Monopoly Problems

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Contents

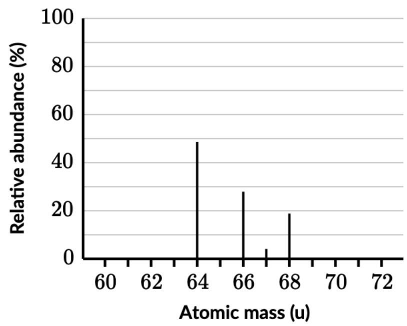
1 Unit 1: Atomic Structure and Properties

Problem 1

Calculate the number of moles in a $7.89kg$ sample of $C_9H_8O_4$

Problem 2

Given this graph, what is true about the element depicted



(a) In an average sample of the element, less than 20% of the atoms have an atomic mass of $66u$.
(b) The most abundant isotope of the element has an atomic mass of $64u$.
(c) The element has an average atomic mass of $64u$.
(d) The element has an average atomic mass between 66 and $68u$.

Problem 3

What is the percent composition of Carbon in $C_{13}H_{18}O_2$?

Problem 4

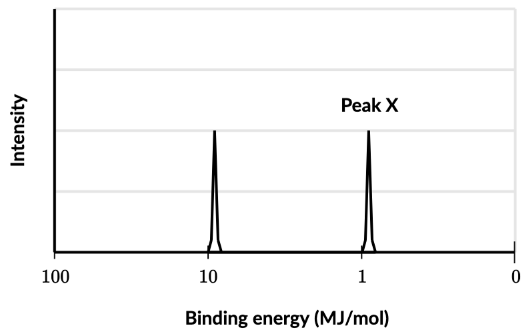
A compound contains 32.38% sodium, 22.65% sulfur, and 44.99% oxygen. What is the emperical forumula.

Problem 5

What is the full electron configuration of mercury?

Problem 6

Below, the photoelectron spectra of the $2s$ electrons of Be and Mg are shown.



Is peak X the peak associated with Be or Mg?

Problem 7

What are the periodic trends of ionization energy, atomic radius, and electronegativity? Why?

2 Unit 2: Molecular and Ionic Compound Structure and Properties

Problem 8

Which of the following bonds is likely to have the most ionic character?
(a) H — F
(b) C — O
(c) Na — F
(d) Mg — O

Problem 9

Based on the information in the table, which of the following arranges the bonds in order of decreasing polarity?

Element	Electronegativity
H	2.2
N	3.0
F	4.0
Cl	3.2
Se	2.6
I	2.7

(a) Se — N > H — I > Cl — F
(b) H — I > Se — N > Cl — F
(c) Cl — F > H — I > Se — N
(d) Cl — F > Se — N > H — I

Problem 10

Why is the lattice energy of CsF smaller than the lattice energy of KF?

Problem 11

What type of structure do metallic elements form and through what bonds?

Problem 12

What are the two types of metallic alloys and what are there differences?

Problem 13

Draw a Lewis Diagram for Acetic Acid CH_3COOH.

Problem 14

Draw the Lewis Diagram for CO_2

Problem 15

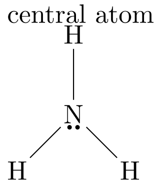
Draw the Lewis Diagram(s) for ozone, O_3

Problem 16

Write the formal charges for all three molecules above.

Problem 17

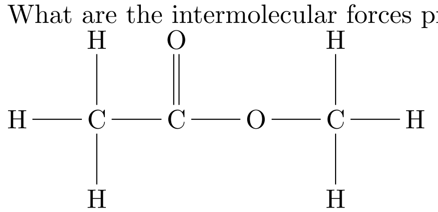
What is the electron geometry, molecular geometry, and hybridization of the central atom in this molecule.



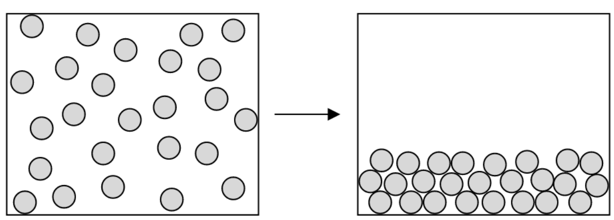
3 Unit 3: Intermolecular Forces and Properties

Problem 18

What are the intermolecular forces present among these molecules.



Problem 19



What phase transition is this?

Problem 20

Originally, a sample of gas is in a rigid container at $299K$ and $0.70atm$. The student increases the temperature of the CO_2(g) in the container to $425K$.
(a) What does raising the temperature do to the mostion of the molecules?
(b) What is the pressure at $425K$?
(c) In terms of Kinetic Molecular Theory, why does the pressure of gas change as it is heated?

Problem 21

A $60.3g$ of $Be(OH)_2$ is dissolved in enough water to produce $1.75L$ of solution. Calculate the concentration of OH^- ions.

Problem 22

Describe the photoelectric effect.

4 Unit 4: Chemical Reactions

Problem 23

Balance this reaction: $C_5H_{10} + O_2 \longrightarrow CO_2 + H_2O$

Problem 24

Balance this redox reaction: $MnO_4{}^- + I^- \longrightarrow I_2 + Mn^{2+}$

Problem 25

Aqueous $FeCl_3$ reacts with KOH to produce a solid precipitate of $Fe(OH)_3$ and aqueous KCl. What is the balanced net ionic equation?

Problem 26

What is the difference between physical changes and chemical changes?

Problem 27

H_2O and Fe are reacted according to the reaction below. There was initially $36.0g$ H_2O and $67.0g$ Fe. What is the limiting reactant, how much of the excess reactant will remain, and how much iron oxide is produced?
$3\,Fe(s) + 4\,H_2O(g) \longrightarrow Fe_3O_4(s)\,4\,H_2(g)$

Problem 28

A $56kg$ sample of CO and $6.0kg$ sample of H_2 are combined into a closed vessel.
$CO(g) + 2\,H_2(g) \longrightarrow CH_3OH(g)$
How many moles of $CH_3OH(g)$ have been produced?

5 Unit 5: Kinetics

Problem 29

For this reaction:
$CH_4(g) + 2\,O_2(g) \longrightarrow CO_2(g) + 2\,H_2O(g)$
What would be rate be in terms of each reactant and product.
CH_4 rate =
O_2 rate =
CO_2 rate =
H_2O rate =

Problem 30

If the rate of dissapearance of CH_4 equals $5.0\frac{M}{s}$ for the above reaction, what is the rate of appearance of H_2O?

Problem 31

For the above reaction, what is the reaction rate if O_2 decreases from $0.1M$ to $0.04M$ in $125ms$?

Problem 32

$A(aq) + 2\,B(aq) \longrightarrow \text{Products}$

Experiment	$[A]_0$	$[B]_0$	Initial Rate
1	$0.10M$	$0.10M$	$1.0 \times 10^{-2}\frac{M}{s}$
2	$0.3M$	$0.10M$	$9.0 \times 10^{-2}\frac{M}{s}$
3	$0.3M$	$0.15M$	$9.0 \times 10^{-2}\frac{M}{s}$

What is the rate law?

Problem 33

N_2O_5 decomposes by a 1st order reaction with $k = 4.80 \times 10^{-4}\frac{1}{s}$. What is the concentration of N_2O_5 after 825 seconds if the intial concentration is $0.0165M$? What is the half-life for this reaction?

Problem 34

This problem relates to problem 35 as well
The reaction $2\,C_4H_6(g) \longrightarrow C_8H_{12}(g)$ is a 2nd order reaction with $k = 4.0 \times 10^{-4}\frac{1}{Ms}$. If the initial concentration of C_4H_6 is $0.100M$ what is the concentration after 6 days?

Problem 35

How long does it take for the concentration to drop to $0.085M$?

Problem 36

What is the net chemical reaction and predict the experimental rate law for a chemical reaction with this chemical mechanism.

$$H_2O_2 + I^- \longrightarrow H_2O + IO^- \quad k_1\,(\text{slow})$$
$$IO^- + H_2O_2 \longrightarrow H_2O + O_2 + I^- \quad k_2\,(\text{fast})$$

Also identify catalysts and intermediates.

Problem 37

Predict the experimental rate law for a chemical reaction that proceeds by the following mechanism:

$$\begin{aligned}
&2\,NO \rightleftharpoons N_2O_2 \quad \text{(Fast equilibrium step)}\\
&N_2O_2 + H_2 \longrightarrow H_2O + N_2O \quad \text{(slow)}\\
&N_2O + H_2 \longrightarrow N_2 + H_2O \quad \text{(fast)}
\end{aligned}$$

6 Unit 6: Thermodynamics

Problem 38

It takes 1.8×10^{-19} calories of energy to break an O—H bond in water. How much energy does it take to break all of the O—H bonds in 50.0 grams of water?

Problem 39

120. grams of an unknown metal at $100.°C$ is dropped in a styrofoam cup that contains $100.0mL$ of water that is at $20.0\deg C$. After some times, the final temperature of the equilibiated system is measured to be $27.3°C$. What is the specific heat capacity of the metal?

Problem 40

How much heat energy is required to vaporize 5.0 liters of $H_2O\,(l)$ where the heat of vaporization of water is $40.72\frac{kJ}{mol}$.

Problem 41

Given these chemical equations
$C_2H_2(g) + 2\,H_2(g) \longrightarrow C_2H_6(g) \qquad \Delta H = -311kJ$
$C_2H_4(g) + H_2(g) \longrightarrow C_2H_6(g) \qquad \Delta H = -136kJ$
Find the enthalpy change for
$C_2H_2(g) + H_2(g) \longrightarrow C_2H_6(g)$

Problem 42

For $C_2H_5OH\,(l) + 2\,O_2(g) \longrightarrow 2\,CO_2(g) + 2\,H_2O\,(l) \qquad \Delta H = -1371kJ$. If $1.5mol$ of oxygen is used, how much energy is released?

Problem 43

When temperature increases, does entropy increase or decrease?

Problem 44

If the standard entropies for $H_2O(g)$, $H_2(g)$, and O_2 are 188.83, 130.58, and 205.0 respectively, what is the entropy change for $2\,H_2O(g) \longrightarrow 2\,H_2(g) + O_2(g)$?

Problem 45

What is $\Delta S_{universe}$ for the equation $CH_4(g) + 2\,O_2(g) \rightleftharpoons CO_2(g) + 2\,H_2O(g)$ where $\Delta H = -802.2\frac{kJ}{mol}$. Use the standard entropy values above and note that $S^\circ = 213.7$ and 186.1 for $CO_2(g)$ and $CH_4(g)$ respectively.

Problem 46

For $N_2(g) + 2\,H_2(g) \rightleftharpoons 2\,NH_3(g)$ where $\Delta H = -91.8kJ$ and $\Delta S^\circ = -197.3\frac{J}{K}$. Calculate ΔG° at $1000K$

Problem 47

For $2\,H_2O(g) \rightleftharpoons 2\,H_2(g) + O_2(g) \qquad \Delta H^\circ = 483.6kJ$. Will the reaction form more or less product when temperature is increased.

7 Unit 7: Equilibrium

Problem 48

What is the concentration equilibrium constant for the reaction $CO(g) + 3\,H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)$

Problem 49

If $K_c = 3.91$ at $1200K$, Will the reactants shift towards products, reactants, or stay the same if the reaction mixture contains $[CO] = 0.0200M$, $[H_2] = 0.0200M$, $[CH_4] = 0.00100M$, and $[H_2O] = 0.00100M$?

Problem 50

For this chemical reaction $2\,CH_4(g) \rightleftharpoons C_2H_2(g) + 3\,H_2(g)$, $K_p = 2.0 \times 10^{-6}$. $14atm$ of methane gas is put into the reaction vessel. What is the expected partial pressure of $C_2H_2(g)$ at equilibrium.

Problem 51

For this reaction $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$, $K_c = 0.16$. What is the molar concentration of each product if $250g$ of ammonium hydrogen sulfide is introduced into a $2.0L$ flask and allowed to reach equilibrium.

8 Answers

8.1 Unit 1

Problem 1

The molar mass of $C_9H_8O_4$ is $1.008 * 8 + 12.01 * 9 + 16.00 * 4 = 180.2\frac{g}{mol}$

$$7.89kg \times \frac{1g}{10^{-3}kg} \times \frac{1mol}{180.2g} = 43.8mol \tag{1}$$

Problem 2

(b), the tallest peak of the graph is the one at $64u$.

Problem 3

In one mole of $C_{13}H_{18}O_2$ is $206.31g$.

$$1mol\,\mathrm{C_{13}H_{18}O_2} \times \frac{13mol\,\mathrm{C}}{1mol\mathrm{C_{13}H_{18}O_2}} \times \frac{12.01g}{1mol\,\mathrm{C}} = 156.31g \tag{2}$$

Thus, the percent composition by weight is $\frac{156.31}{206.31} = 75.764\%$

Problem 4

Take $100g$ of the substance such that there are $32.38g$ sodium, $22.65g$ sulfur, and $44.99g$ oxygen.

$$\begin{aligned} 32.38g\,\mathrm{Na} \times \frac{1mol\,\mathrm{Na}}{22.99g} &= 1.408mol\,\mathrm{Na} \\ 22.65\,g\mathrm{S} * \frac{1\,mol\mathrm{S}}{32.07g} &= 0.7063\,mol\mathrm{S} \\ 44.99\,g\mathrm{O} * \frac{1\,mol\mathrm{O}}{16g} &= 2.812\,mol\mathrm{O} \end{aligned} \tag{3}$$

Take the ratio of each compound with the smallest quantity.

$$\begin{aligned} S : \frac{0.7063}{0.7063} &= 1 \\ Na : \frac{1.408}{0.7063} &= 2 \\ O : \frac{2.812}{0.7063} &= 4 \end{aligned} \tag{4}$$

Therefore, the empirical formula is Na_2SO_4

Problem 5

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10}$

Problem 6

Be. The peak location of the peak on the x-axis means that there is less binding energy for the electrons in element X. Be has fewer protons and both electrons are in the same shell, so it peak must belong to Be.

Problem 7

- The electronegativity increases from left to right across a period. This is because if a valence shell of electrons is less than half full than it requires less energy to lose an electron than gain one. If if the valence shell of electrons is more than half full, it is easier to pull and electron into the valence shell. The electronegativity decreases from the top to the bottom of a group. This is beause there is a greater atomic radius lower on the group.

- The ionization energy increases from left to right in a period. This is because of greater valence shell stability also because of smaller atomic radius. The ionization energy also decreases from top to bottom of a group. This is because of greater electron shielding and greater atomic radius.

- Atomic radius decreases from left to right within a period. This is because there are more protons to the right of the period. Atomic radius increases from top to bottom within a group. This is because of electron shielding and there are more electron shells in the atom.

8.2 Unit 2

Problem 8

The ionic character increase the greater the electronegativity difference. In this case, Na and O had the greatest electronegativity difference.

Problem 9

(c) $\mathrm{Cl} \text{—} \mathrm{F} > \mathrm{H} \text{—} \mathrm{I} > \mathrm{Se} \text{—} \mathrm{N}$

Problem 10

Cs^+ has a larger atomic radius than K^+. So the distance between the cation and anion is greater than in CsF than in KF

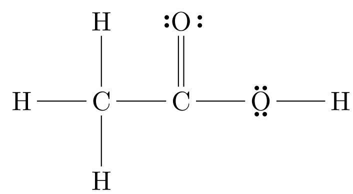
Problem 11

Most metallic elements form crystalline solids at room temperature. Their bonds are metallic bonds due to electrostatic attraction between metal cations and delocalized electrons.

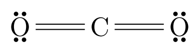
Problem 12

- Substitutional alloys. These alloys form when one atom of a similar size to the host metal replaces an atom of the host metal. The substitute atom must be of similar size. These alloys have good thermal and electrical conductivity.
- Interstitial alloys. These alloys are formed when smaller atoms fill in the gaps between the larger host atoms. This makes the metal harder and less malleable.

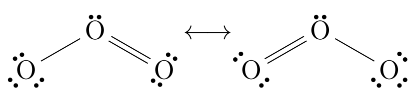
Problem 13



Problem 14

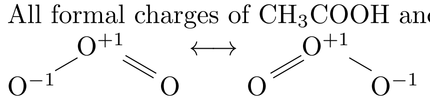


Problem 15



Problem 16

All formal charges of CH_3COOH and CO_2 are zero.



Problem 17

The electron geometry is tetrahedral. The molecular geometry is trigonal pyramidal. Hybridization of N atom is sp^3 since it has tetrahedral electron geometry.

8.3 Unit 3

Problem 18

Dipole-diple and london dispersion forces. The C — O bond is polar and the molecule is asymmetrical so it is polar. There are no H — F, H — O, or H — N bonds, so there is no hydrogen bonding.

Problem 19

Condensation. Both have no regular arrangement, the one on the left is separated by the one on the right is close together, so the molecules are transitioning from gas to liquid.

Problem 20

(a) As you increase the temperature, the average kinetic energy or speed increases as well.
(b) $n_1 = n_2$ and $V_1 = V_2$, so $P_1V_1 = n_1RT_1$ and $P_2V_2 = n_2RT_2$. $\frac{P_2V_2}{RT_2} = \frac{P_1V_1}{RT_1} \implies P_2 = \frac{P_1T_2}{T_1} = \frac{0.7*425}{299} = 0.99atm$
(c) As the temperature increases, the average kinetic energy increases, so the molecules undergo more collisions with the walls of the container.

Problem 21

$$60.3g \times \frac{1mol\,\mathrm{Ba(OH)_2}}{171.35g} \times \frac{2mol\,\mathrm{OH^-}}{1mol\,\mathrm{Ba(OH)_2}} * \frac{1}{1.75L} = 0.402M$$

Problem 22

The photoelectric effect occurs when light of a certain minimum frequency/energy hits the surface of a metal and electrons are ejected.

8.4 Unit 4

Problem 23

$2\,\mathrm{C_5H_{10}} + 15\,\mathrm{O_2} \longrightarrow 10\,\mathrm{CO_2} + 10\,\mathrm{H_2O}$

Problem 24

The oxidation reaction:

$$\begin{aligned}
&\mathrm{I^-} \longrightarrow \mathrm{I_2}\\
&2\,\mathrm{I^-} \longrightarrow \mathrm{I_2}\\
&2\,\mathrm{I^-} \longrightarrow \mathrm{I_2} + 2\,\mathrm{e^-}\\
&10\,\mathrm{I^-} \longrightarrow 5\,\mathrm{I_2} + 10\,\mathrm{e^-}
\end{aligned}$$

The reduction reaction:

$$MnO_4^- \longrightarrow Mn^{2+}$$
$$MnO_4^- \longrightarrow Mn^{2+} + 4\,H_2O$$
$$MnO_4^- + 8\,H^+ \longrightarrow Mn^{2+} + 4\,H_2O$$
$$5\,e^- + MnO_4^- + 8\,H^+ \longrightarrow Mn^{2+} + 4\,H_2O$$
$$10\,e^- + 2\,MnO_4^- + 16\,H^+ \longrightarrow 2\,Mn^{2+} + 8\,H_2O$$

Add the reactions together:
$10\,I^- + 16\,H^+ + 2\,MnO_4^- \longrightarrow 5\,I_2 + 2\,Mn^{2+} + 8\,H_2O$

Problem 25

$Fe^{3+}(aq) + 3\,OH^-(aq) \longrightarrow Fe(OH)_3(s)$

Problem 26

Chemical processes are characterized by changes in intramolecular forces, while physical processes are characterized by changes only in intermolecular forces.

Problem 27

Find the limiting reactant:

$$\begin{aligned} 36.0\,gH_2O * \frac{1\,molH_2O}{18.02\,gH_2O} * \frac{1\,molFe_3O_4}{4\,molH_2O} &= 0.49945\,molFe_3O_4 \\ 67.0\,gFe * \frac{1\,molFe}{55.85\,gFe} * \frac{1\,molFe_3O_4}{3\,molFe} &= 0.39988\,molFe_3O_4 \end{aligned} \tag{5}$$

Therefore, the limiting reactant is Fe_3
Find how much iron oxide is produced: Use the limiting reactant

$$0.39988\,mol\mathrm{Fe_3} * \frac{231.55\,gFe_3O_4}{1\,mol\mathrm{Fe_3}} = 92.6\,gFe_3O_4 \tag{6}$$

Find how much excess reactant is left over:

$$67.0\,gFe * \frac{1\,molFe}{55.85\,gFe} * \frac{4\,molH_2O}{3\,molFe} * \frac{18.02\,gH_2O}{1\,molH_2O} = 28.8\,gH_2O \tag{7}$$

28.8 grams of water is used out of 32.0 grams. So there is 7.2 grams left over of the excess reagent.

Problem 28

$1.5 \times 10^3 mol$

Problem 29

CH_4 rate $= \frac{-\Delta[CH_4]}{\Delta t}$
O_2 rate $= \frac{-1}{2}\frac{\Delta[O_2]}{\Delta t}$
CO_2 rate $= \frac{\Delta[CO_2]}{\Delta t}$
H_2O rate $= \frac{1}{2}\frac{\Delta[H_2O]}{\Delta t}$

Problem 30

$10\frac{M}{s}$

Problem 31

$\frac{(0.04-0.1)M}{125ms} \times \frac{1ms}{10^{-3}s} = -0.48\frac{M}{s}$
rate $= -\frac{1}{2} \times -0.48 = 0.24\frac{M}{s}$

Problem 32

When concentration of B is held constant and the concentration of A is tripled, the initial rate is multiplied by 9 so the order with respect to A is 2. The order with respect to B is 0 because nothing changes when the concetration is increased. Thus the rate law is

$$rate = k[A]^2[B]^0 = k[A]$$

$1.0 \times 10^{-2} = k \times 0.1^2 \implies k = 1.0\frac{1}{ms}$, thus $rate = [A]^2$

Problem 33

$$ln[A]_t = -kt + ln[A]_0$$
$$ln[A]_t = -(4.8 \times 10^{-4})(825) + ln(0.0165)$$
$$[A]_t = e^{-4.50} = 0.0111M$$

Half-life:

$$ln(\frac{1}{2}[A]_0) - ln[A]_0 = -kt$$
$$ln(\frac{1}{2}) = -kt$$
$$t = \frac{ln(2)}{k}$$

Problem 34

$k = 4.0 \times 10^{-4}\frac{1}{Ms} = 35\frac{1}{M \times days}$
$\frac{1}{[A]_t} = 35 * 6 + \frac{1}{0.1} \implies [A]_t = 4.5 \times 10^{-3}$

Problem 35

$\frac{1}{0.085M} = 35t + \frac{1}{0.1M} \implies t = 0.05days$

Problem 36

$2\,H_2O_2 \longrightarrow 2\,H_2O + O_2$ The rate determining step is the slow reaction, so $rate = k[H_2O_2][I^-]$
I^- is the catalyst. IO^- is the intermediate.

Problem 37

Overall: $2\,NO + 2\,H_2 \longrightarrow 2\,H_2O + N_2$
Rate determining step: $rate = k[N_2O_2][H_2]$
Fast equilbium: rate forward = rate back $\implies [N_2O_2] = \frac{k_f}{k_r}[NO]^2$
Thus, $rate = \frac{kk_f}{k_r}[NO]^2[H_2]$

8.5 Unit 6

Problem 38

$50gH_2O \times \frac{1molH_2O}{18.01gH_2O} \times \frac{6.022\times10^{23}H_2O}{1molH_2O} \times \frac{2O-H}{1H_2O} \times \frac{1.8\times10^{-9}cal}{1O-H} \times \frac{4.184J}{1cal} \times \frac{1kJ}{10^3 J} = 2500kJ$

Problem 39

$q_{water} = 7.3 \times 100 \times 4.184$
$q_{water} = -q_{metal}$
$q_{metal} = C_{metal}(27.3 - 100) * 120 \implies C_{metal} = 0.350\frac{J}{g°C}$

Problem 40

$5.0LH_2O \times \frac{1mLH_2O}{10^{-3}LH_2O} \times \frac{1gH_2O}{1mL} \times \frac{1mol}{18.01g} \times \frac{40.72kJ}{1mol} = 11302.32kJ$

Problem 41

$$\begin{aligned} &C_2H_2 + 2\,H_2 \longrightarrow C_2H_6 \\ &C_2H_6 \longrightarrow C_2H_4 + H_2 \qquad \implies C_2H_2 + H_2 \longrightarrow C_2H_4 \end{aligned}$$

Thus, $\Delta H = -175$

Problem 42

$1.5molO_2 \times \frac{1mol_{rxn}}{3molO_2} \times \frac{-1371kJ}{mol_{rxn}} = -685.5kJ$

Problem 43

Increase

Problem 44

$\Delta S = 205.0 + 2 \times 130.58 - 2 \times 188.83 = 88.5\frac{J}{K}$

Problem 45

$\Delta S_{surr} = \frac{-\Delta H}{T} = -\frac{-802.2*1000}{298.15} = 2691\frac{J}{K}$
$\Delta S_{sys} = 2 \times 188.7 + 213.7 - (186.1 + 2 \times 205.0) = -5.0\frac{J}{K}$
$\Delta S_{universe} = -5 + 2691 = 2686\frac{J}{K}$.

Problem 46

$\Delta G = -19800J - (1000) * (-197.3\frac{J}{K}) = 106000J$

Problem 47

More product at high temperature

8.6 Unit 7

Problem 48

$K_c = \frac{[\mathrm{CH_4}][\mathrm{H_2O}]}{[\mathrm{H_2}]^2[\mathrm{CO}]}$

Problem 49

$Q_c = 6.25$. $Q_c > K_c$ so the reaction will shift towards reactants.

Problem 50

$K_p = \frac{(3x)^3 x}{(14-2x)^2} \implies 2.0 \times 10^{-6} \approx \frac{(3x)^3 x}{14^2} \implies x = 0.062atm$. The partial pressure is $0.062atm$.

Problem 51

$x^2 = 0.16 \implies x = 0.4M$. Note that $250g = 4.89mol$ which is clearly enough to produce the $0.4M$ predicted by the equilibrium constant.