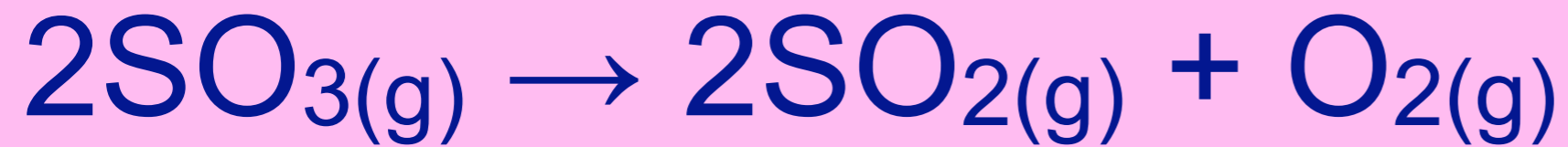


# Thermodynamics

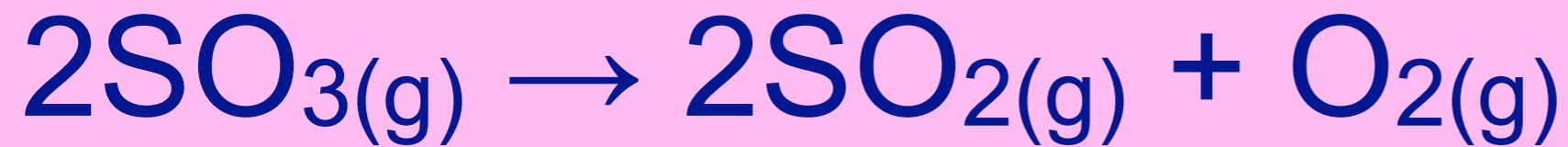
Updates to the pdf posted above

If you are just downloading the pdf today,  
there is no reason to view these  
updates, the pdf online has been  
updated.

Use the thermodynamic tables to calculate  $\Delta G^\circ$  for the reaction below at standard conditions

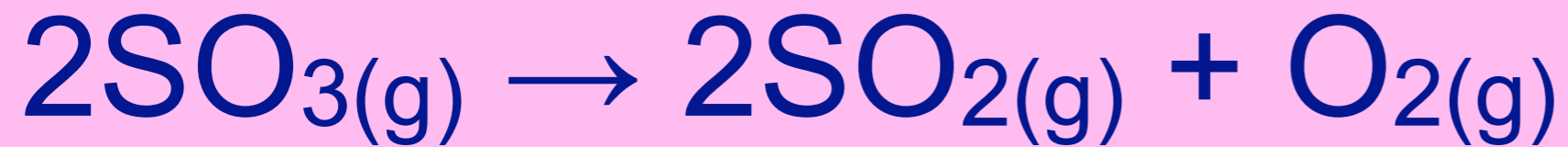


Use the thermodynamic tables to calculate  $\Delta G^\circ$  for the reaction below at standard conditions

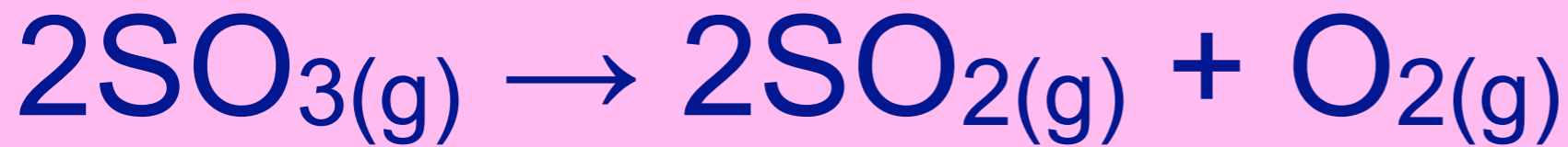


- $\Delta G_{\text{rx}}^\circ = \sum n\Delta G_{\text{f}}^\circ \text{prod} - \sum n\Delta G_{\text{f}}^\circ \text{react}$
- $[-300.4\text{kJ} + 0\text{kJ}] - [2(-379.4\text{kJ})]$
- $\Delta G_{\text{rx}}^\circ = +140 \text{ kJ}$

Use the thermodynamic tables to calculate  $\Delta H^\circ$  and  $\Delta S$  for the reaction below at standard conditions

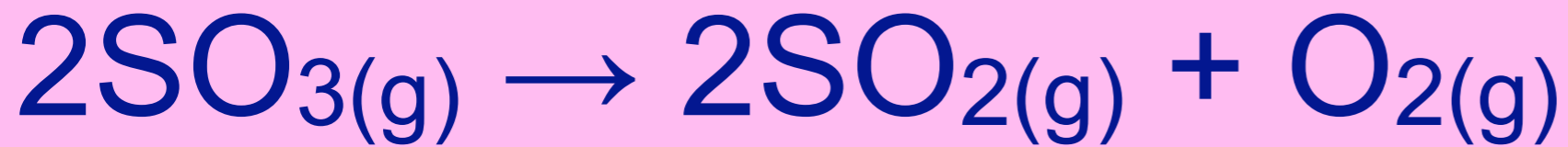


Use the thermodynamic tables to calculate  $\Delta H^\circ$  and  $\Delta S$  for the reaction below at standard conditions



- $\Delta H = [2(-296.9) + 0] - 2(-395.2)$ 
  - $\Delta H = +196.6 \text{ kJ/2mol of SO}_3$
- $\Delta S = [2(+248.5) + 205] - 2(256.2)$ 
  - $\Delta S = +189.6 \text{ J/molK}$

Using the  $\Delta H^\circ$  and  $\Delta S$  just calculated, use them to calculate  $\Delta G$  with Gibbs Free Energy Formula.

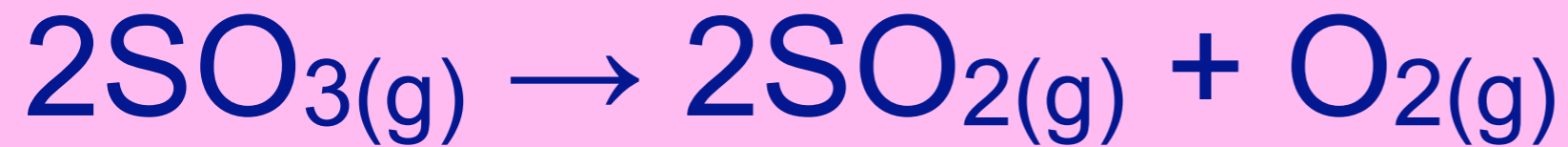


- $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$ 
  - Watch out for the units!!
  - $\Delta G = +196.6\text{kJ} - [298(0.1896\text{kJ})] = +140 \text{ kJ/mole}$
- How does it compare to the +68.71 kJ/mole previously calculated with  $\Delta G_f^\circ$  values?
  - the same.

# Calculating $\Delta G^\circ_{\text{Temp}}$ at other than 25°

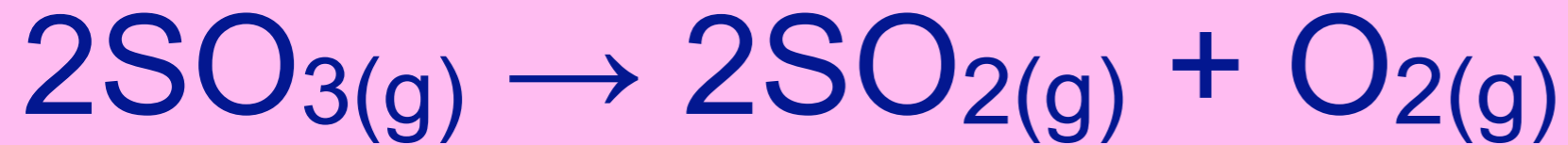
- Conditions are often NOT at 25°C.
- $\Delta G$  is very temperature dependent
  - ✓ notice the T in the formula  $\Delta G = \Delta H - T\Delta S$
- When not at 25°
  - ✓ Do *not* use  $\Delta G_f^\circ$  or  $\Delta G_{\text{Rx}}^\circ = \sum n\Delta G_{f,\text{prod}}^\circ - \sum n\Delta G_{f,\text{react}}^\circ$
  - ✓ You *must* use  $\Delta G^\circ_{\text{temp}} = \Delta H^\circ - T\Delta S^\circ$
- $\Delta H$  and  $\Delta S$  are not nearly so temperature dependent, thus a fairly accurate  $\Delta G^\circ_{\text{temp}}$  can be determined at different temperatures.

Using the  $\Delta H^\circ$  and  $\Delta S$  just calculated and the Gibbs Free Energy Formula, use them to calculate  $\Delta G^\circ_{T,1400}$  at 1400 K.



- $\Delta H^\circ = +196.6 \text{ kJ/mol of C}_2\text{H}_6$
- $\Delta S^\circ = +189.6 \text{ J/Kmol of C}_2\text{H}_6$

Using the  $\Delta H^\circ$  and  $\Delta S$  just calculated and the Gibbs Free Energy Formula, use them to calculate  $\Delta G_{T,1400}$  at 1400 K.



- $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$
- Watch out for the units!!
- $\Delta G = +196.6\text{kJ} - [1400(0.1896\text{kJ})] = -68.84\text{kJ/mole}$
- This is spontaneous !

The next slide is an  
update to slide 84

Which apply to any reaction that proceeds spontaneously to form products from initial standard conditions.

1.  $\Delta G < 0$

- because we know that if the reaction proceeds (spontaneous) it must have a negative  $\Delta G$ .

2.  $K_{eq} > 1$

- because we know at standard conditions of 1 atm, 1M K would always = 1, so if the reaction proceeds K will end up greater than 1 since as the reaction proceeds products will increase and reactants will decrease resulting in K larger than 1.

3.  $\Delta H < 0$

4.  $\Delta S > 0$

The next slide is an  
update to slide 91

When two solutions are combined and a precipitate forms while the solution cools. Which describes the value of  $\Delta G$ , and its components?

1.  $\Delta G < 0, |\Delta H| > |T\Delta S|$

2.  $\Delta G < 0, |\Delta H| < |T\Delta S|$

- Since we know that the solution cools, we know that  $\Delta H$  is positive, and since that is unfavorable,
- although it is completely counter intuitive, the driving force for this reaction *must* be an increase in entropy,
- and for the reaction to be spontaneous ( $\Delta G < 0$ ), the  $|T\Delta S|$  factor must be larger than the  $|\Delta H|$  factor.

3.  $\Delta G > 0, |\Delta H| > |T\Delta S|$

4.  $\Delta G > 0, |\Delta H| < |T\Delta S|$

5.  $\Delta G = 0, |T\Delta S| = |\Delta H|$