June 2000

Chemistry 30

Grade 12 Diploma Examination

Alberta
LEARNING

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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 is 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 scientific calculator.
- 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 and leave any unused boxes blank.**

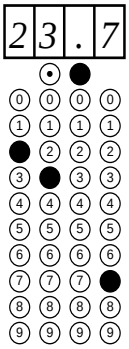
Examples

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

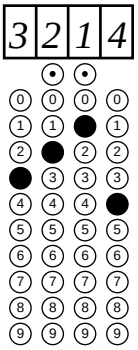
When the following subjects are arranged in alphabetical order, the order is ____ , ____ , ____ , and ____ .

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 →



Written Response

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

A basketball player comes out of the shower, still damp, feeling cooler than he did when he entered the locker room. The player feels cooler because the water on his skin is absorbing heat from his body in order to evaporate.

1. The water on the player's skin undergoes an

A. endothermic phase change
B. endothermic chemical change
C. exothermic phase change
D. exothermic chemical change

2. The human body contains about 70% water by mass. A body temperature close to 37°C is vital to survival. The property of water that allows the body to maintain an almost-constant temperature despite sudden changes in ambient temperature is its high

A. heat of fusion
B. heat of vaporization
C. specific heat capacity
D. enthalpy of formation

3. When 10.0 g of water evaporates with no change in temperature, the water will

A. release approximately 22.6 kJ of energy
B. release approximately 40.8 kJ of energy
C. absorb approximately 22.6 kJ of energy
D. absorb approximately 40.8 kJ of energy

Body chemistry involves a number of chemical systems that are critically dependent on pH, buffering action, and concentration of gas solutes such as $CO_{2(g)}$ and $O_{2(g)}$.

4. The function of chemical buffers in the blood is to

A. control all reactions

B. act as catalysts to increase the rate of reaction

C. withstand the continual addition of acid or base

D. maintain a constant pH when a small amount of acid or base is added

5. One of the buffers present in blood is

A. $HSO_3^-{}_{(aq)} - H_2SO_{3(aq)}$

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

C. $NO_3^-{}_{(aq)} - HNO_{3(aq)}$

D. $Cl^-{}_{(aq)} - HCl_{(aq)}$

Use the following information to answer the next question.

Antibiotics formed by different species of the genus of bacteria *Penicillium* are among the most widely prescribed drugs in the world today.

One of these antibiotics is penicillin G (benzylpenicillinic acid), which is represented as $HPn_{(s)}$. This acid is only slightly soluble in water. The saturated aqueous solution is represented by the equilibrium

$$H_2O_{(l)} + HPn_{(s)} \rightleftharpoons H_3O^+_{(aq)} + Pn^-_{(aq)}$$

6. This system is at equilibrium when the rate of formation of $Pn^-_{(aq)}$ in the forward reaction is

A. favoured over the rate of the formation of $HPn_{(s)}$ in the reverse reaction

B. slower than the rate of the formation of $HPn_{(s)}$ in the reverse reaction

C. faster than the rate of the formation of $HPn_{(s)}$ in the reverse reaction

D. equal to the rate of the formation of $HPn_{(s)}$ in the reverse reaction

---

Numerical Response

1. In organisms, the reaction of sucrose and oxygen produces carbon dioxide, water, and energy. The energy available may be estimated using the reaction for the combustion of sucrose:

$$C_{12}H_{22}O_{11(aq)} + 12\,O_{2(g)} \rightarrow 12\,CO_{2(g)} + 11\,H_2O_{(l)} + 5\,640.3\ kJ$$

The quantity of energy available when 1.00 g of sucrose reacts is _____ kJ.

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

---

7. A redox reaction in which carbon is reduced is

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

B. $HCO_3^-{}_{(aq)} + H_3O^+_{(aq)} \rightarrow H_2CO_{3(aq)} + H_2O_{(g)}$

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

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

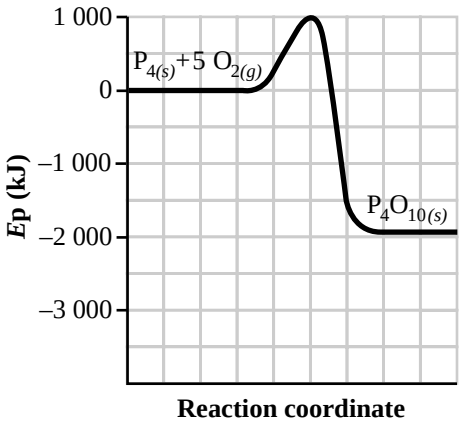
Numerical Response

2. Liquid mercury is used in many thermometers because it has a relatively low freezing point and a relatively high boiling point. A particular mercury thermometer contains 3.21 g of mercury. When the thermometer reading changes from 17.3°C to 101.2°C, the mercury has absorbed _____ J of energy.

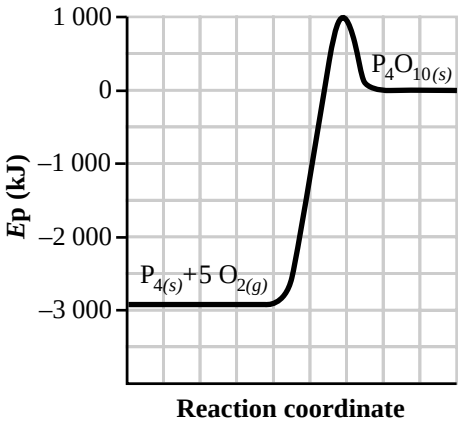
(Record your **three-digit answer** in the numerical-response section on the answer sheet.)

8. When phosphorus, $P_{4(s)}$, is exposed to air, it ignites spontaneously and rapidly releases 2 940 kJ/mol. Which of the following potential energy diagrams best represents this reaction?

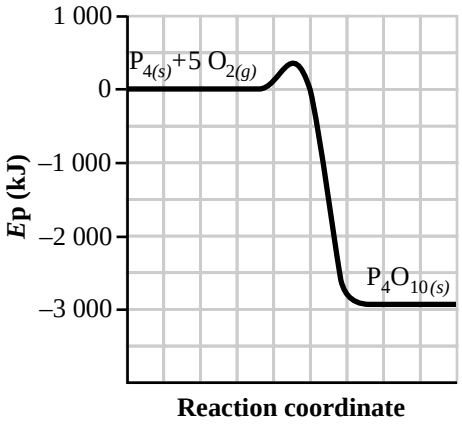
A.



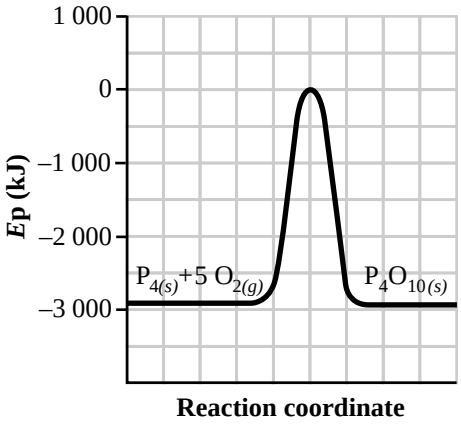
B.



C.



D.



9. A substance undergoes a change that causes the temperature of its surroundings to increase. The temperature of the substance does not change. This occurs as the

A. substance melts at its freezing point

B. substance condenses at its boiling point

C. kinetic energy of the substance decreases

D. potential energy of the substance increases

Superphénix, a nuclear "breeder" reactor in Lyon, France, was shut down for repair in the late 1980s after a liquid sodium leak. The liquid sodium was used as a coolant in the reactor.

10. The liquid sodium used in the reactor can be produced by the electrolysis of molten $NaCl_{(l)}$. During this electrolysis,

A. sodium ions are reduced at the anode

B. oxygen gas is produced at the cathode

C. chloride ions migrate toward the anode

D. the pH around the cathode increases

11. The equation representing a nuclear change in a breeder reactor is

A. $U_{(s)} + 3\,F_{2(g)} \rightarrow UF_{6(s)}$

B. $^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{94}Pu + 2\,{}^{0}_{-1}e$

C. $Na_{(s)} \rightarrow Na_{(l)}$

D. $NaNO_{3(s)} \rightarrow Na^{+}_{(aq)} + NO_3^{-}{}_{(aq)}$

Use the following information to answer the next question.

Reaction Equations

1 $6\,C_{(s)} + 6\,H_{2(g)} + 3\,O_{2(g)} \rightarrow C_6H_{12}O_{6(s)}$

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

3 $6\,CO_{2(g)} + 6\,H_2O_{(g)} \rightarrow C_6H_{12}O_{6(aq)} + 6\,O_{2(g)}$

4 $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{137}_{52}Te + {}^{97}_{40}Zr + 2\,{}^{1}_{0}n$

Numerical Response

3. Identify the equation, as numbered above, that represents each of the reaction types listed below.

Nuclear fusion _____ (Record in the **first** column)

Nuclear fission _____ (Record in the **second** column)

Photosynthesis _____ (Record in the **third** column)

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

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

Numerical Response

4. When the redox reaction

$$\_\_ H_2O_{(l)} + \_\_ NO_2^-{}_{(aq)} + \_\_ Al_{(s)} \rightarrow \_\_ NH_{3(g)} + \_\_ AlO_2^-{}_{(aq)} + \_\_ H^+{}_{(aq)}$$

is balanced using lowest whole number coefficients, the coefficient of

$H_2O_{(l)}$ is _____ (Record in the **first** column)

$NO_2^-{}_{(aq)}$ is _____ (Record in the **second** column)

$Al_{(s)}$ is _____ (Record in the **third** column)

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

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

Leaching technology is used in the mining and refining of copper ore. In the first step of the leaching process, sulphuric acid flows through a copper ore deposit. Under ideal conditions, the copper metal in the ore reacts with the concentrated sulphuric acid to form copper(II) ions. The resulting copper(II) slurry is transferred to an electrolytic cell where pure copper is produced. (Assume that the sulphuric acid completely ionizes to hydrogen ions and sulphate ions.)

12. A non-spontaneous reaction may occur if the concentrations are manipulated. The balanced net ionic equation for the reaction of copper metal with sulphuric acid under these ideal conditions is

A. $Cu_{(s)} + SO_4^{2-}{}_{(aq)} + 4\,H^+_{(aq)} \rightarrow Cu^{2+}_{(aq)} + H_2SO_{3(aq)} + H_2O_{(l)}$

B. $Cu^{2+}_{(aq)} + H_2S_{(aq)} \rightarrow Cu_{(s)} + 2\,H^+_{(aq)} + S_{(s)}$

C. $Cu_{(s)} + H_2S_{(aq)} \rightarrow Cu^{2+}_{(aq)} + H_{2(g)} + S^{2-}_{(aq)}$

D. $Cu_{(s)} + 2\,H^+_{(aq)} \rightarrow Cu^{2+}_{(aq)} + H_{2(g)}$

13. What mass of pure copper is produced from the electrolysis of excess copper(II) ions over a 24.0 h period when the cell is operated at 100 A?

A. 2.84 kg

B. 5.69 kg

C. 11.4 kg

D. 549 kg

14. The net ionic equation for the conversion of copper(II) oxide in copper ore is

$$CuO_{(s)} + 2\,H^+_{(aq)} \rightarrow Cu^{2+}_{(aq)} + H_2O_{(l)}$$

The copper in the copper(II) oxide is

A. reduced

B. oxidized

C. the oxidizing agent

D. neither oxidized nor reduced

Use the following information to answer the next two questions.

In order to "hide" gold during the Second World War, Nobel Prize winner Neils Bohr "dissolved" the gold, stored it in a solution, and recovered it at the end of the war.

One way to "dissolve" gold is to react it with *Aqua-Regia*, a mixture of nitric and hydrochloric acids. The unbalanced equation for this reaction is

$$Au_{(s)} + HNO_{3(aq)} + HCl_{(aq)} \rightarrow HAuCl_{4(aq)} + H_2O_{(l)} + NO_{2(g)}$$

15. The atom that undergoes reduction in this reaction is

A. Au
B. H
C. N
D. Cl

16. When this equation is balanced using lowest whole number coefficients, the coefficient for nitric acid is

A. 2
B. 3
C. 4
D. 5

Use the following information to answer the next question.

ICCP (Impressed Current Cathodic Protection) is a corrosion prevention technique that is used to protect buried metal structures. A low-voltage current (electron flow) is applied to the buried metal structure such that only reduction reactions can occur at its surface.

Numerical Response

5. The ground water surrounding the buried metal structure may contain the following ions.

1 $Pb^{2+}_{(aq)}$
2 $Fe^{2+}_{(aq)}$
3 $Fe^{3+}_{(aq)}$
4 $Cd^{2+}_{(aq)}$

The order in which these ions are reduced on the surface of the metal structure is _____ , _____ , _____ and _____ .

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

---

17. The chemical reaction in which a single species is both oxidized and reduced is known as disproportionation. An example of this type of reaction is

A. $2\,NH_{3(aq)} + NaOCl_{(aq)} \rightarrow N_2H_{4(aq)} + NaCl_{(aq)} + H_2O_{(l)}$

B. $Cl_{2(aq)} + H_2O_{(l)} \rightarrow HOCl_{(aq)} + H^+_{(aq)} + Cl^-_{(aq)}$

C. $2\,F_{2(g)} + O_{2(g)} \rightarrow 2\,OF_{2(g)}$

D. $2\,Na_{(s)} + I_{2(s)} \rightarrow 2\,NaI_{(s)}$

18. In the Hall–Heroult process, aluminum is produced by the electrolysis of molten $Al_2O_{3(l)}$. The half-reactions that occur are:

$$C_{(s)} + 2\,O^{2-}_{(l)} \rightarrow CO_{2(g)} + 4\,e^-$$

$$Al^{3+}_{(l)} + 3\,e^- \rightarrow Al_{(l)}$$

The mass of $Al_{(l)}$ produced for each 1.00 kg of $C_{(s)}$ consumed is

A. 1.69 kg

B. 2.45 kg

C. 3.00 kg

D. 6.00 kg

Use the following information to answer the next question.

The sodium metal in television picture tubes reacts with oxygen that would otherwise oxidize the tungsten and phosphorus found in the tubes. Tungsten and phosphorus are vital to the function of the picture tubes.

Numerical Response

6. The mass of sodium that will react when 0.350 mol of electrons is transferred is _____ g.

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

When a car is started, the starter motor draws a current from the battery.
The battery recharges while the car is running.

19. Before the car is started, the battery's chemical energy is in the form of

A. kinetic energy
B. potential energy
C. vibrational energy
D. translational energy

20. A car is started and then left running to recharge the battery. In these two processes, the battery

A. acts as an electrolytic cell only
B. acts as a voltaic cell only
C. first acts as an electrolytic cell, then as a voltaic cell
D. first acts as a voltaic cell, then as an electrolytic cell

21. An automotive student obtained 500 mL of acid from a car battery. The student poured 50 mL of the acid into beaker I, 100 mL into beaker II, and then conducted several tests. In this investigation, the student determined that

A. both solutions conducted an electric current equally
B. there was a lower $[H_3O^+_{(aq)}]$ in beaker I than in beaker II
C. magnesium metal reacted more quickly in beaker I than in beaker II
D. one drop of methyl red produced a deeper red in beaker II than in beaker I

Use the following information to answer the next question.

A particular voltaic cell is represented by

$$Ag_{(s)} / Ag^{+}_{(aq)} \;//\; Cr_2O_7^{2-}{}_{(aq)}, Cr^{3+}_{(aq)}, H^{+}_{(aq)} / C_{(s)}$$

22. The net ionic equation for this voltaic cell is

A. $6\,Ag_{(s)} + Cr_2O_7^{2-}{}_{(aq)} + 14\,H^{+}_{(aq)} \rightarrow 6\,Ag^{+}_{(aq)} + 2\,Cr^{3+}_{(aq)} + 7\,H_2O_{(l)}$

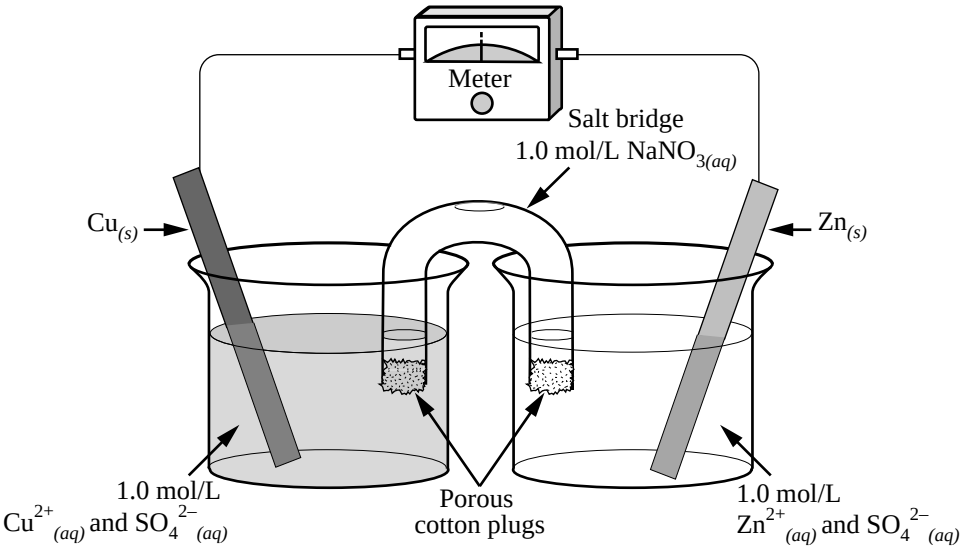
B. $6\,Ag^{+}_{(aq)} + Cr_2O_7^{2-}{}_{(aq)} + 14\,H^{+}_{(aq)} \rightarrow 6\,Ag_{(s)} + 2\,Cr^{3+}_{(aq)} + 7\,H_2O_{(l)}$

C. $Ag^{+}_{(aq)} + Cr_2O_7^{2-}{}_{(aq)} + 14\,H^{+}_{(aq)} \rightarrow Ag_{(s)} + 2\,Cr^{3+}_{(aq)} + 7\,H_2O_{(l)}$

D. $Ag_{(s)} + Cr_2O_7^{2-}{}_{(aq)} + 14\,H^{+}_{(aq)} \rightarrow Ag^{+}_{(aq)} + 2\,Cr^{3+}_{(aq)} + 7\,H_2O_{(l)}$

Use the following information to answer the next question.

An Electrochemical Cell



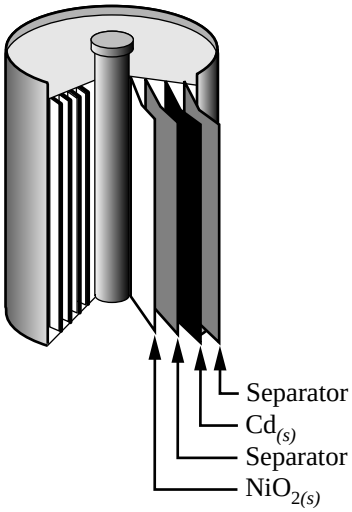
Numerical Response

7. A student attempted to replicate a traditional Daniell Cell by setting up the electrochemical cell shown above. Under standard conditions, the electrical potential of the cell should be +/– _____ V.

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

Use the following information to answer the next two questions.

Voltaic cells are used as portable sources of electrical energy. One common cell is the rechargeable nickel–cadmium cell.



The equation representing the discharge of this cell is

$$NiO_{2(s)} + Cd_{(s)} + 2\,H_2O_{(l)} \rightarrow Cd(OH)_{2(s)} + Ni(OH)_{2(s)}$$

23. The oxidation half-reaction for the discharge of this cell is

A. $Cd_{(s)} + 2\,OH^-_{(aq)} \rightarrow Cd(OH)_{2(s)} + 2\,e^-$

B. $NiO_{2(s)} + 2\,H_2O_{(l)} + 2\,e^- \rightarrow Ni(OH)_{2(s)} + 2\,OH^-_{(aq)}$

C. $NiO_{2(s)} + 2\,H_2O_{(l)} \rightarrow Ni(OH)_{2(s)} + 2\,OH^-_{(aq)} + 2\,e^-$

D. $Cd_{(s)} + 2\,OH^-_{(aq)} + 2\,e^- \rightarrow Cd(OH)_{2(s)}$

24. In this system, the strongest oxidizing agent is

A. $NiO_{2(s)}$

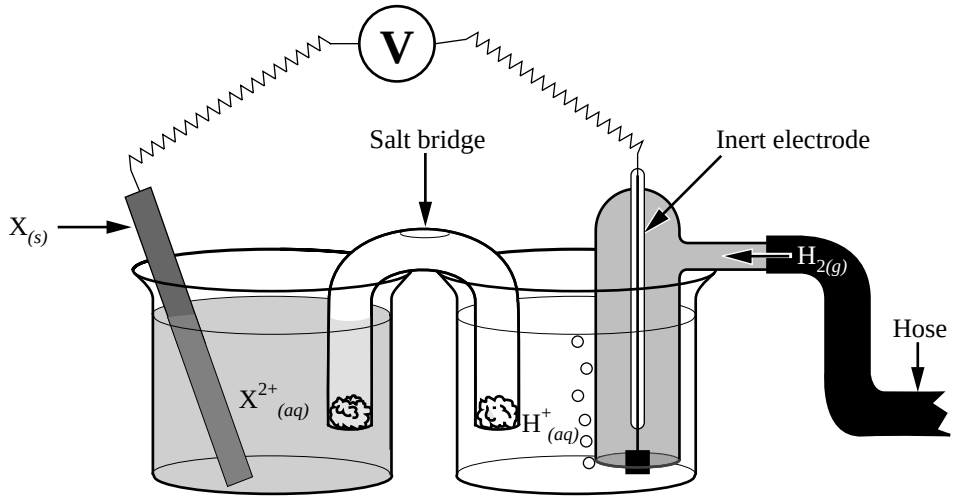
B. $Cd_{(s)}$

C. $Cd(OH)_{2(s)}$

D. $H_2O_{(l)}$

Use the following information to answer the next two questions.

Voltaic Cell



In this apparatus, the anions in the solution move from the hydrogen half-cell solution into the salt bridge and migrate toward the $X_{(s)}$ electrodes.

25. As this cell operates, electrons flow from

A. $X_{(s)}$ to the inert electrode and the pH in the hydrogen half-cell increases

B. $X_{(s)}$ to the inert electrode and the pH in the hydrogen half-cell decreases

C. the inert electrode to $X_{(s)}$ and the pH in the hydrogen half-cell increases

D. the inert electrode to $X_{(s)}$ and the pH in the hydrogen half-cell decreases

26. If the voltmeter reads +0.45 V under standard conditions, then $X_{(s)}$ is most likely

A. $Ni_{(s)}$

B. $Fe_{(s)}$

C. $Zn_{(s)}$

D. $Mg_{(s)}$

Fuel cells used to power electric vehicles are high-efficiency voltaic cells that consume conventional fuels under conditions of controlled combustion. The half-reactions that occur in a propane–oxygen fuel cell are

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

$$C_3H_{8(g)} + 6\,H_2O_{(l)} \rightarrow 3\,CO_{2(g)} + 20\,H^{+}_{(aq)} + 20\,e^{-}$$

27. The balanced net equation and the predicted energy released per mole of propane consumed for this fuel cell are, respectively,

A. $C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(l)}$ $\Delta H = -2\,219.9$ kJ

B. $C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(l)}$ $\Delta H = -103.8$ kJ

C. $C_3H_{8(g)} + 5\,O_{2(g)} \rightarrow 3\,CO_{2(g)} + 4\,H_2O_{(l)}$ $\Delta H = -2\,043.9$ kJ

D. $C_3H_{8(g)} + O_{2(g)} + 4\,H_2O_{(l)} \rightarrow 3\,CO_{2(g)} + 16\,H^{+}_{(aq)} + 16\,e^{-}$ $\Delta H = +66.5$ kJ

Use the following information to answer the next question.

During the operation of a propane–oxygen fuel cell, 15.7 g of gas are consumed at the anode.

28. The number of moles of gas consumed is

A. 9.981 mol

B. 0.693 mol

C. 0.491 mol

D. 0.356 mol

29. The combustion of propane and cellular respiration are similar processes. The reactions that occur in both processes are

A. exothermic, and carbon is reduced

B. exothermic, and carbon is oxidized

C. endothermic, and carbon is reduced

D. endothermic, and carbon is oxidized

30. The substance in the propane–oxygen fuel cell that has a standard heat of formation of zero is

A. $O_{2(g)}$

B. $CO_{2(g)}$

C. $H_2O_{(l)}$

D. $C_3H_{8(g)}$

31. Many scientists believe that the most significant problem caused by $CO_{2(g)}$ emissions is

A. metal corrosion

B. the biomagnification of toxins

C. the destruction of the ozone layer

D. its contribution to the greenhouse effect

Methanoic (formic) acid is the irritant secreted during an ant bite. The irritation is partially due to the ionization of methanoic acid. The equilibrium equation for the ionization can be represented as

$$HCOOH_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + HCOO^-_{(aq)}$$

32. Which of the substances in the equation above could function as an amphiprotic species?

A. $H_2O_{(l)}$ and $H_3O^+_{(aq)}$

B. $H_2O_{(l)}$

C. $H_3O^+_{(aq)}$ and $HCOO^-_{(aq)}$

D. $H_2O_{(l)}$, $H_3O^+_{(aq)}$, and $HCOO^-_{(aq)}$

33. In a comparison of the species present in $HCOOH_{(aq)}$, the

A. $[H_3O^+_{(aq)}]$ is greater than $[HCOOH_{(aq)}]$

B. $[H_3O^+_{(aq)}]$ is equal to $[HCOOH_{(aq)}]$

C. $[HCOOH_{(aq)}]$ is greater than $[HCOO^-_{(aq)}]$

D. $[HCOOH_{(aq)}]$ is equal to $[HCOO^-_{(aq)}]$

34. When a 0.100 mol/L $HCOOH_{(aq)}$ is titrated with 0.100 mol/L $NaOH_{(aq)}$, an appropriate choice of indicator for this titration is

A. orange IV

B. cresol red

C. methyl red

D. indigo carmine

35. The $[OH^-_{(aq)}]$ in 0.10 mol/L $NaHCOO_{(aq)}$ is

A. 1.3×10^{-2} mol/L

B. 4.2×10^{-3} mol/L

C. 2.4×10^{-6} mol/L

D. 7.5×10^{-6} mol/L

*Use your recorded answer from **Multiple Choice 35** to answer **Numerical Response 8**.**

Numerical Response

8. The pH of 0.10 mol/L $NaHCOO_{(aq)}$ is _____ .

(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.**

36. Methanoic acid slowly decomposes to form $CO_{(g)}$ and $H_2O_{(l)}$. The rate of reaction is increased if a catalyst is present. Compared with the uncatalyzed reaction, the catalyzed reaction has

A. the same K_{eq}

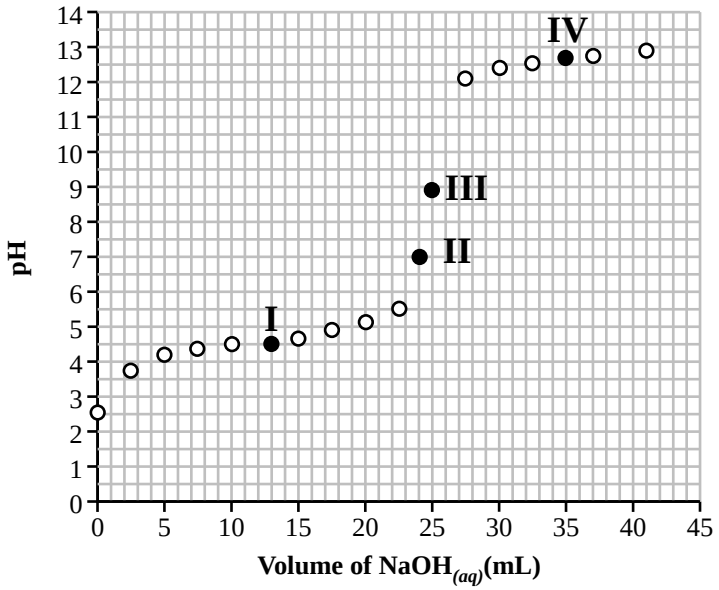
B. a larger K_{eq}

C. a smaller ΔH

D. a larger ΔH

Ethanoic acid (vinegar) has a variety of uses. To ensure that production plants meet concentration specifications, technicians monitor the concentration of the acid by titrating samples of the ethanoic acid as it comes off the production line.

Titration of 10.0 mL of $CH_3COOH_{(aq)}$ with 0.20 mol/L $NaOH_{(aq)}$



37. On this graph, the equivalence point is indicated by Roman numeral

A. I

B. II

C. III

D. IV

*Use your recorded answer from **Multiple Choice 37** to answer **Numerical Response 9**.**

Numerical Response

9. The concentration of this ethanoic acid sample is _____ mol/L.

(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 your recorded answer from **Multiple Choice 37** to answer **Multiple Choice 38**.**

38. The best indicator to use for this titration is

A. indigo carmine

B. phenolphthalein

C. bromothymol blue

D. bromocresol green

***You can receive marks for this question even if question 37 was answered incorrectly.**

Use the following information to answer the next question.

The equilibrium law expression for an industrial method of producing ethanol is

$$K_{eq} = \frac{[C_2H_5OH_{(g)}]}{[C_2H_{4(g)}][H_2O_{(g)}]}$$

Under certain conditions, the $K_{eq} = 300.0$. At equilibrium, a 5 000 L reaction vessel contains 115 mol of $C_2H_{4(g)}$ and 110 mol of $H_2O_{(g)}$.

39. Under these conditions, the equilibrium concentration of $C_2H_5OH_{(g)}$ is

A. 1.60×10^{-6} mol/L

B. 0.152 mol/L

C. 75.0 mol/L

D. 5.92×10^{5} mol/L

Use the following information to answer the next question.

A student was asked to rank the relative strength of the following four acids.

1 Formic acid ($HCOOH_{(aq)}$)

2 Hydrazoic acid ($HN_{3(aq)}$)

3 Hypobromous acid ($HOBr_{(aq)}$)

4 Nitrous acid ($HNO_{2(aq)}$)

The student was given the following information.

$HNO_{2(aq)} + HCOO^-_{(aq)} \rightleftharpoons NO_2^-{}_{(aq)} + HCOOH_{(aq)}$ (Products favoured)

$HN_{3(aq)} + OBr^-_{(aq)} \rightleftharpoons N_3^-{}_{(aq)} + HOBr_{(aq)}$ (Products favoured)

$HN_{3(aq)} + HCOO^-_{(aq)} \rightleftharpoons N_3^-{}_{(aq)} + HCOOH_{(aq)}$ (Reactants favoured)

Numerical Response

10. Based on the reaction evidence, the four acids, ranked from strongest to weakest, are _____ , _____ , _____ and _____ .

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

---

40. To completely react 50 mL of 0.10 mol/L acid, 150 mL of 0.10 mol/L $KOH_{(aq)}$ was required. The number of protons donated by each acid molecule was

A. 1

B. 2

C. 3

D. 4

Sodium hydrogen carbonate, $NaHCO_{3(s)}$ (baking soda), is used in baking. When lactic acid, $HC_3H_5O_{3(aq)}$, and baking soda are present, they cause doughs and batters to rise. Lactic acid, a component of buttermilk, has a $K_a = 1.4 \times 10^{-4}$.

41. The net ionic equation that best illustrates the reaction responsible for the dough rising is

A. $H_3O^+_{(aq)} + HCO_3^-{}_{(aq)} \rightarrow CO_{2(g)} + 2\,H_2O_{(l)}$

B. $HCO_3^-{}_{(aq)} + C_3H_5O_3^-{}_{(aq)} \rightarrow HC_3H_5O_{3(aq)} + CO_3^{2-}{}_{(aq)}$

C. $NaHCO_{3(aq)} + H_3O^+_{(aq)} \rightarrow H_2CO_{3(aq)} + H_2O_{(l)} + Na^+_{(aq)}$

D. $HCO_3^-{}_{(aq)} + HC_3H_5O_{3(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)} + C_3H_5O_3^-{}_{(aq)}$

42. The $[H_3O^+_{(aq)}]$ in 0.20 mol/L $HC_3H_5O_{3(aq)}$ is

A. 2.8×10^{-3} mol/L

B. 5.3×10^{-3} mol/L

C. 2.6×10^{-2} mol/L

D. 7.0×10^{-4} mol/L

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

Numerical Response

11. The pH of the $HC_3H_5O_{3(aq)}$ is _____ .

(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.**

The Stelco Plant in Camrose, Alberta, uses phosphoric acid to remove rust from steel pipes before they are welded. A technician is responsible for ensuring that the proper concentration of phosphoric acid is used. The technician titrated 10.00 mL of the $H_3PO_{4(aq)}$ with 0.125 mol/L $NaOH_{(aq)}$ to the second equivalence point. The technician obtained the following data.

Volume of $NaOH_{(aq)}$ Used

Trial	**1**	**2**	**3**	**4**
Final buret reading (mL)	12.8	24.1	35.5	46.7
Initial buret reading (mL)	0.7	12.8	24.1	35.5

Numerical Response

12. The average volume of sodium hydroxide required to determine the $[H_3PO_{4(aq)}]$ is _____ mL.

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

43. Based on the data gathered at the second equivalence point, the concentration of the phosphoric acid was

A. 47.1 mmol/L

B. 70.6 mmol/L

C. 141 mmol/L

D. 283 mmol/L

44. In 0.10 mol/L $H_3PO_{4(aq)}$, the species present in highest concentration is

A. $H_3PO_{4(aq)}$

B. $H_2PO_4^-{}_{(aq)}$

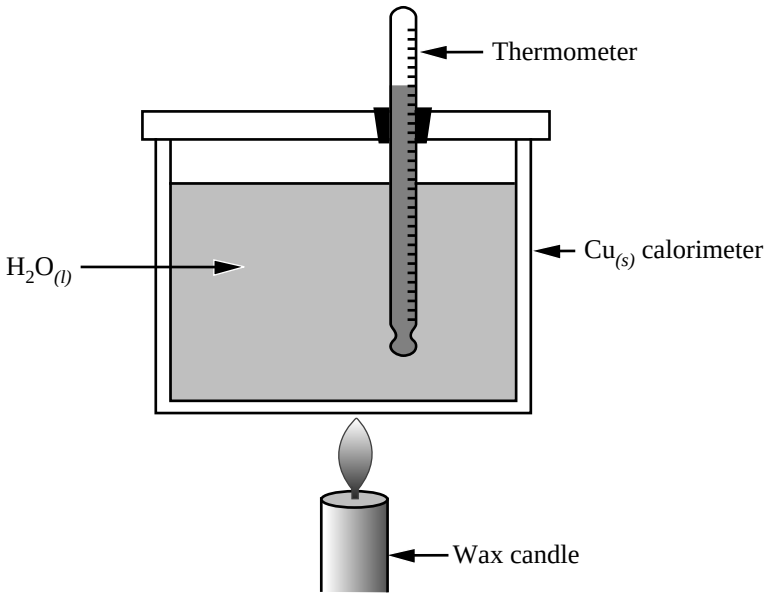
C. $HPO_4^{2-}{}_{(aq)}$

D. $H_3O^+{}_{(aq)}$

The written-response questions follow on the next page.

Written Response—15%

Use the following information to answer the next question.



The above apparatus was used to determine experimentally the molar enthalpy of the combustion of candle wax, $C_{25}H_{52(s)}$.

1. **a.** List all the measurements that must be taken in order to determine the molar enthalpy of combustion.

b. Write a mathematical equation that uses the data collected and that will allow you to determine the molar heat of combustion. Label each of the mathematical variables used in the equation.

c. Suggest two improvements to the experimental design.

Written Response—15%

2. Describe a chemical process that might have caused the changes illustrated by the two photos of the same statue.

Photograph taken early 1900s

Photograph taken after 1960

—from *The Extraordinary Chemistry of Ordinary Things*

Your response should include

- an explanation of the factors causing the changes
- appropriate chemical reactions
- ways in which society addresses the problem

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

Credit

Page 28 Photographs from *The Extraordinary Chemistry of Ordinary Things* (John Wiley & Sons, Inc., 1992). Reprinted by permission of Westfälisches Amt für Denkmalpflege, Münster/Germany.

Tear-out Page

No marks will be given for work done on this page.

Fold and tear along perforation.

Multiple Choice

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

Numerical Response

1.	16.5	**7.**	1.10
2.	37.2	**8.**	8.38 or 8.37*
3.	2431	**9.**	0.50[†]
4.	2121	**10.**	4123
5.	3142	**11.**	2.28[§]
6.	8.05	**12.**	11.3

*If MC 35 was A, then NR 8 is 12.1
B, then NR 8 is 11.6
C, then NR 8 is 8.38 or 8.37*
D, then NR 8 is 8.87, 8.88

[†]If MC 37 was A, then NR 9 is 0.26
B, then NR 9 is 0.48
C, then NR 9 is 0.50[†]
D, then NR 9 is 0.70

[‡]If MC 37 was A, then MC 38 is D
B, then MC 38 is C
C, then MC 38 is B[‡]
D, then MC 38 is A

[§]If MC 42 was A, then NR 11 is 2.55
B, then NR 11 is 2.28[§]
C, then NR 11 is 1.59
D, then NR 11 is 3.15

SAMPLE ANSWER KEY FOR WRITTEN-RESPONSE QUESTIONS

The samples that follow represents only one valid approach to each of the problems. During the diploma examination marking session, provision is made for considering various approaches the student may have used.

1. *Measurements*
   - mass or volume of water
   - mass of $Cu_{(s)}$ calorimeter
   - initial temperature of water
   - highest temperature of water
   - initial mass of candle
   - final mass of candle

Heat produced by combustion = heat absorbed by water + heat absorbed by calorimeter

$nH = mc\Delta t + mc\Delta t$

n = moles of wax burned (m/M)
H = molar enthalpy of combustion
m = mass of water/copper
c = specific heat capacity of water/copper
Δt = temperature change of water/copper

Improvements for product materials:
- use of a bomb calorimeter
- protect the flame from air currents (e.g., surround it with a cylinder)
- include m and c for thermometer
- place in center of calorimeter
- insulate calorimeter/ use stirrer
- t_i is as many °C below room temp. as t_f above room temp.
- do several trials
- calorimeter that conducts heat better than copper

2. **Factors Causing the Changes:**
The photos illustrate the damage that is caused by air pollutants, specifically acid rain. The burning of fossil fuels in industry and transportation creates a variety of oxides such as $NO_{2(g)}$, $CO_{2(g)}$, and $SO_{2(g)}$. These oxides react with water in the air to form acids such as $HNO_{3(aq)}$, $H_2SO_{4(aq)}$, $H_2CO_{3(aq)}$, etc. These acids are flushed from the atmosphere by rain and snow, etc., thus coming in contact with stone building materials such as limestone $CaCO_{3(s)}$.

Possible Reactions:

$$H_2SO_{4(aq)} + CaCO_{3(s)} \rightarrow SO_4{}^{2-}{}_{(aq)} + CO_{2(g)} + H_2O_{(l)} + Ca^{2+}{}_{(aq)}$$

$$2\,HNO_{3(aq)} + CaCO_{3(s)} \rightarrow 2\,NO_3{}^{-}{}_{(aq)} + H_2O_{(l)} + CO_{2(g)} + Ca^{2+}{}_{(aq)}$$

This neutralization process between the acid rain and the limestone gradually breaks down the stone structure. If one considers the statue to be made of metal, then a possible reaction between acid rain and the statue is

$$O_{2(g)} + 4\,H^{+}{}_{(aq)} + 2\,Fe_{(s)} \rightarrow 2\,Fe^{2+}{}_{(aq)} + 2\,H_2O_{(l)}$$

Ways to Address the Problem:
Governments have reacted to the damages caused by acid rain, by imposing tighter regulations on emissions from automobiles and factories. They also encourage use of rapid transit to reduce vehicle emissions in cities. Industry and government are researching alternate energy sources to replace fossil fuel combustion.

or

To reduce corrosion of the statue, it could be painted or covered to reduce exposure from the elements. Perhaps statues in the future could be made of inert materials.