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It must be turned in as a single PDF. Image files for each page will not be accepted.

You can download Adobe Scan on your phone to make the PDF.

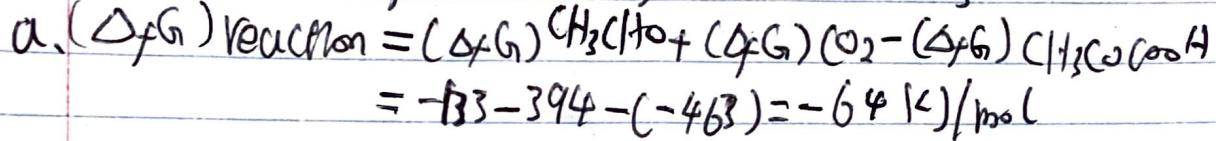
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Who did you work with?

- a. Chaoyi Zheng
- b. Taha Fadlou Allah
- c.
- d.

Who else did you ask for help?

1. The decarboxylation of pyruvic acid occurs via the following reaction



Yes, because G of the reaction under 25°C is negative.

b. $\ln K_p(T_f) = \ln K_p(298.15\text{K}) - \frac{\Delta_f H^\circ}{R} \left(\frac{1}{T_f} - \frac{1}{298.15\text{K}} \right)$
 $= \ln K_p(298.15\text{K}) - \frac{\Delta_f H^\circ}{8.314} \left(\frac{1}{80} - \frac{1}{298.15\text{K}} \right)$

$$\Delta_f H^\circ = (-394 - 166) - (-584)$$

$$= 24 \text{ kJ/mol.}$$

~~Put~~ part into equation.

~~$K_p = 0.026$, put into equation.~~

$$\ln K_p(298\text{K}) = -\frac{\Delta_f H^\circ}{R} = -\frac{-64000}{8.314(298)}$$

$$\ln K_p(298\text{K}) = 25.8$$

$$\ln K_p(80\text{K}) = 25.8 - \left(\frac{24}{8.314} \right) \left(\frac{1}{80} - \frac{1}{298} \right)$$

$$= -0.57$$

$$\boxed{K_p = 0.57}$$

C. K_p is less than 1, so the reactant is favor.

2. For a pure substance

a) derive $\left(\frac{\delta S_m}{\delta V}\right)_T = \frac{B}{nK}$.

We know this is a Maxwell Relation taken under constant Temperature and Volume measure so we start with the expression.

$$\left(\frac{\partial}{\partial V} \left(\frac{\partial U(V,T)}{\partial T} \right)_V \right)_T = \left(\frac{\partial}{\partial T} \left(\frac{\partial U(V,T)}{\partial V} \right)_T \right)_V$$

Substitute $dU = TdS - PdV$ into LHS

$$\delta U \delta V = 0, \quad \delta U \delta T = 0.$$

$$\left(\frac{\partial}{\partial V} \left(\frac{\partial(TdS - PdV)}{\partial T} \right)_V \right)_T = \left(\frac{\partial}{\partial T} \left(\frac{\partial(TdS - PdV)}{\partial V} \right)_T \right)_V.$$

$$\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V.$$

$$\left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial P}{\partial V}\right)_T \left(\frac{\partial T}{\partial P}\right)_V = -1$$

$$B = \frac{1}{V} \left(\frac{\partial r}{\partial T}\right)_P \quad K = -\frac{1}{V} \left(\frac{\partial V}{\partial P}\right)_T$$

Substitution to.

$$\frac{Br}{KV} = -\left(\frac{\partial P}{\partial T}\right)_V \rightarrow \left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial P}{\partial T}\right)_V = \frac{B}{K}$$

$$\delta S_m = \frac{ds}{n} \text{ substitution } \delta S_m \cdot n \text{ to equation.}$$

$$\left(\frac{\delta S_m}{\delta V}\right)_T \cdot n = \frac{B}{K}. \quad \left(\frac{\delta S_m}{\delta V}\right) = \frac{B}{nK}.$$

b. Integrating both sides knows that $\frac{P}{nR}$ is cons gives.

$$\int dS_m = \frac{P}{nR} \int dV$$

$$\Delta S_m = \frac{P}{nR} \Delta V \quad \text{Since } \frac{P}{nR} \text{ is always +, } S_m \text{ increase with } \Delta V \text{ increase.}$$

C. We start with the definition of the Gibbs free energy for b_1, n_2, h_3 .

$$\begin{aligned} dG &= \left(\frac{\partial G}{\partial T}\right)_{P, n_1, b_2, h_3} dT + \left(\frac{\partial G}{\partial P}\right)_{T, n_1, b_2, h_3} dP + \\ &\quad \left(\frac{\partial G}{\partial n_1}\right)_{T, P, b_2, h_3} + \left(\frac{\partial G}{\partial b_2}\right)_{T, P, n_1, h_3} d n_2 \\ &\quad + \left(\frac{\partial G}{\partial h_3}\right)_{T, P, n_1, b_2}. \end{aligned}$$

We define $\left(\frac{\partial G}{\partial n_x}\right)_{P, T}$ to chemical potential ($= \mu$).

$$dG = \left(\frac{\partial G}{\partial T}\right)_{P, n_x} dT + \left(\frac{\partial G}{\partial P}\right)_{T, n_x} dP + \sum \mu_i d n_i$$

$$dG = V dp - \sum \mu_i dn_i.$$

When Temperature concentration $dn = 0$ is const.
 $dT = 0$.

$$V = \left(\frac{\partial G}{\partial P}\right)_{T, n_x} \quad \text{①.}$$

When Temperature pressure are const. Then writing μ_i (gmo).

$$\mu_i = \left(\frac{\partial G}{\partial n_x}\right)_{T, P} \quad \text{②.}$$

We now derive both sides of equation ① w/ regards to total moles, and both of equation ③ w/ regards to press.

$$① \left(\frac{\partial V}{\partial n_x} \right)_{T, P} = \left(\frac{\partial^2 G}{\partial p \partial n_x} \right) \quad \text{equal}$$

$$② \left(\frac{\partial M_i}{\partial P} \right)_{T, n_x} = \left(\frac{\partial^2 G}{\partial n_x \partial P} \right).$$

Thus, $\left(\frac{\partial V}{\partial n_x} \right)_{T, P} + \left(\frac{\partial M_i}{\partial P} \right)_{T, n_x}$.

$$d) \left(\frac{\partial M_{\text{osm}}}{\partial P} \right)_{T, n_{\text{Na}}, n_{\text{Cl}}} = \left(\frac{\partial V}{\partial n_{\text{osm}}} \right)_{T, P, n_{\text{Na}}, n_{\text{Cl}}}$$

The chemical potential conc. At constant T & P, value increase. Increase with an increasing pressure w/ an increase in both moles. Thus,

e) At P, we have. Mark.

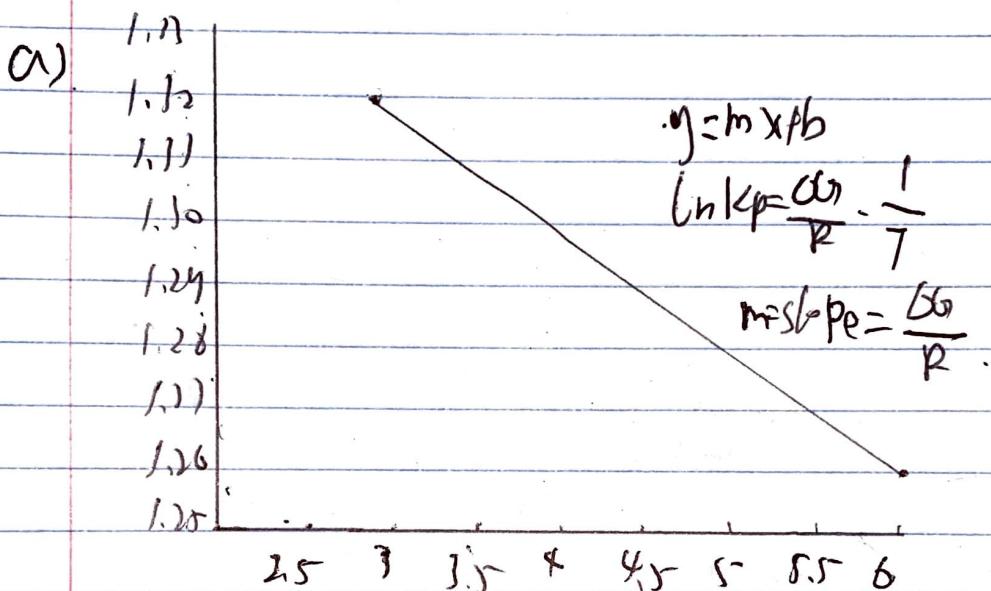
$$\left(\frac{\partial M}{\partial P} \right)_{T, n_{\text{Na}}, n_{\text{Cl}}} = \left(\frac{\partial V}{\partial n_{\text{osm}}} \right)_{P, T, n_{\text{Na}}, n_{\text{Cl}}}$$

$$\int_{M_i}^{M_{\text{osm}}} dM = \left(\frac{\partial V}{\partial n_{\text{osm}}} \right) \int_{P_0}^P -2P.$$

$$(M_{\text{osm}} - M_i) = \left(\frac{\partial V}{\partial n_{\text{osm}}} \right) (P - P_0).$$

3. The following thermodynamic data was measure for a chemical reaction

T	Kp	$\chi - \eta$
167	3.53	$8.9 \times 10^{-3} - 1.26$
250	3.67	$4 \times 10^{-3} - 1.76$
333	3.74	$3 \times 10^{-3} - 1.32$



b) $m = \frac{\Delta \eta}{\Delta x} = \frac{1.50 - 1.26}{(4 \times 10^{-3})(5 \times 10^{-3})} = -21.05$.

$$-21.05 = \frac{\Delta G^\circ}{8.314} \rightarrow \Delta G^\circ = 175 \text{ J/mol}.$$

Reaction is hot spontaneous because $\Delta G^\circ < 0$.

c) It is enthalpically driven as the equation

$$\ln K_p = -\frac{\Delta H^\circ}{R} \cdot \frac{\text{enthalpy}}{\text{no enpny}}$$

4. What is the second law of thermodynamics?

The second law of thermodynamics states that the total entropy of an isolated system can never decrease over time, and is constant if and only if all processes are reversible.

5. What is the third law of thermodynamics? Explain how this makes entropy different from energy or enthalpy.

Third law is stated as regarding the properties of closed systems in thermodynamic equilibrium; the entropy of a system approaches a constant value as its temperature approaches absolute zero. This makes it different than internal energy and enthalpy because we can use S_{∞} at 0 K as a reference state to find the enthalpy at the desired temperature, the same cannot be done with U and H.

6. Why can't we build a perpetual motion machine?

Because energy can be neither created nor destroyed. It simply changes from one form to another. To keep a machine moving, the energy applied should stay with the machine without any losses. Because of this fact, it is impossible to build perpetual motion machines.

7. Why is Gibbs's free energy usually more useful to chemists than Helmholtz energy.

The Helmholtz energy change is equal to the maximum reversible work the system can perform during a process which is not take about the chemical. But Gibbs's free energy is associated with a chemical reaction that can be used to work.

8. Give the mathematical definition of chemical potential. Explain why it's called potential. Include at least one drawing

$$\left(\frac{\partial G}{\partial n}\right)_{T, P, n_1} = \bar{G} = \bar{M}$$

$G = G_{\text{ Gibbs}}$ free energy.

$n = \text{number of molecules}$

$T = \text{Temperature}$.

$P = \text{pressure}$.

Chemical potential is the change in G of a system, which means addition of one mole of a particle's substance at constant temperature and pressure.

Energy stored in matter, which are combination of atoms or that are held by bonds,

The reason that's chemical potential is because it is originated from energy stored in molecules and can do work in the future.

9. Is the mixing of different types of molecules in an ideal gas spontaneous? Justify your answer using mathematical expressions for the chemical potential.

Yes, the mixing of ideal gases is spontaneous.

$\Delta G < 0$ Spontaneous.

$\Delta G > 0$ Non-Spontaneous.

Derive the result $\Delta G_{\text{mix}} < 0$ as shown.

$$\mu = \mu^\circ + k_T \ln \frac{P}{P^\circ}$$

M° = standard enthalpic potential
Let f be presented by P .

$$M = M^\circ + RT \ln P \quad (2)$$

$$G_i = n_A M_A^\circ + n_B M_B^\circ \leftarrow \text{using equation (2)}$$

$$G_i = n_A (M_A^\circ + RT \ln P_A) + n_B (M_B^\circ + RT \ln P_B).$$

n_A and n_B are the number of moles of the 2 ideal gases.

Total pressure $P = P_A + P_B$.

$$\text{After mixing, } G_f = n_A (M_A^\circ + RT \ln P_A) + n_B (M_B^\circ + RT \ln P_B).$$

$$\Delta G_{\text{mix}} = G_f - G_i \\ = n_A RT \ln \frac{P_A}{P} + n_B RT \ln \frac{P_B}{P}.$$

$$x_i = \frac{P_i}{P} \quad \text{and} \quad x_A = \frac{n_A}{n_A + n_B}$$

$$x_B = \frac{n_B}{n_A + n_B}$$

$\underbrace{\quad}_{\text{mole fractions}}$

$$\text{Thus } n_A = b_A x_A$$

$$n_B = b_B x_B$$

$$\Delta G_{\text{mix}} = n_A RT \ln(x_A) + n_B RT \ln(x_B) + \dots + n_n RT \ln(x_n).$$

x_i = mole fraction come never greater than 1.

hence, $\ln x \leq 0$

$$\boxed{\Delta G_{\text{mix}} < 0}$$

Hence, mixing of different pure gases is always spontaneous.

10. For a given chemical reaction involving glasses at equilibrium,
If $\Delta G_{rxn}^{\circ} > 0$, will there be more product formed or more
reactant.

$$\Delta G_{rxn}^{\circ} = -RT \ln K_{eq}$$

If $\Delta G_{rxn}^{\circ} > 0$.

$$-RT \ln K_{eq} < 0$$

can be > 0 only if $\ln K_{eq} < 0$.

\downarrow

is possible if $K_{eq} < 1$.

Because $K_{eq} = \frac{[\text{product}]}{[\text{reactants}]} < 1$, so $[\text{product}] < [\text{reactants}]$.

If equilibrium. $A + 2B \rightleftharpoons C$.

$$\Delta G^{\circ} > 0$$

$$-RT \ln K_{eq} > 0$$

$$K_{eq} < 1$$

$$K_{eq} = \frac{[C]}{[A][B]^2} < 1$$

$$[A][B]^2 > [C]$$

Hence, reactants are favored over products.

$$If \Delta G_{rxn}^{\circ} > 0$$

Extra credit:

If temperature is not much different from 298.15K, it can be assumed that $\Delta H^\circ R$ is constant over temperature interval.

The temperature ~~influence~~ dependence of $\Delta H^\circ R$ is governed by the difference in heat capacities C_p . ~~If the capacities of~~
If heat capacities of reactants and products are nearly same, $\Delta H^\circ R$ is nearly independent of temperature.

$$\ln k_p(T_f) = \ln k_p(298.15K) - \frac{\Delta H^\circ R}{R} \left(\frac{1}{T_f} - \frac{1}{298.15K} \right)$$