Question #: 1
A 10.0 g sample of nitroglycerine, C₃H₅N₃O₉ (molar mass 227.10 g/mol) completely explodes, producing gases according to the reaction equation below.

\[ 4 \text{C}_3\text{H}_5\text{N}_3\text{O}_9(s) \rightarrow 12 \text{CO}_2(g) + 10 \text{H}_2\text{O}(g) + 6 \text{N}_2(g) + \text{O}_2(g) \]

If the total pressure of the gases produced is 2.1 atm, what is the partial pressure of \( \text{O}_2(g) \)?

\[ \text{__1__ atm} \]

Report your answer with **2 significant figures** and **do not include units**.

1. ____

---

Question #: 2
The figure shows the speed distributions of He, Ne, Ar and Kr at 25 °C. Which element is represented by curve #3 (green)?

A. He  
B. Ne  
C. Ar  
D. Kr

---

Question #: 3
The van der Waals equation provides correction factors used to calculate the properties of a gas under nonideal conditions. Which of the following statements describe(s) why real gases behave least ideally at low temperature or high pressure?

Select **all** of the applicable statements.

A. At high pressure, the volume of the gas particles occupies a greater fraction of the total gas volume.  
B. At high pressure, gas molecules move with slower kinetic energies.  
C. At higher temperatures, the average kinetic energy of the gas molecules is lower.  
D. At low temperature, intermolecular attractive forces become so effective that gas pressure is lower than predicted by the ideal gas law.
Question #: 4
\[ \Delta E_{\text{surroundings}} \] for the reaction \( \text{H}_2(g) + \text{Cl}_2(g) \rightarrow 2 \text{HCl}(g) \) depicted below is \( \boxed{1} \) kJ. Report your answer with three significant digits and without units.

\[ \text{Internal energy (kJ)} \]

\[ -182 \]

\[ 2 \text{HCl}(g) \]

1. \( \boxed{_____} \)

Question #: 5
A baby’s ventilator reduced the volume of 1.200 L of air in a balloon to 0.500 L at 1.00 atm of constant pressure, using an additional 0.25 kJ of thermal energy to heat the air. By how much did the internal energy of the air (the system) change?

\[ 101 \text{ J} = 1.00 \text{ L} \cdot \text{atm} \]

A. +0.32 kJ
B. +72.95 kJ
C. +0.18 kJ
D. –0.18 kJ

Question #: 6
The initial conditions of blocks of two substances, A and B, are shown in the figure below. A and B come into contact with one another and reach thermal equilibrium at a final temperature 48.0 °C. What is the specific heat capacity \( (C_s) \) of substance A? No heat is lost during the transfer between the two blocks.

A. 0.30 J/g °C
B. 1.8 J/g °C
C. 2.4 J/g °C
D. 1.3 J/g °C
Question #: 7
A balloon is inflated from 0.010 L to 0.500 L against an external pressure of 1.00 atm. How much work is done?

\[ 101 \text{ J} = 1.00 \text{ L} \cdot \text{atm} \]

A. –49.5 J  
B. –4.85 J  
C. +4.85 J  
D. +1.01 J

Question #: 8
A 21.8 g sample of ethanol (C₂H₅OH, 46.07 g/mol) is burned in a bomb calorimeter, according to the following reaction equation. If the temperature rises from 25.0 °C to 62.3 °C, what is the heat capacity of the calorimeter?

\[ \text{C}_2\text{H}_5\text{OH}(l) + 3 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + 3 \text{H}_2\text{O}(g) \quad \Delta H_{\text{rxn}} = -1235 \text{ kJ} \]

A. 5.65 kJ/°C  
B. 63.7 kJ/°C  
C. 33.1 kJ/°C  
D. 15.7 kJ/°C

Question #: 9
Given the energy diagram below, is this reaction endothermic or exothermic, and is change in enthalpy positive or negative?

A. endothermic, positive \( \Delta H \)  
B. endothermic, negative \( \Delta H \)  
C. exothermic, positive \( \Delta H \)  
D. exothermic, negative \( \Delta H \)
Question #: 10
Use the standard reaction enthalpies below to determine $\Delta H^\circ_{\text{rxn}}$ for the reaction:

$$8 \text{SO}_3(g) \rightarrow \text{S}_8(s) + 12 \text{O}_2(g) \quad \Delta H^\circ_{\text{rxn}} = \boxed{} \text{kJ}$$

Given:

$$8 \text{SO}_2(g) \rightarrow \text{S}_8(s) + 8 \text{O}_2(g) \quad \Delta H^\circ_{\text{rxn}} = +2374 \text{kJ}$$
$$2 \text{SO}_2(g) + \text{O}_2(g) \rightarrow 2 \text{SO}_3(g) \quad \Delta H^\circ_{\text{rxn}} = -198 \text{kJ}$$

Report your answer without units and in scientific notation with three significant digits.

1. ______

Question #: 11
Given the following data, calculate the enthalpy of formation of $\text{B}_2\text{H}_6(g)$.

$$\text{B}_2\text{H}_6(g) + 6 \text{H}_2\text{O}(l) \rightarrow 2 \text{H}_3\text{BO}_3(s) + 6 \text{H}_2(g) \quad \Delta H^\circ = -510 \text{kJ}$$

$\Delta H^\circ_{f}$ of $\text{H}_3\text{BO}_3(s) = -1094 \text{kJ/mol}$
$\Delta H^\circ_{f}$ of $\text{H}_2\text{O}(l) = -286 \text{kJ/mol}$
$\Delta H^\circ_{f}$ of $\text{B}_2\text{H}_6(g) = \boxed{} \text{kJ/mol}.$

Report your answer with two significant figures and do not include units.

1. ______

Question #: 12
Visible light falls immediately between the _____ and _____ regions of the electromagnetic spectrum.
Choose two regions.

A. ultraviolet
B. infrared
C. radio
D. X-ray

Question #: 13
Consider light with a wavelength of $495 \text{ nm}$. The frequency is $\boxed{} \text{s}^{-1}$ and there are $\boxed{} \text{kJ}$ in 1.00 mole of photons.

Answer both to three significant figures and do not include units in your answer.

1. ______
2. ______
Question #: 14
Which of the following statements is true about the atomic spectra below?

A. They are emission spectra for the same element.
B. The emission spectrum of an element is on top and the absorption spectrum for the same element is on the bottom.
C. They are emission spectra for two different elements.
D. They are absorption spectra for two different elements.

Question #: 15
An atom absorbs the most energy when one of its electrons undergoes which transition?

A. $n = 1$ to $n = 2$
B. $n = 2$ to $n = 3$
C. $n = 3$ to $n = 4$
D. $n = 4$ to $n = 5$

Question #: 16
What is the minimum uncertainty in the position of an electron (mass= $9.11 \times 10^{-31}$ kg) moving at a speed of $2.55 \times 10^7$ m/s with an uncertainty in the speed of $4.35 \times 10^5$ m/s?

A. 133 pm
B. 7.53 pm
C. 308 pm
D. 2270 pm

Question #: 17
If two electrons in the same atom have quantum number $l = 1$, they could be in ______. Select all that apply.

A. orbitals at different principal ($n$) levels, but with the same shape.
B. the same orbital.
C. orbitals at the same principal ($n$) level, with the same shape but different orientations.
D. two different $s$ orbitals.
**Question #**: 18
The quantum number \( n \) determines which properties of an atomic orbital? Select **all** that apply.

- A. relative size
- B. relative energy
- C. shape
- D. orientation

**Question #**: 19
What is the electron configuration of a ground-state sulfur atom?

Use this format: 1s\(^2\) 2s\(^2\) 2p\(^3\)...

1. ______

**Question #**: 20
Which of the following sets of quantum numbers \((n, l, m_l)\) does **not** represent an allowed atomic orbital?

A. \((1, 0, 0)\)
B. \((2, 2, 1)\)
C. \((2, 1, -1)\)
D. \((3, 2, 0)\)

**Question #**: 21
A photon with a frequency of \(6.17 \times 10^{14}\) Hz is emitted when an electron in a hydrogen atom moves from a higher energy level to the \( n = 2 \) level. What is the initial energy level?

\( n = \) ______

1. ______

**Question #**: 22
What is the maximum number of electrons that can have both of the quantum numbers, \( n = 5 \) and \( l = 3 \), in an atom?

- A. 7
- B. 10
- C. 14
- D. 18
**Question #**: 23
What are possible quantum numbers \((n, l, m_l)\) for the orbital shown below?

![Orbital Diagram](image)

A. \((5, 3, 0)\)
B. \((3, 2, -2)\)
C. \((4, 1, 0)\)
D. \((5, 0, 0)\)

---

**Question #**: 24
This figure illustrates which effect experienced by 1s and 2s electrons in a beryllium atom?

![Beryllium Atom Diagram](image)

A. Pauli exclusion principle
B. shielding
C. electron affinity
D. Heisenberg uncertainty
Question #: 25
Which orbital diagram shows the ground-state valence electron configuration for Mn$^{2+}$?
A. 
\[
\begin{array}{c}
4s \\
3d
\end{array}
\]
B. 
\[
\begin{array}{c}
4s \\
3d
\end{array}
\]
C. 
\[
\begin{array}{c}
4s \\
3d
\end{array}
\]
D. 
\[
\begin{array}{c}
4s \\
3d
\end{array}
\]

Question #: 26
What is the ground-state electron configuration for silver?
A. [Kr]$5s^24d^9$
B. [Kr]$5s^14d^{10}$
C. [Kr]$5s^25d^9$
D. [Kr]$5s^15d^{10}$

Question #: 27
Which group of elements is sorted from largest to smallest atomic radius?
A. K >Si >S >O
B. Ca >Rb >Al >He
C. B >C >Mg >F
D. Ge >Si >Ga >Be
**Question #**: 28  
Which equation below represents the **electron affinity** of Na?

A. \( \text{Na}(g) + e^- \rightarrow \text{Na}^-(g) \)  
B. \( \text{Na}(g) \rightarrow \text{Na}^+(g) + e^- \)  
C. \( \text{Na}(g) + e^- \rightarrow \text{Na}^+(g) \)  
D. \( \text{Na}^+(g) \rightarrow \text{Na}(g) + e^- \)  

**Question #**: 29  
The first ten ionization energies (kJ/mol) of an element are:

1012; 1907; 2914; 4964; 6274; 21,267; 25,431; 29,872; 35,905; 40,130.

This element belongs to group **1** (numerical label of a column or family) of the periodic table.

1. _____

**Question #**: 30  
Because of the **1** [low, high] ionization energies of alkali metals, they are readily **2** [oxidized, reduced].

Reactivity **3** [increases, decreases] down the column because ionization energy **4** [increases, decreases] down the column.

1. _____

2. _____

3. _____

4. _____
Question #: 1
A 10.0 g sample of nitroglycerine, C₃H₅N₃O₉ (molar mass 227.10 g/mol) completely explodes, producing gases according to the reaction equation below.

\[ 4 \text{C}_3\text{H}_5\text{N}_3\text{O}_9(s) \rightarrow 12 \text{CO}_2(g) + 10 \text{H}_2\text{O}(g) + 6 \text{N}_2(g) + \text{O}_2(g) \]

If the total pressure of the gases produced is 2.1 atm, what is the partial pressure of O₂(g)?

\[ \text{1 atm} \]

Report your answer with 2 significant figures and do not include units.

1. 0.072
2. 0.072
3. 0.073
4. 0.073
5. 0.071
6. 0.071

Question #: 2
The figure shows the speed distributions of He, Ne, Ar and Kr at 25 °C. Which element is represented by curve #3 (green)?

A. He
B. Ne
C. Ar
D. Kr

✓ B. Ne

Question #: 3
The van der Waals equation provides correction factors used to calculate the properties of a gas under nonideal conditions. Which of the following statements describe(s) why real gases behave least ideally at low temperature or high pressure? Select all of the applicable statements.

A. At high pressure, the volume of the gas particles occupies a greater fraction of the total gas volume.
B. At high pressure, gas molecules move with slower kinetic energies.
C. At higher temperatures, the average kinetic energy of the gas molecules is lower.
D. At low temperature, intermolecular attractive forces become so effective that gas pressure is lower than predicted by the ideal gas law.

✓ D. At low temperature, intermolecular attractive forces become so effective that gas pressure is lower than predicted by the ideal gas law.
Question #: 4

\[ \Delta E_{\text{surroundings}} \text{ for the reaction } \text{H}_2(g) + \text{Cl}_2(g) \rightarrow 2 \text{HCl}(g) \text{ depicted below is } 1 \text{ kJ.} \]

Report your answer with three significant digits and without units, using the form 2.22E2 or 2.22E-2 if you use scientific notation.

\[ \begin{array}{c}
\text{Internal energy (kJ)} \\
\text{H}_2(g) + \text{Cl}_2(g) \\
0 \\
\begin{array}{c}
-182
\end{array} \\
\text{2 HCl}(g)
\end{array} \]

1. 1.82E2

Question #: 5

A baby’s ventilator reduced the volume of 1.200 L of air in a balloon to 0.500 L at 1.00 atm of constant pressure, using an additional 0.25 kJ of thermal energy to heat the air. By how much did the internal energy of the air (the system) change?

101 J = 1.00 L•atm

✓ A. +0.32 kJ

B. +72.95 kJ

C. +0.18 kJ

D. –0.18 kJ
Question #: 6
The initial conditions of blocks of two substances, A and B, are shown in the figure below. A and B come into contact with one another and reach thermal equilibrium at a final temperature 48.0 °C. What is the specific heat capacity \( C_s \) of substance A? No heat is lost during the transfer between the two blocks.

![Image of blocks with initial conditions](image)

- A. 0.30 J/g•°C
- B. 1.8 J/g•°C
- C. 2.4 J/g•°C
- D. 1.3 J/g•°C

Question #: 7
A balloon is inflated from 0.010 L to 0.500 L against an external pressure of 1.00 atm. How much work is done?

\[ 101 \text{ J} = 1.00 \text{ L} \cdot \text{atm} \]

- A. –49.5 J
- B. –4.85 J
- C. +4.85 J
- D. +1.01 J

Question #: 8
A 21.8 g sample of ethanol (C\(_2\)H\(_5\)OH, 46.07 g/mol) is burned in a bomb calorimeter, according to the following reaction equation. If the temperature rises from 25.0 °C to 62.3 °C, what is the heat capacity of the calorimeter?

\[ \text{C}_2\text{H}_5\text{OH}(l) + 3 \text{O}_2(g) \rightarrow 2 \text{CO}_2(g) + 3 \text{H}_2\text{O}(g) \quad \Delta H_{\text{rxn}} = -1235 \text{ kJ} \]

- A. 5.65 kJ/°C
- B. 63.7 kJ/°C
- C. 33.1 kJ/°C
- D. 15.7 kJ/°C
**Question #: 9**
Given the energy diagram below, is this reaction endothermic or exothermic, and is change in enthalpy positive or negative?

A. endothermic, positive $\Delta H$
B. endothermic, negative $\Delta H$
C. exothermic, positive $\Delta H$
D. exothermic, negative $\Delta H$

✓ D. exothermic, negative $\Delta H$

**Question #: 10**
Use the standard reaction enthalpies below to determine $\Delta H^\circ_{\text{rxn}}$ for the reaction:

\[8 \text{ SO}_3(g) \rightarrow \text{S}_8(s) + 12 \text{ O}_2(g) \quad \Delta H^\circ_{\text{rxn}} = \text{1 kJ}\]

Given:

\[8 \text{ SO}_2(g) \rightarrow \text{S}_8(s) + 8 \text{ O}_2(g) \quad \Delta H^\circ_{\text{rxn}} = +2374 \text{ kJ}\]

\[2 \text{ SO}_2(g) + \text{O}_2(g) \rightarrow 2 \text{ SO}_3(g) \quad \Delta H^\circ_{\text{rxn}} = -198 \text{ kJ}\]

Report your answer with **3 significant figures** and **do not include units**, using the format 2.2E2 or 2.2E-2 if you use scientific notation.

1. 3.17E3|3.17 E3|+3.17E3|+3.17 E3|3.17E+3|3.17 E+3|

**Question #: 11**
Given the following data, calculate the enthalpy of formation of $\text{B}_2\text{H}_6(g)$.

\[\text{B}_2\text{H}_6(g) + 6 \text{ H}_2\text{O}(l) \rightarrow 2 \text{ H}_3\text{BO}_3(s) + 6 \text{ H}_2(g) \quad \Delta H^\circ = -510 \text{ kJ}\]

$\Delta H^\circ_{f}$ of $\text{H}_3\text{BO}_3(s) = -1094 \text{ kJ/mol}$

$\Delta H^\circ_{f}$ of $\text{H}_2\text{O}(l) = -286 \text{ kJ/mol}$

$\Delta H^\circ_{f}$ of $\text{B}_2\text{H}_6(g) = \text{1 kJ/mol}.$

Report your answer with **two significant figures** and **do not include units**, using the format 2.2E2 or 2.2E-2 if you use scientific notation.

1. 38|39|37|
Question #: 12
Visible light falls immediately between the _____ and _____ regions of the electromagnetic spectrum.
Choose two regions.
✓ A. ultraviolet
✓ B. infrared
C. radio
D. X-ray

Question #: 13
Consider light with a wavelength of 495 nm. The frequency is 1 s⁻¹ and there are 2 kJ in 1.00 mole of photons.
Answer both to three significant figures and do not include units in your answer. Use the form 2.22E2 or 2.22E-2 if you use scientific notation.
1. 6.06E14|6.06e14|6.06 E14|6.06 e14|6.05E14|6.05e14|6.05 E14|6.05 e14|6.05E14|6.05e14|6.05 E14|6.05 e14|
2. 242|241|243|2.42E2|2.41E2|2.43E2|2.42 E2|2.41 E2|2.43 E2|

Question #: 14
Which of the following statements is true about the atomic spectra below?

A. They are emission spectra for the same element.
B. The emission spectrum of an element is on top and the absorption spectrum for the same element is on the bottom.
✓ C. They are emission spectra for two different elements.
D. They are absorption spectra for two different elements.

Question #: 15
An atom absorbs the most energy when one of its electrons undergoes which transition?
✓ A. n = 1 to n = 2
B. n = 2 to n = 3
C. n = 3 to n = 4
D. n = 4 to n = 5
Question #: 16
What is the minimum uncertainty in the position of an electron (mass= 9.11 \times 10^{-31} \text{ kg}) moving at a speed of 2.55 \times 10^7 \text{ m/s} with an uncertainty in the speed of 4.35 \times 10^5 \text{ m/s}?

✓ A. 133 \text{ pm}
B. 7.53 \text{ pm}
C. 308 \text{ pm}
D. 2270 \text{ pm}

Question #: 17
If two electrons in the same atom have quantum number \( l = 1 \), they could be in _______. Select all that apply.

✓ A. orbitals at different principal (\( n \)) levels, but with the same shape.
✓ B. the same orbital.
✓ C. orbitals at the same principal (\( n \)) level, with the same shape but different orientations.
D. two different \( s \) orbitals.

Question #: 18
The quantum number \( n \) determines which properties of an atomic orbital?
Select all that apply.

✓ A. relative size
✓ B. relative energy
C. shape
D. orientation

Question #: 19
What is the electron configuration of a ground-state sulfur atom?

Use this format with spaces but no superscripts: 1s2 2s2 2p3...

1. 1s2 2s2 2p6 3s2 3p4|1s^2 2s^2 2p^6 3s^2 3p^4
   3p^4|1s^2 2s^2 2p6 3s2 3p4|1s^2 2s^2 2p^6 3s^2 3p^4|[Ne] 3s2 3p4|[Ne]3s2 3p4| [Ne]3s2 3p4|[Ne] 3s^2 3p^4|[Ne] 3s2 3p4|

Question #: 20
Which of the following sets of quantum numbers \((n, l, m_l)\) does not represent an allowed atomic orbital?

A. (1, 0, 0)
✓ B. (2, 2, 1)
C. (2, 1, −1)
D. (3, 2, 0)
Question #: 21
A photon with a frequency of $6.17 \times 10^{14}$ Hz is emitted when an electron in a hydrogen atom moves from a higher energy level to the $n = 2$ level. What is the initial energy level?

$n = \underline{1}$

1. 4

Question #: 22
What is the maximum number of electrons that can have both of the quantum numbers, $n = 5$ and $l = 3$, in an atom?

A. 7
B. 10
✓ C. 14
D. 18

Question #: 23
What are possible quantum numbers ($n, l, m_l$) for the orbital shown below?

A. (5, 3, 0)
✓ B. (3, 2, −2)
C. (4, 1, 0)
D. (5, 0, 0)
**Question #24**
This figure illustrates which effect experienced by 1s and 2s electrons in a beryllium atom?

A. Pauli exclusion principle  
✓ B. shielding  
C. electron affinity  
D. Heisenberg uncertainty

**Question #25**
Which orbital diagram shows the ground-state valence electron configuration for Mn^{2+}?

A.  

B.  

✓ C.  

D.  

✓ C.
**Question #**: 26
What is the ground-state electron configuration for silver?
- A. \([\text{Kr}]5s^24d^9\)
- **✓** B. \([\text{Kr}]5s^44d^{10}\)
- C. \([\text{Kr}]5s^25d^9\)
- D. \([\text{Kr}]5s^15d^{10}\)

**Question #**: 27
Which group of elements is sorted from largest to smallest atomic radius?
- **✓** A. K > Si > S > O
- B. Ca > Rb > Al > He
- C. B > C > Mg > F
- D. Ge > Si > Ga > Be

**Question #**: 28
Which equation below represents the electron affinity of Na?
- **✓** A. \(\text{Na}(g) + e^- \rightarrow \text{Na}^-(g)\)
- B. \(\text{Na}(g) \rightarrow \text{Na}^+(g) + e^-\)
- C. \(\text{Na}(g) + e^- \rightarrow \text{Na}^+(g)\)
- D. \(\text{Na}^+(g) \rightarrow \text{Na}(g) + e^-\)

**Question #**: 29
The first ten ionization energies (kJ/mol) of an element are:
1012; 1907; 2914; 4964; 6274; 21,267; 25,431; 29,872; 35,905; 40,130.
This element belongs to group **1** (numerical label of a column or family) of the periodic table.

1. 5A|VA|15|5 A|VA|

**Question #**: 30
Because of the **1** [low, high] ionization energies of alkali metals, they are readily **2** [oxidized, reduced].
Reactivity **3** [increases, decreases] down the column because ionization energy **4** [increases, decreases] down the column.

1. low
2. oxidized
3. increase
4. decreases