Failing to properly bubble in your SIS/Carmen ID #, or your Test Form, will delay the grading of your test.
1. In the past two decades, a new method termed solid-state metathesis (SSM) has been developed to synthesize compounds that are often difficult to produce conventionally. The driving force behind SSM reactions is the formation of stable byproducts. For example, combining gallium iodide with lithium nitride to produce gallium nitride, as given below in the unbalanced reaction:

\[
\text{Gal}_3(s) + \text{Li}_3\text{N}(s) \rightarrow \text{GaN}(s) + 3\text{Li}(s)
\]

When the reaction above is balanced what is the sum of the whole number coefficients for all the reactants and products?

A. 4  B. 5  C. 6  D. 10  E. 12

2. If 3.0 grams of Gal$_3$ reacted fully with 3.0 grams of Li$_3$N, what is the mass of the excess reactant that remains after the reaction is complete?

A. 0.23 grams  B. 0.56 grams  C. 2.44 grams  D. 2.77 grams  E. 7.21 grams

3. Which species in this reaction has the greatest lattice energy?

A. Gal$_3$  B. Li$_3$N  C. GaN  D. Li  E. since all species are solids, they will have the same lattice energy
4. In this reaction gallium has a +3 oxidation state. What is the electron configuration for the Ga³⁺ cation?

A. [Ar] 4s²3d¹⁰4p¹
B. [Ar] 4s²3d⁸
C. [Ar] 3d¹⁰
D. [Ar] 4s²4f⁴4d¹⁰4p¹
E. [Ne] 3s²3p⁶

5. In the vapor phase, Li₃N exists as a discrete molecule. What is its molecular geometry?

A. trigonal planar
B. bent
C. tetrahedral
D. trigonal pyramid
E. t-shaped

6. In the vapor phase, Li₃N exists as a discrete molecule. What would you predict the Li - N bond angles to be?

A. Slightly less than 90°
B. Exactly 90°
C. Slightly less than 109.5°
D. Exactly 109.5°
E. Exactly 120°

7. The list below includes all the possible bonds from the products/reactants in this reaction. Which bond is the most polar?

A. Ga - I
B. Li - N
C. Ga - N
D. Li - I
E. All four bonds are non-polar

most polar: largest electronegativity difference

Li - N
8. This reaction is highly exothermic with a $\Delta H_{\text{rxn}}$ of $-515 \text{ kJ}$. If 5.3 grams of Li(s) is produced, how much energy is released in the reaction?

\[
\frac{5.3 \text{ g Li}}{133.34 \text{ g/mol Li}} \times \frac{1 \text{ mol Li}^+}{3 \text{ mol Li}} \times -515 \text{ kJ} = 6.80 \text{ kJ}
\]

A. 6.80 kJ
B. 20.4 kJ
C. 97.2 kJ
D. 515 kJ
E. 2729 kJ

9. Based on the atomic radii given below (in Angstroms), what would you predict for the trend in ionic radii?

\[
\begin{align*}
\text{Li}^+: & \text{ smaller than } 1.34 \AA \\
\text{N}^3-: & \text{ larger than } 0.75 \AA \\
\text{Ga}^{3+}: & \text{ smaller than } 1.26 \AA \\
\text{I}^-: & \text{ larger than } 1.33 \AA
\end{align*}
\]

A. largest $\text{Li}^+ > \text{N}^3- > \text{Ga}^{3+} > \text{I}^-$ smallest
B. largest $\text{I}^- > \text{Ga}^{3+} > \text{N}^3- > \text{Li}^+$ smallest
C. largest $\text{I}^- > \text{Ga}^{3+} > \text{Li}^+ > \text{N}^3-$ smallest
D. largest $\text{Ga}^{3+} > \text{Li}^+ > \text{I}^- > \text{N}^3-$ smallest
E. largest $\text{I}^- > \text{N}^3- > \text{Li}^+ > \text{Ga}^{3+}$ smallest

10. Which of the following statements is/are true?

I. The 4th ionization energy for Ga is greater than the 4th ionization energy of N. True
II. Iodine has a larger (more negative) electron affinity than Li. False
III. We would expect gallium to react vigorously with water, while lithium will not react with water. True
IV. The electronegativity for nitrogen is greater than iodine. True

A. II only
B. II and IV only
C. I and IV only
D. I, II, and IV
E. I, II, III, and IV

I. 4th IE: $\text{Ga}^{3+} \rightarrow \text{Ga}^{4+} + e^- \text{ e removes } e^- \text{ from filled d block N}
\begin{align*}
\text{N}^{3+} & \rightarrow \text{N}^{4+} + e^- \\
\text{H} & \text{H} \text{ H} \text{ H} \text{ H} \text{ H}
\end{align*}

II. Halogens have large (highly negative) EA. Noble gases core

III. From lecture video, Li reacts vigorously w/ water

IV. N is highly electronegative

EN decreases ↓ $\text{N} > \text{I}$
11. Knowing that F is more electronegative than either B or P, what conclusion can be drawn from the fact that BF₃ has no dipole moment, but PF₃ does?

A. BF₃ is not spherically symmetrical, but PF₃ is.
B. The BF₃ molecule must be trigonal planar
C. The BF₃ molecule must be linear
D. The atomic radius of P is larger than the atomic radius of B.

12. Fe²⁺ has a higher ionization energy than Fe. Which of the following is a reasonable explanation of this fact?

A. Fe²⁺ is larger than Fe → cations are smaller
B. Fe²⁺ is isoelectronic with chromium, which has a higher ionization energy than Fe
C. The outer electrons on Fe²⁺ experience a greater effective nuclear charge than those of Fe → does not explain why
D. Energy had to be put into Fe to ionize it to Fe²⁺

<table>
<thead>
<tr>
<th>Ionization Energies for element X (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>580</td>
</tr>
</tbody>
</table>

13. The ionization energies for an element X are listed in the table above. On the basis of this data, element X is most likely to be

A. Na  B. Mg  C. Al  D. Si  E. P

large jump from 3rd to 4th

\[ \overset{3}{\text{val}}\text{e}^- \rightarrow \overset{4}{\text{Al}} \]
14. The structure of NO$_3^-$ can be described in the Lewis formulation by these three structures.

\[
\begin{align*}
\text{[O-O-O]}^- & \quad \leftrightarrow \quad \text{[O-O-N]}^- \quad \leftrightarrow \quad \text{[O-N-O]}^- \\
\end{align*}
\]

This means that
A. two nitrogen-to-oxygen bonds are single bonds, the third is a double bond
B. three independent forms of the NO$_3^-$ ion coexist in equilibrium
C. the electrons must be rapidly exchanging among the three forms
D. the NO$_3^-$ ion exists in only one form: an average of the three principle structures shown.

15. For questions 15-16, use the following Lewis Structure for acetylsalicylic acid, or aspirin:

\[
\begin{align*}
\text{H} & \quad \sigma \quad \text{C} \quad \sigma \quad \text{C} \quad \sigma \quad \text{O} \quad \sigma \quad \text{H} \\
\text{H} & \quad \sigma \quad \text{C} \quad \sigma \quad \text{O} \quad \sigma \quad \text{H} \\
\end{align*}
\]

How many sigma bonds are in the molecule?
A. 5
B. 8
C. 16
D. 21
E. 26
16. How would you describe the bonding interaction between the hydrogen atom directly above the number 1 with the carbon atom to its immediate right?

A. H 1s - C 2s
B. H 1s - C 2p
C. H 1s - C sp
D. H 1s - C sp²
E. H 1s - C sp³

17. A certain AB₄ molecule has a square-planar molecular geometry. Which of the following statements about the molecule is or are true?

I. The molecule has four electron domains about the central atom A.

II. The B—A—B angles between neighboring B atoms is 90°.

III. The molecule has two nonbonding pairs of electrons on atom A.

A. Only one of the statements is true
B. Statements I and II are true
C. Statements I and III are true
D. Statements II and III are true
E. All three statements are true

18. Types of hybridization exhibited by the C atoms in propene, CH₃CHCH₂, include which of the following?

A. sp only
B. sp³ only
C. sp and sp² only
D. sp² and sp³ only
E. sp, sp², and sp³

19. Consider an AB₃ molecule in which A and B differ in electronegativity. You are told that the molecule has an overall dipole moment of zero. Which of the following could be the molecular geometry of the molecule?

A. trigonal pyramidal
B. trigonal planar
C. T-shaped
D. tetrahedral
E. More than one of the above
20. Formaldehyde has the Lewis Structure:

\[
\begin{align*}
\text{O} & \quad \sigma \\
\sigma& \\
\text{H} & \quad \text{C} & \quad \text{H}
\end{align*}
\]

Considering how the bonds in the formaldehyde molecule are formed in terms of overlaps of hybrid and unhybridized orbitals, which of the following statements about the molecule is or are true?

- **True** I. Two of the electrons in the molecule are used to make the \( \pi \) bond in the molecule. ✔
- **True** II. Six of the electrons in the molecule are used to make the \( \sigma \) bond in the molecule. ✔
- **True** III. The \( \text{C} - \text{O} \) bond length in formaldehyde should be shorter than that in methanol, \( \text{H}_2\text{COH} \).

A. Only one of the statements are true
B. Statements I and II are true
C. Statements I and III are true
D. Statements II and III are true
E. All three statements are true

55.46%

21. Place the following molecular ions in order from smallest to largest bond order: \( \text{C}_2^{2+}, \text{N}_2^-, \text{O}_2^-, \text{and F}_2^- \)

A. \( \text{C}_2^{2+} < \text{N}_2^- < \text{O}_2^- < \text{F}_2^- \)
B. \( \text{F}_2^- < \text{O}_2^- < \text{N}_2^- < \text{C}_2^{2+} \)
C. \( \text{O}_2^- < \text{C}_2^{2+} < \text{F}_2^- < \text{N}_2^- \)
D. \( \text{C}_2^{2+} < \text{F}_2^- < \text{O}_2^- < \text{N}_2^- \)
E. \( \text{F}_2^- < \text{C}_2^{2+} < \text{O}_2^- < \text{N}_2^- \)

32.32%

\[
\begin{align*}
\text{O}_2^- & \quad \text{b.o.} = \frac{8-2}{2} = 3 \\
\text{C}_2^{2+} & \quad \text{b.o.} = \frac{4-2}{2} = 1 \\
\text{N}_2^- & \quad \text{b.o.} = \frac{8+2}{2} = 5
\end{align*}
\]
22. Questions 22 - 24 refer to the following diatomic species.

(A) Li₂
(B) B₂
(C) N₂
(D) O₂
(E) F₂

Which has the largest bond dissociation energy

A. Li₂
B. B₂
C. N₂
D. O₂
E. F₂

23. Which is paramagnetic?

A. B₂
B. B₂
C. N₂
D. O₂
E. F₂

24. Which has one sigma and two pi bonds?

A. Li₂
B. B₂
C. N₂
D. O₂
E. F₂

25. Commercial Vinegar was titrated with NaOH solution to determine the content of acetic acid, HC₃H₃O₂. For 20.0 mL of the vinegar, 26.7 mL of 0.600 M NaOH solution was required. What was the concentration of acetic acid in the vinegar if no other acid was present?

A. 1.60 M
B. 0.800 M
C. 0.600 M
D. 0.450 M
E. 0.343 M

\[
\text{0.600 mol M}_\text{H}_\text{X} \times 0.0267 \text{L} = 0.01602 \text{ mol OH}^- = \text{ mol H}^+ \quad \frac{0.200}{0.800} = 10.800 \text{ M}
\]
Useful Conversion Factors and Relationships

Length

\( \text{SI unit: meter (m)} \)

- \( 1 \text{ km} = 0.62137 \text{ mi} \)
- \( 1 \text{ mi} = 5280 \text{ ft} \)
- \( = 1.6093 \text{ km} \)
- \( 1 \text{ m} = 1.0936 \text{ yd} \)
- \( 1 \text{ in.} = 2.54 \text{ cm (exactly)} \)
- \( 1 \text{ cm} = 0.39370 \text{ in.} \)
- \( 1 \text{ Å} = 10^{-10} \text{ m} \)

Mass

\( \text{SI unit: kilogram (kg)} \)

- \( 1 \text{ kg} = 2.2046 \text{ lb} \)
- \( 1 \text{ lb} = 453.59 \text{ g} \)
- \( = 16 \text{ oz} \)
- \( 1 \text{ amu} = 1.660538782 \times 10^{-24} \text{ g} \)

Temperature

\( \text{SI unit: Kelvin (K)} \)

- \( 0 \text{ K} = -273.15 ^\circ \text{C} \)
- \( = -459.67 ^\circ \text{F} \)
- \( K = ^\circ \text{C} + 273.15 \)
- \( ^\circ \text{C} = \frac{5}{9} (^\circ \text{F} - 32^\circ) \)
- \( ^\circ \text{F} = \frac{9}{5} ^\circ \text{C} + 32^\circ \)

Energy (derived)

\( \text{SI unit: Joule (J)} \)

- \( 1 \text{ J} = 1 \text{ kg-m}^2/\text{s}^2 \)
- \( = 0.2390 \text{ cal} \)
- \( = 1 \text{ C-V} \)
- \( 1 \text{ cal} = 4.184 \text{ J} \)
- \( 1 \text{ eV} = 1.602 \times 10^{-19} \text{ J} \)

Pressure (derived)

\( \text{SI unit: Pascal (Pa)} \)

- \( 1 \text{ Pa} = 1 \text{ N/m}^2 \)
- \( = 1 \text{ kg/m-s}^2 \)
- \( 1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa} \)
- \( = 760 \text{ torr} \)
- \( = 14.70 \text{ lb/in}^2 \)
- \( 1 \text{ bar} = 10^5 \text{ Pa} \)
- \( 1 \text{ torr} = 1 \text{ mm Hg} \)

Volume (derived)

\( \text{SI unit: cubic meter (m}^3) \)

- \( 1 \text{ L} = 10^{-3} \text{ m}^3 \)
- \( = 1 \text{ dm}^3 \)
- \( = 10^3 \text{ cm}^3 \)
- \( = 1.0567 \text{ qt} \)
- \( 1 \text{ gal} = 4 \text{ qt} \)
- \( = 3.7854 \text{ L} \)
- \( 1 \text{ cm}^3 = 1 \text{ mL} \)
- \( 1 \text{ in}^3 = 16.4 \text{ cm}^3 \)
### TABLE 4.1 - Solubility Guidelines for Common Ionic Compounds in Water

<table>
<thead>
<tr>
<th>Soluble Ionic Compounds</th>
<th>Important Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO$_3^-$</td>
<td>None</td>
</tr>
<tr>
<td>CH$_3$COO$^-$</td>
<td>None</td>
</tr>
<tr>
<td>CI$^-$</td>
<td>None</td>
</tr>
<tr>
<td>Br$^-$</td>
<td>Compounds of Ag$^+$, Hg$_2^{2+}$, and Pb$^{2+}$</td>
</tr>
<tr>
<td>I$^-$</td>
<td>Compounds of Ag$^+$, Hg$_2^{2+}$, and Pb$^{2+}$</td>
</tr>
<tr>
<td>SO$_4^{2-}$</td>
<td>Compounds of Sr$^{2+}$, Ba$^{2+}$, Hg$_2^{2+}$, and Pb$^{2+}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Insoluble Ionic Compounds</th>
<th>Important Exceptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>S$^{2-}$</td>
<td>Compounds of NH$_4^+$, the alkali metal cations, Ca$^{2+}$, Sr$^{2+}$, and Ba$^{2+}$</td>
</tr>
<tr>
<td>CO$_3^{2-}$</td>
<td>Compounds of NH$_4^+$ and the alkali metal cations</td>
</tr>
<tr>
<td>PO$_4^{3-}$</td>
<td>Compounds of NH$_4^+$ and the alkali metal cations</td>
</tr>
<tr>
<td>OH$^-$</td>
<td>Compounds of NH$_4^+$, the alkali metal cations, Cu$^{2+}$, Sr$^{2+}$, and Ba$^{2+}$</td>
</tr>
</tbody>
</table>

### TABLE 4.5 - Activity Series of Metals in Aqueous Solution

<table>
<thead>
<tr>
<th>Metal</th>
<th>Oxidation Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lithium</td>
<td>Li(s) $\rightarrow$ Li$^+(aq) + e^-$</td>
</tr>
<tr>
<td>Potassium</td>
<td>K(s) $\rightarrow$ K$^+(aq) + e^-$</td>
</tr>
<tr>
<td>Barium</td>
<td>Ba(s) $\rightarrow$ Ba$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca(s) $\rightarrow$ Ca$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na(s) $\rightarrow$ Na$^+(aq) + e^-$</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Mg(s) $\rightarrow$ Mg$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Aluminum</td>
<td>Al(s) $\rightarrow$ Al$^{3+}(aq) + 3e^-$</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn(s) $\rightarrow$ Mn$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn(s) $\rightarrow$ Zn$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Chromium</td>
<td>Cr(s) $\rightarrow$ Cr$^{3+}(aq) + 3e^-$</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe(s) $\rightarrow$ Fe$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Co(s) $\rightarrow$ Co$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Nickel</td>
<td>Ni(s) $\rightarrow$ Ni$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Tin</td>
<td>Sn(s) $\rightarrow$ Sn$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb(s) $\rightarrow$ Pb$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H$_2(g)$ $\rightarrow$ 2 H$^+(aq) + 2e^-$</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu(s) $\rightarrow$ Cu$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Silver</td>
<td>Ag(s) $\rightarrow$ Ag$^+(aq) + e^-$</td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg(l) $\rightarrow$ Hg$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Platinum</td>
<td>Pt(s) $\rightarrow$ Pt$^{2+}(aq) + 2e^-$</td>
</tr>
<tr>
<td>Gold</td>
<td>Au(s) $\rightarrow$ Au$^{3+}(aq) + 3e^-$</td>
</tr>
</tbody>
</table>
Fundamental Constants*

Atomic mass unit
1 amu = 1.660538782 × 10⁻²⁷ kg
1 g = 6.02214179 × 10²³ amu

Avogadro's number
\( N_A = 6.02214179 \times 10^{23}/\text{mol} \)

Boltzmann's constant
\( k = 1.3806504 \times 10^{-23} \text{ J/K} \)

Electron charge
\( e = 1.6021766487 \times 10^{-19} \text{ C} \)

Faraday's constant
\( F = 9.64853399 \times 10^4 \text{ C/mol} \)

Gas constant
\( R = 0.082058205 \text{ L- atm/mol-K} \)
\( = 8.314472 \text{ J/mol-K} \)

Mass of electron
\( m_e = 5.48579909 \times 10^{-4} \text{ amu} \)
\( = 9.10938215 \times 10^{-31} \text{ kg} \)

Mass of neutron
\( m_n = 1.008664916 \text{ amu} \)
\( = 1.674927211 \times 10^{-27} \text{ kg} \)

Mass of proton
\( m_p = 1.007276467 \text{ amu} \)
\( = 1.672621637 \times 10^{-27} \text{ kg} \)

Pi
\( \pi = 3.1415927 \)

Planck's constant
\( h = 6.62606896 \times 10^{-34} \text{ J-s} \)

Speed of light in vacuum
\( c = 2.99792458 \times 10^8 \text{ m/s} \)

*Fundamental constants are listed at the National Institute of Standards and Technology Web site:
http://www.nist.gov/physlab/data/physicalconst.cfm

---

Energy states of the hydrogen atom: \( E = (-2.18 \times 10^{-18} \text{ J})(1/n^2) \)

\( \lambda = h/mv, \ E = hc/\lambda \)

\( \Delta H_{\text{rxn}} = \Sigma \Delta H_{\text{products}} - \Sigma n \Delta H_{\text{reactants}}, \Delta H_{\text{rxn}} = \Sigma \text{ bonds broken} - \Sigma \text{ bonds formed} \)

\( q = \text{mass} \times \text{specific heat} \times \Delta T, \text{PE of two interacting charges} \ E = k(Q_1 Q_2)/d \)

\( F = ma, \ P = F/A, \ KE = \frac{1}{2}mv^2 \)

\( \left( P + \frac{n^2a}{V^2} \right) (V \ - \ nb) = nRT, \text{ and for an ideal gases: } PV = nRT \)

\( v = \sqrt{\frac{3RT}{M}} \) where \( v \) is rms speed

\( z^2 = x^2 + y^2 \) (diagonal of right angle triangle), \( V_{\text{box}} = \ell \cdot w \cdot h \)

\( S_\ell = k_h P_\ell, \ P_A = X_A P_{A0}, \ \Delta T_b = K_m, \ \Delta T_f = K_m, \ \Pi = (n/V)RT \)

\( \Delta P = X_{\text{solution}} P_{\text{solvent}}^0, \ P_{\text{solution}} = X_{\text{solvent}} P_{\text{solvent}}^0 \)

\( ln\left( \frac{P_2}{P_1} \right) = \frac{\Delta H_v}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \log\left( \frac{P_2}{P_1} \right) = \frac{\Delta H_v}{2.303R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \)

\( \ln(P) = -\frac{\Delta H_v}{R} \left( \frac{1}{T} \right) + C \)
For the general equation: \( aA + bB \rightleftharpoons dD + eE \)

\[
\text{Rate} = -\frac{1}{a} \frac{\Delta [A]}{\Delta t} = -\frac{1}{b} \frac{\Delta [B]}{\Delta t} = \frac{1}{c} \frac{\Delta [C]}{\Delta t} = \frac{1}{d} \frac{\Delta [D]}{\Delta t} = Q = \left[ \frac{[D]^d [E]^e}{[A]^c [B]^b} \right]
\]

\[
K_c = \left[ \frac{[D]^d [E]^e}{[A]^c [B]^b} \right]^f \\
K_p = \frac{(P_d)^d (P_e)^e}{(P_a)^c (P_b)^b} \\
K_r = K_c (RT)^{an}
\]

\[
[A]_t = -kt + [A]_0 \\
\ln [A]_t = -kt + \ln [A]_0 \\
\frac{1}{[A]_t} = kt + \frac{1}{[A]_0}
\]

\[
t_{1/2} = -\frac{\ln 1/2}{k} = \frac{0.693}{k} \\
t_{1/2} = \frac{1}{k[A]_0}
\]

\[
\ln k = -\frac{E_a}{RT} + \ln A
\]

\[
\ln(\frac{k_2}{k_1}) = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) \\
\log(\frac{k_2}{k_1}) = \frac{E_a}{2.303R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)
\]

\[
k = A \ e^{-\frac{E_a}{RT}} \\
\ln(k) = -\left( \frac{E_a}{R} \right) \left( \frac{1}{T} \right) + \ln(A)
\]

Molarity, \( M \) = moles of solute \ / \ liters of solution

Molality, \( m \) = moles of solute \ / \ kilograms of solvent

\[
A = \varepsilon bc
\]

at 25^\circ C, \( K_w = 1.0 \times 10^{-14} \)

\[
K_c = [H_3O^+][OH^-] = K_w.
\]

\[
K_a = \left[ \frac{[H^+][A^-]}{[HA]} \right] \\
pH = -\log[H^+] = -\log[H_3O^+]. \\
K_a \times K_b = K_w \\
pOH = -\log[OH^-]
\]

\[
\% \ ionization = \left[ \frac{[H^+]_{equilibrium}}{[HA]_{initial}} \right] \times 100\% \\
pH = pK_a + \log\left( \frac{[base]}{[acid]} \right)
\]

for \( ax^2 + bx + c = 0 \), \( x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \)
\[ S = k_B \ln W \]
\[ \Delta G = \Delta H - T\Delta S \]
\[ \Delta G = \Delta G^\circ + RT \ln Q \]
\[ \Delta G = -RT \ln K \]
\[ E_{\text{cell}}^\circ = E_{\text{red}}^\circ \text{ (cathode)} - E_{\text{red}}^\circ \text{ (anode)} \]
\[ \Delta G = -nF E_{\text{cell}}^\circ \]
\[ E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0592V}{n} \log Q \]
\[ \ln K = -\Delta H^\circ / R (1/T) + C \]
### Periodic Table of the Elements

<table>
<thead>
<tr>
<th>Periodic Table of the Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Representative Elements</strong></td>
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<tr>
<td><strong>Nonmetals</strong></td>
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<tr>
<td><strong>Metalloids</strong></td>
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<tr>
<td><strong>Transition Metals</strong></td>
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<th>Period 3</th>
<th>Period 4</th>
<th>Period 5</th>
<th>Period 6</th>
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### Accurate Masses

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### Landmark Sources

- The labels on top (1A, 2A, etc.) are common American usage. The labels below these (1', 2', etc.) are those recommended by the International Union of Pure and Applied Chemistry (IUPAC).