10/28/2019 Another way to calculate ΔH°_{rxn}...

using ΔH°_f!

ΔH°_{rxn}

STD conditions: Gases: 1 atm
Solute: 1 M
Solid/Liq: pure

ΔH°_f : ΔH°_{rxn} when we form 1 mol of specified substance from its elements in their most stable form.

formation

ex: Appendix: $\Delta H^\circ_f(CH_4(g)) = -74.6\ kJ/mol$

$$\underbrace{C(s,\text{graphite}) + 2H_2(g)}_{\text{elements}} \longrightarrow \underbrace{\boxed{CH_4(g)}}_{1\ mol} \ ;\ \Delta H^\circ_{rxn} = -74.6\ kJ$$

allotropes: diff't forms of an element
ex: Carbon: graphite, diamond

$\Delta H^\circ_f(NaHCO_3(s)) = -950.8\ kJ/mol$

$$Na(s) + \tfrac{1}{2}H_2(g) + C(s,\text{graphite}) + \tfrac{3}{2}O_2(g) \longrightarrow NaHCO_3(s)\ ;\ \Delta H = -950.8\ kJ$$

oxygen: $O_2(g)$ "oxygen"
$O_3(g)$ ozone (Appendix II)

?

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

$-\Delta H^\circ_f(\text{reacts})$ $\qquad$ $+\Delta H^\circ_f(\text{Products})$

ELEMENTS

sum

$$\Delta H^\circ_{rxn} = \sum_{\text{products}} n \cdot \Delta H^\circ_f - \sum_{\text{reactants}} n \cdot \Delta H^\circ_f$$

#mol

ex: $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$; $\Delta H^\circ_{rxn} = ?$

ΔH°_f (KJ/mol)	-45.9	0	$+91.3$	-241.8

$\Delta H^\circ_f(O_2(g))$? $\quad O_2(g) \longrightarrow O_2(g)$; $\Delta H^\circ_{rxn} = 0$

ΔH°_f (most stable elements) $= \emptyset$

$$\Delta H^\circ_{rxn} = \Big[\underbrace{4\,\text{mol} \times 91.3\,\text{KJ/mol}}_{NO} + \underbrace{6\,\text{mol} \times -241.8\,\text{KJ/mol}}_{H_2O}\Big] - \Big[4\,\text{mol} \times -45.9\,\text{KJ/mol} + 5\,\text{mol} \times \emptyset\Big]$$

$= -902.0\,\text{KJ}$ (very exothermic!)

$-902.0\,\text{KJ} : 4\,\text{mol } NH_3 : 5\,\text{mol } O_2 : 4\,\text{mol } NO : 6\,\text{mol } H_2O$

Q: How much heat is released when $37.0\,g$ NH_3 burns?

$$37.0\,g\,\cancel{NH_3} \times \frac{1\,\cancel{mol\,NH_3}}{17.03\,\cancel{g\,NH_3}} \times \frac{-902.0\,\text{KJ}}{4\,\cancel{mol\,NH_3}} = -490\,\text{KJ}$$

490KJ of heat is lost by rxn

Standard Conditions

- The **standard state** is the state of a material at a defined set of conditions.
  - Pure gas at exactly 1 atm pressure
  - Pure solid or liquid in its most stable form at exactly 1 atm pressure and temperature of interest
    - Usually 25 °C
  - Substance in a solution with concentration 1 M
- The **standard enthalpy change, $\Delta H°$**, is the enthalpy change when all reactants and products are in their standard states.
- The **standard enthalpy of formation,** ΔH_f°, is the enthalpy change for the reaction forming 1 mole of a pure compound from its constituent elements.
  - The elements must be in their standard states.
  - The ΔH_f°, for a pure element in its standard state = 0 kJ/mol.

Pearson

Standard Enthalpies of Formation (1 of 3)

Formula	ΔH_f°, (kJ/mol)
Bromine	
Br(*g*)	111.9
Br_2(*l*)	0
HBr(*g*)	−36.3
Calcium	
Ca(*s*)	0
CaO(*s*)	−634.9
$CaCO_3$(*s*)	−1207.6
Carbon	
C(*s*, graphite)	0
C(*s*, diamond)	1.88

Formula	ΔH_f°, (kJ/mol)
CO(*g*)	−110.5
CO_2(*g*)	−393.5
CH_4(*g*)	−74.6
CH_3OH(*l*)	−238.6
C_2H_2(*g*)	227.4
C_2H_4(*g*)	52.4
C_2H_6(*g*)	−84.68
C_2H_5O H(*l*)	−277.6
C_3H_8(*g*)	−103.85
C_3H_6O(*l*, acetone)	−248.4
C_3H_8O(*l*, isopropanol)	−318.

Pearson

Standard Enthalpies of Formation (2 of 3)

Formula	ΔH_f°, (kJ / mol)	Formula	ΔH_f°, (kJ / mol)
$C_6H_6(l)$	49.1	**Hydrogen**	
$C_6H_{12}O_6(s$, glucose)	−1273.3	$H(g)$	218.0
$C_{12}H_{22}O_{11}(s$, sucrose)	−2226.1	$H_2(g)$	0
Chlorine		**Nitrogen**	
$Cl(g)$	121.3	$N_2(g)$	0
$Cl_2(g)$	0	$NH_3(g)$	−45.9
$HCl(g)$	−92.3	$NH_4NO_3(s)$	−365.6
Fluorine		$NO(g)$	91.3
$F(g)$	79.38	$N_2O(g)$	81.6
$F_2(g)$	0	**Oxygen**	
$HF(g)$	−273.3	$O_2(g)$	0

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Standard Enthalpies of Formation (3 of 3)

Formula	ΔH_f°, (kJ / mol)	Formula	ΔH_f°, (kJ / mol)
$O_3(g)$	142.7	$NaHCO_3(s)$	−950.8
$H_2O(g)$	−241.8	**Sulfur**	
$H_2O(l)$	−285.8	$S_8(s$, rhombic)	0
Silver		$S_8(s$, monoclinic)	0.3
$Ag(s)$	0	$SO_2(g)$	−296.8
$AgCl(s)$	−127.0	$SO_3(g)$	−395.7
Sodium		$H_2SO_4(l)$	−814.0
$Na(s)$	0		
$Na(g)$	107.5		
$NaCl(s)$	−411.2		
$Na_2CO_3(s)$	−1130.7		

Pearson

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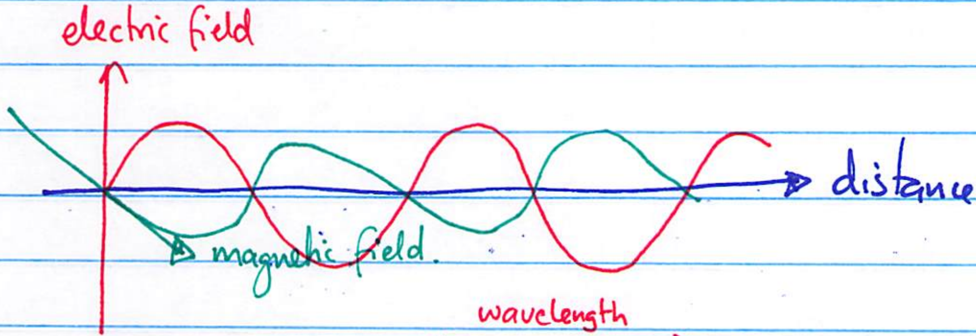
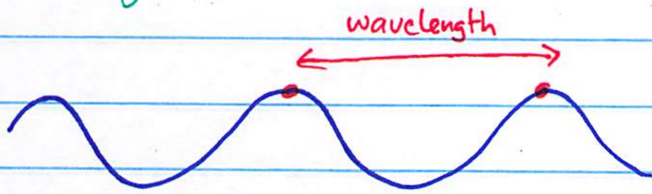
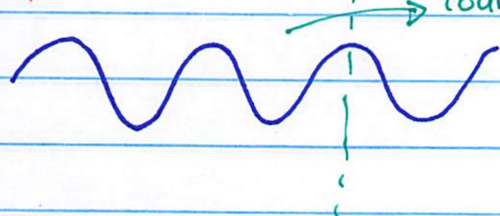
Chapter 8 Quantum mechanics of the atom

light: electromagnetic (EM) wave





λ (lambda) units: m (SI)



count #waves passing thru' every second

ν (nu) ~ frequency of wave : $\frac{\#\text{waves}}{\text{second}}$: units: $\frac{1}{s}$ or s^{-1}, or Hz

Hertz