January 2001

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 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. **NEW**
- You are expected to have cleared your calculator of all information that is stored in the programmable or parametric memory. **NEW**
- 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.**

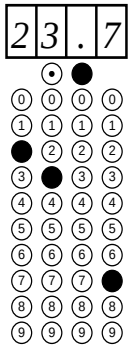
Examples

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

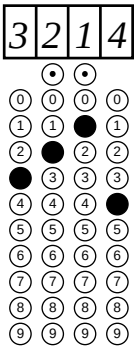
When the following subjects are arranged in alphabetical order, the order is ____ , ____ , ____ , and ____ .

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.

1. Which of the following processes requires the **least** energy per mole?

A. Helium forming hydrogen
B. Ice at 0°C forming liquid water
C. Liquid water at 100°C forming steam
D. Water forming hydrogen and oxygen gas

2. Which of the following processes is always endothermic?

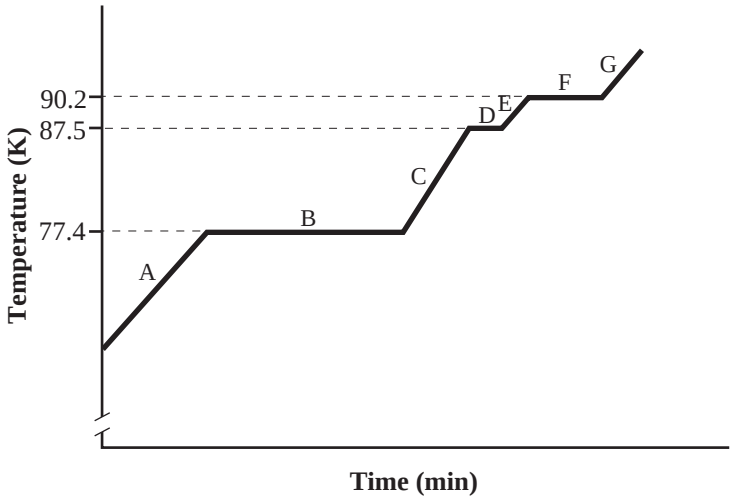
A. Neutralization
B. Photosynthesis
C. Oxidation
D. Reduction

3. Nuclear reactions involve greater enthalpy changes than chemical reactions because

A. nuclear forces are stronger than chemical bonds
B. nuclear explosions are more energetic than chemical explosions
C. nuclear reactions involve different elements than chemical reactions
D. nuclear reactions involve elements with larger atomic numbers than chemical reactions

Use the following information to answer the next question.

Sketch of a Heating Curve for the Distillation of Liquid Air



Through careful distillation, the three main components of liquid air can be separated. Their respective boiling points are

nitrogen	77.4 K
argon	87.5 K
oxygen	90.2 K

4. Which of the following statements about the above graph is true?

A. Sections A, C, E, and G represent changes in potential energy.

B. Sections A, C, and E represent the vaporization of each component of liquid air.

C. Sections B, D, and F represent the vaporization of each component of liquid air.

D. Section B represents melting, section D represents vaporization, and section F represents sublimation.

Use the following information to answer the next question.

One theory to explain firewalking, the ability to walk barefoot across red-hot coals unscathed, is based on the insulating quality of steam formed between the coals and the underside of the firewalker's perspiring feet.

—from *Chemistry, 3rd Edition*, 1993

5. According to this theory, water molecules in perspiration gain

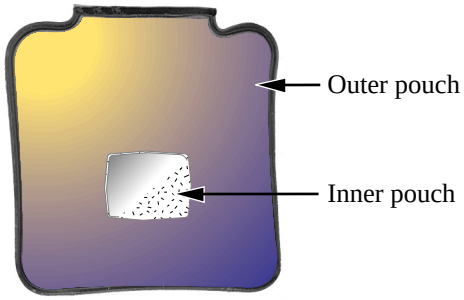
A. vibrational energy as they warm up and translational energy as they vaporize

B. vibrational energy and rotational energy as they warm up and translational energy as they vaporize

C. potential energy as they warm up and vibrational, rotational, and translational energy as they vaporize

D. vibrational, rotational, and translational energy as they warm up and potential energy as they vaporize

Commercially available “cold packs” and “hot packs” contain an inner pouch of a solid ionic compound within an outer pouch containing water. When the inner pouch is broken, the solid dissolves in the water of the outer pouch. When ammonium nitrate dissolves, the water temperature decreases; whereas, when calcium chloride dissolves, the water temperature increases.



6. Based on this information, a student determined that a hot pack could contain

A. calcium chloride, which undergoes an exothermic dissolving process

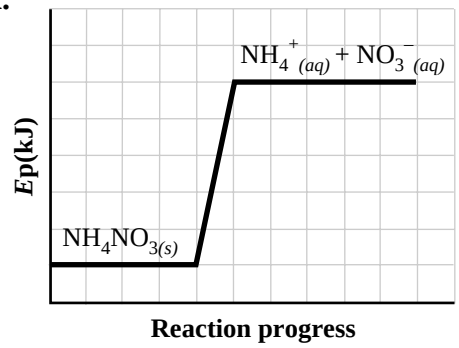
B. calcium chloride, which undergoes an endothermic dissolving process

C. ammonium nitrate, which undergoes an exothermic dissolving process

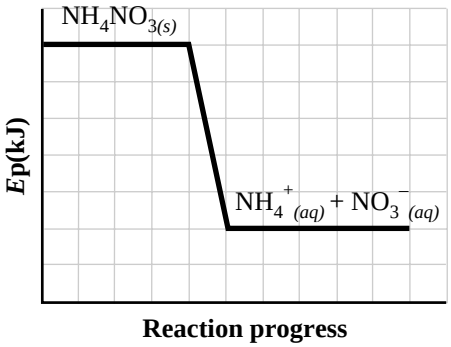
D. ammonium nitrate, which undergoes an endothermic dissolving process

7. Which of the following diagrams represents the heat of solution for either a cold pack or a hot pack?

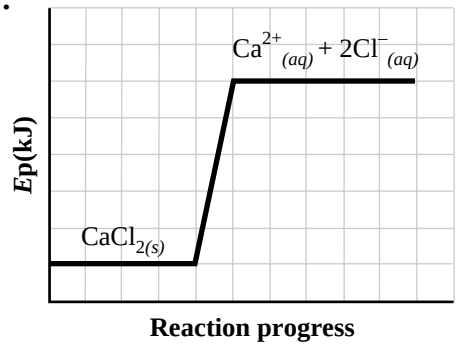
A.



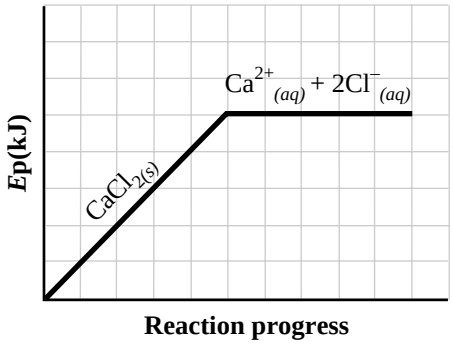
B.



C.



D.



8. When ammonium nitrate dissolves in water, the resulting solution will be

A. basic

B. acidic

C. neutral

D. a non-electrolyte

Use the following information to answer the next question.

A student comparing cellular respiration and hydrocarbon combustion reactions made the following statements.

I In both reactions, C–H bonds break and C=O bonds form.

II Combustion is exothermic, and cellular respiration is endothermic.

III Both reactions are examples of redox reactions.

9. The student's correct statements were

A. I and II

B. I and III

C. II and III

D. I, II, and III

Use the following information to answer the next question.

Standard Heats of Formation

Substance	ΔH_f° (kJ/mol)
X	–22.5
Y	+78.3
Z	–54.8

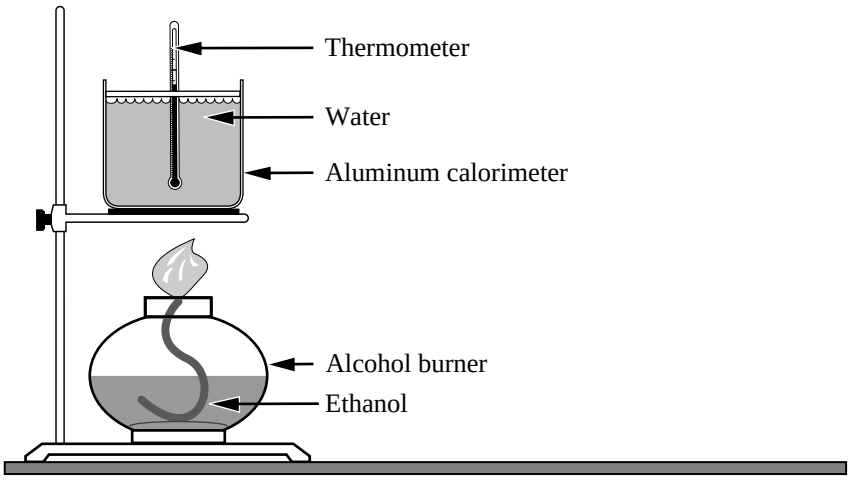
Given: $X + 3Y \rightleftharpoons 2Z + 2W$ $\quad \Delta H = -562.0$ kJ

10. The standard molar heat of formation of substance W is

A. + 442.0 kJ/mol
B. – 120.0 kJ/mol
C. – 240.0 kJ/mol
D. – 451.4 kJ/mol

Ethanol, $C_2H_5OH_{(l)}$, is a very versatile compound that has applications in the fuel, chemical, and pharmaceutical industries. Some properties of ethanol can be studied in the lab by applying thermodynamic principles.

A student assembled the apparatus shown below in order to determine the molar heat of combustion of ethanol.



11. The balanced equation and the appropriate enthalpy change for the combustion of ethanol are

A. $C_2H_5OH_{(l)} + 3\,O_{2(g)} \rightarrow 2\,CO_{2(g)} + 3\,H_2O_{(g)}$ $\Delta H = +1235.3$ kJ

B. $C_2H_5OH_{(l)} + O_{2(g)} \rightarrow CO_{2(g)} + 3\,H_2O_{(l)}$ $\Delta H = -1235.3$ kJ

C. $C_2H_5OH_{(l)} + 3\,O_{2(g)} \rightarrow 2\,CO_{2(g)} + 3\,H_2O_{(g)}$ $\Delta H = -1235.3$ kJ

D. $C_2H_5OH_{(l)} \rightarrow C_{(s)} + 3\,H_{2(g)} + \frac{1}{2}O_{2(g)}$ $\Delta H = +1235.3$ kJ

Use the following information to answer the next question.

Calorimetric Data

1 maximum temperature change of water
2 mass of aluminum calorimeter
3 mass of aluminum calorimeter and water
4 initial temperature of aluminum calorimeter
5 maximum temperature change of ethanol
6 mass change of ethanol

Numerical Response

1. The data required to determine the molar heat of combustion for ethanol, listed in numerical order, are _____ , _____ , _____ , and _____ .

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

Numerical Response

2. In an experiment, a student heated 500 g of water from 25.0°C to 91.0°C using 0.133 mol of ethanol. If it is assumed that all the heat energy was absorbed by the calorimeter water, the experimental molar enthalpy of combustion for ethanol was +/–_____ MJ/mol.

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

12. The thermochemical equation that represents the molar enthalpy of formation for ethanol is

A. $C_2H_5OH_{(l)} + 277.1\ kJ \rightarrow 2\,C_{(s)} + 3\,H_{2(g)} + \frac{1}{2}O_{2(g)}$

B. $C_2H_5OH_{(l)} + 3\,O_{2(g)} \rightarrow 2\,CO_{2(g)} + 3\,H_2O_{(g)} + 1235.3\ kJ$

C. $2\,C_{(s)} + 3\,H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow C_2H_5OH_{(l)} + 277.1\ kJ$

D. $C_2H_5OH_{(l)} + H_2O_{(l)} \rightleftharpoons C_2H_5O^-_{(aq)} + H_3O^+_{(aq)} \qquad K = 1.3 \times 10^{-16}$

Use the following information to answer the next two questions.

Commercial drain cleaners typically contain sodium hydroxide and aluminum. When the solid cleaner is poured down the drain and water is added, the reaction that occurs is represented by the equation

$$2\,NaOH_{(s)} + 2\,Al_{(s)} + 2\,H_2O_{(l)} \rightarrow 2\,NaAlO_{2(aq)} + 3\,H_{2(g)} \qquad \Delta H = -850.0\ kJ$$

13. In this reaction, the oxidation number of aluminum changes from

A. 0 to +1

B. 0 to +3

C. +2 to +6

D. +3 to +6

Numerical Response

3. In the production of 4.00 mol of $NaAlO_{2(aq)}$, the heat released is _____ MJ.

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

14. In a chemistry experiment, 12 g of $(NH_4)_2SO_{4(s)}$ was dissolved in 120 mL of water in a simple calorimeter. A temperature change from 20.2°C to 17.8°C was observed. The experimental molar enthalpy of solution for ammonium sulphate was

A. –13 kJ/mol

B. –1.2 kJ/mol

C. +1.2 kJ/mol

D. +13 kJ/mol

15. How much heat is produced when 1.00 g of butane in a disposable lighter is completely burned to form gaseous carbon dioxide and water vapour?

A. 45.7 kJ

B. 124.7 kJ

C. 2 656.5 kJ

D. 5 313.0 kJ

Numerical Response

4. Canadian five-cent coins (nickels) minted prior to 1982 were made of pure nickel; therefore, they exhibit a type of magnetism called ferromagnetism. If these nickels are heated to 375°C, they will lose their ferromagnetic properties. The energy required to heat a 2.03 g nickel from 25.0°C to 375°C, in scientific notation, is _____ $\times 10^2$ J.

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

At the Banff Wastewater Treatment plant, bacteria are used to treat organic "sludge" $(CH_2O)_{n(s)}$ in a process called autothermal thermophilic aerobic digestion (ATAD). The digestion of the sludge can be represented by the equation

$$(CH_2O)_{n(s)} + n\,O_{2(g)} \xrightarrow{\text{bacteria}} n\,CO_{2(g)} + n\,H_2O_{(l)} + \text{energy}$$

16. At the treatment plant, the enzymes in the bacteria act as

A. buffers
B. reducing agents
C. oxidizing agents
D. biological catalysts

17. The ATAD process is

A. a reduction
B. exothermic
C. endothermic
D. an acid–base reaction

18. During the digestion process, the carbon in the sludge is

A. reduced
B. oxidized
C. amphoteric
D. precipitated

19. A 10.0 mL sample of domestic sewage has an effluent pH of 6.80. After this sewage has been treated, the effluent pH is 7.00. The change in hydronium ion concentration is

A. 0.63 mol/L

B. 0.20 mol/L

C. 2.0×10^{-2} mol/L

D. 5.8×10^{-8} mol/L

Use the following information to answer the next question.

$$U^{3+}_{(aq)} + La_{(s)} \rightarrow La^{3+}_{(aq)} + U_{(s)}$$

$$Y^{3+}_{(aq)} + U_{(s)} \rightarrow \text{no reaction}$$

$$Y^{3+}_{(aq)} + La_{(s)} \rightarrow La^{3+}_{(aq)} + Y_{(s)}$$

20. The oxidizing agents above, listed from strongest to weakest, are

A. $U^{3+}_{(aq)}$, $La^{3+}_{(aq)}$, $Y^{3+}_{(aq)}$

B. $U^{3+}_{(aq)}$, $Y^{3+}_{(aq)}$, $La^{3+}_{(aq)}$

C. $Y^{3+}_{(aq)}$, $U^{3+}_{(aq)}$, $La^{3+}_{(aq)}$

D. $U_{(s)}$, $Y_{(s)}$, $La_{(s)}$

Use the following information to answer the next question.

An acidic solution of nickel(II) nitrate is poured into a tin container.

Chemical Changes

1 does not react
2 is oxidized
3 is reduced
4 reacts but there is no change in its oxidation number

Numerical Response

5. Match each of the chemical changes listed above with the reaction species given below.

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

nitrate ion _____ (Record in the **second** column)

nickel(II) ion _____ (Record in the **third** column)

hydrogen ion _____ (Record in the **fourth** column)

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

---

21. If a block of refined copper were selected to serve as a sacrificial anode and if it were bolted onto the iron hull of a ship, one would expect the

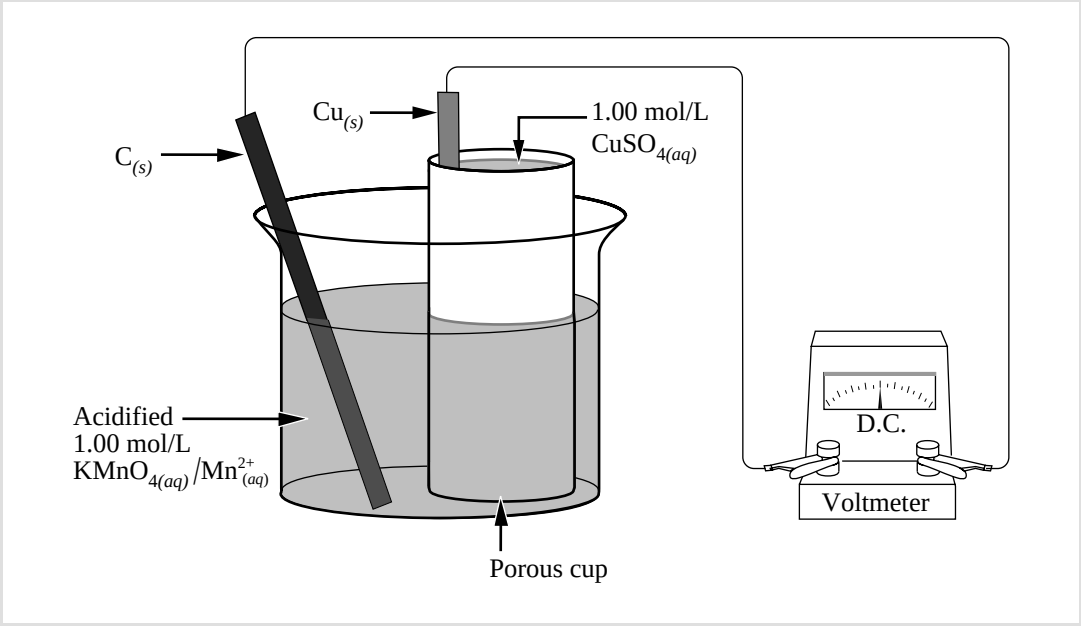
A. iron to oxidize $Cl^-_{(aq)}$

B. copper to oxidize before the iron

C. copper to corrode at a faster rate than the iron

D. copper to remain unchanged and the iron to continue to oxidize

A chemistry student constructs the cell shown below.



22. The net equation and the predicted voltage for the operating cell are

A. $MnO_4^-{}_{(aq)} + 8\,H^+_{(aq)} + Cu_{(s)} \rightarrow Mn^{2+}_{(aq)} + 4\,H_2O_{(l)} + Cu^{2+}_{(aq)}$ $E°_{net} = +1.17$ V

B. $MnO_4^-{}_{(aq)} + 8\,H^+_{(aq)} + Cu_{(s)} \rightarrow Mn^{2+}_{(aq)} + 4\,H_2O_{(l)} + Cu^{2+}_{(aq)}$ $E°_{net} = +1.85$ V

C. $2\,MnO_4^-{}_{(aq)} + 16\,H^+_{(aq)} + 5\,Cu_{(s)} \rightarrow 2\,Mn^{2+}_{(aq)} + 8\,H_2O_{(l)} + 5\,Cu^{2+}_{(aq)}$ $E°_{net} = +1.17$ V

D. $2\,MnO_4^-{}_{(aq)} + 16\,H^+_{(aq)} + 5\,Cu_{(s)} \rightarrow 2\,Mn^{2+}_{(aq)} + 8\,H_2O_{(l)} + 5\,Cu^{2+}_{(aq)}$ $E°_{net} = +1.85$ V

*Use your recorded answer for **Multiple Choice 22** to answer **Numerical Response 6.****

Numerical Response

6. During the operation of this cell, if 0.354 mol of $MnO_4^-{}_{(aq)}$ were consumed, then the mass of the copper electrode would decrease by _____ g.

(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.**

23. During the operation of this cell,

A. electrons flow from the copper electrode to the carbon electrode
B. cations migrate toward the copper electrode
C. anions migrate toward the carbon electrode
D. the concentration of sulphate ions decreases

24. Which of the following statements does **not** apply to the operation of this cell?

A. The oxidation state of the reducing agent changes from 0 to +2.
B. $MnO_4^-{}_{(aq)}$ is reduced at the carbon cathode.
C. $Cu_{(s)}$ is oxidized at the anode.
D. $MnO_4^-{}_{(aq)}$ loses electrons.

Use the following information to answer the next question.

Standard Electrode Potentials

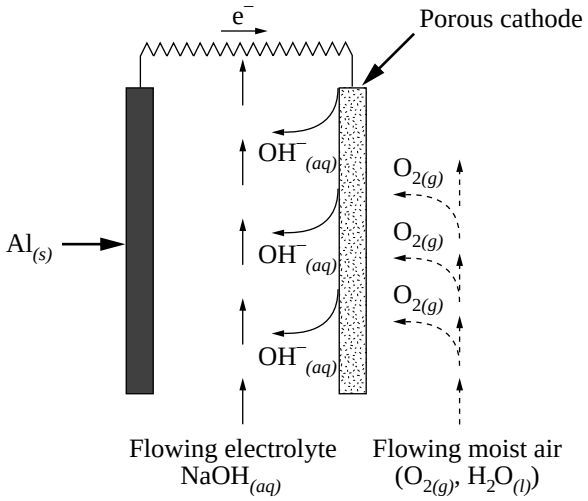
$VO_2^+{}_{(aq)} + 2\,H^+{}_{(aq)} + e^- \rightarrow VO^{2+}{}_{(aq)} + H_2O_{(l)}$	$E^\circ = +0.999$ V
$VO^{2+}{}_{(aq)} + 2\,H^+{}_{(aq)} + e^- \rightarrow V^{3+}{}_{(aq)} + H_2O_{(l)}$	$E^\circ = +0.340$ V
$VO_2^+{}_{(aq)} + 4\,H^+{}_{(aq)} + 5\,e^- \rightarrow V_{(s)} + 2\,H_2O_{(l)}$	$E^\circ = -0.250$ V
$V^{3+}{}_{(aq)} + e^- \rightarrow V^{2+}{}_{(aq)}$	$E^\circ = -0.255$ V

25. Which of the following substances is the strongest reducing agent?

A. $V^{2+}{}_{(aq)}$
B. $V^{3+}{}_{(aq)}$
C. $VO_2^+{}_{(aq)}$
D. $VO^{2+}{}_{(aq)}$

Concern about increased air pollution and the increasing use of non-renewable resources has accelerated research into alternatives to the internal combustion engine. One alternative is a battery-powered electric motor. Several "new" efficient batteries are being tested. The diagram below represents one of these batteries.

Aluminum–Air Battery



26. In this aluminum–air battery, the $O_{2(g)}$ acts as the

A. reducing agent and gains electrons
B. reducing agent and loses electrons
C. oxidizing agent and gains electrons
D. oxidizing agent and loses electrons

27. The reduction half-reaction for this aluminum–air battery is

A. $2\,H_2O_{(l)} + 2\,e^- \rightarrow H_{2(g)} + 2\,OH^-_{(aq)}$
B. $Na^+_{(aq)} + e^- \rightarrow Na_{(s)}$
C. $O_{2(g)} + 4\,H^+_{(aq)} + 4\,e^- \rightarrow 2\,H_2O_{(l)}$
D. $O_{2(g)} + 2\,H_2O_{(l)} + 4\,e^- \rightarrow 4\,OH^-_{(aq)}$

*Use the answer selected for **Multiple Choice 27** to answer **Multiple Choice 28.*** *

28. The standard voltage produced by this aluminum–air cell is

A. + 2.36 V
B. + 2.06 V
C. + 0.83 V
D. – 1.05 V

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

*Use your recorded answer for **Multiple Choice 28** to answer **Numerical Response 7.*** *

Numerical Response

7. When three aluminum–air cells are connected in series, the net voltage generated by the battery is +/– _____ V.

(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 equation to answer the next question.

$$2\,RhCl_6^{3-}{}_{(aq)} + 3\,Zn_{(s)} \rightarrow 3\,Zn^{2+}{}_{(aq)} + 2\,Rh_{(s)} + 12\,Cl^-{}_{(aq)} \qquad E^\circ_{net} = +1.20\ V$$

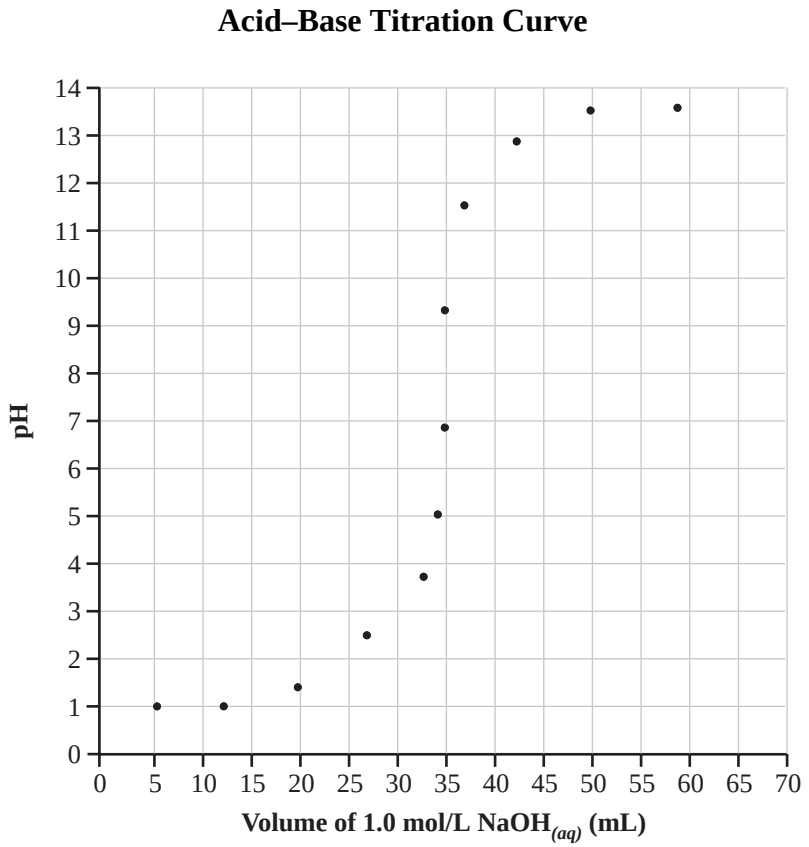
Numerical Response

8. The standard electrode potential for the half-reaction $RhCl_6^{3-}{}_{(aq)} + 3\,e^- \rightarrow Rh_{(s)} + 6\,Cl^-{}_{(aq)}$ is +/– _____ 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.

A group of students performed a titration and graphed their results, as shown below.



29. For this graph, the pH at the equivalence point is approximately

A. 1
B. 2
C. 7
D. 13

30. This titration curve represents the addition of a

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

Use the following information to answer the next question.

0.10 mol/L Solutions

1 $NaNO_{2(aq)}$	**3** $HNO_{3(aq)}$
2 $NaHCO_{3(aq)}$	**4** $Ba(OH)_{2(aq)}$

Numerical Response

9. When the solutions above are ordered from most basic to least basic, the order is _____ , _____ , _____ and _____ .

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

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31. Sour pickles have a pH of about 3.00. The $[OH^-_{(aq)}]$ in a typical sour pickle is

A. 1.0×10^{-11} mol/L

B. 3.0×10^{-11} mol/L

C. 1.0×10^{-3} mol/L

D. 3.0×10^{-3} mol/L

Numerical Response

10. The concentration of $H_3O^+_{(aq)}$ ions in a particular bottle of wine is 3.2×10^{-4} mol/L. The pH of this wine is _____.

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

32. The indicator that would most accurately identify a solution with a pH between 4.00 and 4.30 is

A. thymol blue

B. methyl orange

C. litmus

D. methyl red

33. An equilibrium that would favour the products is

A. $NH_4^+{}_{(aq)} + H_2PO_4^-{}_{(aq)} \rightleftharpoons NH_{3(aq)} + H_3PO_{4(aq)}$

B. $HCN_{(aq)} + HS^-{}_{(aq)} \rightleftharpoons CN^-{}_{(aq)} + H_2S_{(aq)}$

C. $HCO_3^-{}_{(aq)} + HBO_3^{2-}{}_{(aq)} \rightleftharpoons H_2BO_3^-{}_{(aq)} + CO_3^{2-}{}_{(aq)}$

D. $HSO_4^-{}_{(aq)} + HSO_3^-{}_{(aq)} \rightleftharpoons H_2SO_{3(aq)} + SO_4^{2-}{}_{(aq)}$

34. Which of the following mixtures could act as a buffer solution?

A. $HF_{(aq)}$ and $H_2S_{(aq)}$

B. $NaOH_{(aq)}$ and $HCl_{(aq)}$

C. $Na_2CO_{3(aq)}$ and $NH_{3(aq)}$

D. $NaH_2BO_{3(aq)}$ and $Na_2HBO_{3(aq)}$

Use the following information to answer the next question.

During the titration of an unknown base solution with a perchloric acid solution, the following data were collected.

Volume of Acid Added (mL)	pH of Solution
0.0	14.00
20.0	12.63
40.0	12.05
60.0	9.83
70.0	7.56
80.0	6.96
100.0	6.38
120.0	2.20
140.0	1.78

35. The hydronium ion concentration of the original base solution was

A. 1.7×10^{-2} mol/L

B. 7.4×10^{-8} mol/L

C. 1.5×10^{-13} mol/L

D. 1.0×10^{-14} mol/L

36. One important buffer that exists in blood is composed of $H_2PO_4^-{}_{(aq)}$ and $HPO_4^{2-}{}_{(aq)}$. The net ionic equation that represents the reaction of hydrochloric acid with this buffer is

A. $H_3O^+{}_{(aq)} + HPO_4^{2-}{}_{(aq)} \rightleftharpoons H_2O_{(l)} + H_2PO_4^-{}_{(aq)}$

B. $HCl_{(aq)} + H_2PO_4^-{}_{(aq)} \rightleftharpoons Cl^-{}_{(aq)} + H_3PO_{4(aq)}$

C. $H_3O^+{}_{(aq)} + H_2PO_4^-{}_{(aq)} \rightleftharpoons H_2O_{(l)} + H_3PO_{4(aq)}$

D. $HCl_{(aq)} + HPO_4^{2-}{}_{(aq)} \rightleftharpoons Cl^-{}_{(aq)} + H_2PO_4^-{}_{(aq)}$

Numerical Response

11. A certain headache relief tablet is composed of monoprotic acetylsalicylic acid ($C_9H_8O_{4(s)}$) and an inert filler. A 4.00 g tablet was crushed and dissolved to make 40.0 mL of solution. The solution was then titrated with 0.900 mol/L $NaOH_{(aq)}$. The volume of $NaOH_{(aq)}$ needed to neutralize the dissolved tablet was 20.1 mL. The experimental value for the mass of $C_9H_8O_{4(s)}$ present in the tablet was _____ g.

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

Coal and natural gas contain trace amounts of sulphur compounds, which when burned, may lead to acid rain pollution.

Reactions Related to Acid Rain

I $2\,H_2S_{(g)} + 3\,O_{2(g)} \rightleftharpoons 2\,H_2O_{(g)} + 2\,SO_{2(g)}$

II $2\,SO_{2(g)} + O_{2(g)} \rightleftharpoons 2\,SO_{3(g)}$

III $SO_{2(g)} + 2\,H_2O_{(l)} \rightleftharpoons 2\,H_2SO_{3(aq)}$

IV $2\,SO_{3(g)} + 2\,H_2O_{(l)} \rightleftharpoons 2\,H_2SO_{4(aq)}$

37. The equilibrium law expression for reaction I is

A. $K_{eq} = \dfrac{[H_2O_{(g)}]^2 + [SO_{2(g)}]^2}{[H_2S_{(g)}]^2 + [O_{2(g)}]^3}$

B. $K_{eq} = \dfrac{[H_2S_{(g)}]^2 + [O_{2(g)}]^3}{[H_2O_{(g)}]^2 + [SO_{2(g)}]^2}$

C. $K_{eq} = \dfrac{[H_2S_{(g)}]^2\,[O_{2(g)}]^3}{[H_2O_{(g)}]^2\,[SO_{2(g)}]^2}$

D. $K_{eq} = \dfrac{[H_2O_{(g)}]^2\,[SO_{2(g)}]^2}{[H_2S_{(g)}]^2\,[O_{2(g)}]^3}$

38. The conjugate base of $H_2SO_{3(aq)}$ is

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

B. $SO_3^{2-}{}_{(aq)}$

C. $OH^{-}{}_{(aq)}$

D. $H_2O_{(l)}$

Use the following information to answer the next question.

At 900 K, the equilibrium constant for reaction II is 13.0. The equilibrium concentrations are

$[SO_{2(g)}] = 0.361$ mol/L

$[SO_{3(g)}] = 0.840$ mol/L

39. Given the values above, the calculated equilibrium concentration of $O_{2(g)}$ is

A. 0.179 mol/L

B. 0.416 mol/L

C. 2.40 mol/L

D. 5.59 mol/L

Use the following information to answer the next question.

Some of the $SO_{2(g)}$ produced from the burning of coal and natural gas can react with $NO_{2(g)}$ in the atmosphere according to the equation

$$SO_{2(g)} + NO_{2(g)} \rightleftharpoons NO_{(g)} + SO_{3(g)} \qquad \Delta H = -41.9 \text{ kJ}$$

40. The equilibrium concentration of $SO_{3(g)}$ in the reaction could be increased by

A. raising the temperature

B. adding a catalyst

C. removing $SO_{2(g)}$

D. adding $NO_{2(g)}$

Numerical Response

12. If the pH of a sample of rainwater is 3.2, then the pOH is _____.

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

41. Which of the following acid solutions has the lowest pH?

A. 300 mL of 1.00×10^{-2} mol/L $H_2S_{(aq)}$

B. 100 mL of 1.00×10^{-4} mol/L $H_2SO_{3(aq)}$

C. 100 mL of 1.00×10^{-3} mol/L $H_2SO_{4(aq)}$

D. 10.0 mL of 1.00×10^{-4} mol/L $H_2SO_{4(aq)}$

42. A drop of thymol blue indicator in its blue form added to 10.0 mL of 0.10 mol/L $H_2SO_{4(aq)}$ would become

A. yellow because the indicator would gain one proton

B. yellow because the indicator would lose one proton

C. red because the indicator would gain two protons

D. red because the indicator would lose two protons

43. Acid rain is linked to the leaching of heavy metals and their ions in lakes and rivers. Biomagnification of these metals and ions increases levels of disease in fish and wildlife. Based on this information, a decision to reduce sulphur dioxide emissions would be

A. political

B. scientific

C. technological

D. environmental

44. Another contributor to the acidity of precipitation is $CO_{2(g)}$. Atmospheric $CO_{2(g)}$ levels are **not** increased by

A. photosynthesis

B. combustion of fossil fuels

C. respiration of plants and animals

D. cars equipped with catalytic converters

The written-response questions follow on the next page.

Use the following information to answer the next question.

	Representative Antacid	Principal Active Ingredient	Neutralization Reaction
I	Alka-Seltzer	Sodium bicarbonate	$NaHCO_{3(s)} + HCl_{(aq)} \rightarrow NaCl_{(aq)} + H_2CO_{3(aq)}$
II	Phillips' Milk of Magnesia	Magnesium hydroxide	$Mg(OH)_{2(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2\,H_2O_{(l)}$
III	Rolaids	Dihydroxyaluminum sodium carbonate	$Al(OH)_2\,NaCO_{3(s)} + 4\,HCl_{(aq)} \rightarrow AlCl_{3(aq)} + NaCl_{(aq)} + 2\,H_2O_{(l)} + H_2CO_{3(aq)}$
IV	Tums	Calcium carbonate	$CaCO_{3(s)} + 2\,HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2CO_{3(aq)}$
V	Di-Gel	Aluminum hydroxide	$Al(OH)_{3(s)} + 3\,HCl_{(aq)} \rightarrow AlCl_{3(aq)} + 3\,H_2O_{(l)}$
		Magnesium carbonate	$MgCO_{3(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_2CO_{3(aq)}$
		Magnesium hydroxide	$Mg(OH)_{2(s)} + 2\,HCl_{(aq)} \rightarrow MgCl_{2(aq)} + 2\,H_2O_{(l)}$

— Table from *The Extraordinary Chemistry of Ordinary Things* by Carl H. Snyder (John Wiley & Sons, Inc., 1992).
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Written Response—15%

1. Plan an experiment to test the effectiveness of antacids.

Your response should include:

- an experimental design
- a data table for your experimental design
- three factors that should be considered when choosing an antacid

Use the following information to answer the next question.

In some industrial processes, sodium chromate is added to water coolants. When the coolant is drained, the chromate ions can be removed through an electrolysis process that uses an iron anode. The products of the electrolysis are aqueous iron(II) ions and solid chromium(III) hydroxide, a recoverable pollutant. The half-reaction involving the chromate ion is

$$CrO_4^{2-}{}_{(aq)} + 4\,H_2O_{(l)} + 3\,e^- \rightarrow Cr(OH)_{3(s)} + 5\,OH^-{}_{(aq)}$$

Written Response—15%

2. **a.** Provide the half-reactions and a net redox reaction for this electrochemical process.

b. A current of 3.00 A is applied for 48.0 h to a cell containing a 400 g iron anode. What is the final mass of the iron anode?

c. Suggest an alternative anode material that would last longer than iron. Support your answer with relevant calculations and explanations.

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

Credits

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Tear-out Page

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

Fold and tear along perforation.

Multiple Choice

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

Numerical Response

1.	1236+	**7.**	6.18‡
2.	1.04	**8.**	0.44
3.	1.70	**9.**	4213
4.	3.15	**10.**	3.49
5.	2314++	**11.**	3.26
6.	56.2*	**12.**	10.8

+ = any order

++ = accept 2313

Links:

*If MC22 is A or B, then NR6 is 22.5
C or D, then NR6 is 56.2*

†If MC27 is A, then MC28 is C
B, then MC28 is D
C, then MC28 is A
D, then MC28 is B†

‡If MC28 is A, then NR7 is 7.08
B, then NR7 is 6.18‡
C, then NR7 is 2.49
D, then NR7 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. Experimental Design

A number of factors could be tested regarding the effectiveness of the antacids.
Sample Factor to Study: Using the same dose of active ingredient, determine which antacid neutralizes the most acid.

- Obtain the recommended amount of each antacid.
- Dissolve the antacid in 40 mL of deionized water. Add 2–3 drops of bromothymol blue indicator.
- Titrate the antacid with a strong acid ($HCl_{(aq)}$) of known concentration until a colour change occurs.
- Record the volume of $HCl_{(aq)}$ required for the pH to reach 7.

Controlled Variables

Dose of antacid sample.
Concentration of acid, $HCl_{(aq)}$.
pH at end point.

Data Table

Record the volume and concentration of acid added until some indication (pH, colour, bubbles) of when to stop.

Sample ID	Mass of Antacid	Vol. of Acid

Factor Considerations

Mass of sample used, i.e., one big pill to swallow
Liquid versus solid – ease of use
Low solubility so that the antacid does not react before it hits the stomach
Cost factor, taste, toxicity, rate of reaction, or how exothermic
Possible side effects of ingredients:

producing $H_2CO_{3(aq)}$ $\rightarrow$ more "gas" due to $CO_{2(g)}$ evolved
$Mg(OH)_{2(s)}$ or $CaCO_{3(s)}$ $\rightarrow$ needed for strong bones
$\rightarrow$ magnesium causes diarrhea
$Al(OH)_{3(s)}$ $\rightarrow$ linked to Alzheimer's
$Na^+_{(aq)}$ $\rightarrow$ heart problems

2.a.

$$2\,(CrO_4^{2-}{}_{(aq)} + 4\,H_2O_{(l)} + 3\,e^- \rightarrow Cr(OH)_{3(s)} + 5\,OH^-_{(aq)})$$
$$3(Fe_{(s)} \rightarrow Fe^{2+}{}_{(aq)} + 2\,e^-)$$

$$2\,CrO_4^{2-}{}_{(aq)} + 3\,Fe_{(s)} + 8\,H_2O_{(l)} \rightarrow 2\,Cr(OH)_{3(s)} + 10\,OH^-_{(aq)} + 3\,Fe^{2+}{}_{(aq)}$$
$$(\text{or } 3\,Fe(OH)_{2(s)} + 4\,OH^-_{(aq)})$$

b.

$$n_{e^-} = \frac{(3.00\,C/s)(48.0\,h)(3600\,s/h)}{9.65\times10^4\,C/mol} = 5.37\,mol$$

$$n_{Fe} = \frac{1}{2}\,n_{e^-} = 2.69\,mol$$

$$m_{Fe} = 2.69\,mol\,(55.85\,g/mol) = 150\,g$$

$$\Delta m_{anode} = 400\,g - 150\,g = 250\,g$$

c. An aluminum anode would last longer than iron because a smaller mass of aluminum would be consumed under the same circumstances. Any metal with a lower ratio of molar mass to ion charge would be valid because less anode mass would be consumed.

$$m_{Al} = \frac{(3.00C/s)(26.98\,g/mol)\left(\frac{1}{3}\right)(48.0\,h)(3600\,s/h)}{9.65\times10^4\,C/mol}$$

$$= 48.3\,g \text{ used } \textbf{vs } 150\,g \text{ of } Fe_{(s)}$$