

Applied Practice  
in

*Coordination and Organic  
Chemistry*

AP\* Chemistry Series

**RESOURCE GUIDE**

\*AP is a registered trademark of the College Entrance Examination Board, which was not involved in the production of, and does not endorse, this product. Pre-AP is a trademark owned by the College Entrance Examination Board.

**APPLIED PRACTICE**  
**Resource Guide**  
*Coordination and Organic Chemistry*

**Teacher Notes and Strategies**

A Note for Teachers .....	5
Teaching Strategies .....	8
Glossary of Terms .....	14

**Student Practices**

Multiple-Choice Questions .....	21
Transition Metals .....	22
Coordination Compounds.....	26
Organic Compounds .....	29
Functional Groups .....	33
Descriptive Chemistry and Laboratory .....	38
Free-Response Questions.....	43

**Answer Key and Explanations**

Multiple-Choice Answer Key .....	53
Multiple-Choice Answer Explanations.....	57
Free-Response Answers and Scoring Guides .....	67

\*AP is a registered trademark of the College Entrance Examination Board, which was not involved in the production of, and does not endorse, this product.

## A NOTE FOR TEACHERS

The *Applied Practice in AP Chemistry* series was designed for use by teachers as an instructional supplement to major units in the AP Chemistry curriculum. This series was also conceived as a resource for teachers in preparing students for the AP Chemistry Exam. As you teach each unit, your students will have the opportunity to practice and to develop those skills required on the exams.

Each book in the series includes:

- Teaching notes and strategies
- Glossary of terms
- 75 multiple-choice questions replicating Section I of the AP Chemistry Exam
- Multiple-choice answer keys and answer explanations
- 6 free-response questions replicating Section II of the AP Chemistry Exam
- Free-response answer keys and scoring guide

We offer a few suggestions and explanations to help you receive the maximum benefit from our materials:

1. Applied Practice booklets do not purport to duplicate exactly an Advanced Placement Examination. However, questions are modeled on those typically encountered on these exams. Thus, students using these materials will become familiar and comfortable with the format, question types, and terminology of Advanced Placement Examinations.
2. Each Applied Practice booklet focuses on one topic within the AP Chemistry curriculum. These booklets are excellent resources for teachers and their students. Their unique format includes questions designed for use during the initial teaching of the required topics. Other questions are exceptional for the review phase of the course, as students pull the entire year together leading up to the AP Chemistry Exam. The AP exam often will require knowledge in multiple content areas on the same question.
3. You have the option of using the Applied Practice booklets for your own lesson and test preparation or, if you so choose, students may work through an Applied Practice test booklet on their own as they progress through the course. The students can check their own answers with the answer key and read the answer explanations provided in the teacher edition, conferring with the teacher as needed.
4. The order of topics in the Applied Practice booklets has been organized to follow a logical progression that is similar to the sequence in many of the most widely selected AP chemistry textbooks. You will find that they can easily be adapted to whatever sequence you find most productive at your school.

5. The free response questions in each topic were created to provide practice questions similar to both those given in part A of the AP Chemistry Exam, which allows use of a calculator, and those given in part B, in which no calculator is allowed. In a few cases, the specific content is best assessed with a combination of both types.
6. Due to the emphasis on laboratory experience in the College Board's AP Chemistry program, the Applied Practice booklets in AP Chemistry frequently include laboratory-based questions appropriate to the subtopic addressed. A required laboratory-based question does appear on the AP Chemistry Exam. While most Applied Practice booklets in the AP Chemistry series do contain laboratory-based free-response questions, some topics do not lend themselves to the College Board-recommended laboratory experiments. However, each Applied Practice booklet does contain multiple-choice questions related to both laboratory and descriptive chemistry. Only one of the six free-response questions included on the AP Chemistry Exam is laboratory based.
7. Each booklet includes a glossary of terms that applies to the vocabulary of that particular topic.
8. If the teacher wishes to replicate the conditions under which students will take the actual AP Chemistry Exam, he or she should understand the following about multiple-choice versus free-response questions when using Applied Practice booklets: When answering multiple-choice questions (AP Exam, Section I) students are not allowed the use of a calculator, and the only reference information available to them is a periodic table (with only symbol, mass number, atomic number) and a small table of abbreviations/symbols used in the questions. When answering free-response questions (AP Exam, Section II), much more information is available to the student. In addition to the periodic table, a table of standard reduction potentials in aqueous solutions and a relatively complete list of equations, constants, and abbreviations/symbols are provided.

### **COPYRIGHT NOTICE**

**The copyright law of the United States (Title 17, United States Code) governs the making of photocopies or other reproductions of copyrighted material. Reproduction of individual worksheets from this booklet, excluding content intended solely for teacher use, is permissible by an individual teacher for use by his or her students in his or her own classroom. Content intended solely for teacher use may not be reproduced, stored in a retrieval system, or transmitted in any way or by any means (electronic, mechanical, photocopying, or otherwise) without prior written permission from Applied Practice. Reproduction of any portion of this booklet for use by more than one teacher or for an entire grade level, school, or school system, is strictly prohibited. By using this booklet, you hereby agree to be bound by these copyright restrictions and acknowledge that by violating these restrictions, you may be liable for copyright infringement and/or subject to criminal prosecution.**

## GLOSSARY OF TERMS

**alcohol**—an organic molecule that contains a hydroxyl group -OH on a carbon atoms with four bonds

**alkane**—a hydrocarbon whose carbon-carbon bonds are all single bonds; when acyclic of the general formula:  $C_nH_{2n+2}$

**alkene**—a hydrocarbon that contains a carbon-carbon double bond; of the general formula  $C_nH_{2n}$

**amide**—a compound derived from the reaction of ammonia, or an amine, with carboxylic acid; a hydrocarbon having the carbonyl functional group linked to a nitrogen atom

**aromatic compound**—contains a benzene ring in its molecular structure

**bidentate**—referring to the ability of a ligand to attach to the central metal atom at two locations on the ligand; the prefix bi- can be replaced with others as the number of coordinate covalent bonding sites changes

**carbonyl group**—the functional group in a hydrocarbon in which a carbon atom is doubly bonded to an oxygen atom

**carboxylic acid**—an organic acid containing the carboxyl functional group; has a carbonyl and alcohol group on the same end-carbon

**catalyst**—a substance that increases the rate of a chemical reaction without being consumed in the reaction

**chain isomers**—two molecules with the same formula but having different longest carbon chain lengths

**chirality**—two molecules that are nonsuperimposable mirror images of each other; produced by having a carbon atom with four different groups attached; two forms that rotate plane polarized light in different directions

**chromatography**—any type of separation technique in which the rate of movement past a stationary phase is the means of separation

**cis/trans isomers**—two forms of geometric isomers whose only difference is the angle at which they are attached to the same carbon atoms; cis has same group adjacent, trans has same group across the molecule

**complex ion**—a group of atoms with a net charge in which a central metal atom is attached to a ligand(Lewis base) by coordinate covalent bonds

## Transition Metals

The following answer choices can be used in questions 1-3. Each answer may be used once, more than once, or not at all.

- (A) Mn
- (B)  $\text{Mn}_2\text{O}_7$
- (C)  $\text{Mn}^{2+}$
- (D)  $\text{MnO}_4^{2-}$
- (E)  $\text{MnO}_4^-$

1. The species with Mn in the oxidation state +6
2. The species that is pale pink in aqueous solution
3. The species that has Mn with an electronic configuration ending in  $d^1$
4. Which of the following is a common characteristic of transition metals?
  - I. They form ions with more than one oxidation state.
  - II. They form complex ions.
  - III. They form colored compounds.

- (A) I only
- (B) II only
- (C) III only
- (D) I and II only
- (E) I, II, and III

5. Which of the following ions would one expect to be colored in aqueous solution?
  - I.  $\text{Zn}^{2+}$
  - II.  $\text{Ni}^{2+}$
  - III.  $\text{Cu}^{2+}$

- (A) I only
- (B) III only
- (C) I and II only
- (D) II and III only
- (E) I, II, and III

6. The d-block element listed below with the largest number of oxidation states is
- (A) Cu
  - (B) Ni
  - (C) V
  - (D) Zn
  - (E) Sc
7. The oxidation state of vanadium in the ion  $[\text{VO}(\text{H}_2\text{O})_5]^{2+}$  is
- (A) +1
  - (B) +2
  - (C) +3
  - (D) +4
  - (E) +5
8. Which of the following has the electronic configuration  $[\text{Ar}] 4s^1 3d^5$ ?
- (A) Cr+
  - (B)  $\text{Cr}^{2+}$
  - (C) Fe
  - (D)  $\text{Fe}^{2+}$
  - (E) Cr
9. Which of the following pairs have the same electronic configuration?
- (A)  $\text{Mn}^{2+}$  and  $\text{Mn}^{3+}$
  - (B)  $\text{V}^{2+}$  and  $\text{Mn}^{4+}$
  - (C)  $\text{Sc}^{3+}$  and  $\text{Ti}^{2+}$
  - (D)  $\text{Fe}^{3+}$  and  $\text{Cr}^{3+}$
  - (E)  $\text{Fe}^{2+}$  and  $\text{Co}^{2+}$
10. Which of the following ions is green in aqueous solution?
- (A)  $\text{Ni}^{2+}$
  - (B)  $\text{Mn}^{2+}$
  - (C)  $\text{Cu}^{2+}$
  - (D)  $\text{Cu}^+$
  - (E)  $\text{MnO}_4^-$

2. A hydrated coordination compound X is known to have the following composition by mass and to have a molar mass of  $273.5 \text{ g mol}^{-1}$ .

Co 21.57%  
H 4.39%  
O 35.10%  
Cl 38.94%

- (a) Calculate the empirical and the molecular formula for the compound.
- (b) A sample of X with a mass of 0.396575 g is dissolved in 250.000 mL of distilled water, and 25.0000 mL portions are reacted with 0.200000 M silver nitrate solution in a gravimetric titration. It is found that an average volume of 14.5000 mL of silver nitrate is required for complete reaction.
- (i) Write an equation to show the precipitation reaction that occurs. Include state symbols.
- (ii) Calculate the average number of moles of silver nitrate used.
- (iii) Using your answers to (a) and (b)(i) & (ii) above, suggest a formula for X and name the compound.
- (c) Suggest the formula of an isomer of X.
- (d) Would the compound that you have suggested in (c) above react with a larger or smaller volume of 0.200000 M silver nitrate? Explain your answer.