

# Week 4 Recitation

Chapter 3 and Chapter 4

Ch 4 reading: 101-117, 135-138, 143-146 (equations)

Questions?

# HW2 Mistakes: Sign Errors

Some fixed by paying careful attention to the language used:

- Absorbed, stored,  $(+)dT = +$
- Evolved, gives off,  $(-)dT = -$

Others by thinking a bit about the number:

- Does reporting a negative mass make sense?
- What is the sign of  $dH_{\text{vap}}$  for vaporization? Condensation?

Finally, check your answer after executing your code.

# HW2 Mistakes: 3.24b

Process: **Isobaric** expansion of 1 mol water vapor from 20 to 25 L

$$dS = n \cdot C_{p,m} \cdot \ln(V_2/V_1)$$

$$dS = 8.14 \text{ J/K}$$

$$dS = \frac{dq_{rev}}{T} = \frac{C_{p,m} dT}{T}$$

$$\int dS = C_{p,m} \int_{T_1}^{T_2} \frac{1}{T} dT$$

$$\Delta S = C_{p,m} \ln \frac{T_2}{T_1} = C_{p,m} \ln \frac{V_2}{V_1}$$

Some treated as **isothermal** expansion...

$$dS = n \cdot R \cdot \ln(V_2/V_1)$$

$$dS = 1.86 \text{ J/K}$$

$$dS = \frac{dq_{rev}}{T} = \frac{dU - dw_{rev}}{T}, dU = 0$$

$$dS = \frac{-dw_{rev}}{T} = \frac{pdV}{T}, \text{sub. } \frac{p}{T} = \frac{nR}{V}$$

$$\int dS = nR \int_{V_1}^{V_2} \frac{1}{V} dV$$

$$\Delta S = nR \ln \frac{V_2}{V_1} = nR \ln \frac{P_1}{P_2}$$

## Example 3.7: Method 1

$\Delta_r G(T) \cong \Delta_r H(25) - T\Delta_r S(25)$ , where T is not significantly different from 25 deg C

$$\begin{aligned}\Delta_r G(T) - \Delta_r G(25^\circ\text{C}) &= \\ \Delta_r H(25^\circ\text{C}) - \Delta_r H(25^\circ\text{C}) - T\Delta_r S(25^\circ\text{C}) + (298)\Delta_r S(25^\circ\text{C})\end{aligned}$$

$$\Delta_r G(T) - \Delta_r G(25^\circ\text{C}) = -(T - 298)\Delta_r S(25^\circ\text{C})$$

Same equation used to solve Ex. 3.7, but what did Mark mean about pV work?

# $\Delta G$ and pV work

$$\begin{aligned}dG &= dH - TdS - SdT \\&= dU + pdV + Vdp - TdS - SdT \\&= dq_{\text{rev}} + dw_{\text{rev}} + pdV + Vdp - TdS - SdT \\&= TdS + dw_{\text{rev}} + pdV + Vdp - TdS - SdT \\dG &= Vdp - SdT + dw_{\text{other}}\end{aligned}$$

If we disregard non-expansion work:

$$dG = Vdp - SdT$$

Substitute/assume:

$$dH = dU + d(pV)$$

First Law, rev

$$dS = dq_{\text{rev}}/T$$

$$dw_{\text{rev}} = -pdV + dw_{\text{other}}$$

All state variables!

# $\Delta G$ and pV work

Take the equation previously derived and assume constant p:

$$dG_p = -SdT$$

Consider two temperatures, integrate over T1 to T2:

$$\int_{\Delta_r G(T_1)}^{\Delta_r G(T_2)} dG = -\Delta_r S \int_{T_1}^{T_2} dT, \text{ render in terms of a reaction:}$$

$$\Delta_r G(T_2) - \Delta_r G(T_1) = -(T_2 - T_1)\Delta_r S$$

## Example 3.7: Method 2, Gibbs-Helmholtz

$$\int_{\Delta_r G(T_1)}^{\Delta_r G(T_2)} dG = - \int_{T_1}^{T_2} \Delta_r S dT \qquad dS = q_{\text{rev}}/T = dH/T, \text{ div. by } 1/T$$

$$\frac{\Delta_r G(T_2)}{T_2} - \frac{\Delta_r G(T_1)}{T_1} = -\Delta_r H \int_{T_1}^{T_2} \frac{1}{T^2} dT = -\Delta_r H \left[ \frac{1}{T_2} - \frac{1}{T_1} \right]$$

In summary, we can derive an expression for  $dG$  at constant  $p$  that is a function of state variables. This can be further refined into functions of  $dS/dH$ , the calculations for which are simplified at small  $dT$  (i.e. assume  $dS/dH$  are constant).



## 4.2a: ATP hydrolysis

Calculate the free energy change of ATP hydrolysis in muscle at 25C.

[ATP] = 1.25e-3 M, [ADP] = 0.50e-3 M, [Pi] = 2.5e-3 M

$$\Delta_r G' = \Delta_r G + RT \ln(Q)$$

Find the free energy of reaction:

-31.0 kJ/mol (pg. 136-37 Table 4.3)

```
# Ch4, q2
# hydrolysis of ATP: ATP + H2O -> ADP + Pi
# concentrations are 1.25e-3 M ATP, 0.5e-3 M ADP, 2.5e-3 M Pi
import scipy.constants as scc
import numpy as np
dGss = -31.0 # kJ/mol
ATP = 1.25e-3 # M
ADP = 0.50e-3
Pi = 2.5e-3
Q = (ADP*Pi)/ATP
T = 25 + 273.15 # C to K
dGn = dGss + (scc.R/1000)*T*np.log(Q)
print("The free energy change under these conditions is %2.0f kJ/mol." % dGn)
```

The free energy change under these conditions is -48 kJ/mol.

# Calculating K: ATP hydrolysis

$$\Delta_r G = -RT \ln(K)$$

$$K = e^{-\frac{\Delta_r G}{RT}}$$

Assume standard state:

$$\Delta_r G = -31.0 \text{ kJ/mol}$$

```
# You will need to be able to find equilibrium constants.
# Let's use the standard state free energy of ATP hydrolysis.
import math as m
units_bad = dGss*1000 # We don't want units in the exponential.
K_ATPlys = m.exp(-units_bad/(scc.R*T))
print("K of ATP hydrolysis is %2.2g at 25 deg C." % K_ATPlys)
# This is a tad cold for physiological context, let's up the temp.
units_bad = -35.0*1000 # J/mol, decreases at higher temp.
T = 37 + 273.15
K_ATPlys = m.exp(-units_bad/(scc.R*T))
print("K of ATP hydrolysis is %2.2g at 37 deg C." % K_ATPlys)
```

```
K of ATP hydrolysis is 1.7e+05 at 25 deg C.
K of ATP hydrolysis is 7.8e+05 at 37 deg C.
```

# Activities

Not going to cover in-depth here, has yet to be introduced in lecture.

Read pages 108-109, 115-119 for specifics

Read equilibrium sections to better understand the effect of activity on chemical equilibria

Relevant equations: Debye-Huckel, see page 145

# Questions?

Feel free to leave if you're good!