Workshop 5 Solutions (Odd)

1. Use molecular orbital theory to predict which molecule is more reactive.

N_2

$\sigma 2p^*$	___
$\pi 2p^*$	___ ___
$\sigma 2p$	↿⇂
$\pi 2p$	↿⇂ ↿⇂
$\sigma 2s^*$	↿⇂
$\sigma 2s$	↿⇂

N_2 = 2 atoms N. Using the periodic table, we know N has 5 valence electrons because it is in the 5th column. So, $5 \cdot 2 = 10$ total e^-

- Fill with 10 electrons one level at a time, one electron at a time.

- To calculate bond order we say:

$$\frac{\#\text{electrons in a bonding orbital} - \#e^- \text{ in antibonding orbital } (*)}{2}$$

$$\frac{8-2}{2} = \frac{6}{2} = 3$$

O_2

$\sigma 2p^*$	___
$\pi 2p^*$	↿ ↿
$\pi 2p$	↿⇂ ↿⇂
$\sigma 2p$	↿⇂
$\sigma 2s^*$	↿⇂
$\sigma 2s$	↿⇂

O_2 = 2 atoms of O. Using the Periodic table, O has 6 valence electrons. $6 \cdot 2 = 12$ total electrons

- Fill with 12 electrons as we did above.

- To calculate bond order, we use the same equation as above.

$$\frac{\#\text{bonding} - \#\text{antibonding}}{2} \qquad \frac{8-4}{2} = \frac{4}{2} = 2$$

The higher the bond order, the more stable and less reactive the molecule. $3 > 2$, so $N_2 > O_2$. N_2 is more stable and less reactive. O_2 is more reactive. This also makes sense looking at the molecular orbital diagram, O_2 has unpaired electrons while N_2 does not.

3. Reaction for the formation of NaCl

$2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$

elements in natural state under Standard conditions

Reaction for the formation of $C_6H_{12}O_6$

$6C_{(s)} + 6H_{2(g)} + 3O_{2(g)} \rightarrow C_6H_{12}O_{6\,(s)}$

balanced equation

Reaction for the formation of $PbSO_{4(s)}$

$Pb_{(s)} + S_{(s)} + 2O_{2(g)} \rightarrow PbSO_{4(s)}$

5. Calculate ΔH for $\underbrace{CO_{(g)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{2(g)}}$.

This is what you want the 2 equations to add to.

$-1(C_{(graphite)} + \frac{1}{2}O_{2(g)} \rightarrow CO_{(g)})$ $\quad \Delta H = -110.54\ kJ$

$C_{(graphite)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\quad \Delta H = -393.51\ kJ$

- multiply top equation by -1 to flip the equation and cancel terms.

$CO_{(g)} \rightarrow \frac{1}{2}\cancel{O_2}_{(g)} + \cancel{C_{(graphite)}}$ $\quad \Delta H = 110.54\ kJ$

$O_{2(g)} + \cancel{C_{(graphite)}} \rightarrow CO_{2(g)}$ $\quad \Delta H = -393.51\ kJ$

- Cancel only from products to reactants side or vice versa.
- Sum what is left.

$\frac{1}{2}O_{2(g)} + CO_{(g)} \rightarrow CO_{2(g)}$

- Add the ΔH values as: $110.54\ kJ + (-393.51)\ kJ =$

$\boxed{\Delta H_{rxn} = -282.97\ kJ}$

7. Typical homes use 40 kWh/day. Per day, there is only 8 hours of useful sunlight, so 40 kWh/8hr = 5kW.

Also, we know only 18% of the energy is efficient. To get the full efficiency, we divide by 18% or 0.18. $\frac{5kW}{0.18} = 27.8kW$

Thinking that we are looking for an area (m^2) we can use the irradiance of $1kW/m^2$ to cancel kW and get m^2.

$$\frac{27.8\,\cancel{kW}}{1\,\cancel{kW}/m^2} = \boxed{27.8\,m^2}$$

To get to a more familiar unit, we can convert:

$$27.8\,m^2 \times \frac{3\,ft^2}{1\,m^2} \approx 300\,ft^2$$

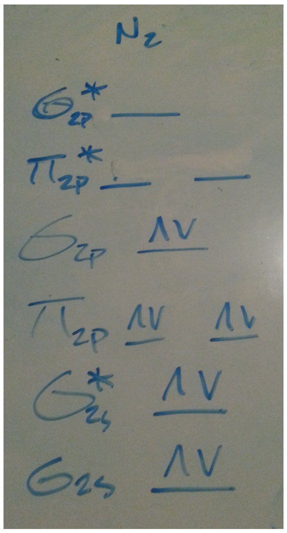
approximate conversion factor.

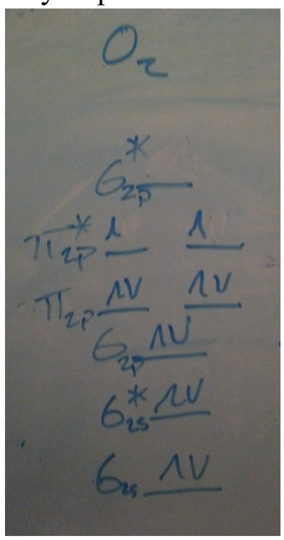
Yes. A Typical roof is big enough.

Matter and Motion Fall 2015
Chemistry Workshop 5

The workshop is intended to be a low-pressure setting where we get to practice problems, ask any questions, and discuss concepts and problem solving methods. Have fun! Work together on whiteboards or scratch paper and then neatly write your solutions in the notebook where you keep chemistry class notes. Your workshop solutions will be included in your portfolio.

1. Use molecular orbital theory to predict which molecule is more reactive.





Bond order of N_2 1/2(2-2+4+2)=3, 3 bonds
Bond order of O_2 1/2(2-2+2+4-2)=2, 2 bonds
O_2 has 2 electrons in π2p* therefore is the more reactive of the two.

2. The blue color in jeans often comes from the dye indigo blue. The structure of the indigo molecule is: a) How many σ and how many π bonds exist in the molecule? b) What hybrid orbitals are used by the carbon atoms in the indigo molecule?

3. The standard enthalpy of formation is the change in enthalpy that accompanies the formation of 1 mole of a compound from its elements, with all substances in their standard states (e.g., the standard state for nitrogen is N_2(g)). Write a reaction for the formation of each of the following compounds: NaCl, $C_6H_{12}O_6$, and $PbSO_4$.

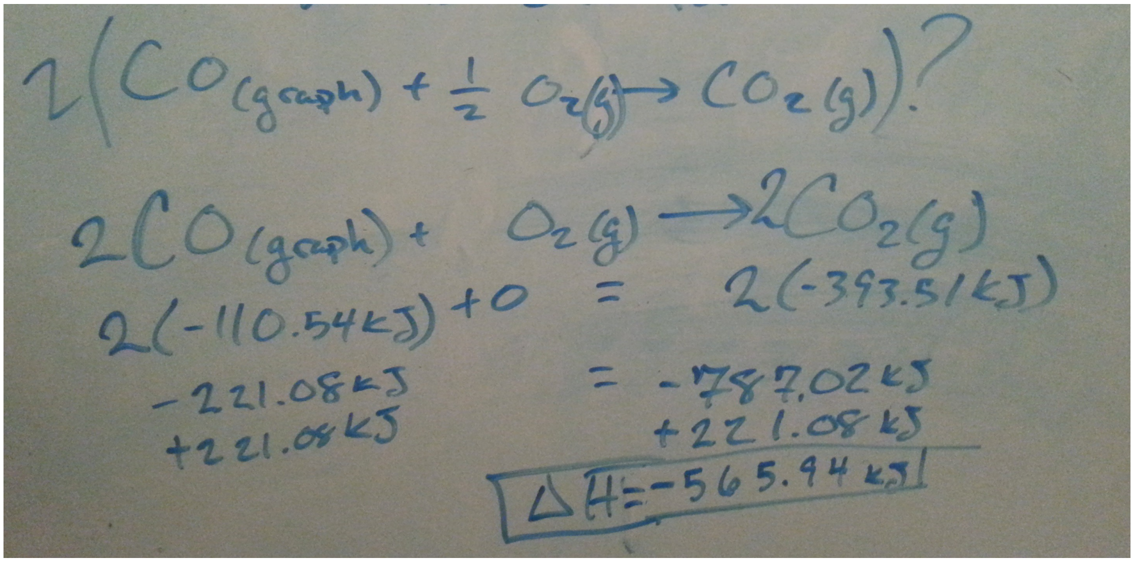
   $2Na(s)+Cl_2(g) \rightarrow 2NaCl(s)$

   $6C(graphite)+6H_2(g)+3O2(g) \rightarrow C_6H_{12}O_6$

   $Pb(s)+S(s)+2O_2(g) \rightarrow PbSO_4(s)$

4. Acid rain is produced from the reaction between sulfur trioxide and water to produce sulfuric acid. Write a balanced chemical equation for this reaction and calculate the standard enthalpy of reaction. You will want to use the table of standard enthalpy of formation found in Appendix 4. You can also find tables of standard enthalpies of formation online if nobody in your group has the book. N2 O2

5. Use Hess's Law to determine ΔH for the reaction CO(g) + ½O2(g) CO2(g), given that: C(graphite) + ½O2(g) CO(g) ΔH = -110.54 kJ C(graphite) + O2(g) CO2(g) ΔH = -393.51 kJ



First thing I did with the equation is multiply both sides by 2 to balance the equation, then I used the ΔH of CO(g) from C(graphite) and O_2(g), ΔH of O_2(g), and ΔH of CO_2 from C(graphite and O_2(g), and combined them to get the ΔH of CO_2(g) from CO(g) and O_2(g).

6. Calculate the internal energy change for each of the following:

a) 200 J of work is required to compress a gas while the gas releases 43 J of heat.

b) A piston is compressed from a volume of 9.30 L to 1.80 L against a constant pressure of 1.90 atm while the gas absorbs 350 J.

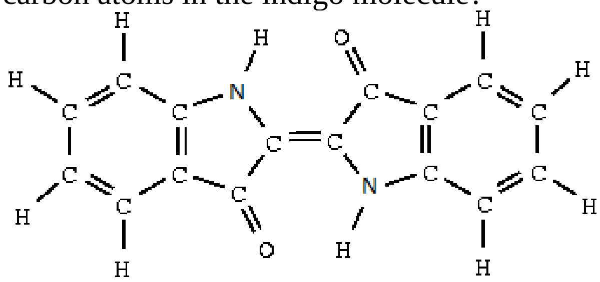
7. Typical homes use about 40 kWh of electricity per day (1 kWh = 1 kilowatt hour where 1 watt = 1 J/s). Assuming 18% efficient solar panels, 8 hours of useful sunlight per day, and solar irradiance (the rate of light energy supplied by the sun) of 1 kW/m2 , calculate the minimum solar panel surface area necessary to provide all of the home's electricity. Do you think a typical roof is big enough to hold all of the necessary solar panels?

$\frac{40\ \cancel{kW}*\cancel{h}}{1\ \cancel{Day}} * \frac{1\ \cancel{Day}}{8\ \cancel{Hours}} * \frac{m^2}{.18\ \cancel{kW}} = 28\ m^2$***, a reasonable answer for a roof to support***

8. Calculate the bond energy for a N—N single bond using the following data: The standard enthalpy of formation for N2H4(g) is 95.4 kJ/mol; the standard enthalpy of formation of N(g) is 472.7 kJ/mol; the standard enthalpy of formation of H(g) is 216.0 kJ/mol; the bond energy of N—H bond is 391 kJ/mol. Hint: write a reaction representing the breakdown of N2H4 into its constituent elements. Compare your calculated value to the literature value provided in Table 4.4 of your text.

chem workshop 5

2) The blue color in jeans often comes from the dye indigo blue. The structure of the indigo molecule is:
a) How many σ and how many π bonds exist in the molecule? b) What hybrid orbitals are used by the carbon atoms in the indigo molecule?



σ bonds: 33 bonds (counting total number of all bonds)
π bonds: 9 bonds (counting the double bonds)

The carbon atoms all have three bonds so: sp2

4)Acid rain is produced from the reaction between sulfur trioxide and water to produce sulfuric acid. Write a balanced chemical equation for this reaction and calculate the standard enthalpy of reaction. You will want to use the table of standard enthalpy of formation found in Appendix 4. You can also find tables of standard enthalpies of formation online if nobody in your group has the book.

SO_2 = - 206.84 kj/mol
SO_3 = -395.7 kj/mol
H_2O(l) = −285.8 kj/mol

Delta H = Products – Reactants
$SO_2 + H_2O \rightarrow SO_3 + H_2$
[-395.7kj/mol + 0kj/mol] - [-206.84kj/mol + -285.8jk/mol] = 99.64 kj/mol

6. Calculate the internal energy change for each of the following: a) 200 J of work is required to compress a gas while the gas releases 43 J of heat. b) A piston is compressed from a volume of 9.30 L to 1.80 L against a constant pressure of 1.90 atm while the gas absorbs 350 J.

Delta E = W + Q

W= -p* Delta(v)

A) Delta E = 200J – 43J = 157joules
200 joules being the work done and -43 joules being the energy released

B)
Delta E = W + Q

Delta E = W + 350joules (absorbs 350 joules)

W=-1.90atm * (9.30/1.80L) = -.981 atm* L
to convert Atm * L we use the conversion factor of 101.3. L*atm=101.3joules
-981*101.3= -99.4428 joules.

Delta E = -99.4428j + 350j = 250.56 joules
notice that we are adding -99.4428joules because work is being done on the system IE compression if the system was doing work then it would be postive

8. Calculate the bond energy for a N—N single bond using the following data: The standard enthalpy of formation for $N_2H_4(g)$ is 95.4 kJ/mol; the standard enthalpy of formation of N(g) is 472.7 kJ/mol; the standard enthalpy of formation of H(g) is 216.0 kJ/mol; the bond energy of N—H bond is 391 kJ/mol. Hint: write a reaction representing the breakdown of N_2H_4 into its constituent elements. Compare your calculated value to the literature value provided in Table 4.4 of your text.

$N_2H_4(g)$ is 95.4 kJ/mol
N(g) is 472.7 kJ/mol
H(g) is 216.0 kJ/mol
N-H bond is 391 kj/mol
N-N bond is X

$N_2H_4(g) \rightarrow N_2(g) + 2H_2(g)$

Delta H = Products – Reactants

Bond energies
[0] - [4(391) + 1x] =- (1564 + x)

enthalpy of formation
[95.4] – [2(472.7) + 4(216)] = -1715

-1564 +x = -1715
seting the equations equal to each other we can determine that: -1715+1564=x
x=151 so the bond energy of the one N-N bond should be 151 kj/mol and the table value is 160kj/mol.

Chemistry Workshop Solution (Even)

2) A) sigma = 33 bonds
pi : 9 bonds

There are 24 single bonds in the molecule and 9 double bonds. This means there are 24 sigma from the single bonds and 9 from the double. Because double bonds have 1 sigma and 1 pi bond.

B) SP_2 hybrid orbital; trigonal planar

4) $SO_{3(g)} + H_2O_{(g)} \Rightarrow H_2SO_{4(l)}$

$SO_{3(g)} = -396\ kJ/mol$
$H_2O_{(g)} = -242\ kJ/mol$
$H_2SO_{4(l)} = -814\ kJ/mol$

ΔH_f^o = products - reactants

$\Delta H_f^o = -814\ kJ/mol - (-396\ kJ/mol + -242\ kJ/mol)$

$\boxed{\Delta H_f^o = -176\ kJ/mol}$

6) $\Delta E = Q + W$

A) $Q = 43J$ heat $\quad \Delta E = (43J) + (200J)$
$W = 200J$ work $\quad \boxed{\Delta E = 243J}$

B) $w = -p \cdot \Delta V \quad w = -1.9\ (7.5)$
$w = -14.25J$

$w = -14.25J \left(\frac{101.3J}{1L\ atm} \right) = -1443.5J$

$\Delta H = \Delta E + \Delta PV$

$350\ J = \Delta E + -1443.5J$
$\boxed{\Delta E = 1793.5J}$

Appendix : 160 kJ/mol

8) $N_2H_4 \rightarrow N_2 + 2H$
Bond energy N-H : 391 kJ/mol

$N_2H_4 \rightarrow 2N + 4H$
95.4 kJ/mol 472.7 216.0

Products - Reactants
$((472.7 \cdot 2)) + (216.4) - 95.4 = 1714\ kJ/mol$

4 NH bonds (391 kJ/mol) = 1564 kJ/mol
subtract bond energies from total

1714 kJ/mol - 1564 kJ/mol = 150 kJ/mol