CHEM 206 section 01 *corrected slide 5*

LECTURE #3 Fri. Jan. 11, 2008

ASSIGNED READINGS:

LAST CLASS' NOTES: included 9.10…

TODAY'S CLASS: finish Ch.6…

NEXT CLASS: Ch. 19.1-19.5

Remember: Chem 101 seminars next week

6.7 Hess's law (useful for any state function…)

The change in enthalpy (or any other state function) for a reaction is the same whether the reaction takes place in one step or via a series of steps.

"Hess's law"

Directly from DEFINITION of state function!

How might this be useful?

- If the reaction we WANT to study is too: to be studied easily / safely…

fast / slow
exothermic / endothermic
toxic, expensive, *etc.*

…we can

a) look at data for other reactions involving the same compounds,

b) combine them in such a way that we OVERALL
- start with our desired REAGENTS *and*
- end up with our desired PRODUCTS

Use Hess's law to predict ΔH_{rxn} for…

a dangerous reaction: $C_2H_{4(g)} + 6F_{2(g)} \rightarrow 2CF_{4(g)} + 4HF_{(g)}$

$H_{2(g)} + F_{2(g)} \rightarrow 2\ HF_{(g)}$ $\Delta H° = -537$ kJ *(per 1mol H_2)*

$C_{(s)} + 2\ F_{2(g)} \rightarrow CF_{4(g)}$ $\Delta H° = -680$ kJ *(per 1mol C)*

$2\ C_{(s)} + 2\ H_{2(g)} \rightarrow C_2H_{4(g)}$ $\Delta H° = +52.3$ kJ *(per 1mol C_2H_4)*

ANS: -2486 kJ *(per 1 mol C_2H_4)*
$= -2.486\times10^3$ kJ

(3)

Using Hess's law to calculate ΔH for a rxn

1.) Find reactions involving all substances in reaction of interest.

2.) Arrange rxns: desired reactants on left & products on right.
Scale up / down to get desired numbers of moles of each.

3.) If a reaction is reversed, reverse the sign of its ΔH also.

$2\ C(s) + 2\ H_2(g) \rightarrow C_2H_4(g)$ $\Delta H = +52.3$ kJ
$C_2H_4(g) \rightarrow 2\ C(s) + 2\ H_2(g)$ $\Delta H = -52.3$ kJ

→ Maintains correct "point of view": endo- *vs.* exothermic

4.) If the coefficients of a reaction are multiplied by an integer, multiply its ΔH by that same integer.

$H_2(g) + F_2(g) \rightarrow 2\ HF(g)$ $\Delta H = -537$ kJ
$2\ H_2(g) + 2\ F_2(g) \rightarrow 4\ HF(g)$ $\Delta H = 2\text{x}(-537\text{ kJ}) = -1074$ kJ

→ Heat released depends on quantity of matter involved *(extensive)*

NOTE: finding rxns to use is easier than you might expect:

Formation rxns = COMPOUND formed by rxn of its constituent elements
$\Delta H°_f$ = "standard enthalpy of formation" of 1 mol of compound
in its standard state at a given temperature

6.8 Using standard enthalpies of formation

$2x[\ H_{2(g)} + F_{2(g)} \rightarrow 2\ HF_{(g)}\ ] \quad \Delta H^o = 2x(-537\ kJ) = 4x\ \Delta H^o_f$

$2x[\ C_{(s)} + 2\ F_{2(g)} \rightarrow CF_{4(g)}\ ] \quad \Delta H^o = 2x(-680\ kJ) = 2x\ \Delta H^o_f$

$-1x[\ 2\ C_{(s)} + 2\ H_{2(g)} \rightarrow C_2H_{4(g)}\ ] \quad \Delta H^o = -(+52.3\ kJ) = -1x\ \Delta H^o_f$

$C_2H_4(g) + 6\ F_2(g) \rightarrow 2\ CF_4(g) + 4\ HF(g) \quad \Delta H^o = -2486\ kJ$

for rxn as written
(per mol C_2H_4)

Once you understand this approach,
SKIP IT & use **Hess's Law in mathematical form**:

$$\Delta H_{reaction} = \Sigma n \Delta H_{f(products)} - \Sigma n \Delta H_{f(reactants)}$$

Sum of ΔH^o_f for appropriate # moles of each product species

Sum of ΔH^o_f for appropriate # moles of each reactant species

$\Delta H^o_{rxn} = [(2\ mol \times -680\ kJ/mol) + (4\ mol \times -268.5\ kJ/mol)]$
$\quad - [(1\ mol \times +52.3\ kJ/mol) + (6\ mol \times 0\ kJ/mol)]$
$\quad = -2486\ kJ$ *(for 1 mol C_2H_4, implied by balanced equation)*
= heat released at const. P if have 100% conversion to products

(5)

"ΔH^o_f" = ΔH for formation of compound from the elements…
for **species in their STANDARD STATES**

** thermodynamic data (*e.g.*, ΔH^o_f) for elements
& common compounds is listed in textbooks ! **

"STANDARD STATES": indicated by the ° *"naught"*

- Elements **(NOTE: ΔH^o_f for elements in std. state = 0 by def'n)**
  = the form in which element exists at:
  1 atm pressure & specified temperature (usually 25°C)
  e.g., $N_2(g)$, $K(s)$
- Compounds
  - For a gas: P = 1 atm
  - For a solution: concentration = 1 M
  - For a liquid or solid: the pure liquid or solid

ΔH^o_{rxn} = heat released at const. P if have **100% conversion** of **reactants in std. states** to **products in std. states**

(6)

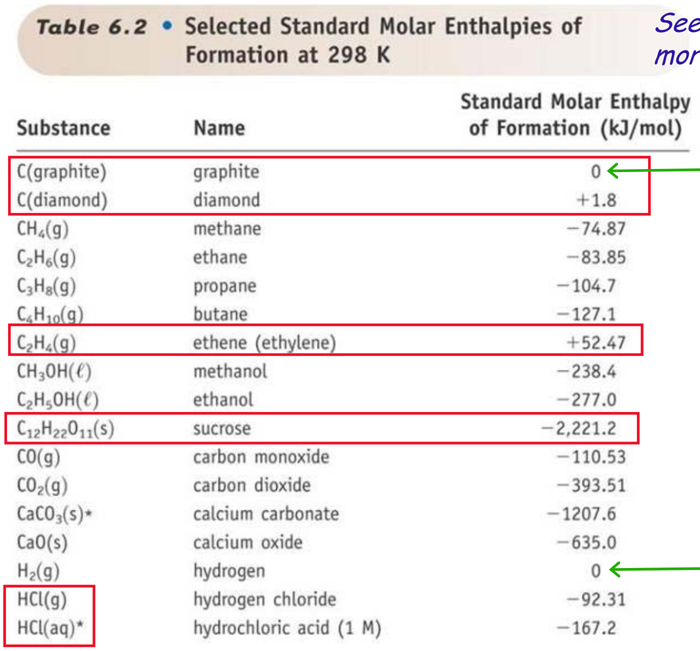

Table 6.2 • Selected Standard Molar Enthalpies of Formation at 298 K

See appendix for more substances

Substance	Name	Standard Molar Enthalpy of Formation (kJ/mol)
C(graphite)	graphite	0
C(diamond)	diamond	+1.8
$CH_4(g)$	methane	−74.87
$C_2H_6(g)$	ethane	−83.85
$C_3H_8(g)$	propane	−104.7
$C_4H_{10}(g)$	butane	−127.1
$C_2H_4(g)$	ethene (ethylene)	+52.47
$CH_3OH(\ell)$	methanol	−238.4
$C_2H_5OH(\ell)$	ethanol	−277.0
$C_{12}H_{22}O_{11}(s)$	sucrose	−2,221.2
CO(g)	carbon monoxide	−110.53
$CO_2(g)$	carbon dioxide	−393.51
$CaCO_3(s)$*	calcium carbonate	−1207.6
CaO(s)	calcium oxide	−635.0
$H_2(g)$	hydrogen	0
HCl(g)	hydrogen chloride	−92.31
HCl(aq)*	hydrochloric acid (1 M)	−167.2

element's most stable allotrope: ΔH^o_f = 0

element… ΔH^o_f = 0

Real processes: must scale for quantity of reactants…

What quantity of heat is released when 10.0g of nitroglycerin is detonated at room temp. against constant atmospheric pressure?

$$4\ C_3H_5N_3O_9(s) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$$

MM 227.1 g/mol

Substance	ΔH^o_f kJ/mol
Nitroglycerin (s)	-364
CO_2 (g)	-393.5
Water vapour	-241.8

ANS: ΔH^o_{rxn} = -62.6 kJ for the 10.0 grams (0.04404 mol…)
= could warm ~200 mL of water 25 → 100°C (verify this…)

VOLUME ↑ ENORMOUS! ⇨ DESTRUCTIVE SHOCK WAVE !

6.9 Product- *or* reactant-favoured reactions and thermochemistry

- Exothermic reactions are OFTEN product-favoured
  - Implies they proceed forward as written
- Endothermic reactions are OFTEN reactant-favoured
  - Implies they don't proceed forward (or not much)

…but predicting this involves <u>more</u> than only thinking about heat flow involved in reaction.

(and so we will study Ch.19…)

Thinking about the energy changes that occur during rxns & other processes will enable us to PREDICT if a rxn should proceed
FORWARD on its own, or not at all, or BACKWARDS!

ASSIGNED READINGS:

BEFORE NEXT CLASS:

Read: rest of Ch.6

+ WORK ON Problems from Ch.6

Next class: Ch. 19.1-19.5