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AP

EXAM IN CHEMISTRY

SCORE HIGH ON YOUR ADVANCED PLACEMENT TEST—AND EARN VALUABLE COLLEGE CREDIT!

Advanced Placement Examination in Chemistry

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Acknowledgements

An AP Chemistry review book has been needed for some time. Publishers have been justifiably reluctant to take on such a project since the mechanicals for chemistry books are expensive. It requires the extensive use of subscripts, superscripts, diagrams, equations and charts to clearly present the information.

But now there is desktop publishing. This book was written, edited, designed, illustrated, and typeset on a Macintosh® computer. The mechanicals were produced on a laser printer.

I wish to thank Linda Bernbach, Senior Editor of ARCO books for recognizing the potential of the project. She enthusiastically guided the idea to a successful approval by the publisher and made sure that we produced a book that is as accurate and attractive as possible.

Sherry Berman-Robinson of Carl Sandburg High School (Orland Park, IL) has a special talent for preparing students successfully for the AP examination, and especially for the Part C Equations. She has shared some of her secrets by writing the draft for the chapter in Part III.

Bob Sims of the Westminster School (Atlanta, GA) has extensive expertise as a chemistry teacher and as the chair of the ACS Examinations Institute Subcommittee II (Advanced). He has contributed to this review by carefully critiquing the review chapters.

Helen Stone of Ben L. Smith High School (Greensboro, NC) spent many hours carefully reviewing the questions and must have worn out many red pens. Her many suggestions have been incorporated into the multiple choice questions, problems and essays.

And a special thanks to my colleague, friend and wife Doris (who teaches AP Studio in Art at Northport High School). Her support and philosophy has been, as always, indispensable.

Introduction

The Advanced Chemistry Review book is written in response to a need to have in one place materials that students will use to prepare efficiently for the examination. A careful investigation of the concepts which should be mastered is the focus of the topics covered in the review. A distillation of current college chemistry courses cannot replace the more complete coverage of topics that is possible during a year's study using a 700–page textbook.

It is neither required, nor expected, that candidates will have mastered the concepts covered in all of the texts. Students awarded the highest score on the AP test do not answer every question correctly. In fact, candidates who answer a little more than half of the Section I multiple choice questions correctly—depending on an equivalent success with the Section II free response questions—can anticipate their effort will be rewarded with a score of 5.0.

The book consists of three parts. The questions and problems are modeled on the AP style, but are not questions which have been used in previous examinations.

Part 1: Review of selected topics.

Part 2: Multiple–choice questions:
Strategy, questions, answers and explanations.

Part 3: Free response section II:
Questions, answers and explanations

Practice questions in addition to those supplied in this book are easy to get.

The College Board has published the:

"Entire 1984 AP Chemistry Examination and Key"
(Item 468223.....$5.00).

They soon will release another, more recent, examination.

Also available from the College Board is a:

"Set of free–response questions used in recent years"
(Item 254932.....$2.00).

Write to the:

Advanced Placement Program
CN 6670
Princeton, NY 08541-6670

The American Chemical Society prepares and publishes standardized multiple–choice tests. The proper level for AP preparation are the tests published biennially by the ACS Examinations Institute and entitled "High School Subcommittee II (Advanced)". The exams are confidential, so a teacher or school official must order and supervise the use of the more recent 1986ADV, 1988ADV or 1990ADV examinations. Earlier examinations are not as confidential.

Some students contend that the ACS/NSTA ADV questions are more rigorous than those used in Section I of the AP examination.

Write to the:

ACS DivCHED Examinations Institute
107 Physical Sciences
Oklahoma State University
Stillwater, OK 74078

The explanations in this book use problem–solving techniques that can be applied to questions dealing with several topics. Current examination usage of units is maintained. A unit like molarity, M, is written in the exam as moles L^{-1}. This should be read as moles per Liter.

The AP examination is a race against the clock. It has been assumed that the candidate who purchases this book will, like an athlete, make sure to have the right equipment. This should include bringing to the exam, and knowing how to use, a hand–held, non–programmable scientific calculator. The calculator should be capable of (in addition to performing the usual addition, multiplication, etc.) computing exponential numbers, logarithms (both ln x and log), powers and roots. No provision has been made in this review to explain how to 'do–it–by–hand' or to explain the use of log–tables.

Part I

Review of Selected Topics

Contents

Chapter 1
Atomic Structure and Periodicity

1. Atomic Theory and Atomic Structure

An atom is electrically neutral since it contains the same number of protons and electrons. The number of protons (the atomic number) determines the identity of the element. The mass number is the sum of the number of protons and neutrons.

Example

Element	Protons	Electrons	Neutrons	Mass #
In	49	49	71	120
Sn	50	50	70	120
Sb	51	51	70	121
Sb	51	51	69	120
Te	52	52	68	120

Atoms of a particular element may vary in mass (isotopes) because of a differing number of neutrons in the nucleus. Particular isotopes are identified by the symbol of the element with the atomic number at the lower-left corner and the mass number at the upper left corner.

Example

Element	Protons	Neutrons	Mass#	Symbol
Sn	50	69	119	$^{119}_{50}Sn$
Sn	50	70	120	$^{120}_{50}Sn$
Sb	51	70	121	$^{121}_{51}Sb$
Sb	51	69	120	$^{120}_{51}Sb$
Te	52	68	120	$^{120}_{52}Te$
Te	52	72	124	$^{124}_{52}Te$

The weighted–average of the naturally occurring isotopes of an element determines the atomic weight.

Example

Element	Mass #	Abundance	Mass x Abund.
Cu	62.9296	69.20%	4355
Cu	64.927	30.80%	2000
Weighted Average = Sum ÷ 100			63.54

Atoms may gain or lose electrons to form electrically charged species called 'ions'.

Example

Element	Protons	Electrons	Mass#	Symbol
Na	11	10	23	$^{23}_{11}Na^{+1}$
Ga	31	28	70	$^{70}_{31}Ga^{+3}$
S	16	18	35	$^{35}_{16}S^{-2}$
Br	35	36	81	$^{81}_{35}Br^{-1}$
Pb	82	78	206	$^{206}_{82}Pb^{+4}$

2. Quantum Numbers and Atomic Orbitals

Electrons in atoms are quantized, which means that electrons in atoms have only certain allowed energy states. The energy of an electron in an atom is determined mainly by the value of *n* the principal quantum number. The principal quantum number defines a shell, at some average distance from the nucleus, capable of holding electrons having about the same energy. The value of the principal quantum number can be any positive integer. The lowest energy electrons have n=1. Only values up to n=7 are necessary to describe the electrons in the first 118 elements.

The shells consist of one or more sub–shells determined by the orbital quantum number, *l*. Allowed values of *l* include any positive integer from zero (0) to (n-1). Usually, instead of integers, values of *l* are assigned the letters *s, p, d* and *f*. Orbital quantum number (*l*) values of 0, 1, 2, and 3 are all that are necessary to list the sub–levels of the known or soon to be known first 118 elements.

Not only does the orbital quantum number indicate differences in energy of electrons within a shell, but it also indicates the shape of the orbital.

l	0	1	2	3
letter	*s*	*p*	*d*	*f*
shape	spherical	dumbells	N.A.	N.A.

Note: N.A. means not appropriate for testing at the A.P. level.

Each sub-shell consists of one or more orbitals of the same energy indicated by the magnetic quantum number, m_l. Permitted values of m_l are integers from $-l$ to $+l$.

Summary for orbitals of the first four periods.

Shell n	Subshell l	Orbital Letter	m_l	No. of Orbitals
1	0	1s	0	1
2	0	2s	0	1
	1	2p	-1 0 +1	3
3	0	3s	0	1
	1	3p	-1 0 +1	3
	2	3d	-2 -1 0 +1 +2	5
4	0	4s	0	1
	1	4p	-1 0 +1	3
	2	4d	-2 -1 0 +1 +2	5
	3	4f	-3 -2 -1 0 +1 +2 +3	7

Electrons behave as if they were spinning. Two electrons can occupy the same orbital, but they must spin in opposite directions, The electron spin is indicated by the spin quantum number, s, which has values of $\pm\frac{1}{2}$.

3. Determining Electron Structure

The electronic configuration of any atom in its ground (most stable and lowest energy) state can be determined by using the aufbau (building up) procedure. Two electrons are added per orbital (lowest energy orbitals first) until the number of added electrons equals the number of protons in the atom (making the atoms electrically neutral).

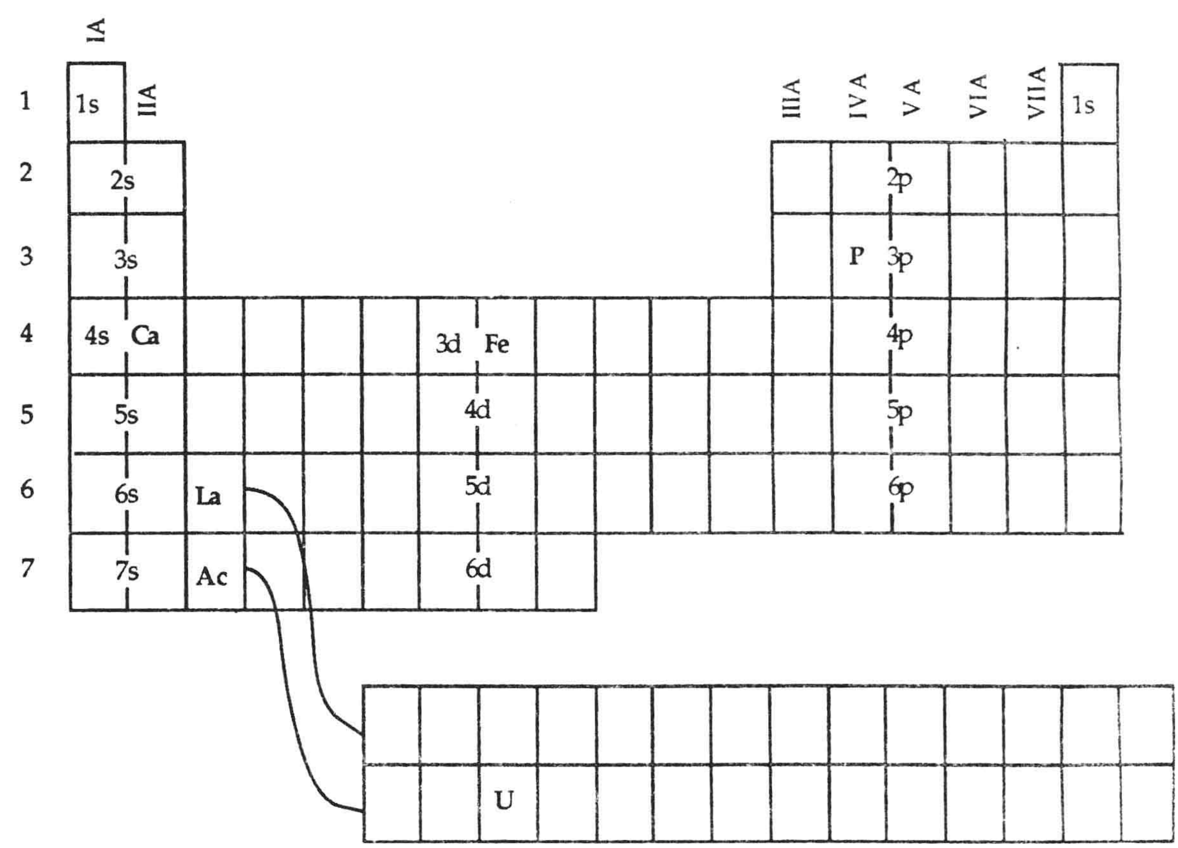
Electrons placed in a subshell consisting of more than one orbital will go into a empty orbital rather than pair up with the first electron in a half-filled orbital (Hund's Rule). And its spin direction will be the same as that of the first electron (parallel spin). Electron configurations and the order of filling subshells can readily be obtained from a periodic table.

Note: n is the period number

Block	Groups	Configuration
s -block:	IA through IIA	ns^1 through ns^2
p -block:	IIIA through VIIA plus Group 0 (Noble Gases)	$ns^2 np^1$ through $ns^2 np^6$
d-block:	Transition elements IIIB through IIB	***$(n-1)d^1 ns^2$ through ***$(n-1)d^{10} ns^2$
f -block:	Inner Transition elements Lanthanide and Actinide series	$(n-2)f^1 (n-1)d^1 ns^2$ through $(n-2)f^{14} (n-1)d^1 ns^2$

***Some irregularity exists, particularly in Groups IB and VIB.

The periodic table shows how the blocks are positioned.



Example

Use the periodic table above to determine the outer electron structure for calcium (Ca), iron (Fe), phosphorus (P) and uranium (U).

Calcium is [Ar]4s ^{2}. Elemental calcium found in the second box of the s-block of period 4.

Iron is [Ar]3*d* ^{6} 4*s* ^{2}. Iron is located in the sixth box of the *d*-block of period 4, after passing through the 4*s* -block. The outer, 4*s* -electrons are written last, even though they are filled before the 3*d* -electrons

Phosphorus is [Ne]3*s* ^{2} 3*p*^{3}. The element phosphorus is found in the third box of the *p*-block of period 3, after passing through the 3*s* -block.

Uranium is [Rn]5*f* ^{3} 6*d*^{1} 7*s* ^{2}. Uranium is located in the third box of the *f* -block of period 7, after passing through the 7*s* -block and through the first box of the 6*d* -block.

4. Ion Structure

Electron configurations for ions can be predicted from their respective atoms. Positive ions are formed when highest energy (generally the outermost) electrons are lost. Negative ions are formed when electrons are added to the outermost subshell.

Examples

Element	Structure	Ion	Structure
Ca	[Ar]4s^{2}	Ca^{2+}	[Ar] or [Ne]3s^{2}3p^{6}
S	[Ne]3s^{2}3p^{4}	S^{2-}	[Ne]3s^{2}3p^{6} or [Ar]
Mn	[Ar]3d^{5}4s^{2}	Mn^{2+}	[Ar]3d^{5}
Ti	[Ar]3d^{2}4s^{2}	Ti^{3+}	[Ar]3d^{1}
Ag	[Kr]4d^{10}5s^{1}	Ag^{1+}	[Kr]4d^{10}

5. Relationships in the Periodic Table

Elements having similar properties are placed in vertical columns called 'Groups'. Horizontal rows, which start when there is a repeat of properties, are called 'Periods'.

The radii of atoms and ions decrease as atomic numbers increase from left to right across a period. The cause is an increased attraction between the increased number of protons in the nucleus and electrons in the valence shell. There is a discontinuity where a change from positive to negative ion formation occurs (at Group VA).

1. Positive ions are smaller than their respective atom.
2. Negative ions are larger than their respective atom.

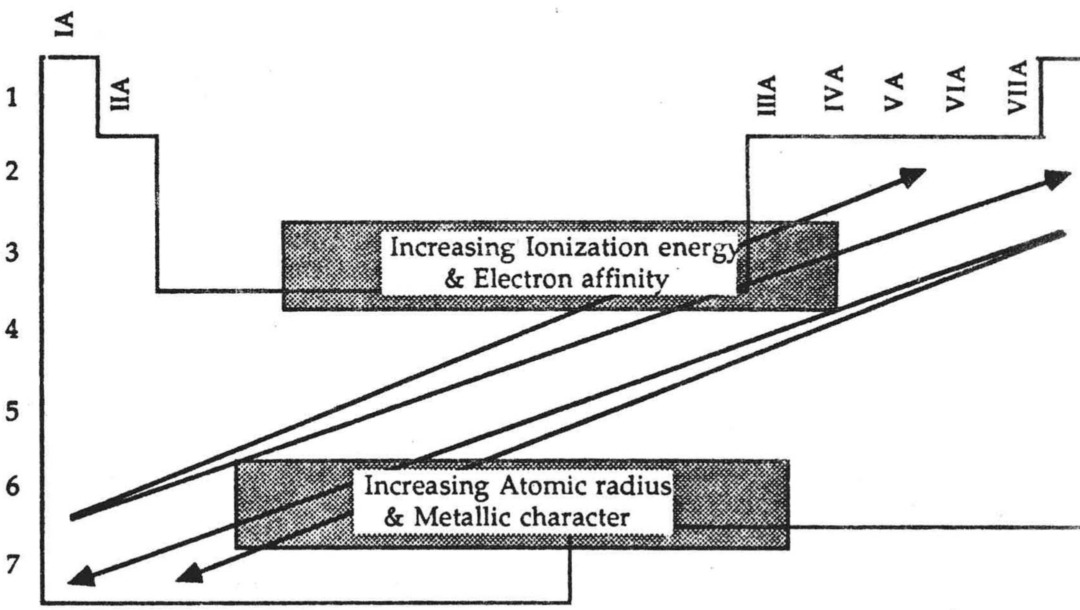
The radii of atoms and ions increase as atomic numbers increase from top to bottom down a group. This is due to an increased number of shells and the shielding effect of all the inner shells.

Ionization energy is a measure of the tightness with which electrons are held by an atom or ion. The ionization energy of atoms and ions increases as the atomic number increases from left to right across a period. There is a discontinuity when there is a change from positive to negative ion formation in the middle of the table.

1. Electrons are held more tightly by positive ions.
2. Electrons are held less tightly by negative ions.

The ionization energy of atoms and ions decreases as the atomic number increases from top to bottom down a group.

Electron affinity is the measure of the attraction of electrons by an atom. The electron affinity of atoms follows the same trend as the ionization energy.



Example

Arrange sets of three elements in order of increasing size and increasing ionization energy (and electron affinity).

a. Be, Mg, Ca
b. S, Cl, F
c. As, N, F
d. Ga, Ge, In
e. Te, I, Xe

Increasing Size	Increasing Ionization Energy
Be < Mg < Ca	Ca < Mg < Be
F < Cl < S	S < Cl < F
F < N < As	As < N < F
Ge < Ga < In	In < Ga < Ge
Xe < I < Te	Te < I < Xe