2021 MCQ

$$4\,\mathrm{FeS}(s)\ +\ 7\,\mathrm{O_2}(g)\ \rightarrow\ 2\,\mathrm{Fe_2O_3}(s)\ +\ 4\,\mathrm{SO_2}(g)$$

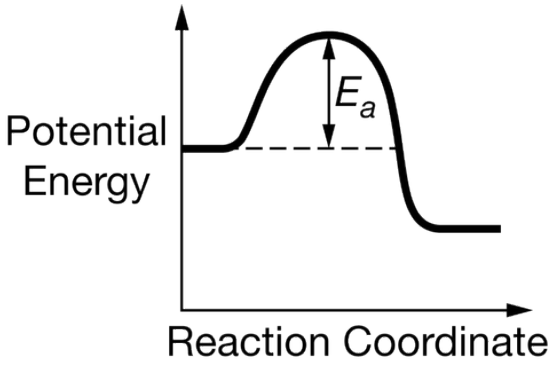
Due to the presence of $\mathrm{FeS}(s)$ as an impurity, the combustion of some types of coal results in the formation of $\mathrm{SO_2}(g)$, as represented by the equation above. Also, $\mathrm{SO_2}(g)$ can react with $\mathrm{O_3}(g)$ to form $\mathrm{SO_3}(g)$, as represented by the equation below.

$$\mathrm{SO_2}(g)\ +\ \mathrm{O_3}(g)\ \rightleftarrows\ \mathrm{SO_3}(g)\ +\ \mathrm{O_2}(g)$$

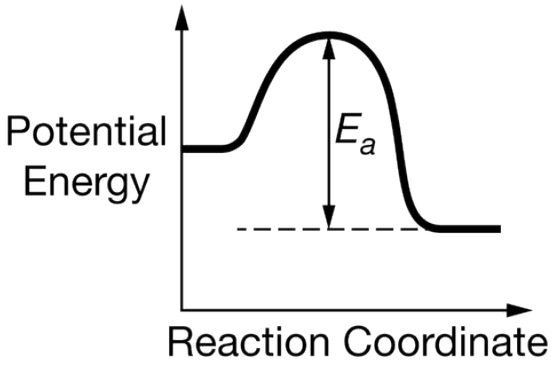
$$\Delta H^\circ_{298} = -242\ \mathrm{kJ/mol}_{rxn}\ ;\ \Delta S^\circ_{298} = -25\ \mathrm{J/(K \cdot mol}_{rxn})$$

1. Which of the following diagrams shows the correctly labeled activation energy, E_a, for the reaction between $\mathrm{SO_2}(g)$ and $\mathrm{O_3}(g)$?

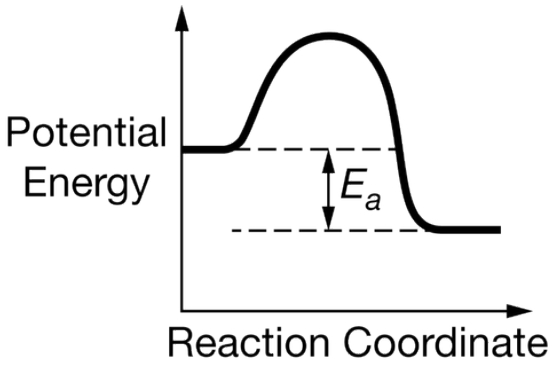
(A)



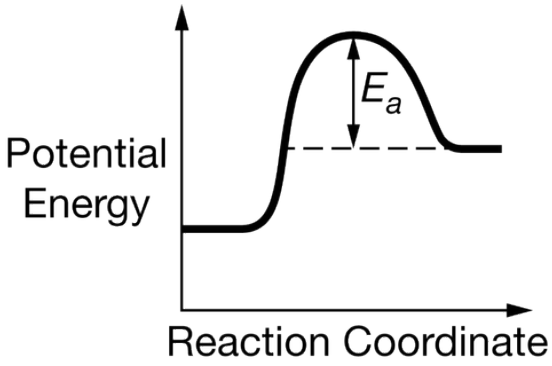
(B)



(C)



(D)



2. Which of the following statements is correct when $2.0\ \mathrm{mol}$ of $\mathrm{FeS}(s)$ reacts with $4.0\ \mathrm{mol}$ of $\mathrm{O_2}(g)$?

(A) $\mathrm{O_2}(g)$ is the limiting reactant and $2.0\ \mathrm{mol}$ of $\mathrm{SO_2}(g)$ is formed.

(B) $\mathrm{O_2}(g)$ is the limiting reactant and $4.0\ \mathrm{mol}$ of $\mathrm{SO_2}(g)$ is formed.

(C) $\mathrm{FeS}(s)$ is the limiting reactant and $4.0\ \mathrm{mol}$ of $\mathrm{SO_2}(g)$ is formed.

(D) $\mathrm{FeS}(s)$ is the limiting reactant and $0.5\ \mathrm{mol}$ of $\mathrm{O_2}(g)$ remains unreacted.

2021 MCQ

3. Which of the following is most likely to be true about the reaction between $SO_2(g)$ and $O_3(g)$ at $298\ K$?

(A) $\Delta G^\circ < 0$ and $T\Delta S^\circ$ is smaller in magnitude than ΔH°.

(B) $\Delta G^\circ < 0$ and $T\Delta S^\circ$ is larger in magnitude than ΔH°.

(C) $\Delta G^\circ > 0$ and $T\Delta S^\circ$ is smaller in magnitude than ΔH°.

(D) $\Delta G^\circ > 0$ and $T\Delta S^\circ$ is larger in magnitude than ΔH°.

4. In his atomic theory, Dalton proposed that all atoms of a given element are identical. Which of the following observations provides the best evidence that the proposal is incorrect?

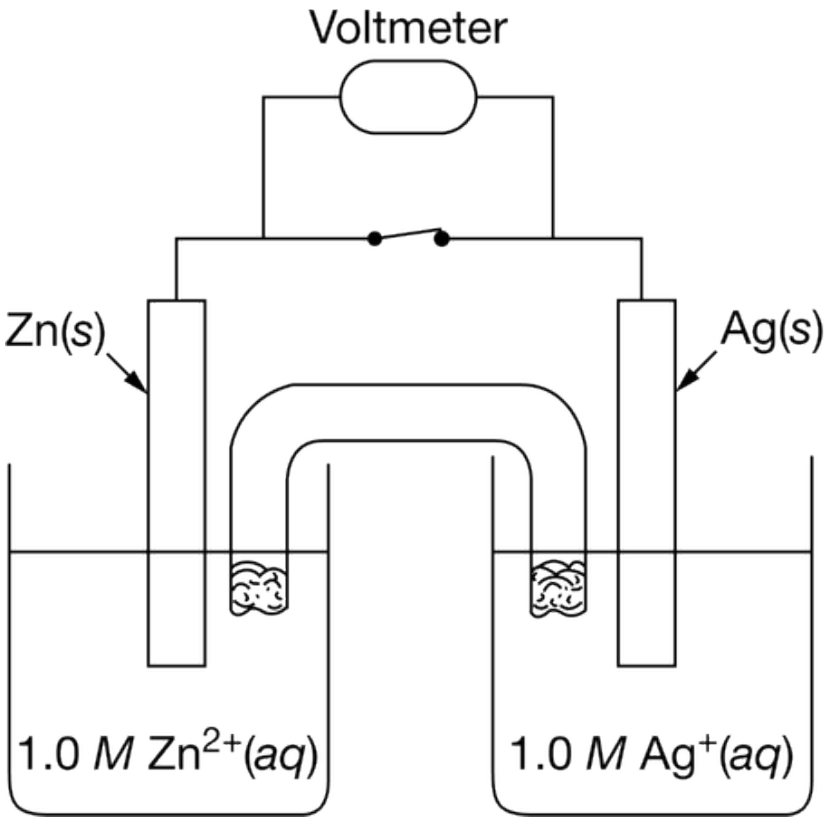
(A) The mass spectrum of Cu has a peak at $63\ amu$ and another peak at $65\ amu$.

(B) The ionic radius of Cl^- is $0.181\ nm$, and the atomic radius of Cl is $0.079\ nm$.

(C) The dipole moment of O_3 is $0.53\ debye$, and the dipole moment of O_2 is $0.00\ debye$.

(D) Elemental P can exist in both white and red forms.

5.



Which of the following substances would be the best choice for filling the salt bridge in the galvanic cell shown above, and why?

(A) Distilled water, because it would avoid contaminating the solutions in the half-cells.

(B) $1.0\ M\ HCl(aq)$, because it would acidify the solutions and catalyze the overall cell reaction.

(C) $1.0\ M\ CH_3OH(aq)$, because it would increase the pH of the solutions and catalyze the overall cell reaction.

(D) $1.0\ M\ KNO_3(aq)$, because the mobile ions would allow charge to flow between the half-cells.

2021 MCQ

6. $\mathrm{CH_4}(g) + 2\,\mathrm{O_2}(g) \rightarrow \mathrm{CO_2}(g) + 2\,\mathrm{H_2O}(g) \qquad \Delta H^\circ < 0$

Which of the following statements must be true for the combustion of $\mathrm{CH_4}(g)$, represented by the equation above?

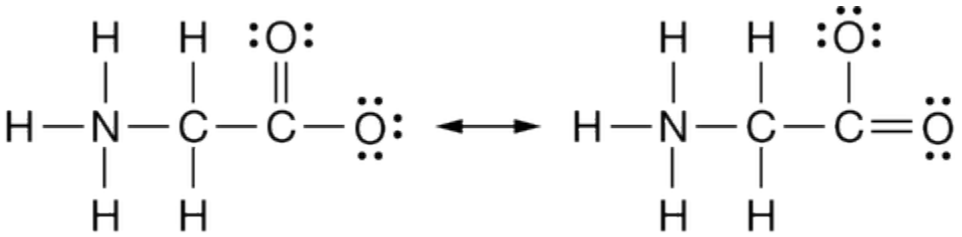
(A) The bond dissociation energy between O atoms in $\mathrm{O_2}$ is greater than the sum of the bond dissociation energies of the two $\mathrm{O-H}$ bonds in $\mathrm{H_2O}$.

(B) More bonds are formed in the products than are broken in the reactants.

(C) The sum of the bond dissociation energies of the product molecules is equal to the sum of the bond dissociation energies of the reactant molecules.

(D) The sum of the bond dissociation energies of the product molecules is greater than the sum of the bond dissociation energies of the reactant molecules.

7.



Based on the resonance structures shown above, what are the bond orders of the two carbon-oxygen bonds?

(A) 1 and 1.5

(B) 1 and 2

(C) 1.5 and 1.5

(D) 2 and 2

8.

Mass of solid	Mass of water	ΔT_{water}
1.0 g	2000.0 g	$+\,2.1^\circ\mathrm{C}$

A sample of a solid organic compound is completely combusted in a calorimeter. The heat generated by combustion is transferred to the water, causing the temperature of the water to increase. Based on the data in the table above, which of the following is the best estimate of the heat of combustion, ΔH_{comb}, of the organic solid? (The specific heat of water is 4.2 J g^{-1} $°C^{-1}$.

(A) $+18\ \mathrm{kJ/g}$

(B) $+8.4\ \mathrm{kJ/g}$

(C) $-8.4\ \mathrm{kJ/g}$

(D) $-18\ \mathrm{kJ/g}$

2021 MCQ

9.

Substance	Specific Heat $(\mathrm{J/(g \cdot {}^\circ C)})$	Mass of Sample (g)
$\mathrm{Fe}(s)$	0.46	1.0
$\mathrm{Al}(s)$	0.91	1.0

Samples of Fe and Al are heated from $25^\circ\mathrm{C}$ to $75^\circ\mathrm{C}$. Based on the information in the table above, the change in the average kinetic energy of the atoms in the samples is

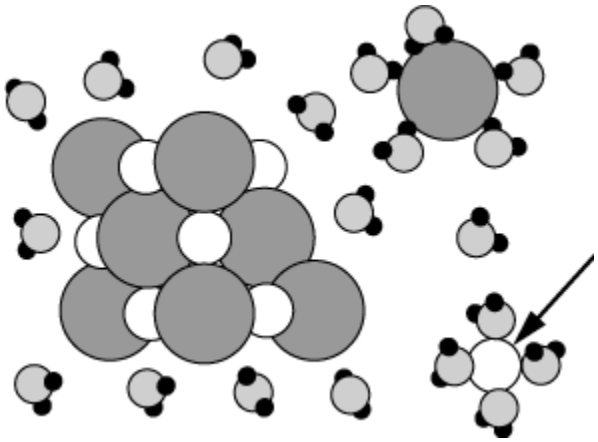
(A) higher for the Fe sample, because with its lower specific heat it absorbs more energy

(B) higher for the Al sample, because with its higher specific heat it absorbs more energy

(C) the same for both metal samples, because the initial and final temperatures are the same

(D) the same for both metal samples, because the masses are equal

10.



An ionic crystal is added to water and starts to dissolve as shown in the particulate representation above. Based on the orientation of the water molecules, what can be assumed about the charge of the hydrated particle indicated by the arrow?

(A) The particle is positively charged, because the oxygen atoms in water are attracted to it.

(B) The particle is negatively charged, because hydrogen atoms in water are attracted to it.

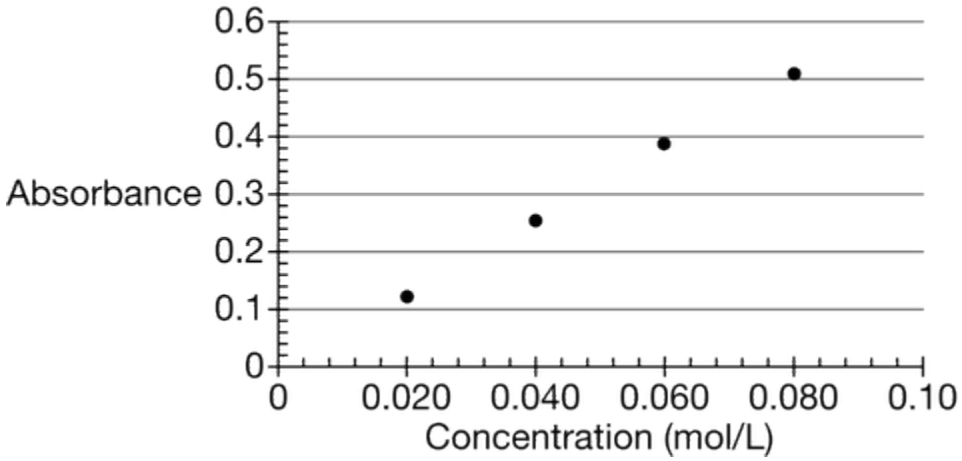
(C) The particle is both positively and negatively charged, because the water molecules are attracted to it.

(D) The particle is neutral, because the dipoles of the water molecules neutralize the charge of the particle.

2021 MCQ

An experiment was performed to investigate the reaction between Zn metal and $\mathrm{Ni}^{2+}(aq)$ at different concentrations. Because the $\mathrm{Ni}^{2+}(aq)$ ion is green, the extent of the reaction was determined using spectrophotometric analysis. Four $20.0\ \mathrm{mL}$ standard solutions of $\mathrm{Ni}^{2+}(aq)$ were prepared by dissolving $\mathrm{NiCl_2 \cdot 6H_2O}$ (molar mass $240\ \mathrm{g/mol}$) in water. The absorbance of each solution was measured; the results are shown both in the table below and in the following plot of the absorbance data.

Solution	$[\mathrm{Ni}^{2+}]$	Absorbance
1	0.020	0.12
2	0.040	0.25
3	0.060	0.39
4	0.080	0.51



11. The concentration of $\mathrm{Cl}^{-}(aq)$ ions in solution 2 was

(A) $0.020\ M$

(B) $0.040\ M$

(C) $0.060\ M$

(D) $0.080\ M$

12. What is the expected absorbance of a standard solution made by dissolving $0.0070\ \mathrm{mol}$ of $\mathrm{NiCl_2 \cdot 6H_2O}$ in water to make $100.\ \mathrm{mL}$ of solution?

(A) 0.0039

(B) 0.0080

(C) 0.045

(D) 0.45

2021 MCQ

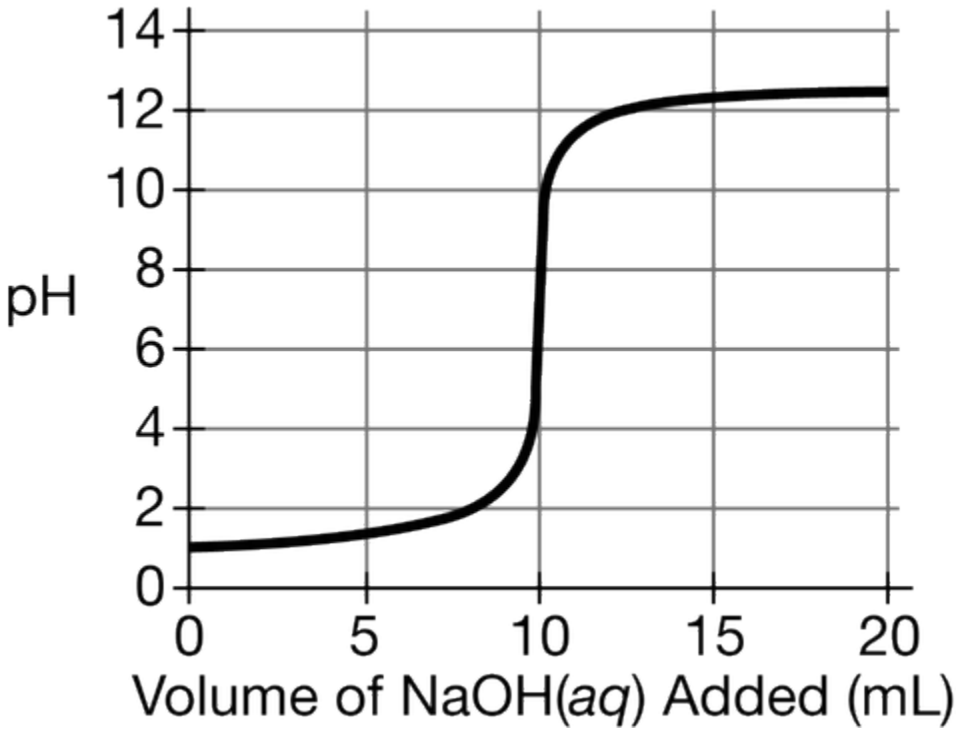
13. Which species is being oxidized in the reaction between Zn metal and $\mathrm{NiCl_2}(aq)$?

(A) Zn
(B) $\mathrm{Zn^{2+}}$
(C) Ni
(D) $\mathrm{Ni^{2+}}$

14. Which of the following equations best represents the reacting species in the reaction between Zn metal and $\mathrm{NiCl_2}(aq)$?

(A) $\mathrm{Zn}(s) + \mathrm{NiCl_2}(aq) \rightarrow \mathrm{Zn^{2+}}(aq) + \mathrm{Ni}(s) + 2\ \mathrm{Cl^-}(aq)$
(B) $\mathrm{Zn}(s) + \mathrm{NiCl_2}(aq) \rightarrow \mathrm{ZnCl_2}(aq) + \mathrm{Ni^{2+}}(aq)$
(C) $\mathrm{Zn^{2+}}(aq) + \mathrm{Ni}(s) \rightarrow \mathrm{Zn}(s) + \mathrm{Ni^{2+}}(aq)$
(D) $\mathrm{Zn}(s) + \mathrm{Ni^{2+}}(aq) \rightarrow \mathrm{Zn^{2+}}(aq) + \mathrm{Ni}(s)$

15.



A $20.0\ \mathrm{mL}$ sample of a $0.125\ M$ monoprotic acid solution is titrated with a $\mathrm{NaOH}(aq)$ solution of unknown concentration. Based on the titration curve above, what is the molar concentration of the $\mathrm{NaOH}(aq)$ solution?

(A) $0.063\ M$
(B) $0.125\ M$
(C) $0.250\ M$
(D) $0.500\ M$

2021 MCQ

16. $\mathrm{HOCN}(aq) \rightleftarrows \mathrm{H}^{+}(aq) + \mathrm{OCN}^{-}(aq) \qquad K_a = 3 \times 10^{-4}$

The ionization of cyanic acid, HOCN, is represented above. A certain solution of HOCN has a pH of 2.0. What is the approximate concentration of unionized $\mathrm{HOCN}(aq)$ in the solution?

(A) $3 \times 10^{-4}\ M$

(B) $1 \times 10^{-2}\ M$

(C) $3 \times 10^{-1}\ M$

(D) $2 \times 10^{0}\ M$

17. Two solid reactants of varying particle size are combined in a vessel. Assuming that the same mass of each reactant is used in each case, which of the following represents the conditions that will result in the fastest reaction rate?

(A) 
Temperature = 950° C

(B) 
Temperature = 500° C

(C) 
Temperature = 500° C

(D) 
Temperature = 950° C

18.

Solution	$\mathrm{p}K_a$
$\mathrm{HF}(aq)$	3.17
$\mathrm{HC_2H_3O_2}(aq)$	4.74
$\mathrm{NH_4}^{+}(aq)$	9.26

Based on the information in the table above, which of the following pairs of solutions can be used to create a buffer with a pH of 9.3 ? (Assume all solutions are $1.0\ M$.)

(A) $100.0\ \mathrm{mL}$ of $\mathrm{HC_2H_3O_2}(aq)$ and $50.0\ \mathrm{mL}$ of $\mathrm{KOH}(aq)$

(B) $50.0\ \mathrm{mL}$ of $\mathrm{HF}(aq)$ and $50.0\ \mathrm{mL}$ of $\mathrm{NaF}(aq)$

(C) $100.0\ \mathrm{mL}$ of $\mathrm{NH_3}(aq)$ and $100.0\ \mathrm{mL}$ of $\mathrm{HCl}(aq)$

(D) $50.0\ \mathrm{mL}$ of $\mathrm{NH_3}(aq)$ and $50.0\ \mathrm{mL}$ of $\mathrm{NH_4Cl}(aq)$

2021 MCQ

19. $2\ H_2O_2(aq)\ \rightarrow\ 2\ H_2O(l)\ +\ O_2(g) \qquad \Delta G^\circ\ =\ -234\ \text{kJ/mol}_{rxn}$

The value of ΔG° for the reaction represented above implies that the decomposition of $H_2O_2(aq)$ is thermodynamically favorable. However, $H_2O_2(aq)$ is typically stable for up to a year stored in a dark bottle at $298\ \text{K}$. The best explanation for this observation is that the decomposition reaction

(A) is only thermodynamically favorable in the presence of a catalyst

(B) occurs with an increase in entropy because $O_2(g)$ is a product

(C) is reversible and $H_2O_2(aq)$ is produced almost as fast as it decomposes

(D) has a slow rate at $298\ \text{K}$ because the activation energy is relatively high

20. The equilibrium constant for a reaction is greater than 1.0 at temperatures above $500\ \text{K}$ but less than 1.0 at temperatures below $500\ \text{K}$. What can be concluded about the values of ΔH° and ΔS° for the reaction? (Assume that ΔH° and ΔS° are independent of temperature.)

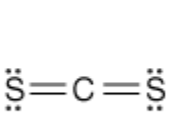
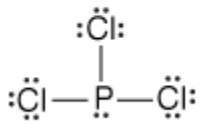
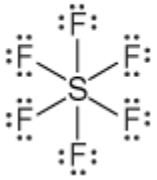
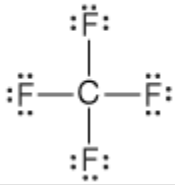
(A) $\Delta H^\circ > 0$ and $\Delta S^\circ > 0$

(B) $\Delta H^\circ > 0$ and $\Delta S^\circ < 0$

(C) $\Delta H^\circ < 0$ and $\Delta S^\circ > 0$

(D) $\Delta H^\circ < 0$ and $\Delta S^\circ < 0$

21.

CS_2	PCl_3	SF_6	CF_4
			

Based on the diagrams shown above, which of the following would have the greatest dipole moment, and why?

(A) CS_2, because the double bonds create an area of higher electron density around the C atom.

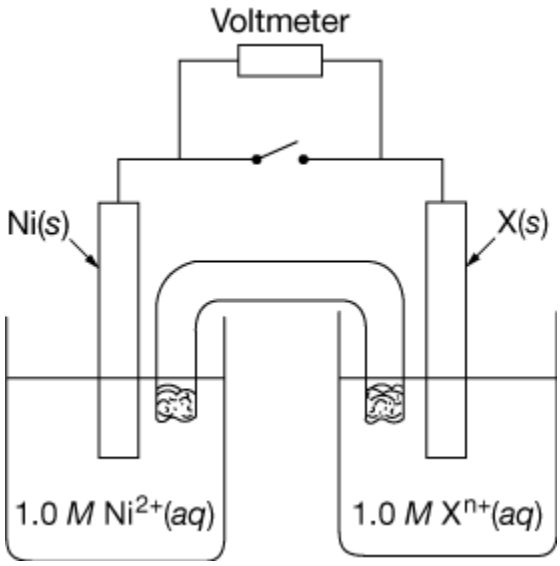
(B) PCl_3, because the Cl atoms draw electron density away from the P atom and the bond dipoles do not cancel one another.

(C) SF_6, because it has the greatest number of polar bonds.

(D) CF_4, because the large electronegativity difference between C and F results in very polar bonds.

2021 MCQ

22.



In the galvanic cell shown above, the voltmeter connected across the electrodes shows a voltage of $0.52\ \text{V}$. Based on the standard reduction potentials given in the table below, which of the following is most likely the identity of the unknown element, X ?

Half-Reaction	E° (V)
$\text{Rh}^{3+}(aq) + 3\,e^- \rightarrow \text{Rh}(s)$	0.76
$\text{Bi}^{3+}(aq) + 3\,e^- \rightarrow \text{Bi}(s)$	0.31
$\text{In}^{+}(aq) + e^- \rightarrow \text{In}(s)$	−0.14
$\text{Ni}^{2+}(aq) + 2\,e^- \rightarrow \text{Ni}(s)$	−0.24
$\text{Zn}^{2+}(aq) + 2\,e^- \rightarrow \text{Zn}(s)$	−0.76

(A) Rh
(B) Bi
(C) In
(D) Zn

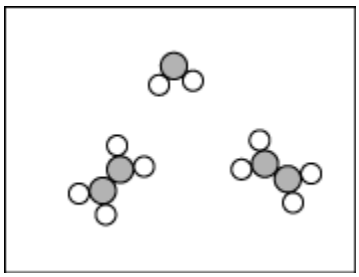
23. A $30.\ \text{g}$ sample of $\text{Al}(s)$ is heated to 50°C and placed in a calorimeter containing $150\ \text{g}$ of water at 20°C. As the system approaches thermal equilibrium, energy is transferred

(A) from the $\text{Al}(s)$ to the water and the temperature of the water decreases
(B) from the $\text{Al}(s)$ to the water and the temperature of the $\text{Al}(s)$ decreases
(C) from the water to the $\text{Al}(s)$ and the temperature of the water increases
(D) from the water to the $\text{Al}(s)$ and the temperature of the $\text{Al}(s)$ increases

2021 MCQ

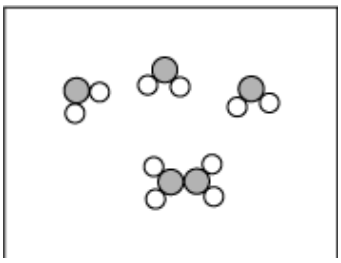
24. $2\,NO_2(g) \rightleftarrows N_2O_4(g) \qquad K_c = 200$

The equilibrium system shown above is represented in the diagram below in which each molecule represents one mole of the substance in a $100.\ L$ container at a constant temperature.

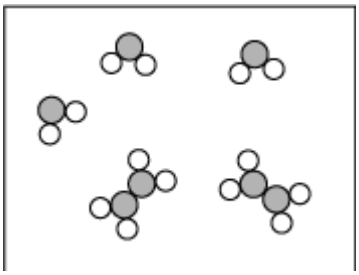


Additional $N_2O_4(g)$ is added to the container and allowed to reestablish equilibrium. Which of the following best represents the system after the equilibrium has been reestablished?

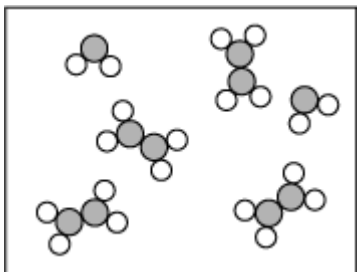
(A)



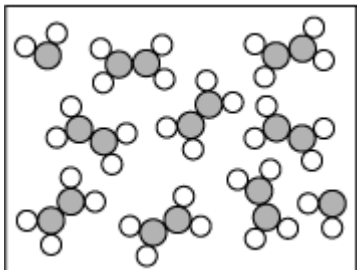
(B)



(C)



(D)



25.

Compound	Melting Point ($^\circ C$)
MgO	2852
NaF	993

The table above shows the melting points of $MgO(s)$ and $NaF(s)$. Which of the following best helps explain why the melting point of $MgO(s)$ is much higher than that of $NaF(s)$?

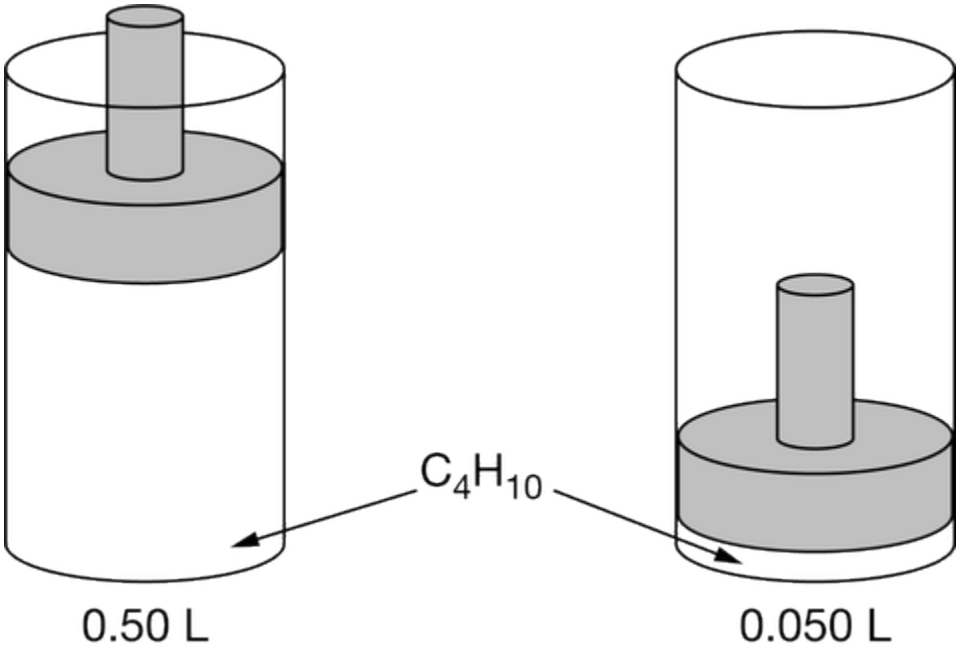
(A) The mass of F^- ions is greater than that of O^{2-} ions.

(B) The mass of Mg^{2+} ions is greater than that of Na^+ ions.

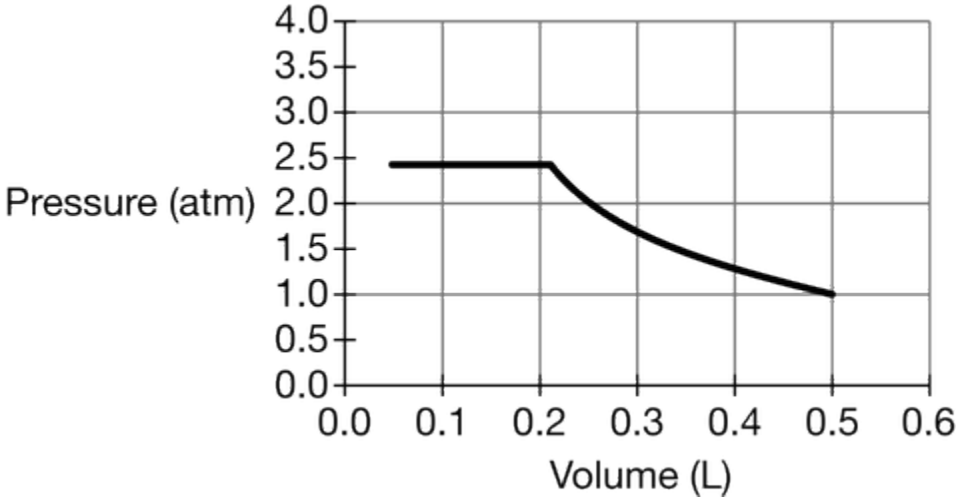
(C) The difference between the electronegativity values of Mg and O is smaller than the difference between the values of Na and F.

(D) The charges of Mg^{2+} and O^{2-} ions are greater than those of Na^+ and F^- ions.

2021 MCQ



A sample of $C_4H_{10}(g)$ is placed in a rigid vessel with a movable piston. The volume of the gas is reduced by moving the piston downward while the temperature is maintained at $25^\circ C$, as shown above. The pressure of the gas versus its volume is plotted in the graph below.



26. Which of the following best explains the increase in pressure of the $C_4H_{10}(g)$ when its volume is decreased from $0.50\ L$ to $0.21\ L$?

(A) The molecules strike the walls of the vessel more frequently.

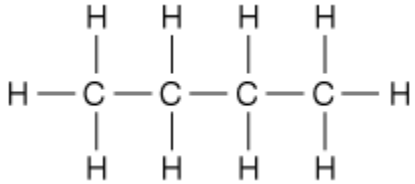
(B) The molecules strike the walls of the vessel with different orientations.

(C) The molecules strike the walls of the vessel with greater force.

(D) The molecules decompose to produce a greater number of particles.

2021 MCQ

27.



The Lewis electron-dot diagram for C_4H_{10} is shown above. Which of the following is the predominant type of intermolecular force among C_4H_{10} molecules?

(A) Hydrogen bonding

(B) London dispersion forces

(C) Dipole-dipole attractions

(D) Dipole-induced dipole attractions

28. Which of the following best accounts for the pressure in the vessel remaining constant as the volume decreases below $0.21\ L$?

(A) The density of the $C_4H_{10}(g)$ increases.

(B) The surface area of the interior of the vessel decreases.

(C) The temperature of the $C_4H_{10}(g)$ decreases.

(D) Some $C_4H_{10}(g)$ condenses to form $C_4H_{10}(l)$.

29. A sample of a pure compound is analyzed and found to contain approximately 30 percent N and 70 percent O by mass. The formula for the compound could be

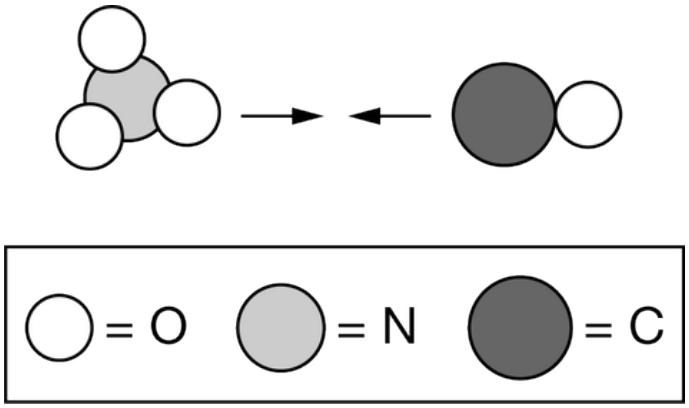
(A) NO

(B) NO_2

(C) N_2O

(D) N_2O_2

30.



The slowest step in a reaction mechanism requires the collision represented above to occur. Which of the following most likely indicates how the addition of a solid catalyst could increase the rate of the reaction?

(A) The catalyst could change the reaction from second order to third order.

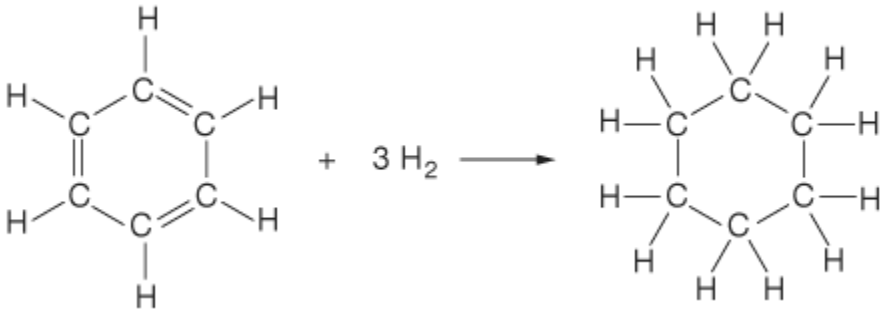
(B) The catalyst could increase the particles' speed, thereby increasing the value of the rate constant, k.

(C) The catalyst could decrease the particles' speed, making it less likely that the particles will rebound without reacting when they collide.

(D) The catalyst could adsorb one of the particles, making a successful (reaction-producing) collision with the other particle more likely.

2021 MCQ

31.

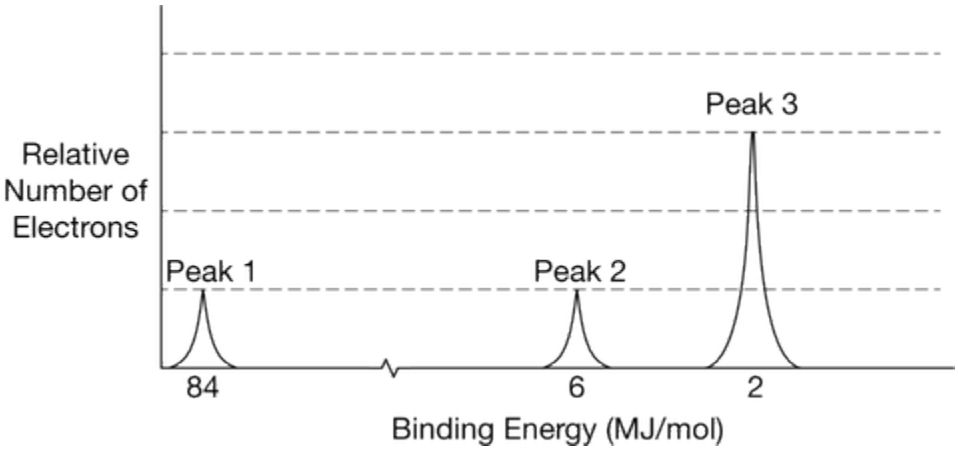


In the reaction represented above, which of the following correctly identifies the hybridization of the C atoms before and after the reaction occurs?

(A) Before: sp^2 After: sp^2
(B) Before: sp^2 After: sp^3
(C) Before: sp^3 After: sp^2
(D) Before: sp^3 After: sp^3

32. A student finds the mass of a pure sample of a metal chloride hydrate. The student heats the sample several times, reaching a constant mass that contains 0.100 mole of anhydrous metal chloride. Which of the following questions about the hydrated metal chloride substance is most likely to be answered by the results of the experiment?

(A) How many moles of water are in one mole of the substance?
(B) How many moles of the metal cation are in one mole of the substance?
(C) What is the identity of the metal cation in the formula of the substance?
(D) What is the melting point of the substance?



The complete photoelectron spectrum of a pure element is shown in the diagram above.

33. According to the complete photoelectron spectrum, which of the following is the identity of the element?

(A) Be
(B) C
(C) O
(D) Ne

2021 MCQ

34. If peaks 1 and 2 represent s sublevels, which of the following sublevels is represented by peak 3?

(A) s

(B) p

(C) d

(D) f

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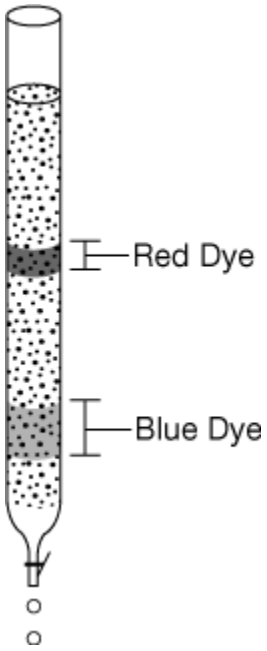
35. In an experiment to estimate the enthalpy change of a reaction, a student makes two aqueous solutions, each containing one of the reactants. The student combines the solutions, both originally at the same temperature, in a calorimeter and records the final temperature of the mixture. In addition to the masses of the solutions and the temperature change of the mixture, which of the following pieces of information does the student need to calculate the enthalpy change of the reaction?

(A) The density of the reaction mixture

(B) The specific heat capacity of the reaction mixture

(C) The boiling point of the reaction mixture

(D) The heat of fusion of the reaction mixture



A student placed a sample of a food coloring that contains a mixture of a blue dye and a red dye at the top of a chromatography column filled with a non-polar stationary phase. When water is poured through the column, two bands of colors are seen in the column, as shown in the diagram above.

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36. Which of the following techniques would be best to investigate molecular vibrations in molecules of the red dye?

(A) Infrared spectroscopy
(B) UV / vis spectroscopy
(C) Mass spectrometry
(D) Gravimetric analysis

37. A student collects a sample of the blue dye from the column in a cuvette. Which of the following is least useful to determine the concentration of the sample using a spectrophotometer set at $640\ \mathrm{nm}$?

(A) The volume of the sample
(B) The path length of the cuvette
(C) The absorbance of the dye at $640\ \mathrm{nm}$
(D) The molar absorptivity of the dye at $640\ \mathrm{nm}$

38. Which of the following will most likely be observed if $\mathrm{CH_3OH}(l)$ is used in the column instead of water? (Assume that both solvents flow through the column at the same rate.)

(A) The dyes will not pass through the column because $\mathrm{CH_3OH}(l)$ is a nonpolar solvent.
(B) The dyes will pass through the column at a slower rate because $\mathrm{CH_3OH}(l)$ is a less polar solvent than water.
(C) The dyes will pass through the column at a faster rate because $\mathrm{CH_3OH}(l)$ has a greater molar mass than water.
(D) No differences will be observed because the polarity of the solvent does not affect the separation of the dyes.

39. Which of the following substances has bonds with the greatest ionic character?

(A) $\mathrm{CCl_4}$
(B) $\mathrm{CuCl_2}$
(C) $\mathrm{CaCl_2}$
(D) $\mathrm{NCl_3}$

40.

$\mathrm{HOCl}(aq)$	$K_a = 3.0 \times 10^{-8}$
$\mathrm{HC_2H_3O_2}(aq)$	$K_a = 1.8 \times 10^{-5}$
$\mathrm{NH_3}(aq)$	$K_b = 1.8 \times 10^{-5}$
$\mathrm{C_6H_5NH_2}(aq)$	$K_b = 3.8 \times 10^{-10}$

The K_a or K_b values of some weak acids and bases are listed in the table above. Which of the following solutions has the highest pH ?

(A) $0.1\ M\ \mathrm{HOCl}(aq)$
(B) $0.1\ M\ \mathrm{HC_2H_3O_2}(aq)$
(C) $0.1\ M\ \mathrm{NH_3}(aq)$
(D) $0.1\ M\ \mathrm{C_6H_5NH_2}(aq)$

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41. $\mathrm{ICl}(g) \rightleftarrows \frac{1}{2}\,\mathrm{I_2}(g) + \frac{1}{2}\,\mathrm{Cl_2}(g) \qquad K_{eq} = 0.1$

Based on the information above, what is the value of K_{eq} for the reaction represented below?

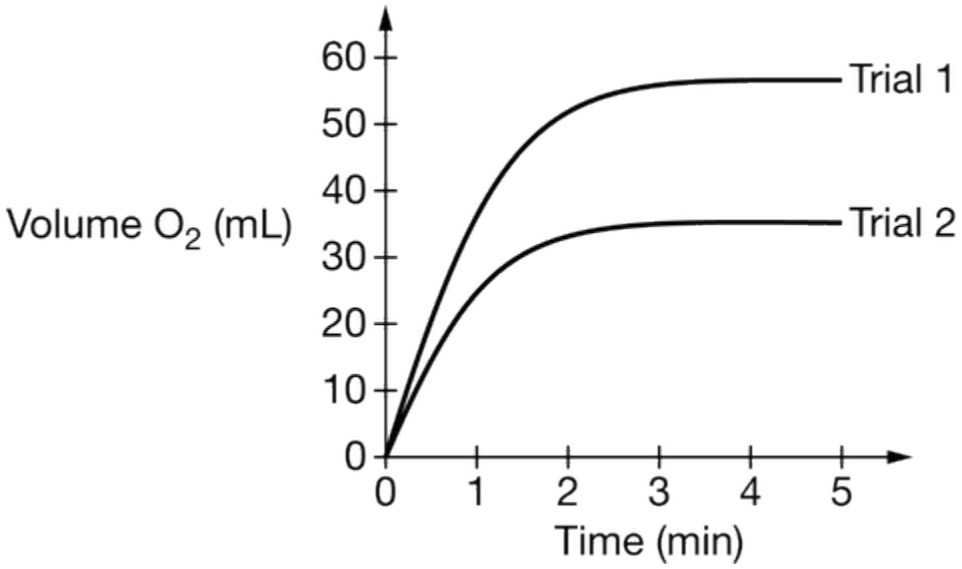
$\mathrm{I_2}(g) + \mathrm{Cl_2}(g) \rightleftarrows 2\,\mathrm{ICl}(g)$

(A) 0.01
(B) 10
(C) 20
(D) 100

42. $2\,\mathrm{H_2O_2}(aq) \xrightarrow{\mathrm{KI}(s)} 2\,\mathrm{H_2O}(l) + \mathrm{O_2}(g)$

$\text{Rate} = k[\mathrm{H_2O_2}]$

A student performed an experiment to study the factors that affect the rate of the first-order catalytic decomposition of $\mathrm{H_2O_2}(aq)$, represented above.



The student monitored the volume of $\mathrm{O_2}(g)$ produced over time as the reaction proceeded. The data from two trials are plotted in the graph above. Which of the following best explains the results of trial 2 compared with those of trial 1 ?

(A) The reaction temperature in trial 2 was higher than it was in trial 1.
(B) The volume of the reaction vessel was larger in trial 2 than it was in trial 1.
(C) The student used a smaller amount of $\mathrm{KI}(s)$ in trial 2 compared with that used in trial 1.
(D) The concentration of $\mathrm{H_2O_2}(aq)$ was lower in trial 2 than it was in trial 1.

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43. $\mathrm{BaCO_3}(s) \rightleftarrows \mathrm{Ba^{2+}}(aq) + \mathrm{CO_3^{2-}}(aq) \qquad K_{sp} = 8.1 \times 10^{-9}$

The dissolution of $\mathrm{BaCO_3}(s)$ in water is represented above. A $20.0\ \mathrm{mL}$ sample of $1.0 \times 10^{-4}\ M\ \mathrm{Ba(NO_3)_2}(aq)$ is mixed with an $80.0\ \mathrm{mL}$ sample of $1.0 \times 10^{-4}\ M\ \mathrm{Na_2CO_3}(aq)$. Which of the following correctly predicts and explains the outcome?

(A) A precipitate will form, because $Q = 1.0 \times 10^{-8}$.

(B) A precipitate will form, because $Q = 1.6 \times 10^{-9}$.

(C) A precipitate will not form, because $Q = 1.0 \times 10^{-8}$.

(D) A precipitate will not form, because $Q = 1.6 \times 10^{-9}$.

44.

Compound	$\left[\mathrm{Pb^{2+}}\right]$ in Saturated Solution
PbS	$1.7 \times 10^{-14}\ M$
$\mathrm{PbCO_3}$	$2.7 \times 10^{-7}\ M$
$\mathrm{PbCrO_4}$	$5.5 \times 10^{-7}\ M$
$\mathrm{PbSO_4}$	$1.6 \times 10^{-4}\ M$

Based on $\left[\mathrm{Pb^{2+}}\right]$ in saturated solutions of the compounds listed in the table above, which of the compounds has the smallest K_{sp} value?

(A) PbS

(B) $\mathrm{PbCO_3}$

(C) $\mathrm{PbCrO_4}$

(D) $\mathrm{PbSO_4}$

45.

$\mathrm{Cl^-}$	Ar	$\mathrm{K^+}$	$\mathrm{Ca^{2+}}$

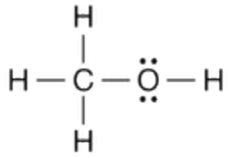
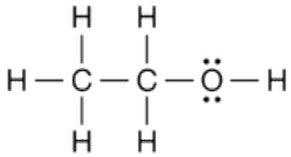
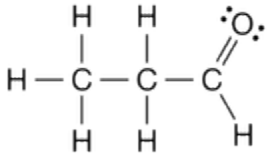
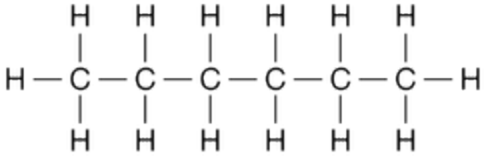
The four species above have the same electron configuration, $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$. Which of the following statements correctly identifies the species with the largest radius and provides an explanation based on Coulomb's law?

(A) $\mathrm{Cl^-}$, because its nuclear charge exerts the least attractive force on the electrons in the $3p$ sublevel.

(B) Ar, because it is a neutral atom and the net force on the electrons in the $3p$ sublevel is zero.

(C) $\mathrm{K^+}$, because the loss of an electron results in a smaller attractive force between the nucleus and the electrons in the $3p$ sublevel.

(D) $\mathrm{Ca^{2+}}$, because the large positive charge on a cation causes increased repulsion among the electrons in the $3p$ sublevel.

Compound	Structure	Boiling Point (°C)
Methanol		65
Ethanol		78
Propanal		49
Hexane		69

46. A $50\ \text{mL}$ sample of $C_6H_{14}(l)$ is mixed with a $50\ \text{mL}$ sample of $H_2O(l)$, and the mixture is shaken vigorously. The two liquids do not stay mixed but instead form two separate layers. The density of hexane is $0.66\ \text{g/mL}$, and the density of water is $1.00\ \text{g/mL}$. A $1.0\ \text{g}$ sample of $I_2(s)$ is added to the mixture, which is shaken again. Which of the following best predicts what happens to the $I_2(s)$?

(A) I_2 will be found mainly in the top layer because it will dissolve more in the $H_2O(l)$.

(B) I_2 will be found mainly in the bottom layer because it will dissolve more in the $H_2O(l)$.

(C) I_2 will be found mainly in the top layer because it will dissolve more in the $C_6H_{14}(l)$.

(D) I_2 will be found mainly in the bottom layer because it will dissolve more in the $C_6H_{14}(l)$.

47. When a $50.\ \text{mL}$ sample of C_2H_5OH is mixed with a $50.\ \text{mL}$ sample of H_2O, the resulting mixture has a volume of $95\ \text{mL}$, and the container is warm to the touch. Which of the following best describes these observations?

(A) A chemical reaction occurs, as evidenced by the volume of the resultant mixture being less than the total volume of the initial components.

(B) A chemical change occurs, as evidenced by the formation of new covalent bonds releasing more energy than is absorbed by the breaking of the existing covalent bonds.

(C) A physical change occurs, and the solvation process is exothermic.

(D) A physical change occurs, and the solvation process is endothermic.

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48. Which of the following best helps to explain why hexane has a higher boiling point than methanol has?

(A) Methanol molecules can form hydrogen bonds with other methanol molecules.

(B) Hexane cannot form hydrogen bonds with other hexane molecules.

(C) Methanol molecules have attractions to one another due to London dispersion forces.

(D) Hexane molecules have electron clouds that are larger than those of methanol molecules.

49. $2\,H_2(g) + 2\,NO(g) \rightarrow N_2(g) + 2\,H_2O(g)$

The experimental rate law for the reaction represented above is $\text{rate} = k[H_2][NO]^2$. Which of the following proposed mechanisms is consistent with the rate law?

(A)

Step 1: $2\,NO \rightarrow N_2O_2$ *fast*

Step 2: $H_2 + N_2O_2 \rightleftarrows N_2O + H_2O$ *fast*

Step 3: $H_2 + N_2O \rightarrow N_2 + H_2O$ *slow*

(B)

Step 1: $2\,NO \rightleftarrows N_2O_2$ *fast*

Step 2: $H_2 + N_2O_2 \rightarrow N_2O + H_2O$ *slow*

Step 3: $H_2 + N_2O \rightarrow N_2 + H_2O$ *fast*

(C)

Step 1: $2\,NO \rightarrow N_2 + O_2$ *slow*

Step 2: $H_2 + O_2 \rightarrow H_2O_2$ *fast*

Step 3: $H_2 + H_2O_2 \rightarrow 2\,H_2O$ *fast*

(D)

Step 1: $2\,NO \rightarrow N_2 + O_2$ *fast*

Step 2: $H_2 + O_2 \rightleftarrows H_2O_2$ *fast*

Step 3: $H_2 + H_2O_2 \rightarrow 2\,H_2O$ *slow*

2021 MCQ

50. $\mathrm{CO}(g) + 3\,\mathrm{H_2}(g) \rightleftarrows \mathrm{CH_4}(g) + \mathrm{H_2O}(g) \qquad K_p = 66 \text{ at } 500^\circ\mathrm{C}$

At a certain time, the partial pressure of the gases in the reaction mixture represented above had the values shown in the table below.

P_{CO}	$P_{\mathrm{H_2}}$	$P_{\mathrm{CH_4}}$	$P_{\mathrm{H_2O}}$
0.02 atm	1.0 atm	0.4 atm	0.4 atm

Based on the information above, which of the following occurred as the reaction mixture moved toward equilibrium?

(A) More $\mathrm{CH_4}(g)$ was produced because the rate of the forward reaction was higher than the rate of the reverse reaction.

(B) More $\mathrm{H_2}(g)$ was produced because the rate of the reverse reaction was higher than the rate of the forward reaction.

(C) More $\mathrm{CH_4}(g)$ was produced because the total pressure of the $\mathrm{H_2}(g)$ and $\mathrm{CO}(g)$ combined was higher than that of the products; thus the reaction shifted to the side with the fewest number of moles of gas.

(D) More $\mathrm{H_2}(g)$ was produced because the pressure of $\mathrm{CO}(g)$ was the least and the reaction shifted to the side with the smaller number of moles of gas.

51. $\mathrm{CCl_4}(g)$ deviates more from ideal gas behavior than $\mathrm{CH_4}(g)$ does. Which of the following statements best explains this observation?

(A) The mass of the $\mathrm{CCl_4}$ molecule is greater than that of the $\mathrm{CH_4}$ molecule.

(B) The bond energy of the $\mathrm{C\text{-}Cl}$ bond is greater than that of the $\mathrm{C\text{-}H}$ bond.

(C) The dipole-dipole forces between $\mathrm{CCl_4}$ molecules are greater than those between $\mathrm{CH_4}$ molecules.

(D) The London dispersion forces between $\mathrm{CCl_4}$ molecules are stronger than those between $\mathrm{CH_4}$ molecules.

52. A $0.08\ M$ solution of $\mathrm{CH_3COOH}$ $(\mathrm{p}K_a = 4.74)$ is titrated with $0.10\ M$ $\mathrm{NaOH}(aq)$. What is the pH at the equivalence point of the titration and why?

(A) $\mathrm{pH} < 7$, because $\mathrm{NaOH}(aq)$ is a strong base.

(B) $\mathrm{pH} = 7$, because the titration reaction is a neutralization reaction.

(C) $\mathrm{pH} > 7$, because $\mathrm{CH_3COO^-}(aq)$ is a weak base.

(D) $\mathrm{pH} > 7$, because the concentration of $\mathrm{NaOH}(aq)$ is greater than that of $\mathrm{CH_3COOH}(aq)$.

53. $\underset{\textit{pink}}{[\mathrm{Co(H_2O)_6}]^{2+}} + 4\,\mathrm{Cl^-} \rightleftarrows \underset{\textit{blue}}{[\mathrm{CoCl_4}]^{2-}} + 6\,\mathrm{H_2O}(l)$

The solvent in the nonaqueous system represented above is 2-propanol. If a small amount of water is added to the system, how will the color of the solution be affected, and why?

(A) The solution will become more pink because more $[\mathrm{Co(H_2O)_6}]^{2+}$ will be produced.

(B) The solution will become more pink because the pH of the solution will increase.

(C) The solution will become more blue because more $[\mathrm{CoCl_4}]^{2-}$ will be produced.

(D) The solution will become more blue because the pH of the solution will decrease.

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54. Which of the following equations represents a reaction with a negative ΔS° ?

(A) $2\ \mathrm{NO}(g)\ +\ \mathrm{O_2}(g)\ \rightarrow\ 2\ \mathrm{NO_2}(g)$

(B) $2\ \mathrm{KClO_3}(s)\ \rightarrow\ 2\ \mathrm{KCl}(s)\ +\ 3\ \mathrm{O_2}(g)$

(C) $\mathrm{PCl_5}(g)\ \rightarrow\ \mathrm{PCl_3}(g)\ +\ \mathrm{Cl_2}(g)$

(D) $\mathrm{C_3H_8}(g)\ +\ 5\ \mathrm{O_2}(g)\ \rightarrow 3\ \mathrm{CO_2}(g)\ +\ 4\ \mathrm{H_2O}(g)$

55.

Element	Second Ionization Energy $(\mathrm{kJ/mol})$
Li	7300
Na	4560
K	3050
Rb	2630

The decrease in the second ionization energy of alkali metals going down the group, as shown in the table above, can be best attributed to a decrease in the coulombic force of attraction due to

(A) the removal of core electrons

(B) an increase in effective nuclear charge

(C) an increase in the average distance of the outermost electron from the nucleus

(D) a decrease in electron-electron repulsion within the outermost shell

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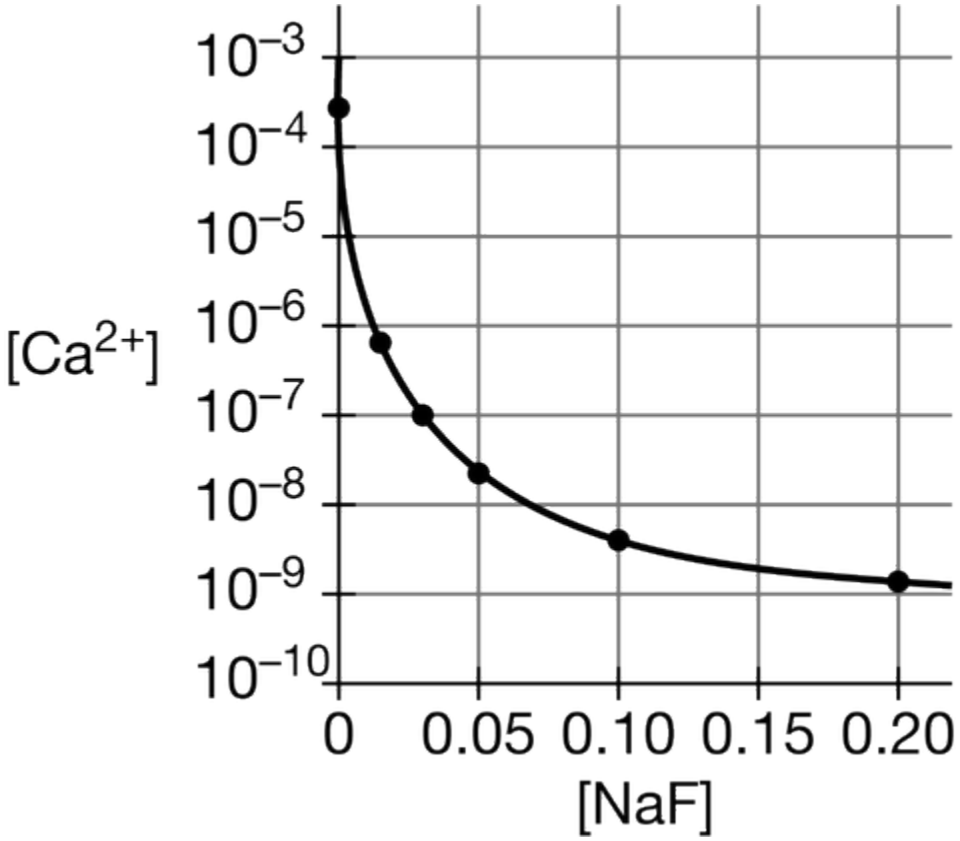
56.



Which of the following statements best explains the trend in the molar solubility of $\mathrm{CaF_2}(s)$ in various concentrations of $\mathrm{NaF}(aq)$ shown in the graph above?

(A) Higher concentrations of $\mathrm{F^-}(aq)$ allow less $\mathrm{CaF_2}(s)$ to dissolve before the solution becomes saturated.

(B) Higher concentrations of $\mathrm{Na^+}(aq)$ lead to more favorable attractions between $\mathrm{Na^+}(aq)$ ions and $\mathrm{F^-}(aq)$ ions, thus less $\mathrm{CaF_2}(s)$ dissolves.

(C) Higher concentrations of $\mathrm{F^-}(aq)$ produce more $\mathrm{OH^-}(aq)$ through hydrolysis, causing $\mathrm{Ca(OH)_2}(s)$ to precipitate, thus more $\mathrm{CaF_2}(s)$ dissolves.

(D) Higher concentrations of $\mathrm{F^-}(aq)$ cause the formation of the $\mathrm{CaF_4}^{2-}(aq)$ complex ion, which allows more $\mathrm{CaF_2}(s)$ to dissolve.

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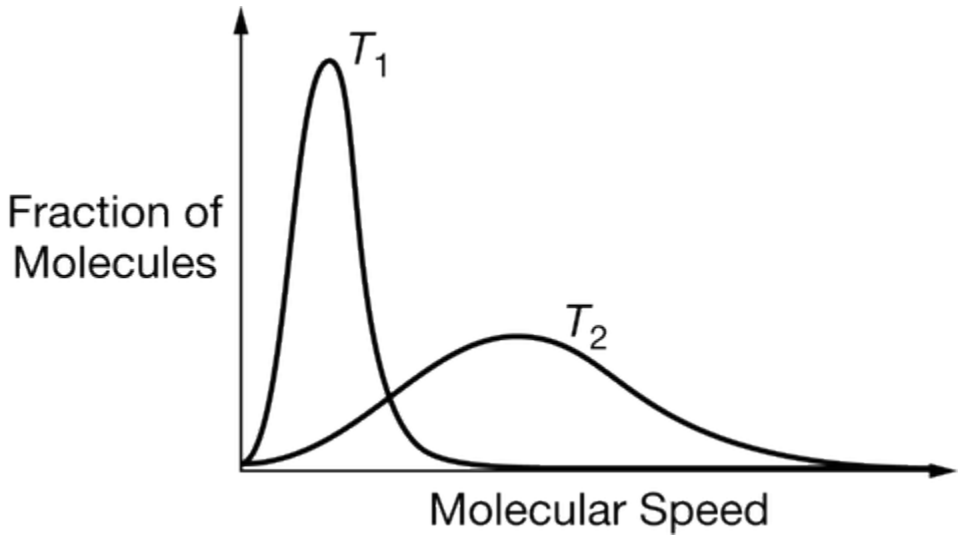
57.



The diagram above shows the distribution of molecular speed in a sample of gas at two different temperatures, T_1 and T_2. Which of the following is a correct interpretation of the information provided by the diagram?

(A) The average speed of the molecules is greater at T_1 than at T_2.

(B) The taller peak corresponds to the higher temperature, T_1.

(C) There are fewer molecules of gas at T_2 than at T_1.

(D) The average kinetic energy of the molecules is greater at T_2 than at T_1.

58. $\mathrm{NH_3}(aq) + \mathrm{CH_3NH_3}^+(aq) \rightleftarrows \mathrm{NH_4}^+(aq) + \mathrm{CH_3NH_2}(aq) \quad K_{eq} = 0.041$

Which of the following species is the strongest base in the reaction represented above?

(A) $\mathrm{NH_3}(aq)$

(B) $\mathrm{CH_3NH_3}^+(aq)$

(C) $\mathrm{NH_4}^+(aq)$

(D) $\mathrm{CH_3NH_2}(aq)$

59. The value of K_w at $37^\circ\mathrm{C}$ is 2.4×10^{-14}. Which of the following statements about the pH and pOH of pure water at $37^\circ\mathrm{C}$ is correct?

(A) $\mathrm{pH} < 7$ and $\mathrm{pOH} > 7$ because water dissociates to a lesser extent at $37^\circ\mathrm{C}$ than at $25^\circ\mathrm{C}$.

(B) $\mathrm{pH} > 7$ and $\mathrm{pOH} < 7$ because the dissociation of water is endothermic, and $\mathrm{pH} + \mathrm{pOH} = 14$.

(C) $\mathrm{pH} = \mathrm{pOH} < 7$ because water dissociates to a greater extent at $37^\circ\mathrm{C}$ than at $25^\circ\mathrm{C}$.

(D) $\mathrm{pH} = \mathrm{pOH} = 7$ because $[\mathrm{H_3O^+}] = [\mathrm{OH^-}]$ for pure water.

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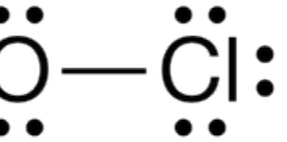
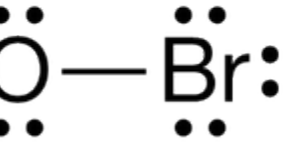
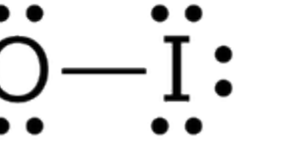
60.

Acid	Structure
HClO	
HBrO	
HIO	

A $0.1\ M$ aqueous solution of which of the acids shown in the table above would have a pH closest to 7.0, and why?

(A) HClO, because Cl has the highest electronegativity.

(B) HBrO, because Br has the lowest electronegativity.

(C) HIO, because I has the lowest electronegativity.

(D) All three solutions will have the same pH because they are all monoprotic acids.