

## Practice Exam 12\_2013 MCQ

1. 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)  $C_6H_6$

**Answer C**

This option is correct. The balanced chemical equation is  $C_4H_8 + 6 O_2 \rightarrow 4 CO_2 + 4 H_2O$ , so combustion produces  $CO_2$  and  $H_2O$  with a mole ratio of 1 to 1, in agreement with the observed equimolar ratio.

- 2.
- | Substance      | Equilibrium Vapor Pressure at 20°C (torr) |
|----------------|-------------------------------------------|
| $C_6H_6(l)$    | 75                                        |
| $C_2H_5OH(l)$  | 44                                        |
| $CH_3OH(l)$    | 92                                        |
| $C_2H_6O_2(l)$ | 0.06                                      |

Based on the data in the table above, which of the following liquid substances has the weakest intermolecular forces?

- (A)  $C_6H_6(l)$   
(B)  $C_2H_5OH(l)$   
(C)  $CH_3OH(l)$  ✓  
(D)  $C_2H_6O_2(l)$

**Answer C**

This option is correct. Since the transition from liquid to vapor breaks the intermolecular interactions, a high vapor pressure indicates weak interactions between molecules. Based on the data, this substance has the highest vapor pressure and thus the weakest intermolecular interactions.

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3.

Ion	Radius (pm)
Zn <sup>2+</sup>	74
Ca <sup>2+</sup>	100
Ba <sup>2+</sup>	135

Based on the data in the table above, which of the following correctly predicts the relative strength of the attraction of Zn<sup>2+</sup>, Ca<sup>2+</sup>, and Ba<sup>2+</sup> ions to water molecules in a solution, from strongest to weakest, and provides the correct reason?

(A) Zn<sup>2+</sup> > Ca<sup>2+</sup> > Ba<sup>2+</sup> because the smaller ions have a stronger coulombic attraction to water ✓

(B) Zn<sup>2+</sup> > Ca<sup>2+</sup> > Ba<sup>2+</sup> because the smaller ions are more electronegative

(C) Ba<sup>2+</sup> > Ca<sup>2+</sup> > Zn<sup>2+</sup> because the larger ions are more polarizable

(D) Ba<sup>2+</sup> > Ca<sup>2+</sup> > Zn<sup>2+</sup> because the larger ions are less electronegative

**Answer A**

This option is correct. The interaction of ions with water is a Coulombic (specifically ion-dipole) interaction. Since all three ions have the same charge (+2), the strength of the interaction is related to distance, with shorter distances leading to the stronger interactions. The smaller ions therefore have stronger coulombic attraction to water, as stated in this option.

4. Zn(s) is used to reduce other compounds in chemical reactions. If a chemist needs a substance that is more effective in its reducing ability, which of the following species would be the best choice?

(A) Na ✓

(B) H<sup>+</sup>

(C) K<sup>+</sup>

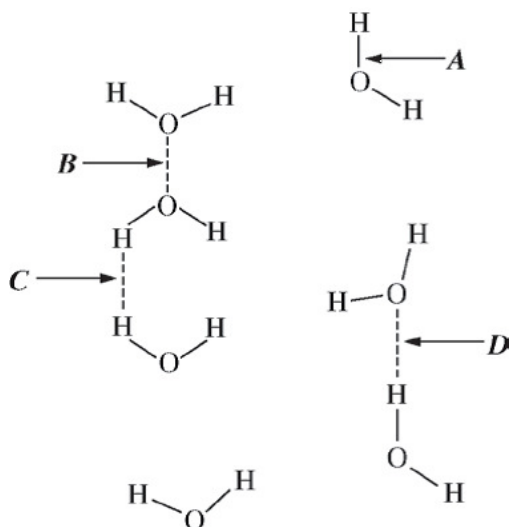
(D) Cl<sup>-</sup>

**Answer A**

This option is correct. Na has a single valence electron and a low first ionization energy and so can readily lose an electron and reduce other species.

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5.



In the diagram above, which of the labeled arrows identifies hydrogen bonding in water?

- (A) *A*  
 (B) *B*  
 (C) *C*  
 (D) *D*

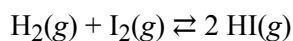
**Answer D**

This option is correct. This interaction correctly identifies a hydrogen bond as being between the hydrogen of one water molecule and the oxygen of an adjacent water molecule.

6. A kinetics experiment is set up to collect the gas that is generated when a sample of chalk, consisting primarily of solid  $\text{CaCO}_3$ , is added to a solution of ethanoic acid,  $\text{CH}_3\text{COOH}$ . The rate of reaction between  $\text{CaCO}_3$  and  $\text{CH}_3\text{COOH}$  is determined by measuring the volume of gas generated at  $22^\circ\text{C}$  and 1 atm as a function of time. Which of the following experimental conditions is most likely to increase the rate of gas production?
- (A) Decreasing the volume of ethanoic acid solution used in the experiment  
 (B) Decreasing the concentration of the ethanoic acid solution used in the experiment  
 (C) Decreasing the temperature at which the experiment is performed  
 (D) Decreasing the particle size of the  $\text{CaCO}_3$  by grinding it into a fine powder



7.



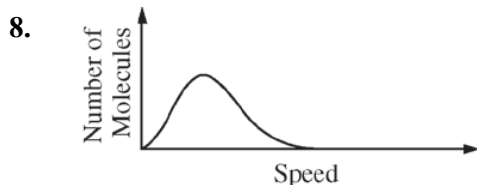
At  $450^\circ\text{C}$ , 2.0 moles each of  $\text{H}_2(\text{g})$ ,  $\text{I}_2(\text{g})$ , and  $\text{HI}(\text{g})$  are combined in a 1.0 L rigid container. The value of  $K_c$  at  $450^\circ\text{C}$  is 50. Which of the following will occur as the system moves toward equilibrium?

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- (A) More  $\text{H}_2(\text{g})$  and  $\text{I}_2(\text{g})$  will form.
- (B) More  $\text{HI}(\text{g})$  will form. ✓
- (C) The total pressure will decrease.
- (D) No net reaction will occur, because the number of molecules is the same on both sides of the equation.

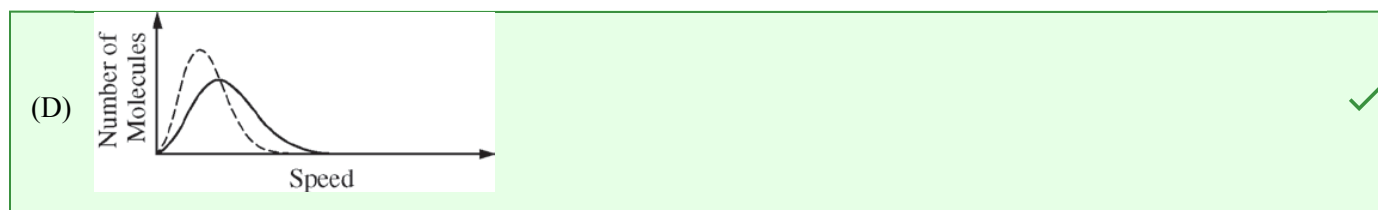
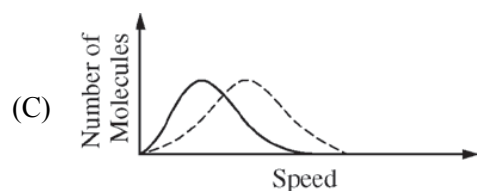
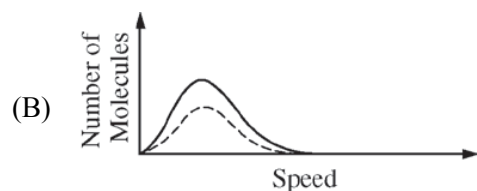
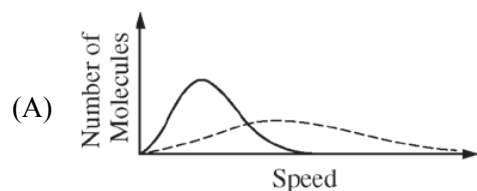
**Answer B**

This option is correct. Since the container is rigid and has a volume of 1.0 L, the original concentrations of the species are  $[\text{H}_2] = [\text{I}_2] = [\text{HI}] = 2.0 \text{ M}$ . The reaction quotient is therefore  $Q = [\text{HI}]^2/([\text{H}_2][\text{I}_2]) = 1$ . Since  $K$  is 50,  $Q < K$  and the reaction proceeds in the forward direction, producing more HI, as stated in this option.



The graph above shows the speed distribution of molecules in a sample of a gas at a certain temperature. Which of the following graphs shows the speed distribution of the same molecules at a lower temperature (as a dashed curve) ?

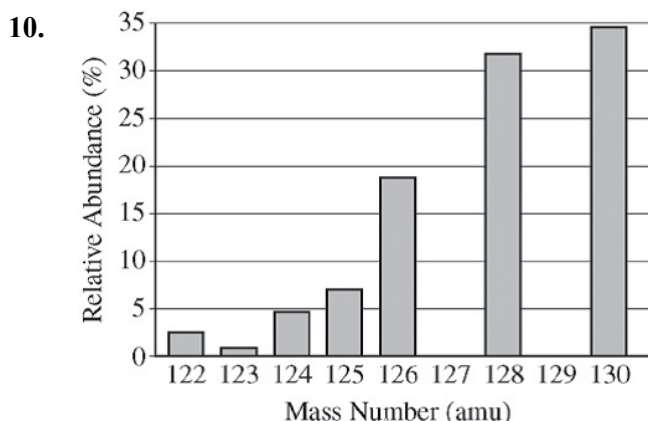
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**Answer D**

This option is correct. A decrease in temperature results in a decrease in the average speed of the molecules, as shown here.

9. A 100g sample of a metal was heated to  $100^{\circ}\text{C}$  and then quickly transferred to an insulated container holding 100g of water at  $22^{\circ}\text{C}$ . The temperature of the water rose to reach a final temperature of  $35^{\circ}\text{C}$ . Which of the following can be concluded?
- (A) The metal temperature changed more than the water temperature did; therefore the metal lost more thermal energy than the water gained.
- (B) The metal temperature changed more than the water temperature did, but the metal lost the same amount of thermal energy as the water gained. ✓
- (C) The metal temperature changed more than the water temperature did; therefore the heat capacity of the metal must be greater than the heat capacity of the water.
- (D) The final temperature is less than the average starting temperature of the metal and the water; therefore the total energy of the metal and water decreased.

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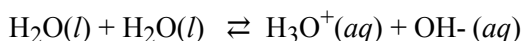
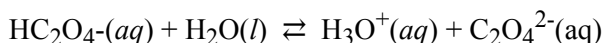
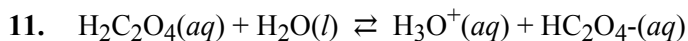


The elements I and Te have similar average atomic masses. A sample that was believed to be a mixture of I and Te was run through a mass spectrometer, resulting in the data above. All of the following statements are true. Which one would be the best basis for concluding that the sample was pure Te?

- (A) Te forms ions with a  $-2$  charge, whereas I forms ions with a  $-1$  charge.
- (B) Te is more abundant than I in the universe.
- (C) I consists of only one naturally occurring isotope with 74 neutrons, whereas Te has more than one isotope. ✓
- (D) I has a higher first ionization energy than Te does.

**Answer C**

This option is correct. The mass spectrum indicates the presence of multiple isotopes in the sample, providing evidence for Te. Furthermore, the graph shows no peak at 127, the mass number of the only stable isotope of I. This shows that there is no I in the sample, and the sample must be pure Te.



All the reactions represented above occur in an aqueous solution of oxalic acid. Which of the following represent a Brønsted-Lowry conjugate acid-base pair?

- (A)  $\text{H}_2\text{C}_2\text{O}_4(aq)$  and  $\text{C}_2\text{O}_4^{2-}(aq)$
- (B)  $\text{HC}_2\text{O}_4^-(aq)$  and  $\text{C}_2\text{O}_4^{2-}(aq)$  ✓
- (C)  $\text{HC}_2\text{O}_4^-(aq)$  and  $\text{H}_2\text{O}(aq)$
- (D)  $\text{H}_3\text{O}^+(aq)$  and  $\text{OH}^-(aq)$

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**Answer B**

This option is correct. Since  $\text{HC}_2\text{O}_4^-$  loses one hydrogen ion to form  $\text{C}_2\text{O}_4^{2-}$ , these species are a conjugate acid-base pair.

12. Which of the following reactions is not thermodynamically favored at low temperatures but becomes favored as the temperature increases?

(A)	Reaction	$\Delta H^\circ$ (kJ/mol <sub>rxn</sub> )	$\Delta S^\circ$ (J/(mol <sub>rxn</sub> K))
	$2 \text{CO}(g) + \text{O}_2(g) \rightarrow 2 \text{CO}_2(g)$	-566	-173

(B)	Reaction	$\Delta H^\circ$ (kJ/mol <sub>rxn</sub> )	$\Delta S^\circ$ (J/(mol <sub>rxn</sub> K))
	$2 \text{H}_2\text{O}(g) \rightarrow 2 \text{H}_2(g) + \text{O}_2(g)$	484	90.0

(C)	Reaction	$\Delta H^\circ$ (kJ/mol <sub>rxn</sub> )	$\Delta S^\circ$ (J/(mol <sub>rxn</sub> K))
	$2 \text{N}_2\text{O}(g) \rightarrow 2 \text{N}_2(g) + \text{O}_2(g)$	-164	149

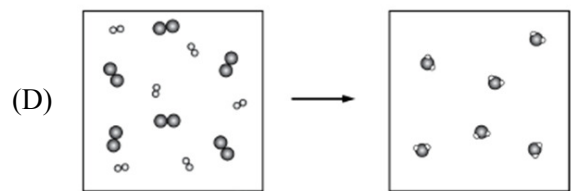
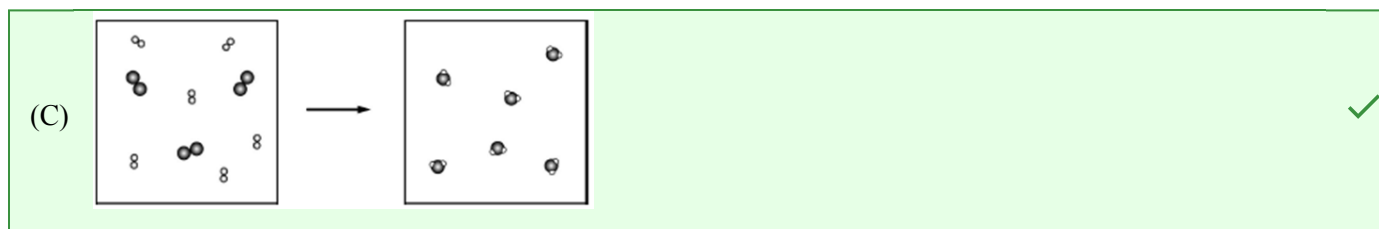
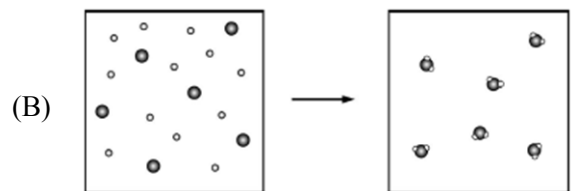
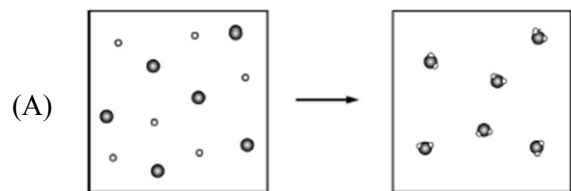
(D)	Reaction	$\Delta H^\circ$ (kJ/mol <sub>rxn</sub> )	$\Delta S^\circ$ (J/(mol <sub>rxn</sub> K))
	$\text{PbCl}_2(s) \rightarrow \text{Pb}^{2+}(aq) + 2 \text{Cl}^-(aq)$	23.4	-12.5

**Answer B**

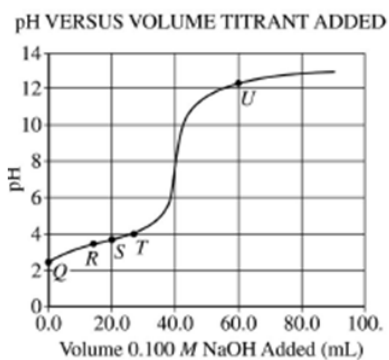
This option is correct.  $\Delta G = \Delta H - T \Delta S$ . At low temperature,  $\Delta G$  is dominated by  $\Delta H$ , and since  $\Delta H > 0$ , the reaction is not favored. At high temperatures,  $\Delta G$  is dominated by  $-T \Delta S$ , and since  $\Delta S > 0$ , the reaction is favored.

13. Which of the following particulate diagrams best shows the formation of water vapor from hydrogen gas and oxygen gas in a rigid container at  $125^\circ\text{C}$ ?

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Refer to the following.



A 50.0 mL sample of an acid, HA, of unknown molarity is titrated, and the pH of the resulting solution is measured with a meter and graphed as a function of the volume of 0.100 M NaOH added.

14. At point R in the titration, which of the following species has the highest concentration?

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(A) HA



(B) A<sup>-</sup>

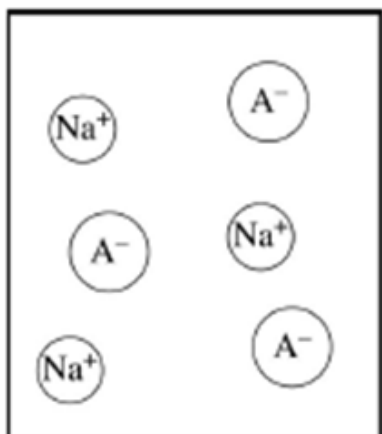
(C) H<sub>3</sub>O<sup>+</sup>

(D) OH<sup>-</sup>

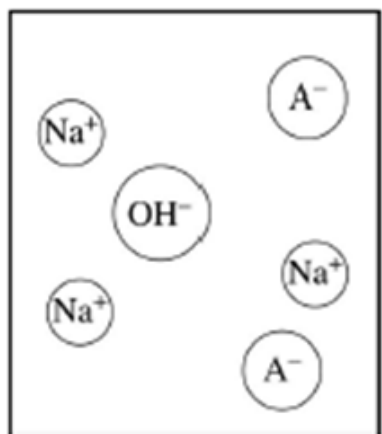
15. Which of the following is the best particulate representation of the species (other than H<sub>2</sub>O) that are present in significant concentrations in the solution at point *U* in the titration?

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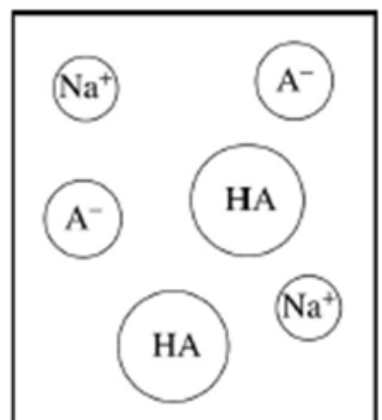
(A)



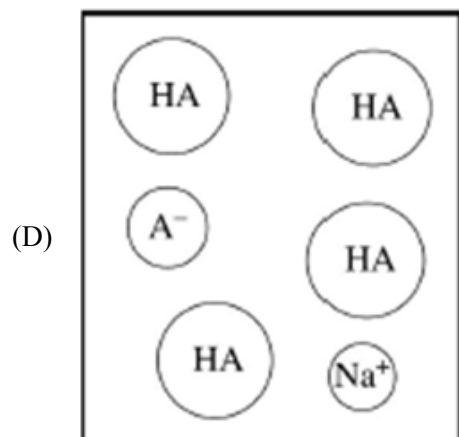
(B)



(C)



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16. At which point on the titration curve is  $[A^-]$  closest to twice that of  $[HA]$ ?

- (A) *R*  
 (B) *S*  
 (C) *T*  
 (D) *U*



17. A student carries out the same titration but uses an indicator instead of a pH meter. If the indicator changes color slightly past the equivalence point, what will the student obtain for the calculated concentration of the acid?

- (A) Slightly less than  $0.0800\ M$   
 (B) Slightly more than  $0.0800\ M$   
 (C) Slightly less than  $0.125\ M$   
 (D) Slightly more than  $0.125\ M$



Refer to three gases in identical rigid containers under the conditions given in the table below.

Container	A	B	C
Gas	Methane	Ethane	Butane
Formula	$CH_4$	$C_2H_6$	$C_4H_{10}$
Molar mass (g/mol)	16	30.	58
Temperature ( $^{\circ}C$ )	27	27	27
Pressure (atm)	2.0	4.0	2.0

18. The average kinetic energy of the gas molecules is

- (A) greatest in container A  
 (B) greatest in container B  
 (C) greatest in container C  
 (D) the same in all three containers



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19. The density of the gas, in g/L, is
- (A) greatest in container A
  - (B) greatest in container B ✓
  - (C) greatest in container C
  - (D) the same in all three containers
20. If the pressure of each gas is increased at constant temperature until condensation occurs, which gas will condense at the lowest pressure?
- (A) Methane
  - (B) Ethane
  - (C) Butane ✓
  - (D) All the gases will condense at the same pressure.
- 
21. The mass percent of carbon in pure glucose,  $C_6H_{12}O_6$ , is 40.0 percent. A chemist analyzes an impure sample of glucose and determines that the mass percent of carbon is 38.2 percent. Which of the following impurities could account for the low mass percent of carbon in the sample?
- (A) Water,  $H_2O$  ✓
  - (B) Ribose,  $C_5H_{10}O_5$
  - (C) Fructose,  $C_6H_{12}O_6$ , an isomer of glucose
  - (D) Sucrose,  $C_{12}H_{22}O_{11}$

**Answer A**

This option is correct. An impurity that contains no carbon will decrease the mass percent of carbon relative to the pure substance. The mass percent of carbon in the sample is lower than that of pure glucose. So this option is consistent with the observation.

22. Caffeine ( $C_8H_{10}N_4O_2$ ) is a weak base with a  $K_b$  value of  $4 \times 10^{-4}$ . The pH of a 0.01 M solution of caffeine is in the range of
- (A) 2–3
  - (B) 5–6
  - (C) 7–8
  - (D) 11–12 ✓

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**Answer D**

This option is correct. The equilibrium expression for a weak base, B, is

$$K_b = \frac{[\text{HB}^+][\text{OH}^-]}{[\text{B}]}$$

. Here  $[\text{B}] = 0.01 \text{ M}$ ,  $K_b = 4 \times 10^{-4}$  and  $[\text{HB}^+] = [\text{OH}^-]$ .

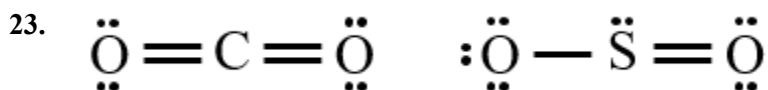
Therefore

$$[\text{OH}^-] = \sqrt{K_b \times 0.01}$$

This corresponds to

$$\sqrt{4 \times 10^{-6}}$$

or  $2 \times 10^{-3}$ . The pOH is therefore somewhat less than 3, making the pH somewhat larger than 11. The pH therefore lies within the range of this option, pH = 11-12.



Lewis electron-dot diagrams for  $\text{CO}_2$  and  $\text{SO}_2$  are given above. The molecular geometry and polarity of the two substances are

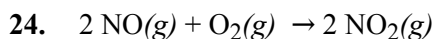
- (A) the same because the molecular formulas are similar
- (B) the same because C and S have similar electronegativity values
- (C) different because the lone pair of electrons on the S atom make it the negative end of a dipole
- (D) different because S has a greater number of electron domains (regions of electron density) surrounding it than C has

**Answer D**

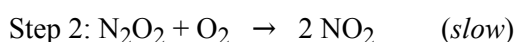
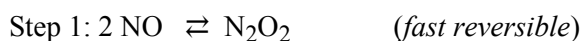
This option is correct. Both the C-O and S-O bonds are polar, due to the different electronegativities of the bonded atoms. However, the  $\text{CO}_2$  molecule is linear and so the bond dipoles cancel and the molecule has no net dipole. In  $\text{SO}_2$ , the molecule is bent and so the bond dipoles do not cancel and a net dipole is

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present. The polarity of the two substances differs because of the differences in geometry, which is a direct consequence of the number of electron domains around the central atom (2 in  $\text{CO}_2$  and 3 in  $\text{SO}_2$ ), as stated in this option.



Consider the following mechanism for the reaction represented above.



Which of the following statements is true?

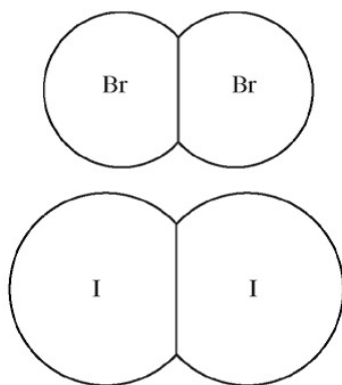
- (A) Step 1 represents a unimolecular reaction.
- (B) Increasing the concentration of NO will decrease the overall rate of the reaction.
- (C) Raising the temperature will have no effect on the numerical value of the rate constant.
- (D) The rate law that is consistent with the mechanism is  $rate = k[\text{NO}]^2[\text{O}_2]$ . ✓

**Answer D**

This option is correct. The fast and reversible character of the first step in the mechanism will establish an equilibrium in which the concentration of the intermediate  $\text{N}_2\text{O}_2$  is directly proportional to  $[\text{NO}]^2$ . The overall rate of the reaction is given by the second step, for which the rate is proportional to the product  $[\text{N}_2\text{O}_2][\text{O}_2]$ . Since  $[\text{N}_2\text{O}_2]$  is directly proportional to  $[\text{NO}]^2$  from step 1, substitution yields an overall reaction rate law of  $rate = k [\text{NO}]^2[\text{O}_2]$ , as stated in this option.

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25.



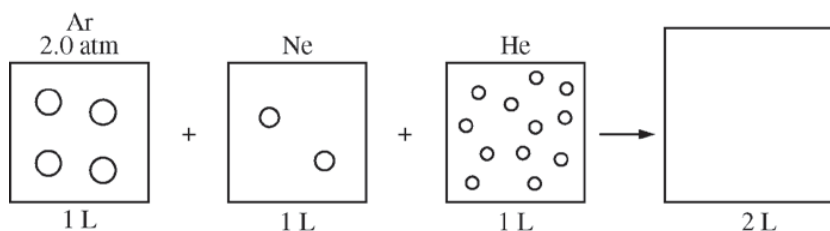
The diagram above shows molecules of  $\text{Br}_2$  and  $\text{I}_2$  drawn to the same scale. Which of the following is the best explanation for the difference in the boiling points of liquid  $\text{Br}_2$  and  $\text{I}_2$ , which are  $59^\circ\text{C}$  and  $184^\circ\text{C}$ , respectively?

- (A) Solid iodine is a network covalent solid, whereas solid bromine is a molecular solid.
- (B) The covalent bonds in  $\text{I}_2$  molecules are weaker than those in  $\text{Br}_2$  molecules.
- (C)  $\text{I}_2$  molecules have electron clouds that are more polarizable than those of  $\text{Br}_2$  molecules, thus London dispersion forces are stronger in liquid  $\text{I}_2$ . ✓
- (D) Bromine has a greater electronegativity than iodine, thus there are stronger dipole-dipole forces in liquid bromine than in liquid iodine.

**Answer C**

This option is correct. Since both  $\text{Br}_2$  and  $\text{I}_2$  are nonpolar, London dispersion forces establish the boiling points. The larger electron cloud in  $\text{I}_2$  gives it a greater polarizability and therefore stronger London dispersion forces. The higher boiling point of  $\text{I}_2$  is therefore due to the greater polarizability of  $\text{I}_2$ , as stated in this option.

26.



The figure above represents three sealed 1.0 L vessels, each containing a different inert gas at 298 K. The pressure of Ar in the first vessel is 2.0 atm. The ratio of the numbers of Ar, Ne, and He atoms in the vessels is 2:1:6, respectively. After all the gases are combined in a previously evacuated 2.0 L vessel, what is the total pressure of the gases at 298 K?

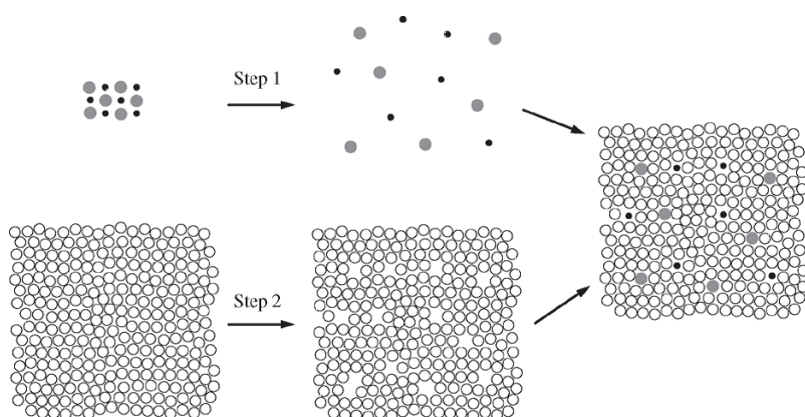
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- (A) 3.0 atm  
 (B) 4.5 atm  
 (C) 9.0 atm  
 (D) 18 atm

**Answer B**

This option is correct. Since the volume of the three original containers are equal, the pressures are proportional to the number of atoms in the containers, which are in the ratio of 2:1:6. The pressure in the first container is given as 2 atm, therefore the pressures in the three containers are 2 atm, 1 atm, and 6 atm, respectively. If these were combined into a single container with a volume equal to that of the original vessels (1 liter), the total pressure would be the sum of these partial pressures, corresponding to 9 atm. The final container has a volume of 2 liters, which lowers the pressure by a factor of 2, to 4.5 atm.

27.



The dissolution of an ionic solute in a polar solvent can be imagined as occurring in three steps, as shown in the figure above. In step 1, the separation between ions in the solute is greatly increased, just as will occur when the solute dissolves in the polar solvent. In step 2, the polar solvent is expanded to make spaces that the ions will occupy. In the last step, the ions are inserted into the spaces in the polar solvent. Which of the following best describes the enthalpy change,  $\Delta H$ , for each step?

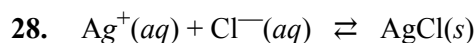
- (A) All three steps are exothermic.  
 (B) All three steps are endothermic.  
 (C) Steps 1 and 2 are exothermic, and the final step is endothermic.  
 (D) Steps 1 and 2 are endothermic, and the final step is exothermic.



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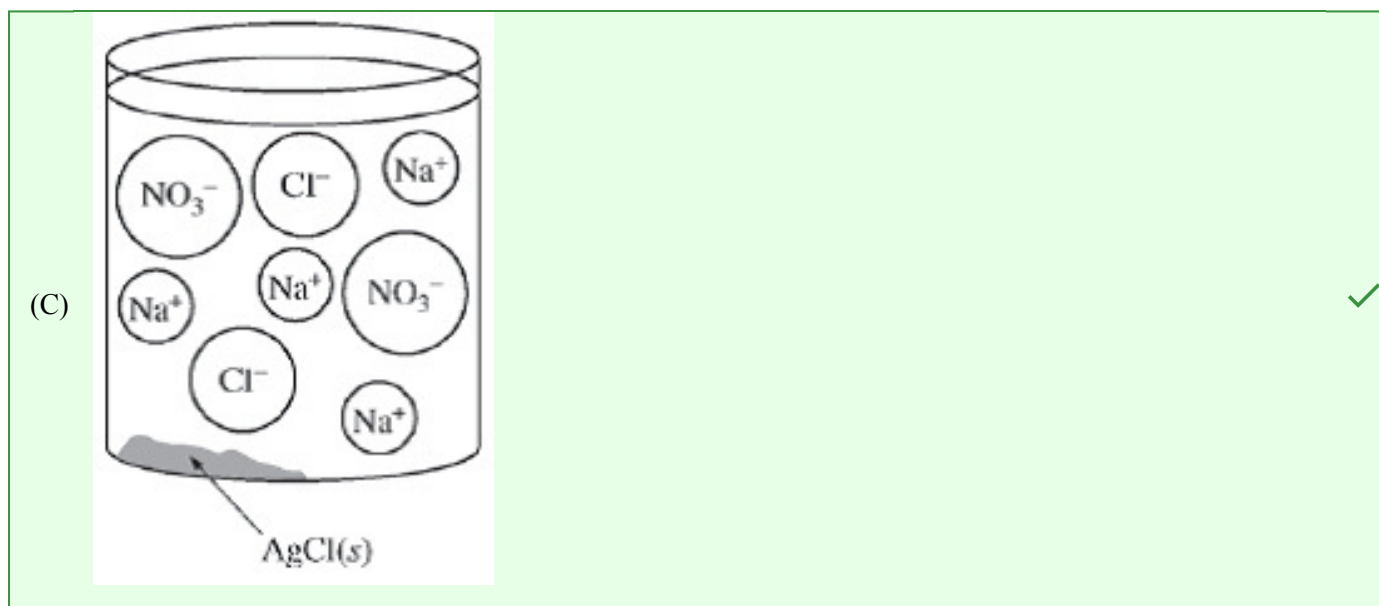
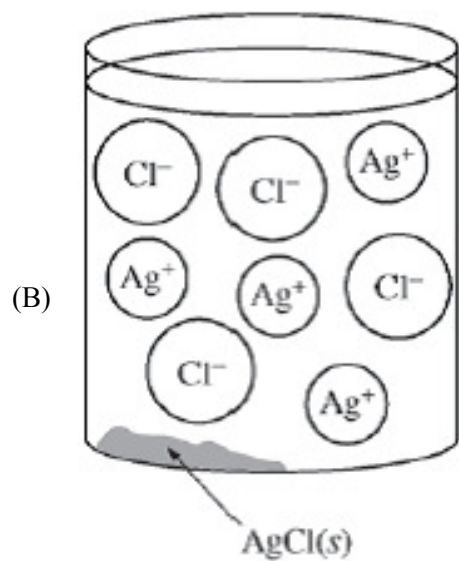
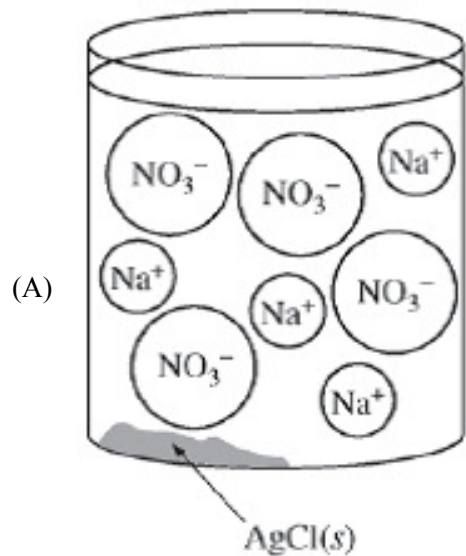
**Answer D**

This option is correct. In steps 1 and 2, favorable intermolecular interactions are broken and this increases the enthalpy, corresponding to an endothermic process. In step 3, favorable intermolecular interactions are established, which decreases the enthalpy, corresponding to an exothermic process. (The sign of the enthalpy change for the overall process is established by the difference in magnitude between these enthalpy changes, and so the overall process can be either endothermic or exothermic.)

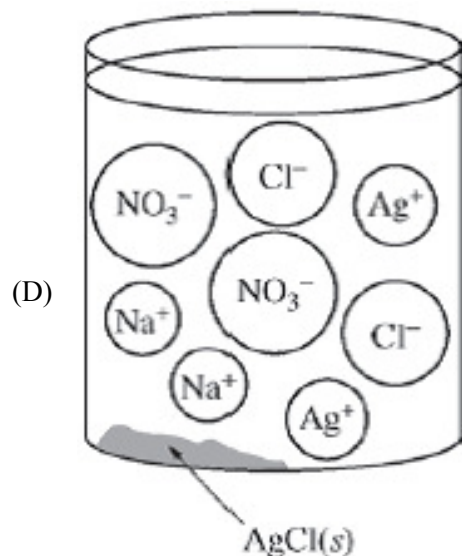


A student mixes dilute  $\text{AgNO}_3(aq)$  with excess  $\text{NaCl}(aq)$  to form  $\text{AgCl}(s)$ , as represented by the net ionic equation above. Which of the diagrams below best represents the ions that are present in significant concentrations in the solution? ( $K_{sp}$  for  $\text{AgCl}$  is  $1.8 \times 10^{-10}$ .)

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**Answer C**

This option is correct. The addition of excess  $\text{NaCl}$  will cause there to be additional  $\text{Na}^+$  and  $\text{Cl}^-$  ions in the solution, along with  $\text{NO}_3^-$  ions remaining from the original  $\text{AgNO}_3$  solution. Due to the low  $K_{sp}$ , almost all of the  $\text{Ag}^+$  ions have precipitated from solution.

Refer to the following.



$\text{PCl}_5(g)$  decomposes into  $\text{PCl}_3(g)$  and  $\text{Cl}_2(g)$  according to the equation above. A pure sample of  $\text{PCl}_5(g)$  is placed in a rigid, evacuated 1.00L container. The initial pressure of the  $\text{PCl}_5(g)$  is 1.00 atm. The temperature is held constant until the  $\text{PCl}_5(g)$  reaches equilibrium with its decomposition products. The figures below show the initial and equilibrium conditions of the system.

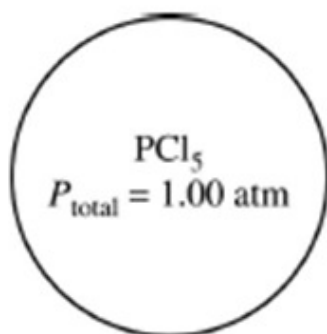


Figure 1: Initial

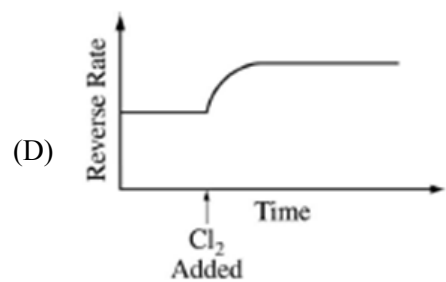
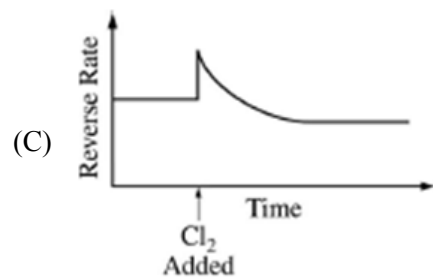
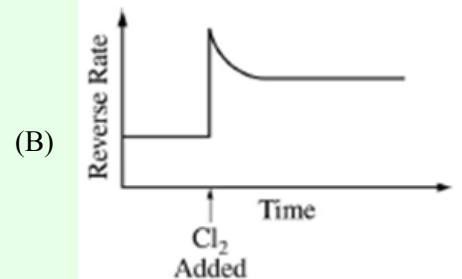
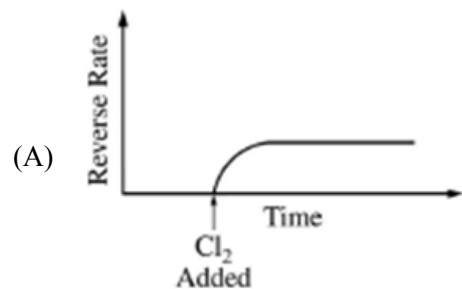


Figure 2: Equilibrium

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29. Which of the following is the most likely cause for the increase in pressure observed in the container as the reaction reaches equilibrium?
- (A) A decrease in the strength of intermolecular attractions among molecules in the flask
  - (B) An increase in the strength of intermolecular attractions among molecules in the flask
  - (C) An increase in the number of molecules, which increases the frequency of collisions with the walls of the container ✓
  - (D) An increase in the speed of the molecules that then collide with the walls of the container with greater force
30. As the reaction progresses toward equilibrium, the rate of the forward reaction
- (A) increases until it becomes the same as the reverse reaction rate at equilibrium
  - (B) stays constant before and after equilibrium is reached
  - (C) decreases to become a constant nonzero rate at equilibrium ✓
  - (D) decreases to become zero at equilibrium
31. If the decomposition reaction were to go to completion, the total pressure in the container will be
- (A) 1.4 atm
  - (B) 2.0 atm ✓
  - (C) 2.8 atm
  - (D) 3.0 atm
32. Which of the following statements about  $K_p$ , the equilibrium constant for the reaction, is correct?
- (A)  $K_p > 1$
  - (B)  $K_p < 1$  ✓
  - (C)  $K_p = 1$
  - (D) It cannot be determined whether  $K_p > 1$ ,  $K_p < 1$ , or  $K_p = 1$  without additional information.
33. Additional  $\text{Cl}_2(\text{g})$  is injected into the system at equilibrium. Which of the following graphs best shows the rate of the reverse reaction as a function of time? (Assume that the time for injection and mixing of the additional  $\text{Cl}_2(\text{g})$  is negligible.)

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The elements K and Cl react directly to form the compound KCl according to the equation above. Refer to the information above and the table below to answer the questions that follow.

Process	$\Delta H^\circ$ (kJ/mol <sub>rxn</sub> )
$\text{K}(s) \rightarrow \text{K}(g)$	$v$
$\text{K}(g) \rightarrow \text{K}^+(g) + e^-$	$w$
$\text{Cl}_2(g) \rightarrow 2 \text{Cl}(g)$	$x$
$\text{Cl}(g) + e^- \rightarrow \text{Cl}^-(g)$	$y$
$\text{K}^+(g) + \text{Cl}^-(g) \rightarrow \text{KCl}(s)$	$z$

34. How much heat is released or absorbed when 0.050 mol of  $\text{Cl}_2(g)$  is formed from  $\text{KCl}(s)$ ?
- (A) 87.4 kJ is released  
 (B) 43.7 kJ is released  
 (C) 43.7 kJ is absorbed ✓  
 (D) 87.4 kJ is absorbed
35. What remains in the reaction vessel after equal masses of  $\text{K}(s)$  and  $\text{Cl}_2(g)$  have reacted until either one or both of the reactants have been completely consumed?
- (A) KCl only  
 (B) KCl and K only  
 (C) KCl and  $\text{Cl}_2$  only ✓  
 (D) KCl, K, and  $\text{Cl}_2$
36. Which of the values of  $\Delta H^\circ$  for a process in the table is (are) less than zero (i.e., indicate(s) an exothermic process)?
- (A)  $z$  only  
 (B)  $y$  and  $z$  only ✓  
 (C)  $x$ ,  $y$ , and  $z$  only  
 (D)  $w$ ,  $x$ ,  $y$ , and  $z$

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37. It is observed that the reaction producing KCl from its elements goes essentially to completion. Which of the following is a true statement about the thermodynamic favorability of the reaction?

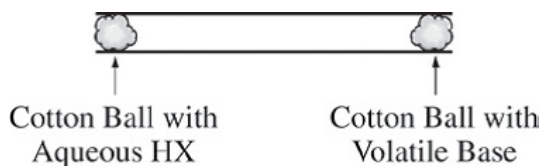
- (A) The reaction is favorable and driven by an enthalpy change only. ✓
- (B) The reaction is unfavorable and driven by an entropy change only.
- (C) The reaction is favorable and driven by both enthalpy and entropy changes.
- (D) The reaction is unfavorable due to both enthalpy and entropy changes.

38.  $\text{Cl}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{g})$

Which of the following expressions is equivalent to  $\Delta H^\circ$  for the reaction represented above?

- (A)  $x + y$
- (B)  $x - y$
- (C)  $x + 2y$  ✓
- (D)  $\frac{x}{2} - y$

- 39.



The experimental apparatus represented above is used to demonstrate the rates at which gases diffuse. When the cotton balls are placed in the ends of a tube at the same time, the gases diffuse from each end and meet somewhere in between, where they react to form a white solid. Which of the following combinations will produce a solid closest to the center of the tube?

- (A) HCl and  $\text{CH}_3\text{NH}_2$  ✓
- (B) HCl and  $\text{NH}_3$
- (C) HBr and  $\text{CH}_3\text{NH}_2$
- (D) HBr and  $\text{NH}_3$

**Answer A**

This option is correct. It demonstrates understanding that gases with similar molar masses ( $\text{HCl} = 36 \text{ g/mol}$  and  $\text{CH}_3\text{NH}_2 = 31 \text{ g/mol}$ ) at the same temperature will travel with similar average speeds, resulting in a solid being formed at roughly equal distances from each cotton ball.

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40.  $\text{N}_2$  molecules absorb ultraviolet light but not visible light.  $\text{I}_2$  molecules absorb both visible and ultraviolet light. Which of the following statements explains the observations?
- (A) More energy is required to make  $\text{N}_2$  molecules vibrate than is required to make  $\text{I}_2$  molecules vibrate.
- (B) More energy is required to remove an electron from an  $\text{I}_2$  molecule than is required to remove an electron from a  $\text{N}_2$  molecule.
- (C) Visible light does not produce transitions between electronic energy levels in the  $\text{N}_2$  molecule but does produce transitions in the  $\text{I}_2$  molecule. ✓
- (D) The molecular mass of  $\text{I}_2$  is greater than the molecular mass of  $\text{N}_2$ .

41.

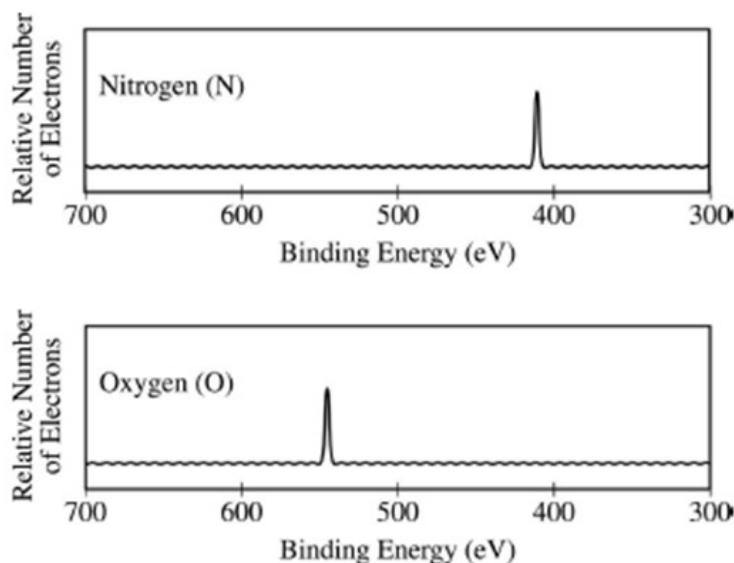
Element	Metallic Radius (pm)	Melting Point ( $^{\circ}\text{C}$ )	Common Oxidation State
Au	144	1064	1+, 3+
Cu	128	1085	1+, 2+
Ag	144	961	1+

To make Au stronger and harder, it is often alloyed with other metals, such as Cu and Ag. Consider two alloys, one of Au and Cu and one of Au and Ag, each with the same mole fraction of Au. If the Au/Cu alloy is harder than the Au/Ag alloy, then which of the following is the best explanation based on the information in the table above?

- (A) Cu has two common oxidation states, but Ag has only one.
- (B) Cu has a higher melting point than Au has, but Ag has a lower melting point than Au has.
- (C) Cu atoms are smaller than Ag atoms, thus they interfere more with the displacement of atoms in the alloy. ✓
- (D) Cu atoms are less polarizable than are Au or Ag atoms, thus Cu has weaker interparticle forces.

## Practice Exam 12\_2013 MCQ

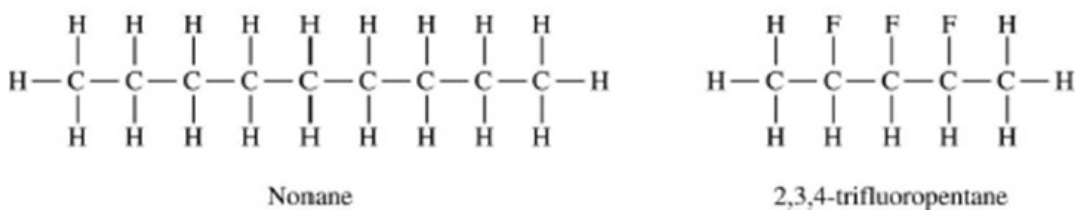
42.



The photoelectron spectra above show the energy required to remove a  $1s$  electron from a nitrogen atom and from an oxygen atom. Which of the following statements best accounts for the peak in the upper spectrum being to the right of the peak in the lower spectrum?

- (A) Nitrogen atoms have a half-filled  $p$  subshell.
- (B) There are more electron-electron repulsions in oxygen atoms than in nitrogen atoms.
- (C) Electrons in the  $p$  subshell of oxygen atoms provide more shielding than electrons in the  $p$  subshell of nitrogen atoms.
- (D) Nitrogen atoms have a smaller nuclear charge than oxygen atoms. ✓

43.



Consider the molecules represented above and the data in the table below.

Compound	Molecular Formula	Molar Mass (g/mol)	Boiling Point ( $^{\circ}\text{C}$ )
Nonane	$\text{C}_9\text{H}_{20}$	128	151
2,3,4-trifluoropentane	$\text{C}_5\text{H}_9\text{F}_3$	126	89

Nonane and 2,3,4-trifluoropentane have almost identical molar masses, but nonane has a significantly higher boiling point. Which of the following statements best helps explain this observation?

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- (A) The C-F is easier to break than the C-H bond.
- (B) The C-F is more polar than the C-H bond.
- (C) The carbon chains are longer in nonane than they are in 2,3,4-trifluoropentane. ✓
- (D) The carbon chains are farther apart in a sample of nonane than they are in 2,3,4-trifluoropentane.

44. Half-cell 1: strip of Al(s) in 1.00 M Al(NO<sub>3</sub>)<sub>3</sub>(aq)  
 Half-cell 2: strip of Cu(s) in 1.00 M Cu(NO<sub>3</sub>)<sub>2</sub>(aq)  
 Half-cell 3: strip of Fe(s) in 1.00 M Fe(NO<sub>3</sub>)<sub>2</sub>(aq)

Galvanic Cell	Half-cells	Cell Reaction	$E_{cell}^{\circ}$ (V)
X	1 and 2	$2 \text{Al}(s) + 3 \text{Cu}^{2+}(aq) \rightarrow 2 \text{Al}^{3+}(aq) + 3 \text{Cu}(s)$	2.00
Y	1 and 3	$2 \text{Al}(s) + 3 \text{Fe}^{2+}(aq) \rightarrow 2 \text{Al}^{3+}(aq) + 3 \text{Fe}(s)$	1.22
Z	2 and 3	$\text{Fe}(s) + \text{Cu}^{2+}(aq) \rightarrow \text{Fe}^{2+}(aq) + \text{Cu}(s)$	?

If the half-cell containing 1.00 M Fe(NO<sub>3</sub>)<sub>2</sub>(aq) in galvanic cells Y and Z is replaced with a half-cell containing 5.00 M Fe(NO<sub>3</sub>)<sub>2</sub>(aq), what will be the effect on the cell voltage of the two galvanic cells?

- (A) The voltage will increase in both cells.
- (B) The voltage will decrease in both cells.
- (C) The voltage will increase in cell Y and decrease in cell Z. ✓
- (D) The voltage will decrease in cell Y and increase in cell Z.

## Answer C

This option is correct. It correctly predicts that increasing the Fe<sup>2+</sup> ion concentration will increase the voltage for cell Y, where Fe<sup>2+</sup> ions are reactants. Increasing the Fe<sup>2+</sup> ion concentration will decrease the voltage for cell Z, where Fe<sup>2+</sup> ions are products.

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Refer to the following.

Concentration ( <i>M</i> )	pH of Acid 1	pH of Acid 2	pH of Acid 3	pH of Acid 4
0.010	3.44	2.00	2.92	2.20
0.050	3.09	1.30	2.58	1.73
0.10	2.94	1.00	2.42	1.55
0.50	2.69	0.30	2.08	1.16
1.00	2.44	0.00	1.92	0.98

The pH of solutions of four acids prepared at various concentrations were measured and recorded in the table above.

The four acids are, in no particular order, chlorous, hydrochloric, lactic, and propanoic.

45. Which of the four acids listed in the table is hydrochloric acid?

- (A) Acid 1  
(B) Acid 2  
(C) Acid 3  
(D) Acid 4

**Answer B**

This option is correct. It is based on recognition that HCl is a strong acid and reasoning that in every case the concentration of Acid 2 is equal to the  $\text{H}_3\text{O}^+$  ion concentration, indicating 100 percent dissociation.

46. For which acid is the value of the acid-dissociation constant,  $K_a$ , the smallest?

- (A) Acid 1  
(B) Acid 2  
(C) Acid 3  
(D) Acid 4

**Answer A**

This option is correct. It correctly identifies that Acid 1 is a weak acid, and that it must have the lowest acid-dissociation constant since it has the highest pH (closest to neutral) at each of the provided concentrations.

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47. Of the following species, which has the greatest concentration in a 1.0 *M* solution of acid 1 at equilibrium?
- (A)  $\text{OH}^-$
  - (B)  $\text{H}_3\text{O}^+$
  - (C) Acid 1
  - (D) The conjugate base of acid 1

**Answer C**

This option is correct. It correctly determines that Acid 1 is a weak acid, which has a small degree of ionization. In the 1.0 *M* solution, the protonated form of the acid will have the highest concentration.

48. If equal volumes of the four acids at a concentration of 0.50 *M* are each titrated with a strong base, which will require the greatest volume of base to reach the equivalence point?
- (A) Acid 1
  - (B) Acid 2
  - (C) Acid 3
  - (D) All the acids will require the same volume of base to reach the equivalence point.

**Answer D**

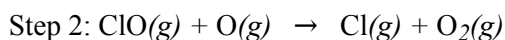
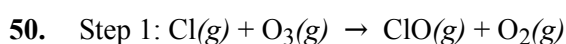
This option is correct. Since the concentrations of the acids are identical, the same volume of base is required to reach the equivalence point.

49. A 25 mL sample of a 1.0 *M* solution of acid 1 is mixed with 25 mL of 0.50 *M* NaOH. Which of the following best explains what happens to the pH of the mixture when a few drops of 1.0 *M*  $\text{HNO}_3$  are added?
- (A) The pH of the mixture increases sharply, because  $\text{HNO}_3$  is a strong acid.
  - (B) The pH of the mixture decreases sharply, because  $\text{H}_3\text{O}^+$  ions were added.
  - (C) The pH of the mixture stays about the same, because the conjugate base of acid 1 reacts with the added  $\text{H}_3\text{O}^+$  ions.
  - (D) The pH of the mixture stays about the same, because the  $\text{OH}^-$  ions in the solution react with the added  $\text{H}_3\text{O}^+$  ions.

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## Answer C

This option is correct. Acid 1 is a weak acid because the starting pH is higher than expected for complete dissociation. The added base converts half of the weak acid to its conjugate base, creating a buffer solution. If concentrated acid is added to the buffer solution, the acid reacts with the conjugate base, thereby keeping the pH roughly constant.



A proposed mechanism for destruction of ozone gas in the stratosphere is represented above. Which of the following is evidence that the mechanism is occurring?

- (A) The presence of  $\text{Cl}(g)$  increases the rate of the overall reaction. ✓
- (B) The presence of  $\text{Cl}(g)$  decreases the rate of the overall reaction.
- (C) The presence of  $\text{Cl}(g)$  increases the equilibrium constant of the overall reaction.
- (D) The presence of  $\text{Cl}(g)$  decreases the equilibrium constant of the overall reaction.

## Answer A

**This option is correct.  $\text{Cl}(g)$  is a catalyst for the reaction. The presence of  $\text{Cl}(g)$  decreases the activation energy and increases the rate.**

51.

	NaF	MgO
Boiling Point (°C)	1695	3600

	$\text{Na}^+$	$\text{Mg}^{2+}$	$\text{F}^-$	$\text{Cl}^-$	$\text{O}^{2-}$
Ionic Radius (pm)	76	72	133	181	140

Based on the data in the tables above, which of the following statements provides the best prediction for the boiling point of  $\text{NaCl}$ ?

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- (A) NaCl will have a lower boiling point than NaF because the coulombic attractions are weaker in NaCl than in NaF. ✓
- (B) NaCl will have a boiling point between that of NaF and MgO because the covalent character of the bonds in NaCl is intermediate between that of MgO and NaF.
- (C) NaCl will have a higher boiling point than MgO because the ions are spaced farther apart in NaCl.
- (D) NaCl will have a higher boiling point than MgO because the energy required to transfer electrons from the anion to the cation is larger in NaCl than in MgO.

52.

Acid	Structure	$K_a$
HNO <sub>2</sub>		$4.0 \times 10^{-4}$
HC <sub>3</sub> H <sub>5</sub> O <sub>2</sub>		$1.3 \times 10^{-5}$
HClO		$3.0 \times 10^{-8}$
HOC <sub>6</sub> H <sub>5</sub>		$1.6 \times 10^{-10}$

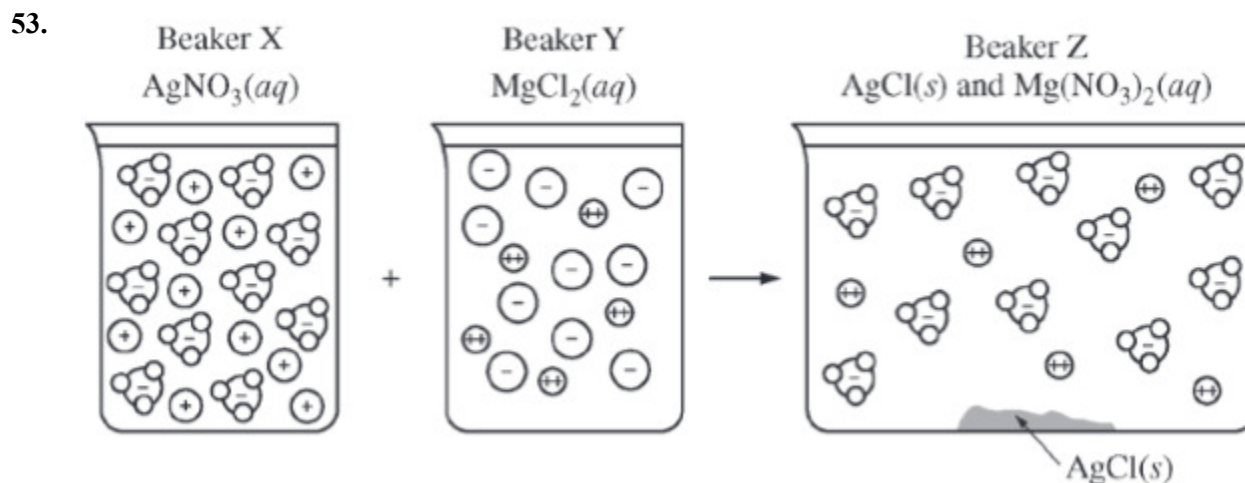
The table above shows the values of  $K_a$  for four weak acids. Which of the following pairs of chemical species, when combined in equimolar amounts, results in a buffer with a pH closest to 7.5 ?

- (A) HNO<sub>2</sub> and OH<sup>-</sup>
- (B) HC<sub>3</sub>H<sub>5</sub>O<sub>2</sub> and C<sub>3</sub>H<sub>5</sub>O<sub>2</sub><sup>-</sup>
- (C) HClO and ClO<sup>-</sup> ✓
- (D) C<sub>6</sub>H<sub>5</sub>OH and C<sub>6</sub>H<sub>5</sub>O<sup>-</sup>

**Answer C**

This option is correct. The  $pK_a$  of HClO is close to 7.5.

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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 white precipitate. Assuming that volumes are additive, which of the following sets of solutions could be represented by the diagram above?

(A)

Beaker X	Beaker Y	Beaker Z
2.0 M $\text{AgNO}_3$	2.0 M $\text{MgCl}_2$	4.0 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$

(B)

Beaker X	Beaker Y	Beaker Z
2.0 M $\text{AgNO}_3$	2.0 M $\text{MgCl}_2$	2.0 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$

(C)

Beaker X	Beaker Y	Beaker Z
2.0 M $\text{AgNO}_3$	1.0 M $\text{MgCl}_2$	1.0 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$

(D)

Beaker X	Beaker Y	Beaker Z
2.0 M $\text{AgNO}_3$	1.0 M $\text{MgCl}_2$	0.50 M $\text{Mg}(\text{NO}_3)_2$ and $\text{AgCl}(s)$

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## Answer D

This option is correct. The concentration of  $\text{Mg}^{2+}$  in Y is half the concentration of  $\text{Ag}^+$  in X. The concentration of  $\text{Mg}^{2+}$  in Z is half of what it is in Y because the volume doubled.



A sample of  $\text{N}_2\text{O}_5$  was placed in an evacuated container, and the reaction represented above occurred. The value of  $P_{\text{N}_2\text{O}_5}$ , the partial pressure of  $\text{N}_2\text{O}_5(\text{g})$ , was measured during the reaction and recorded in the table below.

Time (min)	$P_{\text{N}_2\text{O}_5}$	$\ln(P_{\text{N}_2\text{O}_5})$	$\frac{1}{P_{\text{N}_2\text{O}_5}}$ ( $\text{atm}^{-1}$ )
0	150	5.0	0.0067
100	75	4.3	0.013
200	38	3.6	0.027
300	19	2.9	0.053

Which of the following correctly describes the reaction?

- (A) The decomposition of  $\text{N}_2\text{O}_5$  is a zero-order reaction.
- (B) The decomposition of  $\text{N}_2\text{O}_5$  is a first-order reaction. ✓
- (C) The decomposition of  $\text{N}_2\text{O}_5$  is a second-order reaction.
- (D) The overall reaction order is 3.

55.

Element	Atomic Radius	First Ionization Energy
Calcium	194 pm	590 kJ/mol
Potassium	—	—

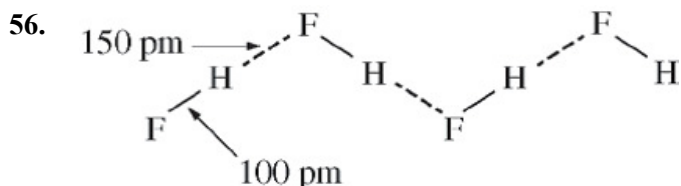
Based on periodic trends and the data in the table above, which of the following are the most probable values of the atomic radius and the first ionization energy for potassium, respectively?

- (A) 242 pm, 633 kJ/mol
- (B) 242 pm, 419 kJ/mol ✓
- (C) 120 pm, 633 kJ/mol
- (D) 120 pm, 419 kJ/mol

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**Answer B**

This option is correct. Potassium is larger than calcium because it has a smaller effective nuclear charge. Because potassium is larger, less energy is required to remove an electron from it than is required to remove an electron from calcium.



The figure above shows that in solid hydrogen fluoride there are two different distances between H atoms and F atoms. Which of the following best accounts for the two different distances?

- (A) Accommodation of the necessary bond angles in the formation of the solid
- (B) Difference in strength between covalent bonds and intermolecular attractions
- (C) Different isotopes of fluorine present in the samples
- (D) Uneven repulsions among nonbonding electron pairs

**Answer B**

This option is correct. There is a shorter covalent bond between H and F within the molecules and longer hydrogen bond between the H in one molecule and the F in a second molecule.



$\text{COCl}_2(\text{g})$  decomposes according to the equation above. When pure  $\text{COCl}_2(\text{g})$  is injected into a rigid, previously evacuated flask at 690 K, the pressure in the flask is initially 1.0 atm. After the reaction reaches equilibrium at 690 K, the total pressure in the flask is 1.2 atm. What is the value of  $K_p$  for the reaction at 690 K?

- (A) 0.040
- (B) 0.050
- (C) 0.80
- (D) 1.0

**Practice Exam 12\_2013 MCQ****Answer B**

This option is correct. Each molecule of  $\text{COCl}_2$  that decomposes creates two moles of gas. When the number of moles of  $\text{COCl}_2$  decreases such that the pressure is 0.8 atm, there is 0.2 mol of each of the product gas. The equilibrium constant  $K = (0.2)(0.2)/(0.8) = 0.050$ .