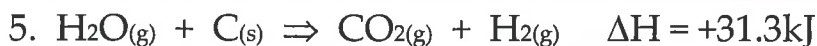
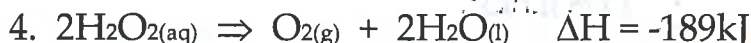
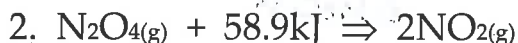


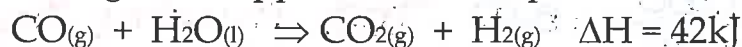
system will tend to favor lower equilibrium.

### Assignment 5: Reaction Predictions

State whether each reaction will go to completion (C), equilibrium (E), or not react (NR)



9. A student predicts that the following reaction will go to completion. Do you agree or disagree? Support with an explanation.



10. For the following reaction, in which direction is enthalpy increasing? In which direction is entropy maximized? Will the reaction reach equilibrium?



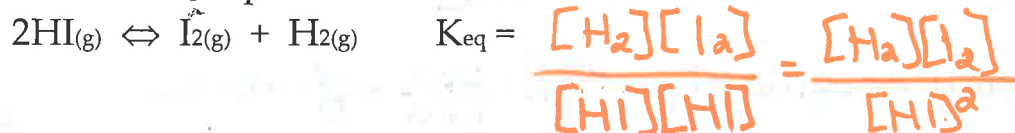
### V) The Equilibrium Constant

molar ratio of products over reactants at equilibrium

The equilibrium constant is called " $K_{\text{eq}}$ " and is found by multiplying product concentrations and dividing that by the result of multiplying reactant concentrations.

Do not include solids and liquids in  $K_{\text{eq}}$  expressions as the concentrations of these remain constant.

Example: Write the  $K_{\text{eq}}$  expression:

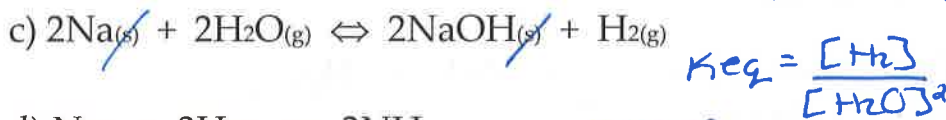
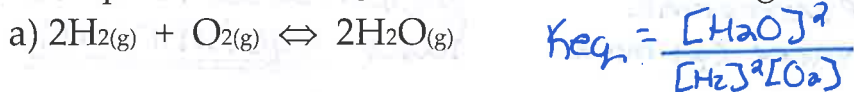


# EQUILIBRIUM LAW: $pA + qB \rightleftharpoons rC + sD$

$$K_{eq} = \frac{[A]^p [B]^q}{[C]^r [D]^s}$$

where  $p, q, r, s$  are the coefficients in the balanced equation.

Examples: Write a  $K_{eq}$  for each of the following:



Go to **page 40 & 41 in Hebden** and look at the tables in #6 & 7 (you did these questions in Assignment 1). Calculate the  $K_{eq}$  constant for the equilibrium that was attained after 10 minutes (bottom of p.40):

$$K_{eq} = \frac{1.00}{0.200} = 5.00$$

Then, the equilibrium was disturbed by increasing [B] (see top of p.41). Calculate the  $K_{eq}$  after a new equilibrium was reached at 18 minutes:

$$K_{eq} = \frac{1.200}{0.300} = 5.00$$

**this is why  $K_{eq}$  is a CONSTANT.**

If equilibrium is disturbed due to a concentration or pressure change, it will shift and eventually return to a new equilibrium, and though the concentrations of each gas and aqueous substance may be different than they were originally, the equilibrium constant ( $K_{eq}$ ) - the ratio of products to reactants - will remain the same, hence why it is called a **CONSTANT**.

However, if equilibrium is disturbed due to a temperature change, the  $K_{eq}$  constant will change.

It is mathematically impossible for the  $K_{eq}$  to remain the same after a temperature change. Because there are no immediate changes in concentration due to a temperature change, when a shift occurs, one side increases and the other side decreases. When you apply this to a fraction (the  $K_{eq}$  expression), it cannot possibly stay constant.

lets say originally...  $K_{eq} = \frac{[P]}{[R]} = \frac{2}{5} = 0.40$   
 after an temp. shift left (products ↓ and reactants ↑)  
 $K_{eq} = \frac{1}{6} = 0.17$  **mathematically, the  $K_{eq}$  MUST change.**  
 (same is true for a shift right.)

So how is it possible that  $K_{eq}$  mathematically can, and actually will, stay the same after a concentration or pressure change?

Because there are immediate concentration changes before shift changes. (spikes in graph)

For example, if you increase  $[HI]$  in this system:  $2HI_{(g)} \rightleftharpoons H_{2(g)} + I_{2(g)}$ , then all concentrations end up with a net increase, so the fraction can, and will, remain the same:

$$\text{For example, originally, } K_{eq} = \frac{(3.0)(3.0)}{(2.0)^2} = 2.25$$

After  $[HI]$  increase,  $K_{eq} = \frac{(4.0)(4.0)}{(2.667)^2} = 2.25$   
all [conc.] ↑

the ratio of  $\frac{[\text{products}]}{[\text{reactant}]}$  remains same

### The Size of the $K_{eq}$ Constant:

Remember,  $K_{eq} = \frac{[\text{products}]}{[\text{reactants}]}$

If the  $K_{eq}$  is small (less than 1), does the equilibrium system contain a higher concentration of reactants or products (look at the fraction above)?

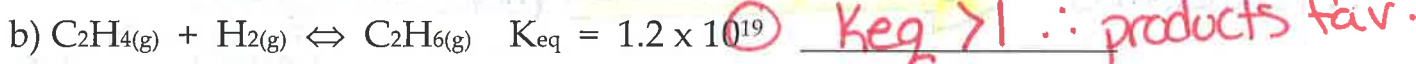
$K_{eq} < 1$  means  $[\text{reactants}] > [\text{products}]$  (denominator is larger #  $\therefore K_{eq} < 1$ )

What if the  $K_{eq}$  is large (greater than 1)?

$K_{eq} > 1$  means  $[\text{reactants}] < [\text{products}]$  (numerator is larger #  $\therefore K_{eq} > 1$ )

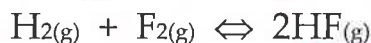
Examples:

Do the following equilibria favour reactants or products?



## Writing the Equation the other way around

For the following reaction:



a) Write the  $K_{\text{eq}}$  equation. The  $K_{\text{eq}} = 0.25$

$$K_{\text{eq}} = \frac{[\text{HF}]^2}{[\text{H}_2][\text{F}_2]} = 0.25 \quad \leftarrow \text{given}$$

b) Now, write the  $K_{\text{eq}}$  expression for this reaction, and find the  $K_{\text{eq}}$  constant value:  $2\text{HF}(\text{g}) \rightleftharpoons \text{H}_2(\text{g}) + \text{F}_2(\text{g})$

$$K_{\text{eq}} = \frac{[\text{H}_2][\text{F}_2]}{[\text{HF}]^2}$$

This is the reciprocal of the equation above.  
 $\therefore$  The  $K_{\text{eq}}$  constant is the reciprocal of 0.25

$$\frac{1}{0.25} = K_{\text{eq}} \\ \therefore K_{\text{eq}} = 4.0$$

## VI) Temperature and the $K_{\text{eq}}$ Constant

↑ If temperature is increased for an equilibrium system, in what direction does the system shift? *endothermic direction is favored.*

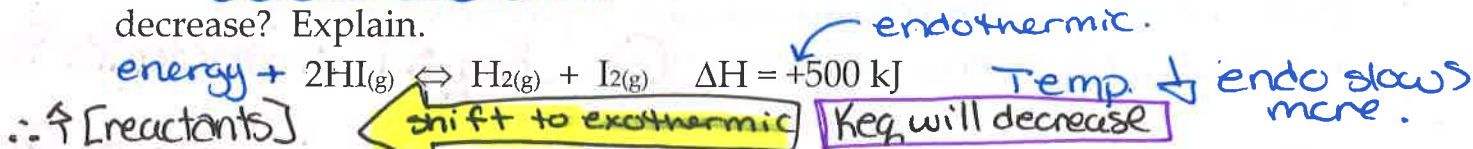
What if temperature is decreased? *exothermic is favored.*

If a shift right results due to temperature change, will the  $K_{\text{eq}}$  increase or decrease?  $\rightarrow$  right shift =  $\uparrow$  [products]  $\therefore K_{\text{eq}}$  will increase

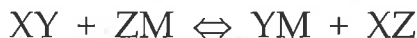
If a shift left results due to a temperature change, will  $K_{\text{eq}}$  increase or decrease?  $\leftarrow$  left shift =  $\uparrow$  [reactants]  $\therefore K_{\text{eq}}$  will decrease

Example:

If the temperature is decreased in the following system, will  $K_{\text{eq}}$  increase or decrease? Explain.



Example: Given the following equation and data:



$$K_{\text{eq}} = 60.0 \text{ at } 300^\circ\text{C}$$

$$K_{\text{eq}} = 45.0 \text{ at } 500^\circ\text{C}$$

*K<sub>eq</sub> ↓ with a temp ↑*



Is the forward reaction endothermic or exothermic? Explain.

- $\uparrow$  temp increase favors a shift in the endothermic direction.
- For  $K_{\text{eq}}$  to decrease [reactants] > [products]
- Therefore a shift left is occurring.
- Therefore the rvs rxn is endothermic  
 i.e. FWD rxn is exothermic.