This print-out should have 30 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

LDE Planck relation 003

001 5.0 points

If a photon's wavelength is 663 nm, what is its energy?

1. 4.40×10^{-37} J

2. 4.40×10^{-40} J

3. 3.00×10^{-22} J

4. 3.00×10^{-25} J

5. 3.00×10^{-19} J **correct**

6. 4.40×10^{-43} J

Explanation:

$\lambda = 663$ nm $\qquad c = 3 \times 10^8$ m/s

$h = 6.626 \times 10^{-34}$ J · s.

For a photon $c = \lambda\,\nu$, so

$$E = h\,\nu = \frac{h\,c}{\lambda}$$

where c is the speed of light and h is Planck's constant.

$$\begin{aligned} E &= \frac{h\,c}{\lambda} \\ &= \left(6.63 \times 10^{-34}\ \text{J} \cdot \text{s}\right)\left(3 \times 10^{8}\ \text{m/s}\right) \\ &\quad \times \left(\frac{1}{663\ \text{nm}}\right)\left(\frac{10^9\ \text{nm}}{1\ \text{m}}\right) \\ &= 3 \times 10^{-19}\ \text{J} \end{aligned}$$

Mlib 50 3003 alt

002 5.0 points

When a given molecule absorbs a photon of microwave radiation,

1. its begins to vibrate.

2. its begins to rotate. **correct**

3. it promotes electrons into delocalized bonding orbitals.

4. its electrons are excited to higher energy levels.

5. it leads to homolytic cleavage.

Explanation:

ChemPrin3e T01 27

003 5.0 points

Calculate the longest-wavelength line in the Balmer series for hydrogen.

1. 122 nm

2. 486 nm

3. 1875 nm

4. 657 nm **correct**

5. 182 nm

Explanation:

$$\begin{aligned} \nu &= \mathcal{R}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \\ &= (3.29 \times 10^{15}\ \text{Hz})\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \\ &= 4.56944 \times 10^{14}\ \text{Hz} \end{aligned}$$

$$\begin{aligned} \lambda &= \frac{c}{\nu} \\ &= \frac{3.0 \times 10^8\ \text{m/s}}{4.56944 \times 10^{14}\ \text{Hz}} \\ &= 6.56535 \times 10^{-7}\ \text{m} \\ &= 656.535\ \text{nm} \end{aligned}$$

ChemPrin3e T01 13

004 5.0 points

Calculate the velocity of an oxygen molecule if it has a de Broglie wavelength of 0.0140 nm.

1. 1780 m/s

2. 3×10^8 m/s

3. 8.9 m/s

4. 445 m/s

5. 891 m/s **correct**

Explanation:
$\lambda = 0.0140 \text{ nm} = 1.4 \times 10^{-11}$ m

$$\begin{aligned} \text{m} &= \frac{32 \text{ g/mol}}{6.022 \times 10^{23}} \\ &= 5.31385 \times 10^{-23} \text{ g} \\ &= 5.31385 \times 10^{-26} \text{ kg} \end{aligned}$$

$$\begin{aligned} \lambda &= \frac{h}{\text{m}\, v} \\ v &= \frac{h}{\text{m}\, \lambda} \\ &= \frac{6.626 \times 10^{-34} \text{ J} \cdot \text{s}}{5.31385 \times 10^{-26} \text{ kg}} \\ &\quad \times \frac{1}{1.4 \times 10^{-11} \text{ m}} \\ &= 890.665 \text{ m/s} \end{aligned}$$

LDE Uncertainty Calculation 006
005 5.0 points

Estimate the minimum uncertainty in the position of a hydrogen atom (of molecular weight 1 g/mol) that has an uncertainty of $2.0 \text{ mm} \cdot \text{s}^{-1}$?

1. 1.6×10^{-8} m

2. 1.6×10^{11} m

3. 8.7×10^{-58} m

4. 1.6×10^{-5} m **correct**

5. 1.6×10^{-28} m

Explanation:

$$\Delta x \cdot \Delta p \geq \frac{\hbar}{2}$$

$$\begin{aligned} \Delta p &= m \cdot \Delta v \\ \Delta x &\geq \frac{\hbar}{2 \cdot m \cdot \Delta v} \\ &\geq \frac{1.05 \times 10^{-34} \text{ J} \cdot \text{s}}{2(0.001/6.02 \times 10^{23})(0.002 \text{ m/s})} \\ &\geq 1.6 \times 10^{-5} \text{ m} \end{aligned}$$

LDE Particle in a Box Theory 002
006 5.0 points

Which of the following statements concerning particle in a box is/are true?

I) For a box of constant length L, the energy difference between $n = 1$ and $n = 2$ is greater than the energy difference between $n = 2$ and $n = 3$.

II) The wavelength λ is inversely proportional to the principle quantum number n.

III) The energy of the particle cannot be equal to zero.

1. II and III **correct**

2. I and III

3. I only

4. II only

5. I, II and III

6. I and II

7. III only

Explanation:
The energy of the particle in the box can never be zero; this is a consequence of the fact that it can never be stationary, and as a massive particle in motion, thus has to have some energy. The length of the box L and the principle energy level n determine the wavelength λ of the system, and because n can only have integer values, λ can only have certain discrete values, which are inversely proportional to n. The energy E of the particle is inversely proportional to L, and thus as L increases,

the different energy levels are closer to total degeneracy. As n increases, the distance between adjacent energy levels also increase; for example, $n = 2$ is more similar in energy E to $n = 1$ than to $n = 3$.

LDE Count Potential Energy Terms 002
007 5.0 points

How many repulsive $V(r)$ terms are found in the solution to the Schrödinger equation for a C^+ ion?

1. 7 $V(r)$ terms

2. 4 $V(r)$ terms

3. 5 $V(r)$ terms

4. 10 $V(r)$ terms **correct**

5. 15 $V(r)$ terms

6. 14 $V(r)$ terms

Explanation:

The C^+ ion has 5 electrons, let's call them a through e, and they repel each other in a pairwise manner;
a and b repel
a and c repel
a and d repel
a and e repel
b and c repel
etc...

The pattern that emerges for all atoms or monatomic ions is that the number of repulsive terms is the sum of all integers below the numbers of electrons. So, 5 electrons, would have 4+3+2+1 = 10 repulsive terms.

It is important to note that the problem is asking exclusively about repulsive terms, which is why 15 (the number of attractive and repulsive terms) is incorrect.

ChemPrin3e T01 32
008 5.0 points

Which set of quantum numbers could correspond to a $4f$ orbital?

1. $n = 4$, $\ell = 3$, $m_\ell = +4$

2. $n = 3$, $\ell = 2$, $m_\ell = 0$

3. $n = 4$, $\ell = 3$, $m_\ell = -3$ **correct**

4. $n = 3$, $\ell = 2$, $m_\ell = +1$

5. $n = 4$, $\ell = 4$, $m_\ell = +3$

Explanation:

A $4f$ orbital has $n = 4$, $\ell = 3$ and $m_\ell = -3, -2, -1, 0, +1, +2, +3$.

Brodbelt 50046
009 5.0 points

How many electrons can possess this set of quantum numbers: principal quantum number $n = 4$, angular quantum number $\ell = 2$?

1. 10 **correct**

2. 4

3. 8

4. 16

5. 0

6. 2

7. 18

8. 14

9. 6

10. 12

Explanation:

Use the rules for the quantum numbers:

If $n = 4$ and $\ell = 2$ (*i.e.*, $4d$), then $m_\ell = -2, -1, 0, +1, +2$ are permitted; there are five different orbitals and $m_s = \pm\frac{1}{2}$, each holding two electrons.

LDE p metal ions 001
010 5.0 points

Which of the following is the most stable configuration for the Bi^{4+} ion?

1. [Xe] $4f^{15}$ $5d^9$ $6s^2$
2. [Xe] $4f^{14}$ $6s^2$
3. [Xe] $4f^{15}$ $5d^6$ $6s^2$ $6p^3$
4. [Xe] $4f^{15}$ $5d^{10}$ $6s^1$ CORRECT
5. [Xe] $5d^9$ $6s^2$
6. [Xe] $6s^2$
7. [Xe] $5d^6$ $6s^2$ $6p^3$

Explanation:

Metals of the p block tend to forms cations by first losing their p ions and then finally their s ions. Their d electrons are actually an the energy level below their p and s electrons and are consequently vary hard to remove.

Electron Config 01
011 5.0 points

Which of the following ions or neutral atoms does NOT possess the electronic configuration [Ar] $4s^2 3d^2$?

1. Fe^{4+}

2. V^- **correct**

3. Ti

4. Ca^{2-}

5. H^{21-}

Explanation:

LDE filled and half filled 001
012 5.0 points

What is the electronic configuration of a cobalt ion(Co^{-2})?

1. [Ar] $4s^2\,3d^5\,4p^3$

2. [Ne] $4s^1\,4d^{10}$

3. [Ar] $4s^2\,3d^9$

4. [Ar] $4s^1\,4d^9$

5. [Ar] $4s^1\,3d^{10}$ **correct**

Explanation:

The enhanced stability afforded by a filled d subshell results in a single $4s$ electron being "borrowed" to fill cobalt's $3d$ subshell; therefore, (Co^{-2}) is [Ar] $4s^1\,3d^{10}$.

LDE Effective nuclear charge
013 5.0 points

Calculate the effective nuclear charge ($Z_{\rm eff}$) experienced by the $1s$ and $2s$ electrons of the Sulfur atom (S).

1. 16, 14 **correct**

2. 16, 10

3. 12, 6

4. 8, 7

5. 2, 0

6. 10, 16

Explanation:

The effective nuclear charge is equal to the number of protons minus the number of shielding electrons $Z_{\rm eff}$ = protons − shielding electrons. S has 16 protons and its $1s$ electrons are shielded by no electrons and have a $Z_{\rm eff} = 16 - 0 = 16$, while the $2s$ electrons are shielded only by the two $1s$ electrons, therefore they experience an effective nuclear charge, $Z_{\rm eff} = 16 - 2 = 14$.

ChemPrin3e 14 07 08 rev LDE
014 5.0 points

Which of the following atoms has the greatest electron affinity?

1. nitrogen

2. sulfur

3. fluorine **correct**

4. arsenic

5. sodium

6. iodine

Explanation:

Electron affinity is a measure of how readily a neutral atom will accept an electron to form a -1 ion. The higher the EA, the more readily this occurs. The GENERAL trend is EA will increase from left to right and from bottom to top; EA increases as you move up and to the right on the periodic table.

DAL 006 0006

015 5.0 points

Rank the following in terms of decreasing ionic radii.

1. $\mathrm{F^-, O^{2-}, N^{3-}, Na^+, Mg^{2+}}$

2. $\mathrm{Mg^{2+}, Na^+, F^-, O^{2-}, N^{3-}}$

3. $\mathrm{Na^+, Mg^{2+}, O^{2-}, N^{3-}, F^-}$

4. $\mathrm{Na^+, Mg^{2+}, N^{3-}, O^{2-}, F^-}$

5. $\mathrm{N^{3-}, O^{2-}, F^-, Na^+, Mg^{2+}}$ **correct**

Explanation:

We only consider ions that yield a Noble gas configuration ($\mathrm{Na^+}$, $\mathrm{Mg^{2+}}$, $\mathrm{O^{2-}}$, $\mathrm{N^{3-}}$, and $\mathrm{F^-}$). We are comparing ions with the same number of electrons: 10 total and 8 valence in this case. The number of protons in the ion is the biggest determinate of the size when electron number is constant.

	# e^-	val.	inner	prot.	eff. charge
$\mathrm{N^{3-}}$	10	8	2	7	+5
$\mathrm{O^{2-}}$	10	8	2	8	+6
$\mathrm{F^-}$	10	8	2	9	+7
$\mathrm{Na^+}$	10	8	2	11	+9
$\mathrm{Mg^{2+}}$	10	8	2	12	+10

The greater the effective nuclear charge, the stronger the attraction between the protons and the electrons, and thus the smaller the radii.

VDB First Ionization Energy 001

016 5.0 points

Which of the following groups of atoms is correctly arranged in order of decreasing first ionization energy?

1. Cd > Ag > Pd > Rh

2. Rh > Pd > Ag > Rh

3. Rh > Ag > Pd > Cd

4. Cd > Pd > Ag > Rh **correct**

Explanation:

Ionization energy increases as one moves from left to right on a given row and increases from bottom to top as one moves up a given family. In the case of Rh, Pd, Ag, and Cd, Pd has a higher ionization energy because removing an electron moves the electron configuration from the stable filled d configuration.

Electron Affinity

017 5.0 points

Rank C, N, O and F in terms of increasing electron affinity.

1. N < C < O < F **correct**

2. N < O < C < F

3. F < O < C < N

4. C < N < O < F

5. C < O < N < F

Explanation:

Msci 06 0323

018 5.0 points

The first ionization potential of the elements B, C, and N (atomic numbers 5, 6, and 7) steadily increases, but that of O is less than that of N. The best interpretation of the lower value for O is that

1. the electron removed from O corresponds to a different value of the quantum number ℓ than that of the electron removed from B, C, or N.

2. the electron removed from O is farther from the nucleus and therefore less tightly bound than that in N.

3. there is more shielding of the nuclear charge in O than in B, C, or N.

4. the ionization potential of N is a maximum and the values decrease steadily for the elements O, F, and Ne.

5. the half-filled set of p orbitals in N makes it more difficult to remove an electron from N than from O. **correct**

Explanation:

The ionization potential is a measure of the ease with which electrons are lost by an atom. The ionization potential increases from left to right across the table. The outer electronic configuration of N atom is $2s^2 2p^3$ (half-filled orbital), which gives it extra stability. This increases the amount of energy needed to remove the first electron from N as compared to O.

Mlib 07 0224
019 5.0 points

Which of the following is the best representation of the compound calcium fluoride?

1. Ca^{2+} , $\left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{F}}}:\right]^{2-}$

2. $2\,\mathrm{Ca}^{+}$, $\left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{F}}}:\right]^{2-}$

3. $3\,\mathrm{Ca}^{2+}$, $2\left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{F}}}:\right]^{3-}$

4. Ca^{+} , $\left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{F}}}:\right]^{-}$

5. None is appropriate because calcium fluoride is a covalent compound.

6. Ca^{2+} , $2\left[:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{F}}}:\right]^{-}$ **correct**

Explanation:

Lewis HCN dash
020 5.0 points

Which of the following is the correct Lewis formula for hydrogen cyanide (HCN)?

1. $:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{H}}}-\mathrm{C}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{N}}}:$

2. ${}^{\cdot\cdot}_{\cdot\cdot}\mathrm{H}=\mathrm{C}=\mathrm{N}^{\cdot\cdot}_{\cdot\cdot}$

3. $:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{H}}}-\overset{\cdot\cdot}{\mathrm{C}}=\mathrm{N}^{\cdot\cdot}_{\cdot\cdot}$

4. $:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{H}}}-\overset{\cdot\cdot}{\mathrm{C}}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{N}}}:$

5. $:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{H}}}-\mathrm{C}\equiv\mathrm{N}:$

6. $:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{H}}}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{C}}}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{N}}}:$

7. $\mathrm{H}-\mathrm{C}\equiv\mathrm{N}:$ **correct**

8. $:\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{H}}}-\overset{\cdot\cdot\;\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{C}}}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{N}}}:$

9. $\mathrm{H}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{C}}}-\mathrm{N}$

10. $\mathrm{H}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{C}}}-\overset{\cdot\cdot}{\underset{\cdot\cdot}{\mathrm{N}}}:$

Explanation:

The Lewis formula for hydrogen cyanide (HCN) is $\mathrm{H}-\mathrm{C}\equiv\mathrm{N}:$

ChemPrin3e 02 40
021 5.0 points

Assuming that all atoms obey the octet rule, how many Lewis structures contribute to the resonance hybrid of the guanidinium ion $\mathrm{C(NH_2)_3^+}$?

1. 6

2. 2

3. 5

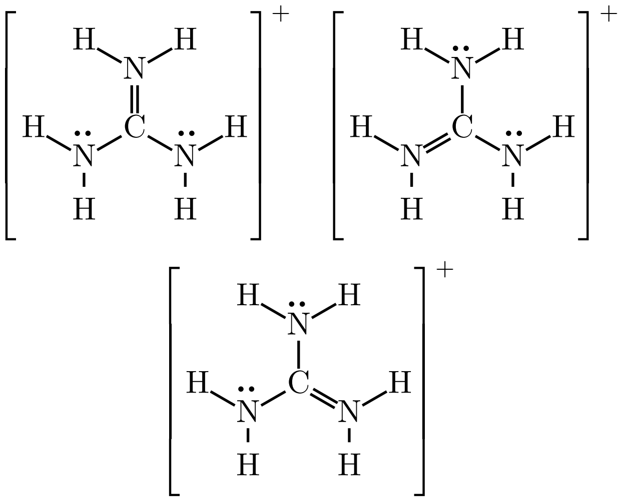
4. 1

5. 4

6. 3 **correct**

Explanation:

The resonant structures are



LDE Lewis Structures 011
022 5.0 points

In the Lewis structure for OCNH, how many total non-bonding electrons are in the molecule?

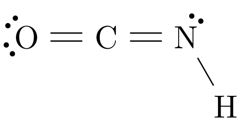
1. 8

2. 5

3. 6 **correct**

4. 3

Explanation:



ChemPrin3e T02 23
023 5.0 points

Draw the Lewis structure of xenon difluoride and give the number of lone pairs of electrons around the central atom.

1. 2

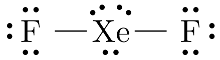
2. 1

3. 4

4. 3 **correct**

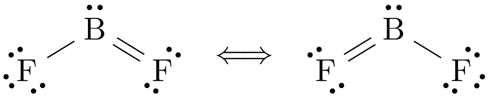
5. 5

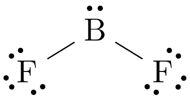
Explanation:

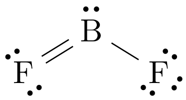
The Lewis structure is 

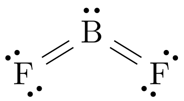
LDE Lewis Structures 009
024 5.0 points

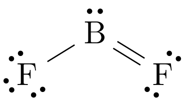
Which of the following is the correct Lewis structure of (BF_2^-)?

1. 

2.  **correct**

3. 

4. 

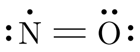
5. 

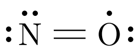
Explanation:

LDE Lewis Structures Exceptions 001
025 5.0 points

Which of the following is the correct Lewis structure of nitric oxide (NO)?

1. 
$:\dot{N}\equiv O:$

2.  **correct**
$:\dot{N}=\ddot{O}:$

3. 
$:\ddot{N}=\dot{O}:$

4. $:\!\mathrm{N}\equiv\dot{\mathrm{O}}\!:$

Explanation:

ChemPrin3e T02 07

026 5.0 points

Which of the following has the highest lattice energy?

1. KI

2. MgO **correct**

3. CaO

4. BaO

5. NaCl

Explanation:

Mg^{2+} and O^{2-} have the highest charge densities.

Msci 03 0914

027 5.0 points

What is the proper order of electronegativity?

1. Ca > Be > C > N

2. Ca > Be > N > C

3. Ca < Be < C < N **correct**

4. Ca < Be < N < C

5. Be > Ca < N < C

Explanation:

Electronegativity generally increases from left to right and from bottom to top of the Periodic Table.

ChemPrin3e T02 27

028 5.0 points

For dinitrogen monoxide, the arrangement of the atoms is N–N–O. In the Lewis structure using only double bonds, what are the formal charges on N, N, and O, in order from left to right?

1. 0, 0, 0

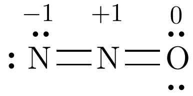
2. −2, +1, +1

3. 0, +1, −1

4. −1, +1, 0 **correct**

5. 0, −1, +1

Explanation:



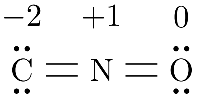
$$:\overset{-1}{\ddot{\mathrm{N}}}=\overset{+1}{\mathrm{N}}=\overset{0}{\underset{\cdot\cdot}{\ddot{\mathrm{O}}}}$$

ChemPrin3e 02 76

029 5.0 points

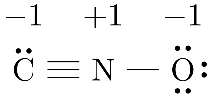
Which of the three Lewis structures is the most important for the fulminate ion (CNO^-)?

I)



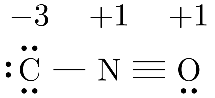
$$\overset{-2}{\underset{\cdot\cdot}{\ddot{\mathrm{C}}}}=\overset{+1}{\mathrm{N}}=\overset{0}{\underset{\cdot\cdot}{\ddot{\mathrm{O}}}}$$

II)



$$\overset{-1}{\ddot{\mathrm{C}}}\equiv\overset{+1}{\mathrm{N}}-\overset{-1}{\underset{\cdot\cdot}{\ddot{\mathrm{O}}}}\!:$$

III)



$$:\!\overset{-3}{\underset{\cdot\cdot}{\ddot{\mathrm{C}}}}-\overset{+1}{\mathrm{N}}\equiv\overset{+1}{\underset{\cdot\cdot}{\mathrm{O}}}$$

1. II and III only

2. III only

3. I only

4. II only **correct**

5. I and III only

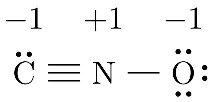
6. All of these are important.

7. I and II only

8. None of these is important.

Explanation:

The Lewis structure



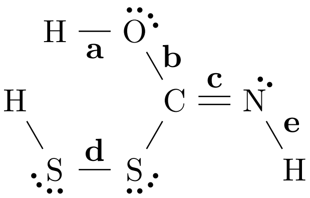
$\overset{-1}{\ddot{\mathrm{C}}} \equiv \overset{+1}{\mathrm{N}} - \overset{-1}{\mathrm{O}}$

is probably the most important as it is the structure with the formal charges of the individual atoms closest to zero.

LDE Identifying Bonds 005

030 5.0 points

Rank the labeled bonds in the molecule



from least to most polar.

1. c < d < e < a < b

2. d < c < e < b < a **correct**

3. d < c < b < e < a

4. c < e < b < a < c

5. c < d < e < b < a

Explanation:

Bonds a, b, c, d, and e have a ΔEN of 1.4, 1.0, 0.5, 0.0, and 0.9, respectively.

LAUDE - CH 301

51390

You may tear off this equation sheet and use it is a cover sheet and as scratch paper. Be sure to write your name on your exam and keep the hard copy. Turn in your scantron and any scratch paper when you are finished with the exam. You must be finished when time is called, so do not wait to bubble in your scantron - bubble in each response as you complete each problem.

Constants

$R = 0.082 L \cdot atm \cdot mol^{-1} \cdot K^{-1}$

standard molar volume = 22.4L

Equations

$$\text{bond order} = \frac{\text{bonding e}^- - \text{antibonding e}^-}{2}$$

$$P_1V_1 = P_2V_2$$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{P_1V_1}{T_1n_1} = \frac{P_2V_2}{T_2n_2}$$

$$MW = \frac{\rho RT}{P}$$

$$\frac{v_1}{v_2} = \frac{m_2}{m_1}^{1/2}$$

$$\left(P + \frac{n^2a}{V^2}\right)\left(V - nb\right) = nRT$$

This print-out should have 30 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

LDE Ranking Bonding Trends 006

001 5.0 points

The following molecules are composed of hydrogen(s) bound to another atom, X. Rank the H—X bonds by polarity, from least polar to most: BeH_2, CH_4, H_2O, HF.

1. $HF < BeH_2 < H_2O < CH_4$

2. $HF < CH_4 < H_2O < BeH_2$

3. $BeH_2 < HF < CH_4 < H_2O$

4. $CH_4 < BeH_2 < H_2O < HF$ **correct**

5. $H_2O < HF < BeH_2 < CH_4$

Explanation:

Note that all of the bonds within BeH_2, CH_4, H_2O are identical to each other and the fact that there are multiple bonds does not change the polarity of the individual bonds. The ΔEN for H—X bonds in BeH_2, CH_4, H_2O, HF are 0.7, 0.3, 1.3, 1.8, respectively. Arranged from least to greatest: $CH_4 < BeH_2 < H_2O < HF$.

Mlib 03 3013

002 5.0 points

Which molecule has a net dipole moment?

1. BF_3

2. $SiCl_4$

3. $AsFCl_4$ **correct**

4. NH_4^+

Explanation:

$AsFCl_4$ has an asymmetric distribution of electrons around the central atom, so it has a dipole moment.

LDE VSEPR Molecular Geometry 003

003 5.0 points

Consider molecules of the form AB_2U_x, where A is a central atom, B is a bonded atom, and U is an unbonded electron pair. What value of x describes a non-polar molecule that is not hypervalent?

1. 1

2. 3

3. 4

4. 0 **correct**

5. 2

Explanation:

Having 2 identical bonded atoms and 0 nonbonding electrons would correspond to linear molecular geometry and be non-polar. Having 1 or 2 non-bonding electron pairs would correspond to angular molecular geometry and be polar. Having 3 or 4 non-bonding electron pairs would be hypervalent.

Mlib 03 2089

004 5.0 points

Which of the following molecules is incorrectly matched with bond angles?

1. SF_6 : 90° and 180°

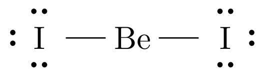
2. AsF_5 : 90°, 120°, and 180°

3. BeI_2 : slightly less than 109° **correct**

4. $SiCl_4$: 109.5°

5. BF_3 : 120°

Explanation:



$$:\overset{\cdot\cdot}{\underset{\cdot\cdot}{I}} — Be — \overset{\cdot\cdot}{\underset{\cdot\cdot}{I}}:$$

BeI_2 is a linear molecule with a 180° bond angle; Be is an exception to the octet rule.

LDE VB Hybridization 004
005 5.0 points

Which of the following statements concerning valence bond theory is/are true?

I) Hybridizing one $2s$ orbital with two $2p$ orbitals would produce three sp^2 orbitals.
II) When sp^3d^2 orbitals are created, three d orbitals remain empty.
III) An sp^3d hybrid orbital has 20% s-character.

1. II, III

2. II only

3. I, III

4. I, II, III **correct**

5. I only

6. I, II

7. III only

Explanation:
Statement I is true because hybridizing any number of atomic orbitals always results in an equal number of hybrid orbitals. Statement II is true because there are five d orbitals and using two of them for hybridization would leave three remaining empty. Statement III is true because an sp^3d hybrid orbital is made from 5 atomic orbitals, 1 of which was an s orbital - giving it 20% s-character.

ChemPrin3e T03 06
006 5.0 points

Predict the electron arrangement in ClF_3.

1. trigonal bipyramidal **correct**

2. pentagonal bipyramidal

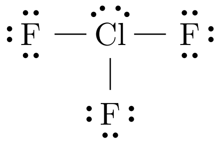
3. tetrahedral

4. linear

5. octahedral

6. trigonal planar

Explanation:
There are five regions of electron density (including two lone pairs) around the central atom:



Mlib 03 2097
007 5.0 points

Which one of the following is not an expected molecular structure of the indicated molecule?

1. SbH_3 : trigonal pyramidal

2. $PbCl_4$: tetrahedral

3. SO_3 : trigonal planar

4. XeF_4 : square planar

5. ICl_5 : trigonal bipyramidal **correct**

Explanation:
ICl_5 has HED = 6, the electronic geometry is octahedral, and the molecular geometry (structure) is square pyramidal.

LDE VB Sigma Pi Bonds 004
008 5.0 points

How many sigma (σ) and pi (π) bonds are in the Lewis structure for $C(COOH)_4$?

1. $8\ \sigma, 4\ \pi$

2. $12\ \sigma, 0\ \pi$

3. $16\ \sigma, 4\ \pi$ **correct**

4. $16\ \sigma, 0\ \pi$

5. $12\ \sigma, 4\ \pi$

Explanation:

LDE VB Sigma Pi Bonds 008

009 5.0 points

What best describes the bond in ClBr?

1. $\sigma_{sp^2,2p}$

2. $\pi_{3p,1s}$

3. $\pi_{3s,2s}$

4. $\sigma_{3s,2s}$ **correct**

5. $\pi_{sp^3,2p}$

6. $\sigma_{sp^2,1s}$

Explanation:
By drawing the Lewis structure of the described molecule, it is evident that neither atom is hybridized and the single bond between them must be a σ bond, which are formed exclusively by overlap of valence electrons from s orbitals. Chlorine has 2s valence electrons, and bromine has 3s valence electrons.

LDE MO Theory 001

010 5.0 points

Which of the following statements concerning molecular orbital theory is true?

I) Bonding orbitals are lower in energy than their corresponding anti-bonding orbitals.
II) If a molecule has an odd number of electrons, then it is paramagnetic.
III) The MO diagrams for O_2, F_2, Ne_2 are **not** filled using the Aufbau principle.

1. I, III

2. II, III

3. I only

4. III only

5. I, II **correct**

6. I, II, III

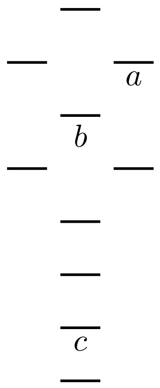
7. II only

Explanation:
Statement III is false, because molecular orbitals are filled from lowest to highest energy according to the aufbau principle just like atomic orbitals.

LDE MO Diagram 002

011 5.0 points

Consider the following molecular orbital diagram:



What are the names of the labeled orbitals, a through c, respectively?

1. $\sigma_{2p}, \pi_{2p}, \sigma_{2s}$

2. $\pi_{2p}, \sigma_{2p}, \sigma^*_{1s}$

3. $\pi^*_{2p}, \sigma_{2p}, \sigma^*_{1s}$ **correct**

4. $\pi_{2p}, \sigma_{2p}, \sigma_{2s}$

5. $\sigma^*_{2p}, \pi_{2p}, \sigma_{1s}$

Explanation:

LDE Bond Order 007

012 5.0 points

All of the species below have the same bond order except for one of them. Which is it?

1. H_2^-

2. B_2^- **correct**

3. Ne_2^+

4. H_2^+

5. F_2^-

Explanation:
All of the species have a bond order of 0.5 except for B_2^-, which has a bond order of 1.5.

LDE Paramagnetism 005
013 5.0 points

Which of the following species is paramagnetic?

1. Be_2^{2-} **correct**

2. N_2

3. C_2^{2-}

4. He_2

Explanation:
The species Be_2^{2-} will have two unpaired electrons in degenerate π bonding orbitals.

LDE Ranking Bonding Trends 010
014 5.0 points

Using molecular orbital theory, rank the following species by bond length, from shortest to longest: O_2, B_2^+, N_2, and F_2.

1. $F_2 < O_2 < B_2^+ < N_2$

2. $N_2 < B_2^+ < O_2 < F_2$

3. $F_2 < N_2 < O_2 < B_2^+$

4. $N_2 < O_2 < F_2 < B_2^+$ **correct**

5. $B_2^+ < O_2 < F_2 < N_2$

Explanation:
Bond order is inversely proportional to bond length, and the bond order for the species O_2, B_2^+, N_2, and F_2 are 2, 0.5, 3 and 1, respectively.

LDE Delocalization 003
015 5.0 points

Choose the species below that has the greatest number of delocalized electrons.

1. ${CO_3}^{2-}$

2. C_6H_6 (benzene) **correct**

3. ${NO_3}^-$

4. O_3

5. ${PO_4}^{3-}$

Explanation:
Benzene has 3 pairs of delocalized electrons. All of the other answer choices have one pair of delocalized electrons.

Mlib 04 1181
016 5.0 points

Which of the following laws cannot be derived directly from the ideal gas law $P\,V = n\,R\,T$?

1. Charles' Law

2. Dalton's Law

3. Graham's law **correct**

4. Avogadro's Law

5. Boyle's Law

Explanation:

$$P\,V = n\,R\,T$$
$$\frac{P_1\,V_1}{P_2\,V_2} = \frac{n_1\,R\,T_1}{n_2\,R\,T_2}$$
$$\frac{P_1\,V_1}{P_2\,V_2} = \frac{n_1\,T_1}{n_2\,T_2}$$

can be used to derive the following equations:
Boyle's Law: $P_1\,V_1 = P_2\,V_2$, when n and T are constants.
Charles' Law: $\dfrac{V_1}{T_1} = \dfrac{V_2}{T_2}$, when P and n are constants.

Avagadro's Law: $\frac{V_1}{n_1} = \frac{V_2}{n_2}$, when T and P are constants.

Dalton's Law: $n_A + n_B + n_C + \cdots = n_{total}$

Therefore, if $P_{total} = \frac{n_{total}\, R\, T}{V}$, we have

$$\begin{aligned} P_{total} &= \frac{n_A\, R\, T}{V} + \frac{n_B\, R\, T}{V} + \frac{n_C\, R\, T}{V} \\ &= P_A + P_B + P_C + \cdots \end{aligned}$$

at constant V and T.

Gases Change 01 W

017 5.0 points

A mole of methane gas is in a sealed container. The temperature is raised from 273 K to 500 K and the pressure changes from 1.00 atm to 4.00 atm. Calculate the final volume of the gas.

1. 3.10 L

2. 164.1 L

3. 10.3 L **correct**

4. 20.6 L

Explanation:

ChemPrin3e T04 25

018 5.0 points

If 250 mL of a gas at STP weighs 2 g, what is the molar mass of the gas?

1. $28.0\ \text{g} \cdot \text{mol}^{-1}$

2. $44.8\ \text{g} \cdot \text{mol}^{-1}$

3. $179\ \text{g} \cdot \text{mol}^{-1}$ **correct**

4. $8.00\ \text{g} \cdot \text{mol}^{-1}$

5. $56.0\ \text{g} \cdot \text{mol}^{-1}$

Explanation:

$V = 250$ mL $\quad P = 1$ atm

$T = 0°\text{C} = 273.15$ K $\quad m = 2$ g

The density of the sample is

$$\rho = \frac{m}{V} = \frac{2\ \text{g}}{0.25\ \text{L}} = 8\ \text{g/L}$$

The ideal gas law is

$$\begin{aligned} P\, V &= n\, R\, T \\ \frac{n}{V} &= \frac{P}{R\, T} \end{aligned}$$

with unit of measure mol/L on each side. Multiplying each by molar mass (MM) gives

$$\frac{n}{V} \cdot \text{MM} = \frac{P}{R\, T} \cdot \text{MM} = \rho\,,$$

with units of g/L.

$$\begin{aligned} \text{MM} &= \frac{\rho\, R\, T}{P} \\ &= \frac{(8\ \text{g/L})(0.08206\ \text{L} \cdot \text{atm/mol/K})}{1\ \text{atm}} \\ &\quad \times (273.15\ \text{K}) \\ &= 179.318\ \text{g/mol} \end{aligned}$$

Brad C12 006

019 5.0 points

If sufficient acid is used to react completely with 21.0 grams of Mg

$$\text{Mg(s)} + 2\,\text{HCl(aq)} \rightarrow \text{MgCl}_2\text{(aq)} + \text{H}_2\text{(g)}$$

what volume of hydrogen at STP would be produced?

1. 22.40 liters

2. 10.60 liters

3. 19.37 liters **correct**

4. 4.84 liters

5. 9.68 liters

Explanation:

$\text{mass}_{\text{ini}} = 21$ g Mg

Four quantities are required to describe the behavior of gases: P (pressure), V (volume), T (temperature in Kelvin), and n (quantity in moles). Thus to know the volume of H_2 produced, we need to know P, T, and n.

Fortunately, we know that the hydrogen is produced at STP. STP implies standard temperature (1 atm or 760 torr) and temperature (0°C or 273.15 K). Thus, to know the volume of gas produced, we need to find n, the number of moles of gas produced.

Mg is the limiting reactant in the equation described, and so we can determine the number of moles of H_2 produced in the reaction:

$$\begin{aligned}\text{mol H}_2 &= 21.0\text{ g Mg}\left(\frac{1\text{ mol Mg}}{24.305\text{ g Mg}}\right)\\ &\quad\times\left(\frac{1\text{ mol H}_2}{1\text{ mol Mg}}\right)\\ &= 0.804\text{ mol H}_2\end{aligned}$$

We can then use the ideal gas law

$$P\,V = n\,R\,T$$

to determine the volume of H_2 gas produced:

$$\begin{aligned}V &= \frac{n\,R\,T}{P}\\ &= \frac{(0.864\text{ mol})\left(\frac{0.08206\text{ L}\cdot\text{atm}}{\text{K}\cdot\text{mol}}\right)}{1\text{ atm}}\\ &\quad\cdot(273.15\text{ K})\\ &= 19.367\text{ L}\end{aligned}$$

LDE Kinetic Theory 002
020 5.0 points

At any given temperature, how much more quickly will H_2 diffuse than N_2?

1. .07 times more quickly

2. 0.3 times more quickly

3. 3.7 times more quickly **correct**

4. 14 times more quickly

5. they will diffuse at the same rate

Explanation:

$$m_1 v_1^2 = m_2 v_2^2$$

$$\frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{28}{2}} = 3.7$$

ChemPrin3e 04 104
021 5.0 points

You were given the values 0.2107, 2.253, 3.392, and 17.58 as the van der Waals parameter a for the gases CO_2, CH_3CN, Ne, and CH_4 but NOT the correspondence of the values to the compounds. What a value shoud be assigned to Ne?

1. Unable to determine

2. 3.392 $\text{L}^2\cdot\text{atm/mol}$

3. 0.2107 $\text{L}^2\cdot\text{atm/mol}$ **correct**

4. 2.253 $\text{L}^2\cdot\text{atm/mol}$

5. 17.58 $\text{L}^2\cdot\text{atm/mol}$

Explanation:

Since the van der Waals parameter a represents the role of attractions, it will become larger as the strength of the intermolecular attractions increases.

Acetonitrile is polar and would be expected to have the strongest intermolecular forces and the highest value of a.

The three non-polar species can be ranked in order of the polarizability of their electron clouds. Carbon dioxide has the largest, most polarizable electron cloud, so it should have the strongest London dispersion forces of these three species and the highest value of a after acetonitrile. Methane would be next, while neon would exhibit the weakest London dispersion forces and the lowest value of a.

We can check this reasoning by first noting that acetonitrile is the only substance that is a liquid at room temperature. In fact, the normal boiling points of these chemical substances, as given in the third column of the table, fall in the same order as their van der Waals a parameters.

a	Substance	B.P. (°C)
17.58	CH_3CN	81.6
3.392	CO_2	−78.5 (subl.)
2.253	CH_4	−164.76
0.2107	Ne	−246.048

LDE Gas Non-ideality 002
022 5.0 points

Which of the following does **not** affect the ideality of gases?

I) the temperature of the gas
II) the density of the gas
III) the size of the gas molecules

1. I and III

2. III only

3. II only

4. I only

5. I, II, and III

6. I and II

7. II and III

8. none of the above **correct**

Explanation:
All of the listed factors influence gas ideality.

Holt da 6 rev 50
023 5.0 points

Arrange the following pairs from strongest to weakest attraction:

a) polar molecule and polar molecule
b) nonpolar molecule and nonpolar molecule
c) polar molecule and ion
d) ion and ion

1. a, b, c, d.

2. d, c, a, b. **correct**

3. b, a, c, d.

4. d, a, c, b.

5. None of these

6. c, d, a, b.

7. b, c, a, d.

8. b, a, d, c.

9. d, c, b, a.

Explanation:
order of molecule pairs = ?
The stronger the electric charge for each molecule, the stronger the attractive force on another molecule. Ions have the greatest electrical charge, followed by polar molecules. Nonpolar molecules exert the weakest forces. The order of the molecule pairs from strongest attraction to weakest is therefore
d, c, a, b.

ChemPrin3e 05 08
024 5.0 points

Which of the following molecules
A) CH_3OCH_3 C) CH_3COOH
B) CH_3CH_2OH D) CH_3CHO
are likely to form hydrogen bonds?

1. C and D only

2. B and C only **correct**

3. A and B only

4. All are likely to form hydrogen bonds.

5. A and D only

6. A and C only

7. None forms hydrogen bonds.

8. B and D only

9. Another combination of compounds

Explanation:
Only molecules with H attached to the elec-

tronegative atoms N, O, and F can hydrogen bond. Of the molecules given, only CH_3COOH and CH_3CH_2OH have hydrogen attached to oxygen, so these are the only ones that can undergo hydrogen bonding.

ChemPrin3e T05 20

025 5.0 points

What are all of the intermolecular forces that are responsible for the existence of ice?

1. hydrogen bonding and dipole-dipole

2. London forces

3. dipole-dipole, London forces, and hydrogen bonding **correct**

4. dipole-dipole and ion-ion

5. dipole-dipole and London forces

Explanation:
Ice is solid H_2O. This molecule exhibits dispersion. Because it is polar it also exhibits dipole-dipole interactions. Finally because of the H bonded to the electronegative O atom it also exhibits hydrogen bonding; this polar bond can orient and interact with the lone pair of an O atom on another H_2O molecule.

Mlib 04 2045

026 5.0 points

Surface tension describes

1. capillary action.

2. the resistance to flow of a liquid.

3. the inward forces that must be overcome in order to expand the surface area of a liquid. **correct**

4. the forces of attraction between surface molecules of a solvent and the solute molecules.

5. the forces of attraction between the surface of a liquid and the air above it.

6. adhesive forces between molecules.

Explanation:
Molecules in the interior of a liquid interact with molecules all around them, whereas molecules at the *surface* of a liquid can only be affected by those beneath the surface layer. This phenomenon leads to a net inward force of attraction on the surface molecules, contracting the surface and making the liquid behave as though it had a skin. Surface tension is a measure of the inward forces that must be overcome to expand the surface area of a liquid.

Sparks viscosity 010

027 5.0 points

Which would you expect to be most viscous?

1. C_8H_{18} at 50°C

2. C_8H_{18} at 30°C **correct**

3. C_4H_8 at 50°C

4. C_4H_8 at 30°C

Explanation:

VP IMF Ranking

028 5.0 points

Rank the compounds
CH_3CH_2OH CH_3NH_2 CH_3OH NaOH
in terms of increasing vapor pressure.

1. NaOH < CH_3OH < CH_3NH_2 < CH_3CH_2OH

2. CH_3CH_2OH < CH_3OH < CH_3NH_2 < NaOH

3. NaOH < CH_3NH_2 < CH_3OH < CH_3CH_2OH

4. NaOH < CH_3CH_2OH < CH_3OH < CH_3NH_2 **correct**

5. $CH_3NH_2 < CH_3OH < CH_3CH_2OH < NaOH$

Explanation:

STIER 305 S09 E021
029 5.0 points

Put the following compounds

LiF, HF, F_2, NF_3

in order of increasing melting points.

1. F_2, HF, NF_3, LiF

2. NF_3, HF, F_2, LiF

3. F_2, NF_3, HF, LiF **correct**

4. NF_3, F_2, HF, LiF

5. LiF, HF, NF_3, F_2

6. LiF, NF_3, HF, F_2

7. LiF, HF, F_2, NF_3

8. LiF, F_2, HF, NF_3

Explanation:

LDE Solid Type 001
030 5.0 points

Which of the following is not a covalent network solid?

1. cellulose

2. diamond

3. glass

4. table sugar **correct**

5. graphite

6. starch

Explanation:
Table sugar is a molecular covalent solid. The other choices are all covalent network solids.

This print-out should have 30 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

First Law Thermo 01
001 5.0 points

What is true about the first law of thermodynamics?

1. $\Delta E_{\text{univ}} = 0$ **correct**

2. $\Delta E_{\text{sys}} > 0$

3. $\Delta E_{\text{sys}} < 0$

4. $\Delta E_{\text{sys}} = 0$

5. $\Delta E_{\text{univ}} < 0$

6. $\Delta E_{\text{univ}} > 0$

Explanation:

Msci 15 0514
002 5.0 points

Which statement is FALSE?

1. ΔH is sometimes exactly equal to ΔE.

2. ΔH is often nearly equal to ΔE.

3. No work is done in a reaction occurring in a bomb calorimeter.

4. The thermodynamic quantity most easily measured in a coffee cup calorimeter is ΔH.

5. ΔH is equal to ΔE for the process $2\,H_2(g) + O_2(g) \to 2\,H_2O(g)$. **correct**

Explanation:

For

$$2\,H_2(g) + O_2(g) \to 2\,H_2O(g)\,,$$

$n_i = 3$ mol gas $n_f = 2$ mol gas
$\Delta n = -1$ mol gas

$$w = -P\,\Delta V = -(\Delta n)\,R\,T \neq 0\,,$$

Since $\Delta E = q + w,\ q = \Delta H$ and $w \neq 0$,

$$\Delta E \neq \Delta H\,.$$

ChemPrin3e T07 68
003 5.0 points

The sublimation of solid carbon dioxide is a spontaneous process. Predict the sign (+, −, or 0) of ΔG°_r, ΔH°_r, and ΔS°_r, respectively.

1. −, 0, +

2. −, +, + **correct**

3. −, −, −

4. −, +, −

5. 0, +, +

Explanation:

ΔG is negative for a spontaneous reaction. Sublimation requires energy to facilitate the solid becoming a gas, so the process is endothermic (ΔH is positive). Finally, the entropy of a gas is more than that of a solid, so disorder increases (ΔS is positive).

LDE Definitions in Thermo 002
004 5.0 points

Which of the following quantities is **not** path independent?

1. enthalpy (H)

2. pressure (P)

3. volume (V)

4. entropy (S)

5. heat (q) **correct**

Explanation:

Heat quantitatively describes a transition **between** states, but not a state itself, and is thus a process quantity (path function), not a state function.

LDE Definitions in Thermo 013

005 5.0 points

Which of the reactions below is a formation reaction?

1. $N_2(\ell) + 2H_2(g) \rightarrow N_2H_4(\ell)$

2. $H_2(g) + C_{\text{graphite}}(s) + \frac{3}{2}O_2(g) \rightarrow CO_2(g) + H_2O(g)$

3. $2H_2(g) + 2C_{\text{graphite}}(s) + O_2(g) \rightarrow 2CH_2O(\ell)$

4. $2Fe(s) + \frac{3}{2}O_2(g) \rightarrow Fe_2O_3(s)$ **correct**

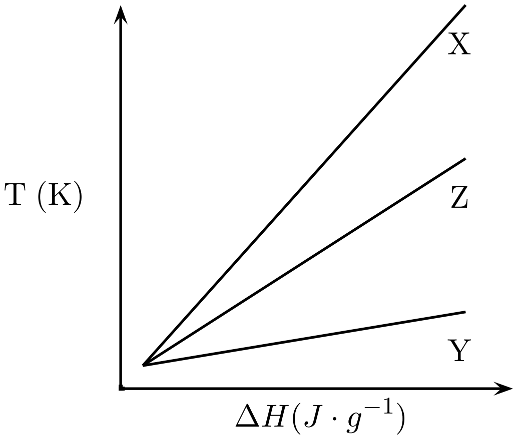
Explanation:

A formation reaction produces exactly one mole of one product from elements in their standard states.

LDE Definitions in Thermo 015

006 5.0 points

Consider the plot below. Which of the answer choices is a true statement?



1. This plot does not provide information about specific heat capacity.

2. Substance Y has the highest specific heat capacity. **correct**

3. The heat capacities of substance X, Y and Z are equal.

4. Substance Z has the highest specific heat capacity.

5. Substance X has the lowest specific heat capacity.

Explanation:

Because substance Y has the smallest change in temperature for a given change in enthalpy, it must have the highest specific heat capacity. In other words, substance Y requires the greatest amount of heat to affect its temperature.

LDE Bomb Calorimeter 001

007 5.0 points

1.14 g of octane (C_8H_{18}) is combusted in a bomb calorimeter surrounded by 1 L of water. The initial and final temperatures of the water are 25°C and 38°C, respectively. Find the molar enthalpy of combustion of octane. Assume that the calorimeter itself absorbs no heat, the density of water is $1.00 \text{ g} \cdot \text{mL}^{-1}$, and the specific heat capacity of water is $4.184 \text{ J} \cdot \text{g}^{-1} \cdot \text{K}^{-1}$.

1. $-5.44 \text{ kJ} \cdot \text{mol}^{-1}$

2. $-54,400 \text{ kJ} \cdot \text{mol}^{-1}$

3. $-54.4 \text{ kJ} \cdot \text{mol}^{-1}$

4. $-544 \text{ kJ} \cdot \text{mol}^{-1}$

5. $-5,440 \text{ kJ} \cdot \text{mol}^{-1}$ **correct**

Explanation:

$$\begin{aligned}\Delta T &= T_f - T_i = 38^\circ\text{C} - 25^\circ\text{C} \\ &= 13^\circ\text{C} = 12.98 \text{ K}\end{aligned}$$

$$m = (1 \text{ L}) \cdot \frac{1000 \text{ mL}}{\text{L}} \cdot \frac{1.00 \text{ g}}{\text{mL}} = 1000 \text{ g}$$

$$n = (1.14 \text{ g octane}) \cdot \frac{114 \text{ g}}{\text{mol}} = 0.01 \text{ mol}$$

$$\begin{aligned}\Delta H_{\text{rxn}} &= -\Delta H_{\text{cal}} = -m\,c\,\Delta T \\ \frac{-m\,c\,\Delta T}{n} &= -\frac{1000 \text{ g} \cdot \frac{4.184 \text{ J}}{\text{g}\cdot\text{K}} \cdot 13 \text{ K}}{0.01 \text{ mol}} \\ &= -5,440 \text{ kJ} \cdot \text{mol}^{-1}\end{aligned}$$

LDE Hess' Law 008

008 5.0 points

Calculate $\Delta H^\circ_{\text{rxn}}$ for the reaction

$$3\,H_2O_2(\ell) + 2\,PCl_3(\ell) \longrightarrow 2\,PH_3(g) + 6\,ClO(g)$$

species	ΔH°_f
$H_2O_2(\ell)$	$-187.78\ \text{kJ}\cdot\text{mol}^{-1}$
$PCl_3(\ell)$	$-320.00\ \text{kJ}\cdot\text{mol}^{-1}$
$PH_3(g)$	$5.47\ \text{kJ}\cdot\text{mol}^{-1}$
$ClO(g)$	$101.22\ \text{kJ}\cdot\text{mol}^{-1}$

1. $-401.09\ \text{kJ}\cdot\text{mol}^{-1}$

2. $614.47\ \text{kJ}\cdot\text{mol}^{-1}$

3. $-1821.6\ \text{kJ}\cdot\text{mol}^{-1}$

4. $401.09\ \text{kJ}\cdot\text{mol}^{-1}$

5. $-614.47\ \text{kJ}\cdot\text{mol}^{-1}$

6. $1821.6\ \text{kJ}\cdot\text{mol}^{-1}$ **correct**

Explanation:

$$\begin{aligned}\Delta H^\circ_{\text{rxn}} &= \sum \Delta H^\circ_{\text{f, products}} - \sum \Delta H^\circ_{\text{f, reactants}}\\ &= [6(101.22) + 2(5.47)]\\ &\quad - [3(-187.78) + 2(-320.00)]\\ &= 1821.6\ \text{kJ}\cdot\text{mol}^{-1}\end{aligned}$$

ChemPrin3e 06 60

009 5.0 points

Calculate the reaction enthalpy for the formation

$$2\,Al(s) + 3\,Cl_2(g) \longrightarrow 2\,AlCl_3(s)\,,$$

of anhydrous aluminum chloride using the data

$2\,Al(s) + 6\,HCl(aq) \longrightarrow 2\,AlCl_3(aq) + 3\,H_2(g)$ $\Delta H^\circ = -1049$ kJ

$HCl(g) \longrightarrow HCl(aq)$ $\Delta H^\circ = -74.8$ kJ

$H_2(g) + Cl_2(g) \longrightarrow 2\,HCl(g)$ $\Delta H^\circ = -185$ kJ

$AlCl_3(s) \longrightarrow AlCl_3(aq)$ $\Delta H^\circ = -323$ kJ

1. -1406.8 kJ **correct**

2. -1502.4 kJ

3. -1826.2 kJ

4. -1450.85 kJ

5. -1100.36 kJ

6. -1883.5 kJ

7. -1225.7 kJ

Explanation:

Using Hess' Law:

The desired reaction is obtained by adding reaction 1; 6 times reaction 2; 3 times reaction 3; and 2 times the reverse of reaction 4:

$$\begin{aligned}&2\,Al(s) + 6\,HCl(aq) \longrightarrow 2\,AlCl_3(aq) + 3\,H_2(g) && \Delta H^\circ = -1049\ \text{kJ}\\ &6\,HCl(g) \longrightarrow 6\,HCl(aq) && \Delta H^\circ = 6\,(-74.8\ \text{kJ}) = -448.8\ \text{kJ}\\ &3\,H_2(g) + 3\,Cl_2(g) \longrightarrow 6\,HCl(g) && \Delta H^\circ = 3\,(-185\ \text{kJ}) = -555\ \text{kJ}\\ &2\,AlCl_3(aq) \longrightarrow 2\,AlCl_3(s) && \Delta H^\circ = 2\,(323\ \text{kJ}) = 646\ \text{kJ}\\ \hline &2\,Al(s) + 3\,Cl_2(g) \longrightarrow 2\,AlCl_3(s) && \Delta H^\circ = -1406.8\ \text{kJ}\end{aligned}$$

LDE Stat Thermo Energy 003

010 5.0 points

What is the internal energy associated with the translation of 5 methane molecules?

1. $\dfrac{45}{2}$ RT

2. $\dfrac{15}{2}$ kT **correct**

3. $\dfrac{15}{2}$ RT

4. 15 kT

5. $\frac{45}{2}$ kT

Explanation:

Five molecules times $\frac{3}{2}$ kT total translational energy per molecule is $\frac{15}{2}$ kT.

LDE Bond Enthalpy 003
011 5.0 points

Using bond enthalpy data, calculate the change in enthalpy for the following reaction.

$$CH_4(g) + 2\,O_2(g) \longrightarrow CO_2(g) + 2\,H_2O(g)$$

bond	Bond enthalpy
C—H	$412\ kJ \cdot mol^{-1}$
O═O	$496\ kJ \cdot mol^{-1}$
C═O	$743\ kJ \cdot mol^{-1}$
O—H	$463\ kJ \cdot mol^{-1}$

1. $698\ kJ \cdot mol^{-1}$

2. $-1420\ kJ \cdot mol^{-1}$

3. $203\ kJ \cdot mol^{-1}$

4. $-698\ kJ \cdot mol^{-1}$ **correct**

5. $1420\ kJ \cdot mol^{-1}$

6. $-203\ kJ \cdot mol^{-1}$

Explanation:

ΔH_{rxn}

$$\begin{aligned} &= \sum BE_{reactants} - \sum BE_{products} \\ &= \Big[(4(412\ kJ \cdot mol^{-1}) + 2(496\ kJ \cdot mol^{-1})\Big] \\ &\quad - \Big[2(743\ kJ \cdot mol^{-1}) + 4(463\ kJ \cdot mol^{-1})\Big] \\ &= -698\ kJ \cdot mol^{-1} \end{aligned}$$

LDE Thermodynamic Work 0034
012 5.0 points

For which of the following reactions at room temperature (25°C) would there be 5.0 kJ of work done on the system?

1. $N_2H_2(g) + CH_3OH(g) \rightarrow CH_2O(g) + N_2(g) + 2\,H_2(g)$

2. $2\,H_2O_2(\ell) \rightarrow 2\,H_2O(\ell) + O_2(g)$

3. $CO_2(g) + 2\,H_2O(g) \rightarrow CH_4(g) + 2\,O_2(g)$

4. $2\,H_2O(\ell) + O_2(g) \rightarrow 2\,H_2O_2(\ell)$

5. $CH_2O(g) + N_2(g) + 2\,H_2(g) \rightarrow N_2H_2(g) + CH_3OH(g)$ **correct**

6. $CH_4(g) + 2\,O_2(g) \rightarrow CO_2(g) + 2\,H_2O(g)$

Explanation:

At room temperature (298 K), the product of the gas constant ($R = 8.314\ J \cdot mol^{-1} \cdot K^{-1}$) and T is very close to $2.5\ kJ \cdot mol^{-1}$. Based on $5.0\ kJ = -\Delta n_{gas}\left(2.5\ kJ \cdot mol^{-1}\right)$, the reaction for which $\Delta n_{gas} = -2$ will be the correct answer.

LDE Definitions in Thermo 005
013 5.0 points

Which of the following is **not** a definition of internal energy or change in internal energy?

1. A measure of the spontaneity of a reaction **correct**

2. The sum of heat (q) and work (w)

3. A measure of the change in heat of a system at constant volume

4. The total energy content of a system

Explanation:

Gibbs free energy is a measure of the spontaneity of a reaction. All of the other statements are mathematical identities describing internal energy or prose restatements of the same.

Msci 15 1004
014 5.0 points

A measurement of the heat produced when a known amount of sugar burns in a constant volume calorimeter would enable us to first calculate the

1. molar enthalpy change for the combustion of sugar.

2. work done per mole by the combustion of sugar.

3. molar entropy change from the combustion of sugar.

4. molar internal energy change for the combustion of sugar. **correct**

5. molar Gibbs free energy change for the combustion of sugar.

Explanation:

$$\Delta E = q + w\,.$$

$w = 0$ for bomb calorimeters because $\Delta V = 0$, so $\Delta E = q$.

LDE Internal Energy Calc 006
015 5.0 points

If the internal energy of a system decreases by 242.6 kJ as 91.88 kJ of work is done on the system, what is the value of q?

1. -242.6 kJ kJ

2. -150.7 kJ kJ

3. 334.5 kJ kJ

4. 150.7 kJ kJ

5. -334.5 kJ kJ **correct**

Explanation:

$$\begin{aligned}\Delta E &= q + w\\ -242.6\ \text{kJ} &= q + 91.88\ \text{kJ}\\ q &= -334.5\ \text{kJ}\end{aligned}$$

LDE Entropy Change Calc 005
016 5.0 points

Rank the reactions

a) $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$
b) $AgNO_3(aq) + NaCl(aq) \longrightarrow NaNO_3(aq) + AgCl(s)$
c) $4\,Fe(s) + 3\,O_2(g) \longrightarrow 2\,Fe_2O_3(s)$
d) $CH_4(g) + 2\,O_2(g) \longrightarrow CO_2(g) + 2\,H_2O(g)$

from most negative to most positive in terms of change in entropy (ΔS_{rxn}):

1. c < d < b < a

2. b < c < d < a

3. c < b < d < a **correct**

4. a < c < b < d

5. d < b < a < c

6. d < a < b < c

Explanation:

Reaction c has a substantial decrease both in total moles and especially in moles of gas; ΔS_{rxn} will likely be a large negative number. Reaction b has no change in total moles, but does form a solid from a pair of aqueous species; ΔS_{rxn} will likely be a small negative number. Reaction d has no change in total moles or moles of gas; ΔS_{rxn} will be close to zero. Reaction a produces more total moles, and importantly evolves a gas; ΔS_{rxn} will likely be a large positive number.

Phase Trans Entropy
017 5.0 points

What is the ΔS_{fus} for mercury if it has a freezing point of $-38.8°$C and a $\Delta H_{\text{fus}} = 2.292$ kJ/mol?

1. -0.06 J/mol · K

2. 0.06 J/mol · K

3. -59 J/mol · K

4. 9.78 J/mol · K **correct**

5. 59 J/mol · K

Explanation:

FP = -38.8°C = 234.35 K
ΔH = 2.292 kJ/mol

$$\begin{aligned}\Delta S_{\text{fus}} &= \frac{\Delta H_{\text{fus}}}{T}\\ &= \frac{2.292\ \text{kJ/mol}}{234.35\ \text{K}}\\ &= 0.00978024\ \text{J/mol}\cdot\text{K}\\ &= 9.78024\ \text{kJ/mol}\cdot\text{K}\end{aligned}$$

CIC T04 21
018 5.0 points

Which is a correct statement of the second law of thermodynamics?

1. Nature allows the conversion of potential energy into kinetic energy, but not vice versa.

2. Heat is the only form of energy that can be converted into work with 100% efficiency.

3. Energy cannot be created nor destroyed, but it can change form.

4. In any natural process, the entropy of the universe must increase. **correct**

Explanation:

This also means that energy conversion is not 100% efficient; some of the energy becomes 'lost' as entropy.

Msci 15 1224
019 5.0 points

Air is cooled until it freezes and the solid air is cooled to nearly 0 K. What value does the entropy of the resulting solid mixture approach as the temperature approaches 0 K?

1. Some negative number

2. Zero by the second law of thermodynamics

3. Zero by the third law of thermodynamics

4. Some positive number **correct**

5. A non-zero number (either positive or negative depending on information which is not given)

Explanation:

The third law of thermodynamics states that the entropy of a pure, perfect crystalline substance is 0 at absolute 0 K. Absolute entropy can not be negative.

In this case, air is not pure, but is a mixture of many things, and it is just a solid, not a perfect crystalline solid, so $S \neq 0$. S must be some positive number in this case.

LDE Thermodynamic Theory 009
020 5.0 points

Which of the following statements about residual entropy is/are true?

I) For a single molecule with one orientation, residual entropy is zero.
II) A species with strong IMF will have an actual residual entropy that is greater than its maximum residual entropy.
III) Residual entropy can be calculated using S = 0.5kT

1. I, II and III

2. II only

3. II and III

4. III only

5. I only **correct**

6. I and III

7. I and II

Explanation:

When only one orientation is available, W = 1 so that S = klnW becomes zero and the absolute entropy is zero. IMF result in a decrease in absolute entropy because they cause on ordered arrangement to be preferred. Absolute entropy is calculated from S = klnW, internal energy, a completely separate concept, is calculated from E = 0.5kT.

LDE Ranking Entropies 001

021 5.0 points

Rank the following systems by entropy, from least to greatest:

a) 1 mol of pure ice

b) 1 mol of water with 1 mol of salt dissolved in it.

c) 1 mol of pure water

1. c < a < b

2. b < a < c

3. c < b < a

4. b < c < a

5. a < c < b **correct**

6. a < b < c

Explanation:

Entropy increases as systems go through endothermic phase transitions and when there is more matter or more dispersed matter present.

LDE Stat Thermo Entropy 003

022 5.0 points

What is the maximum positional entropy of 3 mol of $CHCl_3$ at absolute zero?

1. 1.91×10^{-23} J · mol^{-1} · K^{-1}

2. 34.58 J · mol^{-1} · K^{-1} **correct**

3. 5.74×10^{-23} J · mol^{-1} · K^{-1}

4. 11.53 J · mol^{-1} · K^{-1}

Explanation:

$CHCl_3$ has 4 possible orientations.

$$\begin{aligned} S &= k \ln(4^n) = 3\,R\,\ln 4 \\ &= 34.58 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \end{aligned}$$

ChemPrin3e T07 15

023 5.0 points

The enthalpy of fusion of $H_2O(s)$ at its normal melting point is 6.01 kJ · mol^{-1}. What is the entropy change for freezing 1 mole of water at this temperature?

1. +20.2 J · K^{-1}· mol^{-1}

2. 0 J · K^{-1}· mol^{-1}

3. +22.0 J · K^{-1}· mol^{-1}

4. − 22.0 J · K^{-1}· mol^{-1} **correct**

5. − 20.2 J · K^{-1}· mol^{-1}

Explanation:

$\Delta H_{\text{vap}} = 6010 \text{ J} \cdot \text{mol}^{-1}$

$T_{\text{MP}} = 0°\text{C} = 273.15 \text{ K}$

$$\begin{aligned} \Delta S_{\text{cond}} &= \frac{q}{T} = \frac{\Delta H_{\text{con}}}{T_{\text{MP}}} = \frac{-\Delta H_{\text{vap}}}{T_{\text{MP}}} \\ &= \frac{-6010 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}}{273.15 \text{ K}} \\ &= -22.0026 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1} \end{aligned}$$

BP Benzene

024 5.0 points

What is the boiling point of benzene if it has a standard heat of vaporization of 30.8 kJ/mol and a standard entropy of vaporization of 87.2 J/mol · K?

1. 100°C

2. 353°C

3. −272.6°C

4. 0.35 K

5. 80°C **correct**

Explanation:

$\Delta H_{\text{vap}} = 30.8 \text{ kJ/mol} = 30800 \text{ J/mol}$

$\Delta S_{\text{vap}} = 87.2 \text{ J/mol} \cdot \text{K}$

$$T_{\text{BP}} = \frac{\Delta H_{\text{vap}}}{\Delta S_{\text{vap}}}$$

$$\begin{aligned} &= \frac{30800\ \text{J/mol}}{87.2\ \text{J/mol}\cdot\text{K}} \\ &= 353.211\ \text{K} \\ &= 80.211^\circ\text{C} \end{aligned}$$

LDE Thermo 2nd Law Calc 004

025 5.0 points

Calculate ΔS_universe for the condensation of heavy water (D_2O) at 95°C if the S°_m for $D_2O(g)$ and $D_2O(\ell)$ are $198\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ and $76\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$, respectively. Assume the standard boiling point of heavy water is 101°C and that $\Delta H_\text{system} = -45.6\ \text{kJ}\cdot\text{mol}^{-1}$.

1. $-122\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

2. $2\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$ **correct**

3. $122\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

4. $-124\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

5. $-2\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

6. $124\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$

Explanation:

Since the system in this case is condensing heavy water,

$$D_2O(g) \longleftrightarrow D_2O(\ell)$$

$$\begin{aligned} \Delta S_{system} &= \sum S_{m,products} - \sum S_{m,reactants} \\ &= 76\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \\ &\quad - 198\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \\ &= -122\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \end{aligned}$$

$$\begin{aligned} \Delta H_\text{system} &= T\,\Delta S_\text{system} \\ &= (374\ \text{K})(-122\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}) \\ &= -45628\ \text{J}\cdot\text{mol}^{-1} \end{aligned}$$

Since the only process during a phase change is heat exchange,

$$\begin{aligned} \Delta S_\text{surroundings} &= -\Delta H_\text{system} T_{surroundings} \\ &= \frac{45628\ \text{J}\cdot\text{mol}^{-1}}{368\ \text{K}} \\ &= 123.98\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \end{aligned}$$

$$\begin{aligned} \Delta S_\text{universe} &= \Delta S_\text{system} + \Delta S_\text{surroundings} \\ &= -122\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \\ &\quad + 124\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \\ &= 2\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1} \end{aligned}$$

LDE Sign Conventions 004

026 5.0 points

The formation of ammonia from hydrogen and nitrogen gases becomes less and less spontaneous as temperature is increased, eventually becoming non-spontaenous at sufficiently high temperatures. Which of the following statements must be true?

1. The change in entropy is small.

2. The reaction is endothermic.

3. The reaction is exothermic. **correct**

4. The change in entropy is large.

Explanation:

Since the reaction becomes more and more spontaneous as the temperature is lowered, it must be spontaneous at T = 0 K. Since ΔG = ΔH at T = 0 K, ΔH must be negative and the reaction is exothermic.

ChemPrin3e T07 59

027 5.0 points

For the reaction

$$2\,\text{C(s)} + 2\,\text{H}_2\text{(g)} \rightarrow \text{C}_2\text{H}_4\text{(g)}$$

$\Delta H^\circ_\text{r} = +52.3\ \text{kJ}\cdot\text{mol}^{-1}$ and $\Delta S^\circ_\text{r} = -53.07\ \text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$ at 298 K. The reverse reaction will be spontaneous at

1. all temperatures. **correct**

2. temperatures below 1015 K.

3. temperatures above 985 K.

4. no temperatures.

5. temperatures below 985 K.

Explanation:

$\Delta G = \Delta H - T\Delta S$ is used to predict spontaneity. (ΔG is negative for a spontaneous reaction.) T is always positive; for the reverse reaction, we reverse the sign of ΔH and ΔS. We thus have $\Delta G = (-) - T(+)$ for the reverse reaction, so ΔG will be negative for any physically possible value of T.

LDE Temperature and Phase Changes 006

028 5.0 points

What is the change in entropy (ΔS_{vap}) for the vaporization of ethanol ($\Delta \mathrm{H_{vap}} = 38.6\ \mathrm{kJ \cdot mol^{-1}}$) at its standard boiling temperature (78.4 °C)?

1. $-492\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$

2. $492\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$

3. $-110\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$

4. $110\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$ **correct**

Explanation:

$$\Delta \mathrm{S_{vap}} = \frac{\Delta \mathrm{H_{vap}}}{\mathrm{T}}$$

$$= \frac{38,600\ \mathrm{J \cdot mol^{-1}}}{351.4\ \mathrm{K}} = 110\ \mathrm{J \cdot mol^{-1} \cdot K^{-1}}$$

LDE Gibbs Stability Ranking 001

029 5.0 points

Consider the formation reactions below and pick the most stable species from the answer choices.

$$2\mathrm{C_{graphite}(s)} + 3\mathrm{H_2(g)} \rightarrow \mathrm{C_2H_6(g)}$$

$$\Delta \mathrm{G_f^\circ} = -7.86\ \mathrm{kcal \cdot mol^{-1}}$$

$$3\mathrm{C_{graphite}(s)} + 4\mathrm{H_2(g)} \rightarrow \mathrm{C_3H_8(g)}$$

$$\Delta \mathrm{G_f^\circ} = -5.614\ \mathrm{kcal \cdot mol^{-1}}$$

$$8\mathrm{C_{graphite}(s)} + 9\mathrm{H_2(g)} \rightarrow \mathrm{C_8H_{18}(g)}$$

$$\Delta \mathrm{G_f^\circ} = 4.14\ \mathrm{kcal \cdot mol^{-1}}$$

$$10\mathrm{C_{graphite}(s)} + 11\mathrm{H_2(g)} \rightarrow \mathrm{C_{10}H_{22}(g)}$$

$$\Delta \mathrm{G_f^\circ} = 8.23\ \mathrm{kcal \cdot mol^{-1}}$$

1. $\mathrm{C_{10}H_{22}(g)}$

2. $\mathrm{C_8H_{18}(g)}$

3. $\mathrm{C_2H_6(g)}$ **correct**

4. $\mathrm{C_3H_8(g)}$

Explanation:

The formation of ethane is the most exergonic of the formation reactions and thus ethane is the most stable of the species formed.

DAL 0301 13

030 5.0 points

Consider the following reaction:

$$\mathrm{CO(g)} + \mathrm{Cl_2(g)} \rightarrow \mathrm{COCl_2(g)}$$

Species	ΔH_f^0 kJ/mol	S^0 J/mol·K
CO	−110.5	197.6
$\mathrm{Cl_2}$	0.0	223.0
$\mathrm{COCl_2}$	−223.0	289.2

Calculate ΔG^0 for the reactions at 298 K.

1. 221.1 kJ/mol

2. −7.34 J/mol

3. −500.0 kJ/mol

4. −39.3 kJ/mol

5. -151.6 kJ/mol

6. -73.4 kJ/mol **correct**

Explanation:

The information available to us suggests we should use the standard state Gibbs equation:

$$\Delta G^0 = \Delta H^0 - T\,\Delta S^0\,,$$

However, we have to calculate ΔH^0 and ΔS^0 first. ΔH^0 can be determined using Hess's Law:

$$\begin{aligned}\Delta H^0 &= \sum n\,\Delta H^0_{\text{f products}} \\ &\quad - \sum n\,\Delta H^0_{\text{f reactants}} \\ &= (\Delta H^0_{\text{f}} \text{ for } \mathrm{COCl_2}) - \big(\Delta H^0_{\text{f}} \text{ for } \mathrm{Cl_2}\big) \\ &\quad - \big(\Delta H^0_{\text{f}} \text{ for CO}\big) \\ &= (-223.0 \text{ kJ/mol}) - (-0 \text{ kJ/mol}) \\ &\quad - (-110.5 \text{ kJ/mol}) \\ &= -112.5 \text{ kJ/mol}\end{aligned}$$

Then ΔS^0 can be determined from the equation similar to Hess's Law:

$$\begin{aligned}\Delta S^0 &= \sum n\,\Delta S^0_{\text{products}} - \sum n\,\Delta S^0_{\text{reactants}} \\ &= \big(S^0 \text{ for } \mathrm{COCl_2}\big) \\ &\quad - \big[\big(S^0 \text{ for CO}\big) + \big(S^0 \text{ for } \mathrm{Cl_2}\big)\big] \\ &= (289.2 \text{ J/mol}\cdot\text{K}) \\ &\quad - (197.6 \text{ J/mol}\cdot\text{K}) \\ &\quad - (223.0 \text{ J/mol}\cdot\text{K}) \\ &= -131.4 \text{ J/mol}\cdot\text{K}\end{aligned}$$

With ΔH^0 and ΔS^0 in hand, we can now use the Gibbs equation.

$$\begin{aligned}\Delta G^0 &= (-112.5 \text{ kJ/mol}) \\ &\quad - (298 \text{ K})\left(\frac{-131.4 \text{ J}}{\text{mol}\cdot\text{K}}\right)\cdot\frac{1 \text{ kJ}}{1000 \text{ J}} \\ &= -73.3428 \text{ kJ/mol}\end{aligned}$$

LAUDE - CH 301

51390

You may tear off this equation sheet and use it is a cover sheet and as scratch paper. Be sure to write your name on your exam and keep the hard copy. Turn in your scantron and any scratch paper when you are finished with the exam. You must be finished when time is called, so do not wait to bubble in your scantron - bubble in each response as you complete each problem.

Constants

$1\,\mathrm{atm} = 1.013 \times 10^5\,\mathrm{kPa} = 760\,\mathrm{torr}$

$R = 0.0821\,\mathrm{L \cdot atm \cdot mol^{-1} \cdot K^{-1}}$

$R = Nk = 8.314\,\mathrm{J \cdot mol^{-1} \cdot K^{-1}}$

$R = 1.987\,\mathrm{kcal \cdot mol^{-1} \cdot K^{-1}}$

$k = 1.381 \times 10^{-23}\,\mathrm{J \cdot K^{-1}}$

$N = 6.022 \times 10^{23}$

$K =^\circ C + 273.15$

$c = 3.0 \times 10^8\,\mathrm{m \cdot s^{-1}}$

$h = 6.626 \times 10^{-34}\,\mathrm{J \cdot s}$

$\hbar = h/2\pi = 1.054 \times 10^{-34}\,\mathrm{J \cdot s}$

$m_e = 9.109 \times 10^{-31}\,\mathrm{kg}$

$m_p = 1.674 \times 10^{-27}\,\mathrm{kg}$

$R_{\mathrm{Rydberg}} = 3.289 \times 10^{15}\,\mathrm{Hz}$

$c_{H_2O,\ell} = 4.184\,\mathrm{J \cdot g^{-1} \cdot K^{-1}}$

$\mathrm{STP} = 1\,\mathrm{atm\ and}\ 273\,\mathrm{K}$

Equations

$c = \lambda\nu$

$E = h\nu$

$$\nu = R\left(\frac{1}{n_i^2} - \frac{1}{n_j^2}\right)$$

$$E = hR\left(\frac{1}{n_i^2} - \frac{1}{n_j^2}\right)$$

$$\frac{1}{\lambda} = \frac{R}{c}\left(\frac{1}{n_i^2} - \frac{1}{n_j^2}\right)$$

$p = mv$

$0.5mv^2 = h\nu - \Phi$

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

$$\Delta x \Delta p \geq \frac{\hbar}{2}$$

$$m\Delta v \Delta p \geq \frac{\hbar}{2}$$

$$E = \frac{h^2 n^2}{8mL^2}$$

$$\lambda = \frac{2L}{n}$$

$\Delta EN = |EN_i - EN_j|$

$ENC = Z_{\mathrm{eff}} = p^+ - \mathrm{shielding}\ e^-$

$PV = nRT$

$n = m/MW$

$\rho = g/mL$

$KE = 0.5mv^2$

$P_1V_1 = P_2V_2$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

$$\frac{P_1V_1}{T_1n_1} = \frac{P_2V_2}{T_2n_2}$$

$$MW = \frac{\rho RT}{P}$$

$$v = \left(\frac{3RT}{MW}\right)^{0.5}$$

$$\frac{v_1}{v_2} = \left(\frac{m_2}{m_1}\right)^{0.5}$$

$$\left(P + \frac{n^2 a}{V^2}\right)\left(V - nb\right) = nRT$$

$$\mathrm{bond\ order} = \frac{\mathrm{bonding}\ e^- - \mathrm{antibonding}\ e^-}{2}$$

$P_{\mathrm{total}} = P_1 + P_2$

$\Delta U_{\mathrm{univ}} = \Delta U_{\mathrm{sys}} + \Delta U_{\mathrm{surr}}$

$\Delta U = \Delta E = q + w = q_V$

$U = E = 0.5kT$

$w = -P\Delta V = -\Delta n_{\mathrm{gas}}RT$

$q = mc\Delta T$

$\Delta H = \Delta U + P\Delta V = q_P$

$$\Delta H^\circ_{\mathrm{rxn}} = \sum \Delta H^\circ_{\mathrm{f,\ prod}} - \sum \Delta H^\circ_{\mathrm{f,\ reac}}$$

$\Delta H_{\mathrm{rxn}} = mc\Delta T + c_{\mathrm{cal}}\Delta T$

$$\Delta H_{\mathrm{rxn}} = \sum BE_{\mathrm{reac}} - \sum BE_{\mathrm{prod}}$$

$$\Delta S^\circ_{\mathrm{rxn}} = \sum \Delta S^\circ_{\mathrm{m,\ prod}} - \sum \Delta S^\circ_{\mathrm{m,\ reac}}$$

$$\Delta S = \frac{q}{T} = \frac{-\Delta H}{T}$$

$\Delta S_{\mathrm{univ}} = \Delta S_{\mathrm{sys}} + \Delta S_{\mathrm{surr}}$

$S = k \ln W$

$\Delta G^\circ_{\mathrm{rxn}} = \Delta H^\circ_{\mathrm{rxn}} - T\Delta S^\circ_{\mathrm{rxn}}$

$$\Delta G^\circ_{\mathrm{rxn}} = \sum \Delta G^\circ_{\mathrm{f,\ prod}} - \sum \Delta G^\circ_{\mathrm{f,\ reac}}$$

This print-out should have 50 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

Msci 05 0909

001 5.0 points

What is the energy of a photon of light with a frequency of 6.0×10^{14} s^{-1}?

1. 1.2×10^{18} J

2. 3.9×10^{-19} J **correct**

3. 1.2×10^{-18} J

4. 5.0×10^{-7} J

5. 1.3×10^{-27} J

Explanation:

Energy is equal to Planck's constant times frequency. Planck's constant is 6.6262×10^{-34} J · s, and the frequency is given, so

$$\begin{aligned} E &= h\,\nu \\ &= \left(6.6262 \times 10^{-34}\ \text{J} \cdot \text{s}\right)\left(6.0 \times 10^{14}\ \text{s}^{-1}\right) \\ &= 3.9 \times 10^{-19}\ \text{J} \end{aligned}$$

AtomicSpec Qual

002 5.0 points

In a hydrogen atom which transition would emit the longest wavelength light?

1. n = 4 to n = 3

2. n = 5 to n = 3

3. n = 2 to n = 1

4. n = 1 to n = 2

5. n = 5 to n = 4 **correct**

6. n = 2 to n = 4

Explanation:

To emit the first level needs to be higher energy than the second level. The longest wavelength will be lowest frequency. This will come from the two levels that are closest together. This is the n = 5 to n = 4 transition.

LDE Particle in a Box Theory 004

003 5.0 points

Hint: This problem will likely be easier for you if you draw it out.

Consider a one-dimensional system of length 60 nm. If an electron in this "box" is in the $n = 3$ state, at what positions along the length of the box is the electron **most** likely to be found?

1. 30 nm

2. 10 nm, 30 nm, 50 nm **correct**

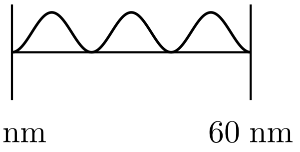
3. 0 nm, 20 nm, 40 nm, 60 nm

4. 15 nm, 30 nm, 45 nm

5. 20 nm, 40 nm

Explanation:

For principle energy level 3, $|\Psi|^2$ for the particle in a box will have 2 nodes (where the probability is zero), and 3 maxima at $\frac{1}{6}$, $\frac{1}{2}$ and $\frac{5}{6}$ the length of the box.



LDE uncertainty calculation 007

004 5.0 points

If the uncertainty in an electron's position is only 10^{-10} m, what is the minimum uncertainty in the electron's velocity, to the nearest order of magnitude? (An electron has a mass of 9.1×10^{-31} kg)

1. 10^{6} m · s^{-1} **correct**

2. 10^{-3} m · s^{-1}

3. 10^9 m · s^{-1}

4. 10^3 m · s^{-1}

5. 1 m · s^{-1}

Explanation:

$$\begin{aligned}\Delta x(m\Delta v) &\geq \frac{h}{4\pi}\\ \Delta v &\geq \frac{h}{4\pi m\Delta x}\\ &\geq \frac{6.626\times10^{-34}\ \mathrm{J\cdot s}}{4\pi\,(9.1\times10^{-31}\ \mathrm{kg})\,(10^{-10}\ \mathrm{m})}\\ &\geq 5.8\times10^{5}\ \mathrm{m\cdot s^{-1}}\end{aligned}$$

De Broglie Wavelength 02 Sparks rev
005 5.0 points

What is the de Broglie wavelength of a bowling ball rolling down a bowling alley lane? Assume the mass of the ball is 5000 g and it is moving at 6.63 m/s.

1. 2×10^{-38} m

2. 5×10^{37} m

3. 1×10^{-40} m

4. 2×10^{-35} m **correct**

5. 5×10^{-32} m

Explanation:

LDE Schrodinger and wave theory
006 5.0 points

Which of the following statements concerning the Schrodinger equation and its solution for the hydrogen atom is/are true?

I) The Schrödinger equation cannot predict exactly where in an atom an electron will be found.

II) The use of spherical coordinates simplifies the solution to the Schrodinger equation for the hydrogen atom.

III) The solution to the Schrodinger equation for the hydrogen atom contains a single potential energy term.

1. I only

2. I and II

3. II only

4. I, II and III **correct**

5. III only

6. I and III

7. II and III

Explanation:
Solutions to the Schrodinger equation are wave functions, which when squared express the probable location of electrons; but, the exact location cannot be known. Attractive potential energy terms are found in all solutions for all atoms. Repulsive potential energy terms are found only in atoms that have more than one electron, i.e. everything beyond hydrogen. Spherical coordinates are preferred for 3-D solutions because they simplify the math.

LDE quantum rules 006
007 5.0 points

Consider a filled $n = 3$ shell. Within that shell, how many electrons will have $m_\ell = 1$ in their set of quantum numbers (n, ℓ, m_ℓ, m_s)?

1. 4 **correct**

2. 8

3. 16

4. 2

5. 18

Explanation:
The quantum number $n = 3$ describes an s, p and d subshell ($\ell = 0$, 1 and 2). However, because $m_\ell = 1$, the s subshell is disallowed

(ℓ must be ≥ 1 for $m_\ell = 1$), leaving only the p and d subshells. Within each of those subshells, each m_ℓ can be assigned to 2 electrons, giving a total of 4 electrons with $m_\ell = 1$.

ChemPrin3e 01 62
008 5.0 points

Which valence-shell configuration

$$\begin{array}{rll} & 4s & 4p \\ \text{I)} & \underline{\uparrow\downarrow} & \underline{\uparrow}\ \underline{\downarrow}\ \underline{\quad} \\ \text{II)} & \underline{\uparrow} & \underline{\uparrow}\ \underline{\uparrow}\ \underline{\uparrow} \\ \text{III)} & \underline{\uparrow\downarrow} & \underline{\uparrow\downarrow}\ \underline{\quad}\ \underline{\quad} \\ \text{IV)} & \underline{\uparrow\downarrow} & \underline{\uparrow}\ \underline{\uparrow}\ \underline{\quad} \end{array}$$

could describe a neutral atom in its ground state?

1. More than one of the configurations

2. IV only **correct**

3. III only

4. I only

5. II only

6. None of the configurations

Explanation:
The atom with a $4s^2\,4p^2$ valence-shell configuration is germanium (Ge). The ground-state configuration is given by

$$\underline{\uparrow\downarrow}\quad \underline{\uparrow}\ \underline{\uparrow}\ \underline{\quad}$$

The other configurations represent excited states.

Msci 05 1656
009 5.0 points

What is the electronic configuration for Zn^{2+}?

1. [Ar] $4s^1\ 3d^9$

2. [Ar] $4s^2\ 3d^8$

3. [Ar] $3d^{10}$ **correct**

4. [Ne] $3d^{10}$

5. [Ar] $4s^2\ 3d^{10}\ 4p^2$

Explanation:

LDE Periodic Trend Theory 002
010 5.0 points

Which of the following correctly rationalizes the increase in atomic radii down and to the left on the periodic table, based on what we discussed in class?

1. The elements are simply larger due to more protons and neutrons.

2. The periodic table was set up to group atoms by size to facilitate comparisons.

3. Because the elements are easier to ionize, they have a larger electronegativity, and therefore their electron affinity is not sufficient to reduce atomic radii.

4. Larger elements have an increasing proportion of d and f orbitals, which are intrinsically larger than all of the s and p orbitals.

5. None of these. Atomic radii increase up and to the right.

6. As you move to the left across a period, decreasing ENC means the outer electrons are less tightly held and can move further from the nucleus. As you move down a group, the electrons occupy orbitals that are further from the nucleus. **correct**

Explanation:
We used ENC to rationalize the overall periodic trends in class. The nuclei are larger due to more protons and neutrons, but not the atom as a whole – most of an atom's size is the space taken up by the electrons, the nucleus is tiny in comparison. Orbital size increases with the principal quantum number n so that a $7s$ orbital would probably be larger than a $4f$ orbital – the d and f orbitals are not automatically larger. The periodic table was

organized by properties of the macroscopic elements, not by the size of the atoms. The other answer choice is just a mindless spewing of chemistry vocabulary.

LDE Rank Electron Affinity 003
011 5.0 points

Rank the following species from least to greatest electron affinity: Si, P, S.

1. S < Si < P

2. Si < S < P

3. S < P < Si

4. P < S < Si

5. Si < P < S

6. P < Si < S **correct**

Explanation:
The electron affinity trend increase as one moves from the lower left corner of the periodic table to the upper right corner of the periodic table, with exceptions occurring at filled and half-filled subshells, which are inherently stable and thus have a lower-than-expected electron affinity. In this case, P has a lower electron affinity than than Si.

LDE Rank Lattice Energy 005
012 5.0 points

Rank the crystal lattice energy of the salts
KCl, CaS, KI, RbI, MgO
from greatest to least.

1. CaS > MgO > RbI > KI > KCl

2. CaS > MgO > KI > KCl > RbI

3. MgO > CaS > KI > KCl > RbI

4. MgO > CaS > KCl > KI > RbI **correct**

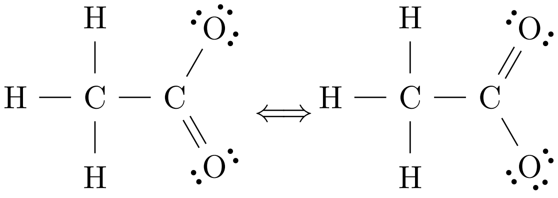
5. CaS > MgO > KI > RbI > KCl

Explanation:
Lattice energy is directly proportional to charge density. Consequently, the salts with the largest charges will have the largest lattice energies. Among salts with the same charges, the ones with the smallest ionic radii will have the largest lattice energies.

---

resonance bond strength 001
013 5.0 points

In the following molecule



1. the carbon/oxygen bonds have two distinct bond strengths and all carbon/hydrogen bonds have two distinct bond strengths

2. all the carbon/hydrogen bonds have the same strength but the carbon/oxygen bonds are found to have two distinct bond strengths

3. all the carbon/oxygen bonds have the same strength but the carbon/hydrogen bonds are found to have two distinct bond strengths

4. all the carbon/oxygen bonds have the same strength and all the carbon/hydrogen bonds have the same strength **correct**

Explanation:
Resonance is when there are two equivalent ways of drawing a Lewis structure, so you draw both, as the true structure is somewhere in between. The true structure is not switching back and forth but is essentially the average of these two structures. Thus the carbon/oxygen bonds are both 1.5 bonds. The molecule does not have two types of carbon/oxygen bonds. The difficult is with our drawings not the molecule. Because we insist on having Lewis structure with only single and double bonds the only way we can capture this idea of a 1.5 bond is to draw two equivalent resonance structures.

Sparks ex2 1
014 5.0 points

The dot structure for CH_2CHCl would indicate a total of

1. one single bond and one triple bond.

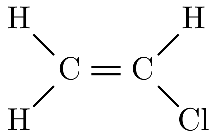
2. four single bonds and one double bond. **correct**

3. three single bonds and two double bonds.

4. four single bonds and one triple bond.

5. one single bond and one double bond.

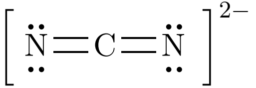
Explanation:
The dot structure CH_2CHCl is

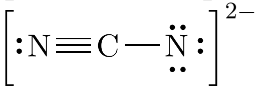


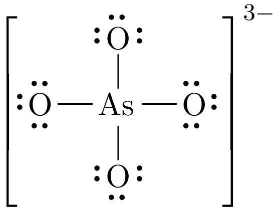
There are 3 C — H single bonds, 1 C — Cl single bond, and a C — C double bond for a total of 4 single bonds and 1 double bond.

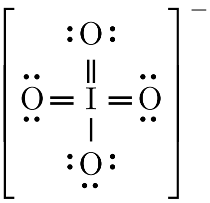
ChemPrin3e 02 46
015 5.0 points

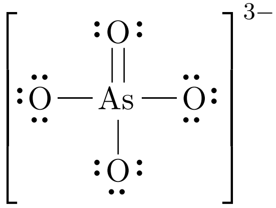
Consider the following sets A, B, and C

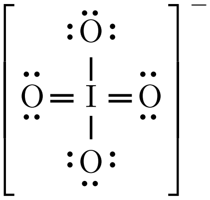
A$_1$)


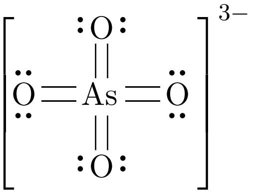
A$_2$)


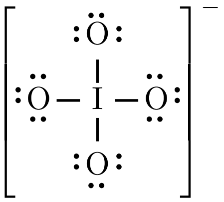
B$_1$)


C$_1$)


B$_2$)


C$_2$)


B$_3$)


C$_3$)


of ions.
Determine the formal charge on each atom and identify the structure of lowest energy for each set A, B, and C.

1. A$_2$, B$_3$, C$_2$

2. A$_1$, B$_2$, C$_3$

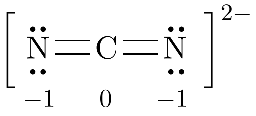
3. A$_1$, B$_2$, C$_1$ **correct**

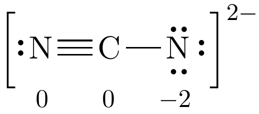
4. A$_2$, B$_3$, C$_3$

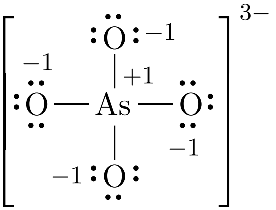
5. A$_2$, B$_2$, C$_2$

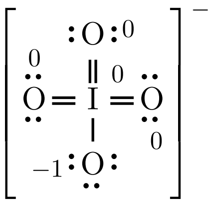
6. A$_1$, B$_1$, C$_1$

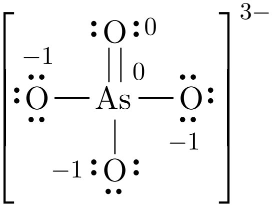
Explanation:

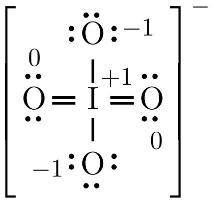
A$_1$)


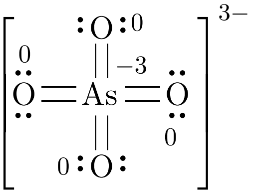
A$_2$)


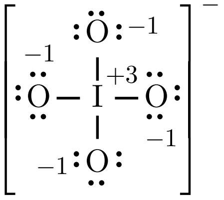
B$_1$)


C$_1$)


B$_2$)


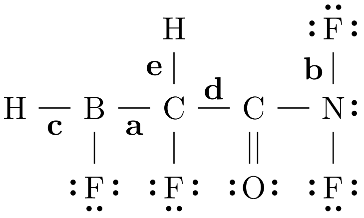
C$_2$)


B$_3$)


C$_3$)


LDE Molecular Polarity 004
016 5.0 points

Consider the labeled bonds in the molecule below and rank them from least to most polar in terms of difference in electronegativity.



1. d < c < e < a < b **correct**

2. c < d < e < b < a

3. d < c < a < e < b

4. e < b < d < c < a

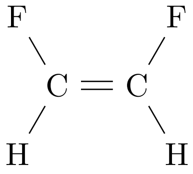
5. a < b < c < d < e

Explanation:
The polarity of a bond is proportional to the difference in electronegativity of the two bonded atoms. The electronegatavity differences of the labeled bonds are 0.5, 1.0, 0.1, 0.0 and 0.4, respectively.

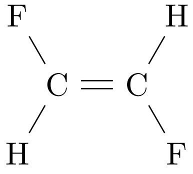
LDE VSEPR Molecular Geometry 002
017 5.0 points

Which of the following molecules is/are polar?

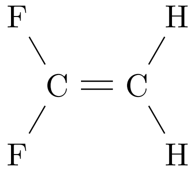
I)



II)



III)



1. I only

2. I, III **correct**

3. I, II, III

4. III only

5. I, II

6. II, III

7. II only

Explanation:
Molecule II is symmetrical and therefore its individual dipole moments cancel, making it non-polar. Molecules I and III are asymmetrical and therefore polar.

LDE VB Hybridization 001
018 5.0 points

Which of the following statements concerning hybrid orbitals is/are true?

I) Hybrid orbitals are energetically degenerate.

II) Any element can form sp^3d^2 hybrid orbitals.

III) Hybridizing a $2s$ and a $2p$ orbital would produce one single sp hybrid orbital.

1. I, II

2. I, II, III

3. I only **correct**

4. II only

5. II, III

6. I, III

7. III only

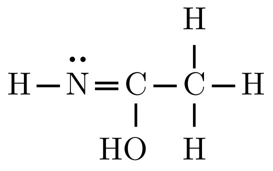
Explanation:
Statement I is true; hybridization was developed as a theoretical framework to explain the energetic degeneracy of bonds in molecules. Statement II is false; hybridization involving d orbitals requires access to empty d orbitals,

and thus begins in period 3. Statement III is false; the number of orbitals used to hybridize is always equal to the number of hybridized orbitals, so using a 2*s* and a 2*p* orbital would result in two *sp* hybrid orbitals.

Brodbelt 8200504abc

019 5.0 points

Give the molecular geometry of each central atom: nitrogen, middle carbon, right carbon, respectively.



$\mathrm{H-\ddot{N}=C(OH)-CH_3}$

1. linear, angular, tetrahedral

2. linear, tetrahedral, tetrahedral

3. tetrahedral, tetrahedral, tetrahedral

4. trigonal planar, trigonal planar, tetrahedral

5. angular, angular, tetrahedral

6. trigonal planar, trigonal planar, trigonal planar

7. angular, trigonal planar, tetrahedral **correct**

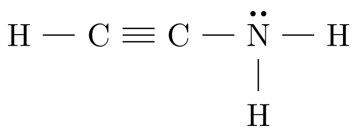
8. linear, linear, linear

Explanation:
Count the RHED on each of the central atoms: three, three, and four as listed in the question. The RHED specifies the electronic geometry. Then count the number of lone pairs for each central atom to find the molecular geometry. If there are no lone pairs then the molecular geometry is the same as the electronic geometry.

LDE Identifying Bonds 007

020 5.0 points

How many σ and π bonds are in the molecule



$\mathrm{H-C\equiv C-\ddot{N}(H)-H}$

1. 6 σ; 1 π

2. 7 σ; 1 π

3. 5 σ; 2 π **correct**

4. 5 σ; 1 π

5. 6 σ; 2 π

Explanation:
Sigma bonds are the first bond formed between any two bonded atoms. Any subsequent bond is a pi bond.

LDE AOs That Comprise MOs 001

021 5.0 points

What atomic orbitals were used to form the π bond in the molecule CH_2SiH_2?

1. sp^3, sp^3

2. 2p, 3p **correct**

3. sp^3, 3p

4. 2s, 3s

5. sp^2, sp^2

6. 2p, 2p

Explanation:
π bonds are always formed from valence p orbitals.

LDE Bond Order 006

022 5.0 points

Rank the following species from strongest to weakest bonds based on bond order: O_2, N_2^+, H_2^-, Li_2, C_2^{2-}.

1. $C_2^{2-} > N_2^+ > O_2 > Li_2 > H_2^-$ **correct**

2. $N_2^+ > O_2 > C_2^{2-} > H_2^- > Li_2$

3. $N_2^+ > C_2^{2-} > O_2 > Li_2 > H_2^-$

4. $C_2^{2-} > N_2^+ > O_2 > H_2^- > Li_2$

5. $N_2^+ > O_2 > C_2^{2-} > Li_2 > H_2^-$

Explanation:
The species O_2, N_2^+, H_2^-, Li_2 and C_2^{2-} have bond orders of 2, 2.5, 0.5, 1 and 3 respectively.

LDE Paramagnetism 008
023 5.0 points

Which of the following species is not paramagnetic?

1. ${B_2}^{2-}$ **correct**

2. ${F_2}^+$

3. ${N_2}^{3+}$

4. ${F_2}^-$

5. ${N_2}^+$

Explanation:
The answer choices ${F_2}^-$, OF, CN, and ${N_2}^{3+}$ all have an odd number of total electrons and therefore must be paramagnetic.

LDE Ranking Bonding Trends 007
024 5.0 points

Using simple bond order arguments, rank the following species in terms of increasing bond length: ${He_2}^+, O_2, F_2$.

1. ${He_2}^+ < O_2 < F_2$

2. $F_2 < {He_2}^+ < O_2$

3. $F_2 < O_2 < {He_2}^+$

4. $O_2 < {He_2}^+ < F_2$

5. $O_2 < F_2 < {He_2}^+$ **correct**

Explanation:
Since bond length is inversely proportional to bond order, ranking by increasing bond length requires ranking by decreasing bond order; the bond orders for ${He_2}^+, O_2, F_2$ are 0.5, 2 and 1 respectively.

Mlib 76 2079
025 5.0 points

Use the ideal gas law to calculate the volume occupied by 0.200 mol of nitrogen gas at 1.00 atm pressure and at 27°C. $R = 0.0821\ \dfrac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}$

1. 4.9 L **correct**

2. 22.4 L

3. 0.0821 L

4. 0.44 L

Explanation:
$n = 0.2$ mol $\qquad T = 27°\text{C} + 273 = 300$ K
$P = 1$ atm
Applying the ideal gas law equation,

$$\begin{aligned} PV &= nRT \\ V &= \frac{nRT}{P} \\ V &= \frac{(0.2\ \text{mol})\left(0.08206\ \frac{\text{L}\cdot\text{atm}}{\text{mol}\cdot\text{K}}\right)(300\ \text{K})}{1\ \text{atm}} \\ &= 4.9236\ \text{L} \end{aligned}$$

ChemPrin3e T04 36
026 5.0 points

Consider the reaction
$4\,KO_2(s) + 2\,CO_2(g) \rightarrow$
$2\,K_2CO_3(s) + 3\,O_2(g)$.
How much KO_2 is needed to react with 75.0 L of carbon dioxide at STP?

1. 13.4 mol

2. 6.70 mol **correct**

3. 0.838 mol

4. 3.35 mol

5. 1.67 mol

Explanation:

$V = 75$ L $\qquad P = 1$ atm

$T = 0°\text{C} + 273.15 = 273.15$ K

The ideal gas law is

$$P\,V = n\,R\,T$$
$$n = \frac{P\,V}{R\,T}$$

For the carbon dioxide,

$$n = \frac{(1\text{ atm})(75\text{ L})}{(0.08206\text{ L}\cdot\text{atm/mol/K})\,(273.15\text{ K})} = 3.34602\text{ mol CO}_2$$

Thus for the KO_2,

$$n = (3.34602\text{ mol CO}_2)\,\frac{4\text{ mol KO}_2}{2\text{ mol CO}_2} = 6.69204\text{ mol KO}_2$$

LDE Kinetic Theory 003

027 5.0 points

At any given temperature, how much more quickly will He effuse than Xe?

1. they will diffuse at the same rate

2. .03 times more quickly

3. 8.1 times more quickly

4. 32.8 times more quickly

5. 0.12 times more quickly

6. 5.7 times more quickly **correct**

Explanation:

$m_1 v_1^2 = m_2 v_2^2$

$$\frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}} = \sqrt{\frac{131.3}{4}} = 5.7$$

LDE Ranking Gases 003

028 5.0 points

Which of the following molecules would have the smallest a and b term, respectively, in the van der Waals' equation: $O_3, CHF_3, SF_5Cl, SiHCl_3, Xe$.

1. $SiHCl_3$ and O_3, respectively

2. Xe and O_3, respectively **correct**

3. Xe and SF_5Cl, respectively

4. Xe and Xe, respectively

5. CHF_3 and CHF_3, respectively

Explanation:

Xenon is the only non-polar species and thus would have the smallest a term. Ozone is the smallest in terms of molecular weight and would thus have the smallest b term.

Msci 13 0245

029 5.0 points

Dispersion (London) forces result from

1. attractive forces between a molecule at the surface of a liquid and those beneath it which are not balanced by corresponding forces from above.

2. attraction between molecules in a liquid and molecules or atoms in a solid surface with which the liquid is in contact.

3. the balance of attractive and repulsive forces between two polar molecules.

4. distortion of the electron cloud of an atom or molecule by the presence of nearby atoms or molecules. **correct**

5. the formation of a loose covalent linkage between a hydrogen atom connected to a very electronegative atom in one molecule and another very electronegative atom in a neighboring molecule.

Explanation:

LDE Intermolecular Forces 011

030 5.0 points

Which of the following species is incorrectly paired with its strongest type of intermolecular force?

1. N_2H_4 (hydrazine), hydrogen bonding

2. O_3 (ozone), dispersion forces **correct**

3. NaCl (table salt), ionic bonding

4. C_6H_6 (benzene), dispersion forces

Explanation:
Ozone is polar and has dipole-dipole interactions.

LDE Ranking by IMF 006
031 5.0 points

Rank the following species by rate of evaporation, from highest to lowest: $\mathrm{CsCl, N_2, HF, HCl}$.

1. $N_2 > HF > HCl > CsCl$

2. $HCl > CsCl > N_2 > HF$

3. $N_2 > HCl > HF > CsCl$ **correct**

4. $HF > HCl > N_2 > CsCl$

Explanation:
Evaporation rate is inversely proportional to intermolecular forces, so ranking by decreasing evaporation rate requires ranking by increasing IMF. Nitrogen gas is non-polar, and thus has very low IMF. Hydrochloric acid is polar and has dipol-dipole interactions. Hydrofluoric acid has hydrogen bonding. Lastly, cesium chloride is a salt, and thus has ion-ion interactions.

LDE Ranking by IMF 002
032 5.0 points

Rank the following liquids by viscosity, from most viscous to least: C_5H_{12}, CH_4, C_3H_8, C_2H_6, C_4H_{10}.

1. $C_5H_{12} > C_4H_{10} > C_3H_8 > C_2H_6 > CH_4$ **correct**

2. $CH_4 > C_2H_6 > C_3H_8 > C_4H_{10} > C_5H_{12}$

3. $C_5H_{12} > C_3H_8 > C_4H_{10} > C_2H_6 > CH_4$

4. $CH_4 > C_2H_6 > C_4H_{10} > C_3H_8 > C_5H_{12}$

5. $CH_4 > C_2H_6 > C_3H_8 > C_5H_{12} > C_4H_{10}$

Explanation:
All of these molecules are non-polar, and viscosity is directly proportional to IMF, so one simply has to rank them from largest to smallest.

LDE Thermodynamic Theory 012 U not E
033 5.0 points

Which of the following statements concerning the laws of thermodynamics is not true?

1. $\Delta U_{\mathrm{univ}} = 0$

2. Entropy always increases in an isolated system.

3. Free energy is conserved in a closed system. **correct**

4. S = 0 for a perfect crystal at absolute zero.

5. $\Delta S_{\mathrm{univ}} > 0$

Explanation:
Free energy is conserved in an isolated system, but not in a closed system.

LDE Thermodynamic Signs 001
034 5.0 points

When wood is burning (i.e. a combustion process is occurring), which of the following quantities is positive?

1. Work.

2. Change in entropy. **correct**

3. Change in Gibbs' free energy.

4. Change in enthalpy.

Explanation:
A burning piece of wood produces a lot of gas and thus does expansion work on the surroundings so work is negative, not positive. It is an exothermic reaction (producing heat) so enthalpy change is negative, not positive. It happens spontaneously so change in free energy is negative, not positive. Finally, all the gas produced yields an increase in entropy so the change is indeed positive.

LDE Thermodynamic Signs 003
035 5.0 points

Consider a reaction that is non-spontaneous at all temperatures. What would be the signs of ΔG_{sys}, ΔH_{sys}, and ΔS_{univ} respectively for such a reaction?

1. +, -, +

2. -, +, +

3. +, -, -

4. +, +, +

5. +, +, - **correct**

6. -, +, -

Explanation:
For a reaction that is non-spontaneous at all temperatures, the free energy of the system will increase and the entropy of the universe will decrease. Such a reaction must be endothermic, and the heat it gains will be lost from the surroundings.

DAL 15 002
036 5.0 points

In a bomb calorimetry measurement, 5 g of a tasty Cheetos snack are combusted at a temperature of 1200 K. A container of water surrounding the bomb calorimeter contains 2180 mL of water that rises in temperature by 23°C. Determine the ΔH for the 5 g of Cheetos. Assume a water density of 1 g/mL and a specific heat for water of 1 cal/g°C. Also, assume that the water absorbs all of the heat energy released in the combustion process.

1. 6 kcal

2. 2400 kcal

3. 6000 kcal

4. 50.14 kcal **correct**

5. 50000 kcal

Explanation:
$V = 2180$ mL $T = 23°$C
density = 1 g/mL SH = 1 cal/g°C
The heat given off by the reaction is absorbed by the water.
Heat absorbed by the water:

$$\left(1\,\frac{\text{cal}}{\text{g}^\circ\text{C}}\right)(23^\circ\text{C})\left(\frac{1\text{ g}}{\text{mL}}\right)(2180\text{ mL})$$
$$= (50000\text{ cal})\left(\frac{1\text{ kcal}}{1000\text{ cal}}\right)$$
$$= 50.14\text{ kcal}$$

Therefore, the heat released by the combustion of 5 g of Cheetos is 50.14 kcal.

ChemPrin3e T06 47 rev LDE
037 5.0 points

Given the following data,

Species	ΔH°_f kJ · mol^{-1}
$C_2H_5OH(\ell)$	-277.69
$CO_2(g)$	-393.51
$H_2O(g)$	-285.83

calculate $\Delta H^\circ_\text{rxn}$ for

$$C_2H_5OH(\ell)+\frac{7}{2}O_2(g) \to 2\,CO_2(g)+3\,H_2O(g)$$

1. -1922 kJ · mol^{-1}

2. -401.7 kJ · mol^{-1}

3. -687.5 kJ · mol^{-1}

4. $-1367\ \mathrm{kJ\cdot mol^{-1}}$ **correct**

5. $-957.0\ \mathrm{kJ\cdot mol^{-1}}$

Explanation:
The balanced equation is

$$C_2H_5OH(\ell)+\frac{7}{2}\,O_2(g)\rightarrow 2\,CO_2(g)+3\,H_2O(g)$$

$$\begin{aligned}\Delta H_{\text{comb}} &= \sum \Delta H^\circ_{\text{f prod}} - \sum \Delta H^\circ_{\text{f react}}\\ &= \left[3\,\Delta H^\circ_{\text{f }H_2O(\ell)} + 2\,\Delta H^\circ_{\text{f }CO_2(g)}\right]\\ &\quad - \Delta H^\circ_{\text{f }C_2H_5OH(\ell)}\\ &= [3\,(-285.83\ \text{kJ/mol})\\ &\qquad +2\,(-393.51\ \text{kJ/mol})]\\ &\quad -(-277.69\ \text{kJ/mol})\\ &= -1367.34\ \mathrm{kJ\cdot mol^{-1}}\end{aligned}$$

LDE Hess' Law 005
038 5.0 points

Given the data

$H_2SO_4(\ell) \longrightarrow H_2S(g) + 2\,O_2(g)$
$\Delta H = +793\ \mathrm{kJ\cdot mol^{-1}}$

$H_2O(g) + SO_3(g) \longrightarrow H_2SO_4(\ell)$
$\Delta H = -176\ \mathrm{kJ\cdot mol^{-1}}$

$H_2O(\ell) + SO_3(g) \longrightarrow H_2S(g) + 2\,O_2(g)$
$\Delta H = +661\ \mathrm{kJ\cdot mol^{-1}}$

calculate ΔH for the reaction

$$H_2O(\ell) \longrightarrow H_2O(g)$$

1. $-44\ \mathrm{kJ\cdot mol^{-1}}$

2. $214\ \mathrm{kJ\cdot mol^{-1}}$

3. $44\ \mathrm{kJ\cdot mol^{-1}}$ **correct**

4. $-1278\ \mathrm{kJ\cdot mol^{-1}}$

5. $1278\ \mathrm{kJ\cdot mol^{-1}}$

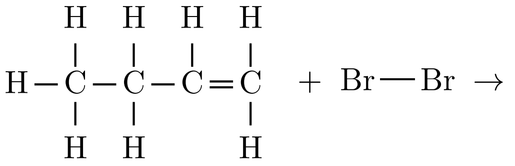
Explanation:
The first two reactions need to be reversed:

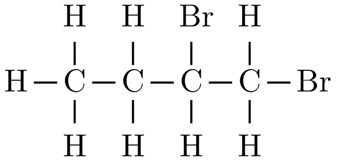
$$\begin{aligned}H_2S(g) + 2\,O_2(g) &\longrightarrow H_2SO_4(\ell)\\ &\qquad \Delta H = -793\ \mathrm{kJ\cdot mol^{-1}}\\ H_2SO_4(\ell) &\longrightarrow H_2O(g) + SO_3(g)\\ &\qquad \Delta H = +176\ \mathrm{kJ\cdot mol^{-1}}\\ H_2O(\ell) + SO_3(g) &\longrightarrow H_2S(g) + 2\,O_2(g)\\ &\qquad \underline{\Delta H = +661\ \mathrm{kJ\cdot mol^{-1}}}\\ &\qquad \Delta H_{\text{rxn}} = 44\ \mathrm{kJ\cdot mol^{-1}}\end{aligned}$$

ChemPrin3e T02 49 rev LDEA
039 5.0 points

Estimate the heat released when 1-butene ($CH_3CH_2CH{=}CH_2$) reacts with bromine to give $CH_3CH_2CHBrCH_2Br$. Bond enthalpies are

C—H : 412 kJ/mol; C—C : 348 kJ/mol;
C=C : 612 kJ/mol; C—Br : 276 kJ/mol;
Br—Br : 193 kJ/mol.





1. 95 kJ/mol **correct**

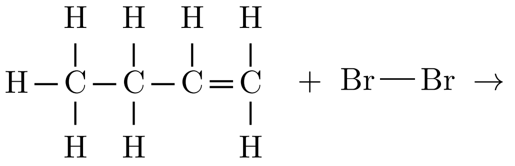
2. 288 kJ/mol

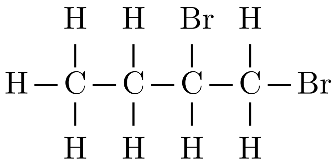
3. 181 kJ/mol

4. 317 kJ/mol

5. 507 kJ/mol

Explanation:





$$\begin{array}{ccccccccccc} & & H & & H & & Br & & H & & \\ & & | & & | & & | & & | & & \\ H & - & C & - & C & - & C & - & C & - & Br \\ & & | & & | & & | & & | & & \\ & & H & & H & & H & & H & & \end{array}$$

$$\begin{aligned} \Delta H &= \sum E_{\text{break}} - \sum E_{\text{make}} \\ &= \Big[(\text{C}{=}\text{C}) + (\text{Br}{-}\text{Br})\Big] \\ &\quad - \Big[2\,(\text{C}{-}\text{Br}) + (\text{C}{-}\text{C})\Big] \\ &= 612\ \text{kJ/mol} + 193\ \text{kJ/mol} \\ &\quad - \Big[2\,(276\ \text{kJ/mol}) + 348\ \text{kJ/mol}\Big] \\ &= -95\ \text{kJ/mol}\,, \end{aligned}$$

which means 95 kJ/mol of heat was released.

LDE Thermodynamic Work 006
040 5.0 points

For all of the reactions below, except for one of them, there would be 2.5 kJ of work done by the system at room temperature. Which reaction below has some other value for work?

1. $CaCO_3(s) + 2HCl(aq) \to CaCl_2(aq) + CO_2(g) + H_2O(\ell)$

2. $CH_2O(\ell) + O_2(g) \to H_2O(g) + CO_2(g)$

3. $CH_4(g) + 2\,O_2(g) \to CO_2(g) + 2\,H_2O(g)$ **correct**

4. $2\,H_2O_2(\ell) \to 2\,H_2O(\ell) + O_2(g)$

5. $CaCO_3(s) \to CO_2(g) + CaO(s)$

Explanation:
At room temperature (298 K), the product of the gas constant ($R = 8.314\ \text{J}\cdot\text{mol}^{-1}\cdot\text{K}^{-1}$) and T is very close to $2.5\ \text{kJ}\cdot\text{mol}^{-1}$. Based on

$$-2.5\ \text{kJ} = -\Delta n_{\text{gas}}\left(2.5\ \text{kJ}\cdot\text{mol}^{-1}\right)$$

, the reaction for which

$$\Delta n_{\text{gas}} \neq 1$$

will be the correct answer.

LDE Definitions in Thermo 010
041 5.0 points

Which of the following is **not** a definition of internal energy or change in internal energy?

1. $\Delta U = q + w$

2. The difference between the final and initial internal energy of a system

3. The heat transferred at constant pressure **correct**

4. The change in enthalpy after correction for PV work

Explanation:
Internal energy is not equal to heat at constant pressure. The other statements are all mathematical identities describing internal energy or prose restatements of the same.

LDE Entropy 002
042 5.0 points

Which of the reactions below will likely have the largest increase in entropy (ΔS_{rxn})?

1. $C_5H_{12}(\ell) + 8\,O_2(g) \to 6\,H_2O(g) + 5\,CO_2(g)$ **correct**

2. $N_2H_4(g) + H_2(g) \to 2\,NH_3(g)$

3. $2\,CH_4(g) + 2O_3(g) \to 4\,H_2O(g) + 2\,CO(g)$

4. $Na^+(g) + Cl^-(g) \to NaCl(s)$

5. $S_3(g) + 9\,F_2(g) \to 3\,SF_6(g)$

Explanation:
The reaction with the greatest positive value for Δn_{gas} will have the greatest value of ΔS_{rxn}.

LDE Ranking Entropies 002
043 5.0 points

Rank the compounds

$$NO(s), NO_2(g), NO_2(\ell), NO(\ell)$$

in terms of decreasing molar entropy.

1. $NO(s) > NO_2(g) > NO_2(\ell) > NO(\ell)$

2. $NO_2(g) > NO(\ell) > NO_2(\ell) > NO(s)$

3. $NO(s) > NO_2(\ell) > NO(\ell) > NO_2(g)$

4. $NO_2(g) > NO(s) > NO(\ell) > NO_2(\ell)$

5. $NO_2(g) > NO_2(\ell) > NO(\ell) > NO(s)$ **correct**

Explanation:
$NO_2(g)$ and NO(s) obviously belong on the extremes, being the most and least entropic on account of their phase. The two liquids can be compared based on their number of bonds, and so $NO_2(\ell)$ has greater molar entropy than $NO(\ell)$.

LDE Entropy Change Calc 001
044 5.0 points

A system releases 900 J of heat to the surroundings, which are at a constant 27°C. What is ΔS of the surroundings?

1. $-33.3\ \mathrm{J \cdot K^{-1}}$

2. $33.3\ \mathrm{J \cdot K^{-1}}$

3. $3\ \mathrm{J \cdot K^{-1}}$ **correct**

4. $-3\ \mathrm{J \cdot K^{-1}}$

Explanation:
Heat released by the system will increase the entropy of the surroundings by an amount equal to

$$\frac{q}{T} = \frac{900\ \mathrm{J}}{300\ \mathrm{K}} = 3\ \mathrm{J \cdot K^{-1}}\,.$$

ChemPrin3e T07 27
045 5.0 points

Use the Boltzmann formula to calculate the entropy at $T = 0$ of 1.00 mol chlorobenzene (C_6H_5Cl) where each molecule can be oriented in any of six ways.

1. $-\ 15\ \mathrm{J \cdot K^{-1}}$

2. $+30\ \mathrm{J \cdot K^{-1}}$

3. $+15\ \mathrm{J \cdot K^{-1}}$ **correct**

4. $-\ 30\ \mathrm{J \cdot K^{-1}}$

5. $0\ \mathrm{J \cdot K^{-1}}$ (at $T = 0$, there is no randomness).

Explanation:
The chlorobenzene molecule is hexagonal, so it has six ways of orienting. Since there is one mole, this means the number of microstates is 6^{N_A} where N_A is Avogadro's number. The residual entropy will be given by

$$\begin{aligned} S &= k\ \ln(6^{N_A}) = k\,N_A\ \ln 6 \\ &= \left(1.3807 \times 10^{-23}\ \frac{\mathrm{J}}{\mathrm{K}}\right)(6.022 \times 10^{23}) \ln 6 \\ &= +14.9948\ \mathrm{J/K} \end{aligned}$$

BP Ethanol
046 5.0 points

For the vaporization of ethanol, $\Delta H_{\mathrm{vap}} = 38.56$ kJ/mol and $\Delta S_{\mathrm{vap}} = 109.7$ J/mol·K. What is the boiling point of ethanol?

1. 273.502 K

2. 351.5 K **correct**

3. 2.84 K

4. 0.352 K

5. 2842 K

Explanation:

$$\begin{aligned} \Delta S_{\mathrm{vap}} &= \frac{q}{T} = \frac{\Delta H_{\mathrm{vap}}}{\mathrm{BP}} \quad \text{so} \\ \mathrm{BP} &= \frac{\Delta H_{\mathrm{vap}}}{\Delta S_{\mathrm{vap}}} \\ &= \frac{38.56 \times 10^3\ \mathrm{J/mol}}{109.7\ \mathrm{J/mol \cdot K}} \\ &= 351.504\ \mathrm{K} \end{aligned}$$

LDE Thermo 2nd Law Calc 006

047 5.0 points

Your roommate left 1 kg of ice out on the counter last night and all of it melted. If $\Delta H = 6.01\ \text{kJ} \cdot \text{mol}^{-1}$ and $\Delta S = 22.0\ \text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ for water melting and the temperature in the room was 25°C, by how much in total has your roommate increased the entropy of the universe?

1. $101.6\ \text{J} \cdot \text{K}^{-1}$ **correct**

2. $1.83\ \text{J} \cdot \text{K}^{-1}$

3. $0\ \text{J} \cdot \text{K}^{-1}$

4. $2340\ \text{J} \cdot \text{K}^{-1}$

Explanation:

$$\begin{aligned}\Delta S_{\text{surr}} &= -\frac{\Delta H}{T} = -\frac{6010\ \text{J} \cdot \text{mol}^{-1}}{298\ \text{K}} \\ &= -20.17\ \text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}\end{aligned}$$

$$\begin{aligned}\Delta S_{\text{univ}} &= \Delta S_{\text{sys}} + \Delta S_{\text{surr}} \\ &= 1.83\ \text{J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}\end{aligned}$$

$$\begin{aligned}1\ \text{kg of water} &= \frac{1000\ \text{g}}{18.0148\ \text{g} \cdot \text{mol}^{-1}} \\ &= 55.5\ \text{mol}\,,\end{aligned}$$

so the total increase is

$$(55.5 \cdot 1.83)\ \text{J} \cdot \text{K}^{-1} = 101.6\ \text{J} \cdot \text{K}^{-1}$$

ChemPrin3e T07 55

048 5.0 points

Consider the following compounds and their standard free energies of formation:

	cpd	energy
1	$C_6H_{12}(\ell)$ cyclohexane	$6.4\ \text{kJ}{\cdot}\text{mol}^{-1}$
2	$CH_3OH(\ell)$ methanol	$-166\ \text{kJ}{\cdot}\text{mol}^{-1}$
3	$N_2H_4(\ell)$ hydrazine	$149\ \text{kJ}{\cdot}\text{mol}^{-1}$
4	$H_2O_2(\ell)$ hydrogen peroxide	$-120\ \text{kJ}{\cdot}\text{mol}^{-1}$
5	$CS_2(\ell)$ carbon disulfide	$65.3\ \text{kJ}{\cdot}\text{mol}^{-1}$

Which of these liquids is/are thermodynamically stable?

1. 2 and 4 only **correct**

2. 1 only

3. 2 and 3 only

4. 1, 3, and 5 only

5. 3 only

Explanation:
A thermodynamically stable compound is one which has a negative value of $\Delta G^\circ_{\text{f}}$.

ChemPrin3e T07 52

049 5.0 points

Calculate $\Delta G^\circ_{\text{r}}$ for the decomposition of mercury(II) oxide

	$2\,\text{HgO(s)} \rightarrow$	$2\,\text{Hg}(\ell) +$	$O_2(g)$
$\Delta H^\circ_{\text{f}}$ $(\text{kJ} \cdot \text{mol}^{-1})$	-90.83	–	–
$\Delta S^\circ_{\text{m}}$ $(\text{J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1})$	70.29	76.02	205.14

at 298 K.

1. $+246.2\ \text{kJ} \cdot \text{mol}^{-1}$

2. $+117.1\ \text{kJ} \cdot \text{mol}^{-1}$ **correct**

3. $-64.5\ \text{kJ} \cdot \text{mol}^{-1}$

4. $-117.1\ \mathrm{kJ \cdot mol^{-1}}$

5. $-246.2\ \mathrm{kJ \cdot mol^{-1}}$

Explanation:
In order to find $\Delta G_\mathrm{r}^\circ$ at 298 K, we must first calculate $\Delta H_\mathrm{r}^\circ$ and $\Delta S_\mathrm{r}^\circ$.

$$\begin{aligned}\Delta S_\mathrm{r}^\circ &= 2 \cdot S^\circ_{\mathrm{Hg}(\ell)} + S^\circ_{\mathrm{O_2(g)}} - 2 \cdot S^\circ_{\mathrm{HgO(s)}}\\ &= 2\left(76.02\ \frac{\mathrm{J}}{\mathrm{K \cdot mol}}\right) + 205.14\ \frac{\mathrm{J}}{\mathrm{K \cdot mol}}\\ &\quad - 2\left(70.20\ \frac{\mathrm{J}}{\mathrm{K \cdot mol}}\right)\\ &= 216.6\ \frac{\mathrm{J}}{\mathrm{K \cdot mol}}\end{aligned}$$

$$\begin{aligned}\Delta H_\mathrm{r}^\circ &= 2 \cdot H^\circ_{\mathrm{Hg}(\ell)} + H^\circ_{\mathrm{O_2(g)}} - 2 \cdot H^\circ_{\mathrm{HgO(s)}}\\ &= 0 - 2\,(-90.83\ \mathrm{kJ/mol})\\ &= 181.64\ \mathrm{kJ/mol}\end{aligned}$$

$$\begin{aligned}\Delta G_\mathrm{r}^\circ &= \Delta H_\mathrm{r}^\circ - T\,\Delta S_\mathrm{r}^\circ\\ &= 181.64\ \mathrm{kJ/mol} - (298\ \mathrm{K})\\ &\quad \times \left(216.6\ \frac{\mathrm{J}}{\mathrm{K \cdot mol}}\right)\left(\frac{1\ \mathrm{kJ}}{1000\ \mathrm{J}}\right)\\ &= 117.093\ \mathrm{kJ/mol}\end{aligned}$$

ChemPrin3e T07 61
050 5.0 points

For the reaction

$$2\,\mathrm{SO_3(g)} \rightarrow 2\,\mathrm{SO_2(g)} + \mathrm{O_2(g)}$$

$\Delta H_\mathrm{r}^\circ = +198\ \mathrm{kJ \cdot mol^{-1}}$ and $\Delta S_\mathrm{r}^\circ = 190\ \mathrm{J \cdot K^{-1} \cdot mol^{-1}}$ at 298 K. The forward reaction will be spontaneous at

1. temperatures above 1042 K. **correct**

2. no temperature.

3. temperatures above 1315 K.

4. all temperatures.

5. temperatures below 1042 K.

Explanation:

$$\Delta H_\mathrm{r}^\circ = +198\ \mathrm{kJ/mol} \qquad \Delta S_\mathrm{r}^\circ = 0.019\ \frac{\mathrm{kJ}}{\mathrm{mol \cdot K}}$$

$$\Delta G^0 = \Delta H^0 - T\Delta S$$

$\Delta G^0 < 0$ for a spontaneous reaction, so

$$\begin{aligned}0 &> \Delta H^0 - T\,\Delta S\\ T &> \frac{\Delta H^0}{\Delta S^0} = \frac{198\ \mathrm{kJ/mol}}{0.019\ \frac{\mathrm{kJ}}{\mathrm{mol \cdot K}}} = 1042.11\ \mathrm{K}\end{aligned}$$

Thus the temperature would need to be > 1042.11 K.