Investigating Chemical Reactions

Name ____ Section (CRN)_______

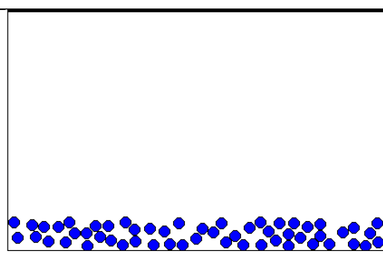
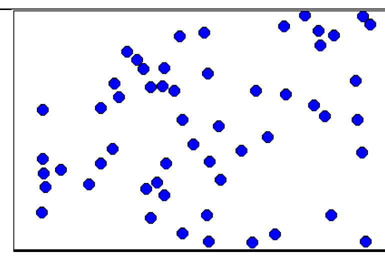
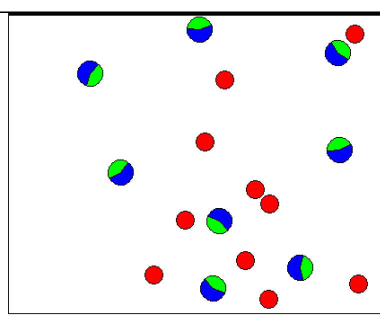
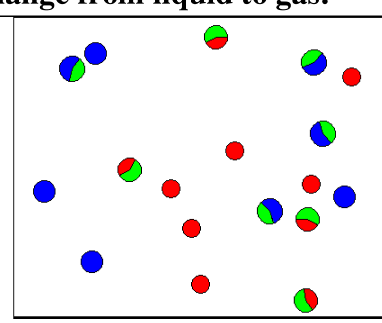
Problem Statement: How are masses of reactants and products related in a chemical reaction?

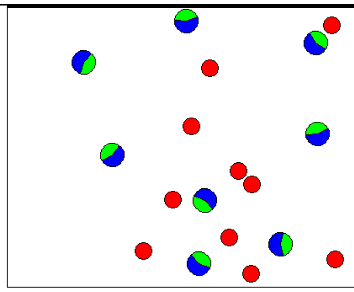
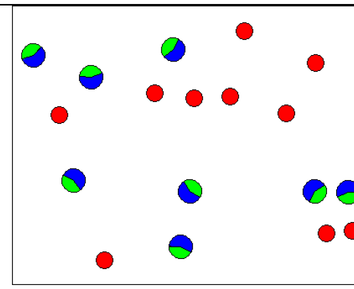
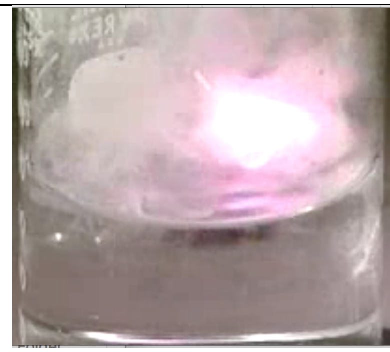
I. Preliminary Information

A. Using your textbook or an online source define/describe a chemical reaction. (Cite your source.)

A chemical reaction is the term used to indicate what happens when two or more substance, mixed together, produce new substances that are chemically distinct from the reactants.

B. For each of the following changes indicate which represents a chemical change and which represents a physical change. For each provide a brief explanation to support your claim.

 Initial	→	 Final **This change is physical, a phase change from liquid to gas.**
 Initial	→	 Final **This change is chemical, a R atom colliding with a BG molecule reacts to produce an RG molecule and a B atom.**

 Initial	→	 Final **Actually there is no change here other than the position of the particles in the container.**
 Initial	→	 Final **This is a chemical change at the macroscopic level (the previous exams were at the particulate level). We can see a flame, which is one characteristic of a chemical change happening.**

C. Answer the questions below regarding the reaction between hydrogen and oxygen to form water.

i) Write the formula for the element, hydrogen.

Formula for hydrogen is H_2.

ii) Write the formula for the element oxygen.

Formula for oxygen is O_2.

iii) Write the formula for the compound water.

Formula for water is H_2O.

iv) Write the balanced chemical equation (using the smallest whole number coefficients) that describes the reaction of hydrogen plus oxygen to form water.

$$2H_2 + O_2 \rightarrow 2H_2O$$

D. The Figure I. below depicts the particulate level (submicroscopic) representation of a container (the box on the left) with a mixture of hydrogen and oxygen molecules before a reaction occurs, and the <u>same</u> container (the box on the right) after a reaction occurs.

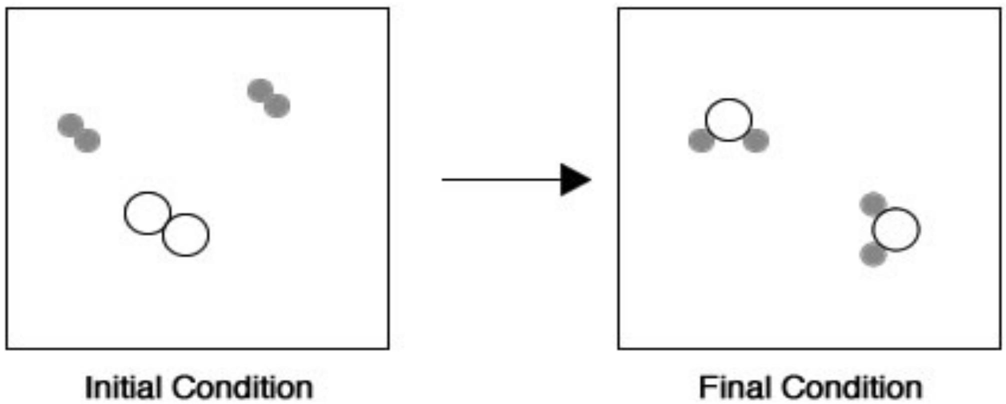
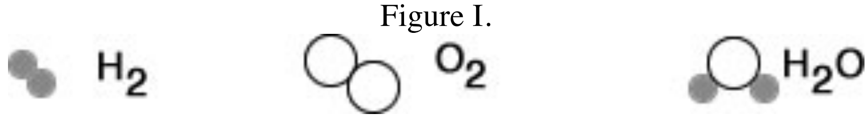


Figure I.



Write the balanced chemical equation (using whole number coefficients) that describes the reaction of hydrogen plus oxygen to form water.

$$2H_2 + O_2 \rightarrow 2H_2O$$

E. The Figure II. below depicts the particulate level (submicroscopic) representation of a container (the box on the left) with a mixture of hydrogen and oxygen molecules before a reaction occurs, and the same container (the box on the right) after a reaction occurs.

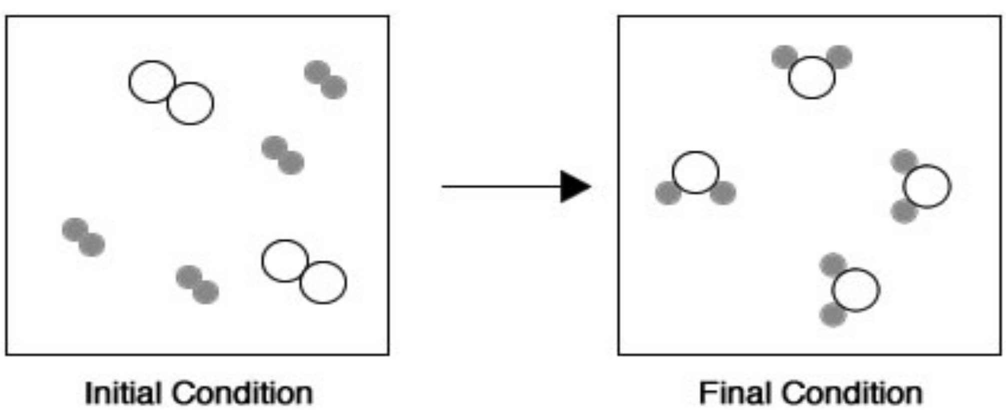
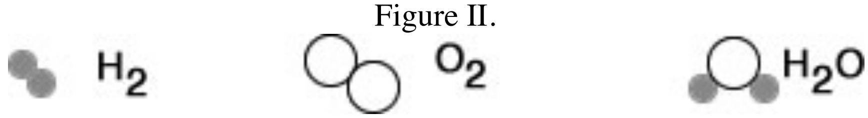


Figure II.



Write the balanced chemical equation (using whole number coefficients) that describes the reaction of hydrogen plus oxygen to form water.

$$\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$$

F. The Figure III. below depicts the particulate level (submicroscopic) representation of a container (the box on the left) with a mixture of hydrogen and oxygen molecules before a reaction occurs, and the same container (the box on the right) after a reaction occurs.

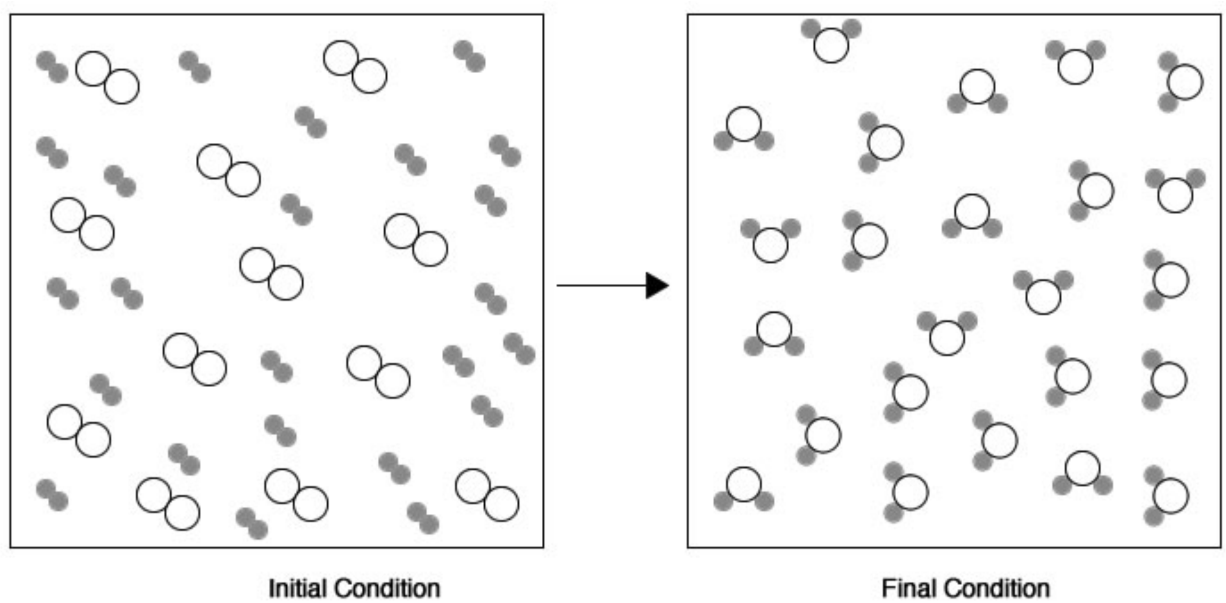
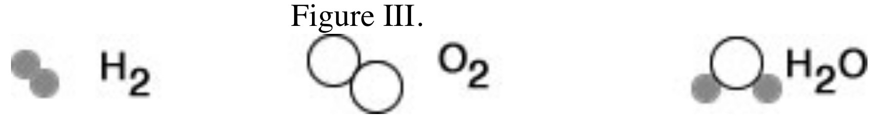


Figure III.



Write the balanced chemical equation (using whole number coefficients) that describes the reaction of hydrogen plus oxygen to form water.

$$\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$$

G. Summarizing parts D – F.

i) What is different about Figures I - III shown above?

They all have different amounts of reactants initially, and therefore, different amounts of products.

ii) What is the same about Figures I - III shown above?

The overall reaction is the same: $2H_2 + O_2 \rightarrow 2H_2O$

H. The Figure IV. below depicts the particulate level (submicroscopic) representation of a container (the box on the left) with a mixture of hydrogen and oxygen molecules before a reaction occurs, and the same container (the box on the right) after a reaction occurs.

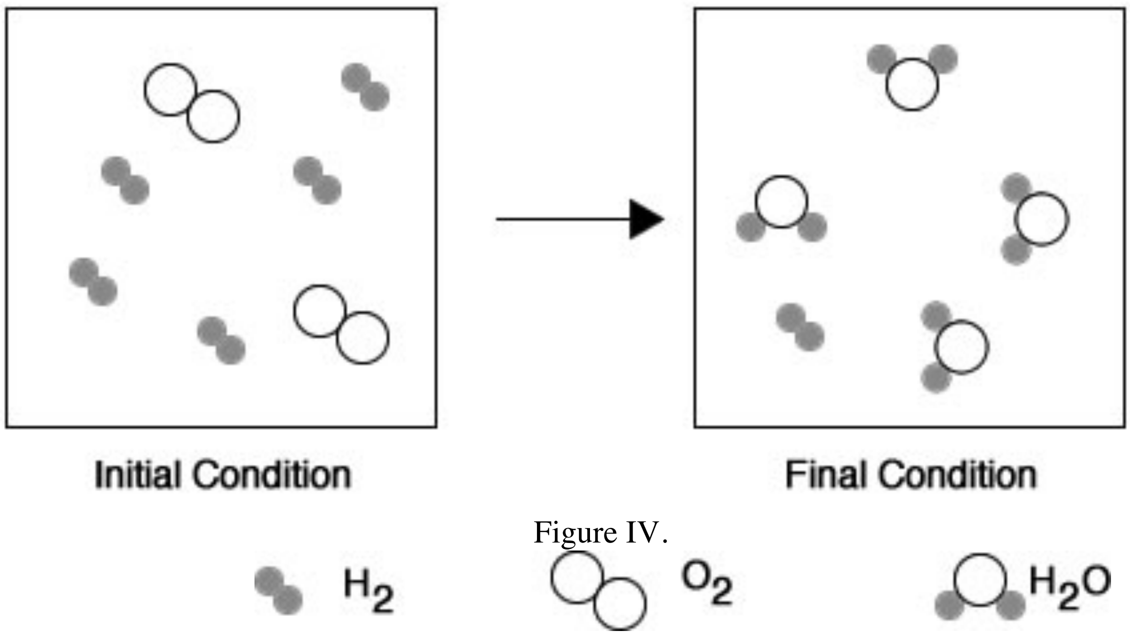


Figure IV.

i) Write the balanced chemical equation (using whole number coefficients) that describes the reaction of hydrogen plus oxygen to form water.

$$\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$$

I. What is different about the Initial condition in Figure IV compared to Figures I - III?

The initial amounts are not stoichiometrically related

J. Consider Figure V below and complete the contents of the Initial Conditions, before the reaction begins.

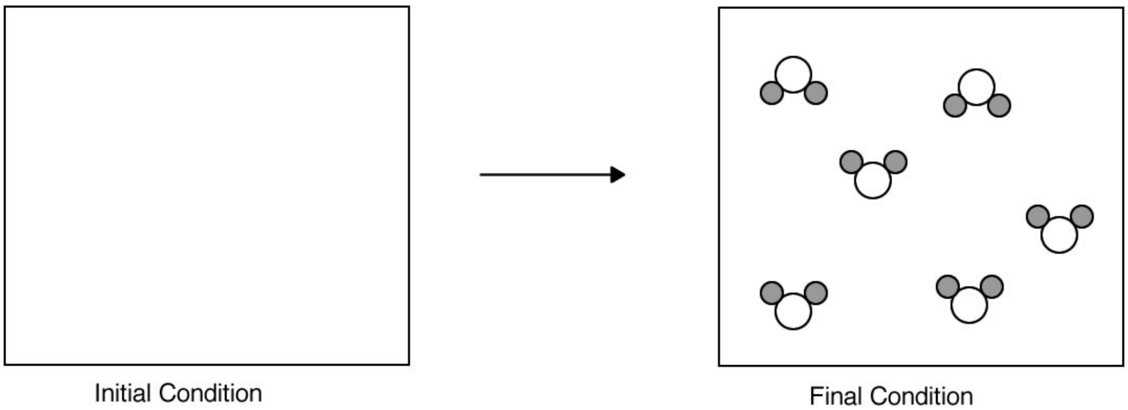


Figure V.

K. One way to summarize the amounts of reactants and products in a chemical reaction is to use a table that shows the Initial amounts of reactants and products, the Final amounts of reactants and products and the Change in the amounts of reactants and products.

Returning to Figure I in part D above, the table that summarizes the amounts of reactants and products in the chemical reaction would look like the following;

Looking at the Initial Conditions

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	2 molecules	1 molecule		0 molecules
Change				
Final				

Looking at the Final Conditions

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	2 molecules	1 molecule		0 molecules
Change				
Final	0 molecules	0 molecules		2 molecules

Determine the Change amounts

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	2 molecules	1 molecule		0 molecules
Change	–2 molecules	–1 molecules		+2 molecules
Final	0 molecules	0 molecules		2 molecules

Complete the tables below for Figures II, III, IV and V.

Figure II:
Initial Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**4**	**2**		**0**
Change				
Final				

Final Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**4**	**2**		**0**
Change				
Final	**0**	**0**		**4**

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**4**	**2**		**0**
Change	**-4**	**-2**		**+4**
Final	**0**	**0**		**4**

Figure III:
Initial Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**24**	**12**		**0**
Change				
Final				

Final Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**24**	**12**		**0**
Change				
Final	**0**	**0**		**24**

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**24**	**12**		**0**
Change	**-24**	**-12**		**+24**
Final	**0**	**0**		**24**

Figure IV:

Initial Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**5**	**2**		**0**
Change				
Final				

Final Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**5**	**2**		**0**
Change				
Final	**1**	**0**		**4**

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**5**	**2**		**0**
Change	**-4**	**-2**		**+4**
Final	**1**	**0**		**4**

Figure V:

Initial Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial				
Change				
Final	**0**	**0**		**6**

Final Condition

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial				**0**
Change	**-6**	**-3**		**+6**
Final	**0**	**0**		**6**

	$2H_2(g)$ +	$O_2(g)$	→	$2H_2O(g)$
Initial	**6**	**3**		**0**
Change	**-6**	**-3**		**+6**
Final	**0**	**0**		**6**

L. Consider the Change amounts for each of the tables above. What is interesting about the ratios of the numbers in the Change row for all four examples.

The ratio in the Change row correspond to the ratio of the coefficients in the balanced chemical equation.

5. In the synthesis reaction

$$2\ SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

Calculate the number of moles of SO_3 formed when:

a. 2.0 moles of SO_2 are mixed with 5.0 moles of O_2 and allowed to react.

From the problem the Initial row can be completed

Reaction	$2\ SO_2(g)$	$+ O_2(g)$	→	$2SO_3(g)$
Initial	2.0 mole	5.0 moles		0
Change				
End				

But this question does not tell us which reactant is in excess, so we must determine that ourselves. So we'll assume that all of SO_2 reacts and see what happens in the Change row of the ICE Table.

Reaction	$2\ SO_2(g)$	$+ O_2(g)$	→	$2SO_3(g)$
Initial	2.0 mole	5.0 moles		0
Change	-2.0 mole			
End				

Assuming that 2.0 mol SO_2 reacts we can use the stoichiometric coefficients to determine how much O_2 reacts

$$2.0\text{ mol }SO_2\left(\frac{1\text{ mol }O_2}{2\text{ mol }SO_2}\right) = 1.0\text{ mol }O_2$$

Reaction	$2\ SO_2(g)$	$+ O_2(g)$	→	$2SO_3(g)$
Initial	2.0 mole	5.0 moles		0
Change	-2.0 mole	-1.0 mol		
End				

Since 1.0 mol O_2 reacts and there are 5.0 mol O_2 initially O_2 is in excess and SO_2 is the limiting reagent. We can now calculate how much SO_3 is formed and finish the ICE table.

$$2.0\text{ mol }SO_2\left(\frac{2\text{ mol }SO_3}{2\text{ mol }SO_2}\right) = 2.0\text{ mol }SO_3$$

Reaction	$2\ SO_2(g)$	$+ O_2(g)$	→	$2SO_3(g)$
Initial	2.0 mol	5.0 mol		0
Change	-2.0 mol	-1.0 mol		+2.0 mol
End	0 mol	4.0 mol		2.0 mol

b. 4.0 moles of SO_2 are mixed with 6.0 moles of O_2 and allowed to react.

From the problem the Initial row can be completed

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	4.0 mole	6.0 moles		0
Change				
End				

But this question does not tell us which reactant is in excess, so we must determine that ourselves. So we'll assume that all of SO_2 reacts and see what happens in the Change row of the ICE Table.

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	4.0 mole	6.0 moles		0
Change	-4.0 mole			
End				

Assuming that 4.0 mol SO_2 reacts we can use the stoichiometric coefficients to determine how much O_2 reacts

$$\mathbf{4.0\ mol\ SO_2\left(\frac{1\ mol\ O_2}{2\ mol\ SO_2}\right) = 2.0\ mol\ O_2}$$

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	4.0 mole	6.0 moles		0
Change	-4.0 mole	-2.0 mol		
End				

Since 2.0 mol O_2 reacts and there are 6.0 mol O_2 initially O_2 is in excess and SO_2 is the limiting reagent. We can now calculate how much SO_3 is formed and finish the ICE table.

$$\mathbf{4.0\ mol\ SO_2\left(\frac{2\ mol\ SO_3}{2\ mol\ SO_2}\right) = 4.0\ mol\ SO_3}$$

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	4.0 mol	6.0 mol		0
Change	-4.0 mol	-2.0 mol		+4.0 mol
End	0 mol	4.0 mol		4.0 mol

c. 5.0 moles of SO_2 are mixed with 9.0 moles of O_2 and allowed to react.

From the problem the Initial row can be completed

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	5.0 mole	9.0 moles		0
Change				
End				

But this question does not tell us which reactant is in excess, so we must determine that ourselves. So we'll assume that all of SO_2 reacts and see what happens in the Change row of the ICE Table.

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	5.0 mole	9.0 moles		0
Change	-4.0 mole			
End				

Assuming that 5.0 mol SO_2 reacts we can use the stoichiometric coefficients to determine how much O_2 reacts

$$5.0\ \text{mol } SO_2 \left(\frac{1\ \text{mol } O_2}{2\ \text{mol } SO_2}\right) = 2.5\ \text{mol } O_2$$

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	5.0 mole	9.0 moles		0
Change	-5.0 mole	-2.5 mol		
End				

Since 2.5 mol O_2 reacts and there are 9.0 mol O_2 initially O_2 is in excess and SO_2 is the limiting reagent. We can now calculate how much SO_3 is formed and finish the ICE table.

$$5.0\ \text{mol } SO_2 \left(\frac{2\ \text{mol } SO_3}{2\ \text{mol } SO_2}\right) = 5.0\ \text{mol } SO_3$$

Reaction	$2\ SO_2(g)$	$+\ O_2(g)$	→	$2SO_3(g)$
Initial	5.0 mol	9.0 mol		0
Change	-5.0 mol	-2.5 mol		+5.0 mol
End	0 mol	6.5 mol		5.0 mol

d. 0.812 moles of SO_2 are mixed with 0.125 moles of O_2 and allowed to react.

From the problem the Initial row can be completed

Reaction	2 SO_2(g)	+ O_2(g)	→	2SO_3(g)
Initial	0.812 mole	0.125 mol		0
Change				
End				

But this question does not tell us which reactant is in excess, so we must determine that ourselves. So we'll assume that all of O_2 reacts and see what happens in the Change row of the ICE Table.

Reaction	2 SO_2(g)	+ O_2(g)	→	2SO_3(g)
Initial	0.812 mole	0.125 mol		0
Change		-0.125 mol		
End				

Assuming that 0.125 mol O_2 reacts we can use the stoichiometric coefficients to determine how much O_2 reacts

$$0.125 \text{ mol } O_2 \left(\frac{2 \text{ mol } SO_2}{1 \text{ mol } O_2} \right) = 0.250 \text{ mol } SO_2$$

Reaction	2 SO_2(g)	+ O_2(g)	→	2SO_3(g)
Initial	0.812 mole	0.125 moles		0
Change	-0.250 mole	-0.125 mol		
End				

Since 0.250 mol SO_2 reacts and there are 0.812 mol SO_2 initially SO_2 is in excess and O_2 is the limiting reagent. We can now calculate how much SO_3 is formed and finish the ICE table.

$$0.125 \text{ mol } O_2 \left(\frac{2 \text{ mol } SO_3}{1 \text{ mol } O_2} \right) = 0.250 \text{ mol } SO_3$$

Reaction	2 SO_2(g)	+ O_2(g)	→	2SO_3(g)
Initial	0.812 mole	0.125 moles		0
Change	-0.250 mole	-0.125 mol		+0.250 mol
End	0.562 mol	0 mol		0.250 mol

e. 20.0 grams of SO_2 are mixed with 15.0 grams of O_2 and allowed to react.

$$\textbf{20.0 grams } SO_2\left(\frac{1 \text{ mol } SO_2}{64 \text{ grams } SO_2}\right) = 0.313 \text{ mol } SO_2$$

$$\textbf{15.0 grams } O_2\left(\frac{1 \text{ mol } O_2}{32 \text{ grams } O_2}\right) = 0.469 \text{ mol } SO_2$$

From the problem the Initial row can be completed

Reaction	2 $SO_2(g)$	+ $O_2(g)$	→	$2SO_3(g)$
Initial	0.313 mole	0.469 mol		0
Change				
End				

But this question does not tell us which reactant is in excess, so we must determine that ourselves. So we'll assume that all of O_2 reacts and see what happens in the Change row of the ICE Table.

Reaction	2 $SO_2(g)$	+ $O_2(g)$	→	$2SO_3(g)$
Initial	0.313 mole	0.469 mol		0
Change	-0.313 mol			
End				

Assuming that 0.313 mol SO_2 reacts we can use the stoichiometric coefficients to determine how much O_2 reacts

$$0.313 \text{ mol } SO_2\left(\frac{1 \text{ mol } O_2}{2 \text{ mol } SO_2}\right) = 0.157 \text{ mol } O_2$$

Reaction	2 $SO_2(g)$	+ $O_2(g)$	→	$2SO_3(g)$
Initial	0.313 mole	0.469 mol		0
Change	-0.313 mol	-0.157 mol		
End				

Since 0.157 mol O_2 reacts and there are 0.469 mol O_2 initially O_2 is in excess and SO_2 is the limiting reagent. We can now calculate how much SO_3 is formed and finish the ICE table.

$$0.313 \text{ mol } SO_2\left(\frac{2 \text{ mol } SO_3}{2 \text{ mol } SO_2}\right) = 0.313 \text{ mol } SO_3$$

Reaction	2 $SO_2(g)$	+ $O_2(g)$	→	$2SO_3(g)$
Initial	0.313 mole	0.469 mol		0
Change	-0.313 mol	-0.157 mol		+0.313 mol
End	0 mol	0.312 mol		0.313 mol

Appendix
Instructions for using Java Applets

This activity use Java applets which can be a little funky at time. Please follow the instructions below to insure the computer you are using is setup properly to access both of these simulations.

Download Java at http://java.com/en/ and follow the instructions.

Continue for a PC

1) Search for Java on the computer by typing java into the search feature. Do not search for Java using a browser, simply search on the computer itself. In the list of items that are provided, open Configure Java and in the window that appears click on the security tab. Near the bottom of the page click 'edit site list'. A new window will appear. Click the Add button and enter http://introchem.chem.okstate.edu in the exception list and then click the Add button then click the OK button, then click the next OK button. (NOTE: If you are interested what this is doing is indicating to the Security feature on the computer that any future software being downloaded from http://introchem.chem.okstate.edu can be trusted.

2) Now open up an Explorer window or a Firefox browser window. (Do not attempt to us Chrome!) Chrome is not equipped to run this particular Java applet (any Java applet?)

3) Copy and paste the link to the java applet into your browser. There maybe a few windoids that appear that you must respond properly to for the software to load. Here are possible windoids and how to respond to the questions.

    a. A screen with what might appear to be a battery icon with the words 'activate Java' below: click on the activate Java link then,
    b. A windoid may appear in the upper left corner with two buttons (Allow and Allow and Remember), click on the Allow and Remember button,
    c. A windoid indicating the version of Java on the computer is out-of-date. Buttons at the bottom of this windoid include, Remind Me Later, Stop/Quit, and Update Java. Click the Remind Me Later button,
    d. A windoid asking you if it is okay to run the software. In this windoid, click Run.
    e. This should result in the simulation working.

4) On a Mac: Assuming you have Java installed, go to System Preferences. Near the bottom you will see a Java icon. Open the Control Panel. Go to the Security tab. In the Exceptions Site List select the Edit Site list button. Click on the Add button and enter 'http://introchem.chem.okstate.edu', then click the OK button. Click OK to exit the Control Panel. You should be able to access the simulation after following these instructions. It is possible you may have to quit your browser and re-open the web site.

5) If you continue to have problems contact please contact me at john.gelder@okstate.edu.