This print-out should have 16 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 10.0 points

What is the main overall driving force for any spontaneous reaction or change? Consider only the reaction system, not the surroundings.

1. To maximize electrostatic interactions.

2. To release heat energy.

3. To obey the laws of gravity.

4. To maximize entropy.

5. To lower the available free energy. **correct**

Explanation:

002 10.0 points

When the chemical reaction

$$\mathrm{A + B \rightleftharpoons C + D}$$

is at equilibrium,

1. the forward reaction has stopped.

2. the sum of the concentrations of A and B equals the sum of the concentrations of C and D.

3. both the forward and reverse reactions have stopped.

4. the reverse reaction has stopped.

5. neither the forward nor the reverse reactions have stopped. **correct**

6. all four concentrations are equal.

Explanation:

Chemical equilibrium is dynamic equilibrium, with both foward and reverse processes occuring at the same rate.

003 10.0 points

Explain why equilibium constants are dimensionless.

1. Every concentration or pressure that enters into K_c or K_p is really divided by the corresponding concentration or pressure of the substance in its standard state. **correct**

2. They are dimensionless because the pressures or concentrations we put in are all for the substances in their standard states.

3. They are dimensionless because concentrations and pressures have no units.

4. The statement is not true. Equilibrium constants have units that involve some multiple of atmospheres or moles per liter.

5. They are not really dimensionless but we must treat them as such in order to be able to take $\ln K$ in the expression $\Delta G^0 = -RT\,\ln K$.

Explanation:

The amount of each component is in terms of activity, which is the measured amount (concentration, pressure) divided by the amount of that component in its standard state in that unit. The units in the numerator and denominator are identical and cancel out.

004 10.0 points

The expression for K_c for the reaction at equilibrium is

$4\ \mathrm{NH_3(g)} + 5\ \mathrm{O_2(g)} \rightleftharpoons 4\ \mathrm{NO(g)} + 6\ \mathrm{H_2O(g)}$

1. $[\mathrm{NH_3}]^4\,[\mathrm{O_2}]^5$

2. $\dfrac{[\mathrm{NH_3}]^4\,[\mathrm{O_2}]^5}{[\mathrm{NO}]^4\,[\mathrm{H_2O}]^6}$

3. $[\mathrm{NO}]^4\,[\mathrm{H_2O}\ ]^6$

4. $\dfrac{[\mathrm{NO}]^4\,[\mathrm{H_2O}]^6}{[\mathrm{NH_3}]^4\,[\mathrm{O_2}]^5}$ **correct**

Explanation:

The equation must be written with the appropriate formula and correctly balanced. K_c is the equilibrium constant for species in solution and equals the mathematical product of the concentrations of the chemical products, divided by the mathematical product of the concentrations of the chemical reactants. In this mathematical expression, each concentration is raised to the power of its coefficient in the balanced equation. For K_c the molar concentrations are used for the activities of the components.

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005 10.0 points

Consider the following reactions at 25°C:

reaction	K_c
$2\,NO(g) \rightleftharpoons N_2(g) + O_2(g)$	1×10^{30}
$2\,H_2O(g) \rightleftharpoons 2\,H_2(g) + O_2(g)$	5×10^{-82}
$2\,CO(g) + O_2(g) \rightleftharpoons 2\,CO_2(g)$	3×10^{91}

Which compound is most likely to dissociate and give $O_2(g)$ at 25°C?

1. NO **correct**

2. CO_2

3. CO

4. H_2O

Explanation:

Only two are dissociation reactions: dissociation of NO and dissociation of H_2O. K_c is greater for dissociation of NO.

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006 10.0 points

At 600°C, the equilibrium constant for the reaction

$$2\,HgO(s) \rightarrow 2\,Hg(\ell) + O_2(g)$$

is 2.8. Calculate the equilibrium constant for the reaction

$$\frac{1}{2}\,O_2(g) + Hg(\ell) \rightarrow HgO(s)\,.$$

1. -1.7

2. 0.36

3. 1.1

4. 1.7

5. 0.60 **correct**

Explanation:

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007 10.0 points

If $K_c = 7.63 \times 10^5$ for the reaction

$$A(g) \rightleftharpoons 2\,B(g)\,,$$

what is K_c for the reaction written as

$$2\,B(g) \rightleftharpoons A(g)\,?$$

Correct answer: 1.31062×10^{-6}.

Explanation:

$K_{c,\,ini} = 7.63 \times 10^5$

$$A(g) \rightleftharpoons 2\,B(g)\,, \quad K_c = \frac{[B]^2}{[A]} = 7.63 \times 10^5$$

$$2\,B(g) \rightleftharpoons A(g)$$

$$K_c^{-1} = \frac{[A]}{[B]^2} = \frac{1}{K_c} = \frac{1}{7.63 \times 10^5} = 1.31062 \times 10^{-6}$$

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008 10.0 points

Consider the reaction

$$2\,HgO(s) \rightleftharpoons 2\,Hg(\ell) + O_2(g)\,.$$

What is the form of the equilibrium constant K_c for the reaction?

1. $K_c = [O_2]$ **correct**

2. $K_c = \dfrac{[Hg]^2\,[O_2]}{[HgO]^2}$

3. $K_c = \dfrac{[O_2]}{[HgO]^2}$

4. None of the other answers is correct.

5. $K_c = [Hg]^2\,[O_2]$

Explanation:
Solids and liquids are not included in the K expression.

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009 10.0 points

$K_c = 2.6 \times 10^8$ at 825 K for the reaction

$$2\,H_2(g) + S_2(g) \rightleftharpoons 2\,H_2S(g)$$

The equilibrium concentration of H_2 is 0.0020 M and that of S_2 is 0.0010 M. What is the equilibrium concentration of H_2S?

1. 1.02 M **correct**

2. 0.10 M

3. 0.0010 M

4. 10 M

Explanation:
$K_c = 2.6 \times 10^8$ $[H_2]_{eq} = 0.0020$ M
$[S_2]_{eq} = 0.0010$ M

$$2\,H_2(g) + S_2 \rightleftharpoons 2\,H_2S$$

$$K_c = \frac{[H_2S]^2}{[H_2]^2\,[S_2]}$$
$$[H_2S] = \sqrt{K_c\,[H_2]^2\,[S_2]}$$
$$= \sqrt{(2.6 \times 10^8)\,(0.0020\text{ M})^2\,(0.0010\text{ M})}$$
$$= 1.0\text{ M}$$

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010 10.0 points

A mixture of $PCl_5(g)$ and $Cl_2(g)$ is placed into a closed container. At equilibrium it is found that $[PCl_5] = 0.71$ M, $[Cl_2] = 0.25$ M and $[PCl_3] = 0.11$ M.

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

What is the value of K_c for the reaction?

1. 0.0387324 **correct**

2. 46

3. 0.0774648

4. 0.0193662

5. 0.116197

Explanation:
$[PCl_5] = 0.71$ M $[Cl_2] = 0.25$ M
$[PCl_3] = 0.11$ M

$$K_c = \frac{[Cl_2]\,[PCl_3]}{[PCl_5]} = \frac{(0.25\text{ M})(0.11\text{ M})}{0.71\text{ M}}$$
$$= 0.0387324\text{ M}$$

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011 10.0 points

At 1000 K the equilibrium pressure of the three gases in one mixture

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$$

were found to be 0.562 atm SO_2, 0.101 atm O_2, and 0.332 atm SO_3. Calculate the value of K_p for the reaction as written.

1. 0.171

2. 0.289

3. 5.83

4. 2.64

5. 3.46 **correct**

Explanation:
$P_{SO_3} = 0.332$ atm $P_{SO_2} = 0.562$ atm
$P_{O_2} = 0.101$ atm

$$K_p = \frac{P^2_{SO_3}}{P^2_{SO_2} \cdot P_{O_2}} = \frac{(0.332)^2}{(0.562)^2(0.101)} = 3.46$$

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012 10.0 points

A 2.000 liter vessel is filled with 4.000 moles of SO_3 and 6.000 moles of O_2. When the reaction

$$2\,SO_3(\text{gas}) \rightleftharpoons 2\,SO_2(\text{gas}) + O_2(\text{gas})$$

comes to equilibrium a measurement shows that only 1.000 mole of SO_3 remains. How many moles of O_2 are in the vessel at equilibrium?

1. 7.500 mol **correct**

2. 7.000 mol

3. 12.000 mol

4. 3.750 mol

5. None of these is correct.

Explanation:
Initially,

$$[SO_3] = \frac{4 \text{ mol}}{2 \text{ L}} = 2 \text{ M} \qquad [O_2] = \frac{6 \text{ mol}}{2 \text{ L}} = 3 \text{ M}$$

	$2\,SO_3$ (g) $\rightleftharpoons$	$2\,SO_2$ (g) +	O_2 (g)
ini, M	2	0	3
Δ, M	$-2x$	$2x$	x
eq, M	$2-2x$	$2x$	$3+x$

At equilibrium,

$$[SO_3]_{eq} = \frac{1 \text{ mol}}{2 \text{ L}} = 0.5 \text{ M, so}$$

$$2 - 2x = 0.5$$
$$-2x = -1.5$$
$$x = 0.75$$

Thus

$$[O_2] = 3 + x = 3.75 \text{ M}$$

$$\text{mol } O_2 = (3.75 \text{ mol/L})\,(2 \text{ L}) = 7.5 \text{ mol}\,.$$

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013 10.0 points

Suppose the reaction

$$A \rightleftharpoons B$$

has an equilibrium constant of 1.0 and the initial concentrations of A and B are 0.5 M and 0.0 M, respectively. Which of the following is the correct value for the final concentration of A?

1. 0.250 M **correct**

2. 1.00 M

3. None of these is correct.

4. 0.500 M

5. 1.50 M

Explanation:
$K = 1.0$ $[A]_{ini} = 0.5$ M
$[B]_{ini} = 0$ M

	A $\rightleftharpoons$	B
ini, M	0.5	0.0
Δ, M	$-x$	x
eq, M	$0.5-x$	x

$$K = \frac{[B]}{[A]} = 1.0$$
$$\frac{x}{0.5 - x} = 1.0$$
$$x = 0.25 \text{ M}$$

$$[A] = 0.5 - x = 0.25 \text{ M}$$

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014 10.0 points

Suppose the reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2\,HI(g)$$

has an equilibrium constant $K_c = 49$ and the initial concentration of H_2 and I_2 is 0.5 M and HI is 0.0 M. Which of the following is the correct value for the final concentration of HI(g)?

1. 0.219 M

2. 0.778 M **correct**

3. 0.599 M

4. 0.389 M

5. 0.250 M

Explanation:
$K_c = 49$ $[H_2]_{ini} = 0.5$ M
$[I_2]_{ini} = 0.5$ M $[HI]_{ini} = 0$ M

	$H_2(g)$	+	$I_2(g)$	$\rightleftharpoons$	$2\,HI(g)$
Ini, M	0.5		0.5		0
Δ, M	$-x$		$-x$		$+2\,x$
Equil, M	$0.5 - x$		$0.5 - x$		$2\,x$

$$K_c = \frac{[HI]^2}{[H_2]\,[I_2]}$$
$$49 = \frac{(2x)^2}{(0.5-x)^2}$$
$$7 = \frac{2x}{0.5-x}$$
$$7(0.5-x) = 2x$$
$$3.5 - 7x = 2x$$
$$3.5 = 9x$$
$$x = \frac{3.5}{9} = 0.389 \text{ M}$$

Looking back at our equilibrium values, we see that the final concentration of HI is equal to $2x$, so $2(0.389) = 0.778$ M.

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015 10.0 points

At $T = 700°$C, $K_c = 121$ for the gas-phase reaction

$$A + B \rightleftharpoons C + D$$

Starting with 1.72 moles each of A and B in a 5.00 liter container, what will be the equilibrium concentration of C at this temperature?

Correct answer: 0.315333 M.

Explanation:

$[A] = \dfrac{1.72 \text{ mol}}{5 \text{ L}} = 0.344$ M $\qquad T = 700°$C

$[B] = \dfrac{1.72 \text{ mol}}{5 \text{ L}} = 0.344$ M $\qquad K_c = 121$

	A	+	B	$\rightleftharpoons$	C	+	D
ini, M	0.344		0.344		0		0
Δ, M	$-x$		$-x$		x		x
eq, M	$0.344 - x$		$0.344 - x$		x		x

$$\frac{[C][D]}{[A][B]} = 121$$
$$\frac{x^2}{(0.344-x)^2} = 121$$
$$\frac{x}{0.344-x} = 11$$
$$x = 3.784 - 11\,x$$
$$x = [C] = 0.315333 \text{ M}$$

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016 10.0 points

Consider the reaction

$$Ni(CO)_4(g) \rightarrow Ni(s) + 4\,CO(g)\,.$$

If the initial concentration of $Ni(CO)_4(g)$ is 1.0 M, and x is the equilibrium concentration of CO(g), what is the correct equilibrium relation?

1. $K_c = \dfrac{x}{1.0 - \dfrac{x}{4}}$

2. $K_c = \dfrac{x^5}{1.0 - \dfrac{x}{4}}$

3. $K_c = \dfrac{x^4}{1.0 - \dfrac{x}{4}}$ **correct**

4. $K_c = \dfrac{x^4}{1.0 - 4x}$

5. $K_c = \dfrac{4\,x}{1.0 - 4x}$

Explanation: