

Ken

IB Chemistry I
Topic 5- Energetics and Thermochemistry
5.2 Hess's Law

Understandings: the enthalpy change for a reaction that is carried out in a series of steps is equal to the sum of the enthalpy changes for the individual steps

Applications and skills:

- Application of Hess's law to calculate enthalpy changes.
- Calculation of ΔH reactions using ΔH_f^\ominus data.

Guidance

- Enthalpy of formation data can be found in the data booklet in section 12.
- An application of Hess's law is

$$\Delta H_{\text{reaction}} = \sum(\Delta H_f^\ominus(\text{products})) - \sum(\Delta H_f^\ominus(\text{reactants}))$$

- Determination of the enthalpy change of a reaction that is the sum of multiple reactions with known enthalpy changes.

Review from 5.1

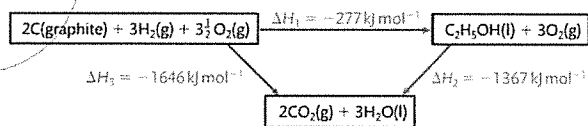
What is enthalpy (H)?

What is ΔH ?

What is ΔH^\ominus ?

Hess's Law is an extension of the law of conservation of energy. What does the law of conservation of energy state?

Handwritten text: "Hess's Law is an extension of the law of conservation of energy"



Consider the clockwise route:

$$\Delta H_1 + \Delta H_2 = -277 + -1367 = -1644 \text{ kJ mol}^{-1}$$

Consider the anticlockwise route:

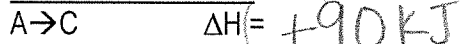
$$\Delta H_3 = -1646 \text{ kJ mol}^{-1}$$

Given the uncertainty of the experimental values, we can conclude that:

$$\Delta H_3 = \Delta H_1 + \Delta H_2$$

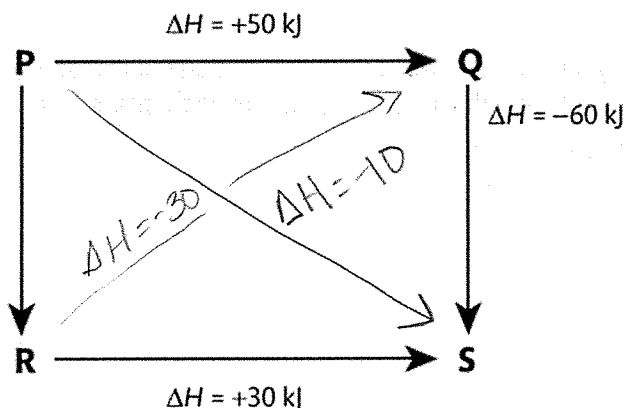
Now try these problems:

1. Use Hess's law to calculate the enthalpy change for the reaction $A \rightarrow C$



Handwritten circled answer: +90 kJ

16 The diagram illustrates the enthalpy changes of a set of reactions.

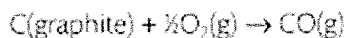


Which of the following statements are correct?

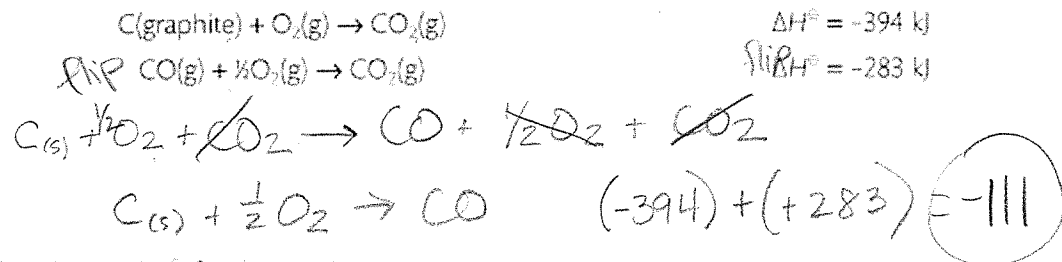
- I $P \rightarrow S$ $\Delta H = -10$ kJ
- II $R \rightarrow Q$ $\Delta H = +90$ kJ
- III $P \rightarrow R$ $\Delta H = +20$ kJ

- A I and II only **B I and III only** C II and III only D I, II, and III

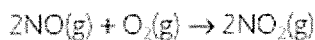
17 Calculate the enthalpy change, ΔH^\ominus , for the reaction:



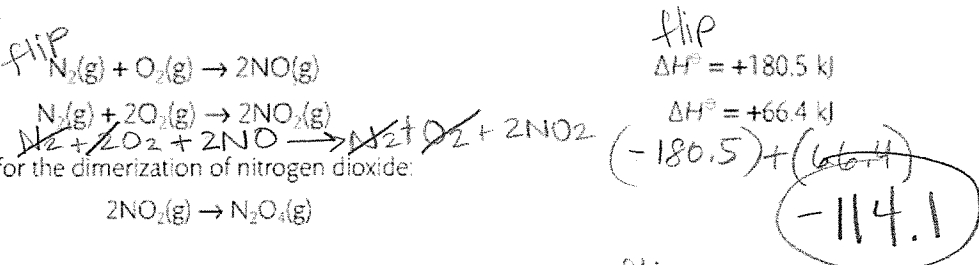
from the information below:



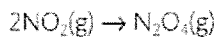
18 Calculate the enthalpy change, ΔH^\ominus , for the reaction:



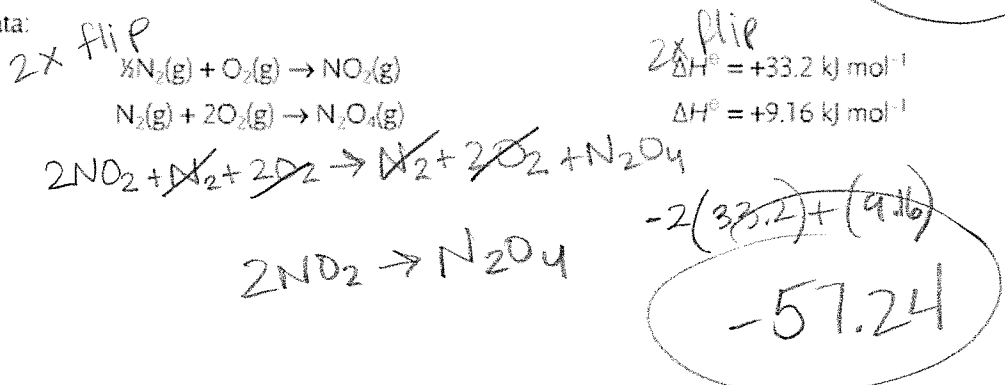
from the information below:



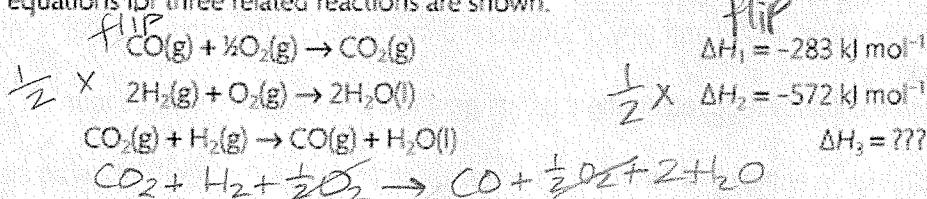
19 Calculate the enthalpy change for the dimerization of nitrogen dioxide:



from the following data:



20 The thermochemical equations for three related reactions are shown.



Determine ΔH_3

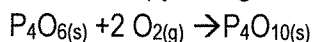
A +289 kJ mol⁻¹

B -3 kJ mol⁻¹

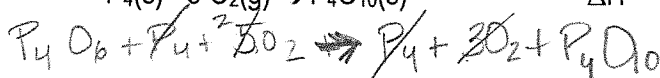
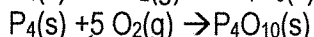
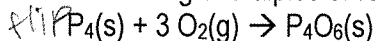
C -289 kJ mol⁻¹

D -855 kJ mol⁻¹

2. Calculate the enthalpy change for the reaction

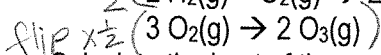
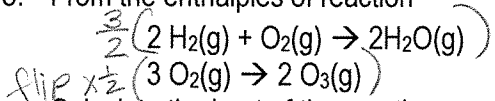


Given the following enthalpies of reaction:

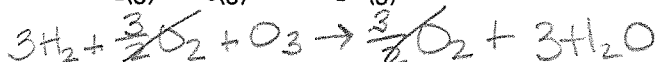
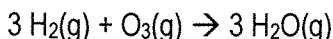


-1300 kJ mol⁻¹

3. From the enthalpies of reaction



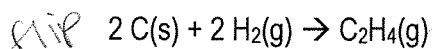
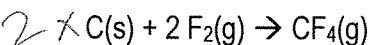
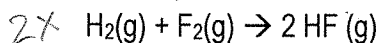
Calculate the heat of the reaction



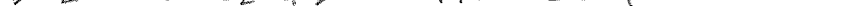
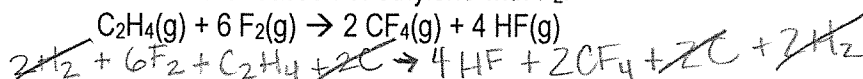
$$\begin{array}{l} \frac{3}{2} (\Delta H = -483.6 \text{ kJ}) = -725.4 \\ \text{flip} \frac{1}{2} (\Delta H = +284.6 \text{ kJ}) = -142.3 \end{array}$$

-867.7

4. From the enthalpies of reaction

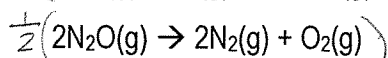
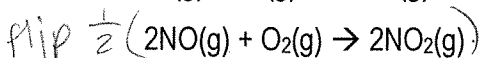
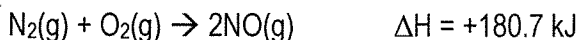


Calculate ΔH for the reaction of ethylene with F_2 :



-2486.3

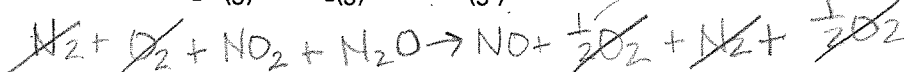
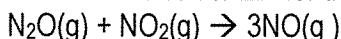
5. Given the data



$$\text{flip} \frac{1}{2} \Delta H = -113.1 \text{ kJ} = 56.55$$

$$\frac{1}{2} (\Delta H = -163.2 \text{ kJ}) = -81.6$$

Use Hess's law to calculate ΔH for the reaction



155.65

STOP [check your answers here- if you are having trouble don't move on yet

Enthalpy of formation problems

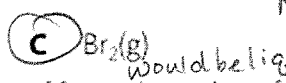
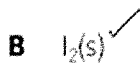
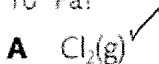
ΔH_f° = the standard enthalpy of formation of a substance (how much enthalpy there is when a substance forms)

More enthalpy required during the change = more unstable = harder to form

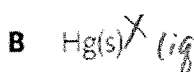
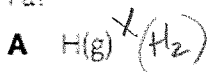
Change in enthalpy of formation of a substance (ΔH_f°) can be zero! When an element forms from itself and is in its most stable form, its standard enthalpy change of formation will be zero. The standard part here is important. It means you have to pay attention to state symbols. For example, the ΔH_f° of $\text{Cl}_{2(g)}$ will be zero, because chlorine is a gas in its standard state, but the of $\text{Cl}_{2(s)}$ will not be zero because chlorine is not a solid in its standard state. Think you got it? Try these questions.

Exercises

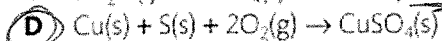
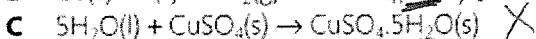
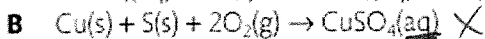
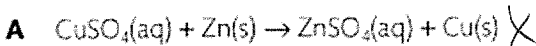
21 Which of the following does **not** have a standard heat of formation value of **zero** at 25 °C and 1.00×10^5 Pa?



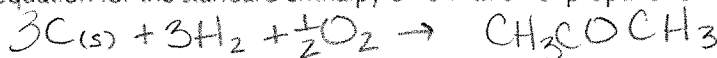
22 Which of the following **does** have a standard heat of formation value of **zero** at 25 °C and 1.00×10^5 Pa?



23 For which equation is the enthalpy change described as an enthalpy change of formation?



24 (a) Write the thermochemical equation for the standard enthalpy of formation of propanone (CH_3COCH_3).



(b) State the conditions under which standard enthalpy changes are measured.

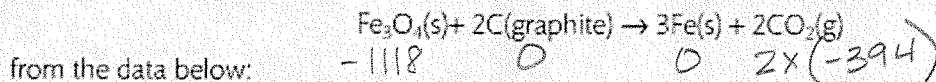


STOP [check your answers here- if you are having trouble don't move on yet

$$\Delta H^\circ = \sum \Delta H_{\text{prod}} - \sum \Delta H_{\text{react}}$$

Exercises

25 Calculate ΔH° (in kJ mol^{-1}) for the reaction



	$\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{Fe}_3\text{O}_4(\text{s})$	-1118
$\text{CO}_2(\text{g})$	-394

$$[2 \times (-394)] - [-1118] = 330 \text{ kJ mol}^{-1}$$

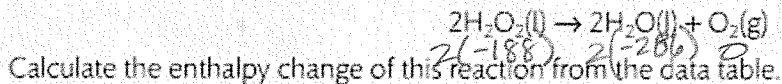
26 Calculate ΔH° (in kJ mol^{-1}) for the reaction



	$\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{NO}_2(\text{g})$	+33.2
$\text{N}_2\text{O}_4(\text{g})$	+9.2

$$[9.2] - [2 \times 33.2] = -57.2 \text{ kJ/mol}$$

27 Hydrogen peroxide slowly decomposes into water and oxygen:



	$\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{H}_2\text{O}_2(\text{l})$	-188
$\text{H}_2\text{O}(\text{l})$	-286

$$[2(-286)] - [2(-188)] = -196 \text{ kJ mol}^{-1}$$

A +98 kJ mol^{-1} B -98 kJ mol^{-1} C +196 kJ mol^{-1} D -196 kJ mol^{-1}

28 Calculate the enthalpy change for the hypothetical reduction of magnesium oxide by carbon, according to the equation below from the data given. Comment on its feasibility.

$$2\text{MgO}(\text{s}) + \text{C}(\text{s}) \rightarrow \text{CO}_2(\text{g}) + 2\text{Mg}(\text{s})$$

$2(-602)$ 0 -394 0

	$\Delta H_f^\circ / \text{kJ mol}^{-1}$
$\text{CO}_2(\text{g})$	-394
$\text{MgO}(\text{l})$	-602

$$[-394] - [2(-602)] = +810 \text{ kJ/mol}$$

NOT feasible - requires a lot of energy. more negative ΔH as stable reactants = more stable

Understandings: the enthalpy change for a reaction that is carried out in a series of steps is equal to the sum of the enthalpy changes for the individual steps

I feel that I have demonstrated understanding of Hess's Law by using manipulating given reactions.

1 (No, I have no idea what I'm doing.) 2 3 4 5 (YES, I HAVE!)

I feel that I have demonstrated understanding of Hess's Law by using heats of formation.

1 (No, I have no idea what I'm doing.) 2 3 4 5 (YES, I HAVE!)

