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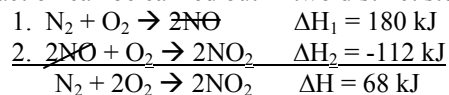
Honors Chemistry

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**Hess's Law**

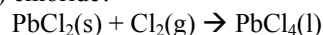
- Since enthalpy is a state function, the change in enthalpy in going from some initial state to some final state is independent of the pathway. Thus, in going from a particular set of reactants to a particular set of products, the change in enthalpy is the same whether the reaction takes place in one step or a series of steps. This principle is known as Hess's law.
- Example:  $\text{N}_2 + 2\text{O}_2 \rightarrow 2\text{NO}_2$   $\Delta H = 68 \text{ kJ}$

This reaction can be carried out in two distinct steps:

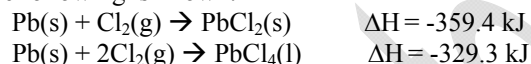
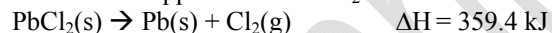
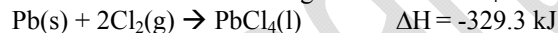
Note:  $\Delta H = \Delta H_1 + \Delta H_2$ 

The two 2NO are cancelled out because one appears as a reactant and the other as a product.

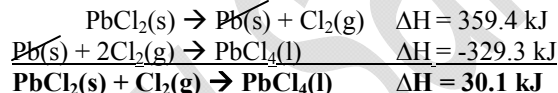
- When using Hess's law, it is important to understand two characteristics of  $\Delta H$  for a reaction:
  - If a reaction is reversed, the sign of  $\Delta H$  is also reversed.
  - If the coefficients in a balanced equation are multiplied by an integer, the value of  $\Delta H$  is multiplied by the same integer.
- Example: What is the standard enthalpy change for the reaction of lead(II) chloride with chlorine to give lead(IV) chloride?



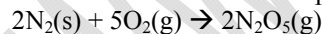
The following is known:

**Solution:**Reaction 1 has to be flipped so that  $\text{PbCl}_2$  is a reactant. The value of  $\Delta H$  is also changed from (-) to (+).Reaction 2 does not need to be changed because  $\text{PbCl}_4$  is already a product.

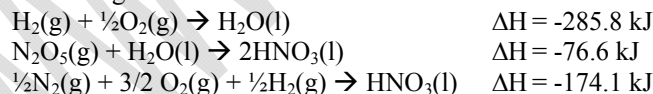
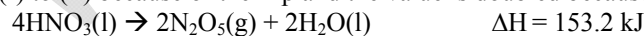
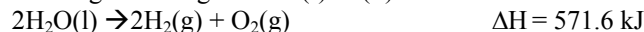
The two reactions are summed:

Since there were two  $\text{Cl}_2$  on the reactant side and one on the product side, ( $2-1 = 1$ ) one  $\text{Cl}_2$  remains as a reactant.

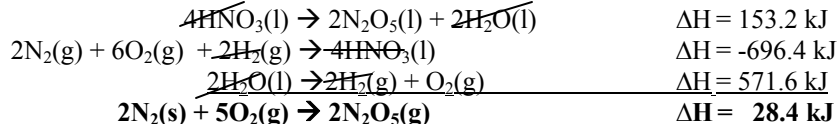
- Example: What is the standard enthalpy change for the reaction below?



The following is known:

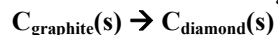
**Solution:**Reaction 2 is flipped and multiplied by 2 in order to get 2 moles  $\text{N}_2\text{O}_5$  on the product side. The sign of  $\Delta H$  is changed from (-) to (+) because of the flip and the value is doubled because the coefficients are doubled.Reaction 3 is multiplied by 4 in order to get 2  $\text{N}_2$  molecules. The  $\Delta H$  value is also multiplied by 4.Reaction 1 has to be flipped and multiplied by 2 so that the  $\text{H}_2$  can cancel the  $\text{H}_2$  from reaction 3 above.  $\Delta H$  is also doubled and the sign is changed from (-) to (+).

The reactions are summed:



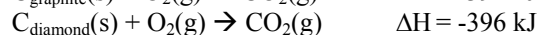
**Homework** Solve each of the following Hess's law problems. Show all work!

1. What is heat of reaction for the following reaction?

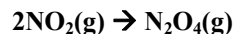


**Answer:  $\Delta H = +2 \text{ kJ}$**

The following is known.

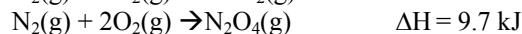
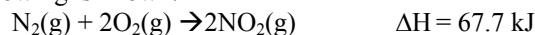


2. Calculate the heat of reaction for the following reaction:

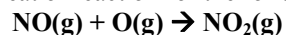


**Answer:  $\Delta H = -58.0 \text{ kJ}$**

The following is known.

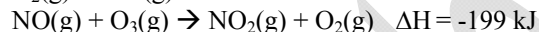
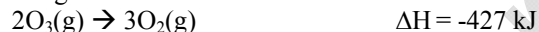


3. Calculate the heat of reaction for the following reaction:

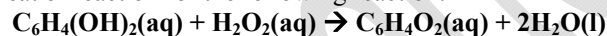


**Answer:  $\Delta H = -233 \text{ kJ}$**

The following is known.

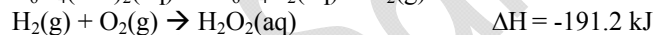
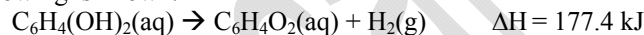


4. Calculate the heat of reaction for the following reaction:



**Answer:  $\Delta H = -202.6 \text{ kJ}$**

The following is known.

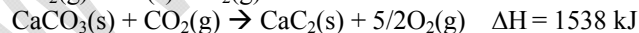


5. Calculate the heat of reaction for the following reaction:

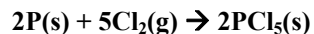


**Answer:  $\Delta H = -1207 \text{ kJ}$**

The following is known.

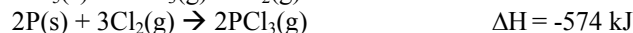


6. Calculate the heat of reaction for the following reaction:

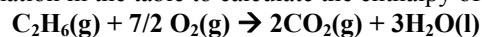


**Answer:  $\Delta H = -750. \text{ kJ}$**

The following is known.



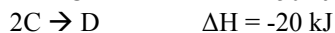
7. Use the information in the table to calculate the enthalpy of this reaction.



Reaction	$\Delta H_f^\circ, \text{kJ}\cdot\text{mol}^{-1}$
$2\text{C}(\text{s}) + 3\text{H}_2(\text{g}) \rightarrow \text{C}_2\text{H}_6(\text{g})$	-84.7
$\text{C}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g})$	-393.5
$\text{H}_2(\text{g}) + 1/2 \text{O}_2(\text{g}) \rightarrow \text{H}_2\text{O}(\text{l})$	-285.8

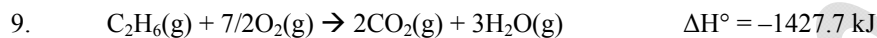
- (A) -764 kJ (B) -1560 kJ (C) -1664 kJ (D) -3120 kJ (E) -595 kJ

8. Given these reactions:



Calculate  $\Delta H$  for the reaction:  $\text{D} + \text{A} \rightarrow 4\text{C}$

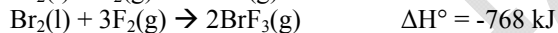
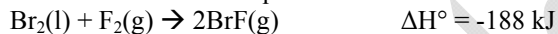
- (A) -100 kJ (B) -60 kJ (C) -40 kJ (D) 100 kJ (E) -30 kJ



If the enthalpy of vaporization for  $\text{H}_2\text{O}(\text{l})$  is 44.0 kJ/mol, what is  $\Delta H^\circ$  for this reaction if  $\text{H}_2\text{O}(\text{l})$  is formed instead of  $\text{H}_2\text{O}(\text{g})$ ?

- (A) -1295.7 kJ (B) -1383.7 kJ (C) -1471.7 kJ (D) -1559.7 kJ (E) -1515.7 kJ

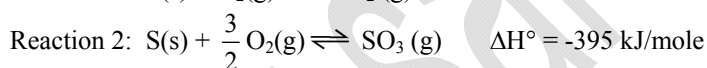
10. Given the thermochemical equations:



Determine  $\Delta H^\circ$  for the reaction:  $\text{BrF}(\text{g}) + \text{F}_2(\text{g}) \rightarrow \text{BrF}_3(\text{g}) \quad \Delta H^\circ = ?$

- (A) -956 kJ (B) -580 kJ (C) -290 kJ (D) -478 kJ (E) 580 kJ

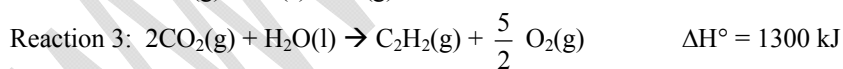
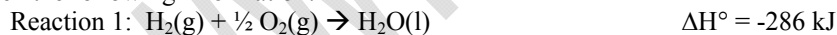
11. Given these two standard enthalpies of formation:



What is the heat of reaction for  $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$  under the same conditions?

- (A) -1380 kJ/mole (B) -690. kJ/mole (C) -295 kJ/mole (D) -200. kJ/mole (E) -100. kJ/mole

12. Given the following information:



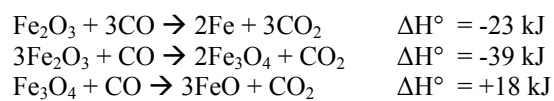
Find  $\Delta H^\circ$  for the reaction:  $\text{C}_2\text{H}_2(\text{g}) \rightarrow 2\text{C}(\text{s}) + \text{H}_2(\text{g})$

- (A) -226 kJ (B) -113 kJ (C) 113 kJ (D) 226 kJ (E) 452 kJ

### Additional Practice Problems

1. Calculate the  $\Delta H^\circ$  the following problems using Hess's law.

Given:



Find:  $\text{FeO} + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$

2. Calculate the  $\Delta H^\circ$  the following problems using Hess's law.

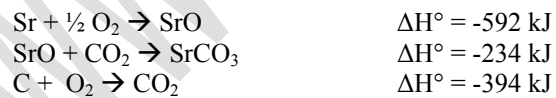
Given:



Find:  $\text{P}_4\text{O}_{10} + 6\text{PCl}_5 \rightarrow 10\text{Cl}_3\text{PO}$

3. Calculate the  $\Delta H^\circ$  the following problems using Hess's law.

Given:



Find:  $\text{Sr} + \text{C} + \frac{3}{2} \text{O}_2 \rightarrow \text{SrCO}_3$