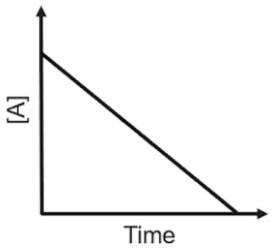
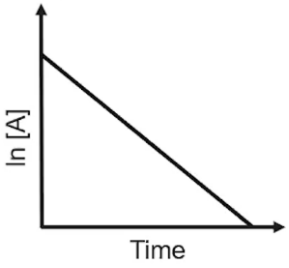
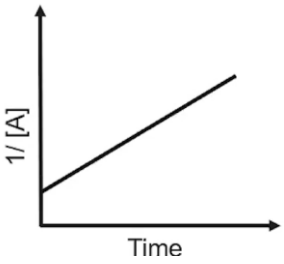
Video % Completed: _____/_____

AP Chemistry Daily Videos: 5.3 Concentration Changes Over Times

Video #1

1. Complete the following table:

Reaction Order	What happens to the rate when the reactant doubles?	Generic Rate Law	Integrated Rate Law	Relationship of k to slope	Graphical representation
Zero					
First					
Second					

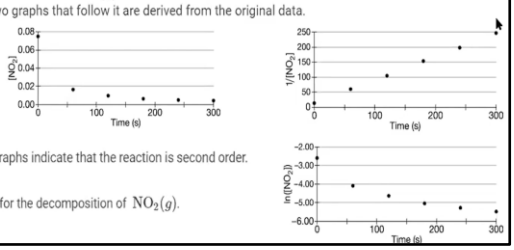
2. What is the purpose of the integrated rate law? What does $[A]_t$ and $[A]_0$ represent?

3. Pause the video at 3:16 and attempt the problem, then evaluate how you did and identify any errors.

Nitrogen dioxide, $NO_2(g)$, is produced as a by-product of the combustion of fossil fuels in internal combustion engines. At elevated temperatures $NO_2(g)$ decomposes according to the equation below.

$$2\ NO_2(g) \rightarrow 2\ NO(g) + O_2(g)$$

The concentration of a sample of $NO_2(g)$ is monitored as it decomposes and is recorded on the graph directly below. The two graphs that follow it are derived from the original data.



(a) Explain how the graphs indicate that the reaction is second order.

(b) Write the rate law for the decomposition of $NO_2(g)$.

4. Pause the video at 4:08 and attempt the problem, then evaluate how you did and identify any errors.

$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g) \qquad \Delta H^\circ = -196\ kJ/mol_{rxn}$

The decomposition of $H_2O_2(aq)$ is represented by the equation above. A student monitored the decomposition of a 1.0 L sample of $H_2O_2(aq)$ at a constant temperature of 300. K and recorded the concentration of H_2O_2 as a function of time. The results are given in the table below.

Which of the following statements is a correct interpretation of the data regarding how the order of the reaction can be determined?

Time (s)	$[H_2O_2]$ (M)
0	2.7
200.	2.1
400.	1.7
600.	1.4

(A) The reaction must be first order because there is only one reactant species.

(B) The reaction is first order if the plot of ln $[H_2O_2]$ versus time is a straight line.

(C) The reaction is first order if the plot of $1/[H_2O_2]$ versus time is a straight line.

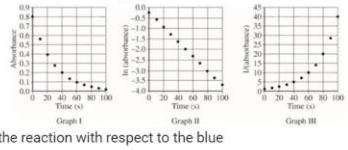
(D) The reaction is second order because 2 is the coefficient of H_2O_2 in the chemical equation.

5. Pause the video at 5:11 and attempt the problem, then evaluate how you did and identify any errors.

$Na_2C_{37}H_{34}N_2S_3O_9 + OCl^- \rightarrow products$

blue *colorless*

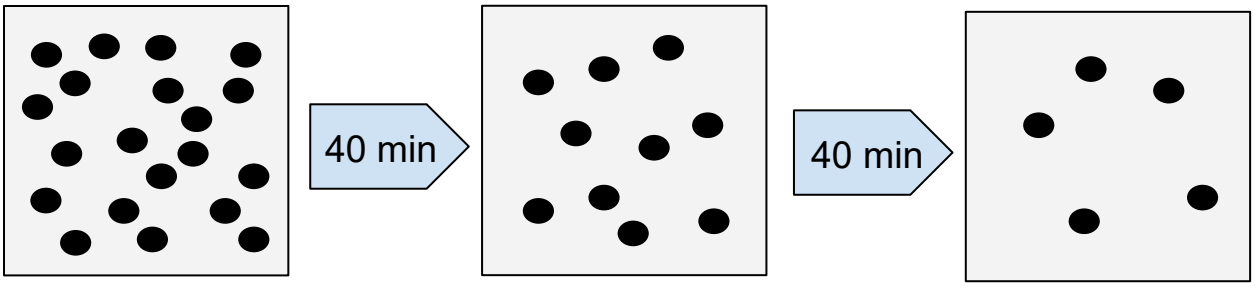
Blue food coloring can be oxidized by household bleach (which contains OCl−) to form colorless products, as represented by the equation above. A student used a spectrophotometer set at a wavelength of 635 nm to study the absorbance of the food coloring over time during the bleaching process. In the study, bleach is present in large excess so that the concentration of OCl− is essentially constant throughout the reaction. The student used data from the study to generate the graphs below.



a. Based on the graphs above, what is the order of the reaction with respect to the blue food coloring?

Video #2

1. Explain in your own words and using this picture what half-life is.



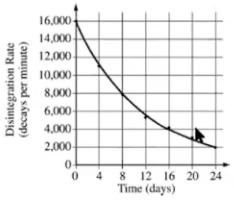
Note that for first order reactions, the concentration of the reactant is decreased by half at a constant rate. You might see this information in a data table or graph. The key is recognizing what is occurring and the rate. The value of $t_{1/2}$ (half-life) can be determined from the graph or data table.

2. Explain how to use this equation to calculate half-life. $t_{1/2} = \frac{0.693}{k}$

3. Pause the video at 1:20 and attempt the problem, then evaluate how you did and identify any errors.

The radioactivity of a sample of I-131 was measured. The data collected are plotted on the graph below.

c. Determine the half-life, $t_{1/2}$, of I-131 using the graph above.

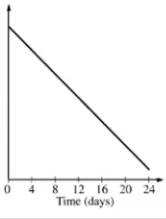


d. The data can be used to show that the decay of I-131 is a first-order reaction, as indicated on the graph below.

i. Label the vertical axis of the graph above.

ii. What are the units of the rate constant, *k*, for the decay reaction? .....

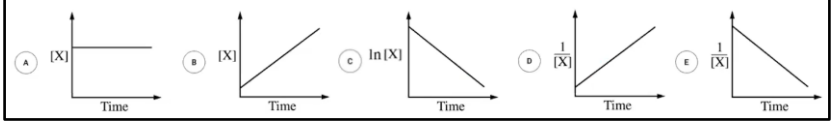
iii. Explain how the half-life of I-131 can be calculated using the slope of the line plotted on the graph.



4. Pause the video at 2:52 and attempt the problem, then evaluate how you did and identify any errors.

$X \rightarrow$ products

The rate constant (k) for the decay of the radioactive isotope X, according to the equation above, is 2.3×10^{-2} days^{-1}. The slope of which of the following graphs is correct for the decay and could be used to confirm the value of k?



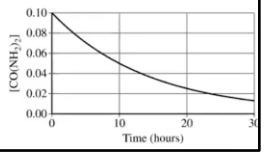
5. Pause the video at 3:34 and attempt the problem, then evaluate how you did and identify any errors.

The ammonium salt of isocyanic acid is a product of the decomposition of urea, $CO(NH_2)_2$, represented below.

$$CO(NH_2)_2(aq) \rightleftarrows NH_4^+(aq) + OCN^-(aq)$$

A student studying the decomposition reaction runs the reaction at 90°C. The student collects data on the concentration of urea as a function of time, as shown by the data table and the graph below.

Time (hours)	$[CO(NH_2)_2]$
0	0.1000
5	0.0707
10	0.0500
15	0.0354
20	0.0250
25	0.0177
30	0.0125



e. The student proposes that the rate law is $rate = k[CO(NH_2)_2]$.

i. Explain how the data support the student's proposed rate law.

ii. Using the proposed rate law and the student's results, determine the value of the rate constant, k. Include units with your answer.

TOPIC: 6.4 HEAT CAPACITY AND CALORIMETRY

LEARNING OBJECTIVE:	
6.4.A	Calculate the heat q absorbed or released by a system undergoing heating/ cooling based on the amount of the substance, the heat capacity, and the change in temperature.
ESSENTIAL KNOWLEDGE:	
6.4.A.1	The heating of a cool body by a warmer body is an important form of energy transfer between two systems. The amount of heat transferred between two bodies may be quantified by the heat transfer equation: EQN: q = mcΔT. Calorimetry experiments are used to measure the transfer of heat.
6.4.A.2	The first law of thermodynamics states that energy is conserved in chemical and physical processes.
6.4.A.3	The transfer of a given amount of thermal energy will not produce the same temperature change in equal masses of matter with differing specific heat capacities.
6.4.A.4	Heating a system increases the energy of the system, while cooling a system decreases the energy of the system.
6.4.A.5	The specific heat capacity of a substance and the molar heat capacity are both used in energy calculations.
6.4.A.6	Chemical systems change their energy through three main processes: heating/cooling, phase transitions, and chemical reactions.
6.4.A.7	In calorimetry experiments involving dissolution, temperature changes of the mixture within the calorimeter can be used to determine the direction of energy flow. If the temperature of the mixture increases, thermal energy is released by the dissolution process (exothermic). If the temperature of the mixture decreases, thermal energy is absorbed by the dissolution process (endothermic).
EQUATION(S):	
	$q = mc\Delta T$

NOTES:

Quantity of heat (q) is the transfer of thermal energy between two bodies that are at different temperatures, from an object at a higher temperature to one that is colder. There are three factors that contribute to the amount of heat (q) transferred; they are the mass of the object (m), the specific heat capacity (C) and the change in temperature (ΔT = Final Temperature – Initial Temperature).

SPECIFIC HEAT CAPACITY

Definition: Amount of energy needed to raise the temperature of one gram of a substance by one ° Celsius.
Each substance has its own specific heat capacity, water has a high specific heat capacity (4.18 J/g °C) while metals have lower specific heat capacities.
Label: C
Units: joules/gram °Celsius (or Kelvin)

HEAT:

Definition: A form of energy that flows between two samples of matter because of their differences in temperature.
Label: q
Units: Joules or calories

Useful conversions:

4.184 Joules = 1 calorie
1000 calories = 1 Calorie
1000 calories = 1 Kilocalorie
1000 Joules = 1 Kilojoule

You can calculate heat when there is a temperature change using the formula:

$$q = m\ C\ \Delta T$$

q = Heat m = mass C* = Specific Heat Capacity ΔT = Change in Temperature

*Some textbooks use "C" for specific heat capacity, some use "c" and others use "s".

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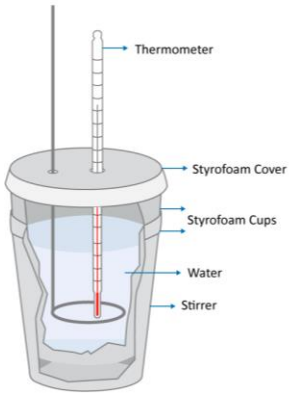
A calorimeter measures the amount of heat transferred during a reaction. A calorimeter is essentially a device that stops the transfer of heat between the inside of the calorimeter and the surroundings.



COFFEE CUP CALORIMETER EXAMPLE

Calorimetry is the measurement of the quantity of heat exchanged. For example, if the energy from an exothermic chemical reaction is absorbed in a container of water, the change in temperature of the water provides a measure of the amount of heat added. The **first law of thermodynamics** states that in an isolated system, heat cannot be lost or gained; it can only be transferred. Since a calorimeter is designed to be an isolated system, the heat lost by one substance is the heat gained by the other. A typical experiment can be used to find the specific heat of an unknown metal by heating the metal to a known temperature then placing the metal into a calorimeter containing water. The heat is transferred from the hot metal to the colder water until they reach thermal equilibrium. We can measure the heat gained by the water to find the heat lost by the metal.

$$-q_{(metal)} = q_{(water)}$$

Since we know that the formula to calculate heat when there is a temperature change is:

$$q = m\ C\ \Delta T$$

We can substitute to form:

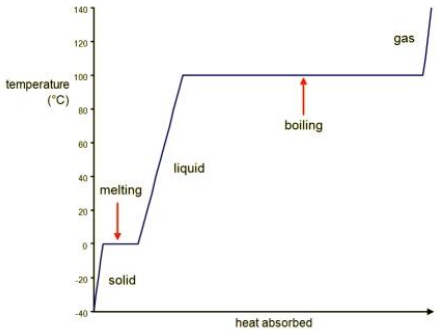
$$-m_{(metal)}\ C_{(metal)}\ \Delta T_{(metal)} = m_{(water)}\ C_{(water)}\ \Delta T_{(water)}$$

Each substance has its own specific heat capacity. Compare aluminum and lead, the specific heat of aluminum is 0.900 J/g °C while the specific heat of lead is 0.160 J/g °C. Adding 1000 J of energy to 100 grams of each substance results in different changes in temperature as shown below:

Aluminum	Lead
$q=mC\Delta T$ $\Delta T = q / mC$ $\Delta T = 1000\ J/((100\ g)(0.900\ J/g°C))$ $\Delta T = 11.1°C$	$q=mC\Delta T$ $\Delta T = q / mC$ $\Delta T = 1000\ J/((100\ g)(0.160\ J/g°C))$ $\Delta T = 62.5°C$

You can see that when the specific heat is higher, the change in temperature is lower and vice versa.

Heating a system results in the system having greater energy because energy is flowing into the system, while cooling a system results in the system having less energy as energy is leaving the system. You can see this on the heating curve for water (right).



Specific heat capacity is a measure of the amount of energy needed to raise **one gram** of a substance by one degree Celsius. Molar heat capacity (C_m) is the specific heat capacity converted into moles using the molar mass of that substance. It is a measure of the amount of energy needed to raise **one mole** of a substance by one degree Celsius. You may be provided with either so always check the units given in the problem.

Chemical systems change their energy through three main processes: heating/cooling, phase transitions, and chemical reactions. We have seen that we can use $q=mC\Delta T$ to calculate the heat when a temperature change occurs, in other words when there is a change in the kinetic energy of the particles. This is shown as the areas with a positive slope on the heating of water curve above.

In the next lesson, 6.5, you will look at how to calculate the heat when phase transition takes place. There is no change in temperature; the energy is used to change the position of the particles relative to one another, in other words the potential energy is changing. When a phase change occurs we need to use a different formula to calculate the heat.

Calorimeter: https://www.ddscalorimeters.com/wp-content/uploads/coffee-cup-calorimeter.png
Heating Curve: https://s3-us-west-2.amazonaws.com/courses-images/wp-content/uploads/sites/752/2016/09/26195026/ating-20curve-20of-20water.jpeg

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When solids dissolve into water, the process can be endothermic or exothermic.

A thermometer will be measuring the effect of the dissolution on the solvent.

For example:

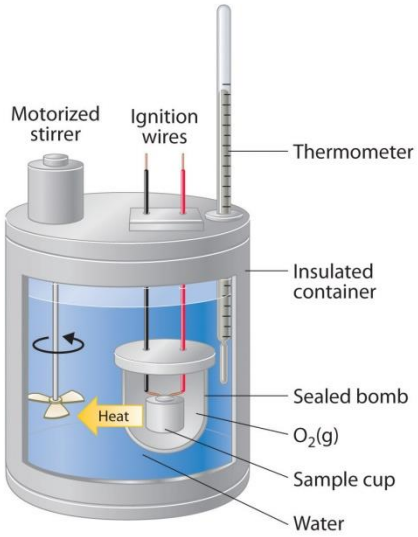
When sodium hydroxide, NaOH, dissolves in water, the process releases heat to the water. This is an exothermic process, and the temperature of the solution will increase, and the container will feel warmer.

When ammonium nitrate, NH_4NO_3, dissolves in water, the process absorbs heat from the water. This is an endothermic process, and the temperature of the solution will decrease, and the container will feel cooler.

I DO:

Almonds and cashews were burned in a bomb calorimeter containing water.
The following data was collected.

	Almonds	Cashews
Mass of Calorimeter Water	2000. mL	1000. mL
Specific Heat of Water	4.18 J/g°C	4.18 J/g°C
Initial Temperature of Water	22.5 °C	22.5 °C
Final Temperature of water	40.5 °C	51.3 °C
Mass of Nut burned	6.00 grams	5.00 grams



Calculate the heat gained by the water for each nut.

Almonds

q = (2000. gram)(4.18 J/g°C)(18.0 °C)

q=150. kJ

Cashews

q = (1000. gram)(4.18 J/g°C)(28.8 °C)

q=120. kJ

Calculate the energy for each nut, which provides more energy per gram?

Almonds

ΔH=q/m

150. kJ / 6.00 g = 25.0 kJ/gram

Cashews

ΔH=q/m

120. kJ / 5.00 g = 24.0 kJ/gram

Almonds provide more energy per gram.

https://chem.libretexts.org/@api/deki/files/58277/c3f2def4f1ad04996c40999978baa644.jpg?revision=1

WE DO:

50.0 mL of 0.500 M HCl was added to 50.0 mL of 0.500 M NaOH, the initial temperature of the solutions was 19.8 °C. The reaction below occurred:

$$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$$

The final temperature of the mixture was 26.3°C.
Calculate the heat gained by the mixture.

What is the heat of reaction per mole of NaOH?

SCAN ME

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YOU DO:

1) A 25.0 g sample of water was cooled from 23.9°C to 12.7°C, how much heat was released? (Assume that the specific heat of water is 4.18 J/g °C)

2) 75.0 grams of an unknown metal was heated to 95.0°C, it was then placed into 150.0 grams of water at 23.1°C, when the metal and water reached thermal equilibrium, the temperature was 27.8°C. Calculate the specific heat of the metal. (Assume that the specific heat of water is 4.18 J/g °C)

3) 15.0 grams of ice, liquid water and water vapor are all heated by 10.2 °C, which required the greatest amount energy?

State	Specific Heat
Solid	2.108 J/g °C
Liquid	4.182 J/g °C
Gas	1.996 J/g °C

4) In an insulated cup of negligible heat capacity, 100. g of water at 50.0 °C is mixed with 80.0 g of water at 10.0°C. What is the final temperature of the mixture?

5) A hot piece of copper was dropped into 155 mL of water at 23.6°C and 2.1 kJ of energy is transferred to the water. What is the final temperature of the water?

6) When 5.00 grams of ammonium chloride, NH_4Cl, is added to 100. mL of water the temperature drops by 4.2°C, how much would the temperature change if 10.0 grams is added to 1000 mL of water?

7) 2.71 grams of a fuel was burned releasing 4.10 kJ of energy into some amount of water. The water changed from 22.2 °C to 53.1 °C. How much water was heated?

8) A 125.0 gram sample of a metal, X, was heated to 400.0 °C and placed onto a 1.000 kg block of ice at 0.0°C. Some of the ice melted, but after the metal and ice reached thermal equilibrium the temperature of the metal, ice and liquid water remained at 0.0°C. If the specific heat of the metal was 0.245 J/g°C, calculate the heat lost by the metal?

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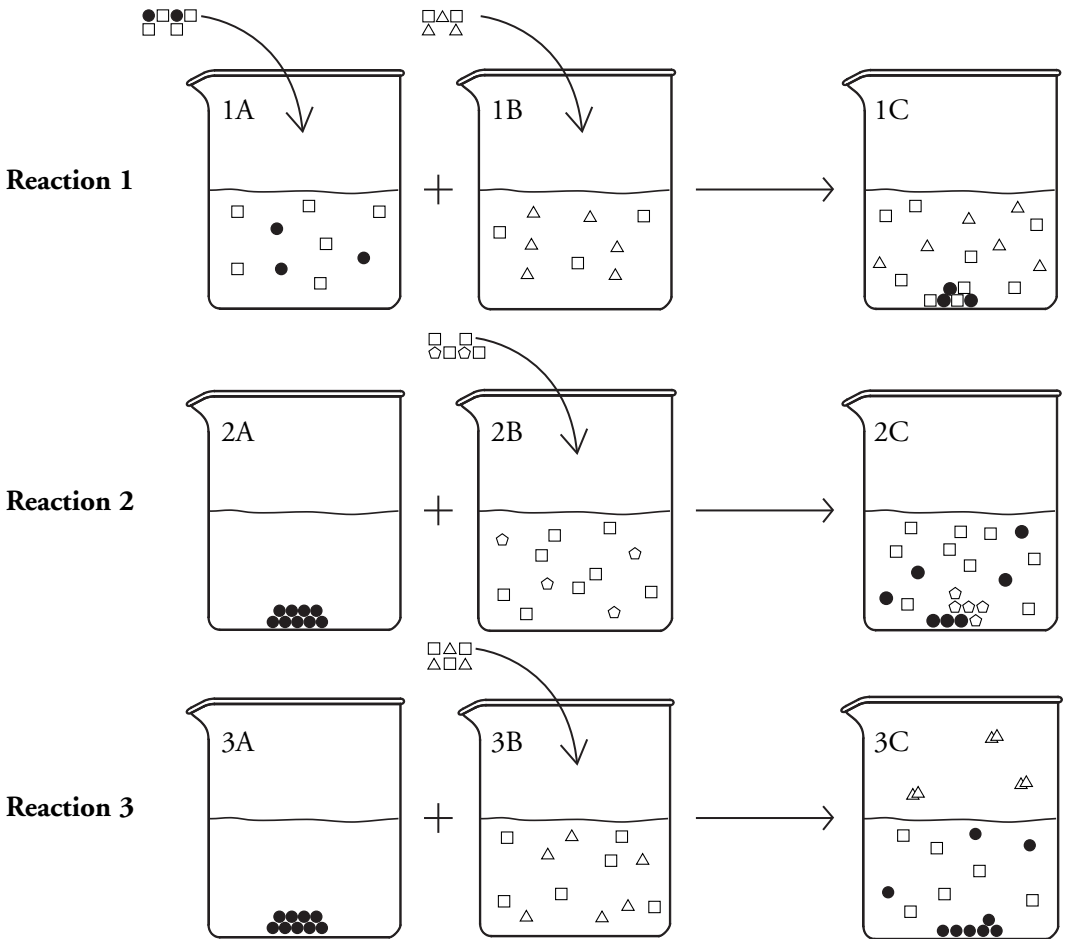
Net Ionic Equations

Do all reactant species participate in a reaction?

Why?

If you were to attend a sporting event on any random weekend you would find there are two types of people in attendance—players and spectators. Although both are important in their own right, they have different functions. This is also the case in chemical reactions. Although a species may be shown in a chemical reaction, it might only be a spectator. In other words it does not actually participate in the breaking and forming of chemical bonds that define the chemical reaction.

Model 1 – Three Reactions



1. Consider the three reactions in Model 1.

   a. Which beakers in the model contain solid, insoluble substances?

   b. What evidence is provided in the model to show that these substances are solids?

c. Which beakers in the model contain solutions of ionic substances?

d. What evidence is provided in the model to show that these substances are ionic compounds?

2. Which of the reactions in Model 1 produces a gas?

3. Three reactions are provided below. Indicate which reaction in Model 1 corresponds to each reaction below. Discuss with your group members the evidence you used from Model 1 to match the reactions, and be prepared to support your choices to the class. Do not assume the reactions are stoichiometric. That is, one reactant may be present in excess.

   $Zn\,(s) + 2HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$

   $Zn\,(s) + Cu(NO_3)_2\,(aq) \rightarrow Zn(NO_3)_2\,(aq) + Cu\,(s)$

   $Zn(NO_3)_2\,(aq) + Na_2CO_3\,(aq) \rightarrow ZnCO_3\,(s) + 2NaNO_3\,(aq)$

4. For each of the reactions in Model 1, write a complete sentence that describes the specific chemical change that occurred.





5. In each of the reactions in Model 1, there are ions present in the solutions that do not participate in the chemical reaction. In other words, they exist in the same form both before and after the reaction. These substances are called **spectator ions**. Identify the spectator ions for each reaction.

Model 2 – Writing a Reaction Three Ways

Molecular Equation	$Zn\,(s) + Cu(NO_3)_2\,(aq) \rightarrow Zn(NO_3)_2\,(aq) + Cu\,(s)$
Ionic Equation	$Zn\,(s) + Cu^{2+}\,(aq) + 2NO_3^{1-}\,(aq) \rightarrow Zn^{2+}\,(aq) + 2NO_3^{1-}\,(aq) + Cu\,(s)$
Net Ionic Equation	$Zn\,(s) + Cu^{2+}\,(aq) \rightarrow Zn^{2+}\,(aq) + Cu\,(s)$

6. Consider the equations in Model 2.

   a. Which equation represents the ionic substances as bonded together in the solution?

   b. Which equation represents the ionic substances as separate ions in solution?

   c. Which of the two equations from parts *a* and *b* is a better representation of how the species take part in the reaction?

7. Compare the **net ionic equation** in Model 2 to the other two equations.

   a. What chemical species is missing in the net ionic equation?

   b. Explain why it is valid to remove this species from the equation.



8. Work as a group to write a definition for a net ionic equation.



9. Write ionic and net ionic equations for the remaining reactions in Model 1.

   a. Molecular Equation $Zn\,(s) + 2HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2\,(g)$

   Ionic Equation

   Net Ionic Equation

   b. Molecular Equation $Zn(NO_3)_2\,(aq) + Na_2CO_3\,(aq) \rightarrow ZnCO_3\,(s) + 2NaNO_3\,(aq)$

   Ionic Equation

   Net Ionic Equation

Read This!

When writing an ionic or net ionic equation for a reaction you must consider what species will divide into ions in solution. For example, strong acids like hydrochloric acid or sulfuric acid will be represented as ions, but weak acids remain mostly in molecular form so these are not divided. Similarly, only soluble ionic substances are represented as separate ions in solution. If the substance is insoluble, it remains written in the molecular form.

10. Write a molecular, ionic and net ionic equation for the reaction between acetic acid and sodium hydroxide.

11. Write a molecular, ionic and net ionic equation for the reaction between solid magnesium carbonate and sulfuric acid.



Extension Questions

12. Choose either Question 10 or 11, and draw a picture representing the reaction at the atomic level.

13. Is the law of conservation of mass obeyed in net ionic reactions? Support your answer with evidence from this activity.

14. In molecular equations, all substances are written as neutral, but in net ionic equations several of the species have charges. Is charge conserved in a net ionic equation? Support your answer with evidence from this activity.

15. What are the advantages and disadvantages to using a net ionic equation to represent a chemical change rather than a molecular equation?