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UNIT I

STRUCTURE OF MATTER
I. STRUCTURE OF MATTER
A. Development of Atomic Theory

2159. What is the shell configuration of electrons for neutral atoms of nickel, _28^Ni, in the ground state?
   (A) 2–8–16–2  (D) 2–18–8–0
   (B) 2–8–10–8  (E) 2–8–16–28
   (C) 2–8–8–10

2161. What is the electron shell configuration for ions of selenium, _34^Se^2–?
   (A) 2–8–18–6  (D) 2–8–18–8
   (B) 2–8–18–8–2  (E) 2–8–14–12
   (C) 2–8–18–4

2162. What is the electron shell configuration for calcium ions, _Ca^{2+}?
   (A) 2–8–8–2  (D) 2–8–6
   (B) 2–8–8  (E) 2–8–6–2
   (C) 2–8–8–4

2477. In the orbital notation 1s^2 the coefficient 1 indicates that
   (A) helium has 1 electron
   (B) helium has an atomic number of 1
   (C) helium has an atomic mass of 1
   (D) helium has an energy level of 1
   (E) helium has 1 neutron

2478. The maximum number of electrons in the second energy level, n = 2, of any atom is
   (A) 8  (D) 4
   (B) 2  (E) 6
   (C) 16

2479. The maximum number of electrons that may be accommodated in the 4th energy level of any atom is
   (A) 4  (D) 16
   (B) 8  (E) 32
   (C) 12

2480. The maximum number of electrons which can occupy the 3rd energy level of any atom is
   (A) 2  (D) 12
   (B) 8  (E) 18
   (C) 9

2481. The maximum number of electrons which can occupy the 1st principal energy level of any atom is
   (A) 8  (D) 18
   (B) 2  (E) 4
   (C) 10
I. STRUCTURE OF MATTER
A. Development of Atomic Theory

2138. When an electron moves from the level where n=4 to the level where n=2, the change in energy is

\[
E = \frac{-1312 \text{ kJ} \cdot \text{mol}^{-1}}{n^2}
\]

(A) +246.\text{kJ} \cdot \text{mol}^{-1}  \quad (D) -307.\text{kJ} \cdot \text{mol}^{-1}

(B) -246.\text{kJ} \cdot \text{mol}^{-1}  \quad (E) -656.\text{kJ} \cdot \text{mol}^{-1}

(C) +307.\text{kJ} \cdot \text{mol}^{-1}

2139. When an electron moves from the level where n=3 to the level where n=1, the change in energy is

\[
E = \frac{-1312 \text{ kJ} \cdot \text{mol}^{-1}}{n^2}
\]

(A) -874.\text{kJ} \cdot \text{mol}^{-1}  \quad (D) +1166.\text{kJ} \cdot \text{mol}^{-1}

(B) +874.\text{kJ} \cdot \text{mol}^{-1}  \quad (E) + 656.\text{kJ} \cdot \text{mol}^{-1}

(C) -1166.\text{kJ} \cdot \text{mol}^{-1}

2140. Movement of an electron from the 5\textsuperscript{th} to the 1\textsuperscript{st} energy level in an atom is:

(A) exothermic and absorbs energy.
(B) \text{exothermic and evolves energy.}
(C) endothermic and absorbs energy.
(D) endothermic and evolves energy.
(E) neither exothermic nor endothermic.

2141. Movement of an electron from the 4\textsuperscript{th} to the 8\textsuperscript{th} energy level in an atom is

(A) exothermic and absorbs energy
(B) \text{exothermic and evolves energy}
(C) \text{endothermic and absorbs energy}
(D) endothermic and evolves energy
(E) neither endothermic nor exothermic

2142. Sunlight, when viewed through a prism or a diffraction grating, shows all of the colors of visible light. This is an example of a

(A) bright line spectrum  \quad (D) visible spectrum

(B) \text{continuous spectrum} \quad (E) ultraviolet spectrum

(C) infrared spectrum

2143. Neon light, when viewed through a prism or a diffraction grating, shows only certain colors of visible light. This is an example of a

(A) bright line spectrum  \quad (D) visible spectrum

(B) continuous spectrum  \quad (E) absorption spectrum

(C) infrared spectrum

2264. A single burst of visible light is released by an atom. Which is an explanation of what happened in the atom? An electron

(A) removed a proton from the nucleus
(B) was changed from a particle to a wave
(C) \text{moved from a higher to a lower energy level}
(D) moved from a lower to a higher energy level
(E) was released from the nucleus

2265. What is the mass number of a potassium ion, K\textsuperscript{+}, consisting of 18 electrons, 19 protons and 20 neutrons?

(A) 36  \quad (D) 39

(B) 37  \quad (E) 57

(C) 38

2485. The light from fluorescent lights, when analyzed in a spectrometer, exhibit the same lines in the yellow, green and blue spectral regions. This is evidence that

(A) fluorescent lights contain fluorine gas
(B) air is present in all fluorescent lights
(C) there are no gases present in fluorescent lights
(D) \text{the same element is present in all the fluorescent lights}
(E) different elements are present in each fluorescent light

2486. The colors of the spectral emission lines produced by the gas in a discharge tube are determined by the

(A) applied voltage  \quad (D) temperature of the gas

(B) pressure of the gas  \quad (E) applied current

(C) gas used in the tube

2989. Which of the following statements are true?

I. The energy of electromagnetic radiation increases as its frequency increases.
II. The energy of an atom is increased as it emits electromagnetic radiation.
III. An excited atom returns to its ground state by absorbing electromagnetic radiation.
IV. The frequency and wavelength of electromagnetic radiation are inversely proportional.
V. An electron in the n = 3 state in the hydrogen atom can go to the n = 1 state by emitting electromagnetic radiation at the appropriate frequency.

(A) II, III, and V only  \quad (D) I, IV, and V only

(B) III and IV only  \quad (E) II, III, and V only

(C) I, II, and III only

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I. STRUCTURE OF MATTER

B. Orbital Model of the Atom

2500. The electronic configuration of the $S^{2-}$ ion is
(A) $1s^22s^22p^63s^23p^5$  (D) $1s^22s^22p^63s^23p^6$
(B) $1s^22s^22p^63s^23p^4$  (E) $1s^22s^22p^63s^23p^4$
(C) $1s^22s^22p^63s^23p^5$

2501. The atomic number of an element whose electronic configuration is $1s^22s^22p^1$ is
(A) 1  (D) 4
(B) 2  (E) 5
(C) 3

2502. Consider the orbital diagram

```
  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲
1s  2s  2p  □  □  □  □  □  □  □  □
```

The species that does not have this orbital occupancy pattern is
(A) $^{18}_{18}$Ar  (D) $^{39}_{19}$K$^+$
(B) $^{34}_{16}$S  (E) $^{32}_{16}$S$^{2-}$
(C) $^{37}_{17}$Cl$^-$

2503. The orbital diagram for an atom of sodium, $^{11}_{11}$Na, in its lowest energy state is
(A) $\text{Na}^+$
(B) $\text{Na}^2+$
(C) $\text{Na}^3+$

2504. Consider the orbital diagram.

```
  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲  ▲
1s  2s  2p  □  □  □  □  □  □  □  □
```

The species that has this orbital configuration is
(A) $^{13}_{7}$N  (D) $^{31}_{15}$P$^{3-}$
(B) $^{27}_{13}$Al  (E) None of the above
(C) $^{27}_{13}$Al$^{3+}$

2505. Which species has the same number of electrons as the magnesium ion, Mg$^{2+}$?
(A) Ca$^{2+}$  (D) Ne$^+$
(B) Na$^+$  (E) Ba$^{2+}$
(C) F

2506. The species having the same number of electrons as Mg$^{2+}$ is
(A) Na  (D) Ar
(B) $^{19}_{19}$K$^+$  (E) Ne$^{1+}$
(C) N$^-$

2507. Which of the species is the most stable?
(A) He(g)  (D) Ne$^+$ (g)
(B) He$^+$ (g)  (E) Xe(g)
(C) Ne(g)

2508. Which shell electron configuration is that of the most reactive nonmetal?
(A) 2, 8, 1  (D) 2, 8, 8
(B) 2, 8, 3  (E) 2, 8, 6
(C) 2, 8, 7

2509. How many electrons are usually left out of the condensed electron dot diagrams of elements with atomic numbers 11 to 18?
(A) 8  (D) 12
(B) 2  (E) 18
(C) 10

2510. The shell electron configuration of a neutral carbon atom is
(A) 1, 5  (D) 2, 2, 4
(B) 2, 4  (E) 2, 2, 2
(C) 2, 6

2511. The ground state electronic configuration for an atom of neon, $^{10}_{10}$Ne, is
(A) $1s^22s^2$  (D) $1s^22s^22p^63s^23p^6$
(B) $1s^22s^22p^6$  (E) $1s^22s^22p^4$
(C) $1s^22s^22p^63s^1$

3850. Which of the following could not represent the electron configuration of a neutral atom in the ground state?
(A) $1s^22s^22p^63s^23p^4$  (D) $1s^22s^22p^63s^2$
(B) $1s^22s^22p^2$  (E) $1s^22s^22p^63s^1$
(C) $1s^22s^22p^63s^33p^4$
1597. Which term best describes the molecular geometry of ethylene, C₂H₄?
(A) Linear (B) Planar (C) Pyramidal (D) Octahedral

1599. The arrangement of atoms in a water molecule, H₂O, is best described as
(A) ring (B) trigonal planar (C) linear (D) trigonal pyramidal (E) bent

1619. The shape of a chloroform molecule, CHCl₃, is
(A) linear (B) octahedral (C) tetrahedral (D) planar triangular (E) seesaw

1632. Which is the shape of the ammonium ion, NH₄⁺?
(A) linear (B) Tetrahedral (C) Trigonal planar (D) pyramidal nondipole (E) bent

1671. What is the geometry of the CHCl₃ molecule?
(A) Bent (B) Linear (C) Tetrahedral (D) Trigonal pyramidal (E) Planar triangular

1672. What is the geometry of the BF₃ molecule?
(A) Bent (B) Linear (C) Tetrahedral (D) pyramidal nondipole (E) planar triangular

1673. What is the geometry of the NH₃ molecule?
(A) Bent (B) Linear (C) Tetrahedral (D) Trigonal pyramidal (E) Planar triangular

1674. What is the geometry of the HBr molecule?
(A) Bent (B) Linear (C) Tetrahedral (D) Trigonal pyramidal (E) Planar triangular

1675. What is the geometry of the SF₃ molecule?
(A) Bent (B) Linear (C) Tetrahedral (D) Trigonal pyramidal (E) Planar triangular

1676. Predict the geometry of the CO₂ molecule.
(A) Bent (B) Linear (C) Tetrahedral (D) Trigonal pyramidal (E) Planar triangular

1677. Predict the geometry of the CH₄ molecule.
(A) Bent (B) Linear (C) Tetrahedral (D) Trigonal pyramidal (E) Planar triangular

1678. Predict the geometry of the HI molecule.
(A) Bent (B) Linear (C) Tetrahedral (D) Trigonal pyramidal (E) Planar triangular

1679. Predict the geometry and polar nature of the PH₃ molecule.
(A) linear dipole (B) linear nondipole (C) pyramidal dipole (D) pyramidal nondipole (E) tetrahedral nondipole

1680. Predict the geometry and polar nature of the BeF₂ molecule.
(A) bent dipole (B) linear dipole (C) linear nondipole (D) pyramidal dipole (E) tetrahedral nondipole

1681. Predict the geometry and polar nature of the FCl molecule.
(A) bent dipole (B) linear dipole (C) linear nondipole (D) pyramidal dipole (E) tetrahedral nondipole

1682. Predict the geometry and polar nature of the NH₃ molecule.
(A) bent dipole (B) linear dipole (C) pyramidal dipole (D) pyramidal nondipole (E) tetrahedral nondipole

1683. Predict the geometry and polar nature of the CCl₄ molecule.
(A) linear dipole (B) linear nondipole (C) pyramidal dipole (D) pyramidal nondipole (E) tetrahedral nondipole

1684. Predict the geometry and polar nature of the H₂O molecule.
(A) bent dipole (B) linear dipole (C) linear nondipole (D) pyramidal dipole (E) tetrahedral nondipole

1685. Predict the geometry and polar nature of the BeFCl molecule.
(A) bent dipole (B) linear dipole (C) linear nondipole (D) pyramidal dipole (E) tetrahedral nondipole
1686. Predict the geometry and polar nature of the CHCl₃ molecule.
(A) bent dipole  (D) tetrahedral dipole
(B) linear dipole  (E) tetrahedral nondipole
(C) linear nondipole

1687. Predict the geometry and polar nature of the CO₂ molecule.
(A) bent dipole  (D) tetrahedral dipole
(B) linear dipole  (E) tetrahedral nondipole
(C) linear nondipole

1781. The shape of the sulfate ion, SO₄²⁻, is most similar to the shape of
(A) N₂H₄  (D) SiH₄
(B) CO₃²⁻  (E) SO₃²⁻
(C) C₂H₄

1796. The molecular geometry of the sulfite ion, SO₃²⁻, is most similar to that of
(A) water, H₂O
(B) the sulfate ion, SO₄²⁻
(C) the ammonium ion, NH₄⁺
(D) the hydronium ion, H₃O⁺
(E) boron chloride, BCl₃

1890. The shape of the carbonate ion, CO₃²⁻ is
(A) linear  (D) tetrahedral
(B) pyramidal  (E) trigonal planar
(C) octahedral

1891. The shape of a BF₃ molecule is
(A) octahedral  (D) tetrahedral
(B) planar triangular  (E) trigonal pyramidal
(C) square pyramidal

1893. Which consists of tetrahedral molecules?
(A) CsCl  (D) H₂O
(B) CO₂  (E) NH₃
(C) CCl₄

1894. The F-B-F angle in a BF₃ molecule is
(A) 90°  (D) 120°
(B) 102°  (E) 180°
(C) 109.5°

1895. The shape of an NF₃ molecule is
(A) tetrahedral  (D) pyramidal
(B) trigonal bipyramidal  (E) trigonal planar
(C) octahedral

1801. Which best describes the geometry of the ammonia molecule, NH₃?
(A)  \[
\begin{array}{c}
\text{H} \\
- \\
\text{N} \\
- \\
\text{H} \\
\end{array}
\]
linear

(B)  \[
\begin{array}{c}
\text{H} \\
| \\
\text{N} \\
| \\
\text{H} \\
\end{array}
\]
T-shaped

(C)  \[
\begin{array}{c}
\text{H} \\
\text{N} \\
\text{H} \\
\end{array}
\]
planar triangular

(D)  \[
\begin{array}{c}
\text{N} \\
\text{H} \\
\text{H} \\
\end{array}
\]
trigonal pyramidal

(E)  \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{N} \\
\end{array}
\]
Square-shaped

1897. Which formula represents a compound whose molecules are tetrahedral?
(A) BH₃  (D) H₂O
(B) C₂H₂  (E) C₂H₆
(C) CH₄

1899. The shape of the BCl₃ molecule is
(A) linear  (D) trigonal pyramidal
(B) octahedral  (E) tetrahedral
(C) planar triangular

1900. A molecule of CH₄ is
(A) bent and polar
(B) linear and nonpolar
(C) tetrahedral and nonpolar
(D) trigonal pyramidal and polar
(E) trigonal planar and nonpolar
1901. A molecule of NH₃ is
(A) bent and polar
(B) linear and nonpolar
(C) tetrahedral and nonpolar
(D) trigonal pyramidal and polar
(E) trigonal planar and nonpolar

1902. The shape of the CO₂ (carbon dioxide) molecule is
(A) bent
(B) octagonal
(C) pyramidal

1903. The shape of CH₂Cl₂ is
(A) linear
(B) planar
(C) pyramidal

1904. The shape of the CH₄ molecule is
(A) octahedral
(B) rectangular
(C) tetrahedral

1905. The H–N–H bond angle in NH₃ is less than the H–C–H angle in CH₄ due to the
(A) pair of nonbonded electrons in ammonia.
(B) repulsion between hydrogen atoms in ammonia.
(C) attraction between hydrogen atoms in methane.
(D) tetrahedral shape of ammonia and methane molecules.
(E) larger size of the nitrogen atom than the carbon atom.

1906. The bonding orbitals on the boron atom in BF₃ molecule are
(A) s orbitals
(B) sp orbitals
(C) sp² orbitals
(D) sp³ orbitals
(E) p orbitals

1907. The shape of a water molecule is
(A) bent
(B) planar
(C) pyramidal

1908. What is the structural shape of the SF₆ molecule?
(A) linear
(B) octahedral
(C) tetrahedral

1909. The shape of an NH₃ molecule is
(A) linear
(B) tetrahedral
(C) planar triangular
(D) trigonal pyramidal
(E) bipyramidal

2067. The shape of methane molecules, CH₄, is
(A) bent
(B) triangular
(C) tetrahedral

2068. The molecule carbon dioxide, CO₂,
(A) is bent
(B) is linear
(C) has two nonbonding electrons
(D) has one double and one single bond
(E) trigonal planar

2069. The shape of the ammonia (NH₃) molecule is
(A) linear
(B) tetrahedral
(C) trigonal planar

2070. A molecule of CO₂ (carbon dioxide) is
(A) bent and polar
(B) linear and polar
(C) bent and nonpolar
(D) pyramidal and polar
(E) linear and nonpolar

3897. Carbon dioxide is
(A) linear and polar
(B) linear and nonpolar
(C) bent and polar
(D) bent and nonpolar
(E) trigonal planar and polar
UNIT II

STATES OF MATTER
II. STATES OF MATTER

A. Ideal Gas Laws

1. Gases

ii. Boyle's Law

2658. A sample of gas occupies 850 ml at 0°C and 710 mmHg. Which expression allows computation of the volume of this sample at standard pressure at constant temperature.

(A) $\frac{850 \text{ ml} \times 710 \text{ mm}}{760 \text{ mm}}$

(B) $\frac{850 \text{ ml} \times 760 \text{ mm}}{710 \text{ mm}}$

(C) $\frac{1}{850 \text{ ml}} \times 710 \text{ mm}$

(D) $\frac{1}{850 \text{ ml}} \times 760 \text{ mm}$

(E) $273 \text{ K} \times 760 \text{ mm}$

2664. A gas occupies a volume of 2.0 liters at 13 atm. How many liters is occupied by this gas at 1.0 atm and the same temperature?

(A) 0.15

(B) 13

(C) 26

2668. A gas occupies a 1.5 liter container at 25°C and 2.0 atmospheres. If the gas is transferred to a 3.0 liter container at the same temperature, what will be the new pressure?

(A) 1.0 atm

(B) 2.0 atm

(C) 3.0 atm

2682. A given mass of dry gas is kept at constant temperature. When the pressure is doubled, the volume is

(A) halved

(B) doubled

(C) unchanged

(D) increased by a factor of four

(E) decreased by a factor of four

2717. An amount of a gas with a volume of 6,300 mL is changed from a pressure of 4,800 to 1,600 mmHg at constant temperature. What would be the approximate new volume?

(A) 1,600 mL

(B) 2,100 mL

(C) 4,800 mL

(D) 9,600 mL

(E) 19,000 mL

2732. Which are inversely proportional?

(A) pressure and moles

(B) pressure and temperature

(C) temperature and volume

(D) pressure and volume

(E) volume and moles

2768. Which curve represents the relationship between the volume of an ideal gas and its pressure for a certain number of molecules at a constant temperature?

(A) Volume vs. Pressure

(B) Volume vs. Pressure

(C) Volume vs. Pressure

(D) None of the above.

2779. A given mass of dry gas is kept at constant temperature. When the pressure is doubled, the volume is

(A) halved

(B) doubled

(C) unchanged

(D) increased by a factor of four

(E) decreased by a factor of four
UNIT III

REACTIONS
III. REACTIONS

C. Bronsted-Lowry Theory

341. What is the hydrogen ion concentration, \([H^+\text{(aq)}]\), in a 0.02 M aqueous solution of nitric acid, \(\text{HNO}_3\)?

(A) \(1 \times 10^{-2}\) M  
(B) \(2 \times 10^{-1}\) M  
(C) \(2 \times 10^{-2}\) M  
(D) \(2 \times 10^{-12}\) M  
(E) \(2 \times 10^{-32}\) M

344. Which gas in moist air will cause respiratory irritation to humans?

(A) \(\text{He}\)  
(B) \(\text{N}_2\)  
(C) \(\text{O}_2\)  
(D) \(\text{CO}_2\)  
(E) \(\text{SO}_2\)

355. What is the difference between a 1.0 M solution of a weak acid and a 1.0 M solution of a strong acid? The weak acid

(A) is more dilute  
(B) does not turn litmus red  
(C) does not conduct electricity  
(D) has fewer hydronium ions per liter  
(E) has more metal ions per liter

368. In the reaction:

\(\text{NH}_3\text{(aq)} + \text{H}_2\text{PO}_4\text{-(aq)} \leftrightarrow \text{NH}_4\text{+(aq)} + \text{HPO}_4^{2-}\text{(aq)}\)

the dihydrogen phosphate ion, \(\text{H}_2\text{PO}_4^-\), acts as

(A) an acid  
(B) a base  
(C) a reducing agent  
(D) an oxidizing agent  
(E) a catalyst

374. Which statement accounts for the facts that:

I Hydrogen chloride in a nonpolar solvent does not conduct electricity.
II A water solution of hydrogen chloride, \(\text{HCl}\), is an excellent conductor of electricity.

(A) Water is an electrolyte  
(B) \text{Hydrogen chloride ionizes in water}  
(C) \text{Hydrogen chloride is a nonelectrolyte}  
(D) \text{Hydrogen chloride releases electrons in water solutions}  
(E) \text{Hydrogen chloride is an ionic substance}

386. The name of a water solution of hydrogen fluoride, \(\text{HF}(g)\), is

(A) \text{fluoric acid}  
(B) \text{fluorous acid}  
(C) \text{perfluoric acid}  
(D) \text{hydrofluoric acid}  
(E) \text{hypofluorous acid}

391. Base your answer to the following question on the data from the chart below.

<table>
<thead>
<tr>
<th>Acid</th>
<th>H+</th>
<th>Base</th>
<th>(K_a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{H}_2\text{SO}_4)</td>
<td>(\text{H}^+) + (\text{HSO}_4^-)</td>
<td>Very Large</td>
<td></td>
</tr>
<tr>
<td>(\text{H}_2\text{SO}_3)</td>
<td>(\text{H}^+) + (\text{HSO}_3^-)</td>
<td>(1.5 \times 10^{-2})</td>
<td></td>
</tr>
<tr>
<td>(\text{H}_2\text{O}_4^-)</td>
<td>(\text{H}^+) + (\text{SO}_4^{2-})</td>
<td>(1.2 \times 10^{-2})</td>
<td></td>
</tr>
<tr>
<td>(\text{H}_3\text{PO}_4)</td>
<td>(\text{H}^+) + (\text{H}_2\text{PO}_4^-)</td>
<td>(7.5 \times 10^{-3})</td>
<td></td>
</tr>
<tr>
<td>(\text{H}_2\text{CO}_3)</td>
<td>(\text{H}^+) + (\text{HCO}_3^-)</td>
<td>(4.3 \times 10^{-7})</td>
<td></td>
</tr>
<tr>
<td>(\text{H}_2\text{PO}_4^-)</td>
<td>(\text{H}^+) + (\text{HPO}_4^{2-})</td>
<td>(6.2 \times 10^{-8})</td>
<td></td>
</tr>
<tr>
<td>(\text{NH}_4^+)</td>
<td>(\text{H}^+) + (\text{NH}_3)</td>
<td>(5.7 \times 10^{-10})</td>
<td></td>
</tr>
</tbody>
</table>
| \(\text{HCO}_3^-\) | \(\text{H}^+\) + \(\text{CO}_3^{2-}\) | \(5.6 \times 10^{-11}\)

Which can never be an acid?

(A) \(\text{NH}_4^+\)  
(B) \(\text{HSO}_3^-\)  
(C) \(\text{SO}_4^{2-}\)  
(D) \(\text{H}_2\text{PO}_4\)  
(E) \(\text{H}_2\text{O}\)

398. Base your answer to the following question on the data from the chart below.

<table>
<thead>
<tr>
<th>Acid</th>
<th>H+</th>
<th>Base</th>
<th>(K_a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{H}_2\text{O}_4^+)</td>
<td>(\text{H}^+) + (\text{H}_2\text{O})</td>
<td>(1.0 \times 10^0)</td>
<td></td>
</tr>
<tr>
<td>(\text{HOOCOCOOH})</td>
<td>(\text{H}^+) + (\text{HOOCOCOO}^-)</td>
<td>(5.9 \times 10^{-2})</td>
<td></td>
</tr>
<tr>
<td>(\text{HNO}_2)</td>
<td>(\text{H}^+) + (\text{NO}_2^-)</td>
<td>(4.6 \times 10^{-4})</td>
<td></td>
</tr>
<tr>
<td>(\text{HOOCOCOO}^-)</td>
<td>(\text{H}^+) + (\text{OOCOCOO}^{2-})</td>
<td>(6.4 \times 10^{-5})</td>
<td></td>
</tr>
<tr>
<td>(\text{H}_2\text{S})</td>
<td>(\text{H}^+) + (\text{HS}^-)</td>
<td>(9.1 \times 10^{-8})</td>
<td></td>
</tr>
</tbody>
</table>
| \(\text{NH}_4^+\) | \(\text{H}^+\) + \(\text{NH}_3\) | \(5.7 \times 10^{-10}\)

Which can never be an acid?

(A) \(\text{HS}^-\)  
(B) \(\text{H}_2\text{O}\)  
(C) \(\text{NH}_3\)  
(D) \(\text{NO}_2^-\)  
(E) \(\text{HOOCOCOO}^-\)

402. What is the name of the 0.1 M aqueous acid solution made using \(\text{H}_2\text{S}\) as the solute?

(A) \text{salicylic acid}  
(B) \text{sulfuric acid}  
(C) \text{hydrogen sulfide}  
(D) \text{hydrosulfurous acid}  
(E) \text{hydrosulfuric acid}
III. REACTIONS

C. Bronsted-Lowry Theory

2. Acids and Bases

i. Acids

403. What is the name of the 1.0 M aqueous acid solution made using \( \text{H}_3\text{PO}_4 \) as the solute?
(A) phosphoric acid  
(B) phosporous acid  
(C) potassium hydroxide

404. What is the name of the 1.0 M aqueous acid solution made using \( \text{CH}_3\text{COOH} \) as the solute?
(A) ammonia  
(B) acetic acid  
(C) oxalic acid

405. What is the formula of the compound which is used as the solute to make the 1.0 M aqueous acid solution that is called chlorous acid?
(A) \( \text{HCl} \)  
(B) \( \text{HClO} \)  
(C) \( \text{HClO}_2 \)

406. What is the formula of the compound which is used as the solute to make the 0.1 M aqueous acid solution that is called carbonic acid?
(A) \( \text{H}_2\text{CO}_3 \)  
(B) \( \text{H}_2\text{CrO}_4 \)  
(C) \( \text{CH}_3\text{COOH} \)

463. Ninety (90.0) mL of distilled water is added to an Erlemeyer flask containing 10.0 mL of 0.095 M \( \text{HCl} \) solution. How many moles of \( \text{H}_3\text{O}^+ \) are present in the flask?
(A) 0.00  
(B) 0.095  
(C) 0.95

3227. Which equilibrium constant expressions represents the first ionization of \( \text{H}_3\text{PO}_4 \) in water?
(A) \[ \frac{[\text{H}_3\text{O}^+] [\text{H}_2\text{PO}_4^-]}{[\text{H}_3\text{PO}_4]} \]
(B) \[ \frac{[\text{H}_3\text{O}^+] [\text{HPO}_4^{2-}]}{[\text{H}_2\text{PO}_4^-]} \]
(C) \[ \frac{[\text{H}_3\text{O}^+] [\text{H}_2\text{PO}_4^-]}{[\text{H}_3\text{PO}_4]} \]
(D) \[ \frac{[\text{H}_3\text{O}^+] [\text{PO}_4^{3-}]}{[\text{HPO}_4^{2-}]} \]
(E) \[ \frac{[\text{H}_3\text{O}^+] [\text{H}_2\text{PO}_4^-]}{[\text{H}_2\text{PO}_4]} \]

3228. Which properties is an acid expected to have?
I electrical conductivity in water  
II increase hydroxide ion concentration  
III neutralize basic solutions  
IV have a pH greater than 7  
V ionize in water
(A) I, III and V only  
(B) I, III and IV only  
(C) II, III and V only  
(D) I, II, III, and V only  
(E) I, III, IV and V only

3229. When \( \text{NaHCO}_3(aq) \) reacts with \( \text{NH}_3(aq) \), the Brönsted–Lowry acid is
(A) \( \text{NH}_3 \)  
(B) \( \text{HCO}_3^- \)  
(C) \( \text{CO}_3^{2-} \)

3230. Water is a Brönsted–Lowry acid when reacting with
(A) \( \text{NH}_3 \)  
(B) \( \text{H}_2\text{S} \)  
(C) \( \text{HCN} \)

3232. Which two act as Brönsted–Lowry acids?
(A) \( \text{HCO}_3^- \) and \( \text{H}_2\text{CO}_3 \)  
(B) \( \text{H}_2\text{BO}_3^- \) and \( \text{H}_2\text{CO}_3 \)  
(C) \( \text{HCO}_3^- \) and \( \text{HBO}_3^{2-} \)
UNIT IV

STOICHIOMETRY
IV. STOICHIOMETRY

A. Mole Interpretation

1. The Mole Concept

792. A mole is
   (A) 22.4 L
   (B) \(6.02 \times 10^{23}\) particles
   (C) one molecule
   (D) one molar mass
   (E) 16 g of oxygen

793. The number of particles in a mole is
   (A) \(23 \times 10^6\)
   (B) \(2.06 \times 10^{23}\)
   (C) \(10 \times 6.02 \times 23\)
   (D) \(2.24 \times 10^{23}\)
   (E) \(6.02 \times 10^{23}\)

794. A mass of 5.58 g of iron consists of the same number of
   (A) 1.00 g of hydrogen
   (B) 20.0 g of calcium
   (C) \(20.7 \text{ g of lead}\)
   (D) 2.24 \(\times 10^{23}\)
   (E) \(6.02 \times 10^{23}\)

795. How many moles of atoms are in 1.0 mole of
   \(\text{Fe}_3(\text{FeCN}_6)_2\)?
   (A) 16
   (B) 17
   (C) 26
   (D) 29
   (E) 39

796. The total number of atoms represented by the
   formula \(\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}\) is
   (A) 15
   (B) 16
   (C) 27
   (D) 36
   (E) 38

797. How many atoms are in one molecule of
   sucrose, \(\text{C}_{12}\text{H}_{22}\text{O}_{11}\)?
   (A) 12
   (B) 34
   (C) 36
   (D) 45
   (E) 55

798. The number of molecules in 2.0 moles of carbon dioxide,
   \(\text{CO}_2\), is
   (A) \(1.8 \times 10^{24}\)
   (B) \(6.0 \times 10^{23}\)
   (C) \(1.2 \times 10^{24}\)
   (D) \(3.6 \times 10^{24}\)
   (E) \(4.48 \times 10^{24}\)

799. How many atoms are in the formula
   \(\text{Na}_2\text{S}_2\text{O}_3 \cdot 5\text{H}_2\text{O}\)?
   (A) 12
   (B) 18
   (C) 22
   (D) 29
   (E) 32

3063. What is the molar mass of elemental sulfur, \(\text{S}_8\)?
   (A) 16 g•mol\(^{-1}\)
   (B) \(32 \text{ g•mol}^{-1}\)
   (C) \(64 \text{ g•mol}^{-1}\)
   (D) \(128 \text{ g•mol}^{-1}\)
   (E) \(256 \text{ g•mol}^{-1}\)

3064. What is the molar mass of magnesium phosphate,
   \(\text{Mg}_3(\text{PO}_4)_2\)?
   (A) 59 g•mol\(^{-1}\)
   (B) \(119 \text{ g•mol}^{-1}\)
   (C) \(130 \text{ g•mol}^{-1}\)
   (D) \(238 \text{ g•mol}^{-1}\)
   (E) \(260 \text{ g•mol}^{-1}\)

3065. Which sample of nitrogen gas at STP occupies the largest
   volume?
   (A) 14 liters
   (B) \(14 \text{ moles}\)
   (C) 14 grams
   (D) \(1.4 \times 10^{24} \text{ molecules}\)
   (E) \(4.2 \times 10^{24} \text{ molecules}\)

800. How many atoms are represented in the formula \(\text{Mg(OH)}_2\)?
   (A) 6
   (B) 2
   (C) 3
   (D) 4
   (E) 5

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UNIT V

EQUILIBRIUM
AND KINETICS
Base your answers to questions 515 and 516 on the graph below which shows the number of molecules with a given kinetic energy plotted as a function of kinetic energy. Four catalysts are available, A, B, C and D, which have associated reaction activation energies $E_A$, $E_B$, $E_C$, and $E_D$ respectively.

515. Which catalyst has an activation energy which results in the shortest reaction time?
(A) Catalyst ‘A’ associated with energy $E_a$
(B) Catalyst ‘B’ associated with energy $E_b$
(C) Catalyst ‘C’ associated with energy $E_c$
(D) Catalyst ‘D’ associated with energy $E_d$
(E) It cannot be determined by the information given.

516. Which catalyst will have an activation energy which will result in the slowest reaction rate?
(A) Catalyst ‘A’ associated with energy $E_a$
(B) Catalyst ‘B’ associated with energy $E_b$
(C) Catalyst ‘C’ associated with energy $E_c$
(D) Catalyst ‘D’ associated with energy $E_d$
(E) It cannot be determined from the information given.

504. Why does a higher gaseous partial pressure increase the reaction rate?
(A) Increased activation energy
(B) Increased number of collisions
(C) Increased average kinetic energy
(D) Increased energy for effective collisions
(E) Increased product potential energy

522. Why does increased concentration increase reaction rate?
(A) Increased activation energy
(B) Increased number of collisions
(C) Increased average kinetic energy
(D) Increased energy for effective collisions
(E) Increased energy of reactants

3928. Given the equilibrium reaction $\text{N}_2 + 3 \text{H}_2 \leftrightarrow 2 \text{NH}_3 + 92.4 \text{kJ/mol}$, which of the following could increase the reverse reaction rate.
(A) increasing the $[\text{N}_2]$
(B) increasing the $[\text{H}_2]$
(C) increasing the $[\text{NH}_3]$
(D) decreasing the $[\text{NH}_3]$
(E) decreasing the temperature

3929. When a reactant is added to a reaction at equilibrium, the equilibrium shifts towards the product side. Which of the following best describes this phenomenon?
(A) Graham's law
(B) the second law of thermodynamics
(C) Gibb's free energy
(D) collision theory of reaction rates
(E) Boyle's law

3930. Given the reaction $\text{H}_2(g) + \text{I}_2(g) + \text{heat} \leftrightarrow 2 \text{HI}(g)$, what effect will increasing the pressure have?
(A) increase the $[\text{H}_2]$
(B) increase the $[\text{I}_2]$
(C) increase the $[\text{HI}]$
(D) decrease the $[\text{HI}]$
(E) none of the above
643. Which compound cannot be formed spontaneously from its elements at 298 K.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Enthalpy of Formation $\Delta H^\circ$ (kJ·mol$^{-1}$)</th>
<th>Free Energy Formation $\Delta G^\circ$ (kJ·mol$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen fluoride HF(g)</td>
<td>-271</td>
<td>-273</td>
</tr>
<tr>
<td>Iodine Chloride ICl(g)</td>
<td>18</td>
<td>-5</td>
</tr>
<tr>
<td>Nitrogen (IV) oxide NO$_2$ (g)</td>
<td>33</td>
<td>51</td>
</tr>
<tr>
<td>Water H$_2$O(g)</td>
<td>-242</td>
<td>-228</td>
</tr>
</tbody>
</table>

(A) A  (B) B  (C) C  (D) D  (E) Both A and B

671. List the compound which cannot be formed spontaneously from its elements at 298 K.

(A) nitrogen (IV) oxide  (B) sodium chloride  (C) sulfur dioxide  (D) water(g)  (E) both nitrogen (IV) oxide and water(g)

618. Four reactions are represented by the reaction diagrams shown at the same scale. Which exothermic reaction occurs most spontaneously?

(A)  (D)  (E)  (B)  (C)

627. The data represents the standard entropy and free energy of four compounds formed from their respective elements at 298 K and 1.0 atm pressure. For which of the four compounds will a temperature increase change the reaction from being nonspontaneous to spontaneous?

<table>
<thead>
<tr>
<th>Entropy of Formation $\Delta S^\circ$ J·mol$^{-1}$·K$^{-1}$</th>
<th>Free Energy of Formation $\Delta G^\circ$ (kJ·mol$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) 140</td>
<td>-100</td>
</tr>
<tr>
<td>(B) 90</td>
<td>70</td>
</tr>
<tr>
<td>(C) -80</td>
<td>50</td>
</tr>
<tr>
<td>(D) -200</td>
<td>-50</td>
</tr>
</tbody>
</table>

(A) A  (D) D  (B) B  (E) Both B and C  (C) C

631. Which decreases during all spontaneous chemical reactions at 25°C and 1.0 atm?

(A) $\Delta G^\circ$  (D) $T\Delta S^\circ$

(B) $\Delta S^\circ$  (E) $T\Delta H^\circ$

(C) $\Delta H^\circ$
3. Most student thermometers have an uncertainty of 0.2 Centigrade degrees. Which is the proper reading of the thermometer shown in the illustration?

(A) 16.0°C  (D) 16.45°C
(B) 16.4°C    (E) 16.405°C
(C) 16.40°C

6. Which measurement has the most uncertainty?
(A) 200 ± 1 g    (D) 2.00 ± 0.05 liter
(B) 1.0 ± 0.1 cm  (E) 500. ± 5 m
(C) 10.0 ± 0.1 mL

8. Which is the proper reading for the buret?

(A) 21.55 mL  (D) 22.45 mL
(B) 21.7 mL   (E) 22.60 mL
(C) 22.3 mL

12. Copper (II) bromide, CuBr₂, changes to copper (I) bromide, CuBr when heated.

\[ 2 \text{CuBr}_2(s) \rightarrow 2 \text{CuBr}(s) + \text{Br}_2(g) \]

Which set of masses could occur in this experiment?

<table>
<thead>
<tr>
<th>test tube</th>
<th>test tube + CuBr₂</th>
<th>test tube + CuBr</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) 20,000 g</td>
<td>18,300 g</td>
<td>18,906 g</td>
</tr>
<tr>
<td>(B) 20,000 g</td>
<td>20,705 g</td>
<td>19,548 g</td>
</tr>
<tr>
<td>(C) 20,000 g</td>
<td>21,636 g</td>
<td>22,105 g</td>
</tr>
<tr>
<td>(D) 20,000 g</td>
<td>23,295 g</td>
<td>22,117 g</td>
</tr>
</tbody>
</table>

(A) A  (D) D
(B) B   (E) None of the above
(C) C

3174. How many 100 mg tetracycline capsules can be made from 1 kg of tetracycline?
(A) 10  (D) 10,000
(B) 100  (E) 100,000
(C) 1,000

3175. An object having a mass of 16.85 grams is placed into a graduated cylinder containing water. The level of the water rose from 19.8 mL to 21.8 mL. Which density is expressed to the proper number of significant figures?
(A) 8 g•mL⁻¹  (D) 8.43 g•mL⁻¹
(B) 8.0 g•mL⁻¹  (E) 8.425 g•mL⁻¹
(C) 8.4 g•mL⁻¹

3176. Two samples are massed using different balances.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.529 g</td>
</tr>
<tr>
<td>2</td>
<td>0.40 g</td>
</tr>
</tbody>
</table>

What is the total mass of the samples to the correct number of significant digits?
(A) 4 g  (D) 3.929 g
(B) 3.9 g  (E) 3.92900 g
(C) 3.93 g

3173. An unknown mass of an element reacts completely with 1.811 g of sulfur and 3.613 g of oxygen to produce 7.124 g of a compound containing the element, S, and O. What additional information is required to determine the unknown mass?
(A) The formula of the product.
(B) The balanced reaction equation.
(C) The molar mass of the unknown element.
(D) The electron configuration of the unknown element.
(E) No additional information is needed.