11/7/2018

Determining ΔH°_{rxn} from standard enthalpies of formation, ΔH°_f

Can calculate ΔH°_{rxn}

$^\circ$ = standard conditions.

SOLID	LIQ	GAS	SOL$^{\underline{N}}$
pure	pure	1 atm	1 M

What's ΔH°_f ?

ΔH°_{rxn} where we make/form 1 mol of a substance from its elements in their most stable form.

- hydrogen: $H_2(g)$
- chlorine: $Cl_2(g)$
- bromine: $Br_2(l)$
- iodine: $I_2(s)$
- carbon: $C(s, graphite)$
  ~~$C(s, diamond)$~~
- phosphorus: $P_4(s)$
- sulfur: $S_8(s)$
- sodium: $Na(s)$

ex: $\Delta H^\circ_f(CH_4(g))$, refers to:

$C(s, graphite) + 2H_2(g) \longrightarrow CH_4(g)$; $\Delta H^\circ_f(CH_4(g)) = -74.6 \frac{kJ}{mol}$

ex: $\Delta H^\circ_f(CH_3CH_2OH(l)) = -277.6\ kJ/mol$

eq: $2C(s, graphite) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow CH_3CH_2OH(l)$; $\Delta H^\circ_f = -277.6 \frac{kJ}{mol}$

TABLE 6.5 Standard Enthalpies (or Heats) of Formation, ΔH_f°, at 298 K

Formula	ΔH_f°(kJ/mol)	Formula	ΔH_f°(kJ/mol)	Formula	ΔH_f°(kJ/mol)
Bromine		C_3H_8O(*l*, isopropanol)	−318.1	***Oxygen***	
Br(*g*)	111.9	C_6H_6(*l*)	49.1	O_2(*g*)	0
Br_2(*l*)	0	$C_6H_{12}O_6$(*s*, glucose)	−1273.3	O_3(*g*)	142.7
HBr(*g*)	−36.3	$C_{12}H_{22}O_{11}$(*s*, sucrose)	−2226.1	H_2O(*g*)	−241.8
Calcium		***Chlorine***		H_2O(*l*)	−285.8
Ca(*s*)	0	Cl(*g*)	121.3	***Silver***	
CaO(*s*)	−634.9	Cl_2(*g*)	0	Ag(*s*)	0
$CaCO_3$(*s*)	−1207.6	HCl(*g*)	−92.3	AgCl(*s*)	−127.0
Carbon		***Fluorine***		***Sodium***	
C(*s*, graphite)	0	F(*g*)	79.38	Na(*s*)	0
C(*s*, diamond)	1.88	F_2(*g*)	0	Na(*g*)	107.5
CO(*g*)	−110.5	HF(*g*)	−273.3	NaCl(*s*)	−411.2
CO_2(*g*)	−393.5	***Hydrogen***		Na_2CO_3(*s*)	−1130.7
CH_4(*g*)	−74.6	H(*g*)	218.0	$NaHCO_3$(*s*)	−950.8
CH_3OH(*l*)	−238.6	H_2(*g*)	0	***Sulfur***	
C_2H_2(*g*)	227.4	***Nitrogen***		S_8(*s*, rhombic)	0
C_2H_4(*g*)	52.4	N_2(*g*)	0	S_8(*s*, monoclinic)	0.3
C_2H_6(*g*)	−84.68	NH_3(*g*)	−45.9	SO_2(*g*)	−296.8
C_2H_5OH(*l*)	−277.6	NH_4NO_3(*s*)	−365.6	SO_3(*g*)	−395.7
C_3H_8(*g*)	−103.85	NO(*g*)	91.3	H_2SO_4(*l*)	−814.0
C_3H_6O(*l*, acetone)	−248.4	N_2O(*g*)	81.6		

Table 6-5 lists ΔH_f° @ 298.15K (25 °C)
- Appendix III

ΔH_f° (most stable form of element) = $\varnothing$

- Can calculate <u>any</u> ΔH°_{rxn} from ΔH_f° !

How?

$$\text{Reactants} \xrightarrow{\Delta H^\circ_{rxn}} \text{Products}$$

$-\Delta H_f^\circ$(all reactants) → elements → $+\Delta H_f^\circ$ (all products)

Can write as:

#mol of each products

#mol ea. reactant

$$\Delta H^\circ_{rxn} = \sum_i n_p \cdot \Delta H_f^\circ(\text{products}) \ominus \sum_i n_r \cdot \Delta H_f^\circ(\text{reactants})$$

Sigma/Sum

ex: $2NH_4NO_3(s) \longrightarrow 4H_2O(g) + 2N_2(g) + O_2(g)$

$$\Delta H^\circ_{rxn} = \left[4\text{mol} \times \Delta H_f^\circ(H_2O(g)) + 2\text{mol} \times \cancel{\Delta H_f^\circ(N_2(g))}^{\,0} + 1\text{mol} \times \cancel{\Delta H_f^\circ(O_2(g))}^{\,0}\right]$$

$$\ominus \left[2\text{ mol} \times \Delta H_f^\circ(NH_4NO_3(s))\right]$$

$$= \left[4\cancel{\text{mol}} \times -241.8 \frac{kJ}{\cancel{mol}}\right] \ominus \left[2\cancel{\text{mol}} \times -365.6 \frac{kJ}{\cancel{mol}}\right] = -236 \text{ kJ}$$

exothermic!

$2NH_4NO_3(s) \longrightarrow 4H_2O(g) + 2N_2(g) + O_2(g)$; $\Delta H^\circ_{rxn} = -236\,kJ$.

What's q_p is 20.2g NH_4NO_3 reacts ?

$$20.2\cancel{g\ NH_4NO_3} \times \frac{1\ mol\ \cancel{NH_4NO_3}}{80.05\cancel{g\ NH_4NO_3}} \times \frac{-236\,kJ}{2\,mol\ \cancel{NH_4NO_3}} = -29.8\,kJ.$$

so, 29.8 kJ of heat was given off

MAS 436.