

Marks
9

- In an experiment, NOCl (2.00 mol) was placed in a closed 1.00 L flask. After equilibrium was established at 25 °C, the concentration of NO(g) was 0.66 M. Calculate the value of K_c at 25 °C for the following reaction.

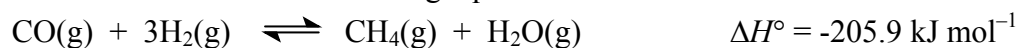
 $K_c =$ Calculate the value of K_p at 25 °C for the reaction above. $K_p =$ Given that ΔH_f° for NOCl(g) = 51.71 kJ mol⁻¹ and ΔH_f° for NO(g) = 90.29 kJ mol⁻¹ at 25 °C, calculate the value of ΔH° for the reaction above. $\Delta H_{\text{rxn}}^\circ =$

What is the effect upon the [NOCl] of an equilibrium mixture if the temperature is increased?

In which direction will the equilibrium shift if the volume of the flask is reduced?

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- Equal volumes of carbon monoxide and hydrogen gas are introduced into a sealed 4.5 L flask at 1200 K and the following equilibrium is established.



At equilibrium, the flask contains 0.22 mol of CH_4 and the total pressure in the flask is 46.4 atm. Calculate the amount of $\text{H}_2\text{(g)}$ (in mol) that was initially introduced into the flask.

Answer:

In a separate experiment, it is determined that the reaction is in equilibrium when the same 4.5 L flask contains 0.18 mol of CH_4 , 0.24 mol of H_2O , 0.82 mol of CO and 0.65 mol of H_2 at 1200 K. Calculate the concentration equilibrium constant, K_c , for this temperature.

 $K_c =$

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Calculate the partial pressure equilibrium constant, K_p , at 1200 K.

$K_p =$

What is the standard free energy change ΔG° for the forward reaction (in kJ mol^{-1}) at 1200 K?

$\Delta G^\circ =$

What will be the effect on the equilibrium if CO(g) is injected into the flask, which maintains a constant volume.

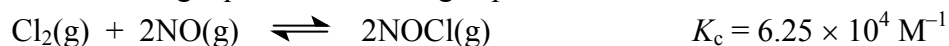
What will be the effect on the equilibrium if the temperature is decreased?

What will be the effect on the equilibrium if the volume of the flask is decreased?

What will be the effect on the equilibrium if the walls of the flask are refrigerated so that liquid water condenses out?

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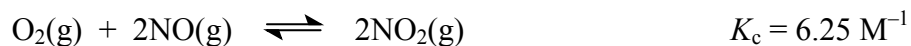
- Consider the following equilibrium in the gas-phase at 35 °C.



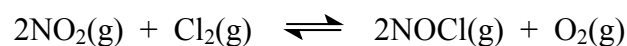
Equimolar amounts of NOCl(g) and Cl₂(g) are introduced into a sealed 1.00 L flask. When the system reaches equilibrium at 35 °C, the concentration of NO(g) in the flask is 4.04×10^{-4} M. What amount of Cl₂(g) (in mol) was initially added to the flask?

Answer:

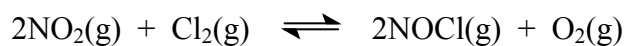
At the same temperature (35 °C) O₂(g) reacts with NO(g) according to the equation:



Determine K_c for the following reaction.

 $K_c =$

Calculate the partial pressure equilibrium constant, K_p , at 35 °C for the reaction:

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 $K_p =$

What is the standard free energy change, ΔG° , for the forward reaction (in kJ mol^{-1}) at 35 °C?

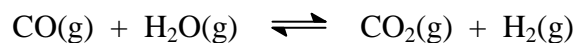
 $\Delta G^\circ =$

If 0.150 mol of $\text{O}_2(\text{g})$ and 3.00×10^{-4} mol of $\text{NO}_2(\text{g})$ are added to the 1.00 L flask, determine the free energy change, ΔG , (in kJ mol^{-1}) as the system moves to its new equilibrium point.

 $\Delta G =$

Will the amount of $\text{NO}_2(\text{g})$ in the flask increase or decrease as the system moves to its new equilibrium position? Explain.

The CO(g) in water gas can be reacted further with H₂O(g) in the so-called “water-gas shift” reaction:



At 900 K, $K_c = 1.56$ for this reaction. A sample of water gas flowing over coal at 900 K contains a 1:1 mole ratio of CO(g) and H₂(g), as well as 0.250 mol L⁻¹ H₂O(g). This sample is placed in a sealed container at 900 K and allowed to come to equilibrium, at which point it contains 0.070 mol L⁻¹ CO₂(g). What was the initial concentration of CO(g) and H₂(g) in the sample?

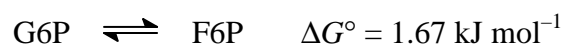
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$$[\text{CO}] = [\text{H}_2] =$$

If the walls of the container are chilled to below 100 °C, what will be the effect on the concentration of CO₂(g)?

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- The isomerisation of glucose-6-phosphate (G6P) to fructose-6-phosphate (F6P) is a key step in the metabolism of glucose for energy. At 298 K,



Calculate the equilibrium constant for this process at 298 K.

Answer:

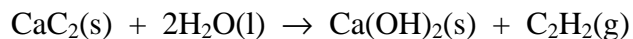
What is the free energy change (in kJ mol^{-1}) involved in a mixture of 3.00 mol of F6P and 2.00 mol of G6P reaching equilibrium at 298 K?

Answer:

Sketch a graph of G_{sys} versus “extent of reaction”, with a curve showing how G_{sys} varies as G6P is converted to F6P. Indicate the position on this curve corresponding to 3.00 mol of F6P and 2.00 mol of G6P.

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- Acetylene, C₂H₂, can be produced by reacting calcium carbide, CaC₂, with water:



A 1.000 g sample of CaC₂ is placed in a sealed vessel that contains 250.0 mL of H₂O(l) and 250.0 mL of N₂(g) at 1.000 atm, and allowed to react completely with the water. The final pressure in the sealed vessel at 22.0 °C is 2.537 atm. Determine the vapour pressure of water in the sealed vessel at 22.0 °C. Give your answer in mmHg. Ignore any change in the volume of the water.

Answer:

The solubility of acetylene in water at 22.0 °C is small. If the temperature were raised, would you expect this solubility to increase or decrease?

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- Consider the reaction $2\text{SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{SO}_3(\text{g})$

$\Delta H^\circ = -198.4 \text{ kJ mol}^{-1}$ and $\Delta S^\circ = -187.9 \text{ J K}^{-1} \text{ mol}^{-1}$ at 25°C .

Show that this reaction is spontaneous at 25°C .

If the volume of the reaction system is increased at 25°C , in which direction will the reaction move?

Calculate the value of the equilibrium constant, K , at 25°C .

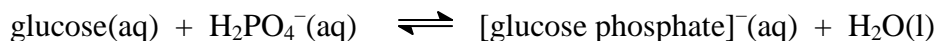
$K =$

Assuming ΔH° and ΔS° are independent of temperature, in which temperature range is the reaction non-spontaneous?

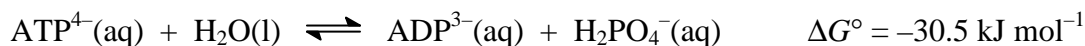
Answer:

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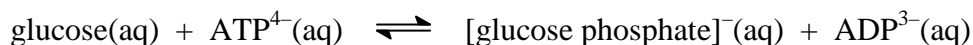
- The first step in the metabolism of glucose in biological systems is the addition of a phosphate group in a dehydration-condensation reaction:



The free energy change associated with this reaction is $\Delta G^\circ = 13.8 \text{ kJ mol}^{-1}$. The reaction is driven forwards by harnessing the free energy associated with the hydrolysis of adenosine triphosphate, ATP^{4-} , to adenosine diphosphate, ADP^{3-} :



The overall reaction is thus:



Calculate the equilibrium constant associated with this overall reaction at body temperature (37 °C).

Answer:

This overall equilibrium reaction is investigated by adding 0.0100 mol of ATP^{4-} to a flask containing 175 mL of a 0.0500 M aqueous solution of glucose at 37 °C. What percentage of the ATP^{4-} will have been consumed when the system reaches equilibrium?

Answer: **87%**

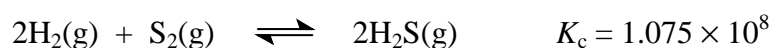
Suggest two simple ways of further reducing the remaining percentage of ATP^{4-} .

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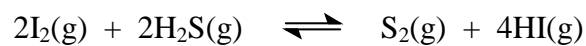
- At 700 °C, hydrogen and iodine react according to the following equation.



Hydrogen also reacts with sulfur at 700 °C:



Determine K_c for the following overall equilibrium reaction at 700 °C.



$K_c =$

What is the standard free energy change at 700 °C for this overall equilibrium reaction?

Answer:

If 0.250 mol of HI(g) is introduced into a 2.00 L flask at 700 °C, what will be the concentration of I₂(g) at equilibrium?

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Answer:

If 0.274 g of H₂S were now introduced into the same flask, what would be the concentration of S₂(g) at equilibrium?

Answer:

• Explain the meanings of the following terms.	Marks 8
Heat	
$P\Delta V$ work	
Internal energy	
Enthalpy change	
Entropy	
Equilibrium constant	
Reaction quotient	
Triple point	

- Consider the following reaction.



Calculate ΔG° (in J mol^{-1}) for this reaction.

$\Delta G^\circ =$

Calculate the reaction quotient, Q , at 25°C when $p(\text{H}_2\text{O}) = 18 \text{ mmHg}$,
 $p(\text{Cl}_2\text{O}) = 2.0 \text{ mmHg}$ and $p(\text{HOCl}) = 0.10 \text{ mmHg}$.

$Q =$

In which direction will the reaction proceed spontaneously at these partial pressures?