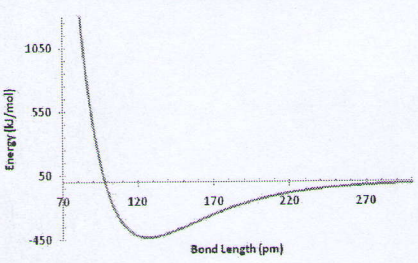
Name Mr. Shank Period AP 1, 2, 3

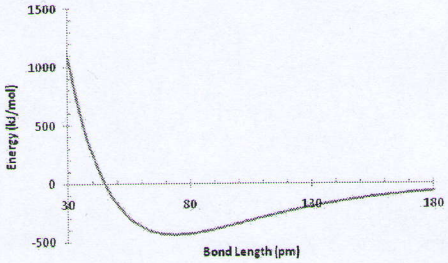
Enthalpy I: *Bond Enthalpy and Heats of Reaction*

The atomic radii of hydrogen and chlorine are r(H) = 38 pm and r(Cl) = 99 pm. The energy vs bond length plots below are for, in no particular order, H_2, Cl_2, HCl.

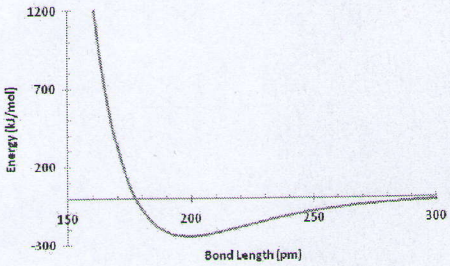
Molecule HCl



Molecule H_2



Molecule Cl_2



1. In the space labeled 'Molecule' above each plot, indicate the molecule to which each plot corresponds (you should use H_2, Cl_2, HCl one time each).
2. Fill in the following table of (approximate) equilibrium bond lengths and enthalpies.

Bond	H-H	Cl-Cl	H-Cl
Eq. Bond Length (pm)	74	199	127
Bond Enthalpy (kJ/mol)	436	243	432

3. Circle (⬭) the weakest bond and box (▭) the strongest bond in the table above.

4. Write a **balanced** chemical equation for the formation of HCl from H_2 and Cl_2 in the space below:

$$H_2 + Cl_2 \rightarrow 2HCl$$

5. Fill in the following table based on your table in question 2 and your balanced chemical equation from question 3:

Bond	H-H	Cl-Cl	H-Cl
Products or **Reactants**?	Reactants	Reactants	Products
Broken or **Formed**?	Broken	Broken	Formed
Total # (Broken/Formed)?	1	1	2
Energy **Released** or **Absorbed**?	Absorbed	Absorbed	Released
Total Energy (Released / Absorbed)?	$1(436) = 436 \frac{kJ}{mol}$	$1(243) = 243 \frac{kJ}{mol}$	$2(432) = 864 \frac{kJ}{mol}$

6. What is meant by the 'heat of reaction'? What symbol do chemists use for heat of reaction?

The heat of a chemical reaction (or its reaction enthalpy) is equal to the difference in energy between the energy absorbed in breaking bonds in the reactants and the energy released in forming bonds in the products. It has the symbol ΔH_{rxn}

7. Write a **general** equation for calculating the heat of reaction from the bond enthalpies of reactants and products in the reaction.

$$\Delta H_{rxn} = \sum \Delta H(\text{bonds broken}) - \sum \Delta H(\text{bonds formed})$$

8. Calculate the enthalpy (heat) of reaction for the formation of hydrochloric acid from hydrogen gas and chlorine gas.

$$\Delta H_{rxn} = \sum \Delta H(\text{bonds broken}) - \sum \Delta H(\text{bonds formed})$$
$$= [1(436)\ kJ/mol + 1(243)\ kJ/mol] - [2(432)\ kJ/mol]$$
$$= [436\ kJ/mol + 243\ kJ/mol] - [864\ kJ/mol]$$
$$\Delta H_{rxn} = -185\ kJ/mol$$

9. Is the formation of hydrochloric acid exothermic or endothermic? How do you know?

Exothermic, since $\Delta H_{rxn} < 0$.

10. How much energy is released if 9 g of hydrogen gas react with 70 g of chlorine gas to form hydrochloric acid?

$$9\ g\ H_2 \times \frac{1\ mol\ H_2}{2.0158\ g\ H_2} \times \frac{1\ mol\ rxn}{1\ mol\ H_2} = 4.46\ mol\ rxn$$

$$70\ g\ Cl_2 \times \frac{1\ mol\ Cl_2}{70.906\ g\ Cl_2} \times \frac{1\ mol\ rxn}{1\ mol\ Cl_2} = 0.99\ mol\ rxn$$

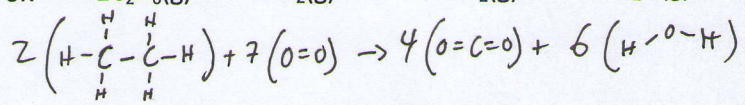
Cl_2 is the limiting reagent.

$$0.99\ mol\ rxn \times \frac{185\ kJ}{1\ mol\ rxn} = 183.15\ kJ$$ released

11. Using the following bond enthalpies (in kJ/mol)

H(C-C) = 347	H(C=C) = 620	H(C≡C) = 812	H(O-O) = 142	H(O=O) = 499
H(H-H) = 436	H(C-H) = 414	H(C-O) = 351	H(C=O) = 745	H(H-O) = 460

calculate the reaction enthalpy of: $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$



$$\Delta H_{rxn} = \sum \Delta H(\text{bonds broken}) - \sum \Delta H(\text{bonds formed})$$
$$= [12\Delta H(C-H) + 2\Delta H(C-C) + 7\Delta H(O=O)] - [8\Delta H(C=O) + 12\Delta H(O-H)]$$
$$= [12(414) + 2(347) + 7(499)] - [8(745) + 12(460)]$$
$$\Delta H_{rxn} = -2,325\ kJ/mol$$