Thermal Equilibrium: "Body Temperature"

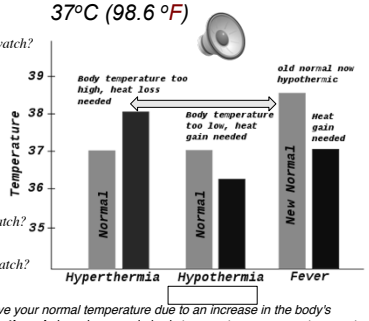
37°C (98.6 °F)

https://www.youtube.com/watch?v=IomqHq6-hMc

Why do we get fevers?

https://www.youtube.com/watch?v=EYxoAJ3Boyc

https://www.youtube.com/watch?v=jRvxnpfCDSo

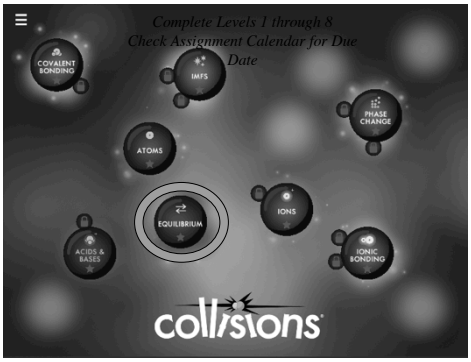


Fever *is a temperature above your normal temperature due to an increase in the body's temperature set-point.* ***Hyperthermia*** *is an increase in body temperature over your temperature set-point, due to either too much heat production or not enough heat loss.* ***Hypothermia*** *is a decrease in body temperature over your temperature set-point, due to too much heat loss.*

The surprising reason you feel awful when you're sick - Marco A. Sotomayor

https://www.youtube.com/watch?v=gVdY9KXF_Sg

https://app.playmada.com/Collisions/



https://app.playmada.com/Collisions/

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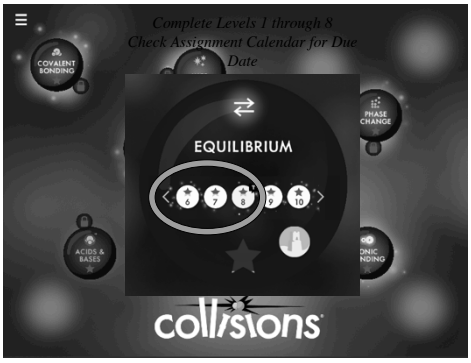


Chemical Equilibrium

A ⇌ B

Reversible Reactions

(Dynamic Chemical Systems)

Dr. Ron Rusay

https://www.youtube.com/watch?v=dUMmoPdwBy4

Crash Course: https://www.youtube.com/watch?v=g5wNg_dKsYY

Dynamic Equilibrium

"The Big Mac Index"

http://www.economist.com/content/big-mac-index

Chemical Equilibrium

- *In many reactions the reactant(s) react completely to form product(s).*
- *But, some reactions are "reversible". That is, products are simultaneously reacting to form reactants, and a certain amount of reactant(s) will always remain in the final reaction mixture, when it has reached a state of "equilibrium".*

Chemical Equilibrium

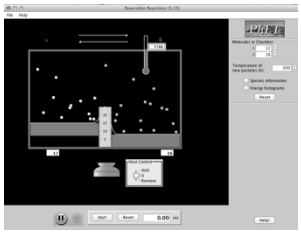
(Definitions)

- *At equilibrium a dynamic system remains in a constant state for a period of time, eg. currency exchange rates. In a chemical system the concentrations of reactants and products remain constant over time.*
- *On the molecular level, the system is dynamic: The rate of change is the same in either the forward or reverse directions.*

Chemical Equilibrium

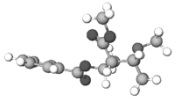
- *Consider:*

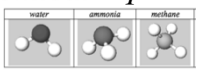
A ⇌ **B**



Simulator:
https://phet.colorado.edu/en/simulation/legacy/reversible-reactions

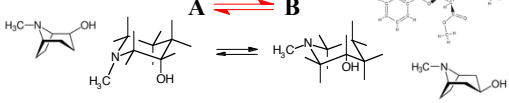
Chemical Equilibrium





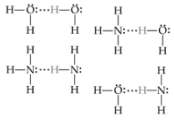
- *Consider:*

A ⇌ **B**

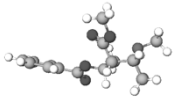


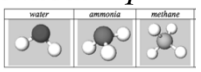
If the reaction begins with just **A**, *as the reaction progresses:*

- [**A**] *decreases to a constant concentration,*
- [**B**] *increases from zero to a constant concentration.*
- *When* [**A**] *and* [**B**] *are constant, equilibrium is reached.*



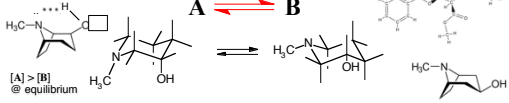
Chemical Equilibrium





- *Consider:*

A ⇌ **B**



If the reaction begins with just **A**, *as the reaction progresses:*

- [**A**] *decreases to a constant concentration,*
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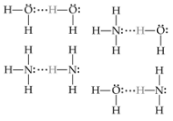
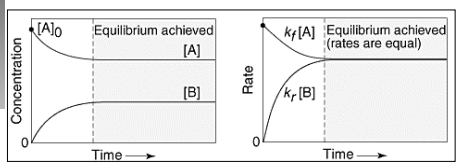
Hydrogen Bonding



Chemical Equilibrium

Graphical Treatment of Rates & Changes



- *Rate of loss of A = -k_f [A]; decreases to a constant,*
- *Rate of formation of B = k_r [B]; increases from zero to a constant.*
- *When -k_f [A] = k_r [B] equilibrium is reached.*

Chemical Equilibrium

(Gases)

https://www.youtube.com/watch?v=o1_D4FscMnU

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

- *Add nitrogen and hydrogen gases together in any proportions. Nothing noticeable occurs.*
- *Add heat, pressure and a catalyst, you smell ammonia; a mixture with constant concentrations of N_2 , H_2 and NH_3 is produced.*
- *Start with just ammonia and catalyst. N_2 and H_2 will be produced until a state of equilibrium is reached.*
- *As before, a mixture with constant concentrations of nitrogen, hydrogen and ammonia is produced.*

Chemical Equilibrium

(Gases)

https://www.youtube.com/watch?v=o1_D4FscMnU

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

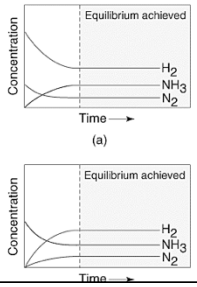
No matter what the starting composition of reactants and products, the same ratio of concentrations is realized when equilibrium is reached at a certain temperature and pressure.

Gas Equilibrium

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

https://www.youtube.com/watch?v=o1_D4FscMnU

The Previous Examples Graphically:



Law of Mass Action

(Equilibrium Constant)

- *For a reaction:*
  - *$jA + kB \leftrightarrows lC + mD$*
- *The law of mass action is represented by the Equilibrium Expression: where K is the Equilibrium Constant. (Units for K will vary.)*

$$K = \frac{[Products]}{[Reactants]}$$

$$K = \frac{[C]^l[D]^m}{[A]^j[B]^k}$$

Equilibrium Expression

- *$4\ NH_3(g) + 7\ O_2(g) \leftrightarrows\ 4\ NO_2(g) + 6\ H_2O(g)$*
- *Write the Equilibrium Expression for the reaction.*

$$K = \frac{[NO_2]^4[H_2O]^6}{[NH_3]^4[O_2]^7}$$

QUESTION

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Which Equilibrium Expression is correct for the reaction above

a. $K = \dfrac{[NH_3]^2}{[N_2]^2\,[H_2]^3}$ b. $K = \dfrac{[N_2]^2\,[H_2]^3}{[NH_3]^2}$

c. $K = \dfrac{[NH_3]^2}{[N_2]\,[H_2]^3}$ d. $K = \dfrac{[N_2]\,[H_2]^3}{[NH_3]^2}$

Answer

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

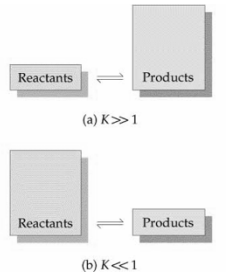
Which Equilibrium Expression is correct for the reaction above

a. $K = \dfrac{[NH_3]^2}{[N_2]^2\,[H_2]^3}$ b. $K = \dfrac{[N_2]^2\,[H_2]^3}{[NH_3]^2}$

c. $K = \dfrac{[NH_3]^2}{[N_2]\,[H_2]^3}$ d. $K = \dfrac{[N_2]\,[H_2]^3}{[NH_3]^2}$

The Equilibrium Constant K

(All Reversible Reactions)



http://chemconnections.org/general/movies/LeChatelier.MOV

Le Châtelier's Principle

Changes to a System:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

1. *Concentration*
2. *Temperature*
3. *Pressure*
4. *Catalyst*

Changes to a System:

How a Homogeneous Mixture Responds

1. *Concentration: The system will shift concentrations away from the added component or towards a removed component. K remains the same.*

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Adding more reactants shifts to produce more product.

QUESTION

https://www.youtube.com/watch?v=o1_D4FscMnU

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Removing ammonia will result in producing more ammonia.

A) TRUE
B) FALSE

ANSWER

https://www.youtube.com/watch?v=o1_D4FscMnU

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Removing ammonia will result in producing more ammonia.

A) TRUE
B) FALSE

Changes to a System:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

1. *Concentration*
2. *Temperature*
3. *Pressure*
4. *Catalyst*

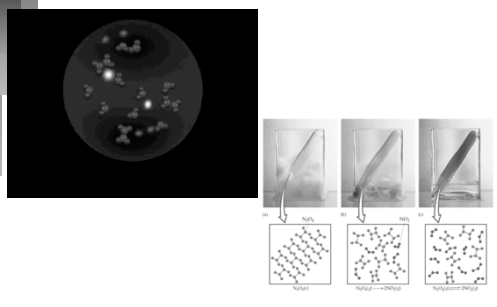
Changes to a System:
How a Homogeneous Mixture Responds

2. *Temperature: K changes depending upon the reaction.*
   - ***If endothermic, heat is treated as a "reactant", if exothermic, heat is a "product".***

Endo- → K increases; Exo- → K decreases

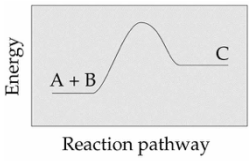
http://chemconnections.org/general/movies/equilibriumdecompositionof.mov

Chemical Equilibrium



QUESTION

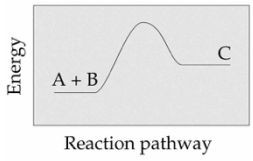
Which is favored by raising the temperature in the following equilibrium reaction?



A) A + B (Reactants)
B) C (Products)

Answer

Which is favored by raising the temperature in the following equilibrium reaction?



A) A + B
B) C (endothermic rxn: shifts to lessen energy in reactants)

Changes on a System (continued)

- *3. Pressure:*

Decreasing the volume increases pressure & shifts the equilibrium toward the side with fewer moles.

Σn_{gas} (products) vs. Σn_{gas} (reactants)

If mole reactants = moles products, no change

***Le Châtelier's Principle**: if pressure is increased, the system shifts to minimize the increase to the side with fewer moles.*

- *Addition of inert gas does not affect the equilibrium position.*

QUESTION

https://www.youtube.com/watch?v=o1_D4FscMnU

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Decreasing the pressure of the reaction mixture will produce more ammonia.

A) TRUE
B) FALSE

ANSWER

https://www.youtube.com/watch?v=o1_D4FscMnU

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Decreasing the pressure of the reaction mixture will produce more ammonia.

Σn_{gas} (products) =2 vs. Σn_{gas} (reactants) =4

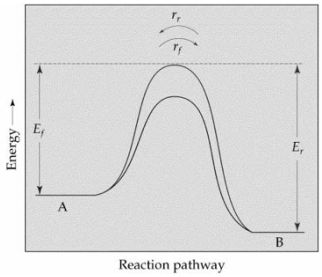
A) TRUE
B) FALSE

Changes on a System (continued)

4. The Effect of Catalysts

- *A catalyst lowers the activation energy barrier for any reaction….in both forward and reverse directions!*
- *A catalyst will decrease the time it takes to reach equilibrium; speeding it up.*
- *A catalyst **does not** change K nor effect the composition of the equilibrium mixture.*

Energy vs. Reaction Pathway



QUESTION

https://www.youtube.com/watch?v=o1_D4FscMnU

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

The above reaction does not occur without a catalyst, but it does with an iron catalyst.

If more iron is added, it will produce more ammonia.

A) TRUE
B) FALSE

QUESTION

https://www.youtube.com/watch?v=o1_D4FscMnU

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

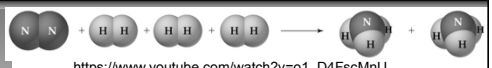
The above reaction does not occur without a catalyst, but it does with an iron catalyst.

If more iron is added, it will produce more ammonia.

A) TRUE
B) FALSE Only affects rate

Putting it all Together

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$



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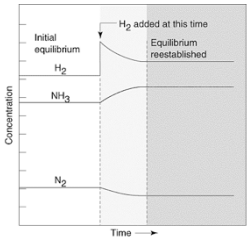

Putting it all Together

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

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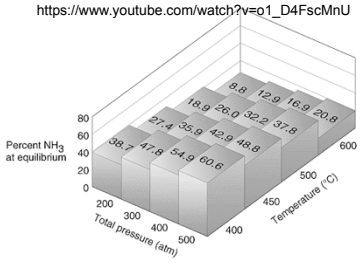

Putting it all Together

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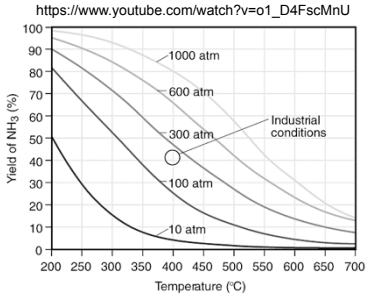


Putting it all Together

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

ht…tml#haber

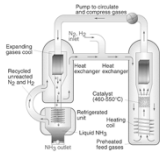
Whi… of over

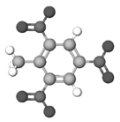
- *N…*
- $NH_3(g) + HNO_3(g) \rightarrow\rightarrow\rightarrow NH_4NO_3(s)$

http://chemconnections.org/general/chem120/assign14.html#haber

Putting it all Together

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$





And, one of the reasons why WW I occurred

http://www.bbc.co.uk/history/0w1/25768752

- $NH_3(g) + 2\ O_2(g) \leftrightarrows HNO_3(g) + H_2O(g)$

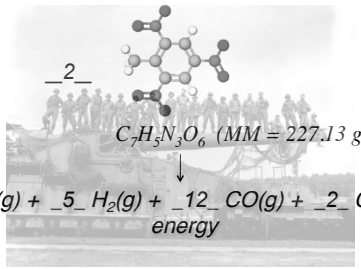
↓

High Explosives: TNT

https://www.youtube.com/watch?v=go4NO8v7Goc

TNT "HE": High Explosive

WW I: > 8-80 mile-100-800 kg Artillery



_2_

$C_7H_5N_3O_6$ *(MM = 227.13 g·mol^{-1})*

↓

_3_ $N_2(g)$ + _5_ $H_2(g)$ + _12_ $CO(g)$ + _2_ $C(s)$ + energy

https://www.youtube.com/watch?v=mjhoJaIgxDM