1 **Which group correctly pairs three of the gases with their uses or hazards?**

A) Nitrogen gas - explosion
Chlorofluorocarbons - refrigeration
Carbon Dioxide - plant respiration

B) Chlorofluorocarbons - ozone depletion
Hydrogen gas - fuel
Carbon Dioxide - global warming

C) Sulphur Dioxide - acid rain
Carbon monoxide - poisoning
Methane Gas - refrigeration

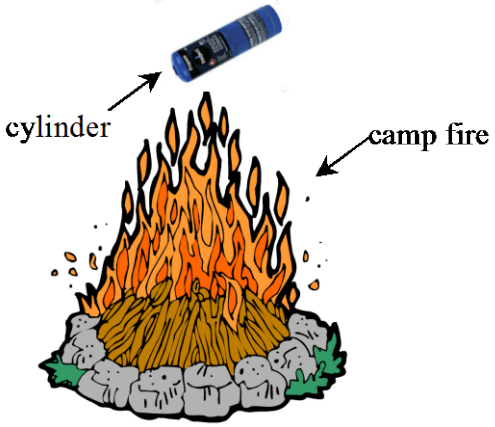
D) Neon Gas - lights
Propane gas - fuel
Nitrogen gas - global warming

2 A company sells gas in steel cylinders. All of the cylinders have the same volume but not the same mass. The mass of each evacuated cylinder is stamped on it. A worker takes the first cylinder, which is stamped 524.3 g and fills it with ammonia gas, NH_3, until its mass is 537.2 g. The worker then takes a second cylinder, stamped 487.6 g, and fills it with fluorine gas, F_2. The contents of both cylinders must be at the same temperature and pressure.

What is the total mass of the second cylinder after it has been filled?

A) 500.5 g
B) 502.0 g
C) 516.4 g
D) 553.1 g

3 A used propane cylinder, containing only air, is accidentally thrown onto a camp bonfire. The initial conditions inside the cylinder are 25°C and 101.3 kPa. The cylinder can withstand an internal pressure of 341 kPa.



Above what temperature will an explosion occur?

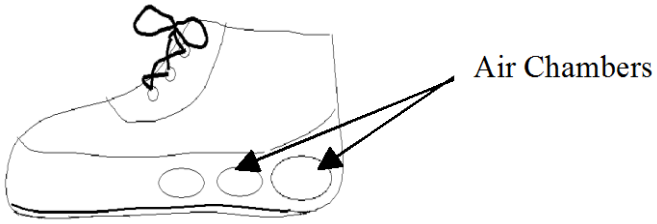
A) 8.42×10^{1} °C

B) 7.30×10^{2} °C

C) 1.00×10^{3} °C

D) 1.28×10^{3} °C

4 To help reduce the stress on the skeletal system, many brands of athletic footwear integrate air chambers into the soles of their shoes. During the hot temperatures of summer, some long distance runners notice that these air chambers enlarge.



Using the kinetic molecular theory of gases, which of the following statements explain why this phenomenon is observed?

A) As the temperature increases, gas molecules increase their volume due to thermal expansion.

B) As the temperature increases, the volume of the gas increases as the pressure inside the air chamber decreases.

C) As the temperature increases, an increase in the collisions between the gas molecules generates heat, causing an increase in the volume of the chambers.

D) As the temperature increases, the gas molecules move faster, resulting in more and stronger collisions that push out the sides of the air chambers into a larger volume.

5 **Which of the following reactions has a reverse reaction that is endothermic?**

A) $2\ H_{2(g)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)} + 572\ kJ$

B) $2\ C_{(s)} + 2\ H_{2(g)} + 52.3\ kJ \rightarrow C_2H_{4(g)}$

C) The decomposition of aluminum chloride absorbs 1408 kJ of energy.

D) $\frac{1}{2}\ H_{2(g)} + \frac{1}{2}\ I_{2(s)} \rightarrow HI_{(g)} \quad \Delta H = +26\ kJ/mol$

6 You have set up a lemonade stand on your street. After a few hours, a customer complained that his lemonade was too warm. You took the temperature of the remaining 250 mL and agreed that lemonade at 24.0°C was indeed unpleasant to drink. Instead of throwing the lemonade out, you simply added 2.0 L of fresh lemonade from the fridge at 4.0°C.

What was the final temperature of the lemonade?
(Assume the density and specific heat capacity of lemonade are the same as water.)

A) 6.2°C

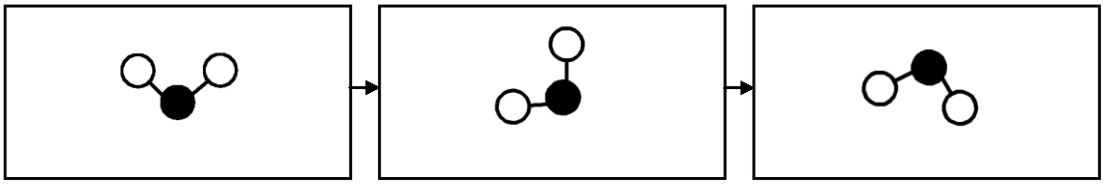
B) 7.0°C

C) 9.3°C

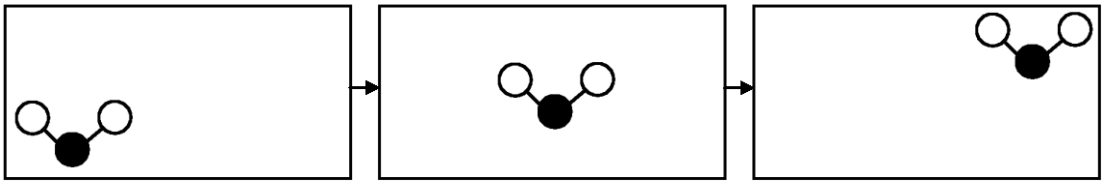
D) 14°C

7 The following diagrams demonstrate various behaviours that a water molecule can exhibit.

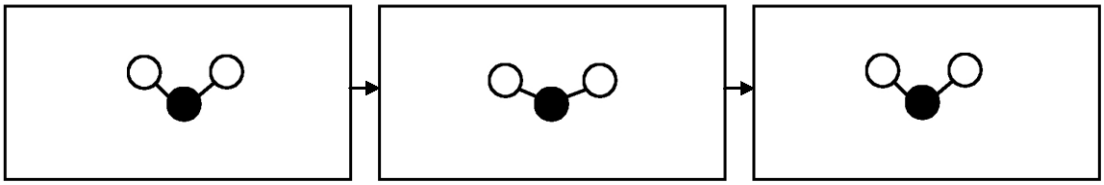
I



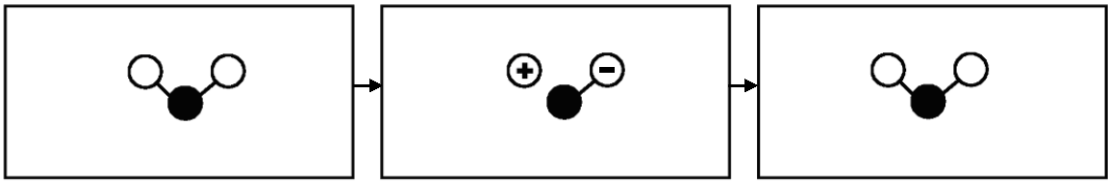
II



III



IV



According to the Kinetic Molecular Theory, which diagrams represent the types of kinetic energy that are predominantly displayed by water molecules in the liquid state?

A) I and II only

B) I and III only

C) II and IV only

D) III and IV only

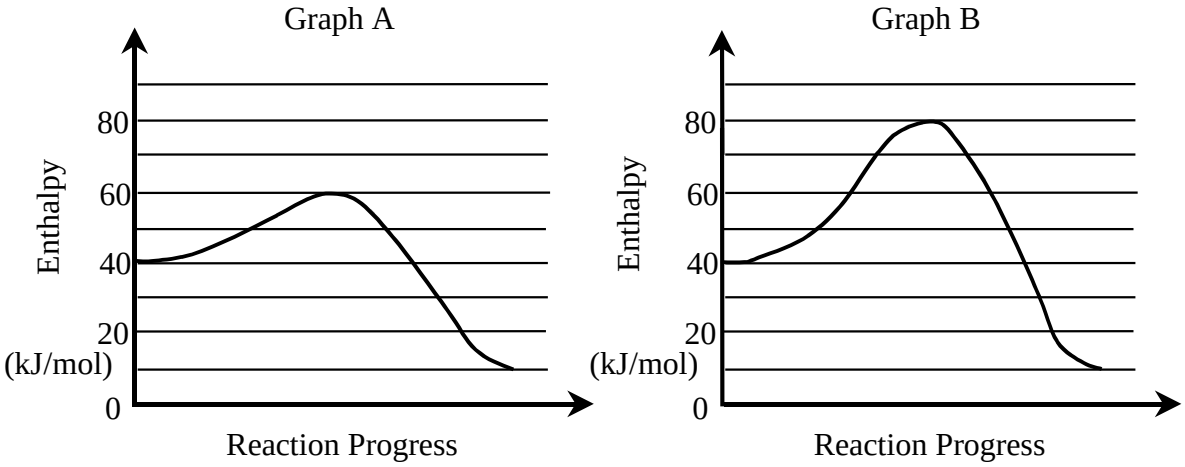
8 Four processes are shown below.

1. Sunlight + 6 $CO_{2(g)}$ + 6 $H_2O_{(l)}$ → $C_6H_{12}O_{6(aq)}$ + 6 $O_{2(g)}$
2. $NaOH_{(s)}$ → $Na^+_{(aq)}$ + $OH^-_{(aq)}$
3. $CH_{4(g)}$ + 2 $O_{2(g)}$ → $CO_{2(g)}$ + 2 $H_2O_{(g)}$
4. $H_2O_{(l)}$ → $H_2O_{(g)}$

Which of these processes are endothermic?

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

9 The following graphs show the enthalpy vs. reaction progress for the same reaction.



Which of the following statements is true?

A) Graph A represents the uncatalyzed reaction and the ΔH is 20 kJ/mol.
B) Graph A represents the uncatalyzed reaction and the ΔH is -30 kJ/mol.
C) Graph B represents the uncatalyzed reaction and the ΔH is 40 kJ/mol.
D) Graph B represents the uncatalyzed reaction and the ΔH is -30 kJ/mol.

10 There are three general categories of forest fires: ground fires, surface fires, and crown fires.

- Ground fires spread across the grass, low-lying vegetation, and through roots. They are fought by digging trenches in the path of the fire.
- Surface fires burn the trunks of trees as well as grass and low-lying vegetation. They are fought by spraying the area with water.
- Crown fires spread across the tops of trees. They are fought by using thick fire retardant foam, usually sprayed from planes.

Which of the following statements is true?

A) Fighting ground fires by digging trenches is effective because it reduces the amount of fuel available to the combustion reaction.

B) Fighting ground fires by digging trenches is effective because it reduces the amount of oxygen available to the combustion reaction.

C) Fighting surface fires by spraying with water is effective because it reduces the amount of oxygen available for the combustion reaction.

D) Fighting crown fires using foam is effective because it reduces the amount of heat available to the combustion reaction.

11 A student wrote the equilibrium constant expressions, K_c, for each of the four reactions below, but only one is correct.

For which equation did the student write the correct K_c expression?

A) $2\ C_2H_{2(g)} + 5\ O_{2(g)} \leftrightarrow 4\ CO_{2(g)} + 2\ H_2O_{(l)}$ $K_c = \dfrac{[CO_2]^4\,[H_2O]^2}{[C_2H_2]^2\,[O_2]^5}$

B) $N_{2(g)} + 2\ O_{2(g)} \leftrightarrow 2\ NO_{2(g)}$ $K_c = \dfrac{[NO_2]}{[N_2][O_2]}$

C) $4\ HCl_{(aq)} + O_{2(g)} \leftrightarrow 2\ H_2O_{(l)} + 2\ Cl_{2(g)}$ $K_c = \dfrac{[HCl]^4\,[O_2]}{[Cl_2]^2}$

D) $2\ KClO_{3(s)} \leftrightarrow 2\ KCl_{(s)} + 3\ O_{2(g)}$ $K_c = [O_2]^3$

12 The ionization equation for water can be written as:

$$H_2O_{(l)} \leftrightarrow H^+_{(aq)} + OH^-_{(aq)}$$

The value for K_w at 25°C is 1.00×10^{-14}. This reaction is endothermic. The temperature is increased to 70°C.

Using Le Chatelier's principle, which of the following could be the pH value of water at 70°C?

A) 6.4 C) 7.5

B) 7.0 D) 14

13 The acidity constants (K_a values) for two different reactions are given below.

I) $H_3PO_{4(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + H_2PO_4^-{}_{(aq)}$ $K_a = 7.1 \times 10^{-3}$

II) $H_2CO_{3(aq)} + H_2O_{(l)} \leftrightarrow H_3O^+_{(aq)} + HCO_3^-{}_{(aq)}$ $K_a = 4.4 \times 10^{-7}$

Which of the following statements is true?

A) $H_2PO_4^-$ is a stronger acid than $H_3PO_{4(aq)}$.

B) H_3PO_4 is a stronger acid than $H_2CO_{3(aq)}$.

C) In reaction II, equilibrium favours the formation of HCO_3^- ions.

D) If additional water is added to the H_2CO_3 solution, the K_a will decrease.

14 A lab technician had an unidentified solution. He poured small amounts of it into three different containers (aluminum, iron, and copper) to determine the most appropriate storage vessel. He observed reactions in the aluminum and iron containers but not in the copper container.

What could the unidentified solution have been?

A) Silver nitrate C) Lead nitrate

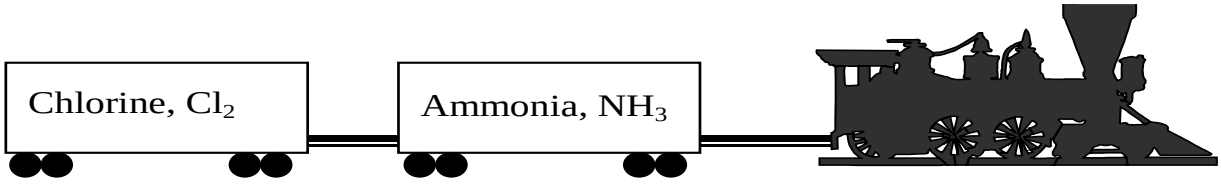
B) Magnesium nitrate D) Aluminum nitrate

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 train is carrying two large tanks of industrial chemicals. During a derailment, the tanks are damaged and two different poisonous gases are released into the atmosphere. Chlorine gas is yellow-green in colour and smells like a mixture of pineapple and pepper. Ammonia gas is colourless and is easily identified by many people because it is commonly used in household cleaners.



Which gas will the students at the nearby high school smell first?

Justify your answer, showing appropriate calculations.

16 A tire store fills its tires with nitrogen gas, N_2. At two o'clock when the temperature is 23°C, the store fills a tire to 315 kPa of pressure and finds that it requires 84.0 g of nitrogen gas. Unfortunately, the tire valve is leaking. At eight o'clock, when the temperature is 15°C, a worker checks the pressure and finds that it has decreased to 235 kPa.

What mass of nitrogen remained in the tire?
(Assume that the capacity of the tire did not change.)

17 A student wants to determine the value of the universal gas constant, R, by studying the following chemical reaction:

$$2\ NaClO_{3(s)} \rightarrow 2\ NaCl_{(s)} + 3\ O_{2(g)}$$

She measures 3.42 g of solid sodium chlorate, $NaClO_3$, into an Erlenmeyer flask and inserts a one-hole rubber stopper fitted with a glass tube. She seals the glass tube with an empty plastic bag. She then slowly heats the Erlenmeyer flask and the plastic bag inflates. When no more gas is being produced, she removes the bag and finds that the volume of gas produced is 1240 mL. The temperature of the gas is 74°C and the pressure is 102.5 kPa.

Calculate the experimental value of the universal gas constant using this data.

18 Ammonia gas, NH_3, is reacted with sulfuric acid, H_2SO_4, to form the important fertilizer ammonium sulphate, $(NH_4)_2SO_4$.

$$2\ NH_{3(g)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(s)}$$

What mass of ammonium sulfate can be produced from 85.0 kL of ammonia gas at STP?

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 During two experiments, students determine the heats of reaction for the following thermochemical equations:

$$NaOH_{(s)} \rightarrow NaOH_{(aq)} \square\square + 44.2\ kJ$$
$$NaOH_{(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)} + 100.1\ kJ$$

In a third experiment, 150.0 mL of aqueous sodium hydroxide, $NaOH_{(aq)}$, is mixed with 150.0 mL of hydrochloric acid, $HCl_{(aq)}$ and the temperature of the solution rises from 25.0°C to 38.0°C.

This reaction is represented by the following equation:

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

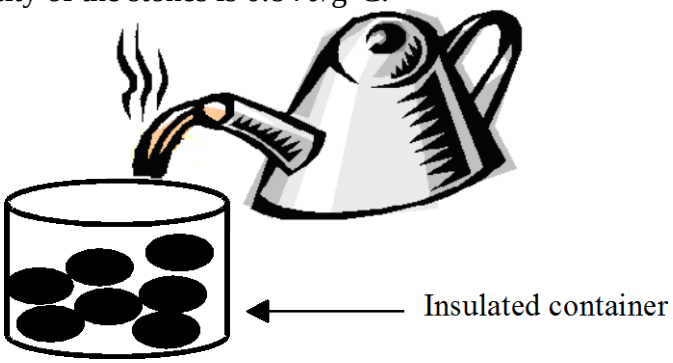
How many moles of NaOH reacted in the third experiment?
(Assume $NaOH_{(aq)}$ and $HCl_{(aq)}$ have the same specific heat capacity and density as water.)

20 Salicylic acid ($C_7H_6O_3$) is a key ingredient in many skin-care products for the treatment of acne, psoriasis, calluses, and corns. Salicylic acid is also used as an active ingredient in gels that remove warts. To make the gel, chemists must first dissolve tablets containing salicylic acid in water. The heat of solution (ΔH) of salicylic acid is -3.02 kJ/mol.

One tablet containing 3.84 g of salicylic acid is placed in 0.100 L of water.

What is the change in the temperature (ΔT) of the water?

21 During a hot stone massage, smooth pieces of black volcanic rock that absorb and retain heat well are used to relax and prepare muscles for deep tissue treatments. The stones, stored at a room temperature of 21.0°C, must be sanitized and brought to the ideal temperature of 63.0°C by pouring boiling water at 100.0°C over them. Each treatment requires 3.0 kg of stones. The specific heat capacity of the stones is 0.84 J/g°C.



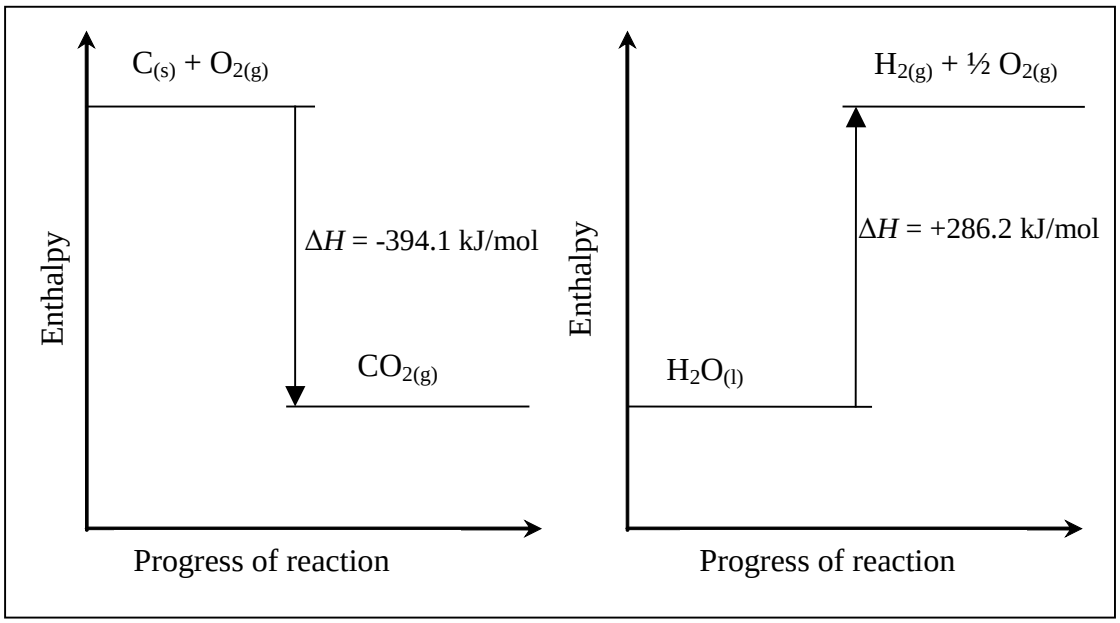
What volume of boiling water must be prepared?
(Assume complete heat transfer between the water and the stones.)

22 Glucose, $C_6H_{12}O_6$, is the fundamental energy source for humans.

$$C_6H_{12}O_{6(s)} + 6O_{2(g)} \rightarrow 6\,CO_{2(g)} + 6\,H_2O_{(l)}$$

Determine the amount of heat produced by the combustion of 90.0 g of glucose using the information below.

$$6\,C_{(s)} + 6\,H_{2(g)} + 3\,O_{2(g)} \rightarrow C_6H_{12}O_{6(s)} \qquad \Delta H = -1274.5\ \text{kJ/mol}$$



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 following reaction takes place very slowly under room temperature conditions.

$$4\ HCl_{(aq)} + O_{2(g)} \rightarrow 2\ H_2O_{(l)} + 2\ Cl_{2(g)}$$

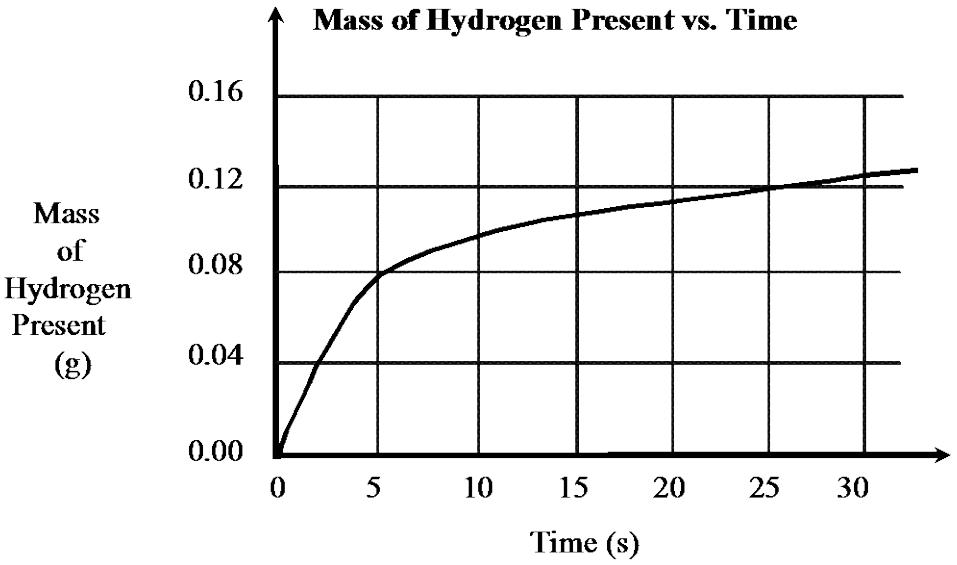
State four modifications that would increase the rate of this reaction.

For each modification, use the collision theory to explain why the modification would increase the rate.

24 A scientist is studying the rate of the following reaction:

$$2\ Ag_{(s)} + 2\ HNO_{3(aq)} \rightarrow H_{2(g)} + 2\ AgNO_{3(aq)}$$

He produces the following graph for this reaction.



Based on this graph, what is the average rate of consumption (g/s) of silver, Ag, between 5 s and 25 s?

Express your answer in grams per second.

25 A student neutralizes 1.00 L of hydrochloric acid, HCl, by adding calcium carbonate, $CaCO_3$.

The following reaction takes place:

$$2\ HCl_{(aq)} + CaCO_{3(s)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

The student uses a pH meter to check the progress of the reaction. It takes 25 seconds for the pH of the solution to change from 1.00 to 2.00.

What was the average rate of formation of carbon dioxide gas, CO_2, during this time?

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 During the decomposition of hydrogen peroxide, $H_2O_{2(aq)}$, water, $H_2O_{(l)}$ and oxygen gas, $O_{2(g)}$ are produced in the following exothermic reaction:

$$2\ H_2O_{2(aq)} \leftrightarrow 2\ H_2O_{(l)} + O_{2(g)}$$

Using the terminology of Le Chatelier's principle, state four stresses that can be placed on the system to shift the equilibrium in order to increase the production of oxygen gas. Justify each of your proposed changes to the system.

27 The following reaction takes place in a closed 4.0 L container.

$$2\ SO_{2(g)} + O_{2(g)} \leftrightarrow 2\ SO_{3(g)}$$

Initially, only 1.20 moles of SO_2 and 1.00 mole of O_2 are present in the container. At equilibrium, 0.40 moles of SO_2 remain unreacted.

What is the value of the equilibrium constant, K_c, for this reaction?

28 A solution of acetic acid, CH_3COOH, has a concentration of 0.30 mol/L and a K_a of 1.8×10^{-5}.

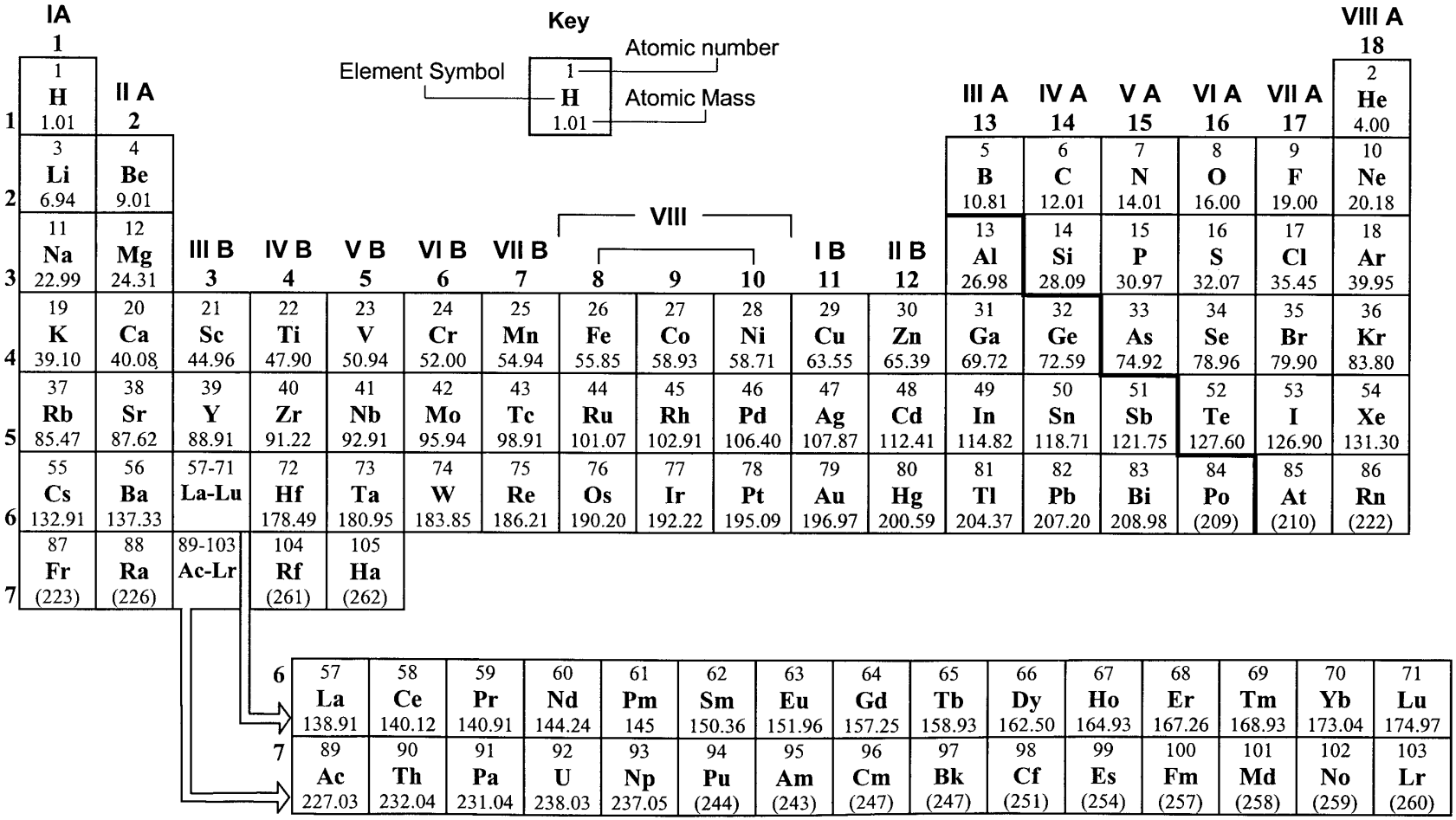
$$CH_3COOH_{(aq)} \leftrightarrow H^+_{(aq)} + CH_3COO^-_{(aq)}$$

What is the pH of this solution of acetic acid?

29 Zinc, Zn, can be used to reduce iron (III) ions, Fe^{3+}, to iron (II) ions, Fe^{2+}.

1. **Give the balanced net oxidation-reduction reaction.**
2. **Determine the E^o value of this reaction.**
3. **Identify the oxidizing agent.**
4. **Would increasing the concentration of $Zn^{2+}_{(aq)}$ favour the reduction of iron (III) ions, Fe^{3+}, to iron (II) ions, Fe^{2+}? Justify your answer using Le Chatelier's principle.**

PERIODIC TABLE OF THE ELEMENTS



FORMULAS

$$Q = mc\Delta T$$

$$PV = n\,RT$$

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

PHYSICAL CONSTANTS

SYMBOL	NAME	VALUE
c_{H_2O}	Specific heat capacity of water	4190 J/(kg•°C) or 4.19 J/(g•°C)
ρ_{H_2O}	Density of water	1.00 g/mL
R	Molar gas constant	8.31 kPa • L/(mol•K)

Standard Reduction Potentials

ION CONCENTRATION of 1 mol/L at 25°C and 101.3 kPa.

Reduction Half-reaction				Reduction Potential (V)
$F_2(g)$	$+ 2e^-$	$\rightarrow$	$2F^-(aq)$	E° = + 2.87
$Au^{3+}(aq)$	$+ 3e^-$	$\rightarrow$	$Au(s)$	E° = + 1.50
$Cl_2(g)$	$+ 2e^-$	$\rightarrow$	$2Cl^-(aq)$	E° = + 1.36
$Br_2(aq)$	$+ 2e^-$	$\rightarrow$	$2Br^-(aq)$	E° =+ 1.09
$Br_2(l)$	$+ 2e^-$	$\rightarrow$	$2Br^-(aq)$	E° =+ 1.07
$Ag^+(aq)$	$+ e^-$	$\rightarrow$	$Ag(s)$	E° = + 0.80
$Hg^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Hg(l)$	E° = + 0.78
$Fe^{3+}(aq)$	$+ e^-$	$\rightarrow$	$Fe^{2+}(aq)$	E° = + 0.77
$I_2(s)$	$+ 2e^-$	$\rightarrow$	$2I^-(aq)$	E° = + 0.53
$Cu^+(aq)$	$+ e^-$	$\rightarrow$	$Cu(s)$	E° = + 0.52
$Cu^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Cu(s)$	E° = + 0.34
$2H^+(aq)$	$+ 2e^-$	$\rightarrow$	$H_2(g)$	E° = + 0.00
$Pb^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Pb(s)$	E° = - 0.13
$Sn^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Sn(s)$	E° = - 0.14
$Ni^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Ni(s)$	E° = - 0.26
$Co^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Co(s)$	E° = - 0.28
$Fe^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Fe(s)$	E° = - 0.44
$Cr^{3+}(aq)$	$+ 3e^-$	$\rightarrow$	$Cr(s)$	E° = - 0.74
$Zn^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Zn(s)$	E° = - 0.76
$Cr^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Cr(s)$	E° = - 0.91
$Mn^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Mn(s)$	E° = - 1.18
$Al^{3+}(aq)$	$+ 3e^-$	$\rightarrow$	$Al(s)$	E° = - 1.66
$Be^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Be(s)$	E° = - 1.85
$Mg^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Mg(s)$	E° = - 2.37
$Na^+(aq)$	$+ e^-$	$\rightarrow$	$Na(s)$	E° = - 2.71
$Ca^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Ca(s)$	E° = - 2.87
$Sr^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Sr(s)$	E° = - 2.89
$Ba^{2+}(aq)$	$+ 2e^-$	$\rightarrow$	$Ba(s)$	E° = - 2.91
$Cs^+(aq)$	$+ e^-$	$\rightarrow$	$Cs(s)$	E° = - 2.92
$K^+(aq)$	$+ e^-$	$\rightarrow$	$K(s)$	E° = - 2.93
$Rb^+(aq)$	$+ e^-$	$\rightarrow$	$Rb(s)$	E° = - 2.98
$Li^+(aq)$	$+ e^-$	$\rightarrow$	$Li(s)$	E° = - 3.04