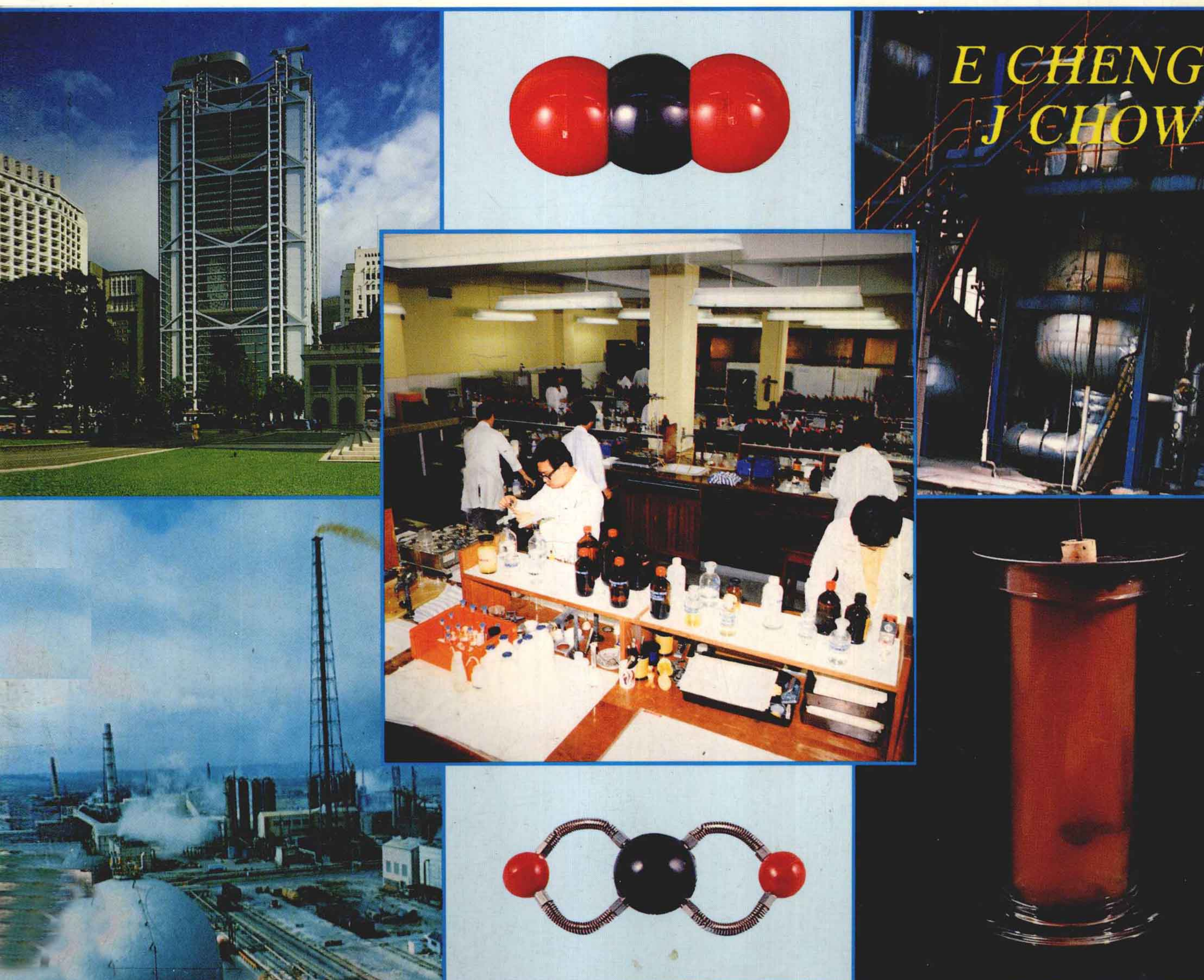
CHEMISTRY
A MODERN VIEW
(SECOND EDITION)



E CHENG
J CHOW

BOOK 2

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PREFACE

CHEMISTRY – A MODERN VIEW is a modern chemistry course for students who are studying for the Hong Kong Certificate of Education examination in chemistry. This book is based on the *revised* C.D.C. Chemistry Syllabus (F.4 to F.5) recommended by the Hong Kong Education Department. It is intended to satisfy the requirements of the HKCE Chemistry Syllabus (issued by the Hong Kong Examinations Authority) which is to be examined for the first time in 1984.

The course consists of a textbook and an accompanying experiment workbook, each written in two volumes. Volume 1 is to be used in Form 4, while Volume 2 is to be used in Form 5 (or at the teacher's discretion).

The topics in the textbook are arranged in a logical sequence. Each chapter follows a regular structural pattern. The theory, experiments and worked examples are integrated to give students clear concepts, based on the spirit of enquiry. A brief review at the end of each chapter summarizes the main points covered. In addition, the problems (with detailed answers) included, both in structured type and multiple-choice form, should prove helpful for revision purposes.

Cross-references are provided in the textbook relating to experiments in the workbook. For example, Expt. 15.1 found in the margin of the textbook (p. 183) refers to Experiment 15.1 in the workbook.

The experiment workbook contains experiments designed to give students an opportunity to make careful observations and to work out their own explanations. Some of the experiments are for demonstration purposes, but majority can be done by students individually or in small groups. The workbook is the essential investigational part of the course, providing ample opportunity for learning by discovery, the most exciting part of scientific activity. It gives detailed instructions on how to carry out an experiment (except where students are asked to design an experimental method), and provides spaces for recording results and answering questions. Precautions to be taken are also given for potentially hazardous operations.

A Teacher's Edition of the experiment workbook is available, providing additional information for teachers' reference.

In writing this book, every effort has been made to present chemistry as it is today, modern concepts being embodied with a new approach. Modern recommended nomenclature and SI units have been used throughout the book where appropriate.

It is our sincere hope that this new publication will give some contemporary views on elementary chemistry and will provide a valuable guide to students.

Last but not the least, we wish to express our gratitude to Mr. D. Yu, B.Sc. (Hons.), Mr. W.K. Chan and Dr. D. Ying, Ph.D. (Stanford) for their constant help and advice.

January 1982

E. Cheng & J. Chow

PREFACE TO SECOND EDITION

CHEMISTRY – A MODERN VIEW has been widely adopted by local and oversea schools since its publication in 1981. In order to update materials and to make improvements, the book is now completely revised. The present book in its *Second Edition* has a number of new features.

A major feature of the new book is its simplicity in language and approach. Thus English has been much simplified. In addition, *Chinese translations* for important terms and difficult words are provided at the bottom of each page. Unimportant details are cut short or deleted. All these would enable students to follow the course easily.

Other new features of the Second Edition are:

(1) The book is printed in *large type-face* in *full colours*.
(2) All chemicals mentioned in the book are named in strict accordance with the *'Guidelines for Systematic Chemical Nomenclature'* published by the Hong Kong Examinations Authority in October, 1988.
(3) A comprehensive *glossary* lists out important terms, with *Chinese translations*.
(4) *Classroom discussion questions* are integrated with the text to test understanding and to stimulate learning.
(5) Many more photographs, figures, worked examples and summary tables are added.
(6) Many more questions (including HKCEE chemistry conventional questions over the past 10 years) are added to the exercises. They are carefully graded in the order of topics appearing in the book. Full answers are provided for all questions except those marked with * or †.
(7) Definitions and important facts are highlighted in boxes.
(8) Everyday applications of chemistry are emphasized, illustrated with numerous original photographs.

The following accompanying volumes are available for teachers, providing additional information for their reference:

CHEMISTRY – A MODERN VIEW (*Teacher's Edition*)
CHEMISTRY – A MODERN VIEW Experiment Workbook (*Teacher's Edition*)
CHEMISTRY – A MODERN VIEW (*Teacher's Guide*)

It is our pleasure to acknowledge with gratitude the helpful comments received from chemistry teachers during the preparation of the Second Edition. We are particularly indebted to Mr. W.K. Chan, Mr. S.S. Chow, Mr. K.C. Kwan and Dr. D. Ying, Ph.D. (Stanford) for their constant help and advice.

March 1990

E. Cheng & J. Chow

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20 PERIODICITY AND FAMILIES OF ELEMENTS

20.1 INTRODUCTION TO PERIODICITY

PERIODIC TABLE AND PERIODICITY

You have learnt in Chapter 5 that when elements are arranged in horizontal rows in increasing order of *atomic number*, a *Periodic Table* is formed. The Periodic Table is very helpful for the systematic study of elements and their compounds. It organizes many facts into simple patterns which are easy to understand. Some of these patterns repeat themselves at regular (or approximately regular) intervals. They are said to show **periodicity**.

A familiar example of periodicity is the alternation of the four seasons: spring, summer, autumn and winter. Now let us look at an example of periodicity in chemistry.

Across Period 2, there is a gradual change from a reactive metal (lithium), through a less reactive metal (beryllium), a metalloid (boron), less reactive non-metals (carbon, nitrogen), to reactive non-metals (oxygen, fluorine), and finally to a noble gas (neon). See Figure 20.1. This pattern is more or less repeated in Period 3 (and other periods as well). See Figures 20.1 and 20.2. Thus the change of metal/non-metal character across a period shows **periodicity* (or **periodic pattern**).

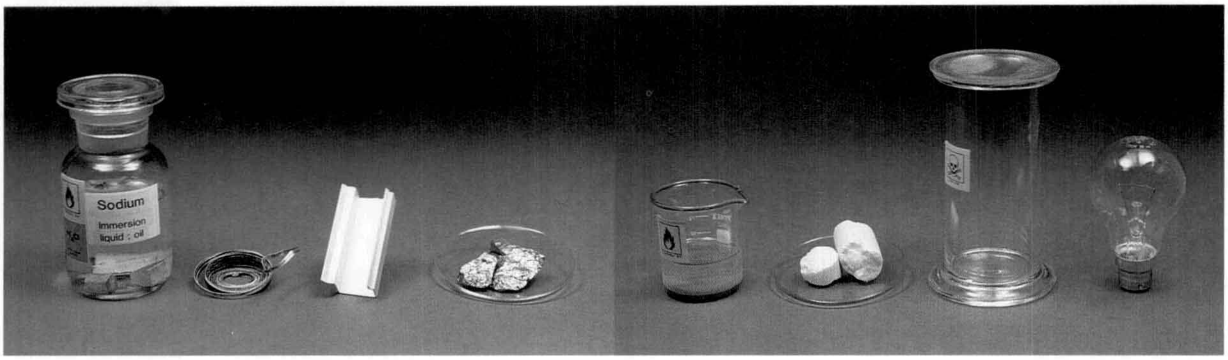
*Alternatively, we can say the metal/non-metal character varies *periodically* with atomic number.

introduction 序論 periodicity 週期性 horizontal rows 橫排 increasing order 依次序由小至大
systematic study 有系統的研究 organizes 組織 patterns 模式 regular intervals 有規則的間歇
familiar example 日常的例子 alternation 交替 seasons 季 gradual change 逐漸的 more or less 大約
character 特性 alternatively 或者 varies 改變

Figure 20.1
Change of metal/non-metal character in Periods 2 and 3 of the Periodic Table.

Period \ Group	I	II	III	IV	V	VI	VII	0
2	Li	Be	B	C	N	O	F	Ne
3	Na	Mg	Al	Si	P	S	Cl	Ar
	reactive metals	less reactive metals		metalloids	less reactive non-metals		reactive non-metals	noble gases

Figure 20.2
The Period 3 elements. (Argon is contained in light bulb.)



Q20.1
Rubidium belongs to Group I and Period 5 of the Periodic Table. Predict its metal/non-metal character and reactivity.

PERIODICITY OF PROPERTIES

We can classify properties of an element into three main types:

(1) ***Atomic properties*** (e.g. electronic configuration, atomic size, electronegativity)
(2) ***Physical properties*** (e.g. melting point, boiling point, density)
(3) ***Chemical properties***

In Sections 20.2, 20.3 and 20.4, we shall look for periodic patterns in properties of some elements.

20.2 PERIODICITY OF SOME ATOMIC PROPERTIES

ELECTRONIC CONFIGURATION

Electronic configurations of some elements in the Periodic Table are given below:

	Group I	*Group IV*	*Group VII*	*Group 0*	*(no. of occupied electron shells)*
Period 2	Li 2, 1	C 2, 4	F 2, 7	Ne 2, 8	2
Period 3	Na 2,8, 1	Si 2,8, 4	Cl 2,8, 7	Ar 2,8, 8	3
Period 4	K 2,8,8, 1	Ge 2,8,18, 4	Br 2,8,18, 7	Kr 2,8,18, 8	4
Period 5	Rb 2,8,18,8, 1	Sn 2,8,18,18, 4	I 2,8,18,18, 7	Xe 2,8,18,18, 8	5
Period 6	Cs 2,8,18,18,8, 1	Pb 2,8,18,32,18, 4	At 2,8,18,32,18, 7	Rn 2,8,18,32,18, 8	6

reactive 活潑的　less reactive 較不活潑的　noble gas 貴氣體　light bulb 燈泡　predict 預測
reactivity 活潑性　classify 將……分類　main types 主要類型　atomic properties 原子性質
electronic configuration 電子組態　electronegativity 負電性　physical properties 物理性質
chemical properties 化學性質　electron shells 電子(殼)層

You can notice that for elements in main groups, the following rules apply:

(1) Number of *occupied* electron shells = period number
(2) Number of electrons in outermost shell = group number (except for hydrogen and Group 0 elements)

In moving across Period 2 (from Li to Ne), the number of outer shell electrons increases from 1 to 8. This pattern is repeated in Period 3 (from Na to Ar) and in other periods (except Period 1 and transition elements). The pattern is thus clearly periodic.

Q20.2
An element *X* has an electronic configuration of 2,8,18,32,18,8,2.
(a) To which period and group of the Periodic Table does *X* belong?
(b) By referring to the Periodic Table, name element *X*.

ATOMIC SIZE

Though atoms are extremely small particles, scientists have succeeded in measuring their sizes.

Across Period 2 (from Li to F), a general tendency (*trend*) is that atomic size *decreases*. See Figure 20.3. This pattern is repeated in Period 3 (from Na to Cl).

In going down a group, atomic size *increases* (Figure 20.3). This is due to increase in number of occupied electron shells.

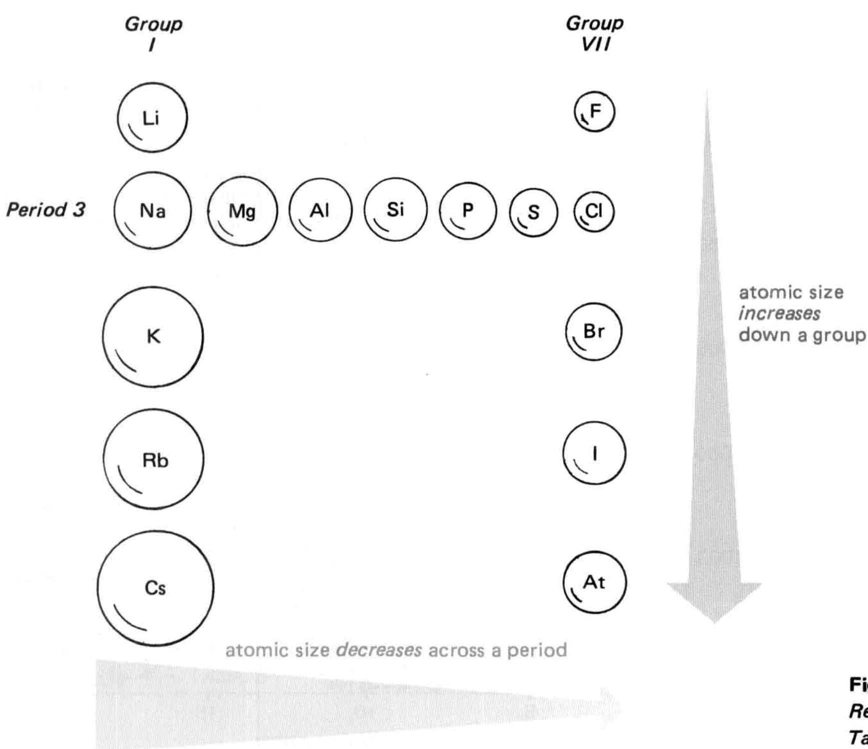


Figure 20.3
Relative sizes of some atoms in the Periodic Table.

notice 注意到 main groups 主屬 rules 規則 apply 適用 transition elements 過渡元素 periodic 週期性
extremely small particles 極小粒子 succeeded 成功 trend 趨勢 due to 由於 relative sizes 相對大小

ELECTRONEGATIVITY

Trends in electronegativity were discussed in Book 1 (p. 98). In moving across Period 2, electronegativity value of an element increases. This pattern is repeated in other periods as well. Hence again we observe a periodic pattern.

20.3 PERIODICITY OF SOME PHYSICAL PROPERTIES

In the following discussion, we shall consider only the first twenty elements of the Periodic Table (Figure 20.4).

Group / Period	I	II	III	IV	V	VI	VII	0
1	H							He
2	Li	Be	B	C	N	O	F	Ne
3	Na	Mg	Al	Si	P	S	Cl	Ar
4	K	Ca						

Figure 20.4
The first twenty elements of the Periodic Table.

MELTING POINT

A graph of melting point against atomic number is shown in Figure 20.5. There is a periodic variation in melting points of the elements.

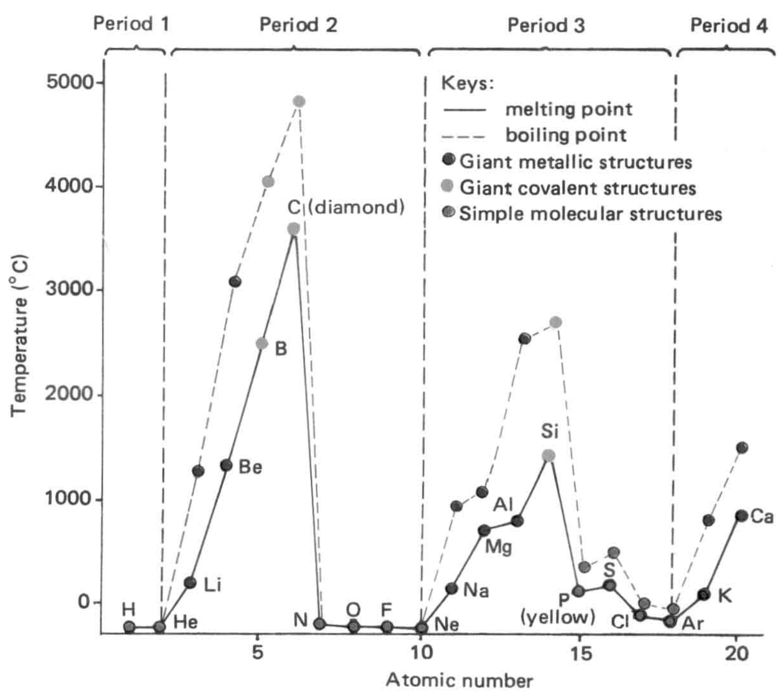


Figure 20.5
Variation of melting point (black line) and boiling point (blue dotted line) with atomic number of the first twenty elements in the Periodic Table.

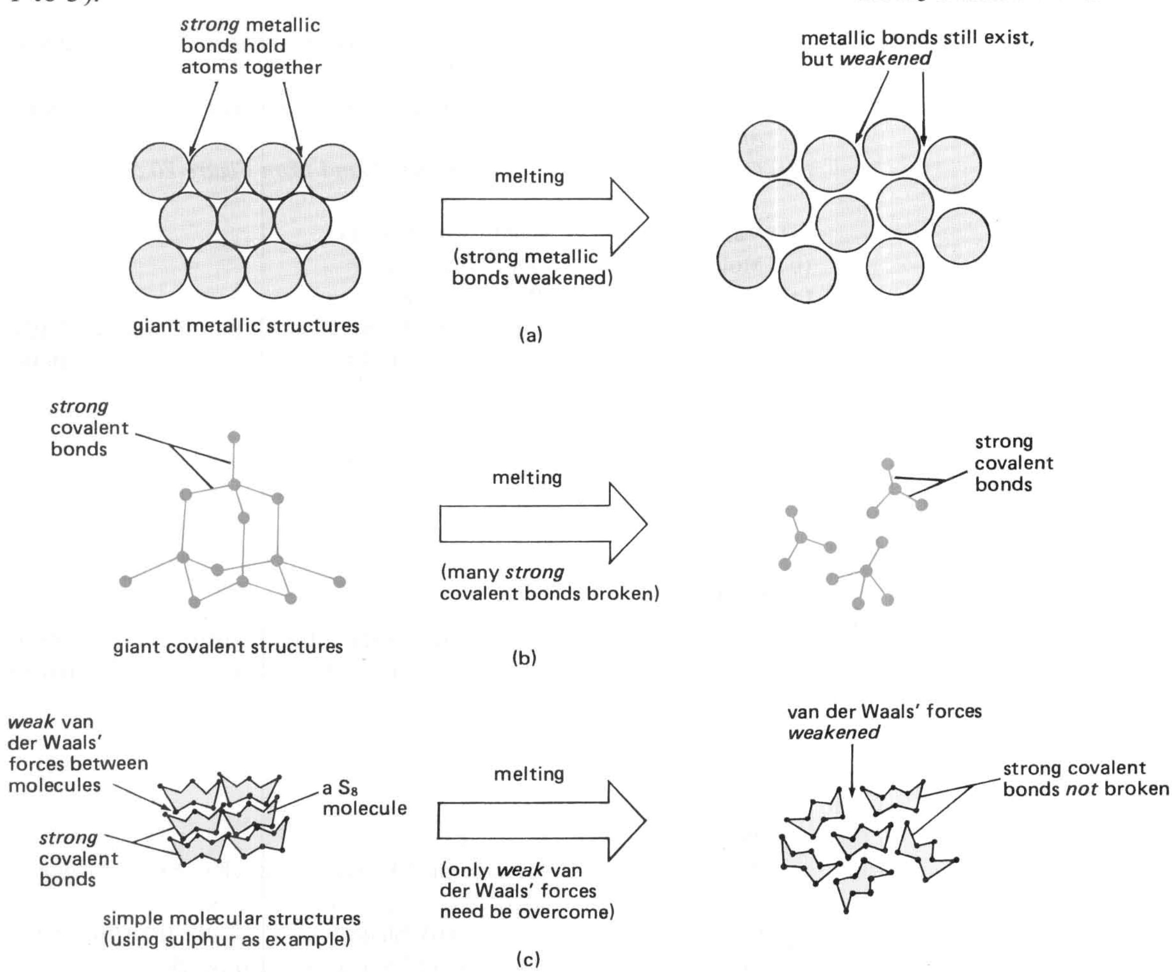
discussion 討論　graph (線)圖　periodic variation 週期性變化　keys 註釋　dotted line 虛線
giant metallic structures 巨型金屬結構　giant covalent structures 巨型共價結構
simple molecular structures 簡單分子結構

On moving across a period from left to right, melting point of an element rises from Group I to a maximum in Group IV. Then it drops sharply to Group V, and reaches a minimum in Group 0.

When a substance melts, the particles are separated further apart. In so doing, energy is required to overcome the attractive forces binding the particles together in the solid. If a lot of energy is required (to overcome *strong* attractive forces), the melting point is high. If only a little energy is required (to overcome *weak* attractive forces), the melting point is low.

Elements in Group I to III have *giant metallic structures (Figure 20.6a). Their atoms are bound together by strong metallic bonds. In melting a metal, the metallic bonds in the structure need be *weakened* only, not broken. Hence melting points of metals may not be very high. Across a period from Group I to Group III, the melting point increases. This is because the strength of metallic bonds increases as the number of delocalized electrons (outer shell electrons) increases (from 1 to 3).

Figure 20.6
The changes in structure that occur during melting of some elements.



*An exception is boron which is a metalloid with giant covalent structure.

maximum 最高點 drops sharply 劇跌 minimum 最低點 overcome 克服 attractive forces 引力
metallic bonds 金屬鍵 weakened 使變弱 broken 斷裂 strength 強度 delocalized electrons 離域電子
exist 存在 exception 例外 boron 硼 metalloid 類金屬

For Group IV elements (C and Si), there is interlinking of a large number of atoms to form a giant covalent structure (Figure 20.6b). Many *strong* covalent bonds have to be broken before melting can occur. Thus a very high temperature is required, corresponding to a maximum in the graph.

For Group V to 0, the elements have simple molecular structures (Figure 20.6c). Molecules are attracted only by *weak* van der Waals' forces. In melting the solids, only these weak forces (and *not* strong covalent bonds) need to be overcome. So their melting points are low.

Example 20.1

Yellow phosphorus (P_4), rhombic sulphur (S_8), chlorine (Cl_2) and argon (Ar) are elements consisting of molecules.

(a) What type of binding forces must be overcome when each of the above elements melts?
(b) Judging from their formulae, arrange the elements in decreasing order of molecular size.
(c) Based on the order in (b), arrange the elements in decreasing order of melting point. Give reasoning.
(d) Compare the order in (c) with that found from Figure 20.5.

(a) Van der Waals' forces between molecules.
(b) Molecular size: $S_8 > P_4 > Cl_2 > Ar$
(c) Melting point: $S_8 > P_4 > Cl_2 > Ar$
The larger the molecular size, the greater will be the van der Waals' forces between molecules, and the higher will be the melting point of the element.
(d) Both give the same order,
i.e. melting point: $S_8 > P_4 > Cl_2 > Ar$

BOILING POINT

The variation of boiling point with atomic number is similar to that of melting point (Figure 20.5). Similar explanations can be given.

Q20.3
What type of binding force must be overcome when the following elements boil?
(a) Magnesium (b) Silicon (c) Chlorine
In each case, describe the binding force as strong or weak.

interlinking 連鎖 occur 發生 corresponding to 相對於 yellow phosphorus 黃磷 rhombic sulphur 斜方晶硫
binding force 連接力 judging from 由……判斷 molecular size 分子大小 based on 基於 order 次序
reasoning 推理 compare 比較 similar 相似的 describe 描述