

[TP] The figure shows how the partial pressures of the N_2O_4 and NO_2 change with time due to the chemical reaction

$N_2O_4 \rightarrow 2\ NO_2$

for certain initial conditions. At these initial conditions (far left), the following is known about the chemical reaction.

25% 1. It is spontaneous
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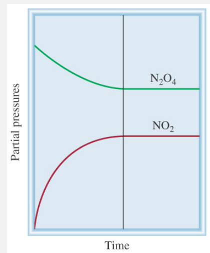

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Lecture 12 CH102 A2 (MWF 11:15 am)
Tuesday, February 19, 2019

- Complete review: Colligative properties

Begin ch13: Dynamic Chemical Equilibrium

- Reaction quotient, Q, spontaneity, and equilibrium

Next: Predicting direction of change; Q depends on how a reaction is written; Knowing K does not fix individual concentrations. Disturbing equilibrium (Le Chatelier)

Roadmap of osmotic pressure calculations

Osmotic pressure $\Pi = i\ c\ R\ T$.

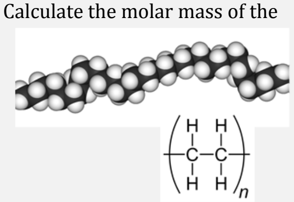
1. Use measured osmotic pressure, Π, and temperature, T, to evaluate concentration, $c = \Pi/(i\ R\ T)$, in mol/L.
2. Use cell volume to express concentration in terms of moles, $n = c\ V$.
3. Use solute mass to calculate molar mass, $M = \text{mass}/n$.

5

Osmotic pressure $\Pi = i\ c\ R\ T$

1.40 g of polyethylene ($i = 1$) dissolved in 100. mL of benzene generates an osmotic pressure of 0.248 kPa at 25 °C. Calculate the molar mass of the polyethylene.

1. Calculate the concentration…



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Osmotic pressure $\Pi = i\,c\,R\,T$

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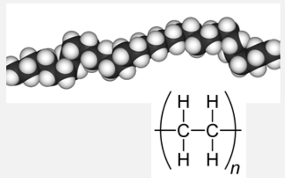

1. Calculate the concentration…

   1.00×10^{-4} mol/L

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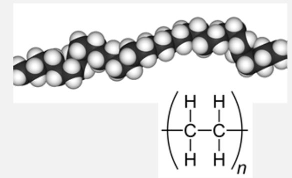

1. Calculate the concentration…

   1.00×10^{-4} mol/L

2. Calculate the moles…

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Osmotic pressure $\Pi = i\,c\,R\,T$

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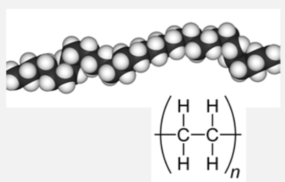

1. Calculate the concentration…

   1.00×10^{-4} mol/L

2. Calculate the moles…

   10^{-5} mol

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Osmotic pressure $\Pi = i\,c\,R\,T$

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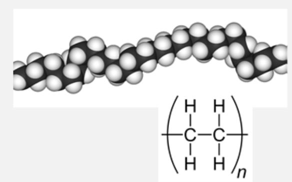

1. Calculate the concentration…

   1.00×10^{-4} mol/L

2. Calculate the moles…

   10^{-5} mol

3. Calculate the molar mass…

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Osmotic pressure $\Pi = i\ c\ R\ T$

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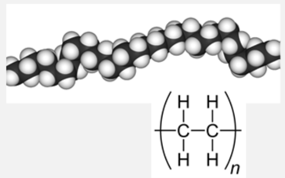

1. Calculate the concentration…

   1.00×10^{-4} mol/L

2. Calculate the moles…

   10^{-5} mol

3. Calculate the molar mass…

   $1.40 \times 10^{+5}$ g/mol

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[TP] 1.0 mg of a substance dissolved in 1.0 mL of water generates an osmotic pressure of 1.0 kPa, at 25 °C. The molar mass of the solute ($i = 1$) is …

0% 1. 250 g/mol
0% 2. 500 g/mol
0% 3. 1000 g/mol
0% 4. 2500 g/mol
0% 5. 5000 g/mol
0% 6. Some other value

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Practice question

What height column of benzene ($D = 0.876$ g/mL) generates a pressure of 248 Pa? Express your answer in cm, to the correct number of significant figures. Recall that $\Pi = Dgh$, Pa = kg/(m s^2), and $g = 9.80665$ m/s^2.

Answer: 2.89 cm

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Begin ch 13

Dynamic chemical equilibrium

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Spontaneity of “reactants” → “products”

If products (right side) increase with time, we say …
the reaction is spontaneous.

If reactants (left side) increase with time, we say …
the reaction is nonspontaneous.

If the amount of reactants and products do not change with time, we say …
the reaction is at equilibrium.

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Reaction quotient Q measures progress

$A \rightarrow B + C$

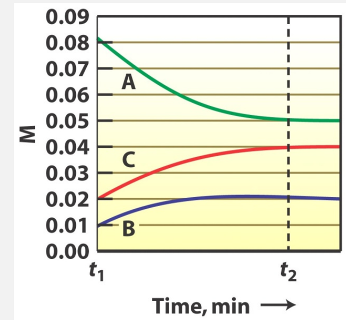
$Q = \frac{\text{products}}{\text{reactants}} = \frac{[B][C]}{[A]}$

Q at t_1 is smaller (less products)

Q at t_2 is larger (more products)

Q for $t > t_2$ no longer changes

For $t > t_2, Q = K$, equilibrium constant



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Writing Q

For a A + b B → c C

$Q = (C)^c/((A)^a(B)^b)$

(X) = conc of X/ref value

As discussed in Mahaffy et al., 2e, p498, such ratios are called activities, dimensionless measures of effective concentration.

Reference concentrations

Solutes:	ref value = 1 M
Gases:	ref value = 1 bar
Liquids:	ref value = conc of pure liquid
Solids:	ref value = conc of pure solid

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Writing Q

2 A(aq, .20 M) → B(g, .60 bar)
$Q = .60/(.20)^2 = 15$ (no units, always!)

2 A(aq, .10 M) → B(g, 1.20 bar)
$Q = 1.20/(.10)^2 = 120$

2 A(aq, 1.5 M) → B(g, 0 bar)
$Q = 0/(1.5)^2 = 0$ (only reactants)

2 A(aq, 0 M) → B(g, 4 bar)
$Q = 4/(0)^2 = \infty$ (only products)

2 C(aq, 3 M) → 3 D(s)
$Q = (1)^3/(3)^2 = 1/9$ (solids and liquid contribute 1)

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Reaction quotient Q measures progress

For A → B + C, the reaction quotient is …

$$Q = \frac{[B][C]}{[A]}$$

The numerical value of the reaction quotient when the concentrations have their equilibrium values $[A]_e$, $[B]_e$ and $[C]_e$ …

and so no longer change with time, is called the equilibrium constant …

$$Q = K = \frac{[B]_e[C]_e}{[A]_e}$$

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Q versus K is the key to assessing spontaneity

If $Q < K$, product must form to get to equilibrium,
so spontaneous

If $Q > K$, reactants must form to get to equilibrium,
so nonspontaneous

If $Q = K$, no change in amounts of reactants and products,
so equilibrium

So, Q/K is the key quantity to monitor.

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$N_2O_4 \rightarrow 2\ NO_2$

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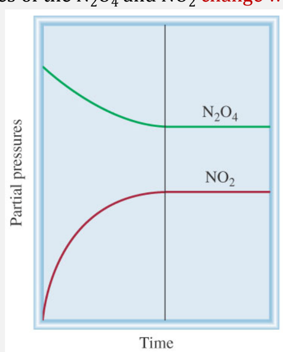
for certain initial conditions (far left).



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$N_2O_4 \rightarrow 2\ NO_2$

The reaction quotient is

$$Q = [NO_2]^2/[N_2O_4]$$

The numerical value of the reaction quotient when the concentrations have their equilibrium values

$$[N_2O_4]_e \text{ and } [NO_2]_e$$

and so no longer change with time, is called the equilibrium constant

$$K = [NO_2]_e^2/[N_2O_4]_e$$

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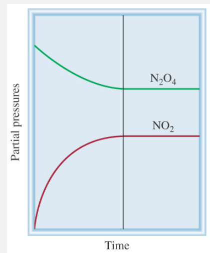

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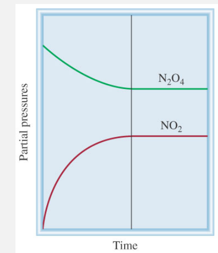
[TP] At the initial conditions (far left) for the reaction

$N_2O_4 \rightarrow 2\ NO_2$

the following is known about the ratio Q/K.

25% 1. It is greater than 1
25% 2. It is equal to 1
25% 3. It is less than 1
25% 4. The ratio is not known without further information



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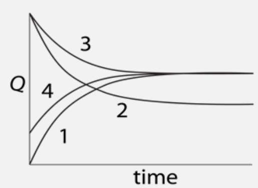
[TP] For the reaction

$N_2O_4 \rightarrow 2\ NO_2$

which curve on the right shows the corresponding change of Q with time?

20% 1. 1
20% 2. 2
20% 3. 3
20% 4. 4
20% 5. None



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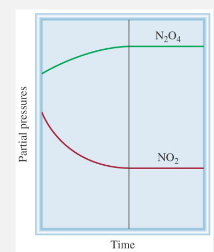

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