This exam will be machine graded using a bubble sheet. On the bubble sheet you must enter your full name, username, your UNIVERSITY ID (nine-digit #), and recitation number (see reverse of this page).

If you fail to bubble in your UNIVERSITY ID, there is a chance that your exam score will be lost, and even if we recover your score, you will be penalized 4 points.

For all questions there is only one correct answer. Each question is worth 4 points.

Completely darken the bubbles (stay in the lines): you will lose points if the machine cannot read your bubbles; if you do not bubble in your UNIVERSITY ID completely and heavily, there is a chance that your exam will not be graded, and you will receive a score of zero.

The answer you fill in on your bubble sheet is the only one that will count.

You should circle the answer on this exam booklet for your own reference.

Questions are written on both sides on each page. There is a periodic table, equations, and constants on the last page. You may remove this page and use it as scratch paper.

Turn off all cell phones and other internet-ready devices and put them away. Translators are not permitted.

This is a closed-book, closed-notes exam. You may use a scientific calculator and the issued card-stock periodic table. The answer key will be posted on Canvas.

You may keep the exam booklet at the end of the test.

You must return the bubble sheet and sign the check-out form (keep the exam booklet).

The proctor (instructor or TA) may ask students to change seats at any time during the exam.

Any kind of academic dishonesty will not be tolerated, and it will be reported to the Dean of Students and your academic adviser. Incidents of academic dishonesty may result in F grade for this course.
Regrade Policy: Graded exams will be returned to you during recitation. If you have a request for regrade, you MUST submit your exam to your TA before leaving the recitation room and clearly state which question(s) you would like us to regrade on the back of the bubble sheet. We may regrade the entire exam. If an error in the scoring is found, the grade will be corrected accordingly, whether or not it is in your favor. Do not tamper with the bubble sheet. Do not modify any answers if you wish to submit a regrade request. All regrades will be checked against your scanned exam, the copy of your bubble sheet as you submitted it at the end of the exam. Any discrepancies will be addressed as academic dishonesty. Please see syllabus for more details.
The answer you fill in on your bubble sheet is the one that will count. You should circle the answer on this sheet for your own reference.

1. You can only get the 4 points for this question if you have filled in your university ID on the bubble sheet and you completely and darkly filled in the bubbles.

Do you understand this?

A) yes

2. Blue light with a wavelength of \( \lambda = 400 \text{ nm} \) causes the emission of an electron from the surface of potassium by the photoelectric effect. What is the energy in J of a photon with \( \lambda = 400 \text{ nm} \)?

\[
E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \text{ J} \cdot \text{s}}{400 \text{ nm} \times 10^{-9} \text{ m/nm}} = 4.98 \times 10^{-19} \text{ J}
\]

A) \( 4.98 \times 10^{-19} \text{ J} \)
B) \( 1.03 \times 10^{-19} \text{ J} \)
C) \( 3.07 \times 10^{-23} \text{ J} \)
D) \( 6.05 \times 10^{-18} \text{ J} \)

3. Which electronic transition in the H atom emits a photon with the greatest energy?

A) \( n = 5 \rightarrow n = 1 \)
B) \( n = 5 \rightarrow n = 2 \)
C) \( n = 5 \rightarrow n = 3 \)
D) \( n = 5 \rightarrow n = 4 \)

4. An electron in which orbital is described by the following quantum numbers:

\( n = 3, l = 1, m_l = 1, m_s = -\frac{1}{2} \)?

A) \( 3s \)  B) \( 3p \)  C) \( 3d \)  D) \( 3f \)

5. Which one of the following represents a \( p \) orbital?

A) \( \bigcirc \)  B) \( \bigcirc \)  C) \( \bigcirc \)  D) \( \bigcirc \)
6. How many nodes does a 3s orbital have? The radial distribution function is shown for your consideration.

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

A node is where $\psi$ changes sign thus, where $\psi^2 = 0$ also, # nodes = $n - 1$

7. Which one of the following is the correct ground-state electron configuration for a silicon (Si) atom?

- A) [Ne] 2$s^2$ 2$p^2$
- B) [Ne] 3$s^2$ 3$p^4$ 3$d^{10}$
- C) [Ne] 3$s^2$ 3$p^2$
- D) [Ar] 5$s^2$ 5$p^4$ 4$d^{10}$

8. Which one of the following is the correct ground-state orbital diagram representation for the valence electrons of a nitrogen (N) atom?

- A)

- B)

- C)

- D)

8. Which one of the following is the correct ground-state orbital diagram representation for the valence electrons of a nitrogen (N) atom?

- A)

- B)

- C)

- D)

Hund’s rule: degenerate orbitals are filled singly first

9. What is the short-hand electron configuration of the ion of calcium?

- A) [Ar] 4$s^2$
- B) [Ar] 4$s^2$ 4$p^2$
- C) [Ar]
- D) [Kr]

10. Rank the following atoms from smallest atomic radius to largest atomic radius: B F Ne Na

- A) Na < Ne < F < B
- B) B < F < Ne < Na
- C) Ne < F < B < Na
- D) Na < B < F < Ne
11. How many core and valence electrons are there in a ground-state phosphorus, P, atom?

A) 2 and 13
B) 8 and 5
C) 12 and 3
D) 10 and 5

12. Consider the periodic table. Which one of the following statements is false?

A) Atomic size increases moving down a group.
B) Atomic size decreases moving right on a period.
C) Ionization energies decrease moving right on a period.
D) Effective nuclear charge is effected by shielding.

13. Which of the following statements is correct?

A) The size of O\(^2^−\) is greater than the size of O
B) The size of O is greater than the size of O\(^2^−\)
C) O\(^2^−\) and O have the same size
D) O\(^2^−\) does not exist so the comparison is nonsense.

14. Which of the following equations represents the first ionization of phosphorus?

A) P (g) + e\(^−\) → P\(^+\) (g)
B) P (g) → P\(^+\) (g) + e\(^−\)
C) P\(^−\) (g) → P (g) + e\(^−\)
D) P\(^+\) (g) + e\(^−\) → P (g)

15. A listing of the first four ionization energies (in kJ/mol) for the element silicon (Si) and one other main group element (X) from the 3\(^{rd}\) period are reported below. What element is X?

<table>
<thead>
<tr>
<th></th>
<th>I(_1) (kJ/mol)</th>
<th>I(_2) (kJ/mol)</th>
<th>I(_3) (kJ/mol)</th>
<th>I(_4) (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>786</td>
<td>1577</td>
<td>3232</td>
<td>4356</td>
</tr>
<tr>
<td>X</td>
<td>578</td>
<td>1817</td>
<td>2745</td>
<td>11577</td>
</tr>
</tbody>
</table>

A) Al
B) P
C) C
D) Ge

I\(_4\) larger for X than for Si: X must be to the left of Si.
16. Which is the most electronegative atom?

A) Na  B) Sr  C) P  D) O

17. Rank the C-X bonds in C-X = CF, CCl, CBr, Cl from most polar (most ionic) to least polar (most covalent)
(> means “more polar than”).

A) CF > CCl > CBr > Cl  
B) CBr > CCl > CF > Cl
C) Cl > CBr > CCl > CF  
D) C-X bonds always have the same polarity.

18. In the Lewis structure of carbon monoxide (CO), the formal charges are ____ on carbon and ____ on oxygen.

\[\begin{align*}
  : & \, C \equiv O : \\
  \text{A)} & \, 0, +1 \\
  \text{B)} & \, 0, -1 \\
  \text{C)} & \, +1, -1 \\
  \text{D)} & \, -1, +1 \\
\end{align*}\]

19. The type of compound that is most likely to contain a covalent bond is ________.

A) one that is composed of a metal from the far left of the periodic table and a nonmetal from the far right of the periodic table  
B) a solid metal  
C) one that is composed of only nonmetals  
D) held together by the electrostatic forces between oppositely charged ions

20. How many indistinguishable resonance structures does benzene (C₆H₆) have? Obey the octet rule!

A) 1  B) 2  C) 3  D) 4

21. Consider N₂O. The three distinguishable resonance structure for the molecule are represented below, all respecting the total number of valence electrons and the octet rule. Which one is the most abundant (most favorable)? *Hint: consider formal charges.*

\[\begin{align*}
  \text{A)} & \, \text{N=N} \rightarrow \text{O} : \\
  \text{B)} & \, \text{N=O} : \\
  \text{C)} & \, \text{N=N} = \text{O} : \\
  \text{D)} & \, \text{they are all equally abundant} \\
\end{align*}\]

**-1 or more electronegative element (O)**
22. What is the correct Lewis structure for SF₄?

A) ![Lewis structure A]

B) ![Lewis structure B]

C) ![Lewis structure C]

D) ![Lewis structure D]

23. Consider ethane (C₂H₆), ethene (C₂H₄), and ethyne (C₂H₂). Which has the shortest C-C bond?

A) C₂H₆

B) C₂H₄

C) C₂H₂

D) They all have the same C-C bond distance

24. What is the shape of ammonia, NH₃?

A) linear

B) bent

C) trigonal planar

D) trigonal pyramidal

25. Which value below most closely represents the H-O-H bond angle in a molecule of water, H₂O?

A) 45°

B) 90°

C) 109.5°

D) 120°

26. Which of the molecules below is polar?

A) CF₄

B) CO₂

C) CHCl₃

D) CH₄
Formulas and Equations

\[
\lambda \cdot v = c \quad E = hv \quad E = \frac{hc}{\lambda}
\]

Planck constant, \( h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \)

Speed of light, \( c = 2.998 \times 10^8 \text{ m/s} \)

Avogadro’s Number, \( N_A = 6.022 \times 10^{23} \)

Density of water = 1.000 g/ml at 25 °C

1 in = 2.54 cm \hspace{1cm} 100 cm = 1 m \hspace{1cm} 1,000 mm = 1 m \hspace{1cm} 1 \mu m = 10^{-6} \text{ m}

1 nm = 10^{-9} \text{ m} \hspace{1cm} 1 \text{ cm}^3 = 1 \text{ mL} \hspace{1cm} 1,000 mg = 1 \text{ g} \hspace{1cm} 1 \text{ kg} = 2.20 \text{ lb}

1 atm = 760 torr = 760 mmHg = 101.32 kPa \hspace{1cm} R = 0.0821 \text{ L atm/mol K}

### Periodic Table of the Elements

<table>
<thead>
<tr>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
<th>5A</th>
<th>6A</th>
<th>7A</th>
<th>8A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1H</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>1.01</td>
<td>Li</td>
<td>Be</td>
<td>B</td>
<td>C</td>
<td>N</td>
<td>O</td>
<td>F</td>
</tr>
<tr>
<td>6.94</td>
<td>9.01</td>
<td>11</td>
<td>Na</td>
<td>Mg</td>
<td>Al</td>
<td>Si</td>
<td>P</td>
</tr>
<tr>
<td>23.0</td>
<td>24.3</td>
<td>13</td>
<td>K</td>
<td>Ca</td>
<td>Sc</td>
<td>Ti</td>
<td>V</td>
</tr>
<tr>
<td>39.1</td>
<td>40.1</td>
<td>19</td>
<td>Rb</td>
<td>Sr</td>
<td>Y</td>
<td>Zr</td>
<td>Nb</td>
</tr>
<tr>
<td>85.5</td>
<td>87.6</td>
<td>37</td>
<td>Cs</td>
<td>Ba</td>
<td>La</td>
<td>Hf</td>
<td>Ta</td>
</tr>
<tr>
<td>133</td>
<td>137</td>
<td>55</td>
<td>Fr</td>
<td>Ra</td>
<td>Ac</td>
<td>Rf</td>
<td>Db</td>
</tr>
<tr>
<td>223</td>
<td>226</td>
<td>87</td>
<td>59</td>
<td>89</td>
<td>104</td>
<td>105</td>
<td>106</td>
</tr>
<tr>
<td>2A</td>
<td>3A</td>
<td>4A</td>
<td>5A</td>
<td>6A</td>
<td>7A</td>
<td>8A</td>
<td>18</td>
</tr>
<tr>
<td>2</td>
<td>He</td>
<td>18</td>
<td>Ne</td>
<td>Ar</td>
<td>Kr</td>
<td>Xe</td>
<td>4.00</td>
</tr>
<tr>
<td>11</td>
<td>Na</td>
<td>K</td>
<td>Rb</td>
<td>Cs</td>
<td>Fr</td>
<td>Ra</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Mg</td>
<td>Ca</td>
<td>Sr</td>
<td>Ba</td>
<td>Ac</td>
<td>Ra</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Al</td>
<td>Sc</td>
<td>Y</td>
<td>La</td>
<td>Db</td>
<td>Rf</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Si</td>
<td>Ti</td>
<td>Zr</td>
<td>Hf</td>
<td>Ac</td>
<td>Rf</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>P</td>
<td>V</td>
<td>Nb</td>
<td>Ta</td>
<td>Db</td>
<td>Rf</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>O</td>
<td>Cr</td>
<td>Mo</td>
<td>W</td>
<td>U</td>
<td>Pu</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>F</td>
<td>Mn</td>
<td>Tc</td>
<td>Re</td>
<td>Np</td>
<td>Am</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>N</td>
<td>Fe</td>
<td>Ru</td>
<td>Os</td>
<td>Pu</td>
<td>Cm</td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>Cl</td>
<td>Co</td>
<td>Rh</td>
<td>Ir</td>
<td>Am</td>
<td>Bk</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Ar</td>
<td>Ni</td>
<td>Pd</td>
<td>Pt</td>
<td>Cm</td>
<td>Cf</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Br</td>
<td>Cu</td>
<td>Ag</td>
<td>Au</td>
<td>Bk</td>
<td>Es</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>Kr</td>
<td>Zn</td>
<td>Cd</td>
<td>Hg</td>
<td>Cm</td>
<td>Fm</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Rb</td>
<td>Ga</td>
<td>In</td>
<td>Sn</td>
<td>Bk</td>
<td>Md</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Sr</td>
<td>Ge</td>
<td>Sn</td>
<td>Sb</td>
<td>Bk</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Cs</td>
<td>Ga</td>
<td>Se</td>
<td>Te</td>
<td>Bk</td>
<td>Lr</td>
<td></td>
</tr>
</tbody>
</table>

Lanthanides

| 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 |
| Cc | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | Lu |
| 140| 141| 144| 145| 150| 152| 157| 159| 162| 165| 167| 169| 173| 175|

Actinides

| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100| 101| 102| 103|
| Th | Pa | U  | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr |