

**Part A****Questions 1 to 14****Blacken the letter that corresponds to your answer in the answer booklet.****1**

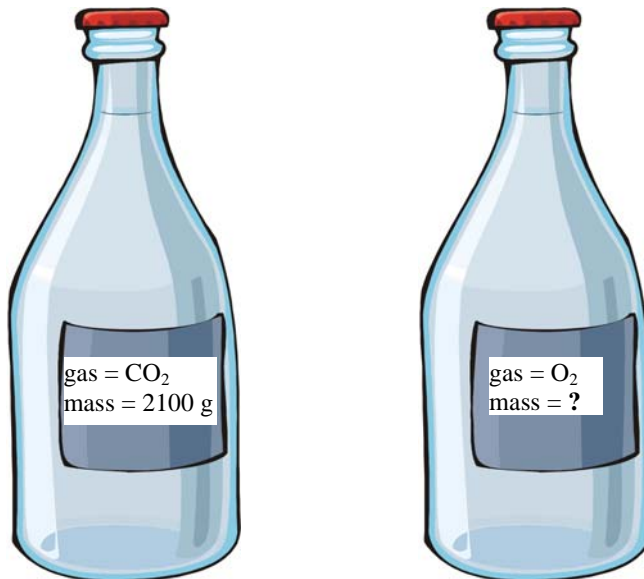
On a cold winter morning, the tires on a car appear flat.  
(Assume that no air has leaked out of the tires.)

**Which of the following statements explains this phenomenon?**

- A) As the outside temperature increases, the pressure inside de tire decreases.
- B) As the outside temperature decreases, the pressure inside de tire decreases.
- C) As the outside pressure decreases, the volume inside de tire increases.
- D) As the outside pressure increases, the volume inside de tire increases.

**2**

Two identical tanks contain different gases at the same temperature and pressure. One tank contains  $\text{CO}_{2(g)}$ , the other contains  $\text{O}_{2(g)}$ . The tank containing  $\text{CO}_{2(g)}$  has a label indicating the mass of its contents.



**What is the mass of  $\text{O}_{2(g)}$  indicated on the other label?**

- A)  $4.8 \times 10^1$  g
- B)  $7.6 \times 10^2$  g
- C)  $1.5 \times 10^3$  g
- D)  $2.1 \times 10^3$  g

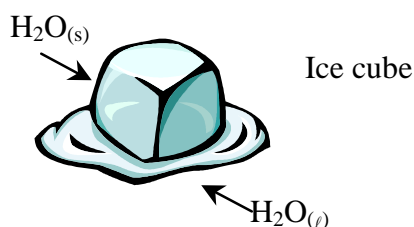
3 A 300-mL container holds 5.00 g of oxygen gas at a temperature of  $-25.0^{\circ}\text{C}$ .

What pressure is exerted by the oxygen gas?

- A)  $1.10 \times 10^0$  kPa  
B)  $1.29 \times 10^2$  kPa  
C)  $2.15 \times 10^2$  kPa  
D)  $1.07 \times 10^3$  kPa

4 Heat energy is always transferred from objects of higher temperature to objects of lower temperature.

With regard to molecular motion, which of the following statements best describes the differences in the two states of matter in the diagram?



- A)  $\text{H}_2\text{O}_{(s)}$  has vibrational and rotational motion, while  $\text{H}_2\text{O}_{(l)}$  has vibrational motion.  
B)  $\text{H}_2\text{O}_{(s)}$  has vibrational motion, while  $\text{H}_2\text{O}_{(l)}$  has vibrational and rotational motion.  
C)  $\text{H}_2\text{O}_{(s)}$  has rotational motion, while  $\text{H}_2\text{O}_{(l)}$  has vibrational motion.  
D)  $\text{H}_2\text{O}_{(s)}$  has translational motion, while  $\text{H}_2\text{O}_{(l)}$  has vibrational and translational motion.

5 Which of the following may be identified as an endothermic process?

1. The baking of bread
2. Formation of snow in the clouds
3. Sublimation of iodine crystals to purple gas
4. Dissolving sodium hydroxide in water
5. The breakdown of a water molecule by electrolysis to form hydrogen and oxygen gas

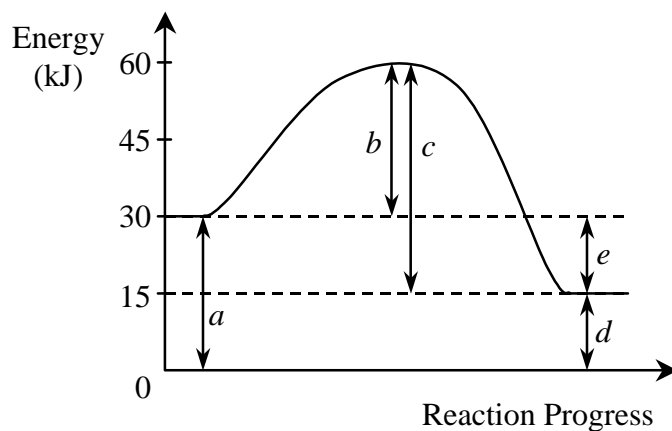
- A) 1, 2 and 4  
B) 1, 3 and 5  
C) 2, 3 and 5  
D) 2, 4 and 5

6 A student placed 3.50 g of  $\text{Mg}(\text{OH})_2$  in a bomb calorimeter containing 250.0 mL of water. When the substance was completely dissolved he noted a temperature increase of  $22.8^\circ\text{C}$ .

**What is the molar heat of solution?**

- A)  $1.40 \times 10^0$  kJ/mol                      C)  $3.98 \times 10^2$  kJ/mol  
B)  $2.39 \times 10^1$  kJ/mol                      D)  $1.43 \times 10^3$  kJ/mol

7 Below is a graph representing the enthalpy change of a thermochemical reaction as a function of reaction progress.



**In the graph, which letters refer to the following concepts?**

- I.  $\Delta H$  of the reaction  
II. Activation energy of the forward reaction  
III. Energy of the products

- A) I- e      II- b      III- d  
B) I- e      II- c      III- a  
C) I- c      II- a      III- d  
D) I- b      II- e      III- c

**8**

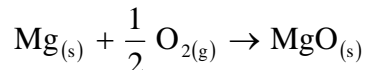
Scientists such as Helmholtz, Hess, Kelvin, and Nobel have contributed to expanding our knowledge of thermochemistry.

**Which of the concepts below is associated with Hess's contribution to the field of thermochemistry?**

- A) Nitroglycerine and dynamite
- B) The absolute temperature scale
- C) The heat of summation
- D) The law of conservation of mechanical energy

**9**

The combustion of magnesium, Mg, produces magnesium oxide, MgO, according to the following equation:



**Which of the following would produce the fastest reaction rate?**

1. The combustion of a magnesium ribbon
2. The combustion of magnesium powder
3. The combustion of magnesium in air
4. The combustion of magnesium in a pure oxygen environment

- A) 1 and 3
- B) 1 and 4
- C) 2 and 3
- D) 2 and 4

**10** During the science fair, Tammy wanted to simulate a volcanic eruption by mixing together baking soda,  $\text{NaHCO}_3$ , and vinegar,  $\text{HCH}_3\text{COO}$ .

**Which of the following combinations should she use in order to produce the slowest rate of reaction?**

- A) 0.5 M  $\text{HCH}_3\text{COO}$  and a 4.0 g block of  $\text{NaHCO}_3$
- B) 0.5 M  $\text{HCH}_3\text{COO}$  and 4.0 g of powdered  $\text{NaHCO}_3$
- C) 1.0 M  $\text{HCH}_3\text{COO}$  and a 4.0 g block of  $\text{NaHCO}_3$
- D) 1.0 M  $\text{HCH}_3\text{COO}$  and 4.0 g of powdered  $\text{NaHCO}_3$

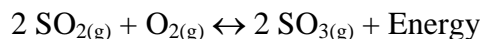
**11** Consider the following systems:

1. A can of soda pop fizzes after being opened.
2. An alcohol thermometer reads  $27^\circ\text{C}$ .
3. A cup of coffee cools on the top of a desk.
4. A stoppered test-tube contains distilled water.

**Which of the above are examples of a closed system?**

- A) 1 and 2
- B) 1 and 3
- C) 2 and 3
- D) 2 and 4

**12** Consider the following system at equilibrium:



**Which of the following changes would result in an increase of products?**

- A) Increase the pressure and decrease the temperature.
- B) Increase the pressure and increase the temperature.
- C) Decrease the pressure and increase the temperature.
- D) Decrease the pressure and decrease the temperature.

**13** Anthony wants to know which of five acids is the strongest. He refers to a table of Acid Dissociation Constants ( $K_a$ ).

After consulting the table below, which acid did he decide was the strongest?

Name	Formula	$K_a$
Arsenic acid	$H_3AsO_4$	$5.0 \times 10^{-3}$
Carbonic acid	$H_2CO_3$	$4.3 \times 10^{-7}$
Oxalic acid	$H_2C_2O_4$	$6.5 \times 10^{-2}$
Phosphoric acid	$H_3PO_4$	$7.5 \times 10^{-3}$
Sulfurous acid	$H_2SO_3$	$1.5 \times 10^{-2}$

- A) Arsenic acid                      C) Oxalic acid  
B) Carbonic acid                    D) Sulfurous acid

**14** Four strips of different metals are placed in solutions containing different metallic ions. The results are recorded in the table below. An X indicates that a reaction has occurred.

	$Pd_{(aq)}^{2+}$	$Pt_{(aq)}^{2+}$	$Ir_{(aq)}^{3+}$	$Au_{(aq)}^{+}$
$Pd_{(s)}$		X	X	X
$Pt_{(s)}$				X
$Ir_{(s)}$		X		X
$Au_{(s)}$				

Which of the following combinations correctly arranges these metals in decreasing order of oxidation?

- A) Pd, Ir, Pt, Au                      C) Au, Pt, Ir, Pd  
B) Pd, Au, Pt, Ir                    D) Ir, Pt, Au, Pd

Parts B, C, D and E of the examination comprise questions for which you must show all your work. Answer these questions in the answer booklet. Show all the work needed to solve the problem: **data given, explanations, formulas and calculations**. Then write your answer in the space provided. You will be given no marks if you provide the right answer without showing your work. However, you will be given part marks for work that is partially correct. Where necessary, **the correct unit of measurement must be included in the answer**; however, significant figures will not be considered.

**Part B** Questions 15, 16, 17 and 18 (Answer three questions only.)

If you answer all questions in this section, **draw a line through the question that you do not want to have corrected**. If you do not, questions 15, 16 and 17 will be corrected.

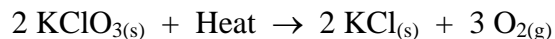
- 15** A student performs an experiment to find the relationship between the volume of a gas and its pressure.

He places books on a syringe plunger and measures the volume of air in the syringe as a function of pressure. He obtains the following data:

Pressure (in number of books)	Volume (mL)
1	90.0
2	45.0
3	30.0
4	22.5

**What will be the volume when 12 books are placed on the syringe?**

- 16** In a laboratory experiment, a student decomposed 1.27 g of potassium chlorate,  $\text{KClO}_3$ , producing potassium chloride,  $\text{KCl}$ , and oxygen gas,  $\text{O}_2$ . The decomposition reaction can be summarized as follows:



A volume of 468 mL of the gas was collected at a pressure of 94.7 kPa and a temperature of 20.0°C.

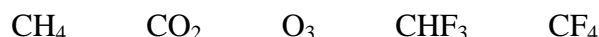
**Can the gas be considered an ideal gas?**

**17** Greenhouse gases are a natural part of the atmosphere. They trap the sun's warmth, and maintain the earth's surface temperature at a level necessary to support life. The problem we now face is that human activity - particularly the burning of fossil fuels (coal, oil and natural gas), the use of refrigerants, farming, industrial processes and land clearing - are increasing the concentrations of these gases, creating the prospect of global climate change. This is called the enhanced greenhouse effect.

A sample of gas that was collected at an industrial site must be identified. The data below was recorded:

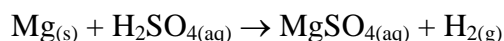
Volume of evacuated flask	334 mL
Mass of evacuated flask	51.02 g
Mass of flask and unknown gas	51.96 g
Pressure	98.0 kPa
Temperature	20.0°C

**Which of the following greenhouse gases is most likely the unknown gas?**



Show all your calculations and justify your choice.

**18** In an experiment, a student places magnesium metal in aqueous sulfuric acid, H<sub>2</sub>SO<sub>4</sub>, according to the following equation:



The student must produce 174.1 mL of hydrogen gas by reacting magnesium with an excess of H<sub>2</sub>SO<sub>4(aq)</sub>, at a temperature of 30.0°C and a pressure of 100 kPa.

**What mass of magnesium is needed?**



**Part C** Questions 19, 20, 21 and 22 (Answer three questions only.)

If you answer all questions in this section, **draw a line through the question that you do not want to have corrected.** If you do not, questions 19, 20 and 21 will be corrected.

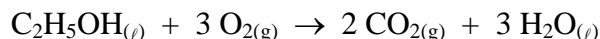
- 19** After completing an experiment, a researcher was left with an excess of 225 mL of a 1.00 M HNO<sub>3</sub> solution. In order to safely dispose of this solution, she mixed it with 375 mL of a 1.00 M LiOH solution. The temperature of the new solution increased by 30.0°C.

**What is the molar heat,  $\Delta H$ , of neutralization of the nitric acid, HNO<sub>3</sub>?**

(Assume that the specific heat capacity and density of the solution are the same as that of water.)

- 20** With so much instability in the current world oil market, many are seeking out alternative fuels to power cars. Ethanol is a possible alternative fuel.

The combustion of ethanol is the following equation:



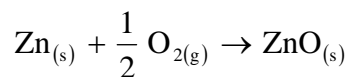
The combustion of octane (C<sub>8</sub>H<sub>18</sub>) provides 5509 kJ/mol of energy.

**How many grams of ethanol would be required to produce the same amount of energy as 1 mole of octane?**

	<b>Equations</b>	<b><math>\Delta H_f</math> (kJ/mol)</b>
1	$\text{C}_{(\text{s})} + \text{O}_{2(\text{g})} \rightarrow \text{CO}_{2(\text{g})}$	-394
2	$\text{H}_{2(\text{g})} + \frac{1}{2} \text{O}_{2(\text{g})} \rightarrow \text{H}_2\text{O}_{(\ell)}$	-285
3	$2 \text{C}_{(\text{s})} + 3 \text{H}_{2(\text{g})} + \frac{1}{2} \text{O}_{2(\text{g})} \rightarrow \text{C}_2\text{H}_5\text{OH}_{(\ell)}$	-278
4	$\text{H}_{2(\text{g})} + \frac{1}{2} \text{O}_{2(\text{g})} \rightarrow \text{H}_2\text{O}_{(\text{g})}$	-242

**21** Because zinc oxide can absorb U.V. light, it can be used in ointments, creams, and lotions to protect against sunburn.

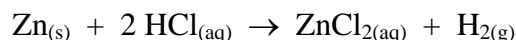
You need to find the molar heat of formation for zinc oxide according to the following equation:



Given that this is difficult to do in a lab, you perform a series of experiments to find the molar heat of formation indirectly.

**First Experiment:**

The reaction of 0.200 g of granular zinc with 50.0 mL of 1 mol/L of HCl according to the following equation:

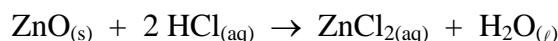


**Results:**

Zinc	HCl	Initial temperature	Final temperature
0.200 g	50.0 mL	20.0°C	22.7°C

**Second Experiment:**

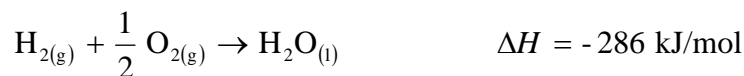
The reaction of 0.390 g of zinc oxide with 50.0 mL of 1 mol/L HCl according to the following equation:



**Results:**

Zinc oxide	HCl	Initial temperature	Final temperature
0.390 g	50.0 mL	19.0°C	21.1°C

Consulting your chemistry text, you find that the molar heat of formation for water is:



**Based on the results obtained, what is the molar heat of formation for zinc oxide?**  
(Assume the density and specific heat for all solutions to be equal to that of water.)

22

An 80.5-g piece of brass is heated to a temperature of  $95.7^{\circ}\text{C}$  in a hot water bath. The brass is transferred to a calorimeter containing 105 g of water at a temperature  $15.6^{\circ}\text{C}$ .

The final temperature of the water bath is  $23.8^{\circ}\text{C}$ .

**What is the specific heat capacity of the piece of brass?**

**Part D** Questions 23, 24 and 25 (Answer two questions only.)

If you answer all questions in this section, **draw a line through the question that you do not want to have corrected.** If you do not, questions 23 and 24 will be corrected.

- 23** The rate of a chemical reaction is influenced by many factors. Two of these factors are the nature of the reactants and the state of the reactants.

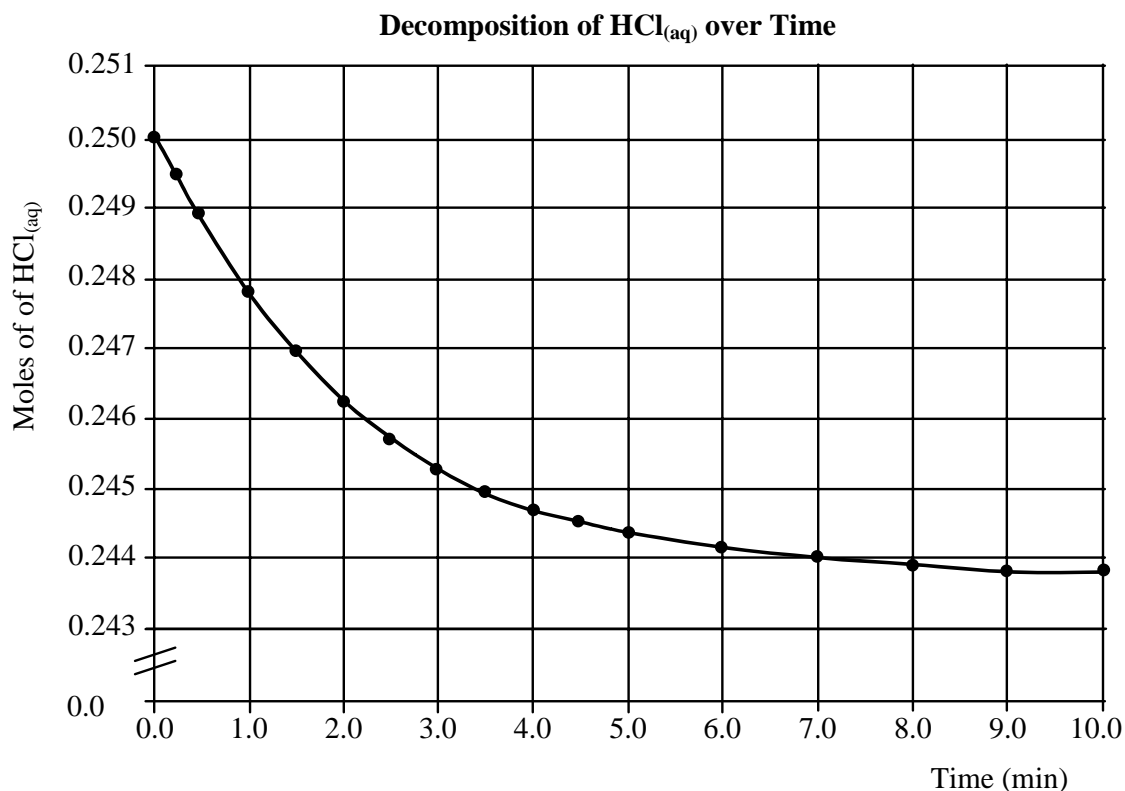
Below are two groups of reactants. For each group, choose the fastest reacting substance and justify your answer.

Group A	Group B
CH <sub>4(g)</sub>	CH <sub>3OH(g)</sub>
C <sub>2</sub> H <sub>6(g)</sub>	CH <sub>3OH(l)</sub>
C <sub>3</sub> H <sub>8(g)</sub>	CH <sub>3OH(s)</sub>

- 24** Stomach acid acts upon CaCO<sub>3</sub> in antacid tablets according to the following equation:

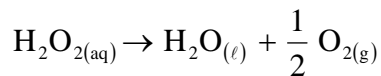


The following graph reveals the decomposition of HCl<sub>(aq)</sub> as a function of time.



**What is the average rate of formation of CO<sub>2</sub> gas in the first seven minutes of this reaction?**

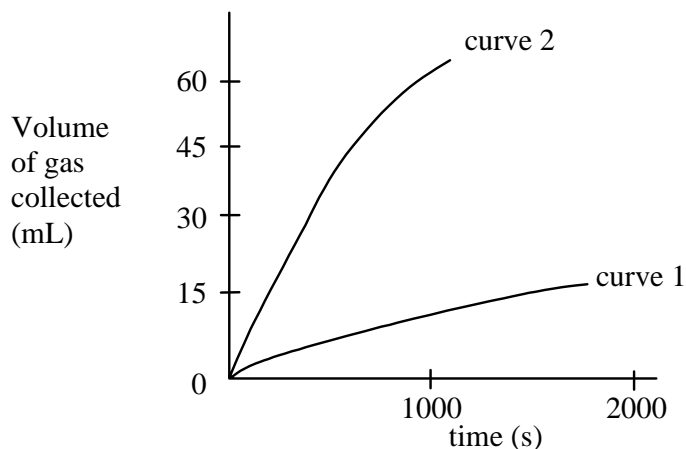
Hydrogen peroxide,  $\text{H}_2\text{O}_{2(\text{aq})}$  decomposes to produce water,  $\text{H}_2\text{O}_{(\ell)}$ , and oxygen,  $\text{O}_{2(\text{g})}$  according to the following equation.



Scientists often use a potassium iodide catalyst to control the rate of the reaction.

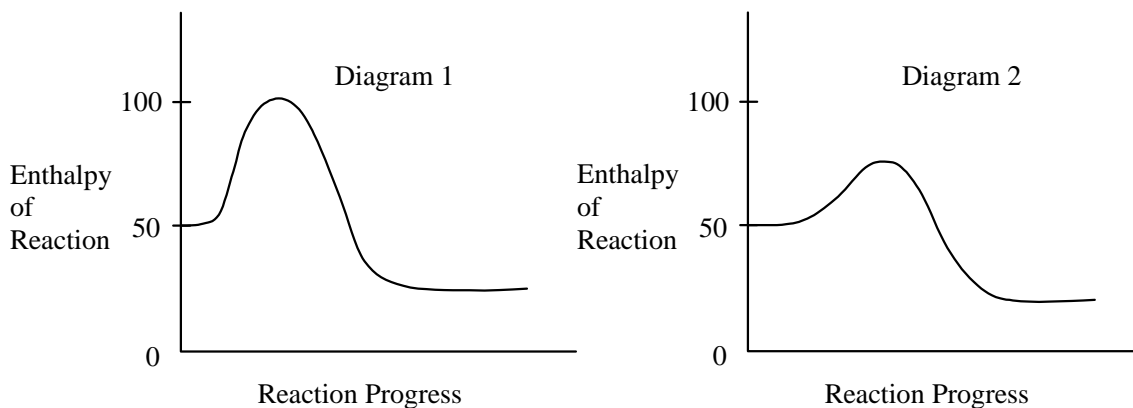
Question A

**On the graph below, which curve represents the reaction without a catalyst? Justify your answer.**



Question B

**Which enthalpy diagram represents the reaction with a catalyst? Justify your answer.**

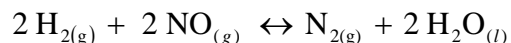


**Part E** Questions 26, 27, 28 and 29 (Answer three questions only.)

If you answer all questions in this section, **draw a line through the question that you do not want to have corrected.** If you do not, questions 26, 27 and 28 will be corrected.

**26** The pollutant nitrogen monoxide,  $\text{NO}_{(g)}$ , can be partially eliminated by reacting it with hydrogen gas,  $\text{H}_2$ .

The equilibrium equation for the reaction is:

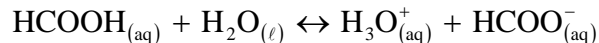


A technician initially mixes 4.0 moles of  $\text{H}_2$  gas with 4.0 moles of  $\text{NO}$  gas in a 2.0-L flask.

At equilibrium he measures 0.8 moles of  $\text{N}_2$  gas.

**What is the equilibrium constant,  $K_c$ , for this reaction?**

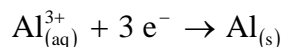
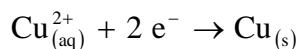
**27** A 0.1 mol/L solution of formic acid,  $\text{HCOOH}$ , ionizes in water according to the following equation:



The acid dissociation constant,  $K_a$ , of formic acid is  $1.77 \times 10^{-4}$ .

**What is the pH of the formic acid solution?**

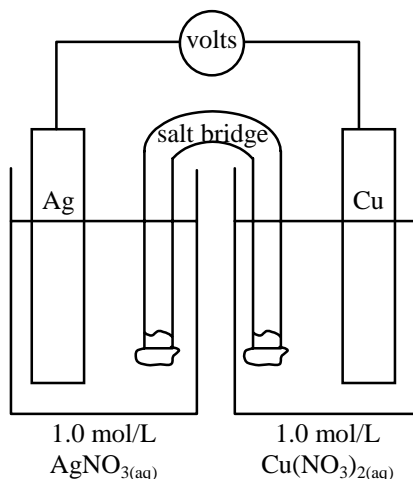
**28** A voltaic cell is constructed using electrodes with the following half-reactions:



- A) Which electrode is oxidized?  
 B) What is the overall cell reaction?  
 C) What is the standard (net) cell potential of the voltaic cell? (Include units)  
 D) Which half-cell reaction occurs as a reduction?

**29** A copper,  $\text{Cu}_{(\text{s})}$ , rod is placed into a beaker of 1.0 mol/L of copper (II) nitrate,  $\text{Cu}(\text{NO}_3)_2(\text{aq})$ , and a silver,  $\text{Ag}_{(\text{s})}$ , rod is placed into a beaker of 1.0 mol/L silver nitrate,  $\text{AgNO}_3(\text{aq})$ .

An electrochemical cell is then constructed, as illustrated below.



- A) What is the overall cell reaction?  
 B) What is the standard (net) cell voltage? (Include units)  
 C) Based on Le Chatelier's Principle, explain what can be done to increase the standard (net) cell voltage.  
 D) Based on Le Chatelier's Principle, explain what would happen to the standard (net) cell voltage if a solution of sodium chloride,  $\text{NaCl}$ , (forms a precipitate with  $\text{AgNO}_3(\text{aq})$ ) were added to the system.

