

# Monopoly Problems

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## 1 Unit 1: Atomic Structure and Properties

### Problem 1

Calculate the number of moles in a  $7.89\text{kg}$  sample of  $\text{C}_9\text{H}_8\text{O}_4$

### 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  $\text{C}_{13}\text{H}_{18}\text{O}_2$ ?

### Problem 4

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

### 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)  $\text{Se} - \text{N} > \text{H} - \text{I} > \text{Cl} - \text{F}$   
 (b)  $\text{H} - \text{I} > \text{Se} - \text{N} > \text{Cl} - \text{F}$   
 (c)  $\text{Cl} - \text{F} > \text{H} - \text{I} > \text{Se} - \text{N}$   
 (d)  $\text{Cl} - \text{F} > \text{Se} - \text{N} > \text{H} - \text{I}$

### 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 their differences?

### Problem 13

Draw a Lewis Diagram for Acetic Acid  $\text{CH}_3\text{COOH}$ .

### Problem 14

Draw the Lewis Diagram for  $\text{CO}_2$

### Problem 15

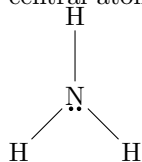
Draw the Lewis Diagram(s) for ozone,  $\text{O}_3$

### Problem 16

Write the formal charges for all three molecules above.

### Problem 17

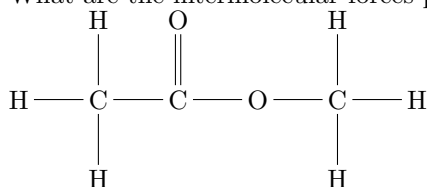
What is the electron geometry, molecular geometry, and hybridization of the central atom in this molecule.



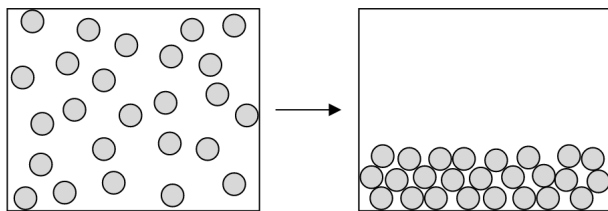
## 3 Unit 3: Intermolecular Forces and Properties

### 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  $425K$ .

- What does raising the temperature do to the motion of the molecules?
- What is the pressure at  $425K$ ?
- 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:  $\text{C}_5\text{H}_{10} + \text{O}_2 \longrightarrow \text{CO}_2 + \text{H}_2\text{O}$

### Problem 24

Balance this redox reaction:  $\text{MnO}_4^- + \text{I}^- \longrightarrow \text{I}_2 + \text{Mn}^{2+}$

### Problem 25

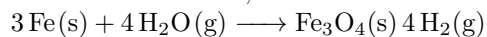
Aqueous  $\text{FeCl}_3$  reacts with  $\text{KOH}$  to produce a solid precipitate of  $\text{Fe}(\text{OH})_3$  and aqueous  $\text{KCl}$ . What is the balanced net ionic equation?

### Problem 26

What is the difference between physical changes and chemical changes?

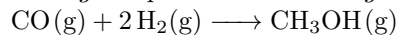
### Problem 27

$\text{H}_2\text{O}$  and  $\text{Fe}$  are reacted according to the reaction below. There was initially  $36.0\text{g}$   $\text{H}_2\text{O}$  and  $67.0\text{g}$   $\text{Fe}$ . What is the limiting reactant, how much of the excess reactant will remain, and how much iron oxide is produced?



### Problem 28

A  $56\text{kg}$  sample of  $\text{CO}$  and  $6.0\text{kg}$  sample of  $\text{H}_2$  are combined into a closed vessel.

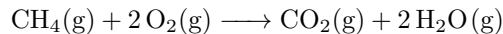


How many moles of  $\text{CH}_3\text{OH}(\text{g})$  have been produced?

## 5 Unit 5: Kinetics

### Problem 29

For this reaction:



What would be rate be in terms of each reactant and product.

$\text{CH}_4$  rate =

$\text{O}_2$  rate =

$\text{CO}_2$  rate =

$\text{H}_2\text{O}$  rate =

### Problem 30

If the rate of disappearance of  $\text{CH}_4$  equals  $5.0 \frac{M}{s}$  for the above reaction, what is the rate of appearance of  $\text{H}_2\text{O}$ ?

### Problem 31

For the above reaction, what is the reaction rate if  $\text{O}_2$  decreases from  $0.1M$  to  $0.04M$  in  $125ms$ ?

### Problem 32

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

Experiment	$[\text{A}]_0$	$[\text{B}]_0$	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

$\text{N}_2\text{O}_5$  decomposes by a 1st order reaction with  $k = 4.80 \times 10^{-4} \frac{1}{s}$ . What is the concentration of  $\text{N}_2\text{O}_5$  after 825 seconds if the initial concentration is  $0.0165M$ ? What is the half-life for this reaction?

### Problem 34

**This problem relates to problem 35 as well**

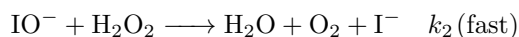
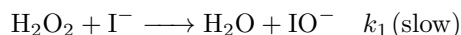
The reaction  $2\text{C}_4\text{H}_6(\text{g}) \longrightarrow \text{C}_8\text{H}_{12}(\text{g})$  is a 2nd order reaction with  $k = 4.0 \times 10^{-4} \frac{1}{Ms}$ . If the initial concentration of  $\text{C}_4\text{H}_6$  is  $0.100M$  what is the concentration after 6 days?

### 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.



Also identify catalysts and intermediates.



## 6 Answers

### 6.1 Unit 1

#### Problem 1

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

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

#### 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  $206.31g$ .

$$1mol C_{13}H_{18}O_2 \times \frac{13mol C}{1mol C_{13}H_{18}O_2} \times \frac{12.01g}{1mol C} = 156.31g \quad (2)$$

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.

$$\begin{aligned} 32.38g Na \times \frac{1mol Na}{22.99g} &= 1.408mol Na \\ 22.65g S \times \frac{1mol S}{32.07g} &= 0.7063mol S \\ 44.99g O \times \frac{1mol O}{16g} &= 2.812mol O \end{aligned} \quad (3)$$

Take the ratio of each compound with the smallest quantity.

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

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 its 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 then it requires less energy to lose an electron than gain one. If the valence shell of electrons is more than half full, it is easier to pull an electron into the valence shell. The electronegativity decreases from the top to the bottom of a group. This is because 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.

## 6.2 Unit 2

### Problem 8

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

### Problem 9

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

### Problem 10

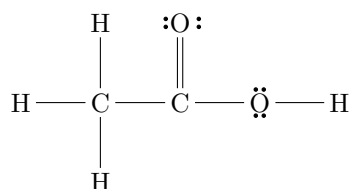
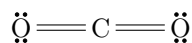
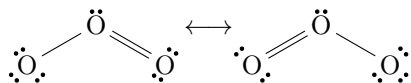
$\text{Cs}^+$  has a larger atomic radius than  $\text{K}^+$ . So the distance between the cation and anion is greater than in CsF than in KF

### Problem 11

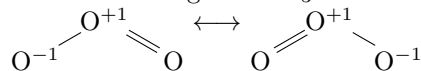
Most metallic elements form crystalline solids at room temperature. Their bonds are metallic bonds due to electrostatic attraction between metal cations and delocalized electrons.

**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  $\text{CH}_3\text{COOH}$  and  $\text{CO}_2$  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.

**6.3 Unit 3****Problem 18**

Dipole-dipole and London dispersion forces. The  $\text{C} - \text{O}$  bond is polar and the molecule is asymmetrical so it is polar. There are no  $\text{H} - \text{F}$ ,  $\text{H} - \text{O}$ , or  $\text{H} - \text{N}$  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  $P_2V_2 = n_2RT_2$ .  $\frac{P_2V_2}{RT_2} = \frac{P_1V_1}{RT_1} \implies P_2 = \frac{P_1T_2}{T_1} = \frac{0.7 \times 425}{299} = 0.99 \text{ atm}$

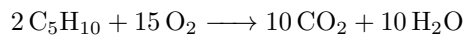
(c) As the temperature increases, the average kinetic energy increases, so the molecules undergo more collisions with the walls of the container.

**Problem 21**

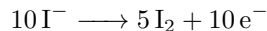
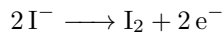
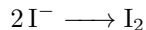
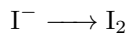
$$60.3g \times \frac{1 \text{ mol Ba(OH)}_2}{171.35g} \times \frac{2 \text{ mol OH}^-}{1 \text{ mol Ba(OH)}_2} * \frac{1}{1.75L} = 0.402M$$

**Problem 22**

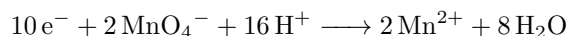
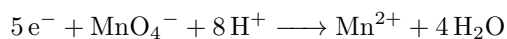
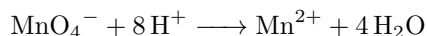
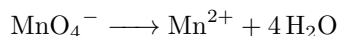
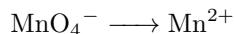
The photoelectric effect occurs when light of a certain minimum frequency/energy hits the surface of a metal and electrons are ejected.

**6.4 Unit 4****Problem 23****Problem 24**

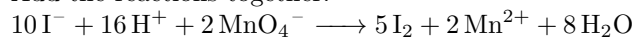
The oxidation reaction:



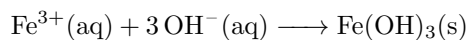
The reduction reaction:



Add the reactions together:



### Problem 25



### 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:

$$\begin{aligned} 36.0 \text{ gH}_2\text{O} * \frac{1 \text{ molH}_2\text{O}}{18.02 \text{ gH}_2\text{O}} * \frac{1 \text{ molFe}_3\text{O}_4}{4 \text{ molH}_2\text{O}} &= 0.49945 \text{ molFe}_3\text{O}_4 \\ 67.0 \text{ gFe} * \frac{1 \text{ molFe}}{55.85 \text{ gFe}} * \frac{1 \text{ molFe}_3\text{O}_4}{3 \text{ molFe}} &= 0.39988 \text{ molFe}_3\text{O}_4 \end{aligned} \quad (5)$$

Therefore, the limiting reactant is  $\text{Fe}_3$

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

$$0.39988 \text{ molFe}_3 * \frac{231.55 \text{ gFe}_3\text{O}_4}{1 \text{ molFe}_3} = 92.6 \text{ gFe}_3\text{O}_4 \quad (6)$$

Find how much excess reactant is left over:

$$67.0 \text{ gFe} * \frac{1 \text{ molFe}}{55.85 \text{ gFe}} * \frac{4 \text{ molH}_2\text{O}}{3 \text{ molFe}} * \frac{18.02 \text{ gH}_2\text{O}}{1 \text{ molH}_2\text{O}} = 28.8 \text{ gH}_2\text{O} \quad (7)$$

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

$$1.5 \times 10^3 \text{ mol}$$

**Problem 29**

$$\begin{aligned} \text{CH}_4 \quad \text{rate} &= \frac{-\Delta[\text{CH}_4]}{\Delta t} \\ \text{O}_2 \quad \text{rate} &= \frac{-1}{2} \frac{\Delta[\text{O}_2]}{\Delta t} \\ \text{CO}_2 \quad \text{rate} &= \frac{\Delta[\text{CO}_2]}{\Delta t} \\ \text{H}_2\text{O} \quad \text{rate} &= \frac{1}{2} \frac{\Delta[\text{H}_2\text{O}]}{\Delta t} \end{aligned}$$

**Problem 30**

$$10 \frac{M}{s}$$

**Problem 31**

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

**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 concentration is increased. Thus the rate law is

$$\text{rate} = k[A]^2[B]^0 = k[A]^2$$

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

**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:

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

$$\ln\left(\frac{1}{2}\right) = -kt$$

$$t = \frac{\ln(2)}{k}$$

**Problem 34**

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

**Problem 35**

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

**Problem 36**

$2\text{H}_2\text{O}_2 \longrightarrow 2\text{H}_2\text{O} + \text{O}_2$  The rate determining step is the slow reaction, so  
 $rate = k[\text{H}_2\text{O}_2][\text{I}^-]$   
 $\text{I}^-$  is the catalyst.  $\text{IO}^-$  is the intermediate.