January 2002

Chemistry 30

Grade 12 Diploma Examination

Alberta
LEARNING

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January 2002

Chemistry 30

Grade 12 Diploma Examination

Description

Time: This examination was developed to be completed in 2.5 h; however, you may take an additional 0.5 h to complete the examination.

This is a **closed-book** examination consisting of

- 44 multiple-choice and 12 numerical-response questions of equal value, worth 70% of the examination
- 2 written-response questions of equal value, worth 30% of the examination

This examination contains sets of related questions.

A set of questions may contain multiple-choice and/or numerical-response and/or written-response questions.

When required, a grey bar will be used to indicate the end of a set.

A chemistry data booklet is provided for your reference.

Note: *The perforated pages at the back of this booklet may be torn out and used for your rough work.* ***No marks*** *will be given for work done on the tear-out pages.*

Instructions

- You are expected to provide your own calculator. You may use any scientific calculator or a graphing calculator approved by Alberta Learning.
- You are expected to have cleared your calculator of all information that is stored in the programmable or parametric memory.
- Use only an HB pencil for the machine-scored answer sheet.
- Fill in the information required on the answer sheet and the examination booklet as directed by the presiding examiner.
- Read each question carefully.
- Consider all numbers used in the examination to be the result of a measurement or observation.
- When performing calculations, use the values of the constants provided in the data booklet. Do **not** use the values programmed in your calculator.
- If you wish to change an answer, erase **all** traces of your first answer.
- Do not fold the answer sheet.
- The presiding examiner will collect your answer sheet and examination booklet and send them to Alberta Learning.
- Now turn this page and read the detailed instructions for answering machine-scored and written-response questions.

Multiple Choice

- Decide which of the choices **best** completes the statement or answers the question.
- Locate that question number on the separate answer sheet provided and fill in the circle that corresponds to your choice.

Example

This examination is for the subject of

A. chemistry
B. biology
C. physics
D. science

Answer Sheet

● Ⓑ Ⓒ Ⓓ

Numerical Response

- Record your answer on the answer sheet provided by writing it in the boxes and then filling in the corresponding circles.
- If an answer is a value between 0 and 1 (e.g., 0.25), then be sure to record the 0 before the decimal place.
- **Enter the first digit of your answer in the left-hand box. Any boxes on the right that are not needed are to remain blank.**

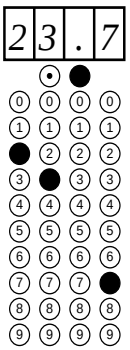
Examples

Calculation Question and Solution

The average of the values 21.0, 25.5, and 24.5 is _____.
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Average = (21.0 + 25.5 + 24.5)/3
= 23.666
= 23.7 (rounded to three digits)

Record 23.7 on the answer sheet →



Correct-Order Question and Solution

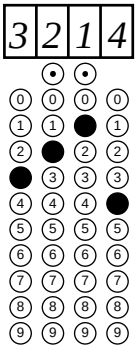
When the following subjects are arranged in alphabetical order, the order is ____ , ____ , ____ , and ____ .

1 physics
2 chemistry
3 biology
4 science

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Answer 3214

Record 3214 on the answer sheet →



Positive/Negative Question and Solution

If a water sample at 5.87°C decreases in temperature by 10.00°C, then the final temperature of the water sample will be

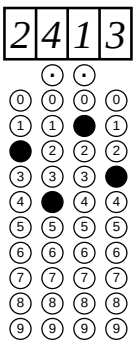
If + record **1**
If − record **2**

first column	**second** column	**third** column	**fourth** column	
	_____	• _____	_____	°C

(**Note:** The placement of the decimal is provided for you; therefore, record your **four-digit answer** in the numerical-response section on the answer sheet.)

Answer −4.13 Record as 2413

Record 2413 on the answer sheet →



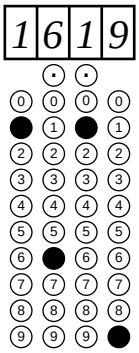
Scientific Notation Question and Solution

The charge on an electron is $-\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ C.
The values of ***a***, ***b***, ***c***, and ***d*** are ____, ____, ____, and ____ .

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Answer: -1.6×10^{-19} C

Record 1619 on the answer sheet →



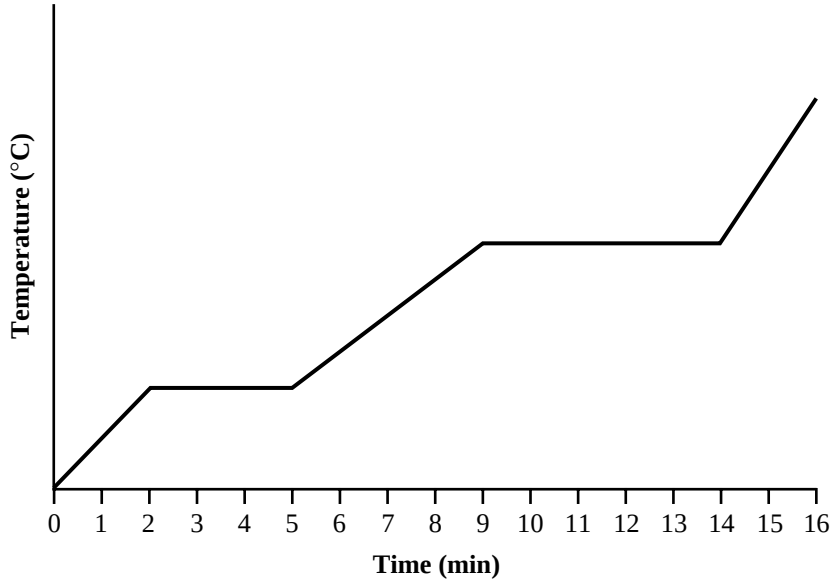
Written Response

- Write your responses in the examination booklet as neatly as possible.
- For full marks, your responses must address **all** aspects of the question.
- Descriptions and/or explanations of concepts must include pertinent ideas, diagrams, calculations, and formulas.
- Your responses must be presented in a well-organized manner using complete sentences, correct units, and correct significant digits where appropriate.
- Relevant scientific, technological, and/or societal concepts and examples must be identified and made explicit.

Use the following information to answer the first question.

An oven provides a constant supply of 15 kJ/min of energy to heat a solid substance. The temperature changes of the substance are graphed below.

Temperature–Time Graph



1. According to the graph, between 2 min and 5 min, the

A. kinetic energy of the sample increased by 45 kJ

B. potential energy of the sample increased by 45 kJ

C. kinetic energy and potential energy of the sample increased in equal amounts

D. kinetic energy of the sample decreased as the potential energy increased by 45 kJ

The main ingredient in rubbing alcohol is isopropyl alcohol, $CH_3CH(OH)CH_{3(l)}$. Isopropyl alcohol acts as a disinfectant and is flammable and volatile (evaporates readily at room temperature).

2. When rubbing alcohol is placed on skin, the skin immediately feels

A. warmer because evaporation is endothermic
B. warmer because evaporation is exothermic
C. cooler because evaporation is endothermic
D. cooler because evaporation is exothermic

Use the following information to answer the next two questions.

In an experiment, 115.24 g of isopropyl alcohol at 20.1°C was mixed with 56.31 g of water at 50.3°C. After thermal equilibrium was reached, the temperature of the mixture was 36.5°C.

3. The energy lost by the water was

A. 3.26 kJ
B. 8.61 kJ
C. 11.9 kJ
D. 26.2 kJ

*Use your recorded answer from **Multiple Choice 3** to answer **Numerical Response 1.****

Numerical Response

1. The experimental specific heat capacity of isopropyl alcohol is _____ J/(g·°C).

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if the previous question was answered incorrectly.**

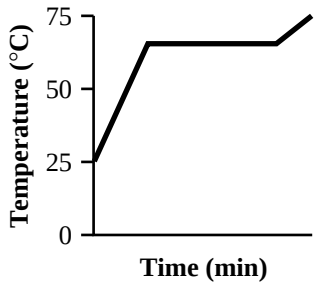
Use the following information to answer the next two questions.

Methanol ($CH_3OH_{(l)}$), known commercially as both methyl hydrate and gas line antifreeze, is widely used as a solvent. Some properties of methanol are listed below.

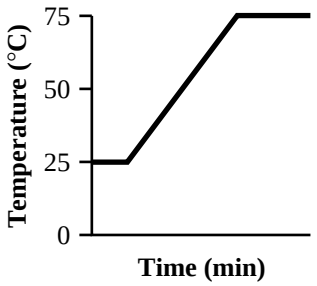
melting point	–94.0°C
boiling point	65.0°C
specific heat capacity (liquid)	2.55 J/(g·°C)
molar heat of fusion	2.16 kJ/mol
molar heat of vaporization	34.4 kJ/mol
molar heat of combustion	–638.1 kJ/mol

4. A sample of methanol is heated at a constant rate from 25°C to 75°C. A temperature–time graph that depicts the heating of methanol is

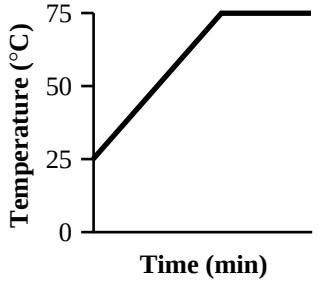
A.



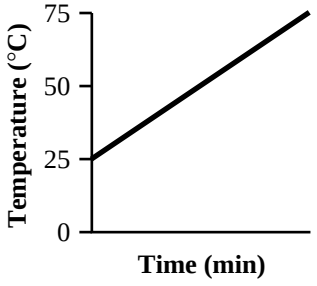
B.



C.



D.



5. The energy required to vaporize 1.00 L (793 g) of methanol at its boiling point is

A. 1.10 kJ

B. 131 kJ

C. 851 kJ

D. 1.07×10^3 kJ

Use the following reaction equations to answer the next question.

Reaction Equations

1 $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)}$

2 $CH_{4(g)} + 2\,O_{2\,(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$

3 ${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{4}_{2}He$

4 $CH_3OH_{(l)} + \frac{3}{2}O_{2(g)} \rightarrow CO_{2(g)} + 2\,H_2O_{(g)}$

Numerical Response

2. For the reactions represented above, when their enthalpy changes are ranked from largest to smallest according to magnitude, the order of the equations is _____ , _____ , _____ , and _____ .

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

Numerical Response

3. When 0.500 g of peanut oil was burned, the temperature of 0.950 kg of water in a calorimeter increased by 4.60°C. The enthalpy of combustion of the peanut oil was

If + record **1**
If − record **2**

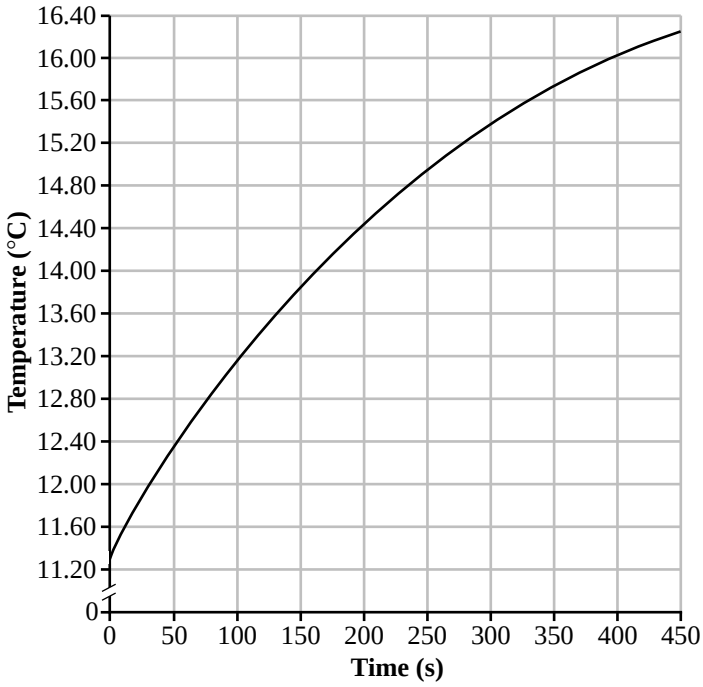
first column	**second** column	**third** column	• **fourth** column
_____	_____	_____	_____ kJ/g

(**Note:** The placement of the decimal is provided for you; therefore, record your **four-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next two questions.

A student using a computer-based laboratory (CBL) temperature probe attempted to determine the amount of energy released by a commercial heat pack. The student activated the heat pack and placed it in an insulated calorimeter containing 1.00 kg of water at 11.30°C. A graph of the results obtained is given below.

Temperature–Time Graph



6. To more accurately determine the total heat released by the heat pack, the student should

A. use more water

B. use a larger heat pack

C. start with colder water

D. collect results for a longer period

7. If the energy change of the plastic container is not considered, the calculated energy change for the water from 0 s to 200 s is

A. 13.0 kJ

B. 14.4 kJ

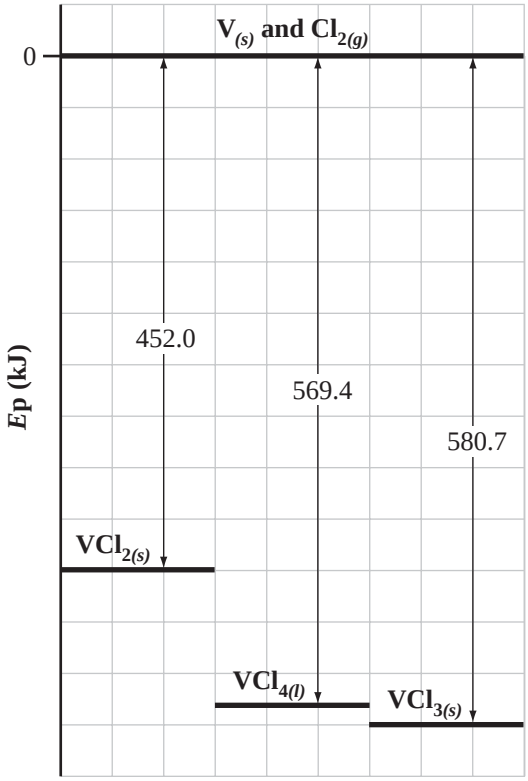
C. 60.3 kJ

D. 838 kJ

Use the following information to answer the next question.

The following diagram illustrates the formation enthalpies of $V_{(s)}$, $Cl_{2(g)}$, and a selection of their compounds.

Formation Enthalpies of Vanadium Chlorides



Numerical Response

4. The amount of energy absorbed when 0.350 mol of $VCl_{4(l)}$ decomposes to form $VCl_{2(s)}$ and $Cl_{2(g)}$ is _____ kJ.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

In beer, dissolved carbon dioxide forms carbonic acid, which ionizes in water according to the equation

$$H_2CO_{3(aq)} + H_2O_{(l)} \rightleftharpoons HCO_3^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

8. In this equilibrium, a conjugate acid–base pair is

A. $H_2CO_{3(aq)}$ and $HCO_3^-{}_{(aq)}$

B. $H_2CO_{3(aq)}$ and $H_3O^+{}_{(aq)}$

C. $H_2CO_{3(aq)}$ and $H_2O_{(l)}$

D. $H_2O_{(l)}$ and $HCO_3^-{}_{(aq)}$

---

9. Acid rain in the form of sulphuric acid could be neutralized by

A. $NaCl_{(s)}$

B. $CaCO_{3(s)}$

C. $NaHSO_{4(aq)}$

D. $CH_3COOH_{(aq)}$

Use the following information to answer the next question.

Apple growers in British Columbia's Okanagan Valley are coping with trees that are stunted and have blistered bark as a result of a dramatic increase in the acidity of the region's soil. Nitrogen fertilizers are one of the main causes of the high acidity level of the soil.

10. To solve this problem, Agriculture Canada has suggested that apple growers work lime into the soil in their orchards because lime is

A. a base

B. an acid

C. a neutral ionic compound

D. a neutral molecular compound

Use the following information to answer the next question.

Blood pH is influenced by the concentration of buffers and gas solutes, such as carbon dioxide, which is formed during cellular respiration. In red blood cells, the enzyme carbonic anhydrase catalyzes the equilibrium

$$CO_{2(aq)} + H_2O_{(l)} \underset{\text{carbonic anhydrase}}{\rightleftharpoons} HCO_3^-{}_{(aq)} + H^+{}_{(aq)}$$

11. In this equilibrium, carbonic anhydrase

A. increases the concentration of $HCO_3^-{}_{(aq)}$ formed at equilibrium

B. decreases the concentration of $HCO_3^-{}_{(aq)}$ formed at equilibrium

C. decreases the concentration of $CO_{2(g)}$ at equilibrium

D. increases the speed at which equilibrium is reached

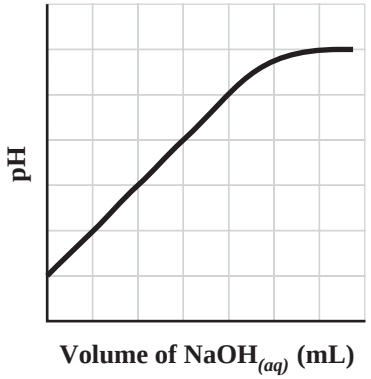
Use the following information to answer the next question.

A buffer system present in some of Alberta's lakes consists of $HCO_3^-{}_{(aq)}$ and $CO_3^{2-}{}_{(aq)}$, as represented by the equilibrium

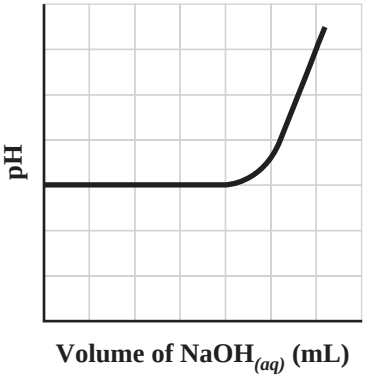
$$HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + CO_3^{2-}{}_{(aq)}$$

12. The graph that best represents the titration of the $CO_3^{2-}{}_{(aq)} - HCO_3^-{}_{(aq)}$ buffer with $NaOH_{(aq)}$ is

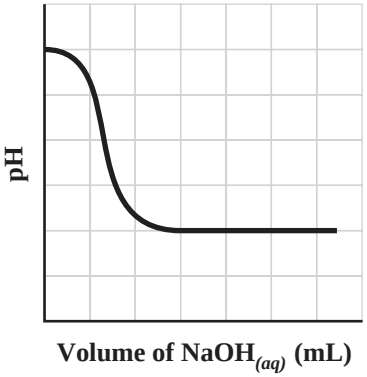
A.



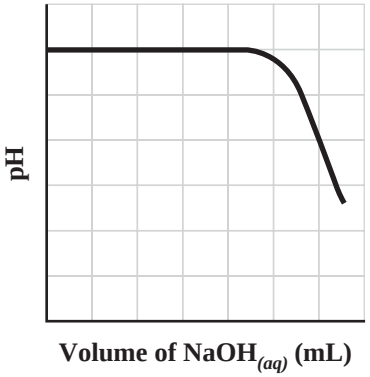
B.



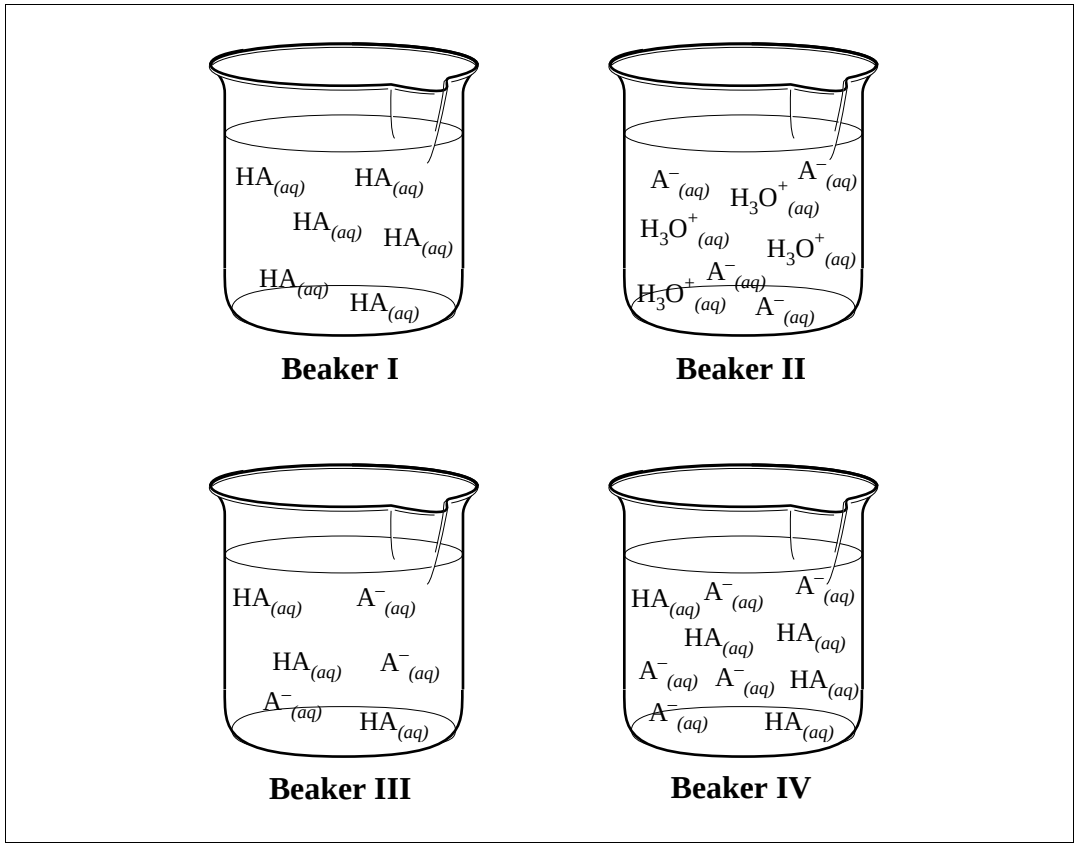
C.



D.



Use the following diagram to answer the next question.



13. The beakers that best represent a buffer solution in which $HA_{(aq)}$ is a weak acid are those labelled

A. I and II

B. I and III

C. II and III

D. III and IV

Use the following information to answer the next question.

Oxoacids of Chlorine

Acid	K_a
$HClO_{4(aq)}$	very large
$HClO_{3(aq)}$	5.1×10^{2}
$HClO_{2(aq)}$	1.1×10^{-2}
$HClO_{(aq)}$	2.9×10^{-8}

14. Acids are classified as either strong or weak. Of the acids listed above, only

A. $HClO_{(aq)}$ is a strong acid

B. $HClO_{4(aq)}$ is a strong acid

C. $HClO_{4(aq)}$ and $HClO_{3(aq)}$ are strong acids

D. $HClO_{4(aq)}$, $HClO_{3(aq)}$, and $HClO_{2(aq)}$ are strong acids

---

Use the following information to answer the next question.

A technician performed a titration to determine the concentration of a 27.0 mL sample of $NaOH_{(aq)}$. A few drops of phenol red indicator were added to the base, which was then titrated with a 0.24 mol/L solution of $HCl_{(aq)}$ until the indicator changed colour from red to orange.

Volume of Acid Used

Final buret reading (mL)	25.8
Initial buret reading (mL)	7.8

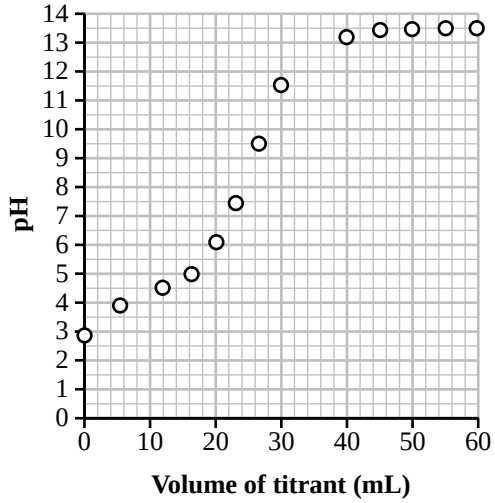
Numerical Response

5. The concentration of the $NaOH_{(aq)}$ solution was _____ mol/L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

To determine the identity of a compound, a student dissolved 0.72 g of the compound in enough water to make a 25 mL solution. This solution was titrated with a 0.20 mol/L standardized solution. The student used a pH meter to collect data during the titration and then plotted the data on the graph below.

Titration of the Solution



15. This titration likely involved a

A. strong base added to a strong acid
B. strong base added to a weak acid
C. strong acid added to a strong base
D. strong acid added to a weak base

16. The pH of the solution at the equivalence point for this titration is approximately

A. 4.5
B. 8.5
C. 11.5
D. 13.5

17. For this titration, a suitable indicator and its corresponding colour change are

A. phenolphthalein and colourless to pink

B. indigo carmine and blue to yellow

C. thymol blue and blue to yellow

D. phenol red and red to yellow

Numerical Response

6. The K_b for the conjugate base of the ammonium ion, expressed in scientific notation, is _____ $\times 10^{-5}$.

(Record your answer in the numerical-response section on the answer sheet.)

Use the following equilibrium information to answer the next question.

For the equilibrium

$$PCl_{5(g)} \rightleftharpoons PCl_{3(g)} + Cl_{2(g)}$$

the equilibrium constant at two temperatures is given below.

Temperature	K_{eq}
227°C	2.24
486°C	33.3

18. According to this information, as the temperature of the system increases, the equilibrium shifts

A. left and the reaction is exothermic

B. left and the reaction is endothermic

C. right and the reaction is exothermic

D. right and the reaction is endothermic

Use the following information to answer the next question.

A source of hydrogen for the Haber process is "syngas," which is produced by a reaction of methane and water at 1 000°C.

$$CH_{4(g)} + H_2O_{(g)} + \text{heat} \overset{\text{nickel catalyst}}{\rightleftharpoons} CO_{(g)} + 3\,H_{2(g)}$$

Numerical Response

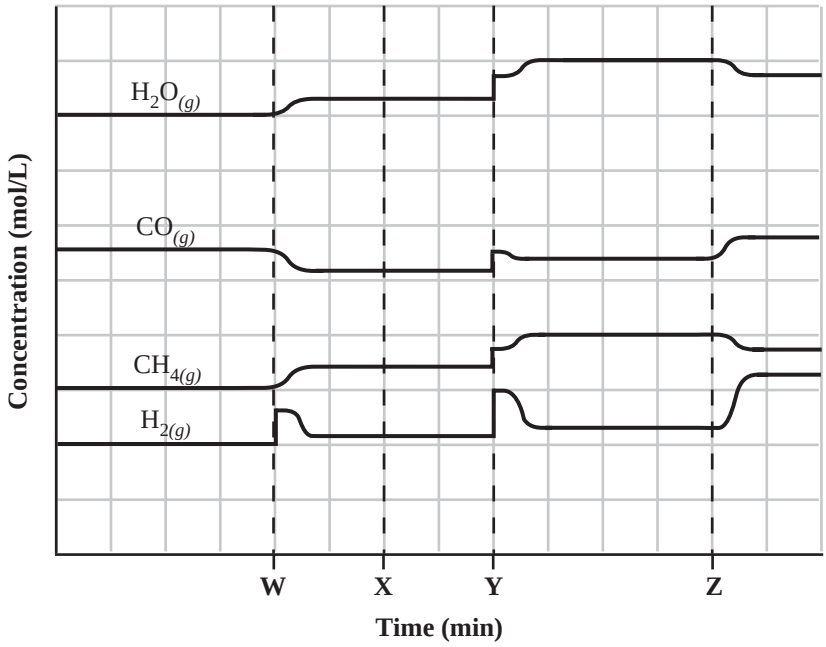
7. If, at equilibrium, the $[CH_{4(g)}] = 2.97$ mol/L, $[H_2O_{(g)}] = 7.94$ mol/L, $[CO_{(g)}] = 5.45$ mol/L, and $[H_{2(g)}] = 2.10$ mol/L, then the K_{eq} is _____.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

Manipulations of an Equilibrium System

$CH_{4(g)} + H_2O_{(g)} + \text{heat} \rightleftharpoons CO_{(g)} + 3\,H_{2(g)}$



Stresses

1 Addition of heat
2 Addition of neon while a constant volume is maintained
3 Addition of hydrogen
4 Pressure increased by decreasing the volume

Numerical Response

8. Match each of the stresses identified above with the letter on the graph that indicates the time at which the stress was applied.

Stress applied: _____ _____ _____ _____
Time: **W** **X** **Y** **Z**

(Record all **four digits** of your answer in the numerical-response section on the answer sheet.)

The beautiful patterns of butterfly wings, the stripes on zebra pelts, and the myriad of colours of tropical fish all result from oscillating chemical reactions. These chemical reactions can be studied in a much simpler form in the laboratory. In 1958, the Russian chemist B.P. Belousoz discovered a complex reaction sequence in which the concentration of reactants and products oscillated over time.

Unbalanced Reaction Equations

I $\_\_H^+_{(aq)} + \_\_BrO_2^-{}_{(aq)} + \_\_BrO_3^-{}_{(aq)} \rightleftharpoons \_\_BrO_{2(aq)} + \_\_H_2O_{(l)}$

II $\_\_Ce^{3+}_{(aq)} + \_\_BrO_{2(aq)} \rightleftharpoons \_\_Ce^{4+}_{(aq)} + \_\_BrO_2^-{}_{(aq)}$

III $\_\_BrO_2^-{}_{(aq)} \rightleftharpoons \_\_BrO_3^-{}_{(aq)} + \_\_BrO^-_{(aq)}$

Numerical Response

9. When reaction equation I is balanced with lowest whole number coefficients, the coefficient of

$H^+_{(aq)}$ is _____ (Record in the **first** column)

$BrO_2^-{}_{(aq)}$ is _____ (Record in the **second** column)

$BrO_3^-{}_{(aq)}$ is _____ (Record in the **third** column)

$BrO_{2(aq)}$ is _____ (Record in the **fourth** column)

(Record your answer in the numerical-response section on the answer sheet.)

19. In reaction III, the bromine in $BrO_2^-{}_{(aq)}$

A. undergoes oxidation only

B. undergoes reduction only

C. both loses and gains protons

D. both loses and gains electrons

20. If the $[H^+_{(aq)}]$ in reaction I is 0.020 mol/L, then the pH and pOH are, respectively,

A. 1.05 and 12.95

B. 1.40 and 12.60

C. 1.70 and 12.30

D. 2.00 and 12.00

Use the following information to answer the next question.

Common household bleach is an aqueous solution that contains approximately 5% sodium hypochlorite. The equilibrium involved in the production of bleach from chlorine can be represented by the reaction equation

$$Cl_{2(g)} + 2\,OH^-_{(aq)} \rightleftharpoons ClO^-_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$$

21. In the production of bleach, the reduction half-reaction is

A. $Cl_{2(g)} + 2\,e^- \rightarrow 2\,Cl^-_{(aq)}$

B. $2\,Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2\,e^-$

C. $4\,OH^-_{(aq)} \rightarrow O_{2(g)} + 2\,H_2O_{(l)} + 4\,e^-$

D. $ClO^-_{(aq)} + H_2O_{(l)} + 2\,e^- \rightarrow Cl^-_{(aq)} + 2\,OH^-_{(aq)}$

22. A student has one coin made of copper and one coin made of nickel. Which of the following solutions could the student use to demonstrate which of these metals is the stronger reducing agent?

A. $Hg^{2+}_{(aq)}$

B. $Fe^{3+}_{(aq)}$

C. $Fe^{2+}_{(aq)}$

D. $Sn^{4+}_{(aq)}$

The oil that Syncrude mines from the Athabasca Tar Sands contains large amounts of undesirable sulphur. To remove most of the sulphur, Syncrude uses a chemical process known as the Claus process, which results in a low-sulphur "sweet" crude oil. Two steps involved in the Claus process are shown below.

Step I $H_2S_{(g)} + \frac{3}{2}O_{2(g)} \overset{950°C\ –1200°C}{\rightleftharpoons} SO_{2(g)} + H_2O_{(g)} \quad \Delta H = –518\ kJ$

Step II $SO_{2(g)} + 2\,H_2S_{(g)} \overset{170°C\ –\ 370°C}{\underset{\text{catalyst}}{\rightleftharpoons}} 3\,S_{(l)} + 2\,H_2O_{(g)} \quad \Delta H = –93\ kJ$

Syncrude solidifies and stores approximately 1.36 Gg of sulphur per day.

23. The net equation and enthalpy of reaction for the Claus process are

A. $3\,H_2S_{(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3\,S_{(l)} + 3\,H_2O_{(g)} \quad \Delta H = +425\ kJ$

B. $3\,H_2S_{(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3\,S_{(l)} + 3\,H_2O_{(g)} \quad \Delta H = –611\ kJ$

C. $3\,H_2S_{(g)} + \frac{3}{2}O_{2(g)} \rightarrow 3\,S_{(l)} + 3\,H_2O_{(g)} \quad \Delta H = –704\ kJ$

D. $2\,H_2S_{(g)} + O_{2(g)} \rightarrow 2\,S_{(l)} + 2\,H_2O_{(g)} \quad \Delta H = –425\ kJ$

24. As the $H_2S_{(g)}$ forms $S_{(l)}$, the sulphur atoms

A. gain $2\,e^-$ and are oxidized

B. lose $2\,e^-$ and are oxidized

C. gain $2\,e^-$ and are reduced

D. lose $2\,e^-$ and are reduced

Use the following information to answer the next two questions.

If $H_2S_{(g)}$ is released into the atmosphere, it dissolves in atmospheric water to form hydrosulphuric acid. The ionization of $H_2S_{(aq)}$ can be represented by the equilibrium

$$H_2S_{(aq)} + H_2O_{(l)} \rightleftharpoons HS^-_{(aq)} + H_3O^+_{(aq)}$$

25. The K_a expression for this ionization is

A. $K_a = \dfrac{[H_2S_{(aq)}]}{[HS^-_{(aq)}][H_3O^+_{(aq)}]}$

B. $K_a = \dfrac{[H_2S_{(aq)}][H_2O_{(l)}]}{[HS^-_{(aq)}][H_3O^+_{(aq)}]}$

C. $K_a = \dfrac{[HS^-_{(aq)}][H_3O^+_{(aq)}]}{[H_2S_{(aq)}][H_2O_{(l)}]}$

D. $K_a = \dfrac{[HS^-_{(aq)}][H_3O^+_{(aq)}]}{[H_2S_{(aq)}]}$

26. The $[H_3O^+_{(aq)}]$ in a 0.050 mol/L $H_2S_{(aq)}$ solution is

A. 5.5×10^{-9} mol/L

B. 7.4×10^{-5} mol/L

C. 3.3×10^{-4} mol/L

D. 0.10 mol/L

Poisonous oxalic acid is found in non-toxic concentrations in vegetables such as spinach and rhubarb. Manufacturers of spinach juice are required to analyze the concentration of oxalic acid to avoid problems that could arise from unexpectedly high concentrations of oxalic acid. The reaction of oxalic acid with acidified potassium permanganate can be represented by the following equation.

$$5\,HOOCCOOH_{(aq)} + 2\,MnO_4^-{}_{(aq)} + 6\,H^+{}_{(aq)} \rightarrow 2\,Mn^{2+}{}_{(aq)} + 8\,H_2O_{(l)} + 10\,CO_{2(g)}$$

27. If 15.0 mL of oxalic acid solution is completely reacted with 20.0 mL of 0.0015 mol/L acidified permanganate solution, then the oxalic acid concentration will be

A. 8.0×10^{-4} mol/L

B. 2.4×10^{-3} mol/L

C. 5.0×10^{-3} mol/L

D. 6.0×10^{-3} mol/L

28. A technician reacting oxalic acid with acidified potassium permanganate is **not** likely to observe

A. an increase in electrical conductivity

B. a visible colour change

C. a slight increase in pH

D. the formation of a gas

29. Acidic permanganate solutions and acidic dichromate solutions are often used in redox titrations because they are strong

A. reducing agents that change colour when they are oxidized

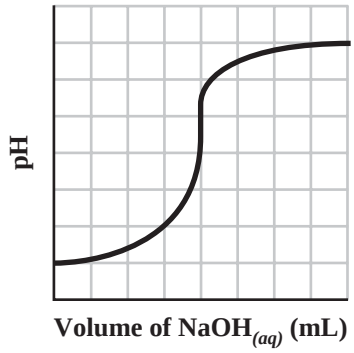
B. oxidizing agents that change colour when they are reduced

C. reducing agents that change colour when the acid is neutralized

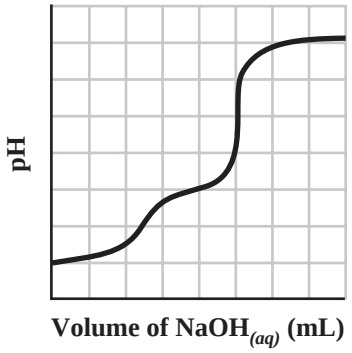
D. oxidizing agents that change colour when the acid is neutralized

30. When oxalic acid is titrated with $NaOH_{(aq)}$, the titration curve that would be predicted is

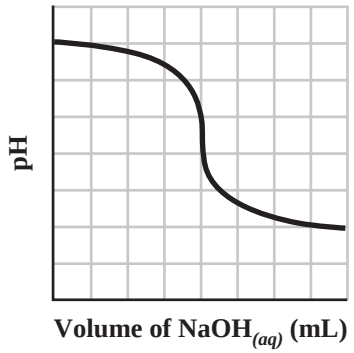
A.



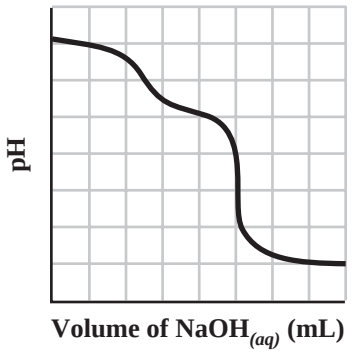
B.



C.



D.



Use the following information to answer the next two questions.

Alfred Nobel was the first person to patent a process to commercially produce dynamite. Dynamite contains nitroglycerine, $C_3H_5(NO_3)_{3(l)}$, an explosive compound that when absorbed by a support material, becomes safer to handle and transport. Nitroglycerine can undergo an explosive decomposition, as represented by the equation

$$4\,C_3H_5(NO_3)_{3(l)} \rightarrow 12\,CO_{2(g)} + 10\,H_2O_{(g)} + 6\,N_{2(g)} + O_{2(g)}$$

31. In the decomposition equation, the product species that would have an oxidation state of zero are

A. hydrogen and nitrogen

B. carbon and hydrogen

C. nitrogen and oxygen

D. carbon and oxygen

32. Reactions producing carbon dioxide cause concern among environmentalists because $CO_{2(g)}$ is

A. a poisonous gas

B. a major greenhouse gas

C. a major contributor to acid rain

D. an important component of combustion

Use the following information to answer the next question.

Tiny iron filings are added as a mineral supplement to many breakfast cereals in minute quantities. The iron can be collected by mixing the cereal with water and placing it in a bag with a powerful magnet. When the bag is shaken the magnet collects the tiny iron filings. Once ingested, the iron reacts with the hydrochloric acid in the stomach. The iron is then converted into a form that can be absorbed by the body.

33. In the stomach, the reaction between hydrochloric acid and iron occurs because the

A. iron donates protons to the acid

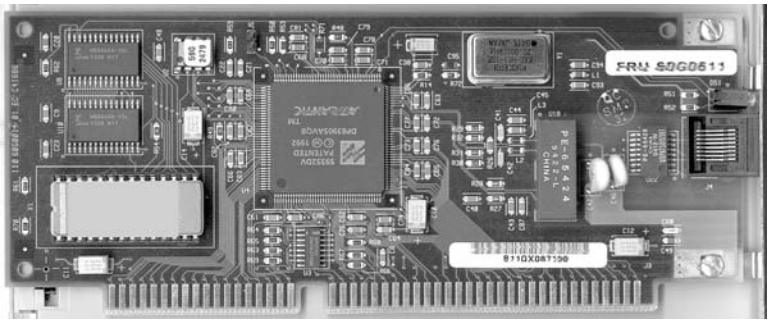
B. acid donates electrons to the iron

C. iron accepts protons from the acid

D. acid accepts electrons from the iron

Use the following information to answer the next two questions.

Electronic circuit boards can be made by etching a copper board that is coated with plastic on one side. A special masking tape is applied to the surface of the copper board in the shape of the desired circuit pattern. The circuit board is then etched by reacting it with $FeCl_{3(aq)}$ to remove the unwanted copper.



34. The net equation for the spontaneous reaction that occurs when the circuit board is immersed in $FeCl_{3(aq)}$ is

A. $Fe^{2+}_{(aq)} + Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + Fe_{(s)}$

B. $Cu^{+}_{(aq)} + Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + Cu_{(s)}$

C. $2\,Fe^{3+}_{(aq)} + Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2\,Fe^{2+}_{(aq)}$

D. $2\,Fe^{3+}_{(aq)} + 3\,Cu_{(s)} \rightarrow 3\,Cu^{2+}_{(aq)} + 2\,Fe_{(s)}$

35. In this reaction, the copper acts as the

A. oxidizing agent and is oxidized

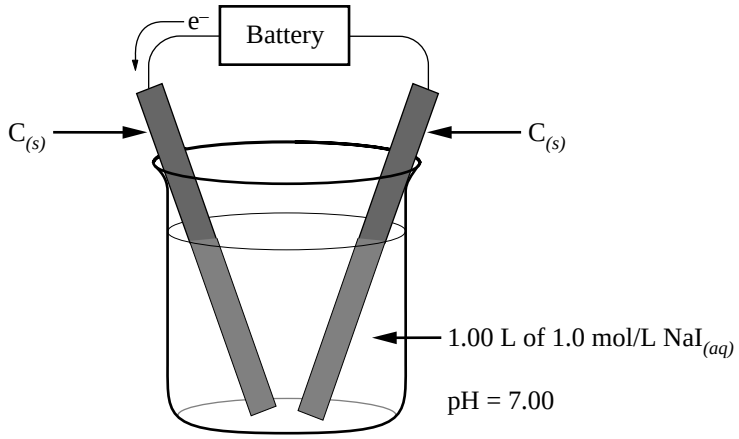
B. oxidizing agent and is reduced

C. reducing agent and is oxidized

D. reducing agent and is reduced

Use the following information to answer the next question.

Electrochemical Cell



The diagram above provides a representation of the process of electrolysis.

36. Which of the following statements describes what happens during the operation of this cell?

A. Chemical energy is converted to electrical energy.

B. Electrical energy is converted to chemical energy.

C. Electrons flow toward the anode.

D. Plating takes place at the anode.

---

37. A solution containing a metal ion with a 3+ charge was electrolyzed by a 5.0 A current for 10.0 min. If 1.19 g of the metal was electroplated, then the metal was likely

A. indium

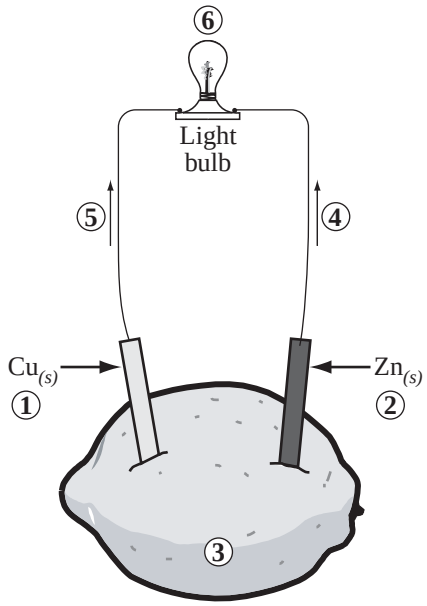
B. scandium

C. aluminum

D. potassium

Use the following information to answer the next question.

A voltaic cell capable of lighting a small light bulb can be made by placing copper and zinc strips in a lemon.



Numerical Response

10. Identify the part of the voltaic cell, as numbered above, that corresponds to each of the descriptors listed below.

Anode _____ (Record in the **first** column)

Cathode _____ (Record in the **second** column)

Electron flow _____ (Record in the **third** column)

Electrolyte _____ (Record in the **fourth** column)

(Record your answer in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

A possible alternative to the internal combustion engine used in present-day automobiles is an electric motor powered with energy supplied by an aluminum–air battery, which uses a sodium hydroxide solution as an electrolyte. When air is bubbled through the sodium hydroxide solution, the half-reaction that occurs at the cathode is

$$O_{2(g)} + 2\,H_2O_{(l)} + 4\,e^- \rightarrow 4\,OH^-_{(aq)}$$

38. The reduction potential for this half-reaction is

A. −0.40 V

B. +0.40 V

C. −0.70 V

D. +0.70 V

Use the following information to answer the next question.

Some car manufacturers have designed an anticorrosion system that sends a weak electric current from the battery to the frame of the car. The current provides a source of electrons, which reduces corrosion of the steel frame.

39. Which of the following methods could **not** be used as an alternative to the method of corrosion prevention described above?

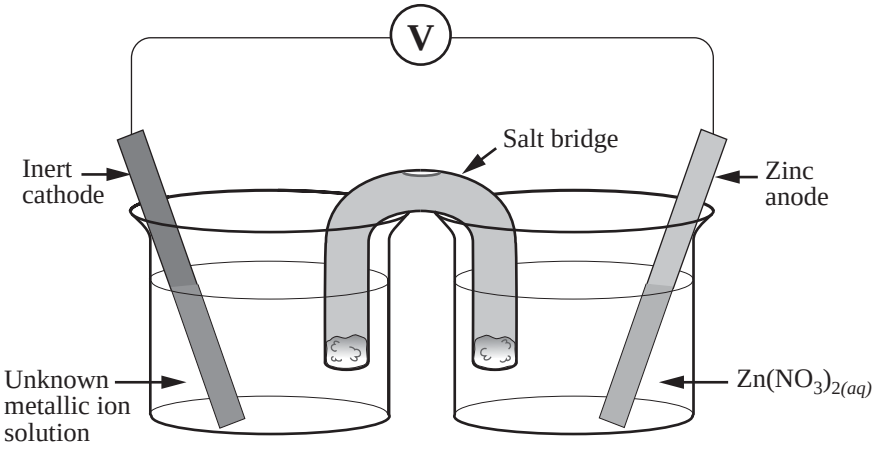
A. Galvanize the steel frame with zinc.

B. Coat the steel frame with inert plastic polymers.

C. Use a paint that prevents contact of the steel frame with the environment.

D. Bolt sacrificial anodes made of copper to the steel frame.

To determine the identity of an unknown metallic ion in a solution, a student designed the voltaic cell shown below.



40. The student chose zinc for the anode because zinc

A. gains electrons easily

B. can be easily reduced

C. is an oxidizing agent

D. is a reducing agent

41. If the cell generates a voltage of +1.24 V under standard conditions, the half-reaction occurring at the cathode will have an electrode potential of

A. +2.00 V

B. –2.00 V

C. +0.48 V

D. –0.48 V

42. If the zinc anode loses 200 g of mass during the operation of the cell, then the number of moles of electrons transferred is

A. 1.53 mol

B. 3.06 mol

C. 6.12 mol

D. 12.2 mol

*Use your recorded answer from **Multiple Choice 42** to answer **Numerical Response 11.****

Numerical Response

11. If the charge on the unidentified metal ion is 3+, then the number of moles of the metal produced when the zinc anode decreases in mass by 200 g is _____ mol.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

***You can receive marks for this question even if the previous question was answered incorrectly.**

Use the following information to answer the next question.

Most lead storage batteries in automobiles are made up of six voltaic cells connected in series. Each of the cells consists of a lead electrode ($Pb_{(s)}$), a lead (IV) oxide electrode ($PbO_{2(s)}$), and sulphuric acid electrolyte ($H_2SO_{4(aq)}$).

43. In cold weather, an automobile will sometimes be difficult to start because in the battery, the

A. ions in the electrolyte move very slowly

B. atoms in the lead plate move very slowly

C. concentration of the electrolyte decreases

D. concentration of the lead (IV) oxide decreases

Use the following information to answer the next question.

A 0.532 mol/L solution of $Ce^{4+}_{(aq)}$ was used to titrate a 25.0 mL sample of $Sn^{2+}_{(aq)}$.

Volume Used	
Final buret reading (mL)	43.5
Initial buret reading (mL)	12.6

The half-reaction for cerium(IV) can be represented by

$$Ce^{4+}_{(aq)} + e^- \rightarrow Ce^{3+}_{(aq)} \qquad E^\circ = +1.61 \text{ V}$$

Numerical Response

12. The $[Sn^{2+}_{(aq)}]$ of the sample, expressed in scientific notation, is _____ $\times 10^{-1}$ mol/L.

(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

Use the following information to answer the next question.

Some pacemakers use specialized lithium cells as a power source. The half-reactions and electrode potentials in these cells are

$$2\,SOCl_{2(aq)} + 4\,e^- \rightarrow 4\,Cl^-_{(aq)} + S_{(s)} + SO_{2(aq)} \qquad E^\circ = +0.36\ V$$

$$Li^+_{(aq)} + e^- \rightarrow Li_{(s)} \qquad E^\circ = -3.04\ V$$

44. The net equation and potential of this lithium cell are

A. $2\,SOCl_{2(aq)} + Li^+_{(aq)} \rightarrow 4\,Cl^-_{(aq)} + S_{(s)} + SO_{2(aq)} + Li_{(s)} \qquad E^\circ_{net} = +3.40\ V$

B. $2\,SOCl_{2(aq)} + 4\,Li^+_{(aq)} \rightarrow 4\,Cl^-_{(aq)} + S_{(s)} + SO_{2(aq)} + 4\,Li_{(s)} \qquad E^\circ_{net} = +2.68\ V$

C. $2\,SOCl_{2(aq)} + Li_{(s)} \rightarrow 4\,Cl^-_{(aq)} + S_{(s)} + SO_{2(aq)} + Li^+_{(aq)} \qquad E^\circ_{net} = +2.68\ V$

D. $2\,SOCl_{2(aq)} + 4\,Li_{(s)} \rightarrow 4\,Cl^-_{(aq)} + S_{(s)} + SO_{2(aq)} + 4\,Li^+_{(aq)} \qquad E^\circ_{net} = +3.40\ V$

The written-response questions follow on the next page.

Use the following information to answer the next question.

$HOCl_{(aq)}$, a weak acid, is the active ingredient used in the disinfecting of swimming pools. It can be formed by adding $Ca(OCl)_{2(s)}$ tablets to pool water.

The pH of a swimming pool should be kept between 7.2 and 7.8 so that the equilibrium $[HOCl_{(aq)}]$ is optimal. Phenol red is used by lifeguards to test pH. Based on the test results with phenol red, a lifeguard may

- adjust the pH by adding $Na_2CO_{3(s)}$
- adjust the pH by adding $HCl_{(aq)}$
- not do anything

Written Response—15%

1. **a.** Write the net ionic equation that illustrates the formation of $HOCl_{(aq)}$ when $Ca(OCl)_{2(s)}$ tablets are added to a swimming pool.

b. Identify two characteristics of this system, or of any system, at equilibrium.

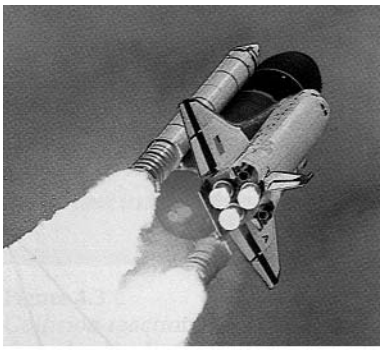
c. Based on the indicator colour, the lifeguard may choose any one of the three different courses of action. Relate each indicator colour to a course of action.

Use the following information to answer the next question.

A space shuttle uses more than one type of rocket fuel. The two solid rocket boosters use a fuel mixture of aluminum and ammonium perchlorate that reacts according to the equation

$$\underbrace{3\,Al_{(s)} + 3\,NH_4ClO_{4(s)}}_{\text{solid fuel}} \rightarrow Al_2O_{3(s)} + AlCl_{3(s)} + 3\,NO_{(g)} + 6\,H_2O_{(g)}$$

In the three main shuttle engines, a mixture of hydrogen and oxygen form a second fuel. The hydrogen and oxygen are carried as compressed liquids in a large tank adjoining the shuttle and react to produce energy according to the reaction $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)}$



Relevant Heats of Formation

H_f° of $NH_4ClO_{4(s)}$	=	–295.3 kJ/mol
H_f° of $AlCl_{3(s)}$	=	–705.6 kJ/mol

Written Response—15%

2. Compare the two rocket fuels as energy sources for powering the space shuttle.

Your response should also include

- the calculated energy released for each fuel
- an analysis of the energy-to-mass ratio for each fuel
- environmental concerns related to each fuel

You have now completed the examination.
If you have time, you may wish to check your answers.

Credit

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C1	C2	C3	C4

CHEMISTRY 30 JANUARY 2002

Multiple Choice

1.	B	**23.**	B
2.	C	**24.**	B
3.	A	**25.**	D
4.	A	**26.**	B
5.	C	**27.**	C
6.	D	**28.**	A
7.	A	**29.**	B
8.	A	**30.**	B
9.	B	**31.**	C
10.	A	**32.**	B
11.	D	**33.**	D
12.	B	**34.**	C
13.	D	**35.**	C
14.	C	**36.**	B
15.	B	**37.**	A
16.	B	**38.**	B
17.	A	**39.**	D
18.	D	**40.**	D
19.	D	**41.**	C
20.	C	**42.**	C
21.	A	**43.**	A
22.	D	**44.**	D

Numerical Response

1.	1.72*	**7.**	2.14
2.	3241	**8.**	3241
3.	2366	**9.**	2112
4.	41.1	**10.**	2143
5.	0.16	**11.**	2.04†
6.	1.72 or 1.7	**12.**	3.29

Links:

If MC 3 is A, then NR 1 is 1.72
B, then NR 1 is 4.56
C, then NR 1 is 6.30, 6.28
D, then NR 1 is 13.9

*Note: For NR1, 1.72 is always scored as correct regardless of the response to MC 3.

†If MC 42 is A, then NR 11 is 0.51
B, then NR 11 is 1.02
C, then NR 11 is 2.04†
D, then NR 11 is 4.07,4.08

†Note: For NR 11, 2.04 is always scored as correct regardless of the response to MC 42.

CHEMISTRY 30 JANUARY 2002

SAMPLE ANSWERS FOR WRITTEN RESPONSE QUESTIONS

1. a. $OCl^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HOCl_{(aq)} + OH^-_{(aq)}$

or $Ca(OCl)_{2(s)} + 2\,H_2O_{(l)} \rightleftharpoons 2\,HOCl_{(aq)} + 2\,OH^-_{(aq)} + Ca^{2+}_{(aq)}$ (**or** $Ca(OH)_{2(s)}$)

b. Equilibrium systems have no measurable macroscopic changes in system properties (e.g., pH, temperature, concentration, mass, amount of reactants or products, colour, and pressure all remain constant)

and/or

Equilibrium sytems have dynamic microscopic properties, e.g., rate of forward reaction equals rate of reverse reaction

and/or

Equilibrium sytems are closed systems, e.g. no energy or matter can enter or leave the system

c. $HPr_{(aq)} \rightarrow Pr^-_{(aq)}$

yellow red

6.6 8.0

i) The solution with the indicator in yellow form indicates that the pH is less than 6.6. The addition of $Na_2CO_{3(aq)}$, a base, is required to raise pH.

ii) The solution with the indicator in the red form has a pH that is above 8.0. The addition of $HCl_{(aq)}$, an acid, is required to lower the pH.

iii) The solution with the indicator in orange form indicates that the pH may be in the desired range, which is an acceptable result and need not be adjusted.

2. Energy Comparison:

$$3\,Al_{(s)} + 3\,NH_4ClO_{4(s)} \rightarrow Al_2O_{3(s)} + AlCl_{3(s)} + 3\,NO_{(g)} + 6\,H_2O_{(g)}$$

ΔH = [1 mol(–1675.7 kJ/mol) + 1 mol(–705.6 kJ/mol)
+ 3 mol(+90.2 kJ/mol) + 6 mol(–241.8 kJ/mol)]
– [3 mol(–295.3 kJ/mol)]

ΔH = –2675.6 kJ (Energy released by the solid rocket fuel is 2675.6 kJ)

$$H_{2(g)} + \tfrac{1}{2}O_{2(g)} \rightarrow H_2O_{(g)} \qquad \Delta H = -241.8\text{ kJ}$$

(Energy released by the hydrogen–oxygen fuel is 241.8 kJ)

Energy released per gram of $Al_{(s)}/NH_4ClO_{4(s)}$ fuel:

$$\frac{2\,675.6\text{ kJ}}{3\text{ mol}(26.98\text{ g/mol}) + 3\text{ mol}(117.50\text{ g/mol})} = 6.17\text{ kJ/g fuel (or 6.1729 kJ/g)}$$

Energy released per gram of hydrogen–oxygen fuel:

$$\frac{241.8\text{ kJ}}{1\text{ mol}(2.02\text{ g/mol}) + \frac{1}{2}\text{ mol}(32.00\text{ g/mol})} = 13.4\text{ kJ/g fuel (or 13.42 kJ/g)}$$

Environmental Concerns:

The solid rocket fuel:

- produces $NO_{(g)}$, which is an atmospheric pollutant and precursor to acid rain
- produces solid aluminum compounds, which are atmospheric particulates
- produces $NO_{(g)}$, which can deplete the ozone layer
- uses $Al_{(s)}$, the production of which causes environmental damage

The hydrogen–oxygen fuel:

- is more environmentally friendly because it produces $H_2O_{(g)}$.
- requires hydrogen produced directly/indirectly from fossil fuels