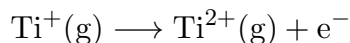This print-out should have 50 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

---

001   2.0 points

The second ionization energy of Ti is given by the reaction:

$$Ti^+(g) \longrightarrow Ti^{2+}(g) + e^-$$

This electron is removed from the:

1. 4p subshell

2. 4d subshell

3. 3s subshell

4. 3d subshell

5. 3p subshell

6. 4s subshell **correct**

Explanation:

When removing electrons from transition metals, you must acknowledge that the filled d orbitals are lower in energy than the filled s orbitals. Therefore, the electrons removed will be the higher energy s subshell electrons.

---

002   2.0 points

Name the bond in carbon dioxide (CO_2) that forms as a result of head-on overlap on the internuclear axis.

1. σ_{2p-2p}

2. π_{2p-2p}

3. $\pi_{sp^3-sp^3}$

4. $\pi_{sp^2-sp^2}$

5. σ_{sp-sp}

6. σ_{sp-sp^2} **correct**

7. $\sigma_{sp^2-sp^2}$

8. σ_{sp^2-2p}

Explanation:

A sigma bond forms from head-on overlap. For oxygen, this is $\sigma_{sp^2-sp^2}$. For nitrogen, this is σ_{sp-sp}. For carbon dioxide, this is σ_{sp-sp^2}.

---

003   2.0 points

When an endothermic reaction has a positive internal energy change for the system,

I. the internal energy of the system is the sum of all energy (potential and kinetic) in the system

II. $\Delta H_{rxn} > 0$

III. there is an overall energy change in the universe

IV. heat enters the system from the surroundings

1. I and IV only

2. I, II, and IV only **correct**

3. III and IV only

4. I and II only

5. II only

6. I, II, III and IV

7. I only

Explanation:

The first law of thermodynamics can be summed up with the idea that energy is always conserved in the universe. Mathematically, this means that:

$$\Delta U_{sys} = -\Delta U_{surr}$$

$$\Delta U_{universe} = \Delta U_{sys} + \Delta U_{surr}$$

$$\Delta U_{universe} = 0$$

Internal energy is defined as the total energy content of a system. This can be represented as the sum of heat and work or as the sum of potential and kinetic energy. For an endothermic reaction, the heat flows from the

surroundings to the system.

---

004   2.0 points

Rank the following ionic compounds from least to greatest lattice energy:

$CaCl_2$, MgO, $MgCO_3$, NaF

1. $MgCO_3 < CaCl_2 < MgO < NaF$

2. $MgO < NaF < CaCl_2 < MgCO_3$

3. $NaF < CaCl_2 < MgO < MgCO_3$

4. $MgCO_3 < CaCl_2 < NaF < MgO$

5. $NaF < CaCl_2 < MgCO_3 < MgO$ **correct**

Explanation:

Lattice energy depends on charge and ionic radius. Rank first based on a charge so that the largest charges have the highest lattice energy. The smallest lattice energy in the list is NaF and the highest lattice energy is MgO. If two compounds have the same charges, the highest lattice energy will be the smaller ionic compound. This gives a final answer of:

$NaF < CaCl_2 < MgCO_3 < MgO$

---

005   2.0 points

Based on the hard sphere model of gases, which of the following gases is most likely to deviate from ideal behavior?

1. Ne

2. Kr

**3.** Xe **correct**

4. Ar

5. He

Explanation:

The hard sphere model adjusts the ideal gas law based on the volume of the particles. Therefore, ideal gas behavior is best modeled when the gas particles are smaller in volume, which correlates with lower molecular weight. Larger gas particles (high molecular weight)

are expected to deviate from ideal behavior.

---

006   2.0 points

The graph shows the approximate Maxwell-Boltzmann distribution plots for three different gases at the same temperature.
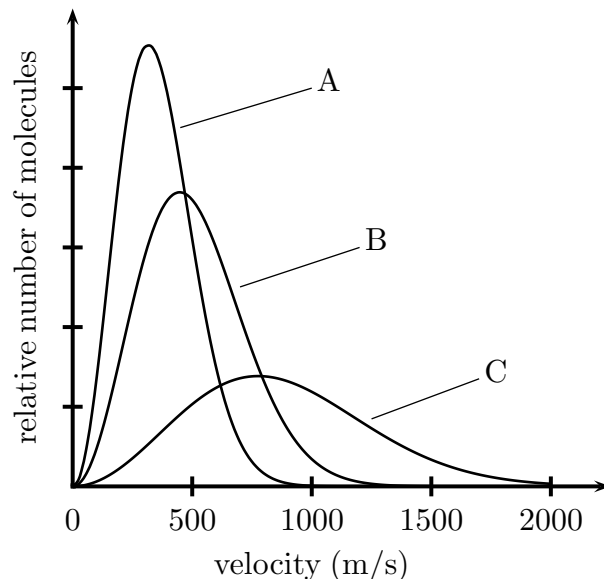
Which of the following statements is true?

1. Gas C has the greatest kinetic energy

2. The v_{rms} for Gas A is 1500 m/s

3. Gas B is heavier than Gas A

4. The gas with the highest molecular weight is Gas A **correct**

Explanation:

The gas with the highest molecular weight is Gas A

---

007   2.0 points

Rank the following substances in order of vapor pressure: Cl_2, I_2, Br_2, F_2

1. $I_2 < F_2 < Cl_2 < Br_2$

2. $Br_2 < Cl_2 < I_2 < F_2$

3. $F_2 < Cl_2 < Br_2 < I_2$

4. $F_2 < Cl_2 < I_2 < Br_2$

5. $I_2 < Br_2 < Cl_2 < F_2$ **correct**

Explanation:
When determining the relative IMFs within a group, you should rank based on polarizability (molecular weight). Therefore, the ranking is: $F_2 < Cl_2 < Br_2 < I_2$ Vapor pressure goes opposite of IMF strength, giving the answer: $I_2 < Br_2 < Cl_2 < F_2$.

---

008   2.0 points
A 5.58 gram gas sample has a volume of 4.15 L, a pressure of 0.78 atm, and a temperature of 311 K. Which of the following gases is it?

1. O_2

2. CO_2 **correct**

3. Ne

4. SO_2

5. SF_6

6. NH_3

Explanation:
MWt = mass (m)/moles(n)
$n = PV/RT$
MWt $= mRT/PV$
$= 5.58(0.08206)(311)/(0.78 \cdot 4.15)$
$= 44$ g/mol which is CO_2

---

009   2.0 points
How many moles are in 63.0 g of $(NH_4)_2Cr_2O_7$?

1. 1.00 mol

2. 4.00 mol

3. 0.500 mol

4. 0.250 mol **correct**

Explanation:
m = 63.0 g
Calculate the formula weight of $(NH_4)_2Cr_2O_7$:

$$2\left(14 \frac{\text{g N}}{\text{mol}}\right) + 8\left(1 \frac{\text{g H}}{\text{mol}}\right) + 2\left(52 \frac{\text{g Cr}}{\text{mol}}\right)$$
$$+7\left(16 \frac{\text{g C}}{\text{mol}}\right) = 252 \text{ g/mol cmpd}$$

Given 63.0 g of $(NH_4)_2Cr_2O_7$, convert to moles by using the formula weight:

$$n_{\text{cmpd}} = 63.0 \text{ g cmpd}$$
$$\times \frac{1 \text{ mol cmpd}}{252 \text{ g cmpd}}$$
$$= 0.250 \text{ mol cmpd}$$

---

010   2.0 points
Which set of quantum numbers is possible for an electron in the p subshell found in the ground state of Br?

1. $n = 4, \ell = 1, m_\ell = +1, m_s = -\frac{1}{2}$ **correct**

2. $n = 4, \ell = 0, m_\ell = 0, m_s = +\frac{1}{2}$

3. $n = 1, \ell = 1, m_\ell = +2, m_s = -\frac{1}{2}$

4. $n = 4, \ell = 4, m_\ell = +2, m_s = +\frac{1}{2}$

5. $n = 3, \ell = 2, m_\ell = +2, m_s = +\frac{1}{2}$

6. $n = 4, \ell = 2, m_\ell = +1, m_s = -\frac{1}{2}$

Explanation:
The subshell of an electron indicates the angular momentum quantum number, ℓ. The p subshell has an ℓ number equal to 1. The value of n for Br can be any integer up to 4 for the s and p orbitals, and up to 3 for the d orbitals. The value of m_ℓ is -1 to $+1$. Lastly, m_s can be $+\frac{1}{2}$ or $-\frac{1}{2}$. Only one answer choices matches these rules for the p subshell of Br.

---

011   2.0 points
The rate of effusion for carbon monoxide (CO) is ____ times the rate of effusion for xenon (Xe) gas .

1. 2.17 **correct**

2. 1.59

3. 4.69

4. 3.06

5. 1.16

Explanation:
The rate of effusion can be interchanged with v_{rms} to give a ratio equal to:

$$\frac{v_1}{v_2} = \sqrt{\frac{M_2}{M_1}}$$

Solving for the ratio of CO : Xe gives

$$\frac{v_1}{v_2} = \sqrt{\frac{131.29}{28.01}} = 2.17$$

012   2.0 points
A 115 nm beam of light is shined on a gold surface. What is the maximum velocity of the excited electrons? The work function of gold is 5.10 eV.

1. -1000 km/s

2. 1200 km/s

3. 2.001×10^9 km/s

4. 1000 km/s

5. 1×10^6 km/s

6. 1415 km/s **correct**

7. No electrons are emitted

Explanation:
Using the photoelectric equation:

$$E_k = h\nu - \phi$$

The KE of any photoelectron produced is the remainder after the work function has been subtracted from the energy of the photon.

$$E_{photon} = \frac{(6.626 \times 10^{-34} Js)(3.00 \times 10^8 \frac{m}{s})}{115 \times 10^{-9} m}$$

$$E_{photon} = 1.73 \times 10^{-18} \text{ J}$$

$$\text{Work function} = 5.10 \text{ eV } (1.60 \times 10^{-19} \frac{J}{eV})$$
$$= 8.17 \times 10^{-19} \text{ J}$$

The kinetic energy is the difference between the photon energy and the work function, which is 9.12×10^{-19} J. Finally, the kinetic energy equation gives $E_k = 1/2mv^2$, which can be used to solve for the velocity in m/s. Answering in km/s gives us 1415 km/s.

---

013   2.0 points
Consider the combustion of propane (C_3H_8) run at constant temperature and pressure:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$
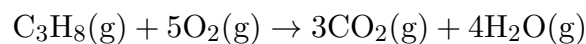
If 2.60 L propane is reacted with 15.6 L oxygen, what is the final volume of all gases?

1. 2.60 L

2. 20.8 L **correct**

3. 18.2 L

4. 41.6 L

5. 15.6 L

Explanation:
Pentane is the limiting reactant with 2.60 L. You can use the amount of pentane to solve for the total volume of each product and the excess volume of oxygen.

Solve for the volume of carbon dioxide:
$$2.60 \text{ L } C_3H_8 \times \frac{3 \text{ L } CO_2}{1 \text{ L } C_3H_8} = 7.80 \text{ L}$$

Solve for the volume of water vapor:
$$2.60 \text{ L } C_3H_8 \times \frac{4 \text{ L } H_2O}{1 \text{ L } C_3H_8} = 10.4 \text{ L}$$

Solve for the volume of excess oxygen:
$$15.6 \text{ L } O_2 - \left(2.60 \text{ L } C_3H_8 \times \frac{5 \text{ L } O_2}{1 \text{ L } C_3H_8} \right)$$

$= 2.60\,\text{L}$

Solve for the total pressure:

$7.80 + 10.4 + 2.60 = 20.8\,\text{L total}$

---

014   2.0 points

Consider the van der Waals equation for non ideal gases. Which of the following statements is true?

1. $(V - nb)$ represents the total volume of the gaseous system

2. Attractions cause the ideal pressure to be greater than the measured (real) pressure **correct**

3. $(P + \dfrac{an^2}{V^2})$ represents the measured pressure

4. This equation can only be used to model ideal gases

5. A large b value correlates with a low molecular weight

Explanation:
The van der Waals equation for non ideal gases is given below:

$$(P + \frac{an^2}{V^2})(V - nb) = nRT$$

In this equation, $(P + \dfrac{an^2}{V^2})$ represents the ideal pressure and $(V - nb)$ represents the available volume after making the corrections. The a term corrects for attractions and the b term corrects for the size of the particles (repulsions). Mathematically, the measured pressure is less than the ideal pressure. The available volume is less than the total volume.

---

015   2.0 points

Which of the following molecules is non-polar?

1. PCl_3

2. H_2O

3. BeF_2 **correct**

4. NH_3

5. CH_3Cl

Explanation:
BeF_2 has polar bonds, but they are canceled out by its symmetric molecular and electronic structure.

---

016   2.0 points

Consider the following balanced chemical reaction:

$$2HOCl(g) \rightarrow 2HCl(g) + O_2(g)$$

At a certain temperature, 98.2 grams of hypochlorous acid (HOCl) fully decomposes to give a final pressure of 680 torr. What is the partial pressure of oxygen in the final reaction system?

1. 680 torr

2. 1020 torr

3. 227 torr **correct**

4. 1223 torr

5. 340 torr

Explanation:
This question can be easily reduced to a simple partial pressure problem by conceptually understanding that when HOCl reacts completely, it will be create a ratio of $2HCl : 1O_2$ no matter what. Therefore, we don't need to solve for the exact quantities.

$P_{O_2} = X_{O_2} P_{\text{tot}}$

$227 = (1/3)(680)$

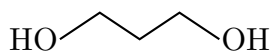### 017   2.0 points

Which of the following has the highest boiling point?

1.

2. OH

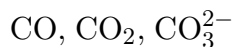**3.** O

4. HO OH **correct**

5. NH$_2$
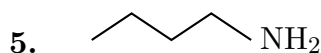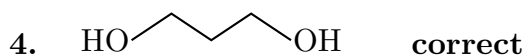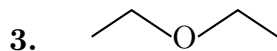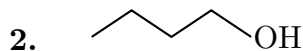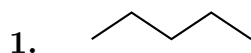
Explanation:
The molecule that has the highest boiling point will have the strongest IMF's. Of the molecules shown, the molecule will the strongest IMF's will exhibit the most hydrogen bonding.

HO OH

---

018   2.0 points
Consider the following molecules:

CO, CO$_2$, CO$_3^{2-}$

Which molecule has the weakest covalent bonds?

1. All carbon-oxygen bonds have the same strength bonds

2. CO

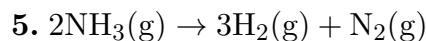**3.** Both CO$_3^{2-}$ and CO$_2$ have the weakest bonds
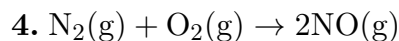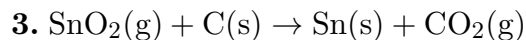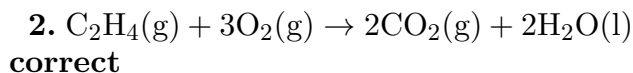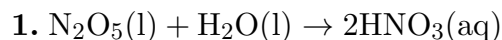
4. CO$_2$

5. CO$_3^{2-}$ **correct**

Explanation:
Carbon monoxide contains a triple bond between carbon and oxygen. Carbon dioxide contains a double bond between the carbon and oxygen atoms. Carbonate is a resonance structure that contains a double bond and two single bonds. Averaged, this results in approximate 1.33 bonds between the carbon and oxygen atoms. Therefore, carbon monoxide has the strongest and shortest bonds. Carbonate has the weakest and longest bonds.

---

019   2.0 points
For which of the following reactions is $\Delta U_{\text{sys}} > \Delta H_{\text{sys}}$ at constant external pressure?

1. $N_2O_5(l) + H_2O(l) \rightarrow 2HNO_3(aq)$

2. $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$ **correct**

3. $SnO_2(g) + C(s) \rightarrow Sn(s) + CO_2(g)$

4. $N_2(g) + O_2(g) \rightarrow 2NO(g)$

5. $2NH_3(g) \rightarrow 3H_2(g) + N_2(g)$

Explanation:
Based on the first law equation:

$$\Delta U = \Delta H - \Delta nRT,$$

it can be seen that this question is essentially asking to either identify the compression reaction ($\Delta U_{\text{sys}} > \Delta H_{\text{sys}}$) or the expansion reaction ($\Delta U_{\text{sys}} < \Delta H_{\text{sys}}$).

The compression reaction:

$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l)$$

The expansion reaction:

$$2NH_3(g) \rightarrow 3H_2(g) + N_2(g)$$

---
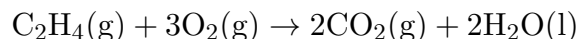
020   2.0 points

In an acceptable Lewis structure for NO_2^-, what is the formal charge on the central atom?

1. -2

2. None of the above

3. 0 **correct**

4. +1

5. +2

6. -1

Explanation:
Formal charge can be expressed with the following basic formula:

$$F.C. = V.E. - (Bonds + L.E.)$$

The nitrogen has one lone pair and is connected to three bonds total, resulting in a formal charge of 0.

---

021   2.0 points
Arrange the following substances in order from highest to lowest melting point:

C(s, diamond), CH_3CH_2OH, RbF, $MgCO_3$

1. C(s, diamond) > $MgCO_3$ > CH_3CH_2OH > RbF

2. C(s, diamond) > $MgCO_3$ > RbF > CH_3CH_2OH **correct**

3. CH_3CH_2OH > $MgCO_3$ > RbF > C(s, diamond)

4. C(s, diamond) > RbF > $MgCO_3$ > CH_3CH_2OH

5. CH_3CH_2OH > RbF > $MgCO_3$ > C(s, diamond)

Explanation:
C(s, diamond) is a network covalent solid. Both $MgCO_3$ and RbF are ionic solids, but $MgCO_3$ has a greater charge density. CH_3CH_2OH is a molecular solid. Thus, arranging the compounds in order from highest

to lowest melting point, we get:

C(s, diamond) > $MgCO_3$ > RbF > CH_3CH_2OH .

---

022   2.0 points
Consider the diagram shown below of two glass bulbs connected through a valve. The volume for each gas (A and B) is shown under the bulbs and the gases also happen to be at the same temperature (337K) and pressure (685 torr).

51 L   16 L
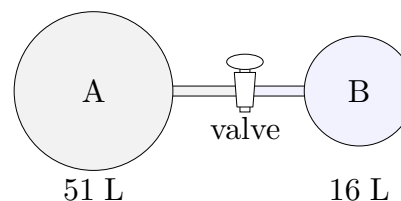
After the valve is opened, the two gases mix completely. What is the partial pressure of gas A in this new (opened valve) state?

1. 214.9 torr

2. 163.6 torr

3. 521.4 torr **correct**

4. 685 torr

5. 2183 torr

Explanation:
When the valve is opened the total available volume for both gases is now 67 liters, but the total pressure remains 420 torr. This means (Boyle's Law) that the gas A pressure will drop by a factor of 51/67.

$(51/67)(685) = 521.4$ torr for gas A.

---

023   2.0 points
Use bond energy data to determine ΔH_{rxn} for the following reaction:

$CH_4 + 2Cl_2 \rightarrow CCl_4 + 2H_2$
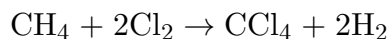
1. 45 kJ/mol

2. -45 kJ/mol

3. -90 kJ/mol **correct**

4. -180 kJ/mol

5. 90 kJ/mol

Explanation:
Drawing a Lewis Structure for each product and reactant will show the number of each type of bond in the reaction. Subtracting the enthalpy of bonds on the reactant side (bonds broken) by the enthalpy of bonds on the products side (bonds formed) gives -90 kJ/mol.

---

024   2.0 points

Which of the following can form hydrogen bonds with another molecule of itself?

I. Ammonia

II. Ethanol

III. CH_3OCH_3

IV. H_2CO

1. I only

2. I, II, III, IV

3. I, III, IV only

4. I, II only **correct**

Explanation:
The only molecules listed capable of making a hydrogen bond are ammonia and ethanol.

---

025   2.0 points

When a 0.401 g sample of a clean-burning hydrocarbon (molecular weight = 42.05 g/mol) is combusted in a rigid container, the temperature increases from 24.987°C to 28.623°C. The total volume of water is 0.746 L. The sum of all hardware components of the calorimeter have a heat capacity of 2.24 kJ/°C. Calculate the internal energy of combustion for one mole of this hydrocarbon.

1. -19.4936 kJ/mol

2. +2044.15 kJ/mol

3. +3.26600 kJ/mol

4. -3.26600 kJ/mol

5. +8150.74 kJ/mol

6. -2044.15 kJ/mol **correct**

7. +19.4936 kJ/mol

8. +48.6124 kJ/mol

Explanation:
Heat released by the combustion reaction:

$$q = mC\Delta T + C\Delta T$$

$$q_{cal} = (746)(4.184)(3.636) + (2.24 \times 1000)(3.636)$$

$$q_{cal} = 19493.6 J$$

For the system, q_v = -q_{cal}:

$$q_v = -19.4936 kJ$$

This is how much heat was released when 0.401 g of hydrocarbon was combusted (we consider it to be negative). Convert to this to how much heat would be released per mole of ethylene combusted.

$$\frac{-19.4936\,\text{kJ}}{0.401\,\text{g}} \times \frac{42.05\,\text{g}}{1\,\text{mol}} = -2044.15\,\text{kJ/mol}$$

---

026   2.0 points

Which of the following choices is the correct line structure for propionaldehyde, CH_3CH_2CHO?

1.

```
        H  :O—H
        |   |
    H—C—C=C—H
        |   |
        H   H
```

2.

```
        H  H  :O:
        |  |   ‖
    H—C—C—C—H      correct
        |  |
        H  H
```

3.

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{..}{\underset{..}{C}}-\overset{..}{\underset{..}{O}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-H$$

4.

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}=\overset{..}{\underset{..}{O}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-H$$

5.

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle :O:}{||}}{C}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-H$$

6.

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{..}{\underset{..}{C}}=\overset{..}{\underset{..}{O}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-H$$

7.

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{..}{\underset{..}{O}}H$$

Explanation:

Acetone:

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle :O:}{||}}{C}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-H$$

Propionaldehyde:

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle :O:}{||}}{C}-H$$

Propanol:

$$H-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{\overset{\textstyle H}{|}}{\underset{\underset{\textstyle H}{|}}{C}}-\overset{..}{\underset{..}{O}}H$$
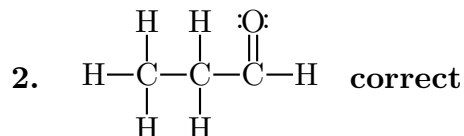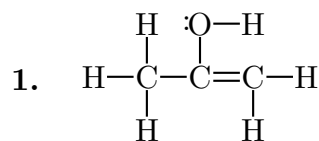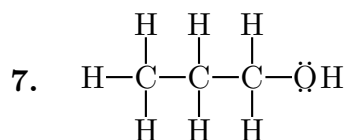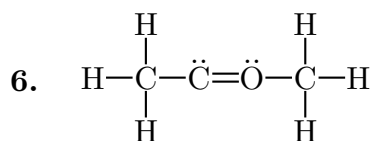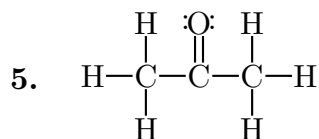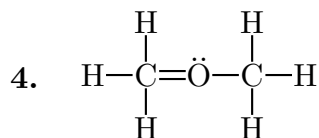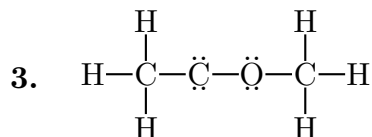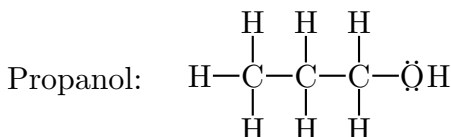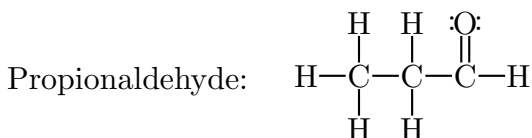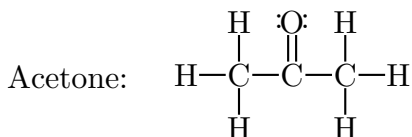
027   2.0 points

Select the option that correctly lists the substances in order of INCREASING boiling points.

1. None of these places the substances in correct order of increasing boiling points

2. O_2, NH_3, C_2H_6, C_3H_8, H_2O, CaO, NaCl

3. O_2, C_2H_6, C_3H_8, NH_3, H_2O, NaCl, CaO

correct

4. O_2, NH_3, C_3H_8, C_2H_6, NaCl, CaO, H_2O

5. O_2, C_3H_8, C_2H_6, NH_3, H_2O, NaCl, CaO

Explanation:

Consider the following IMF's in increasing order: dispersion forces, dipole-dipole, hydrogen-bonding, ionic. Therefore, the boiling points of the substances listed will following this same trend: O_2, C_2H_6, C_3H_8, NH_3, H_2O, NaCl, CaO

028   2.0 points

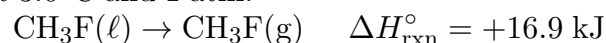Calculate the ΔS_{surr} for the following reaction at 3.0°C and 1 atm.

$$CH_3F(\ell) \rightarrow CH_3F(g) \quad \Delta H^\circ_{\text{rxn}} = +16.9 \text{ kJ}$$

1. 61.2 J/K

2. -5.63 J/K

3. -2820 J/K

4. 5630 J/K

5. 5.63 J/K

6. -61.2 J/K **correct**

Explanation:

In general for any process:

$$\Delta S_{\text{surr}} = \frac{-\Delta H_{\text{sys}}}{T_{\text{surr}}}$$

This is because the heat flow in the surroundings is just the opposite of the heat flow for the system ($q_{\text{surr}} = -q_{\text{sys}}$) and at constant pressure the heat is equal to ΔH.

therefore $\Delta S_{\text{surr}} = -16900/(3.0 + 273.15)$
$$= -61.2 \text{ J/K}$$

029   2.0 points

When a cold gas absorbs white light, you see a continuous absorption spectrum broken by thin black lines in the blue and purple region. Which of the following best describes the emission spectrum of this gas when it is excited with electricity?

1. A continous spectrum broken by black lines shifted to slightly longer wavelengths

2. Mostly black with thin lines in the blue and purple region **correct**

**3.** Mostly black with thin lines in the yellow and orange region

4. A continuous spectrum broken by black lines in the yellow and orange region

Explanation:
The emission spectrum will be opposite of the absorption spectrum. Therefore, you will see a mostly black spectrum with thin lines in the blue and purple region. Both spectra depict the discrete energy levels of electrons, so you will not see patterns at other wavelengths (such as yellow or orange).

030   2.0 points

Consider the following molecule:

$$:\ddot{C}l - \ddot{X} - \ddot{C}l:$$
$$:\ddot{C}l: \quad :\ddot{C}l:$$
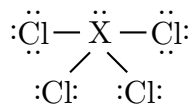
What is the identify of the central atom, X?

1. Oxygen

2. Selenium **correct**

3. Phosphorus

4. Nitrogen

5. Carbon

6. Chlorine

Explanation:
The molecule shown has a central atom with a formal charge equal to 0. You can solve for the valence using the formula:

$$\text{F.C.} = \text{V.E.} - (\text{Bonds} + \text{L.E.})$$
$$0 = \text{V.E.} - 6$$

Therefore, your central atom must be in group 6. It is also exhibiting expanded valence, meaning it must be at least a 3rd period element. X = Selenium.

031   2.0 points
The compressibility factor (Z) for a gas at 400 atm is less than one. How can you make an accurate gas law calculation for this gas at 400 atm?

1. This gas can be modeled ideally at this pressure because $PV = nRT$

2. This gas can be modeled ideally at this pressure because $PV < nRT$

3. You must correct for repulsive forces because $PV > nRT$

4. You must correct for attractive forces because $PV < nRT$ **correct**

5. You must correct for repulsive forces because $PV < nRT$

6. This gas can be modeled ideally at this pressure because $PV > nRT$

7. You must correct for attractive forces because $PV > nRT$

Explanation:
The compressibility factor can have three conditions.

If $PV > nRT$, $Z > 1$ and repulsions dominate.

If $PV < nRT$, $Z < 1$ and attractions dominate.

If $PV = nRT$, $Z = 1$ and the gas can be modeled ideally.

032   2.0 points
VSEPR theory can estimate imperfect bond angles based on the fact that

1. bonding regions are more repulsive than lone pair regions

2. bonding regions attract each other while lone pair regions repel each other

**3.** lone pair regions are more repulsive than bonding regions **correct**

4. molecular orbitals hybridize

Explanation:
Lone pair regions on the central atom are pulled closer toward the nucleus. Therefore, the repulsive forces are stronger than in a bonding region. This causes bond angles to be slightly less than predicted by the electronic geometry. Molecular orbitals do hybridize, but this is not an explanation for why a molecule will form imperfect bond angles.

---

033   2.0 points
Carbon dioxide is a unique substance that sublimes at atmospheric pressure. Assuming no excess heat is supplied to the system at constant pressure, what are the signs of ΔH, ΔS, and w for the following phase change reaction at -78.5°C?

$$CO_2(s) \rightarrow CO_2(g)$$
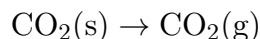
1. $\Delta H > 0, \Delta S > 0, w > 0$

2. $\Delta H > 0, \Delta S < 0, w < 0$

3. $\Delta H > 0, \Delta S > 0, w < 0$ **correct**

4. $\Delta H < 0, \Delta S < 0, w = 0$

5. $\Delta H > 0, \Delta S > 0, w = 0$

Explanation:
The phase change from (s) to (g) requires energy, which is a positive change in enthalpy. Creating a gas from a solid is a positive change in entropy and a negative change in work (work is done on the system via compression).

---

034   2.0 points
Consider the MO diagram for N_2^{2+}. What is the bond order? Is N_2^{2+} paramagnetic or diamagnetic?

1. 2, paramagnetic

2. 1.5, paramagnetic

3. 2.5, paramagnetic

4. 2, diamagnetic **correct**

5. 2.5, diamagnetic

6. 1, diamagnetic

7. 1.5, diamagnetic

Explanation:
N_2^{2+} has 6 bonding electrons and 2 anti-bonding electrons.

$$\begin{aligned} \text{BO} &= \frac{1}{2}[(\text{bonding e}^-) - (\text{antibonding e}^-)] \\ &= \frac{1}{2}(6-2) = 2 \end{aligned}$$

N_2^{2+} does not have unpaired electrons and is therefore diamagnetic.

---

035   2.0 points
Which of the following terms is path-dependent?

1. Work **correct**

2. Heat Capacity

3. Enthalpy

4. Free Energy

5. All of the above

Explanation:
The only path function of the choices is Work.

---

036   2.0 points
What is the wavelength of a 5.80 $\times 10^{14}$ Hz light ray?

1. 789 nm

2. 441 nm

3. 0.666 nm

4. 882 nm

5. 0.792 nm

6. 0.288 nm

7. 992 nm

8. 517 nm **correct**

Explanation:
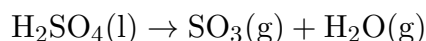Using the relationship between light, wavelength, and frequency:

$$c = \lambda\nu$$

$$\lambda = c/\nu$$

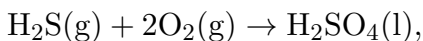You must calculate for wavelength and convert from meters to nanometers:
$$(2.998 \times 10^8 / 5.80 \times 10^{14}) \times 10^9$$

$$= 517 \text{ nm}$$

---

037   2.0 points
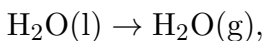Consider the following balanced chemical reaction:

$$H_2SO_4(l) \rightarrow SO_3(g) + H_2O(g)$$

To solve for the ΔH°_{rxn} for this reaction, you collect the following data in the lab:

$H_2S(g) + 2O_2(g) \rightarrow H_2SO_4(l)$,

$$\Delta H^\circ_{rxn} = \text{-241.3 kJ/mol}$$

$H_2S(g) + 2O_2(g) \rightarrow SO_3(g) + H_2O(l)$,

$$\Delta H^\circ_{rxn} = \text{-205.6 kJ/mol}$$

$H_2O(l) \rightarrow H_2O(g)$,
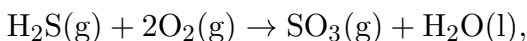
$$\Delta H^\circ_{rxn} = 41.9 \text{ kJ/mol}$$

What is the ΔH°_{rxn} of the overall balanced reaction?

1. 77.6 kJ/mol **correct**

2. 489 kJ/mol

3. -646 kJ/mol

4. 319 kJ/mol

5. -405 kJ/mol

Explanation:
The objective is to arrange the three reactions so that the sum of the reactions gives you the overall balanced chemical reaction. This is accomplished simply by reversing the first reaction and flipping the sign of that enthalpy of reaction. From there:

$\Delta H^\circ_{rxn} = -(-241.3) + (-205.6) + (41.9) = 77.6\text{kJ/mol}$

---

038 (part 1 of 3) 2.0 points
The molecule shown below is a rare alkaloid found in plants native to South America with profound cultural significance.
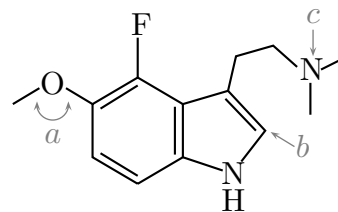
What is the correct empirical formula for this compound?

1. $C_{13}H_{12}FN_2O$

2. $C_{13}H_{19}FN_2O$

3. $C_{15}H_{17}FN_2O$

4. $C_{12}H_{15}FN_2O$

5. $C_{13}H_{19}N_2O$

6. $C_{13}H_{17}FN_2O$ **correct**

Explanation:
The empirical formula is $C_{13}H_{17}FN_2O$.

---

039 (part 2 of 3) 2.0 points
Which of the following best represents the bond angle labeled a?

1. $109.5°$

2. 178°

3. 90°

4. 104.5° **correct**

5. 120°

6. 118°

7. 180°

Explanation:
There are two (not shown) lone pairs on the O there which means there are 4 electron regions and therefore a tetrahedral electronic geometry which has a bond angle of 109.5°. The lone pairs are more repulsive than the bonding pairs and therefore pushes the angles down to about 104.5°.

---

040 (part 3 of 3) 2.0 points
What is the electronic geometry around the central atom labeled b?

1. Tetrahedral

2. Trigonal pyramid

3. Bent

4. Trigonal planar **correct**

5. Seesaw

Explanation:
In the line drawing, b has an understood hydrogen atom attached, giving the carbon a trigonal planar structure. The nitrogen labeled c has an understood lone pair, which gives it a tetrahedral electronic geometry.

---

041 (part 1 of 2) 2.0 points

Use the following structure to answer the next two questions:
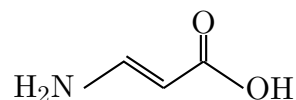
How many sigma and pi bonds are in the organic structure above?

1. 12 σ and 2 π

2. 12 σ only

3. 10 σ and 2 π **correct**

4. 10 σ and 4 π

5. 8 σ and 2 π

Explanation:
Accounting for the "understood" hydrogen atoms, there are a total of 8 single bonds and 2 double bonds. This is a total of 10 σ and 2 π.

---

042 (part 2 of 2) 2.0 points
For the structure shown above, what is the hybridization around the carbonyl carbon (i.e. the carbon with the double bond to oxygen)?

1. sp^3

2. sp^3d

3. sp^2 **correct**

4. sp^3d^2

5. sp

Explanation:
The carbonyl carbon (i.e. the carbon with the double bond to oxygen) has three regions of electron density, corresponding to a sp^2 hybridization.

---

043   2.0 points
Consider a reaction that has a negative change in entropy and a negative change in enthalpy. Which of the following conditions will favor spontaneity?

1. This reaction is non-spontaneous at all temperatures

2. This reaction is spontaneous at all temperatures

3. Low Temperatures **correct**

4. High Temperatures

Explanation:
For this reaction, the spontaneity will be driven by the enthalpy term. This reaction will spontaneous only at low temperatures.

---

044   2.0 points
A chemical reaction absorbs 55.3 kJ heat while 16.9 kJ work is done on the system via compression. What is the change in the internal energy (ΔU) for the system?

1. 33.4 kJ

2. 72.2 kJ **correct**

3. 67.2 kJ

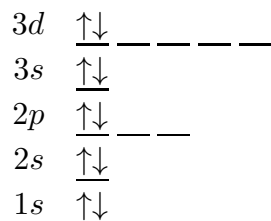**4.** 38.4 kJ

5. 89.1 kJ

6. -38.4 kJ

Explanation:

$$\Delta U_{\text{sys}} = q + w$$

$$72.2\text{kJ} = (55.3\text{kJ}) + (16.9\text{kJ})$$

---

045   2.0 points
A fellow student completes an electron filling diagram for a ground state atom as shown below:

$3d$ ↑↓ __ __ __ __

$3s$ ↑↓

$2p$ ↑↓ __ __

$2s$ ↑↓

$1s$ ↑↓

Understanding that your fellow student's electron filling diagram is not necessarily correct (*i.e.*, the electrons have not necessarily been placed in the correct orbitals), what is the electron configuration for this atom?

1. $1s^2 2s^2 2p^2 3s^2 3d^2$

2. $1s^2 2s^2 2p^6$ **correct**

3. $1s^2 2s^2 2p^6 3s^2$

4. $1s^1 2s^1 2p^3 3s^1 3d^4$

5. $1s^2 2s^2 2p^3 3s^2 3d^1$

Explanation:
The electron filling diagram is not properly filling the electrons in accordance with The Aufbau Principle and Hund's Rule. Properly filling the diagram gives you the electron configuration for neon, which is $1s^2 2s^2 2p^6$.

---

046   2.0 points
For which of the following chemical equations would $\Delta H^\circ_{\text{rxn}} = \Delta H^\circ_{\text{f}}$?

1. $CH_4(g) \rightarrow C(s, \text{graphite}) + 2H_2(g)$

2. $C(s, \text{graphite}) + O_2(g) \rightarrow CO_2(g)$ **correct**

3. $2C(s, \text{diamond}) + O_2(\ell) \rightarrow 2CO(g)$

4. $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$

5. $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$

Explanation:
If $\Delta H^\circ_{\text{rxn}} = \Delta H^\circ_{\text{f}}$, the reaction written must be a formation reaction. A formation reaction is a single mole of products formed from its constituent elements in their standard states.

---

047   2.0 points
A closed tube used to transport methane has a volume of 65 L at 320°C and 965 torr. How many moles of gas are in the tube?

1. 2580

$$= -9018\,\mathrm{J}$$

2. 6450

3. 1.70 **correct**

3) Cool the ice from 0°C to -18°C:

4. 1290

$$\mathrm{q} = mC\Delta T = (27\,\mathrm{g})(2.09\frac{\mathrm{J}}{\mathrm{g}°\mathrm{C}})[-18°\mathrm{C} - 0°\mathrm{C}]$$

5. 4.31

$$= -1016\,\mathrm{J}$$

6. 2.16

Total heat required:

7. 1930

$$(-4632\,\mathrm{J}) + (-9018\,\mathrm{J}) + (-1016\,\mathrm{J}) = -14670\,\mathrm{J}$$

8. 12.7

Explanation:
You can solve directly for moles (n) by re-arranging the ideal gas law equation, such that:
$n = PV/RT$
$= (965)(65)/(62.36)(320 + 273.15)$
$= 1.70$

---

049   2.0 points
An excited hydrogen electron emits a photon in the Balmer series when it falls from $n = 6$. What is the energy of the photon emitted?

1. 2.44×10^6 J

2. 4.84×10^{-19} J **correct**

3. 2.44×10^{-17} J

---

048   2.0 points
A 27 mL sample of liquid water at 41°C is frozen and cooled to a final temperature of -18°C. Calculate the heat of this process.

1. -10030 J

4. -4.84 $\times 10^{-17}$ J

2. -543.2 J

5. 4.84×10^{-17} J

3. 13650 J

6. -2.44 $\times 10^{-17}$ J

Explanation:
$$\Delta E = R(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

4. -14670 J **correct**

$$\Delta E = (2.18 \times 10^{-18}\,\mathrm{J})(\frac{1}{2^2} - \frac{1}{6^2})$$

5. 14670 J

$$\Delta E = 4.84 \times 10^{-19}\,\mathrm{J}$$

Explanation:
You will need to make three different calculations for this problem:

---

050   2.0 points
Consider three closed 10L containers at room temperature. Container 1 contains 0.5 moles neon gas. Container 2 contains 0.5 moles argon gas. Container 3 contains 0.5 moles hydrogen gas. Which of the following properties, if any, are different between the containers?

1) Cool liquid water from 41°C to 0°C:

$$\mathrm{q} = mC\Delta T = (27\,\mathrm{g})(4.184\frac{\mathrm{J}}{\mathrm{g}°\mathrm{C}})[0°\mathrm{C} - (41\,°\mathrm{C})]$$
$$= -4632\,\mathrm{J}$$

   I. Average velocity of gas particles

   II. Number density

2) Freeze the ice at constant temperature:

   III. Kinetic energy

$$\mathrm{q} = (m)(-\Delta H_{\mathrm{fus}}) = (27\,\mathrm{g})(334\frac{\mathrm{J}}{\mathrm{g}})$$

IV. Pressure

1. I only **correct**

2. None of the above

3. I, II, III and IV

4. III only

5. I and III only

6. I and IV only

7. II, III, and IV only

8. II and IV only

Explanation:
When comparing different ideal gases at the same temperature, pressure, and volume, the only key differences will be the mass density and the average velocity (both of these are dependent on the molecular weight). The number of moles, number density, and kinetic energy will all be the same between the three containers.