CHEMISTRY

Chemistry 30 Exemplars

Item Writing and Field Test Development Knowledge, Skill, and STS Outcomes

Alberta Education

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Distribution: This document is posted on the Alberta Education website at http://education.alberta.ca.

This document outlines some of the general principles of item construction used by exam developers at Learner Assessment, contains the Chemistry 30 Program of Studies outcome statements, and includes numerous exemplars.

The following document was prepared by committees of teachers from various jurisdictions. The teachers developed questions and identified questions from past diploma examinations relating to each curricular concept. The purpose of this document is threefold:

- *To provide exemplars that indicate how a particular concept could be assessed*
- *To help item writers produce relevant and varied questions*
- *To have an efficient and consistent means for classification of items, not only in terms of content, but also in terms of skills, STS connections, expectations, and cognitive levels*

Teachers using this document for item writing and field-test development should understand that it is open-ended. If necessary, it can be supplemented or revised as each committee uses it. Teachers should not feel limited to what is in this document, as it is to be used only as a general guideline during item writing and field-test development.

Introduction

> *"To begin with the end in mind means to start with a clear understanding of your destination."*
>
> —Stephen R. Covey,
> *The Seven Habits of Highly Effective People*, 1989.

Chemistry 30 Exemplars have been developed to assist Grade 12 teachers of chemistry in interpreting curriculum outcomes, planning lessons, and developing assessment tools that will ultimately improve student learning and performance in chemistry classrooms.

The first step in designing effective lessons is to determine the scope of the curriculum, the expected outcomes, and a method to assess the learning.

The objective of these questions is to provide an example of how a particular concept could be assessed. The questions in this document are not intended to be exhaustive, but are intended, rather, to provide teachers with examples. Teachers may use any number of these exemplars, or they may choose to use other assessment tools to obtain evidence that the desired learning has been achieved.

Chemistry 30 Exemplars are written for each specific outcome in the Chemistry 30 Program of Studies. Each outcome is identified with a code. The first number in the code indicates the general outcome, and the second number and letter indicate the specific outcome. The capital letter refers to the unit in the program of studies. The following lowercase letters are used to identify the general learner expectations in the program of studies:

k	– KNOWLEDGE
s	– SKILLS
sts	– SCIENCE, TECHNOLOGY, & SOCIETY

Example: 30-A1.1k indicates that the specific outcome is for Chemistry 30, unit A, general outcome 1, specific outcome 1, and an outcome for knowledge.

As a guideline for the grading of written-response questions, refer to Sample Student Responses in the subject bulletin.

You can find diploma examination-related materials on the Alberta Education website at www.education.alberta.ca.

At the home page, click on the link *Teachers*; then, under the *Additional Programs and Services* heading, click on the link *Provincial Testing*. Next click on *Diploma Exams* and then one of the specific links listed under the *Diploma Examinations* heading.

Guidelines for Item Writing and Field-Test Building

We use guidelines when developing questions in order to produce a **valid** and **reliable** assessment tool. In this document, we will refer to any question as an **item**. Important questions to consider when developing test items are as follows:

- Does the item have curricular validity?
- Does the item test something worthwhile?

When possible, we try to incorporate current and real-world settings that apply to everyday chemistry seen around us.

> *"... [I]t is extremely desirable to have assessment occur in the context of students working on problems, projects, or products that genuinely engage them, that hold their interest and motivate them to do well."*
>
> —Howard Gardner
> *Multiple Intelligences: The Theory in Practice*, 1993.

In the Chemistry 30 diploma examinations, scenarios may cover more than one unit, but it is important to keep the scenario language simple, concise, and relevant. We do not want to increase the difficulty of an item by adding excess, irrelevant material. Significant digits should be consistent throughout the item, and any data included on the item should be based on realistic values. When writing items, provide as much information as possible in the scenario box or stem so that students do not have to read through the distractors to determine what the item is asking.

Share ideas and items with someone else to incorporate feedback. Items evolve through a progression, and that is why it is important to share your items as you develop them. Included on the following pages are exemplars indicating the various stages through which some of our items have progressed from the time they are submitted in their raw form, through revision, through editing, to the final field-test product.

ORIGINAL SUBMISSION — July 2, 2004

Use the following information to answer the next question.

Toluene (1–methylbenzene, $C_7H_8(g)$) is an important organic solvent and a precursor to many other important organic compounds such as TNT (trinitrotoluene).
Toluene can be produced according to the following equilibrium.

$$C_7H_{14}(g) + \text{energy} \rightleftharpoons C_7H_8(g) + 3\,H_2(g)$$

1. When 3.00 mol of $C_7H_{14}(g)$ was introduced into a 1.00 L container, 1.20 mol of $H_2(g)$ was produced at equilibrium. Determine the K_c of the reaction.

A. 0.266

B. 0.185

C. 1.15

D. 0.800

FINAL VERSION — April 1, 2005

Use the following information to answer the next question.

Toluene, $C_7H_8(g)$, is an important organic solvent and can be produced by the following equilibrium equation.

$$C_7H_{14}(g) + \text{energy} \rightleftharpoons C_7H_8(g) + 3\,H_2(g)$$

A technician placed 3.00 mol of $C_7H_{14}(g)$ into a 1.00 L flask. The flask was then stoppered and allowed to reach equilibrium. At equilibrium, 1.20 mol of $H_2(g)$ was present in the flask.

1. The value of the equilibrium constant is

A. 0.185

B. 0.266

C. 0.800

D. 1.15

Key: B

ORIGINAL SUBMISSION — July 2, 2004

2. As the temperature of the system increases, the value of K_c will

A. decrease due to more products formed

B. increase due to more products formed

C. decrease due to more reactants formed

D. increase due to more reactants formed

FINAL VERSION — March 15, 2005

Use the following information to answer the next question.

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g) + 197.8\ kJ$$

2. *If the temperature of the system at equilibrium is increased, then the value of the equilibrium constant, K_c, will* ___***i***___ *and the amount of* ___***ii***___ *will increase.*

The statement above is completed by the information in row

Row	***i***	***ii***
A.	decrease	products
B.	decrease	reactants
C.	increase	products
D.	increase	reactants

Key: B

ORIGINAL SUBMISSION — July 2, 2004

3. Toluene is reacted with nitric acid to produce TNT (trinitrotoluene), a powerful explosive. The reaction requires $H_2SO_4(aq)$ to act as a catalyst. Without $H_2SO_4(aq)$ the reaction would

A. react faster

B. react slower

C. produce more TNT

D. produce less TNT

REVIEW — March 9, 2005

Use the following information to answer the next question.

Toluene is used as a reactant to produce other organic compounds such as trinitrotoluene (TNT). Toluene and nitric acid react, with the addition of a catalyst, to produce TNT.

3. Without the addition of a catalyst, the reaction would

A. react faster

B. react slower

C. produce less TNT

D. produce more TNT

FINAL VERSION — April 13, 2005

Use the following information to answer the next question.

Toluene is used as a reactant to produce other organic compounds such as trinitrotoluene (TNT). Toluene and nitric acid react with the addition of a catalyst to produce TNT.

3. Without the addition of a catalyst, the forward reaction would

A. react faster

B. react slower

C. have a larger ΔH

D. have a smaller ΔH

After an item has been field-tested, feedback provided by students and teachers, in addition to the statistics from the field-test analysis, is reviewed before the item is deemed acceptable for a diploma examination. Before an item appears on a diploma examination, it is edited and reviewed again, internally and externally, by a committee of teachers and professionals working in the chemistry field.

Below is a list of specific guidelines to check when building field tests.

Primary Components to Check

- ☐ Ensure that all items fit within the program of studies and that the concept has been correctly categorized (for knowledge, skill, and STS components).
- ☐ Balance items in terms of difficulty and quantitative versus qualitative type.
- ☐ Balance items to reflect the program of studies. If there is duplication of a concept, ensure that the items are addressing different aspects of the concept.
- ☐ Check that the current data booklet values are used and that the science is accurate.
- ☐ Include only plausible distractors. If the distractors are a result of a calculation, include how each distractor is calculated.
- ☐ Linked items must be linked from a multiple-choice item to a numerical-response item. All linked items must be identified so that students who complete the first item incorrectly in a series of linked items still have a chance of completing the next item correctly.
- ☐ All numerical-response answers must fill all four fields in the numerical-response section on the answer sheet (possible types of responses are 1245, 45.2, and 2.38).
- ☐ If possible, do not start or end calculated numerical-response items with a zero.
- ☐ Indicate the correct response for each machine-scored item and provide a scoring guide with a sample response for each written-response item.

Secondary Components to Check

- ☐ Diagrams are clearly drawn and labelled. Provide a reference for the source, if one was used.
- ☐ Distractors are approximately equal in length.
- ☐ Scenarios are relevant (trim out extra information) and include any sources used.
- ☐ Scenarios consist of a minimum of three items.

How to Start

- ☐ Develop a blueprint for the field test that covers as much of the program of studies as possible and includes a range of cognitive levels. Start by finding the written-response component. The written-response question determines the other questions that can be put on the field test so that concepts are not covered more than once. Next, look for two to three scenarios to fit your blueprint. Group and order your items/scenarios according to units as follows: thermochemical changes, electrochemical changes, chemical changes of organic compounds, and chemical equilibrium focusing on acid–base systems. Scenarios that include information from more than one unit should appear at the end of the units they cover. Fill in any remaining spots with individual items or add items to the existing scenarios.

Unit A—Thermochemical Changes

General Outcome 1:
Determine and interpret energy changes in chemical reactions

Knowledge
30–A1.1k Recall the application of $Q = mc\Delta t$ to the analysis of heat transfer.

Knowledge
30–A1.8k Use calorimetry data to determine the enthalpy changes in chemical reactions.

Use the following information to answer the next question.

$$2\,CH_3OH(l) + 3\,O_2(g) \rightarrow 2\,CO_2(g) + 4\,H_2O(g) \qquad \Delta H^\circ = -1\,275.8\ kJ$$

1. The amount of methanol that must be burned to raise the temperature of 250.0 g of water from 20.0 °C to 35.0 °C is

A. 6.16×10^{-3} mol
B. 1.23×10^{-2} mol
***C.** 2.46×10^{-2} mol
D. 2.46×10^{1} mol

This question also applies to:

Skill
30–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- compare energy changes associated with a variety of chemical reactions through the analysis of data and energy diagrams

Skill
30–A1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- use appropriate International System of Units (SI) notation, fundamental and derived units and significant digits

Use the following information to answer the next question.

Calorimetry Experiment Data

1 Mass change of ethanol
2 Mass of aluminium calorimeter
3 Mass of aluminium calorimeter and water
4 Initial temperature of aluminium calorimeter
5 Maximum temperature change of ethanol
6 Maximum temperature change of aluminium calorimeter and water

2. The calorimetry experiment data required to determine the molar enthalpy of combustion of ethanol are _____, _____, _____, and _____.

Key: 1236

Use the following information to answer the next question.

Two fuels that can be used in camping stoves are gasoline (assume pure octane) and propane.

3. **Design** a calorimetry experiment that would allow you to choose the best fuel to use for heating water on a camping stove.

Your response should include

- a detailed procedure
- identification of the controlled, manipulated, and responding variables
- two reasons to support your choice of the best fuel

This question also applies to:

Skill

30–A1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- design a method to compare the molar enthalpy change when burning two or more fuels *(e.g., octane, propane, ethanol, and historic fuels such as seal or whale oil)*, identifying and controlling major variables.

Science, Technology, and Society

30–A1.1sts explain that the goal of technology is to provide solutions to practical problems

- provide examples of personal reliance on the chemical potential energy of matter, such as the use of fossil fuels
- identify ways to use energy more efficiently

30–A2.2sts explain that the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability

- assess, qualitatively, the risks and benefits of relying on fossil fuels as energy sources

30–A2.3sts explain that the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve problems

- evaluate the economic and environmental impacts of different fuels by relating carbon dioxide emissions and the heat content of a fuel

Knowledge

30–A1.2k Explain, in a general way, how stored energy in the chemical bonds of hydrocarbons originated from the Sun.

4. *During photosynthesis, energy that originated from the* ___***i***___ *is converted to* ___***ii***___ *energy and stored in chemical bonds.*

The statement above is completed by the information in row

Row	***i***	***ii***
A.	Sun	light
***B.**	Sun	chemical
C.	plant	light
D.	plant	chemical

Use the following information to answer the next question.

Processes

1 Combustion
2 Photosynthesis
3 Bacterial decay
4 Energy from the Sun

5. From the formation of methane to its eventual use as automobile fuel, the order of the processes listed above is _____, _____, _____, and _____.

Key: 4231

Knowledge

30–A1.3k Define enthalpy and molar enthalpy for chemical reactions.

Use the following information to answer the next question.

Fuel	Molar Enthalpy of Combustion
Methane	–802.5 kJ/mol
Ethane	–1 428.4 kJ/mol
Butane	–2 657.3 kJ/mol
Octane	–5 074.1 kJ/mol

6. An interpretation that applies to the data in the table above is that the greater the number of carbon atoms in a fossil fuel molecule, the

A. lower the energy stored in the molecule

B. greater the strength of each covalent bond

*__C.__ greater the energy released during combustion

D. lower the moles of oxygen required for complete combustion

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7. If 44.7 kJ of energy is transferred when 1.65 g of ethanal, $CH_3CHO(l)$, is burned in a calorimeter, then the molar enthalpy of combustion of ethanal is

A. –1.67 kJ/mol

B. -2.71×10^1 kJ/mol

C. -7.38×10^1 kJ/mol

*__D.__ -1.19×10^3 kJ/mol

This question also applies to:

Skill

30–A1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- use appropriate International System of Units (SI) notation, fundamental and derived units and significant digits

Knowledge

30–A1.4k Write balanced equations for chemical reactions that include energy changes.

8. Which of the following equations represents the balanced chemical equation for the decomposition of water and the energy transfer during the reaction?

A. $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) + 285.8\ kJ$

B. $H_2O(l) \rightarrow H_2(g) + O_2(g) + 285.8\ kJ$

C. $2\,H_2O(l) + 285.8\ kJ \rightarrow 2\,H_2(g) + O_2(g)$

*__D.__ $H_2O(l) + 285.8\ kJ \rightarrow H_2(g) + \frac{1}{2}O_2(g)$

9. When used as a fuel in automobiles, ethanol burns more efficiently than fossil fuels. The balanced equation, including the appropriate enthalpy change for the combustion of ethanol, is

A. $C_2H_5OH(l) + 3\,O_2(g) \rightarrow 2\,CO_2(g) + 3\,H_2O(g)$ $\Delta H° = +1\,234.8\ kJ$

*__B.__ $C_2H_5OH(l) + 3\,O_2(g) \rightarrow 2\,CO_2(g) + 3\,H_2O(g)$ $\Delta H° = -1\,234.8\ kJ$

C. $C_2H_5OH(l) \rightarrow 2\,C(s) + 3\,H_2(g) + \frac{1}{2}O_2(g)$ $\Delta H° = +277.6\ kJ$

D. $C_2H_5OH(l) \rightarrow 2\,C(s) + 3\,H_2(g) + \frac{1}{2}O_2(g)$ $\Delta H° = -277.6\ kJ$

Knowledge

30–A1.5k Use and interpret ΔH notation to communicate and calculate energy changes in chemical reactions.

10. The energy released when 0.500 mol of AgI(s) is formed from its elements is _____kJ.

Key: 30.9

Use the following information to answer the next question.

The combustion of sucrose can be represented by the following equation.

$$C_{12}H_{22}O_{11}(s) + 12\,O_2(g) \rightarrow 12\,CO_2(g) + 11\,H_2O(g) \qquad \Delta H° = -5\,155.7\ kJ$$

11. *If 1.00 g of sucrose reacts as represented by the equation above, then* ___***i***___ *of energy is* ___***ii***___ *the surroundings.*

The statement above is completed by the information in row

Row	***i***	***ii***
A.	15.1 kJ	absorbed from
***B.**	15.1 kJ	released to
C.	0.066 4 kJ	absorbed from
D.	0.066 4 kJ	released to

Knowledge
30–A1.6k Predict the enthalpy change for chemical equations using standard enthalpies of formation.

Use the following information to answer the next two questions.

Disposable lighters contain butane gas which undergoes combustion, as represented by the following equation.

$$2\,C_4H_{10}(g) + 13\,O_2(g) \rightarrow 8\,CO_2(g) + 10\,H_2O(g)$$

12. When used as a fuel in automobiles, ethanol burns more efficiently than fossil fuels. The balanced equation, including the appropriate enthalpy change for the combustion of ethanol, is

***A.** –2 657.3 kJ/mol

B. –2 877.3 kJ/mol

C. –5 314.6 kJ/mol

D. –5 754.6 kJ/mol

*Use your recorded answer from **Multiple Choice 12** to answer **Numerical Response 13.****

13. The enthalpy change for the combustion of 1.00 g of butane gas is _____ kJ.

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

Key: 91.3 or 91.4 (if uncleared calculator is used for the calculation)

Acceptable Responses for Linked Item 13:

If MC12 is A, then NR13 is 45.7
B, then NR13 is 49.5
C, then NR13 is 91.4
D, then NR13 is 99.00

Note: Alberta Education requires students to carry rounded answers from one linked question to another.
*Within a question, rounding occurs only for the final answer (see bulletin reference).

This question also applies to:

Knowledge
30–A1.5k

Use the following information to answer the next question.

Nitrogen dioxide gas is a toxic, reddish brown gas. At high temperatures in automobile engines, nitrogen gas and oxygen gas in the air react to produce nitrogen dioxide gas, as represented by the following equation.

$$N_2(g) + 2\,O_2(g) \rightleftharpoons 2\,NO_2(g)$$

14. **Analyze** the production of nitrogen dioxide gas in terms of energy and equilibrium. **Identify** two characteristics of the reaction in terms of energy and two characteristics of the reaction in terms of equilibrium.

Your response should include

- an enthalpy calculation per mole of nitrogen dioxide gas
- an explanation of the two characteristics in terms of energy you have identified
- an explanation of the two characteristics in terms of equilibrium you have identified

This question can also apply to:

Knowledge
30–D1.1k
30–D1.2k
30–D1.3k

Knowledge

30–A1.7k Explain and use Hess' law to calculate energy changes for a net reaction from a series of reactions.

Use the following information to answer the next question.

$C_3H_6(g) + \frac{9}{2} O_2(g) \rightarrow 3\,CO_2(g) + 3\,H_2O(l)$	$\Delta H° = -1\,959.2$ kJ
$C(s) + O_2(g) \rightarrow CO_2(g)$	$\Delta H° = -393.5$ kJ
$2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(l)$	$\Delta H° = -571.6$ kJ

15. The molar enthalpy of formation of cyclopropane, $3\,C(s) + 3\,H_2(g) \rightarrow C_3H_6(g)$, is +/–_____ kJ.

Key: 78.7

Knowledge

30–A1.8k Use calorimetry data to determine the enthalpy changes in chemical reactions.

Use the following information to answer the next question.

A student uses an aluminium calorimeter to determine the molar enthalpy of solution for solid ammonium nitrate. The student assumes that the calorimeter neither gains nor loses heat during the experiment; that the density and specific heat capacity for the final solution are the same as those of water; and that the mass of the final solution is 150.00 g. The data were collected and recorded in the following table.

Mass of aluminum calorimeter	25.45 g
Mass of aluminum calorimeter and contents	175.45 g
Mass of aluminum nitrate	1.68 g
Initial temperature of calorimeter and contents	22.30 ºC
Final temperature of calorimeter and contents	20.98 ºC

16. The molar enthalpy of solution for ammonium nitrate in the calorimetry experiment is _____ kJ/mol.

Key: 39.5

Knowledge

30–A1.9k Identify that liquid water and carbon dioxide gas are reactants in photosynthesis and products of cellular respiration and that gaseous water and carbon dioxide gas are the products of hydrocarbon combustion in an open system.

17. Which of the following substances is produced during the combustion of octane in automobiles and is also produced during cellular respiration?

A. $NO_2(g)$

B. $SO_2(g)$

***C.** $CO_2(g)$

D. $O_2(g)$

18. *The products of photosynthesis are* ___***i***___ *, and the products of hydrocarbon combustion are* ___***ii***___ *.*

The statement above is completed by the information in row

Row	***i***	***ii***
A.	$CO_2(g)$ and $H_2O(l)$	$CO_2(g)$ and $H_2O(g)$
B.	$CO_2(g)$ and $H_2O(l)$	$CO_2(g)$ and $H_2O(l)$
***C.**	$C_6H_{12}O_6(s)$ and $O_2(g)$	$CO_2(g)$ and $H_2O(g)$
D.	$C_6H_{12}O_6(s)$ and $O_2(g)$	$CO_2(g)$ and $H_2O(l)$

Knowledge

30–A1.10k Classify chemical reactions as endothermic or exothermic, including those for the processes of photosynthesis, cellular respiration and hydrocarbon combustion.

19. One reason that could explain why dynamite releases a large quantity of energy when it explodes is that the reaction is

A. endothermic, and the products have more potential energy than the reactants

B. endothermic, and the reactants have more potential energy than the products

C. exothermic, and the products have more potential energy than the reactants

***D.** exothermic, and the reactants have more potential energy than the products

Use the following information to answer the next question.

Type of Reaction
1 Endothermic
2 Exothermic

20. Match the type of reaction numbered above with the reactions given below.

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

Cellular respiration _____ (Record in the **second** column)

Formation of glucose _____ (Record in the **third** column)

Combustion of propane _____ (Record in the **fourth** column)

Key: 1222

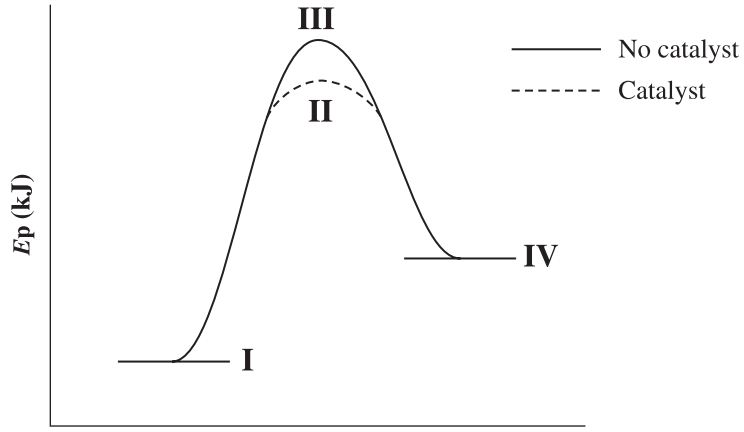
General Outcome 2:
Explain and communicate energy changes in chemical reactions

Knowledge

30–A2.1k Define activation energy as the energy barrier that must be overcome for a chemical reaction to occur.

Use the following information to answer the next question.

Potential Energy Diagram



21. *The energy barrier that must be overcome for the forward reaction to occur is called the* ___***i***___ *, and in the diagram above, it is the difference between* ___***ii***___ *.*

The statement above is completed by the information in row

Row	*i*	*ii*
A.	enthalpy change	I and II
B.	enthalpy change	I and III
***C.**	activation energy	I and II
D.	activation energy	I and III

Use the following information to answer the next question.

$$C_3H_8(g) + 6\,H_2O(g) \rightarrow 3\,CO_2(g) + 10\,H_2(g)$$

22. **Explain** how the reaction represented by the equation above both requires energy and releases energy to the surroundings.

Your response should include

- an explanation of the energy requirements for the reaction
- a molar enthalpy calculation in kJ/mol
- an explanation of the energy changes that occur during the reaction

This question could also apply to:

Knowledge
30–A2.2k

Skill
30–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- draw and interpret enthalpy diagrams for chemical reactions

Knowledge

30–A2.2k Explain the energy changes that occur during chemical reactions, referring to bonds breaking and forming and changes in potential and kinetic energy.

23. *The energy changes that occur when propane undergoes combustion are primarily due to changes in* ___***i***___ *energy resulting from* ___***ii***___ .

The statement above is completed by the information in row

Row	***i***	***ii***
***A.**	potential	a rearrangement of bonds
B.	potential	an increase in molecular motion
C.	kinetic	a rearrangement of bonds
D.	kinetic	an increase in molecular motion

Use the following information to answer the next question.

$$Na(s) + \tfrac{1}{2} H_2(g) + C(s) + \tfrac{3}{2} O_2(g) \rightarrow NaHCO_3(s) + 947.7\ kJ$$

24. *In the reaction represented by the equation above, energy is* ___***i***___ *the surroundings because the bonds in the products contain* ___***ii***___ *energy than the reactants.*

The statement above is completed by the information in row

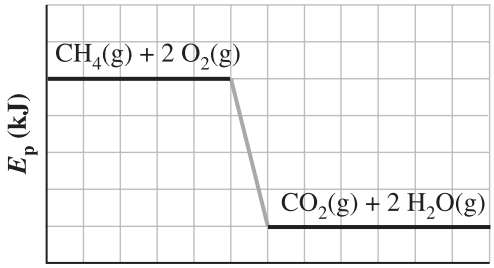
Row	***i***	***ii***
A.	absorbed from	more potential
B.	absorbed from	more kinetic
***C.**	released to	less potential
D.	released to	less kinetic

Knowledge

30–A2.3k Analyze and label energy diagrams of a chemical reaction, including reactants, products, enthalpy change and activation energy.

Use the following information to answer the next question.

Combustion of Methane Gas



25. According to the diagram above, the enthalpy change for the combustion of 1.00 mol of methane gas is

A. endothermic and represented by a negative ΔH value

B. endothermic and represented by a positive ΔH value

***C.** exothermic and represented by a negative ΔH value

D. exothermic and represented by a positive ΔH value

This question also applies to:

Skill

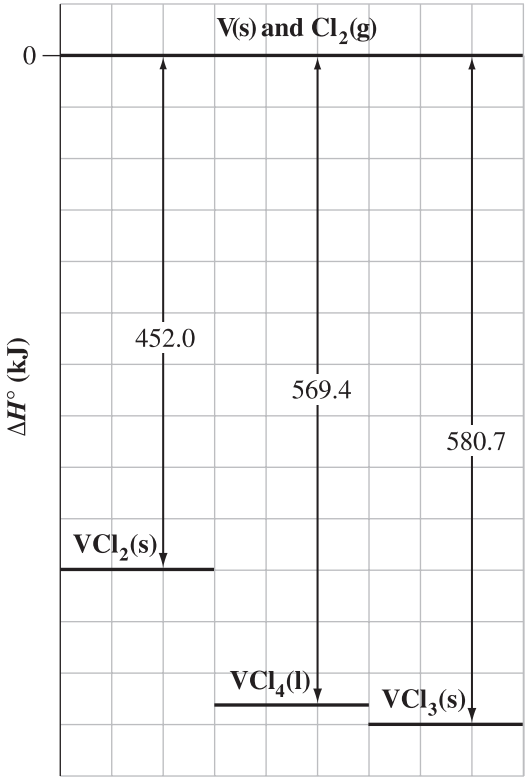
30–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- draw and interpret enthalpy diagrams for chemical reactions

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.

Enthalpies for the Formation of Vanadium Chlorides



26. The energy absorbed when 0.350 mol of $VCl_4(l)$ decomposes to form $VCl_2(s)$ and $Cl_2(g)$ is _____ kJ.

Key: 41.1

This question also applies to:

Skill

30–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- compare energy changes associated with a variety of chemical reactions through the analysis of data and energy diagrams

30–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- draw and interpret enthalpy diagrams for chemical reactions

Knowledge

30–A2.4k Explain that catalysts increase reaction rates by providing alternate pathways for changes, without affecting the net amount of energy involved; *e.g., enzymes in living systems.*

Use the following information to answer the next question.

The decomposition of hot potassium chlorate to solid potassium chloride and oxygen gas occurs at a faster rate in the presence of solid manganese(IV) oxide, as represented by the following equation.

$$2\,KClO_3(s) \xrightarrow{MnO_2(s)\ catalyst} 2\,KCl(s) + 3\,O_2(g)$$

27. When manganese(IV) oxide is used as a catalyst, the enthalpy change for the decomposition of potassium chlorate

*__A.__ stays the same

__B.__ becomes more exothermic

__C.__ becomes more endothermic

__D.__ changes from exothermic to endothermic

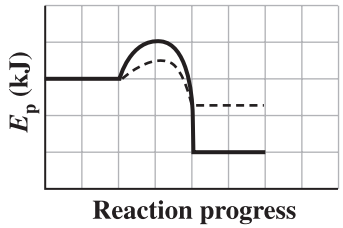
Use the following information to answer the next question.

One of the byproducts of the cracking process used at oil-refining plants is ethyne, $C_2H_2(g)$. In the presence of a palladium catalyst, the ethyne forms ethene and ethane, as represented by the following equation.

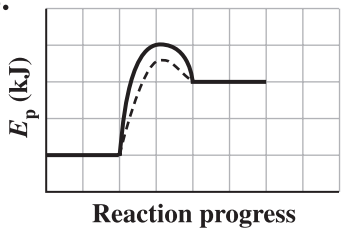
$$2\,C_2H_2(g) + 3\,H_2(g) \rightarrow C_2H_4(g) + C_2H_6(g) + 486.4\ kJ$$

28. Which of the following energy diagrams represents the energy changes for both the catalyzed and uncatalyzed reactions?

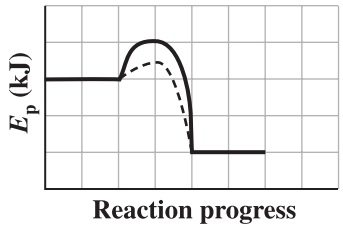
A.



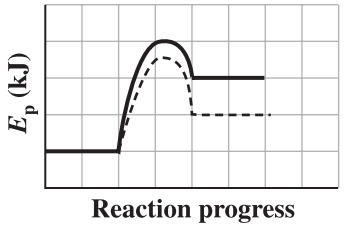
B.



*** C.**



D.



- - - - - Catalyzed

——— Uncatalyzed

This question also applies to:

Skill

30–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- draw and interpret enthalpy diagrams for chemical reactions

Skill

30–A2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- explain the discrepancy between the theoretical and actual efficiency of a thermal energy conversion system

Use the following information to answer the next question.

In a calorimetry experiment, a student found that the theoretical value for the molar enthalpy of combustion for methanol was higher than the value that she obtained in the laboratory.

29. Which of the following explanations could account for the discrepancy between the experimental value and the theoretical value for the molar enthalpy of combustion for methanol?

A. The mass of methanol was lower than measured.

B. The final temperature of the calorimeter contents was higher than measured.

C. The initial temperature of the calorimeter contents was lower than measured.

***D.** The incomplete combustion of methanol produced a mixture of CO(g) and CO_2(g) in the calorimeter.

Unit B—Electrochemical Changes

General Outcome 1:
Students will explain the nature of oxidation–reduction reactions

Knowledge

30–B1.1k Define oxidation and reduction operationally and theoretically.

Use the following information to answer the next question.

Statements	
I	Sulfur forms stable ions by gaining electrons.
II	Magnesium forms stable ions by losing electrons.
III	The oxidation number of iron changes from +3 to +2.
IV	The oxidation number of oxygen changes from –2 to –1.

30. The statements numbered above that refer to oxidation are

A. I and III

B. I and IV

C. II and III

***D.** II and IV

Use the following information to answer the next question.

Leaching technology is used in the mining and refining of copper ore. In the first step of the leaching process, concentrated aqueous sulfuric acid flows through a copper ore deposit. Solid copper(II) oxide reacts with sulfuric acid as represented by the following net ionic equation.

$$CuO(s) + 2\,H^{+}(aq) \rightarrow Cu^{2+}(aq) + H_2O(l)$$

The resulting solution that contains copper(II) ions is transferred to an electrolytic cell where pure copper is produced.

31. In the reaction represented by the equation above, copper undergoes

A. reduction only

B. oxidation only

C. both oxidation and reduction

***D.** neither oxidation nor reduction

---

32. Which of the following statements is an operational definition of the metal undergoing reduction?

A. Iron metal undergoes a formation reaction with oxygen gas.

B. Magnesium metal increases in mass when heated in air.

C. Iron(III) hydroxide reacts with oxygen in the air to form ionic compounds.

***D.** Zinc sulfide ore is roasted in the presence of oxygen gas to produce zinc metal.

Knowledge

30–B1.2k Define oxidizing agent, reducing agent, oxidation number, half-reaction, disproportionation.

Use the following information to answer the next question.

$$2\,H_2S(g) + 3\,O_2(g) \rightarrow 2\,SO_2(g) + 2\,H_2O(g)$$

33. *In the reaction represented by the equation above, oxygen acts as the* ___***i***___ *agent, and the oxidation number of the sulfur atom increases by* ___***ii***___ .

The statement above is completed by the information in row

Row	***i***	***ii***
A.	oxidizing	2
***B.**	oxidizing	6
C.	reducing	2
D.	reducing	6

34. Which of the following equations represents a disproportionation reaction?

A. $2\,Na(s) + I_2(s) \rightarrow 2\,NaI(s)$

B. $2\,F_2(g) + O_2(g) \rightarrow 2\,OF_2(g)$

***C.** $Cl_2(aq) + H_2O(l) \rightarrow HOCl(aq) + H^+(aq) + Cl^-(aq)$

D. $2\,NH_3(aq) + NaOCl(aq) \rightarrow N_2H_4(aq) + NaCl(aq) + H_2O(l)$

Knowledge

30–B1.3k Differentiate between redox reactions and other reactions, using half-reactions and/or oxidation numbers.

35. Which of the following equations represents a redox reaction?

A. $NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(l)$

***B.** $2\,AgNO_3(aq) + Cu(s) \rightarrow 2\,Ag(s) + Cu(NO_3)_2(aq)$

C. $H_2SO_4(aq) + 2\,KOH(aq) \rightarrow K_2SO_4(aq) + 2\,H_2O(l)$

D. $CaCl_2(aq) + Ba(OH)_2(aq) \rightarrow Ca(OH)_2(aq) + BaCl_2(aq)$

Use the following information to answer the next question.

The equilibrium constants for two reactions at 900 K are represented by the following equations.

Equation I $2\,H_2S(g) + 3\,O_2(g) \rightleftharpoons 2\,SO_2(g) + 2\,H_2O(g) + 1\,036.0\ kJ$ $K_c = 377$

Equation II $2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g) + 197.8\ kJ$ $K_c = 13$

36. **Compare** the two reactions represented by the equations above in terms of redox and equilibrium. **Identify** one similarity or difference in terms of redox and one similarity or difference in terms of equilibrium.

Your response should include

- an explanation of the similarity and/or difference you have identified in terms of redox
- an explanation of the similarity and/or difference you have identified in terms of equilibrium

This question can also apply to:

Knowledge

30–B1.4k
30–D1.2k
30–D1.3k

Knowledge

30–B1.4k Identify electron transfer, oxidizing agents and reducing agents in redox reactions that occur in everyday life, in both living systems *(e.g., cellular respiration, photosynthesis)* and nonliving systems; i.e., corrosion.

Use the following information to answer the next question.

Cellular Respiration

$$C_6H_{12}O_6(s) + 6\,O_2(g) \rightarrow 6\,CO_2(g) + 6\,H_2O(l)$$

37. During cellular respiration, the oxidizing agent is

*__A.__ $O_2(g)$

__B.__ $CO_2(g)$

__C.__ $H_2O(l)$

__D.__ $C_6H_{12}O_6(s)$

Use the following information to answer the next question.

Metallurgical Processes

__I__ $2\,Al_2O_3(s) \rightarrow 4\,Al(s) + 3\,O_2(g)$

__II__ $2\,PbO(s) + C(s) \rightarrow 2\,Pb(s) + CO_2(g)$

__III__ $Zn(s) + 2\,HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

__IV__ $Cu(s) + 4\,HNO_3(aq) \rightarrow Cu(NO_3)_2(aq) + 2\,NO_2(g) + 2\,H_2O(l)$

38. The metallurgical processes in which the metal loses electrons are

__A.__ I and II

__B.__ I and III

__C.__ II and IV

*__D.__ III and IV

Knowledge

30–B1.5k Compare the relative strengths of oxidizing and reducing agents, using empirical data.

Use the following information to answer the next question.

	$Be^{2+}(aq)$	$Cd^{2+}(aq)$	$Ra^{2+}(aq)$	$V^{2+}(aq)$
Be(s)	×	✓	×	✓
Cd(s)	×	×	×	×
Ra(s)	✓	✓	×	✓
V(s)	×	✓	×	×

✓ evidence of a spontaneous reaction
× no spontaneous reaction

39. When listed in order from strongest to weakest, the oxidizing agents are

A. Ra(s), Be(s), V(s), Cd(s)

B. Cd(s), V(s), Be(s), Ra(s)

C. $Ra^{2+}(aq)$, $Be^{2+}(aq)$, $V^{2+}(aq)$, $Cd^{2+}(aq)$

*__D.__ $Cd^{2+}(aq)$, $V^{2+}(aq)$, $Be^{2+}(aq)$, $Ra^{2+}(aq)$

Use the following information to answer the next question.

A student collected the data below.

$M^{2+}(aq) + 2\,e^- \rightarrow M(s)$ $\quad E° = +1.21$ V

$Q^{+}(aq) + e^- \rightarrow Q(s)$ $\quad E° = +1.03$ V

$Z^{3+}(aq) + 3\,e^- \rightarrow Z(s)$ $\quad E° = -0.21$ V

$X_2(aq) + 2\,e^- \rightarrow 2\,X^-(aq)$ $\quad E° = -1.23$ V

40. From the student's data, the strongest reducing agent is

A. $M^{2+}(aq)$

*__B.__ $X^-(aq)$

C. $X_2(aq)$

D. M(s)

Use the following information to answer the next question.

A student wants to store a tin(II) chloride solution in a container made of either iron, zinc, aluminium, or copper.

41. **Design** an experiment that will enable you to determine which type of container—iron, zinc, aluminium, or copper—is best to use in terms of reactivity for storing a tin(II) chloride solution.

Your response should include

- an explanation and rationale to support your choice
- relevant half-reaction equations
- two other criteria you would use, other than reactivity, to determine the best storage container

This question also applies to:

Skill

30–B1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- design an experiment to determine the reactivity of various metals

Skill

30–B1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions.

- evaluate data from an experiment to derive a simple reduction table
- interpret patterns and trends in data derived from redox reactions
- identify the limitations of data collected from redox experiments

Knowledge

30–B1.6k Predict the spontaneity of a redox reaction, based on standard reduction potentials, and compare the predictions to experimental results.

42. Which of the following equations represents a spontaneous redox reaction?

A. $Zn^{2+}(aq) + Pb(s) \rightarrow Zn(s) + Pb^{2+}(aq)$

*__B.__ $Sn^{4+}(aq) + Fe(s) \rightarrow Sn^{2+}(aq) + Fe^{2+}(aq)$

C. $Zn^{2+}(aq) + Co(s) \rightarrow Zn(s) + Co^{2+}(aq)$

D. $O_2(g) + 2\,H_2O(l) + 4\,Br^-(aq) \rightarrow 2\,Br_2(l) + 4\,OH^-(aq)$

43. The reducing agent that can convert 1.0 mol/L $Sn^{4+}(aq)$ ions to $Sn^{2+}(aq)$ but **not** 1.0 mol/L $Sn^{2+}(aq)$ to Sn(s) is

A. Cu(s)

*__B.__ Pb(s)

C. Ni(s)

D. Cr(s)

Knowledge

30–B1.7k Write and balance equations for redox reactions in acidic and neutral solutions by

- using half-reaction equations obtained from a standard reduction potential table
- developing simple half-reaction equations from information provided about redox changes
- assigning oxidation numbers, where appropriate, to the species undergoing chemical change

Use the following information to answer the next question.

$$\_\_OCl^-(aq) + \_\_I^-(aq) + \_\_H+(aq) \rightarrow \_I_2(aq) + \_Cl^-(aq) + \_H_2O(l)$$

44. *When the equation above is balanced under acidic conditions, the whole number coefficient for $H^+(aq)$ is* ___***i***___ *and the amount of electrons transferred is* ___***ii***___ *.*

The statement above is completed by the information in row

Row	***i***	***ii***
A.	1	1 mol
B.	1	2 mol
C.	2	1 mol
***D.**	2	2 mol

Use the following information to answer the next question.

Chlorine gas and aqueous sodium hyposulfite react as represented by the following **unbalanced** equation.

$$Cl_2(g) + S_2O_3^{2-}(aq) + H_2O(l) \rightarrow SO_4^{2-}(aq) + H^+(aq) + Cl^-(aq)$$

45. The balanced oxidation half-reaction equation is

A. $Cl_2(g) + 2\,e^- \rightarrow 2\,Cl^-(aq)$

B. $S_2O_3^{2-}(aq) + H_2O(l) \rightarrow SO_4^{2-}(aq) + 2\,H^+(aq) + 4\,e^-$

***C.** $S_2O_3^{2-}(aq) + 5\,H_2O(l) \rightarrow 2\,SO_4^{2-}(aq) + 10\,H^+(aq) + 8\,e^-$

D. $S_2O_3^{2-}(aq) + 5\,H_2O(l) + 4\,e^- \rightarrow 2\,SO_4^{2-}(aq) + 10\,H^+(aq)$

Knowledge

30–B1.8k Perform calculations to determine quantities of substances involved in redox titrations.

46. Iron metal is easily oxidized to $Fe^{2+}(aq)$ by an acidified potassium dichromate solution during a redox titration.

a. **Write** the net ionic equation for this process and **determine** the mass of iron metal oxidized by 50.0 mL of a 0.250 mol/L acidified $K_2Cr_2O_7(aq)$ solution **(3 marks)**

b. Oxidation of iron is often an undesirable reaction in the environment. There are several methods to prevent corrosion of iron. **Describe** one of these methods and **explain** how this method prevents iron from corroding. **(2 marks)**

This question also applies to:

Science, Technology, and Society

30–B1.1sts explain how the goal of technology is to provide solutions to practical problems

- describe the methods and devices used to prevent corrosion; i.e., physical coatings and cathodic protection

Use the following information to answer the next question.

A standardized 0.125 mol/L potassium dichromate solution was used to titrate 20.0 mL samples of acidified $Sn^{2+}(aq)$. The data is represented in the following table.

Titration Data

Trial	**I**	**II**	**III**
Final burette volume (mL)	27.2	44.5	30.1
Initial burette volume (mL)	10.1	27.2	12.9

47. The amount of potassium dichromate solution required to complete this titration is

A. 8.33×10^{-4} mol

B. 6.45×10^{-3} mol

C. 2.50×10^{-3} mol

*__D.__ 2.15×10^{-3} mol

*Use your recorded answer from **Multiple Choice 47** to answer **Numerical Response 48.****

48. The concentration of $Sn^{2+}(aq)$ in the sample used in the titration, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ mol/L. The values of ***a, b, c,*** and ***d*** are _____, _____, _____, and _____.

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

Key: 3231

Acceptable Responses for Linked Item 48:

*If MC47 is A, then NR48 is 1251
B, then NR48 is 9681
C, then NR48 is 3751
D, then NR48 is 3231*

General Outcome 2:
Students will apply the principles of oxidation–reduction to electrochemical cells

Knowledge

30–B2.1k Define anode, cathode, anion, cation, salt bridge/porous cup, electrolyte, external circuit, power supply, voltaic cell and electrolytic cell.

49. The anode of an electrochemical cell is the site at which

*__A.__ oxidation occurs

__B.__ cations gain electrons

__C.__ cations are attracted to the electrode

__D.__ electrons are attracted to the electrode

50. **Illustrate** and **describe** a working voltaic cell that incorporates a standard nickel half-cell and has a cell potential greater than 1.00 V.

Your response should include

- relevant balanced half-reaction equations and an E°_{cell} calculation
- a labelled cell diagram
- evidence that a reaction has occurred in each half-cell

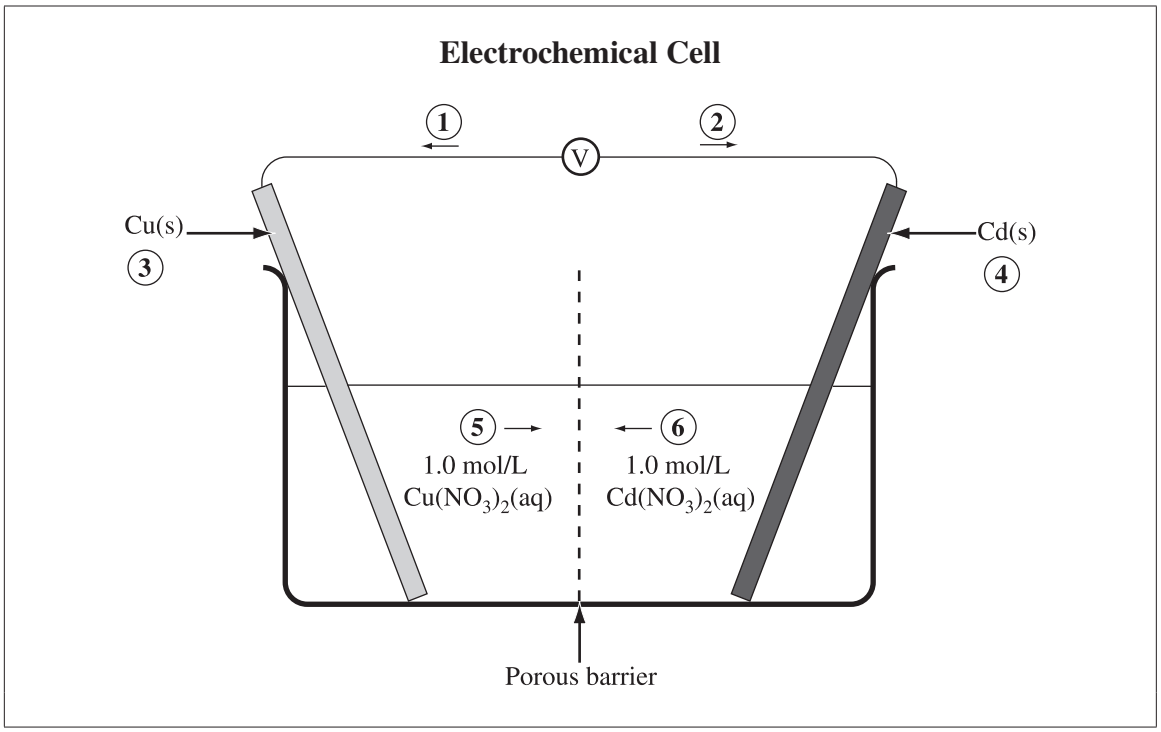
This question also applies to

Skill

30–B2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues.

- design an experiment, including a labelled diagram, to test predictions regarding spontaneity, products and the standard cell potential for reactions occurring in electrochemical cells

Use the following information to answer the next question.



51. Match the numbers in the diagram above with their appropriate labels given below.

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

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

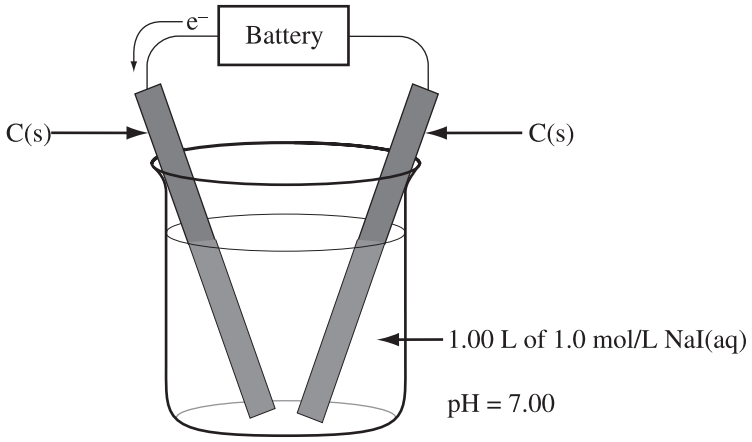
Anion movement _____ (Record in the **third** column)

Electron movement _____ (Record in the **fourth** column)

Key: 4351

Use the following information to answer the next question.

Electrochemical Cell



52. Which of the following rows identifies the type of electrochemical cell in the diagram above and describes what happens during its operation?

Row	Type of Cell	What Happens
A.	Voltaic	Electrons move toward the cathode
B.	Voltaic	$I^-(aq)$ moves toward the cathode
***C.**	Electrolytic	Electrons move toward the cathode
D.	Electrolytic	$I^-(aq)$ moves toward the cathode

Knowledge

30–B2.2k Identify the similarities and differences between the operation of a voltaic cell and that of an electrolytic cell.

53. An electrolytic cell differs from a voltaic cell in that the electrolytic cell

*__A.__ is spontaneous

__B.__ consumes electricity

__C.__ has a positive E°_{cell} value

__D.__ has an anode and a cathode

Use the following information to answer the next question.

Statements About Electrochemical Cells

1 Oxidation occurs at the anode.

2 The oxidizing agent reacts at the cathode.

3 Cations move through the wire to the cathode.

4 Cations move through the electrolyte to the cathode.

5 Electrons move through the wire to the cathode.

6 Electrical energy is converted to chemical energy.

7 Chemical energy is converted to electrical energy.

54. The statements numbered above that apply to both electrolytic cells and voltaic cells are _____, _____, _____, and _____.

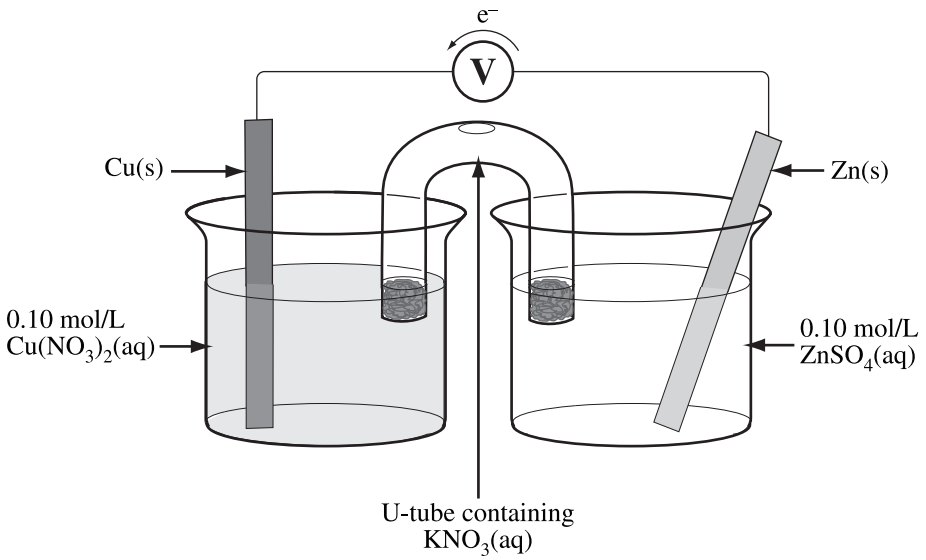
Key: 1245

Knowledge

30–B2.3k Predict and write the half-reaction equation that occurs at each electrode in an electrochemical cell.

Use the following information to answer the next question.

Electrochemical Cell



55. *The reduction half-reaction that occurs during the operation of the electrochemical cell represented in the diagram above is* ___***i***___ *, and this reaction occurs at the* ___***ii***___ .

The statement above is completed by the information in row

Row	*i*	*ii*
A.	$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	anode
***B.**	$Cu^{2+}(aq) + 2\,e^- \rightarrow Cu(s)$	cathode
C.	$Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$	anode
D.	$Zn^{2+}(aq) + 2\,e^- \rightarrow Zn(s)$	cathode

This question also applies to:

Skill

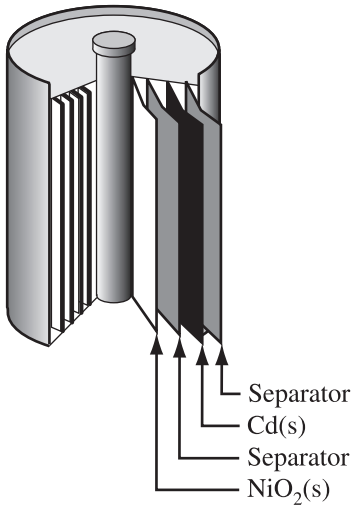
30–B2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- identify the products of electrochemical cells
- compare predictions with observations of electrochemical cells

Use the following information to answer the next question.

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

Nickel–Cadmium Cell



The net equation representing the discharge of the nickel–cadmium cell is

$$NiO_2(s) + Cd(s) + 2\,H_2O(l) \rightarrow Cd(OH)_2(s) + Ni(OH)_2(s)$$

56. The half-reaction that occurs at the anode during the discharge of the nickel–cadmium cell is

*__A.__ $Cd(s) + 2\,OH^-(aq) \rightarrow Cd(OH)_2(s) + 2\,e^-$

__B.__ $Cd(s) + 2\,OH^-(aq) + 2\,e^- \rightarrow Cd(OH)_2(s)$

__C.__ $NiO_2(s) + 2\,H_2O(l) + 2\,e^- \rightarrow Ni(OH)_2(s) + 2\,OH^-(aq)$

__D.__ $NiO_2(s) + 2\,H_2O(l) \rightarrow Ni(OH)_2(s) + 2\,OH^-(aq) + 2\,e^-$

This question also applies to:

Skill

30–B2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- identify the products of electrochemical cells
- compare predictions with observations of electrochemical cells

Knowledge

30–B2.4k Recognize that predicted reactions do not always occur; *e.g., the production of chlorine gas from the electrolysis of brine*.

Use the following information to answer the next question.

Predicted reactions do not always occur when tried in a laboratory.

57. a. **Identify** and **describe** an occurrence which may result in a predicted reaction not occurring. **(2 marks)**

b. **Write** the net ionic equation and calculate the cell potential for a reaction that occurs which was not predicted. **(3 marks)**

Knowledge

30–B2.5k Explain that the values of standard reduction potential are all relative to 0 volts, as set for the hydrogen electrode at standard conditions.

58. For the standard reference half-cell, the reduction half-reaction equation and electrical potential are

A. $H_2(g) \rightarrow 2\,H^+(aq) + 2\,e^-$ $E° = 0.00$ V

*__B.__ $2\,H^+(aq) + 2\,e^- \rightarrow H_2(g)$ $E° = 0.00$ V

C. $2\,H_2O(l) + 2\,e^- \rightarrow H_2(g) + 2\,OH^-(aq)$ $E° = -0.83$ V

D. $H_2(g) + 2\,OH^-(aq) \rightarrow 2\,H_2O(l) + 2\,e^-$ $E° = +0.83$ V

59. If the standard iodine half-cell is chosen as the reference half-cell instead of the hydrogen half cell, then the cell potential for a silver–nickel cell is +/–_____ V.

Key: 1.06

Knowledge

30–B2.6k Calculate the standard cell potential for electrochemical cells.

Use the following information to answer the next question.

$$2\,Ag^{+}(aq) + Zn(s) \rightarrow 2\,Ag(s) + Zn^{2+}(aq)$$

60. The cell potential for the redox reaction represented by the equation above is

A. +0.04 V

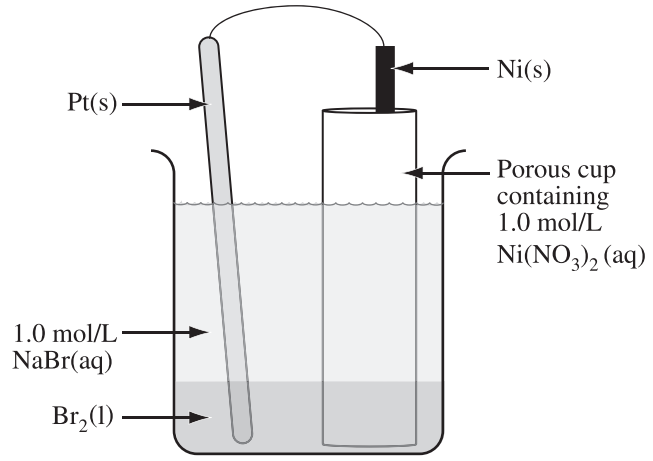
*__B.__ +0.84 V

C. +1.56 V

D. +2.36 V

Use the following information to answer the next question.

Electrochemical Cell



61. The cell potential for the electrochemical cell in the diagram above is _____ V.

Key: 1.33

Knowledge

30–B2.7k Predict the spontaneity or nonspontaneity of redox reactions, based on standard cell potential, and the relative positions of half-reaction equations on a standard reduction potential table.

Use the following information to answer the next question.

A student constructed two standard electrochemical cells using $Pb^{2+}(aq)$ and $Ni^{2+}(aq)$. In both cells a Pb(s) electrode was placed in the $Pb^{2+}(aq)$ solution. In the first cell a Ni(s) electrode was placed in the $Ni^{2+}(aq)$ solution. In the second cell an inert C(s) electrode was placed in the $Ni^{2+}(aq)$ solution instead of the Ni(s) electrode.

62. Which of the following statements describes what occurs in each cell?

A. In both cells a power source is needed.

B. In both cells a spontaneous reaction occurs and Pb(s) is produced.

C. In the first cell Ni(s) is produced, and in the second cell a power source is needed.

***D.** In the first cell the reaction is spontaneous, and in the second cell the reaction is nonspontaneous.

Knowledge

30–B2.8k Calculate mass, amounts, current and time in single voltaic and electrolytic cells by applying Faraday's law and stoichiometry.

Use the following information to answer the next question.

The reduction half-reaction for a Hall–Héroult electrolytic cell is represented by the following equation.

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

63. If a current of 10.0 A is applied for 5.00 h to the Hall–Héroult electrolytic cell, then the amount of electrons transferred is

A. 5.60 mol

*__B.__ 1.87 mol

C. 6.22×10^{-1} mol

D. 5.18×10^{-4} mol

Use the following information to answer the next question.

A Hall-Héroult electrolytic cell is used to produce molten aluminium from molten aluminium oxide, as represented by the following simplified equation.

$$2\,Al_2O_3(l) \rightarrow 4\,Al(l) + 3\,O_2(g)$$

64. In the Hall-Héroult electrolytic cell, the time required for the cell to operate at 5.55×10^3 A to produce 20.0 kg of aluminium is _____ h.

Key: 10.7 or 10.8 (depending on number of decimal places carried during intermediate steps)

Science, Technology, and Society

30–B2.2sts describe science and technology applications that have developed in response to human and environmental needs

- investigate the use of technology, such as galvanism, metallurgy, magnesium coupling, painting, cathodic protection, to solve practical problems related to corrosion

Use the following information to answer the next question.

A particular company manufactures plastic tape containing small pieces of magnesium. The tape is completely wrapped around iron pipes that will be buried underground.

65. **Explain** in chemical terms the purpose(s) of each component of the tape.

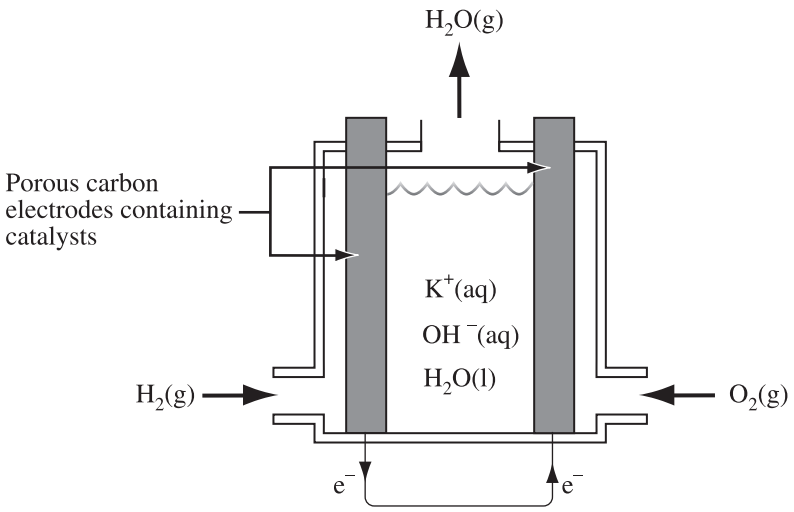
Your response should include

- an explanation of the corrosion of iron
- an explanation of how the plastic tape and magnesium pieces prevent the corrosion of iron
- relevant half-reaction equations

Use the following information to answer the next question.

Hydrogen–oxygen fuel cells have been used for years in spacecraft and more recently in small-scale power plants to generate electricity. Now, some governments and companies are working together to perfect this type of fuel cell for automobile use, and experiments are currently being conducted with operational prototypes. A diagram of a hydrogen–oxygen fuel cell is shown below.

Hydrogen–Oxygen Fuel Cell



66. From an ecological perspective, a reason why hydrogen–oxygen fuel cells should **not** be used to power automobiles is that

*__A.__ hydrogen fuel can be produced through the electrolysis of seawater by using the energy produced from burning fossil fuels

__B.__ cars powered by a hydrogen–oxygen fuel cell would be up to 30% more efficient than cars powered by gasoline

__C.__ water vapour is the primary by-product of the cell

__D.__ oxygen is readily available from the atmosphere

Unit C—Chemical Changes of Organic Compounds

General Outcome 1:

Students will explore organic compounds as a common form of matter

Knowledge

30–C1.1k Define organic compounds as compounds containing carbon, recognizing inorganic exceptions such as carbonates, cyanides, carbides and oxides of carbon.

67. Which of the following chemical compounds is **not** considered an organic compound?

A. $C_2H_5COOCH_3(l)$

B. $C_6H_5COOH(s)$

C. $CH_3CH_2OH(l)$

D. $NH_4CN(s)$

Use the following information to answer the next question.

Chemical Compounds

1	$CO_2(g)$	**5**	$Co(OH)_2(s)$
2	$CH_3OH(l)$	**6**	$HCN(g)$
3	$H_2CO_3(aq)$	**7**	$CH_3COOCH_3(aq)$
4	$ClCH_3(l)$	**8**	$HCOOH(l)$

68. The chemical compounds numbered above that represent organic compounds are _____, _____, _____, and _____.

Key: 2478

Knowledge

30–C1.2k Identify and describe significant organic compounds in daily life, demonstrating generalized knowledge of their origins and applications; *e.g., methane, methanol, ethane, ethanol, ethanoic acid, propane, benzene, octane, glucose, polyethylene*.

Use the following information to answer the next question.

Ethanol and methanol are organic compounds commonly used in industry.

69. a. **Draw** the structural diagrams for ethanol and methanol, and **compare** the two diagrams by identifying one similarity and one difference. **(3 marks)**

b. **Identify** another commonly used organic compound other than methanol or ethanol. **Describe** the origin and an application of this compound. **(2 marks)**

This question also applies to:

Knowledge

30–C1.3k

Science, Technology, and Society

30–C1.1sts explain how science and technology are developed to meet societal needs and expand human capability

- describe where organic compounds are used in processes and common products, such as in hydrogenation to produce margarine and esters used as flavouring agents

Science, Technology, and Society

30–C2.3sts explain how science and technology have both intended and unintended consequences for humans and the environment

- assess the positive and negative effects of various reactions involving organic compounds, relating these processes to quality of life and potential health and environmental issues, e.g.,
  - *burning fossil fuels and climate change*
  - *production of pharmaceuticals and foods*
  - *byproducts (CO_2, dioxins) of common reactions*
  - *recycling of plastics*
  - *impact of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) on the ozone layer*
  - *transfats in the diet*
- evaluate the implications of the development of nanoscience and nanotechnology, for application in the petrochemical industry and the medical sciences, on society and the environment

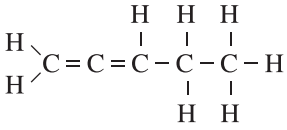
Knowledge

30–C1.3k Name and draw structural, condensed structural and line diagrams and formulas, using International Union of Pure and Applied Chemistry (IUPAC) nomenclature guidelines, for saturated and unsaturated aliphatic (including cyclic) and aromatic carbon compounds.

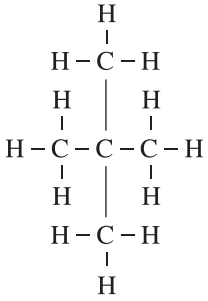
- containing up to 10 carbon atoms in the parent chain *(e.g., pentane; 3-ethyl-2,4-dimethylpentane)* or cyclic structure *(e.g., cyclopentane)*
- containing only one type of a functional group (with multiple bonds categorized as a functional group; *e.g., pent-2-ene*), including simple halogenated hydrocarbons *(e.g., 2-chloropentane)*, alcohols *(e.g., pentan-2-ol)*, carboxylic acids *(e.g., pentanoic acid)* and esters *(e.g., methyl pentanoate)*, and with multiple occurrences of the functional group limited to halogens *(e.g., 2-bromo-1-chloropentane)* and alcohols *(e.g., pentane-2,3-diol)*

70. The structural diagram that represents $CH_3C(CH_3)_2CH_3$ is

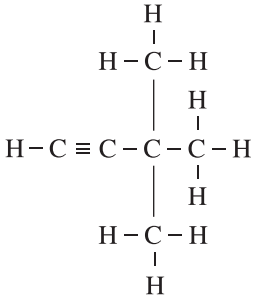
A.



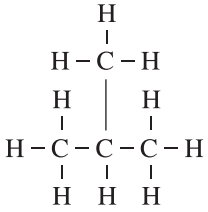
B.



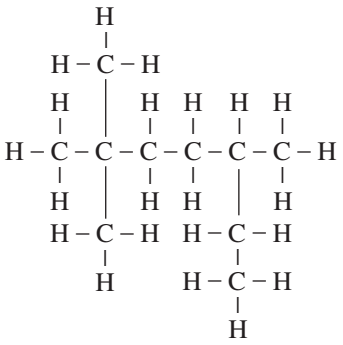
C.



D.



Use the following information to answer the next question.



71. The IUPAC name for the structural diagram above is

A. 2,2,5-trimethylheptane

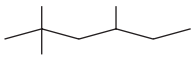
B. 3,6,6-trimethylheptane

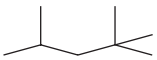
C. 2-ethyl-5,5-dimethylhexane

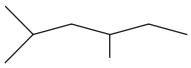
D. 5-ethyl-2,2-dimethylhexane

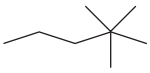
---

72. Which of the following line diagrams represents 2,2,4-trimethylpentane?

A. 

***B.** 

C. 

D. 

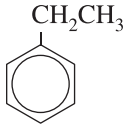
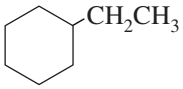
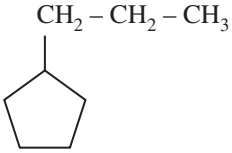
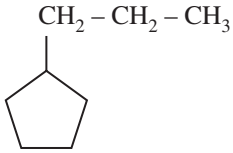
73. **a.** **Draw** and **name** a five-carbon organic compound. **Identify** if the compound you drew is saturated or unsaturated. **(3 marks)**

b. **Draw** and **name** a structural isomer of the compound that you drew above. **(2 marks)**

This question also applies to:

Knowledge
30–C1.5k

74. Which of the following rows identifies the structural diagram and the corresponding IUPAC name of the compound with the chemical formula $C_8H_{16}(l)$?

Row	Structural Diagram	IUPAC Name
A.		ethylbenzene
***B.**		ethylcyclohexane
C.		cyclopentylpropane
D.		propylcyclopentene

Use the following information to answer the next question.

$$C_6H_6(l) + Cl_2(g) \rightarrow C_6H_5Cl(l) + HCl(g) \qquad \Delta H^\circ = -80.5 \text{ kJ}$$

75. **a.** **Identify** and name the two organic compounds in the reaction represented by the equation above. **(3 marks)**

b. **Calculate** the molar enthalpy of formation for $C_6H_5Cl(l)$. **(2 marks)**

This question also applies to:

Knowledge
30–A1.6k

Use the following information to answer the next question.

A student added a bromine solution to a hydrocarbon sample that contains an isomer of $C_6H_{12}(l)$ in the absence of light. After shaking the sample, the student observed that the colour of the bromine solution changed from orange to colourless.

76. *An interpretation that could be made from the student's observation is that the hydrocarbon sample is* ___***i***___ *and the IUPAC name of the sample could be* ___***ii***___ .

The statement above is completed by the information in row

Row	***i***	***ii***
A.	saturated	hex-2-ene
B.	saturated	cyclopentane
***C.**	unsaturated	hex-2-ene
D.	unsaturated	cyclopentane

This question also applies to:

Skill

30–C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- follow appropriate IUPAC guidelines when writing the names and formulas of organic compounds
- compile and organize data to compare the properties of structural isomers; *e.g., pairs of hydrocarbon isomers and primary, secondary and tertiary alcohols*
- interpret the results of a test to distinguish between a saturated and an unsaturated aliphatic, using aqueous bromine or potassium permanganate solutions

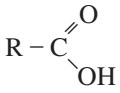
Knowledge

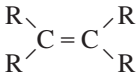
30–C1.4k Identify types of compounds from the hydroxyl, carboxyl, ester linkage, and halogen functional groups, given the structural formula.

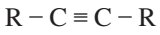
Use the following information to answer the next question.

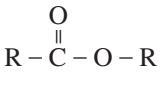
General Structural Diagrams

1 

2 

3 

4 

5 

6 

R—any chain of carbon and hydrogen atoms

77. Match the general structural diagrams numbered above with the class of the compound below.

Carboxylic acid _____ (Record in the **first** column)

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

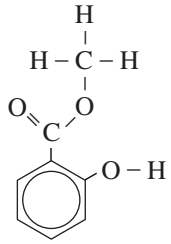
Alcohol _____ (Record in the **third** column)

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

Key: 2615

Use the following information to answer the next question.

The structural diagram of the active ingredient in many pain-relief medications is shown below.



78. *The structural diagram above represents an* ___***i***___ *compound that contains a* ___***ii***___ *and an* ___***iii***___ *functional group.*

The statement above is completed by the information in row

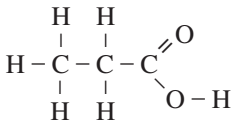
Row	***i***	***ii***	***iii***
A.	aromatic	carboxyl	alkene
***B.**	aromatic	hydroxyl	ester
C.	aliphatic	carboxyl	alkene
D.	aliphatic	hydroxyl	ester

Knowledge

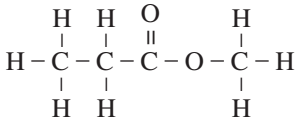
30–C1.5k Define structural isomerism as compounds having the same empirical formulas, but with different structural formulas, and relate the structures to variations in the properties of the isomers.

Use the following information to answer the next question.

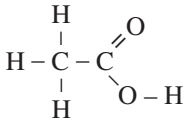
I



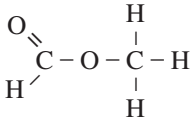
II



III



IV



79. Which of the structural diagrams numbered above represent isomers?

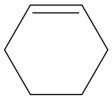
A. I and II

B. I and IV

C. II and III

*__D.__ III and IV

80. Which of the following rows identifies the condensed structural diagram or line diagram and the IUPAC name of an isomer of C_6H_{12}?

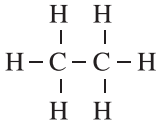
Row	Condensed Structural Diagram or Line Diagram	IUPAC Name
***A.**		Methylcyclopentane
B.		Cyclohexene
C.	$CH \equiv C - \underset{\displaystyle CH_3}{\underset{\vert}{CH}} - CH_2 - CH_3$	4-methylpentyne
D.	$CH_3 - CH_2 - C \equiv C - CH_2 - CH_3$	Hex-3-yne

Knowledge

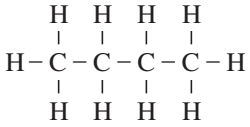
30–C1.6k Compare, both within a homologous series and among compounds with different functional groups, the boiling points and solubility of examples of aliphatics, aromatics, alcohols, and carboxylic acids.

81. Which of the following structural diagrams represents the compound with the lowest boiling point?

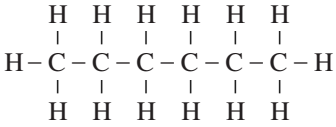
***A.**



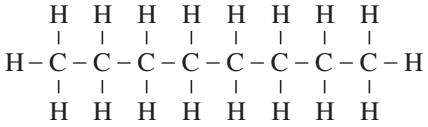
B.



C.



D.



Use the following information to answer the next question.

Compound	Boiling Point (°C)	Solubility in Water at 25 °C
I Cyclobutane	12	very low
II Propan-1-ol	98	high
III Pentan-1-ol	138	high

82. a. **Draw** structural diagrams for compounds I, II, and III. **(3 marks)**

b. **Explain** why the boiling point of compound III is higher than the boiling point of compound II, and **explain** why compound II is more soluble than compound I. **(2 marks)**

This question also applies to:

Knowledge
30-C1.3k

Skill
30–C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- follow appropriate IUPAC guidelines when writing the names and formulas of organic compounds
- compile and organize data to compare the properties of structural isomers; *e.g., pairs of hydrocarbon isomers and primary, secondary, and tertiary alcohols*
- interpret the results of a test to distinguish between a saturated and an unsaturated aliphatic, using aqueous bromine or potassium permanganate solutions

Knowledge

30–C1.7k Describe, in general terms, the physical, chemical and technological processes (fractional distillation and solvent extraction) used to separate organic compounds from natural mixtures or solutions;
e.g., petroleum refining, bitumen recovery.

83. a. **Name** and **draw** three hydrocarbons. **(3 marks)**

b. **Describe** a physical, chemical, or technological process that could be used to separate a mixture of hydrocarbons. **(2 marks)**

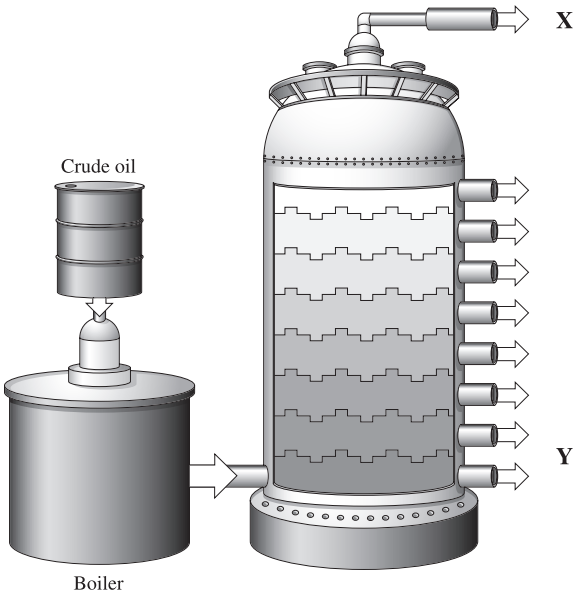
This question also applies to:

Knowledge

30-C1.3k

Use the following information to answer the next question.

The apparatus shown below is used to separate crude oil, a mixture of hydrocarbons, into individual hydrocarbons by their boiling points.



84. The method of separating the mixture of hydrocarbon compounds in crude oil that is represented in the diagram above is

A. titration

B. precipitation

C. solvent extraction

***D.** fractional distillation

This question also applies to:

Skill

30–C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- follow appropriate IUPAC guidelines when writing the names and formulas of organic compounds
- compile and organize data to compare the properties of structural isomers; *e.g., pairs of hydrocarbon isomers and primary, secondary and tertiary alcohols*
- interpret the results of a test to distinguish between a saturated and an unsaturated aliphatic, using aqueous bromine or potassium permanganate solutions

General Outcome 2:
Students will describe chemical reactions of organic compounds

Knowledge

30–C2.1k Define, illustrate, and provide examples of simple addition, substitution, elimination, esterification and combustion reactions.

Use the following information to answer the next question.

Common Organic Reactions

1 $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

2 $C_2H_5OH(l) \rightarrow C_2H_4(g) + H_2O(l)$

3 $C_6H_6(l) + Br_2(l) \rightarrow C_6H_5Br(l) + HBr(g)$

4 $CH_3COOH(l) + CH_3OH(l) \rightarrow CH_3COOCH_3(l) + H_2O(l)$

85. Match each equation representing the reactions numbered above with the type of reaction it exemplifies below.

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

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

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

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

Key: 1324

Knowledge

30–C2.2k Predict products and write and interpret balanced equations for simple addition, substitution, elimination, esterification and combustion reactions.

86. When methanol and ethanoic acid react, the products are

A. ethyl methanoate only

B. methyl ethanoate only

C. ethyl methanoate and water

*__D.__ methyl ethanoate and water

This question also applies to:

Skill

30–C2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems, and issues

- predict the ester formed from an alcohol and an organic acid

87. *The type of reaction that occurs when ethene gas and chlorine gas react is* ___***i***___ *, and the name of the organic compound produced is* ___***ii***___ .

The statement above is completed by the information in row

Row	***i***	***ii***
***A.**	addition	1,2-dichloroethane
B.	addition	1-chloroethene
C.	substitution	1,2-dichloroethane
D.	substitution	1-chloroethene

Use the following information to answer the next question.

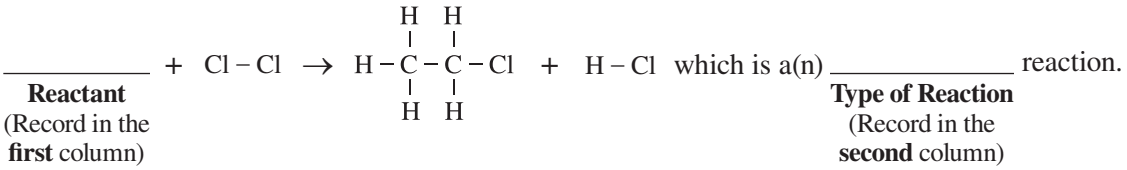
There are several methods of producing chloroethane, which can be used as a solvent and a refrigerant.

Reactants	
1	Ethane
2	Ethene
3	Ethyne
4	Ethanol

Type of Reaction	
5	Addition
6	Condensation
7	Elimination
8	Substitution

88. Match the reactants and type of reaction numbered above with two of the methods of producing chloroethane below.

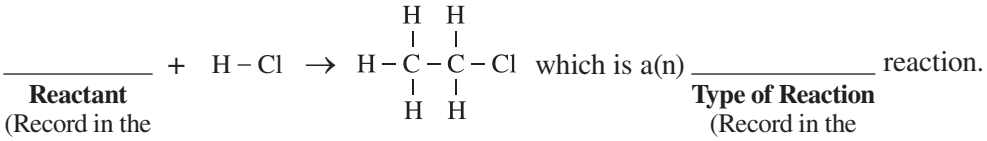
Method I



Reactant (Record in the **first** column)

Type of Reaction (Record in the **second** column)

Method II



Reactant (Record in the **third** column)

Type of Reaction (Record in the **fourth** column)

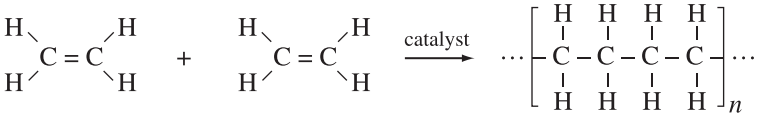
Key: 1825

Knowledge

30–C2.3k Define, illustrate, and provide examples of monomers *(e.g., ethylene)*, polymers *(e.g., polyethylene)* and polymerization in living systems *(e.g., carbohydrates, proteins)* and nonliving systems *(e.g., nylon, polyester, plastics).*

Use the following information to answer the next question.

Reaction Equation



IUPAC Names and Organic Terms

1	Ethane	**5**	Monomer
2	Ethene	**6**	Polymer
3	Ethyne	**7**	Polymerization
4	Polyethene		

89. Match the IUPAC name or the organic term numbered above with its descriptor below.

Product name _____ (Record in the **first** column)

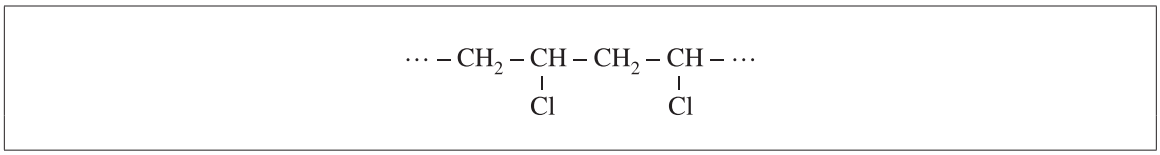
Reactant name _____ (Record in the **second** column)

Type of organic reaction _____ (Record in the **third** column)

Classification of product _____ (Record in the **fourth** column)

Key: 4276

Use the following information to answer the next question.



90. Which of the following monomers is required to produce the polymer in the structural diagram above?

A. CH_2–Cl–CH_2–Cl

B. CH_3–CH_2–Cl

***C.** CH_2=CHCl

D. CH≡CCl

Knowledge

30–C2.4k Relate simple addition, substitution, elimination, esterification and combustion reactions to major reactions that produce thermal energy and economically important compounds from fossil fuels.

Use the following information to answer the next question.

An economically important reaction involving the fossil fuel propane is represented by the following equation.

$$C_3H_8(g) + 5\,O_2(g) \rightarrow 3\,CO_2(g) + 4\,H_2O(g)$$

91. *During this* ___***i***___ *reaction, energy is* ___***ii***___ *the surroundings.*

The statement above is completed by the information in row

Row	***i***	***ii***
***A.**	combustion	released to
B.	combustion	absorbed from
C.	elimination	released to
D.	elimination	absorbed from

91. **Identify** one monomer that has economic importance in Alberta.

a. **Draw** the structural formula and provide the IUPAC name for the monomer that you chose. **(2 marks)**

b. **Identify** one use of the polymer formed from the monomer that you chose, and **write** the equation that represents the formation of the polymer. **(3 marks)**

This question also applies to:

Knowledge
30–C2.3k

Science, Technology, and Society
30–C2.1sts explain how science and technology are developed to meet societal needs and expand human capability

- describe processes for obtaining economically important compounds from fossil fuels
- describe major reactions used in the petrochemical industry in Alberta, such as in the production of methanol, ethylene glycol, polyethylene, polyvinyl chloride (PVC), and urea formaldehyde

Unit D—Chemical Equilibrium Focusing on Acid–Base Systems

General Outcome 1:

Students will explain that there is a balance of opposing reactions in chemical equilibrium systems

Knowledge

30–D1.1k Define equilibrium and state the criteria that apply to a chemical system in equilibrium; i.e., closed system, constancy of properties, equal rates of forward and reverse reactions.

93. Which of the following statements applies to a system at equilibrium?

*__A.__ The rate of the forward reaction is equal to the rate of the reverse reaction.

__B.__ The concentration of the reactants equals the concentration of the products.

__C.__ The rate of the forward reaction is greater than the rate of the reverse reaction.

__D.__ The concentration of the products is greater than the concentration of the reactants.

Use the following information to answer the next question.

$$\underset{\text{colourless}}{N_2O_4(g)} + \text{heat} \rightleftharpoons \underset{\text{brown}}{2\,NO_2(g)}$$

94. Which of the following properties would **not** be used to determine if the equilibrium system represented by the equation above is at equilibrium?

__A.__ Temperature

__B.__ Pressure

__C.__ Colour

*__D.__ Mass

Knowledge
30–D1.2k Identify, write and interpret chemical equations for systems at equilibrium.

95. The equation that represents the equilibrium of phosphoric acid is

A. $H_3PO_4(aq) \rightleftharpoons 3\,H^+(aq) + PO_4^{3-}(aq)$

B. $H_3PO_4(aq) \rightleftharpoons H_3O^+(aq) + PO_3^{3-}(aq)$

C. $H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + OH^-(aq)$

***D.** $H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq)$

Use the following information to answer the next question.

A technician placed a sample of $I_2(g)$ and $H_2(g)$ in an empty flask and allowed the contents to reach equilibrium. At equilibrium it was determined that HI(g) was present along with $H_2(g)$ and $I_2(g)$.

96. a. **Write** the balanced equation that represents the equilibrium system. **(2 marks)**

b. **Identify** three stresses that when applied to the system would increase the concentration of HI(g). **(3 marks)**

This question also applies to:

Knowledge
30-D1.3k

Knowledge

30–D1.3k Predict, qualitatively, using Le Châtelier's principle, shifts in equilibrium caused by changes in temperature, pressure, volume, concentration or the addition of a catalyst and describe how these changes affect the equilibrium constant.

97. When applied to an equilibrium system, which of the following stresses would cause a change in the K_c value after the equilibrium has been re-established?

A. Addition of a catalyst

*__B.__ Decrease in temperature by cooling the system

C. Addition of an inert gas to increase the pressure

D. Decrease in concentration by removing a product

Use the following information to answer the next question.

$$2\,NO_2(g) \rightleftharpoons N_2O_4(g) + \text{heat}$$

brown colourless

Stresses Applied to an Equilibrium System

1	Increase volume	**5**	Increase $NO_2(g)$ concentration
2	Decrease volume	**6**	Decrease $NO_2(g)$ concentration
3	Increase temperature	**7**	Increase $N_2O_4(g)$ concentration
4	Decrease temperature	**8**	Decrease $N_2O_4(g)$ concentration

98. The stresses numbered above that will cause the equilibrium system to shift to the left are _____, _____, _____, and _____.

Key: 1367

99. **Design** a procedure that would allow you to apply a stress to the equilibrium system represented by the following equation, and **explain** what happens to the system when the stress is applied.

$$\underset{\text{brown}}{2\,NO_2(g)} \rightleftharpoons \underset{\text{colourless}}{N_2O_4(g)} + 101.4\ kJ$$

Your response should include

- an explanation, based on Le Châtelier's principle, of how the stress would shift the equilibrium
- a detailed procedure of how to apply the stress
- a prediction of what evidence there would be that the shift had occurred

This question also applies to:

Skill

30–D1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems, and issues

- predict variables that can cause a shift in equilibrium
- design an experiment to show equilibrium shifts, *e.g., colour change, temperature change, precipitation*

Knowledge

30–D1.4k Define K_c to predict the extent of the reaction and write equilibrium law expressions for given chemical equations, using lowest whole number coefficients.

Use the following information to answer the next question.

$$HNO_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + NO_2^-(aq) \qquad K_a = 5.6 \times 10^{-3}$$

100. *The equilibrium law expression for the equation above is* ___***i***___ *, and at equilibrium the amount of products present is* ___***ii***___ *the amount of reactants present.*

The statement above is completed by the information in row

Row	*i*	*ii*
***A.**	$K_a = \dfrac{[H_3O^+(aq)][NO_2^-(aq)]}{[HNO_2(aq)]}$	less than
B.	$K_a = \dfrac{[H_3O^+(aq)][NO_2^-(aq)]}{[HNO_2(aq)][H_2O(l)]}$	greater than
C.	$K_a = \dfrac{[HNO_2(aq)][H_2O(l)]}{[H_3O^+(aq)][NO_2^-(aq)]}$	less than
D.	$K_a = \dfrac{[HNO_2(aq)]}{[H_3O^+(aq)]\,[NO_2^-(aq)]}$	greater than

101. The equation that is represented by the equilibrium law expression

$$K_a = \frac{[NO_2(g)]^2}{[NO(g)]^2\,[O^2(g)]} \text{ is}$$

A. $2\,NO_2(g) \rightleftharpoons 2\,NO(g) + O_2(g)$

***B.** $2\,NO(g) + O_2(g) \rightleftharpoons 2\,NO_2(g)$

C. $NO_2(g) \rightleftharpoons NO(g) + O_2(g)$

D. $NO(g) + O_2(g) \rightleftharpoons NO_2(g)$

Knowledge

30–D1.5k Describe Brønsted–Lowry acids as proton donors and bases as proton acceptors.

102. Which of the following substances can act as a Brønsted–Lowry base?

A. NaCl(aq)

B. $CH_3OH(aq)$

C. HCOOH(aq)

***D.** $NaHCO_3(aq)$

Use the following information to answer the next question.

$$HCO_3^-(aq) + HSO_3^-(aq) \rightleftharpoons H_2CO_3(aq) + SO_3^{2-}(aq)$$

103. The Brønsted–Lowry acids in the equation above are

A. $HCO_3^-(aq)$ and $HSO_3^-(aq)$

B. $HCO_3^-(aq)$ and $H_2CO_3(aq)$

***C.** $HSO_3^-(aq)$ and $H_2CO_3(aq)$

D. $HSO_3^-(aq)$ and $SO_3^{2-}(aq)$

Knowledge

30–D1.6k Write Brønsted–Lowry equations, including indicators, and predict whether reactants or products are favoured for acid–base equilibrium reactions for monoprotic and polyprotic acids and bases.

104. Which of the following equations represents an equilibrium system that favours the products?

A. $HOCl(aq) + HCO_3^-(aq) \rightleftharpoons OCl^-(aq) + H_2CO_3(aq)$

B. $H_2SO_3(aq) + CN^-(aq) \rightleftharpoons HSO_3^-(aq) + HCN(aq)$

***C.** $HF(aq) + NO_2^-(aq) \rightleftharpoons F^-(aq) + HNO_2(aq)$

D. $H_2S(aq) + F^-(aq) \rightleftharpoons HS^-(aq) + HF(aq)$

105. Which of the following rows identifies the equilibrium equation and solution colour that would occur when a few drops of phenol red indicator, $HPr(aq)/Pr^-(aq)$, are added to a 100.00 mL sample of 0.50 mol/L nitrous acid?

Row	Equilibrium Equations	Solution Colour
***A.**	$HNO_2(aq) + Pr^-(aq) \rightleftharpoons NO_2^-(aq) + HPr(aq)$	Yellow
B.	$HNO_2(aq) + Pr^-(aq) \rightleftharpoons NO_2^-(aq) + HPr(aq)$	Red
C.	$HNO_2(aq) + HPr(aq) \rightleftharpoons NO_2^-(aq) + H_2Pr^+(aq)$	Yellow
D.	$HNO_2(aq) + HA(aq) \rightleftharpoons NO_2^-(aq) + H2Pr^+(aq)$	Red

106. Which of the following equations represents a weak base system at equilibrium?

***A.** $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$

B. $NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$

C. $NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$

D. $HNO_2(aq) + CN^-(aq) \rightleftharpoons NO_2^-(aq) + HCN(aq)$

Knowledge
30–D1.7k Identify conjugate pairs and amphiprotic substances.

107. Which of the following substances is an amphiprotic species?

A. $CH_4(g)$

B. $CH_3OH(aq)$

C. $CH_3COO^-(aq)$

***D.** $HOOCCOO^-(aq)$

Use the following information to answer the next question.

$$HNO_2(aq) + H_2BO_3^-(aq) \rightleftharpoons NO_2^-(aq) + H_3BO_3(aq)$$

108. *In the reaction represented by the equation above, an amphiprotic species is* ___***i***___ *, and a conjugate acid–base pair is* ___***ii***___ .

The statement above is completed by the information in row

Row	***i***	***ii***
A.	$HNO_2(aq)$	$HNO_2(aq)$ and $NO_2^-(aq)$
B.	$HNO_2(aq)$	$H_2BO_3^-(aq)$ and $NO_2^-(aq)$
***C.**	$H_2BO_3^-(aq)$	$HNO_2(aq)$ and $NO_2^-(aq)$
D.	$H_2BO_3^-(aq)$	$H_2BO_3^-(aq)$ and $NO_2^-(aq)$

Knowledge

30–D1.8k Define a buffer as relatively large amounts of a weak acid or base and its conjugate in equilibrium that maintain a relatively constant pH when small amounts of acid or base are added.

109. Which of the following pairs of chemical compounds can act as a buffer system?

A. HCl(aq) and NaOH(aq)

B. HCl(aq) and H_2SO_4(aq)

C. CH_3COOH(aq) and HCl(aq)

***D.** CH_3COOH(aq) and $NaCH_3COO$(aq)

Use the following information to answer the next question.

A 100.00 mL sample of a 0.100 mol/L solution of H_2CO_3(aq) is combined with a 100.00 mL sample of a 0.100 mol/L solution of $NaHCO_3$(aq) and the following equilibrium system is established.

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

110. Which of the following rows identifies the direction of the shift in equilibrium and the effect on the pH of the system when a small quantity of hydrochloric acid is added to the equilibrium system above?

Row	Direction of Shift	Effect on pH
A.	Toward the products	No change
B.	Toward the products	Decrease
***C.**	Toward the reactants	No change
D.	Toward the reactants	Decrease

This question also applies to:

Knowledge

30–D1.3k

Skill

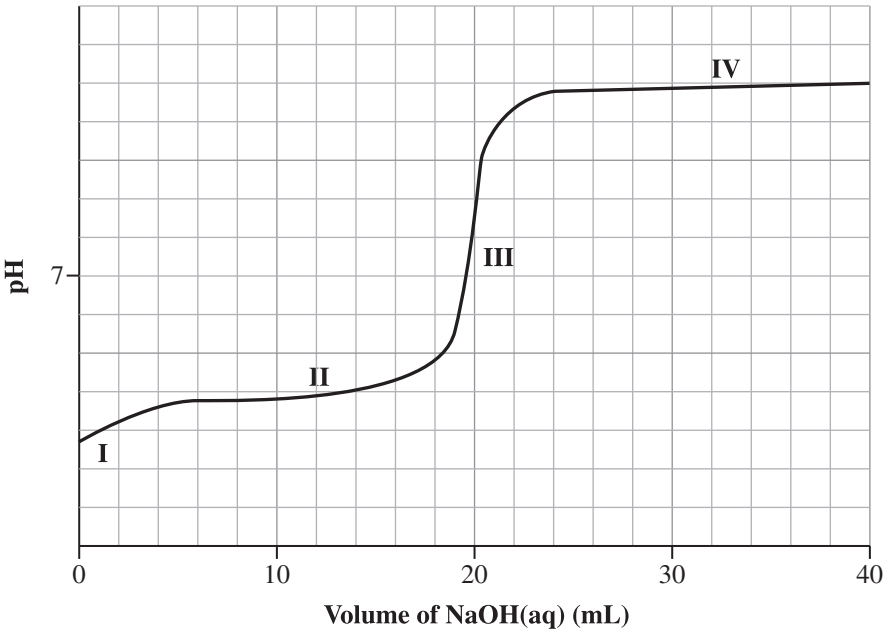
30–D1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- write the equilibrium law expression for a given equation
- analyze, qualitatively, the changes in concentrations of reactants and products after an equilibrium shift
- interpret data from a graph to determine when equilibrium is established and to determine the cause of a stress on the system
- interpret, qualitatively, titration curves of monoprotic and polyprotic acids and bases for strong acid-weak base and weak acid-strong base combinations, and identify buffering regions

Use the following information to answer the next question.

A student titrated an unknown sample of an aqueous acid with aqueous sodium hydroxide. The student graphed the data as shown in the diagram below.

Graph of Titration Data



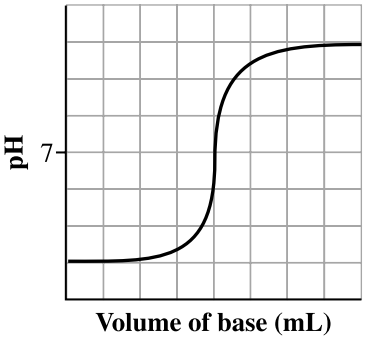
111. *The graph of the student's titration data shows the titration of a* ___***i***___ *acid with a strong base, and on the graph, buffering occurs at* ___***ii***___ .

The statement above is completed by the information in row

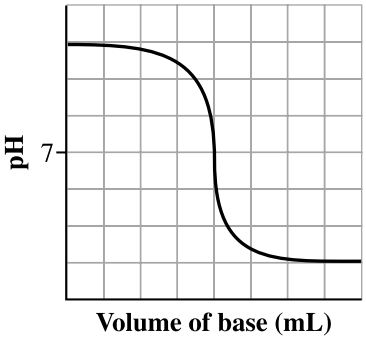
Row	*i*	*ii*
A.	strong	region II only
B.	strong	regions II and IV
***C.**	weak	region II only
D.	weak	regions II and IV

112. Which of the following diagrams represents the titration of a polyprotic acid with a strong base?

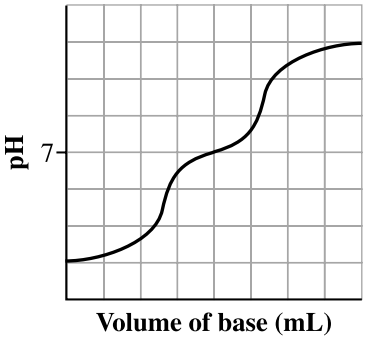
A.



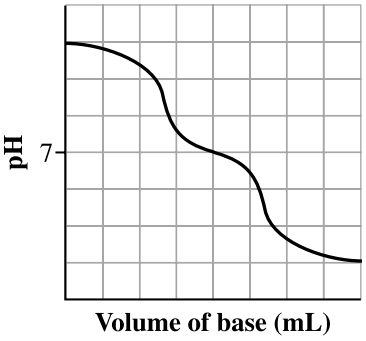
B.



C.



D.



General Outcome 2:
Students will determine quantitative relationships in simple equilibrium systems

Knowledge

30–D2.1k Recall the concepts of pH and hydronium ion concentration and pOH and hydroxide ion concentration, in relation to acids and bases.

113. If the pH of a solution changes from 2 to 4, then the hydronium ion concentration

A. is doubled

B. is halved

C. increases by a factor of 100

*__D.__ decreases by a factor of 100

114. The hydroxide ion concentration in a solution with a pH of 3.50, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$ mol/L. The values of ***a, b, c,*** and ***d*** are _____, _____, _____, and _____.

Key: 3211

Knowledge

30–D2.2k Define K_w, K_a, K_b and use these to determine pH, pOH, $[H_3O^+]$ and $[OH^-]$ of acidic and basic solutions.

115. The K_b for the ethanoate ion, $CH_3COO^-(aq)$, expressed in scientific notation, is $\boldsymbol{a.b} \times 10^{-\boldsymbol{cd}}$. The values of ***a, b, c,*** and ***d*** are _____, _____, _____, and _____.

Key: 5610

Use the following information to answer the next question.

If hydrogen sulfide gas is released into the atmosphere, it dissolves in atmospheric water to form aqueous hydrosulfuric acid. The ionization of aqueous hydrosulfuric acid can be represented by the following equilibrium equation.

$$H_2S(aq) + H_2O(l) \rightleftharpoons HS^-(aq) + H_3O^+(aq)$$

116. *If the concentration of a sample of aqueous hydrosulfuric acid is 0.050 mol/L, then the hydronium ion concentration is* ___***i***___ *and the pOH of the solution is* ___***ii***___ .

The statement above is completed by the information in row

Row	***i***	***ii***
A.	5.0×10^{-2} mol/L	1.30
B.	5.0×10^{-2} mol/L	9.82
C.	6.7×10^{-5} mol/L	1.30
***D.**	6.7×10^{-5} mol/L	9.82

Use the following information to answer the next question.

Household bleach contains sodium hypochlorite, which is a weak base with a K_b of 3.4×10^{-7}. The ionization of sodium hypochlorite can be represented by the following equilibrium equation.

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

117. The pOH of a 0.012 5 mol/L solution of sodium hypochlorite is

A. 1.90

***B.** 4.19

C. 8.37

D. 9.81

Knowledge

30–D2.3k Calculate equilibrium constants and concentrations for homogeneous systems and Brønsted–Lowry acids and bases (excluding buffers) when

- concentrations at equilibrium are known
- initial concentrations and one equilibrium concentration are known
- the equilibrium constant and one equilibrium concentration are known

Note: Examples that require the application of the quadratic equation are excluded; however, students may use this method when responding to open-ended questions.

Use the following information to answer the next question.

$$CN^-(aq) + H_2O(l) \rightleftharpoons HCN(aq) + OH^-(aq) \qquad K_b = 1.61 \times 10^{-5}$$

118. If the pH of a solution of NaCN(aq) is 8.710, then the equilibrium concentration of $CN^-(aq)$, expressed in scientific notation, is $\boldsymbol{a.bc} \times 10^{-\boldsymbol{d}}$ mol/L. The values of ***a, b, c,*** and ***d*** are _____, _____, _____, and _____.

Key: 1636

Use the following information to answer the next question.

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

$$K_c = \frac{[C_2H_5OH(g)]}{[C_2H_4(g)]\,[H_2O(g)]}$$

Under certain conditions, $K_c = 300.0$. At equilibrium, a 5 000 L reaction vessel contains 115 mol of $C_2H_4(g)$ and 110 mol of $H_2O(g)$.

119. Under these conditions, the equilibrium concentration of $C_2H_5OH(g)$ is

A. 1.60×10^{-6} mol/L

*__B.__ 1.52×10^{-1} mol/L

C. 7.50×10^{1} mol/L

D. 5.92×10^{5} mol/L

Use the following information to answer the next question.

Sulfur dioxide gas and oxygen gas react to form sulfur trioxide gas, as represented by the following equation.

$$2\,SO_2(g) + O_2(g) \rightleftharpoons 2\,SO_3(g)$$

In order to obtain the equilibrium system represented in the equation above, a technician injects 2.60 mol of $SO_2(g)$ and 2.30 mol of $O_2(g)$ into a 1.00 L container at 200 °C. When the system reaches equilibrium, the concentration of the remaining $SO_2(g)$ is 1.32 mol/L.

120. a. Calculate the equilibrium constant for this system at 200 °C. **(3 marks)**

b. Identify two characteristics of the system in terms of redox. **(2 marks)**

This question also applies to:

Knowledge
30-D1.4k
30-B1.2k
30-B1.4k

Skill
30–D1.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- write the equilibrium law expression for a given equation
- analyze, qualitatively, the changes in concentrations of reactants and products after an equilibrium shift
- interpret data from a graph to determine when equilibrium is established and to determine the cause of a stress on the system
- interpret, qualitatively, titration curves of monoprotic and polyprotic acids and bases for strong acid-weak base and weak acid-strong base combinations, and identify buffering regions

Skill
30–D2.3s Analyze data and apply mathematical and conceptual models to develop and assess possible solutions.

- use experimental data to calculate equilibrium constants