This is a **50-minute** exam, and contains **23** multiple-choice questions and **3** free response problems. Point values for the different questions are as indicated. There should be **10** numbered pages, including this one. Page 10 is blank and can be used for scratch work if needed. There is also a periodic table attached to the back of the exam; you may tear the periodic table page off, and you do not need to turn that page in.

**Questions 1 – 23 should be answered on the scantron provided to you. Problems 24 – 26 should be answered on the exam paper, with ALL of your work shown as clearly as possible.** This will help us award partial credit. Answers without supporting work may not receive credit. You may use a calculator for this exam, but you may NOT retrieve or use any alphanumeric information or algorithms that might be stored in your calculator’s memory.

Please PRINT your name and UIN number above, and **SIGN the honor code statement below.** Also, please put your name on every page of the exam, in case a page gets detached from the exam.

**Physically Useful Information**

**PHYSICAL CONSTANTS**

<table>
<thead>
<tr>
<th>Physical Constant</th>
<th>Formula</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avogadro’s Number</td>
<td>$N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$</td>
<td></td>
</tr>
<tr>
<td>Gas Constant</td>
<td>$R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$</td>
<td>$= 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$</td>
</tr>
<tr>
<td></td>
<td>$= 62.364 \text{ L torr mol}^{-1} \text{ K}^{-1}$</td>
<td>$0^\circ \text{C} = 273.15 \text{ K}$</td>
</tr>
<tr>
<td>Planck’s Constant</td>
<td>$h = 6.626 \times 10^{-34} \text{ J s}$</td>
<td>$1 \text{ m} = 10^9 \text{ nm} = 10^6 \mu\text{m}$</td>
</tr>
<tr>
<td>Speed of light</td>
<td>$c = 2.9979 \times 10^8 \text{ m s}^{-1}$</td>
<td>$1 \text{ L} = 1,000 \text{ mL}$</td>
</tr>
<tr>
<td></td>
<td>$1 \text{ kJ} = 1,000 \text{ J}$</td>
<td>$1 \text{ MJ} = 1,000 \text{ kJ}$</td>
</tr>
</tbody>
</table>

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this exam."

**SIGNATURE:** ___________________________________________

**PLEASE DO NOT OPEN YOUR EXAM UNTIL TOLD TO DO SO.**
True or False? (For each statement, choose A for True or B for false. 2 points each.)
These can be subtle, so be sure that you read the statements very carefully.

(2 pts) 1. The ideal gas law works best when the temperature is high and the pressure is low.
   (A) True  (B) False

(2 pts) 2. As the frequency of a visible light source increases, the light will appear brighter.
   (A) True  (B) False

(2 pts) 3. Electronegativity is usually measured in units of kJ/mol.
   (A) True  (B) False

(2 pts) 4. Metals tend to lose electrons to form cations in most of their chemical compounds.
   (A) True  (B) False

(2 pts) 5. The ionization energy of an element is the minimum amount of energy required to remove an
electron from the neutral atom and form a cation.
   (A) True  (B) False

(2 pts) 6. Electron affinity is defined as a measure of an atom’s ability to attract electrons toward itself
in a chemical bond.
   (A) True  (B) False

(2 pts) 7. The complete photoelectron spectrum for either silicon or argon would show peaks
   corresponding to five different electron binding energies.
   (A) True  (B) False
For questions 8 – 10, consider three gas samples, all at the same temperature, pressure, and volume. Sample A contains \( \text{SO}_2 \), Sample B contains \( \text{O}_2 \), and Sample C contains \( \text{CH}_4 \).

(3 pts) 8. In which sample would the density of the gas be the lowest?

(A) Sample A  
(B) Sample B  
(C) Sample C  
(D) All 3 have the same density  
(E) Not enough information to tell

(3 pts) 9. In which sample would the molecules have the lowest average speed?

(A) Sample A  
(B) Sample B  
(C) Sample C  
(D) All 3 have the same average speed  
(E) Not enough information to tell

(3 pts) 10. In which sample would the molecules have the lowest average kinetic energy?

(A) Sample A  
(B) Sample B  
(C) Sample C  
(D) All 3 have the same average KE  
(E) Not enough information to tell

For questions 11 – 13, consider a particular electron in a silicon atom (Si, \( Z = 14 \)). The electron has the following quantum numbers: \( n = 3, \ell = 1, m_\ell = 0 \).

(3 pts) 11. What type of orbital does this electron occupy?

(A) 1s  
(B) 2s  
(C) 3s  
(D) 3p  
(E) 3d

(3 pts) 12. Assuming the atom is in its ground state electron configuration, what is the maximum number of electrons in any one silicon atom that could have this set of quantum numbers?

(A) 1  
(B) 2  
(C) 3  
(D) 6  
(E) 14

(3 pts) 13. What are all of the possible values for the \( m_\ell \) quantum number for this electron?

(A) \( +\frac{1}{2} \)  
(B) \( -\frac{1}{2} \)  
(C) \(-1, 0, +1 \)  
(D) \( +\frac{1}{2}, 0, -\frac{1}{2} \)  
(E) \( +\frac{1}{2}, -\frac{1}{2} \)
14. The solid line in each graph shown below is a plot of $V$ vs. $T$ for a 1-mol sample of an ideal gas at constant pressure. In which of the graphs does the dashed line correctly show what the graph would look like for a 2-mol sample (still at the same constant pressure)?

(A) $V$ vs. $T$ (°C)

(B) $V$ vs. $T$ (°C)

(C) $V$ vs. $T$ (°C)

(D) $V$ vs. $T$ (°C)

(E) The graph would not change

15. A sample of helium occupies a volume of 9.6 L at 99°C. The temperature of the gas is then adjusted at constant pressure until its volume decreases to 3.2 L. Assuming the gas behaves ideally, what is its final temperature?

(A) 0°C    (B) 33°C    (C) 297°C    (D) 843°C    (E) −149°C
(4 pts) 16. Which of the following sequences correctly ranks the following atoms and ions in order of decreasing radius (from largest radius to smallest)?

\[ \text{I, Rb, Rb}^+ , \text{Sr}^{2+} \]

(A) \( \text{Sr}^{2+} > \text{Rb}^+ > \text{I} > \text{Rb} \)
(B) \( \text{Rb} > \text{I} > \text{Sr}^{2+} > \text{Rb}^+ \)
(C) \( \text{I} > \text{Rb} > \text{Rb}^+ > \text{Sr}^{2+} \)
(D) \( \text{Rb} > \text{I} > \text{Rb}^+ > \text{Sr}^{2+} \)
(E) None of those is the correct sequence

(4 pts) 17. Which of the following sequences correctly ranks the following atoms and ions in order of increasing ionization energy (from smallest IE to largest)?

\[ \text{Cl}^-, \text{Ca}^{2+}, \text{K}^+, \text{Ar}, \text{S}^{2-} \]

(A) \( \text{S}^{2-} < \text{Cl}^- < \text{K}^+ < \text{Ca}^{2+} < \text{Ar} \)
(B) \( \text{Ca}^{2+} < \text{K}^+ < \text{Ar} < \text{Cl}^- < \text{S}^{2-} \)
(C) \( \text{S}^{2-} < \text{Cl}^- < \text{Ar} < \text{K}^+ < \text{Ca}^{2+} \)
(D) \( \text{Cl}^- < \text{Ca}^{2+} < \text{K}^+ < \text{Ar} < \text{S}^{2-} \)
(E) None of those is the correct sequence

(4 pts) 18. Which of the following sequences correctly ranks the following bonds in order of increasing polarity (from least polar to most)?

\[ \text{C—H}, \text{H—H}, \text{H—F}, \text{K—F} \]

(A) \( \text{H—H} < \text{C—H} < \text{K—F} < \text{H—F} \)
(B) \( \text{H—H} < \text{C—H} < \text{H—F} < \text{K—F} \)
(C) \( \text{K—F} < \text{H—F} < \text{C—H} < \text{H—H} \)
(D) \( \text{C—H} < \text{H—H} < \text{H—F} < \text{K—F} \)
(E) None of those is the correct sequence

(3 pts) 19. How many of the following atoms or ions would be paramagnetic in their ground state electron configurations?

\[ \text{Ar, Al, Al}^{3+}, \text{Ca}, \text{Ca}^+, \text{P}, \text{S} \]

(A) 1 (B) 2 (C) 3 (D) 4 (E) 5
For questions 20 – 23, consider the following electron configurations. (Use the letters A – E on the configurations as the answer choices for these questions.)

(A) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$
(B) $1s^2, 2s^2, 2p^6, 3s^3$
(C) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^1$
(D) $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 4d^{10}, 4p^1$
(E) $1s^2, 2s^2, 2p^6, 3s^2, 3p^4, 5s^1$

(3 pts) **20.** Which one of the electron configurations above represents the ground state of gallium (Ga, $Z = 31$)?

(3 pts) **21.** Which one of the electron configurations above could represent an excited state of chlorine (Cl, $Z = 17$)? (Such an excited state might be formed if a chlorine atom absorbs a photon, for example.)

(3 pts) **22.** Which one of the electron configurations above represents the ground state of the chloride anion?

(3 pts) **23.** Which one of the electron configurations above is not possible because it would violate the Pauli exclusion principle?
24. An argon atom is initially in its lowest possible energy level (or ground state). The atom absorbs a photon with a wavelength of 88.13 nm, and then emits a photon with a frequency of $3.16 \times 10^{15}$ Hz.

(a) Draw an energy level diagram summarizing this process. Your diagram should show the transitions and energy levels involved, and should show which photon goes with which transition. While the diagram need not be drawn to scale, it should be as qualitatively accurate as possible. Please read part (b) before you start drawing.

(b) At the end of the process described above, the atom will still be in an energy level above the ground state. Find the energy of this resulting excited state, assuming we assign a value of $E = 0$ to the ground state.
(10 pts) 25. A metallic wafer is known to be cesium, chromium, lithium, or potassium. The electron binding energies for these metals are listed below.

<table>
<thead>
<tr>
<th>Metal</th>
<th>Electron binding energy (J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cesium</td>
<td>$3.11 \times 10^{-19}$</td>
</tr>
<tr>
<td>chromium</td>
<td>$7.21 \times 10^{-19}$</td>
</tr>
<tr>
<td>lithium</td>
<td>$3.94 \times 10^{-19}$</td>
</tr>
<tr>
<td>potassium</td>
<td>$3.60 \times 10^{-19}$</td>
</tr>
</tbody>
</table>

One way to identify the element might be through a photoelectric effect experiment. Such an experiment was performed three times, each time using a different laser as the light source. The results are summarized below. (The kinetic energy of the ejected photoelectrons was not measured.)

<table>
<thead>
<tr>
<th>Laser wavelength</th>
<th>Photoelectrons seen?</th>
</tr>
</thead>
<tbody>
<tr>
<td>630 nm</td>
<td>No</td>
</tr>
<tr>
<td>532 nm</td>
<td>Yes</td>
</tr>
<tr>
<td>337 nm</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Based on this information, identify the metal. In order to receive credit, you MUST show sufficient calculations and include an explanation of the reasoning you used to reach your conclusion!
(10 pts) **26.** Dimethyldichlorosilane \((\text{CH}_3\text{SiCl}_2)\) is one of the starting materials for the production of silicone polymers. Dimethyldichlorosilane itself can be produced from silicon and methyl chloride by the following reaction.

\[
\text{Si(s)} + 2 \text{CH}_3\text{Cl(g)} \rightarrow \text{(CH}_3\text{)}_2\text{SiCl}_2\text{(g)}
\]

A 5.65-L flask initially contains \(\text{CH}_3\text{Cl}\) at a pressure of 649 torr at 20.0°C. Then 2.05 g of solid silicon are added, and the reaction above goes to completion. If the temperature at the end of the reaction is 85.0°C, what will be the final total pressure in the flask?