This print-out should have 20 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 10.0 points
What would you propose as the rate law for the reaction of bromine with nitric oxide if the second step of a proposed mechanism is the rate determining step?

Step 1: NO + Br$_2$ → NOBr$_2$
Step 2: NOBr$_2$ + NO → 2 NOBr

1. $k [NO]^2 [Br^2] [NOBr_2]^{-1}$
2. $k [NO] [Br_2] [NOBr_2]^{-1}$
3. $k [NO]^2$
4. $k [NO] [Br_2] [NOBr_2]$
5. $k [NO]^2 [Br_2]$ correct

Explanation:

002 10.0 points
The graph describes the energy profile of a reaction.

What are the values for $\Delta H$ and $E_a$, respectively, for the reaction in the direction written?

1. $-250$ kJ, $-100$ kJ
2. $-250$ kJ, $100$ kJ
3. $250$ kJ, $350$ kJ correct
4. $-250$ kJ, $350$ kJ
5. $250$ kJ, $100$ kJ

Explanation:

003 10.0 points
The graph is a plot of $\ln A$ vs $t$ for the reaction

$A \rightarrow B$

rate = $k [A]$ is the rate law for this reaction. What was the initial concentration of $[A]$?

1. $1.8$ M
2. $3.0$ M correct
3. $5$ M
4. $0.6$ M
5. $1.1$ M

Explanation:

004 10.0 points
Which of the following statements regarding collision and transition state theory are true?
I) Reactants must collide to form products.
II) Activation energy is always positive.
III) Reactant molecules must absorb energy to form the transition state.
IV) Reactant collisions must be oriented properly to form products.

1. II and III only
2. I, III, and IV only
3. I, II, III, and IV correct
4. I and IV only
5. II, III, and IV only

Explanation:

005 10.0 points
In the reaction
$$3 \text{Mg}(s) + 2 \text{Fe}^{2+}(aq) \rightarrow 2 \text{Fe}(s) + 3 \text{Mg}^{2+}(aq),$$
$$\frac{\Delta[\text{Fe}]}{\Delta t} = 2.4 \times 10^{-4} \text{M/s}. \text{What is } \frac{\Delta[\text{Mg}]}{\Delta t}?$$
1. $-3.6 \times 10^{-4} \text{M/s}$ correct
2. $-1.6 \times 10^{-4} \text{M/s}$
3. $+3.6 \times 10^{-4} \text{M/s}$
4. $+1.6 \times 10^{-4} \text{M/s}$
5. $+1.2 \times 10^{-4} \text{M/s}$

Explanation:

006 10.0 points
A reaction has a rate constant of $k = 5.5 \times 10^{-4} \text{M}^2\text{s}^{-1}$. What is the reaction order?
1. $-2$
2. 0
3. 1
4. 2
5. $-1$ correct

Explanation:

007 10.0 points
What is the rate law for the reaction
$$\text{A} + \text{B} + \text{C} \rightarrow \text{D}$$
if the following data were collected?

<table>
<thead>
<tr>
<th>Exp</th>
<th>$[A]_0$</th>
<th>$[B]_0$</th>
<th>$[C]_0$</th>
<th>Initial Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4</td>
<td>1.2</td>
<td>0.7</td>
<td>$2.32 \times 10^{-3}$</td>
</tr>
<tr>
<td>2</td>
<td>1.3</td>
<td>1.2</td>
<td>0.9</td>
<td>$7.54 \times 10^{-3}$</td>
</tr>
<tr>
<td>3</td>
<td>0.4</td>
<td>4.1</td>
<td>0.8</td>
<td>$9.25 \times 10^{-2}$</td>
</tr>
<tr>
<td>4</td>
<td>1.3</td>
<td>1.2</td>
<td>0.2</td>
<td>$7.54 \times 10^{-3}$</td>
</tr>
</tbody>
</table>

1. rate = $3.36 \times 10^{-3} [A]^1 [B]^3 [C]^0$ correct
2. rate = $1.79 \times 10^{-3} [A]^0 [B]^2 [C]^1$
3. rate = $1.49 \times 10^{-3} [A]^0 [B]^3 [C]^1$
4. rate = $4.48 \times 10^{-3} [A]^1 [B]^2 [C]^1$
5. rate = $5.37 \times 10^{-3} [A]^1 [B]^3 [C]^0$

Explanation:

008 10.0 points
The decomposition of hydrogen peroxide to form water is a first order process. If it takes 20 minutes for the initial concentration to fall from 1.6 M to 0.8 M, how much time has passed when only 0.05 M of the initial 1.6 M remains?
1. 100 minutes correct
2. 120 minutes
3. 80 minutes
4. 160 minutes
5. 40 minutes

Explanation:

009 10.0 points
At 0°C and 1 atmosphere of pressure, which of the following gases would have the lowest average molecular speed?

1. H₂
2. NH₃
3. N₂
4. CO₂ correct
5. Ar

Explanation:
Light molecules have higher velocities (or speeds) than heavier molecules at a given temperature, so you need to consider the molecular weights of these molecules:

\[
\begin{align*}
\text{MW}_{\text{N}_2} & = 28 \text{ g/mol} \\
\text{MW}_{\text{NH}_3} & = 17 \text{ g/mol} \\
\text{MW}_{\text{H}_2} & = 2 \text{ g/mol} \\
\text{MW}_{\text{Ar}} & = 40 \text{ g/mol} \\
\text{MW}_{\text{CO}_2} & = 44 \text{ g/mol}
\end{align*}
\]

CO₂ is the heaviest molecule, so its average molecular speed will be the lowest.

010 10.0 points
What is the molecular weight of a (hypothetical) gas that diffuses 1.414 times faster than nitrogen (N₂)?

1. 23.5 g/mol
2. 32.6 g/mol
3. 14.0 g/mol correct
4. 46.6 g/mol
5. 4.85 g/mol

Explanation:

In an improved version of the gas law, \( P \) is replaced by \( \left( P + \frac{n^2 a}{V^2} \right) \). In this expression, the second term, \( \frac{n^2 a}{V^2} \), accounts for

1. the forces of repulsion between molecules.
2. the excluded volume of the molecules.
3. the forces of attraction between molecules. correct
4. the size of the molecules.
5. the size of the container.

Explanation:
At high pressures, gas molecules are closer together than they would be at lower pressures. The attractive forces between gas molecules then become important.

When more molecules are present (greater \( n \)) and when the molecules are close together (smaller \( V^2 \) in the denominator), the correction term becomes larger.

1. CO₂ < Ne < Kr < Cl₂
2. Kr < Cl₂ < CO₂ < Ne correct
3. Cl₂ < Kr < Ne < CO₂
4. Ne < CO₂ < Cl₂ < Kr

Explanation:

Effusion is when gas molecules escape through the tiny holes in their container. Lighter, faster molecules effuse more quickly than heavy, slow ones.

\[
\begin{align*}
\text{Kr}_{(\text{MW}=84 \text{ g/mol})} & < \text{Cl}_2_{(\text{MW}=71 \text{ g/mol})} \\
& < \text{CO}_2_{(\text{MW}=44 \text{ g/mol})} \\
& < \text{Ne}_{(\text{MW}=20 \text{ g/mol})}
\end{align*}
\]
In this correction term, large values of $a$ indicate strong attractive forces, and the correction term as a whole is added to compensate for attractive forces between gas molecules.

013 10.0 points
Under which of the following conditions is a real gas most likely to deviate from ideal behavior?

1. Tuesdays and Thursdays
2. zero pressure
3. if it is a noble gas
4. high volume
5. low pressure
6. low temperature correct
7. new moon
8. low density

Explanation:
Deviations from ideality occur due to molecular attractions or repulsions. More attractions or repulsions can occur when the molecules are closer together. Low pressure, high volume, and low density all correspond to molecules being far apart. Low temperature often corresponds to molecules being close together. It also corresponds to low kinetic energy which allows molecules to 'stick together' easier.

014 10.0 points
If 250 mL of a gas at STP weighs 2 g, what is the molar mass of the gas?

1. 8.00 g · mol$^{-1}$
2. 44.8 g · mol$^{-1}$
3. 56.0 g · mol$^{-1}$
4. 28.0 g · mol$^{-1}$
5. 179 g · mol$^{-1}$ correct

Explanation:

\[
V = 250 \text{ mL} \quad P = 1 \text{ atm} \\
T = 0^\circ C = 273.15 \text{ K} \quad m = 2 \text{ g}
\]

The density of the sample is
\[
\rho = \frac{m}{V} = \frac{2 \text{ g}}{0.25 \text{ L}} = 8 \text{ g/L}
\]

The ideal gas law is
\[
P V = n R T
\]
with unit of measure mol/L on each side. Multiplying each by molar mass (MM) gives
\[
\frac{n}{V} \cdot \text{MM} = \frac{P}{RT} \cdot \text{MM} = \rho,
\]
with units of g/L.

\[
\text{MM} = \frac{\rho RT}{P} = \frac{(8 \text{ g/L})(0.08206 \text{ L} \cdot \text{atm/mol}/\text{K})}{1 \text{ atm}} \times (273.15 \text{ K}) = 179.318 \text{ g/mol}
\]

015 10.0 points
At constant temperature, the rate of effusion of H$_2$ is

1. None of these
2. one-fourth that of oxygen gas.
3. twice that of helium gas.
4. four times that of oxygen gas. correct
5. one-half that of helium gas.

Explanation:

\[
\frac{\text{Rate of effusion of O}_2}{\text{Rate of effusion of H}_2} = \frac{\sqrt{\text{MW}_{\text{H}_2}}}{\sqrt{\text{MW}_{\text{O}_2}}}
\]

\[
\frac{\text{Eff}_{\text{O}_2}}{\text{Eff}_{\text{H}_2}} = \sqrt{\frac{2}{32}} = 0.25 = \frac{1}{4}
\]
\[
\text{Eff}_{\text{O}_2} = \frac{1}{4} \text{Eff}_{\text{H}_2}
\]
Which of the following molecules would have the smallest $a$ and $b$ term, respectively, in the van der Waals' equation: O₃, CHF₃, SF₅Cl, SiHCl₃, Xe.

1. Xe and SF₅Cl, respectively
2. Xe and O₃, respectively correct
3. CHF₃ and CHF₃, respectively
4. Xe and Xe, respectively
5. SiHCl₃ and O₃, respectively

Explanation:
Xenon is the only non-polar species and thus would have the smallest $a$ term. Ozone is the smallest in terms of molecular weight and would thus have the smallest $b$ term.

If a 10 L gaseous system at 400 K and 4 atm is heated to 800 K and allowed to expand to 20 L, what will the new pressure of the system be?

1. 2 atm
2. 16 atm
3. 4 atm correct
4. 1 atm
5. 8 atm

Explanation:
Doubling the temperature from 400 K to 800 K will double the pressure and doubling the volume from 10 L to 20 L will halve the pressure, resulting in no net change in pressure.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$P_2 = \frac{P_1 V_1 T_2}{V_2 T_1} = \frac{4 \cdot 10 \cdot 800}{20 \cdot 400} = 4 \text{ atm}$$

A sample of gas occupies 10.5 L at 600 torr and 50°C. What volume will it occupy at STP?

1. 7.01 L correct
2. 9.81 L
3. 11.2 L
4. 15.7 L

Explanation:
$$P_1 = 600 \text{ torr} \quad P_2 = 760 \text{ torr}$$
$$V_1 = 10.5 \text{ L} \quad T_2 = 273.15 \text{ K}$$
$$T_1 = 50^\circ \text{C} + 273.15 = 323.15 \text{ K}$$

We can use the combined gas law and solve for $V_2$:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$V_2 = \frac{P_1 V_1 T_2}{T_1 P_2} = \frac{(600 \text{ torr})(10.5 \text{ L})(273.15 \text{ K})}{(323.15 \text{ K})(760 \text{ torr})} = 7.00687 \text{ L}$$

If the temperature of an ideal gas is raised from 100°C to 200°C, while the pressure remains constant, the volume

1. increases by a factor of 100.
2. None of these correct
3. remains the same.
4. doubles.
5. goes to $\frac{1}{2}$ of the original volume.

Explanation:
$$T_1 = 100^\circ \text{C} + 273 = 373 \text{ K}$$
$$T_2 = 200^\circ \text{C} + 273 = 473 \text{ K}$$

Volume is directly proportional to temperature expressed on the Kelvin scale:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$
\[ \frac{V_2}{V_1} = \frac{T_2}{T_1} \]

The temperature changes by a factor of
\[ \frac{T_2}{T_1} = \frac{473 \text{ K}}{373 \text{ K}} = 1.27 , \]

so the volume increases by the same factor 1.27. None of the specific answers gives this factor.

\[ \textbf{020} \quad 10.0 \text{ points} \]

The molar volume of a gas at STP is

1. 22.4 liters. **correct**

2. 12.4 gallons.

3. \(6.02 \times 10^{23}\) liters.

4. 12.4 liters.

**Explanation:**

Avogadro’s Law states that at the same temperature and pressure, equal volumes of all gases contain the same number of molecules. The standard molar volume of an ideal gas is taken to be 22.414 liters per mol at STP.