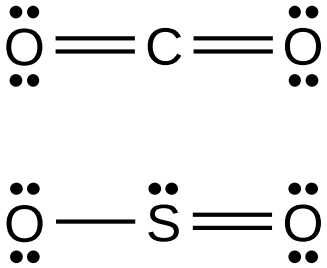
(C)



(D)



Questions 26 – 27 refer to the following information.



Element	Electronegativity
H	2.1
C	2.5
O	3.5
F	4.0
Si	1.8
S	2.5
Cl	3.0

26. Consider the Lewis electron-dot diagrams for CO_2 and SO_2 and the electronegativity information in the table above. The molecular geometry and the polarity of the two substances CO_2 and SO_2 are

(A) the same, because the molecular formulas are similar

(B) the same, because C and S have the same electronegativity values

(C) different, because the lone pair of electrons on the S atom make it the negative end of a dipole

(D) different, because S has a greater number of electron domains surrounding it than C has

27. On the basis of the information in the table above, which of the following has arranged these three bonds in order of increasing bond polarity?

(A) C–H < Si–Cl < S–F

(B) Si–Cl < C–H < S–F

(C) S–F < Si–Cl < C–H

(D) Si–Cl < S–F < C–H

28. In a certain experiment, 100. mL of 6.0 *M* HCl(*aq*) is added to 10.6 g of Na_2CO_3(*s*). Bubbles of CO_2(*g*) are produced during the reaction, which proceeds until one of the reactants is completely consumed. What is the theoretical yield of NaCl(*s*) that should be present in the solution at the end of the reaction? (The molar masses of Na_2CO_3 and NaCl are equal to 106.0 and 58.5, respectively.)

(A) 5.85 g NaCl

(B) 10.6 g NaCl

(C) 11.7 g NaCl

(D) 14.6 g NaCl

Questions 29 – 30 refer to the following reaction.

$$Fe(s) + 2\ HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

29. When a student adds 30.0 mL of 1.00 *M* HCl(*aq*) to 0.56 g of powdered Fe(*s*), a reaction occurs according to the equation above. When the reaction is complete at 273 K and 1.0 atm, which of the following is true?

(A) 0.010 mol of Fe remains unreacted.

(B) 0.020 mol of HCl remains unreacted.

(C) 0.015 mol of $FeCl_2$ has been produced.

(D) 0.22 L of H_2 has been produced.

30. Which element is being reduced in the reaction shown above, and what is the element's change in oxidation number?

(A) iron, which changes from 0 to +2

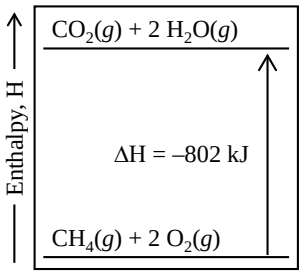
(B) hydrogen, which changes from +1 to 0

(C) chlorine, which changes from 0 to –1

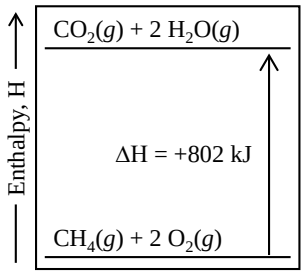
(D) chlorine, which changes from –1 to –2

31. Which of the following diagrams is most likely to represent the relative enthalpies of the reactants and products and the correct sign of ΔH for the combustion of $CH_4(g)$?

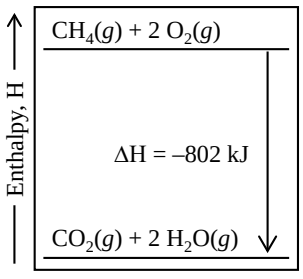
(A)



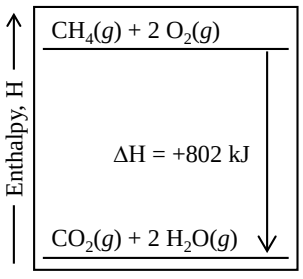
(B)



(C)



(D)



32. Which of the following are the most probable values for the carbon–carbon bond length and bond energy in the substances C_2H_2 and C_2H_6?

(A)

	Carbon-Carbon Bond Length	Carbon-Carbon Bond Enthalpy
C_2H_2	120 pm	350 kJ/mol
C_2H_6	154 pm	840 kJ/mol

(C)

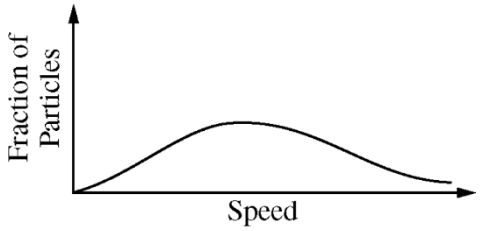
	Carbon-Carbon Bond Length	Carbon-Carbon Bond Enthalpy
C_2H_2	154 pm	350 kJ/mol
C_2H_6	120 pm	840 kJ/mol

(B)

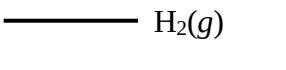
	Carbon-Carbon Bond Length	Carbon-Carbon Bond Enthalpy
C_2H_2	120 pm	840 kJ/mol
C_2H_6	154 pm	350 kJ/mol

(D)

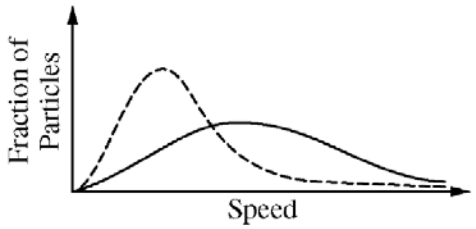
	Carbon-Carbon Bond Length	Carbon-Carbon Bond Enthalpy
C_2H_2	154 pm	840 kJ/mol
C_2H_6	120 pm	350 kJ/mol



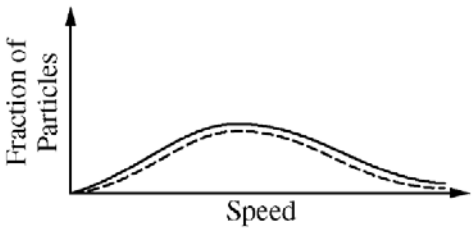
33. The distribution of speeds of $H_2(g)$ molecules at 273 K and 1 atm is shown in the diagram above. Which of the following best shows the speed distribution of He(g) atoms under the same conditions of temperature and pressure?



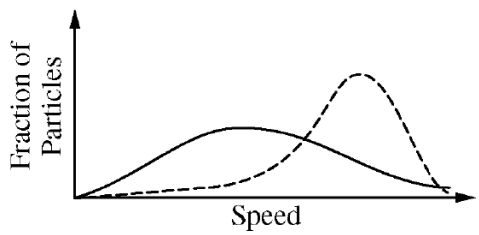
(A)



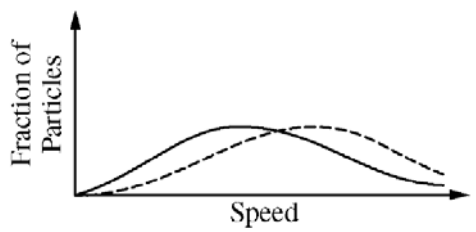
(C)



(B)



(D)



34. A hot iron ball is dropped into a 200. g sample of water initially at 25°C. If 8.4 kJ of heat is transferred from the ball to the water, what is the final temperature of the water?
(The specific heat of water is 4.2 J/(g·°C).)

(A) 26°C

(B) 30°C

(C) 35°C

(D) 45°C

$$MgO(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l) \qquad \Delta H^o = -150\ kJ/mol_{rxn}$$

35. In a certain experiment, 4.0 g MgO(*s*) is combined with 100. mL of 4.0 *M* HCl(*aq*) and allowed to react as completely as possible until one of the reactants is completely consumed. Which of the following identifies the limiting reactant and the amount of heat released in this experiment?
(The molar mass of MgO is 40.3 g/mol.)

	Limiting Reactant	Amount of Heat Released
(A)	MgO	15 kJ
(B)	MgO	30 kJ
(C)	HCl	15 kJ
(D)	HCl	30 kJ

Bond	Bond Energy (kJ/mol)
H–H	430
Cl–Cl	240
H–Cl	430

36. Based on the bond energies shown in the table above, which of the following is the most accurate description of the reaction represented below?

$$H_2(g) + Cl_2(g) \rightarrow 2\ HCl(g)$$

(A) It is an endothermic reaction, and $\Delta H_{rxn} = +190\ kJ/mol_{rxn}$.

(B) It is an endothermic reaction, and $\Delta H_{rxn} = +240\ kJ/mol_{rxn}$.

(C) It is an exothermic reaction, and $\Delta H_{rxn} = -190\ kJ/mol_{rxn}$.

(D) It is an exothermic reaction, and $\Delta H_{rxn} = -240\ kJ/mol_{rxn}$.

Type of Food	Mass of Food Sample	Mass of Water in Calorimeter	Initial Temperature of Water (before combustion)	Final Temperature of Water (after combustion)
cashew	1.0 g	1000. g	20.0°C	25.0°C
marshmallow	3.0 g	2000. g	25.0°C	30.0°C

37. A calorimetry experiment was performed in which two different samples of food were burned. The amount of heat released from the combustion of each food sample was transferred to water in a calorimeter. Based on the data in the table above, which of the following represents the most likely conclusion about the energy content for 1.0 g each type of food?
(The specific heat of water is 4.2 J/(g·°C).)

(A) The combustion of 1.0 g of cashew releases less energy than the combustion of 1.0 g of marshmallow.

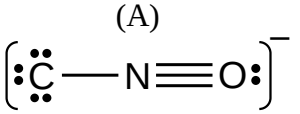
(B) The combustion of 1.0 g of cashew releases the same amount of energy as the combustion of 1.0 g of marshmallow.

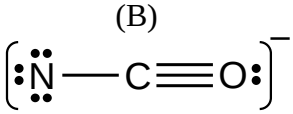
(C) The combustion of 1.0 g of cashew releases more energy than the combustion of 1.0 g of marshmallow.

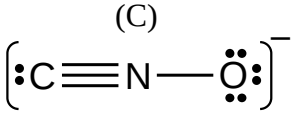
(D) No comparison can be made because the two systems started with different masses of food, different masses of water, and different initial temperatures.

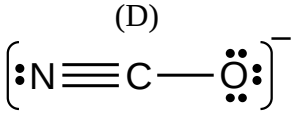
1. The dominant Lewis structure is generally the one in which the atoms bear formal charges closest to zero.
2. A Lewis structure in which any negative charges reside on the more electronegative atoms is generally more dominant than a Lewis structure that has negative charges on the less electronegative atoms.

38. If it is possible to draw more than one Lewis electron-dot structure for a molecule or ion, there are certain guidelines for choosing the more dominant Lewis structure. Which of the following Lewis structures is the most dominant based on the guidelines shown above?

(A) 

(B) 

(C) 

(D) 

39. Which of the following has correctly identified the both the hybridization of the nitrogen atom and the H–N–H bond angle present in the NH_3 molecule?

	Hybridization of the Nitrogen Atom in NH_3	H–N–H Bond Angle in NH_3
(A)	sp^2	107^o
(B)	sp^2	120^o
(C)	sp^3	107^o
(D)	sp^3	120^o

40. A sample of pure $CO_2(g)$ in a rigid container has a pressure of 2 atm at a temperature of 0^oC. What is the approximate density of this gas sample?

(A) 1 g/L

(B) 2 g/L

(C) 3 g/L

(D) 4 g/L

AP CHEMISTRY MIDTERM EXAM Name _____

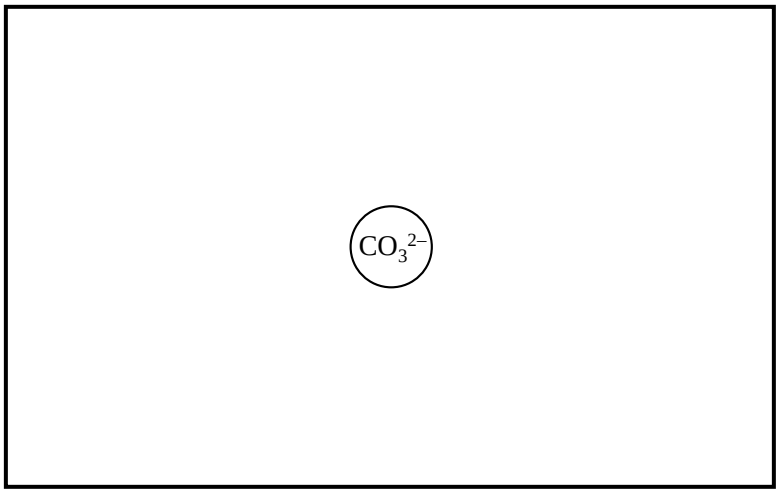
FREE RESPONSE – CALCULATOR IS ALLOWED

Substance	Chemical Formula	Molar Mass (g/mol)
lithium carbonate	Li_2CO_3	73.9
sodium carbonate	Na_2CO_3	106.0
potassium carbonate	K_2CO_3	138.2

1. A student is given a sample of a pure, anhydrous salt. The identity of this salt is one of the three substances listed in the table above.

   (a) The student measures out 1.00 g of the unknown salt and dissolves it completely into 100. mL of distilled water. This solution contains carbonate ions. In the box below, complete a particle diagram that includes four water molecules with proper orientation around the carbonate ion.

   Represent water molecules as 



   (b) The student then adds 25 mL of 1.6 *M* $CaCl_2$(*aq*) to the solution prepared in part (a). After mixing the resulting solution thoroughly, a solid precipitate is formed which contains carbonate ions.

      (i) Calculate the number of moles of $CaCl_2$ added to the solution of the unknown salt during this step in the experiment.

      (ii) Write the balanced net-ionic equation for the formation of the solid precipitate. (Symbols for states of matter such as (*aq*) or (*s*) are not required.)

mass of unknown salt (Li_2CO_3, Na_2CO_3, or K_2CO_3)	1.00 g
mass of filter paper	0.65 g
mass of filter paper + precipitate	2.02 g

1. (c) The precipitate formed in this experiment is filtered, dried, and weighed. Data from the experiment is shown in the table above.

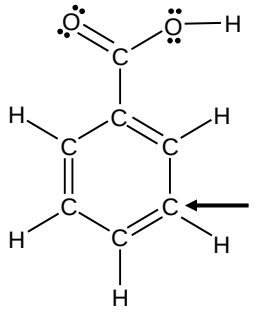
(i) Calculate the mass of the precipitate recovered from this experiment: _____

(ii) Calculate the number of moles of the precipitate recovered from this experiment. Show your work below, and round your answer to the proper number of significant figures.

(iii) The formula that is most likely to represent the identity of the unknown salt used in this experiment is (Li_2CO_3 Na_2CO_3 K_2CO_3)

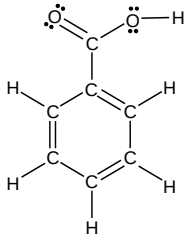
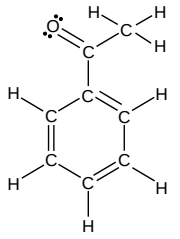
(iv) Show your work below for the calculation, based on laboratory data, that provides the best evidence that the formula you circled in part (c)(iii) is likely to be the correct answer.

(d) When an aqueous solution of the unknown salt is mixed with 1.0 *M* HCl(*aq*), a reaction occurs in which bubbles of gas are observed. Write the balanced net-ionic equation for this reaction, that produces both a gas and H_2O. (Symbols for states of matter such as (*aq*) or (*g*) are not required.)



2. The structural formula of benzoic acid (C_6H_5COOH) is shown above.

   (a) Identify the hybridization (sp, sp^2, or sp^3) of the carbon atom indicated by the arrow in the diagram above. _____

Substance	Structural Formula	Molar Mass (g/mol)	Boiling Point (K)
benzoic acid		122.1	522
acetophenone		120.1	?

   (b) The table above shows information about benzoic acid and acetophenone.

      (i) Identify <u>all</u> of the intermolecular forces that each substance experiences.

      benzoic acid: _____

      acetophenone: _____

      (ii) Make a prediction regarding the boiling point of acetophenone by selecting one of the statements below.

      _____ The boiling point of acetophenone is less than 522 K.

      _____ The boiling point of acetophenone is equal to 522 K.

      _____ The boiling point of acetophenone is greater than 522 K.

2. (b) (iii) Justify the prediction you made in part (b)(ii) by comparing the strengths of the intermolecular forces that you identified in part (b)(i).

(c) It is known that the combustion of 1.00 g of benzoic acid produces 26.4 kJ of heat.

(i) Balance the following combustion equation using the lowest possible whole numbers as coefficients.

$$\_\_\_\_\_ C_6H_5COOH(s) + \_\_\_\_\_ O_2(g) \rightarrow \_\_\_\_\_ CO_2(g) + \_\_\_\_\_ H_2O(l)$$

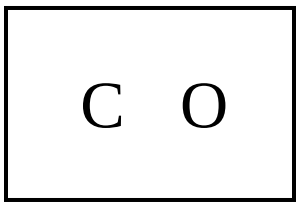
(ii) Calculate the change in enthalpy, ΔH, for the balanced equation written in part (c)(i). Show your work below, and express your answer in units of kJ/mol_{rxn}. Make sure to include the sign of ΔH in your answer.

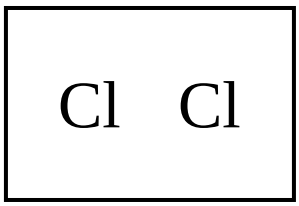
(iii) In a certain experiment, 2.25 g of benzoic acid was burned completely in a bomb calorimeter. Calculate the amount of heat released from the combustion of 2.25 g of benzoic acid.

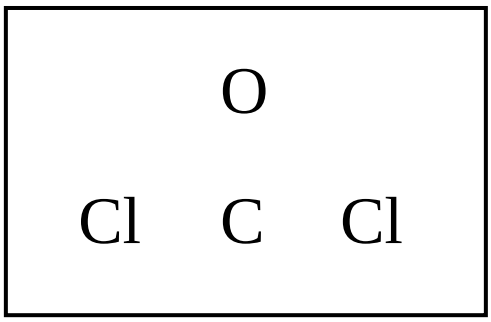
(iv) Assuming that all of the heat generated from the combustion of 2.25 g of benzoic acid is completely transferred to a 500. g sample of water (specific heat = 4.18 $J/(g \cdot {}^oC)$) at 25.0°C, calculate the final temperature you would expect to observe in this sample of water after it is heated.

3. Answer the following questions about the substances CO, Cl_2, and $COCl_2$.

(a) In the boxes below, complete the Lewis electron-dot diagrams for each molecule by drawing all of the bonding and nonbonding electron pairs. Each atom should obey the octet rule.
In the diagram for the $COCl_2$ molecule, the formal charge on each atom should be equal to zero.







(b) Although the atoms in the Lewis diagram for the CO molecule obey the octet rule, the formal charge on each atom is not zero. Based on the Lewis diagram for CO that you drew in part (a), calculate the formal charge of each atom.

Formal Charge on C: _____ Formal Charge on O: _____

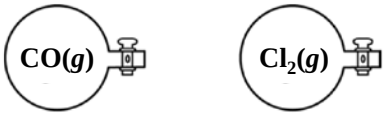
(c) Fill in the missing information in the table below for the $COCl_2$ molecule.

Molecular Geometry	Is this Molecule Polar or Nonpolar?	Number of sigma (σ) bonds present in the molecule	Number of pi (π) bonds present in the molecule

Bond	Bond Energy (kJ/mol)
C–O	358
C=O	799
C≡O	1072
C–Cl	328
Cl–Cl	242

(d) Use the data from the table above to calculate the value of ΔH for the following reaction.

$$CO(g) + Cl_2(g) \rightarrow COCl_2(g)$$



1.0 L
2.0 atm
25°C

1.0 L
1.0 atm
25°C

(e) Samples of $CO(g)$ and $Cl_2(g)$ are placed in separate 1.0 L containers at 25°C. The pressure in each flask is shown in the diagram above. Answer the following questions about these two gas samples.

(i) Indicate whether the average kinetic energy of the $CO(g)$ molecules is less than, equal to, or greater than the average kinetic energy of the $Cl_2(g)$ molecules. Justify your answer.

(ii) Indicate whether the average speed of the $CO(g)$ molecules is less than, equal to, or greater than the average speed of the $Cl_2(g)$ molecules. Justify your answer.

(iii) Calculate the mass of $CO(g)$ gas present in the flask on the left. Show your work below.