

Energy — heat and work

work is "pressure-volume work"

$$W = -P_{\text{ext}} \Delta V$$

$\Delta V = V_f - V_i$
constant external pressure

Expanding gas has $\Delta V > 0$ so $W < 0$ work done by system on surroundings

compressing gas has $\Delta V < 0$ so $W > 0$ work done on system by surroundings

$$q + W = \text{total change in energy} = \Delta U = U_f - U_i$$

ΔU "internal energy"

difficult to measure ΔU directly so usually measure q and w individually

q, w path funcs

↓
depends on process

ΔU state func

↓
doesn't depend on process only start + finish

usually chem.istry done @ constant pressure

$$\Delta U = q_p - P_{\text{ext}} \Delta V$$

q @ const pressure

rearrange to $\underline{q_p = \Delta U + P_{\text{ext}} \Delta V}$

q_p = heat at constant pressure = useful to know

$$q_p = \Delta U + P_{\text{ext}} \Delta V = \Delta H$$

ΔH change in "enthalpy"

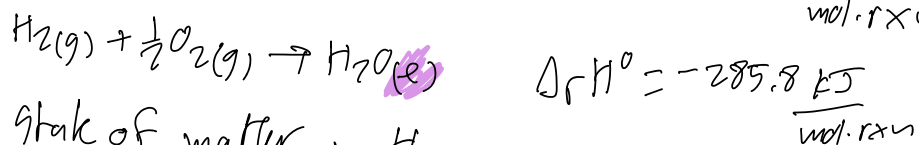
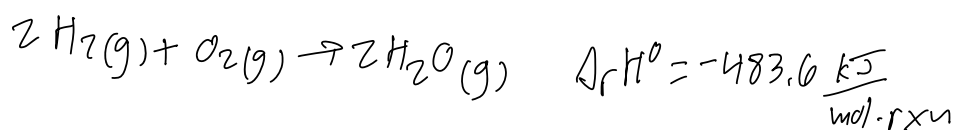
ΔH and ΔU differ by $P_{\text{ext}} \Delta V$

if $\Delta V = 0$ then $\Delta H = \Delta U$

ΔH will be our main focus in chemistry

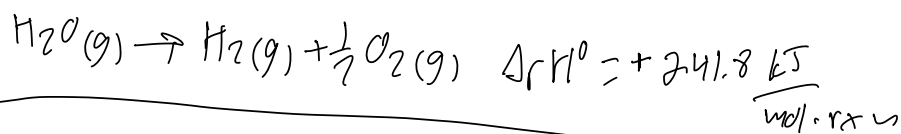
$\Delta_r H^\circ$ ← under standard conditions = pure substances / 1 bar pressure
↳ for a reaction * need to specify temp

units of $\Delta_r H^\circ$ are $\frac{J}{mol \cdot rxn}$ ← for the reaction as written

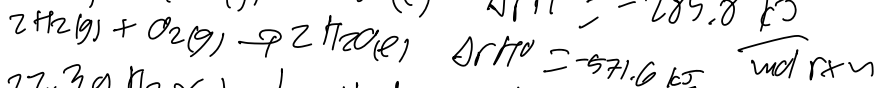
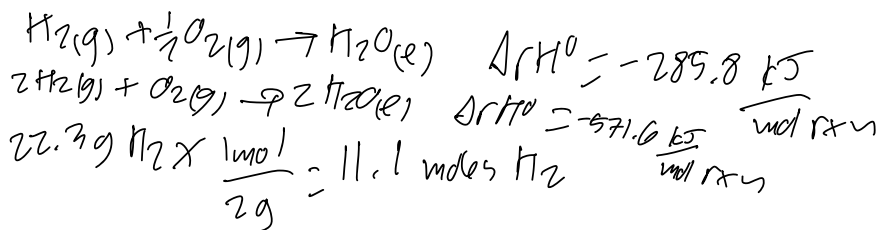


* state of matter matters

→ write it backwards



Ex: (22.3 g $H_2(g)$ is reacted w/ 35.0 g of O_2 to make liquid water - what is $\Delta_r H^\circ$ for this process)



$$22.3 \text{ g } H_2 \times \frac{1 \text{ mol}}{2 \text{ g}} = 11.1 \text{ moles } H_2$$

$$35 \text{ g } O_2 \times \frac{1 \text{ mol}}{32 \text{ g}} = 1.1 \text{ moles } O_2 \leftarrow \text{L.R.}$$

$$1.1 \text{ mol } O_2 \times \frac{-285.8 \text{ kJ}}{0.5 \text{ moles } O_2} = -629 \text{ kJ} - \Delta H$$

$$\frac{1.1 \text{ mole } O_2 \times -571.6 \text{ kJ}}{1 \text{ mole } O_2}$$

Where does $\Delta_r H^\circ$ come from

- Experiment
- looking stuff up

Experiment is calorimetry

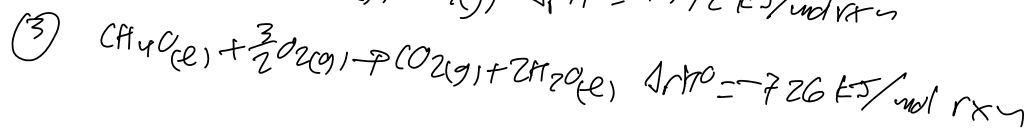
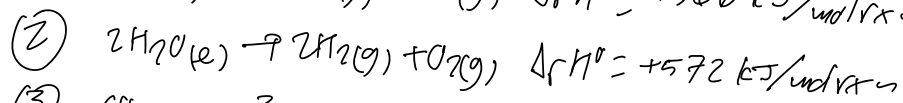
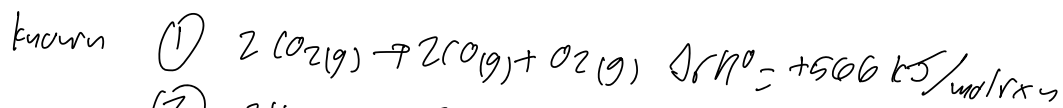
- do reaction in a bucket of water
- reaction will either give off heat into water or take in heat from water
- measure ΔT of water, know mass of water
- Find q_{H_2O}

$$q_{rxn} = -q_{H_2O}$$

b/c constant pressure $q_p = \Delta H$

$\Delta_r H^\circ$ from looking things up

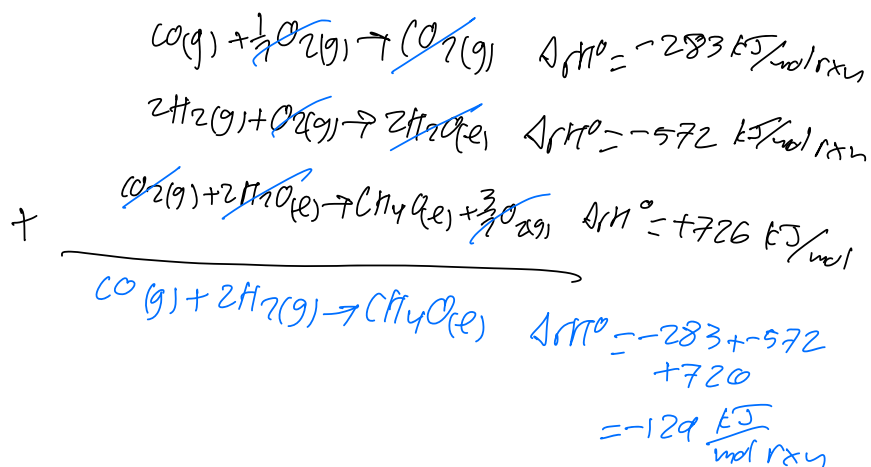
Hess's Law - combine reactions and their $\Delta_r H^\circ$ to "make" the one we want



Reverse (1) and divide by 2

Reverse (2)

Reverse (3)



Other way to calc $\Delta_r H^\circ$ is to use what is (g/l)

$\Delta_f H^\circ$
formation

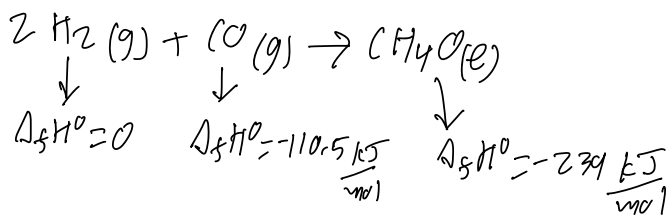
$\Delta_f H^\circ$ is $\Delta_r H^\circ$ for forming 1 mole of a compound from its elements

$\Delta_f H^\circ = 0$ for pure element

For $\text{NH}_3\text{(g)}$

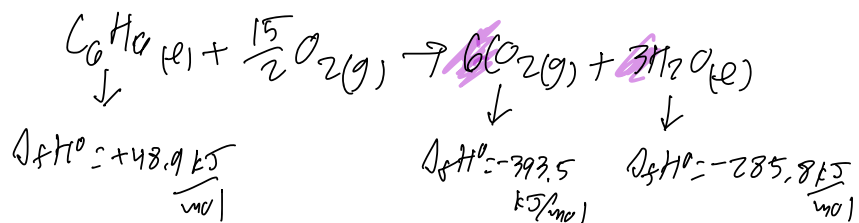
$\Delta_f H^\circ_{\text{NH}_3}$ is $\Delta_r H^\circ$ for $\frac{1}{2}\text{N}_2\text{(g)} + \frac{3}{2}\text{H}_2\text{(g)} \rightarrow \text{NH}_3\text{(g)}$

$$\Delta_f H^\circ_{\text{NH}_3} = -45.9 \frac{\text{kJ}}{\text{mol}}$$

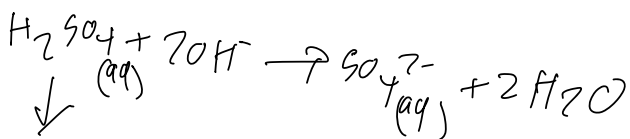
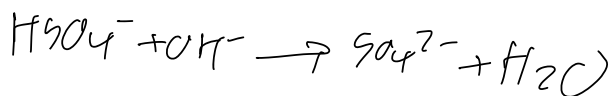


$$\Delta_r H^\circ = [\text{sum of } \Delta_f H^\circ \text{ of all products}] - [\text{sum of } \Delta_f H^\circ \text{ of all reactants}]$$

$$\Delta_r H^\circ = -239 \frac{\text{kJ}}{\text{mol}} - -110.5 \frac{\text{kJ}}{\text{mol}} \approx -129 \frac{\text{kJ}}{\text{mol}}$$

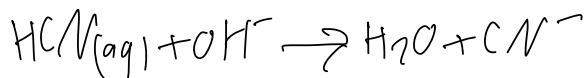
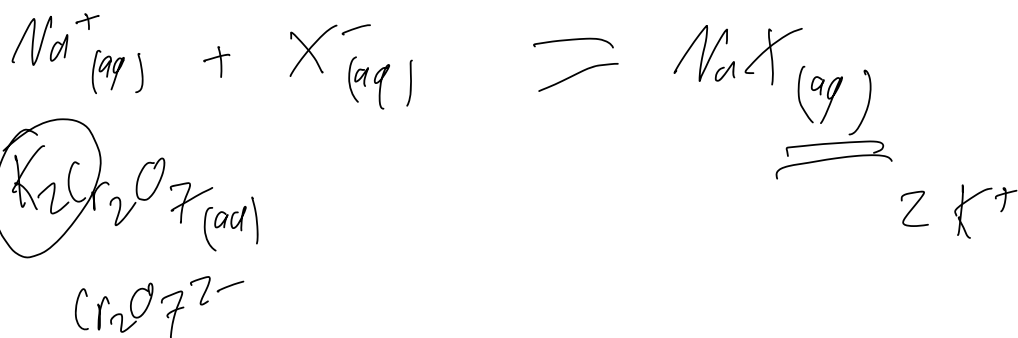


$$\Delta_r H^\circ = \left[6 \times -393.5 \frac{\text{kJ}}{\text{mol}} + 3 \times -285.8 \frac{\text{kJ}}{\text{mol}} \right] - \left[48.9 \frac{\text{kJ}}{\text{mol}} \right] = -3267.3 \frac{\text{kJ}}{\text{mol rxn}}$$



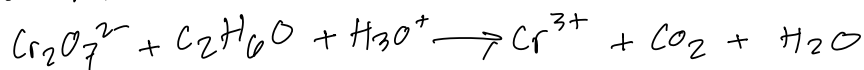
Not same $2\text{H}_3\text{O}^+ + \text{SO}_4^{2-}$

50 mL of 0.1 M H_2SO_4
 0.005 moles H_2SO_4
 $\times 2 \text{ mol OH}^-$
 $\hline 1 \text{ mol H}_2\text{SO}_4$



HX is an acid. 0.72M HX solution has pH of 1.75. Is HX a strong acid?

Redox titration

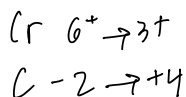
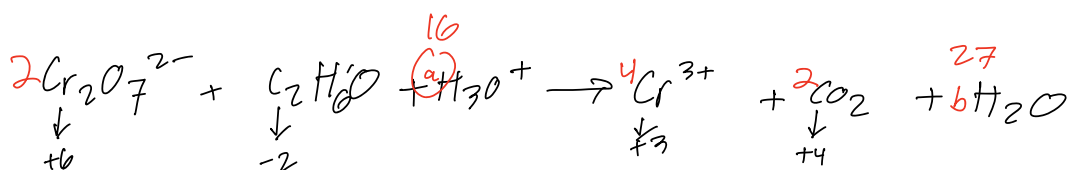


37.5 mL blood sample requires 19.25 mL of 0.085M $\text{K}_2\text{Cr}_2\text{O}_7$ to titrate
 what is $[\text{C}_2\text{H}_5\text{OH}]$? what is v/v% of BAC

HCl/NaOH titration

25.00 mL HCl titrated w/ 17.35 mL of 0.25M NaOH to get
 to equiv pt. pH of original HCl? what pH in flask if we add
 1.7 mL NaOH after equiv pt

C_6H_{14} combustion. If you burn 75g how many grams CO_2 produced



Oxygens

$$15 + a = 4 + b$$

$$11 + a = b$$

hydrogens

$$6 + 3a = 2b$$

$$6 + 3a = 2b$$

$$6 + 3a = 22 + 2a$$

$$a = 16$$