Chemical Notation Using the Nemeth Braille Code

2023

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Preface to the 1997 Edition

This code is based on *The Nemeth Braille Code for Mathematics and Science Notation, 1972 Revision*. Since the Nemeth Code does not include symbols and rules for chemistry notation, transcriptions of chemical material have varied greatly depending on the ideas of the individual transcriber. The Mathematics Technical Committee of the Braille Authority of North America (BANA) felt there was a great need for uniformity and the BANA Board agreed.

The BANA Mathematics Technical Committee examined chemistry textbooks and examples submitted by transcribers to this committee and to the National Braille Association Mathematics Committee for many years to decide the content of a code. Symbols for bonds, electron dots, and other symbols not included in the Nemeth Code were carefully selected and rules for their use were formulated.

Transcribers and readers have been involved in this endeavor. They have reviewed the code, evaluated it, and offered comments and suggestions to improve it. Those who have used it have found it effective.

The BANA Mathematics Technical Committee thanks all who have been involved in this work. Special thanks are extended to Priscilla Harris and Robin Banker, who have assisted in the production of this document.

BANA MATHEMATICS TECHNICAL COMMITTEE

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Joyce Van Tuyl
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Preface to the 2023 Edition

In 2012, the Braille Authority of North America (BANA) formed the Ad Hoc Committee on Chemistry whose charge was to evaluate the efficacy of the 1997 edition of the Chemistry Code and to identify and list areas of the code in need of revision. In 2014, the committee was given the task of updating and revising the Braille Code for Chemical Notation to align with Unified English Braille (UEB) and to reflect current developments in chemical notation. Professional chemistry faculty, braille transcribers, and representatives from the Committee on Nomenclature, Terminology, and Symbols of the American Chemical Society have been involved in this effort. Sections of the Chemistry Code were rearranged, and examples were reorganized and updated to reflect the rule under study. A new section recommending the use of tactile graphics was developed for certain types of molecular structures. A concerted effort was made to standardize representation in braille for chemical signs which are not standardized in print publications.

The BANA Ad Hoc Committee on Chemistry thanks all who have been involved in this work.

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Introduction

Chemical Notation Using the Nemeth Braille Code, 2023 is derived from *The Nemeth Braille Code for Mathematics and Science Notation, 2022* (Nemeth Code). *Chemical Notation Using the Nemeth Braille Code, 2023* uses the terminology of the Nemeth Code, where "sign" denotes the printed mark and "symbol" (lowercase) denotes the braille representation of that sign. SYMBOL (uppercase) denotes a chemical element from the Periodic Table of the Elements.

Conventions Used in this Document

Braille Examples: A 40-cell line is used in the braille examples, unless otherwise noted.

Section 1
Basic Principles

BRIEF CONTENTS

1.1 General Assumptions

1.1.1 **Code Books and Guidelines.** The rules of *Chemical Notation Using the Nemeth Braille Code* ("Chemistry Code") are derived from *The Nemeth Code for Mathematics and Science Notation* ("Nemeth Code"). When the Chemistry Code does not address a particular technical issue, the rules and symbols of the Nemeth Code are to be used. Chemistry transcriptions also rely on techniques presented in *Guidelines and Standards for Tactile Graphics*. The transcription is formatted according to a mix of Chemistry Code formats, Nemeth Code formats, and formats set forth in the most recent edition of *Braille Formats Principles of Print-to-Braille Transcription* ("Braille Formats"). Familiarity with these code books and guidelines is essential to the production of a professional chemistry transcription.

1.1.2 **Considerations Regarding Use of the Chemistry Code.** Making the decision whether to use the Chemistry Code in a Nemeth transcription should be based on the following criteria. Chemistry Code is not required for mathematical texts if the chemistry symbol exists in the Nemeth Code. Examples include the use of chemical nomenclature, element SYMBOLS, or certain chemical arrows that use the same braille symbol in both codes. When a text contains chemical notation that is not addressed in the Nemeth Code, or when a text includes chemical arrows that have unique braille symbols in this code, the rules and symbols of the Chemistry Code should be used.

UEB methods for transcribing chemistry symbols are not used in a Nemeth transcription. An agency may decide whether to apply Chemistry Code rules to the entire transcription or just to a chapter, section, or problem set. In any case, a transcriber's note must inform the reader of the use of the Chemistry Code.

1.1.3 **Code Switching**. Narrative text is transcribed according to *The Rules of Unified English Braille* ("UEB"). Technical notation is transcribed in Nemeth Code or the Chemistry Code, as applicable. Nemeth Code switch indicators signal the beginning and the end of math or chemistry notation. Details regarding use and layout of the code switch indicators is discussed in the Nemeth Code, Rule 4.

1.2 Transcriber-Generated Pages

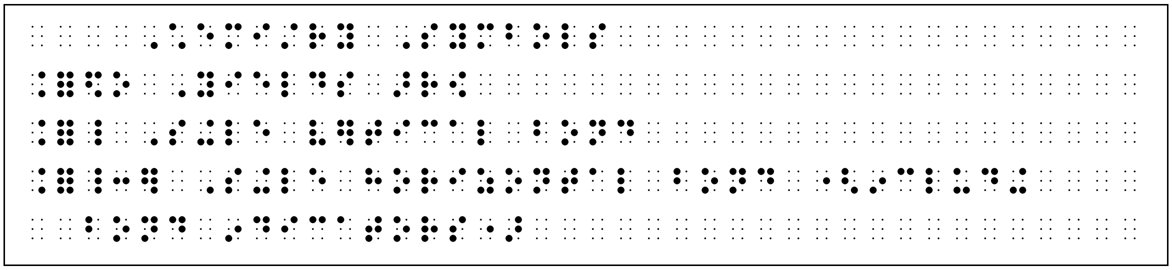
Guidelines regarding transcriber-generated pages are found in Braille Formats.

1.2.1 **Transcriber's Notes Page.** When a Nemeth transcription contains chemistry notation, cite the use of this Chemistry Code along with its date of adoption on the Transcriber's Notes page.

1.2.2 **Special Symbols Page.** Chemistry symbols and indicators used in the volume are to be listed on the Special Symbols page under a cell-5 heading "Chemistry Symbols". Identify each symbol with its chemical name. It may be helpful to refer to the list of chemistry symbols and indicators provided in Appendix C, Index of Braille Symbols for Chemical Notation, which lists the symbols in braille order.

Chemical element SYMBOLS are not listed on the Special Symbols page. See Section 4.1.1 for a definition of chemical element SYMBOLS.

Example 1-1: Special Symbols Page Excerpt



Observe: Items are listed in braille order, preceded by the UEB dot locator for mention.

1.2.3 **Graphic Symbols Page.** Section 10 discusses the use of graphics in a chemistry transcription. When the lines and textures used in the diagrams do not replicate the print image exactly, the variant line styles and/or textures are to be made known to the reader. If they occur frequently, a Graphic Symbols page should be included. Rules regarding the creation of a Graphic Symbols page are outlined in the BANA publication titled *Guidelines and Standards for Tactile Graphics*.

1.3 Chemical Formulae and Equations

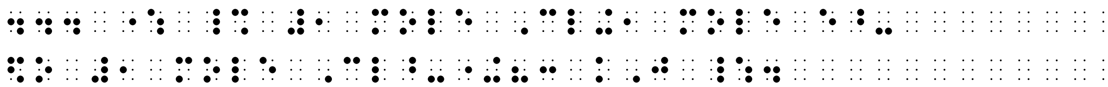
Chemical formulae and equations often contain mathematical notation such as operation and comparison signs, superscripts, subscripts, abbreviations, and other signs. The rules of the Nemeth Code are followed for the mathematical notation unless superseded by rules of the Chemistry Code.

Chemical formulae and equations also contain chemical notation such as bonds, chemical arrows, electron dots, and other signs. Symbols for such notation and rules for their use are provided in this Chemistry Code.

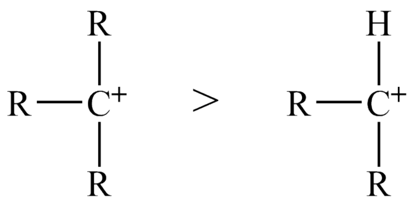
Note the use of Nemeth Code rules and symbols in the following examples.

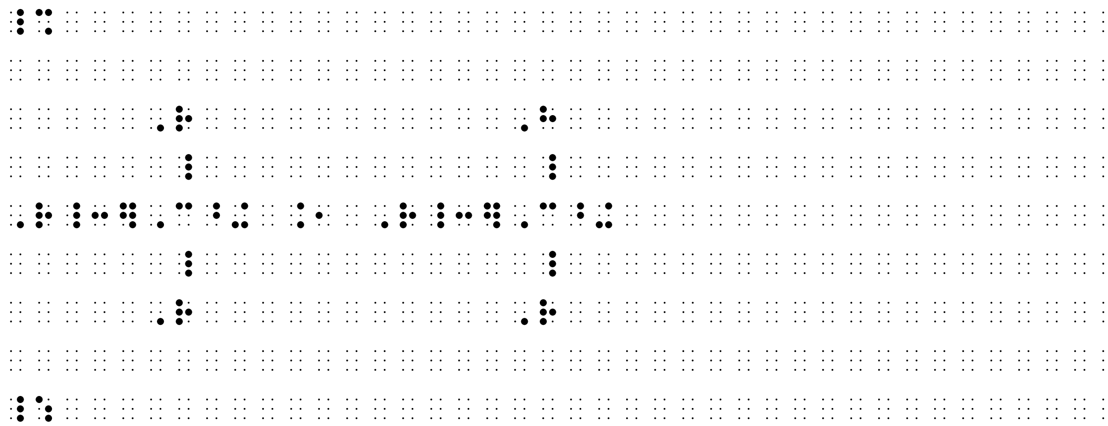
Example 1-2: Chemical Equation

... where 1 mole Cl + 1 mole $e^{-} \rightarrow$ 1 mole $Cl^{-} + 83\ kJ$.



Example 1-3: Molecular Diagram



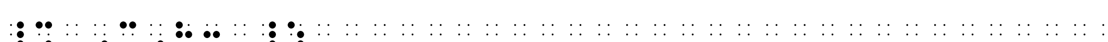


The three major types of chemical formulae are illustrated below.

1.3.1 **Empirical Formula.** An empirical formula gives the composition of a compound but does not specify the structural arrangement or proportion.

Example 1-4: Empirical Formula for Ethane

CH_3



1.3.2 **Molecular Formula.** A molecular formula gives the kinds of atoms or radicals and the number of each kind in a molecular compound.

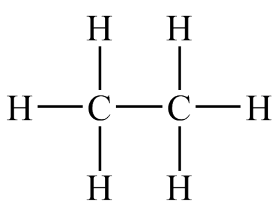
Example 1-5: Molecular Formula for Ethane

C_2H_6

⠸⠩⠀⠠⠉⠆⠠⠓⠖⠀⠸⠱

1.3.3 **Structural Formula.** A structural formula illustrates the chemical bonds between the atoms of a molecule. The structure usually has vertical and horizontal aspects.

Example 1-6: Structural Formula for Ethane



```
⠸⠩

⠀⠀⠀⠀⠀⠠⠓⠀⠀⠀⠠⠓
⠀⠀⠀⠀⠀⠀⠸⠀⠀⠀⠀⠸
⠠⠓⠸⠒⠻⠠⠉⠸⠒⠻⠠⠉⠸⠒⠻⠠⠓
⠀⠀⠀⠀⠀⠀⠸⠀⠀⠀⠀⠸
⠀⠀⠀⠀⠀⠠⠓⠀⠀⠀⠠⠓

⠸⠱
```

Example 1-7: Structural Formula for Chlorine

Here is the structure of a diatomic molecule, chlorine: Cl — Cl .

⠀⠀⠠⠐⠓⠀⠊⠎⠀⠮⠀⠌⠗⠥⠉⠞⠥⠗⠑⠀⠷⠀⠁⠀⠙⠊⠁⠞⠕⠍⠊⠉
⠍⠕⠇⠑⠉⠥⠇⠑⠂⠀⠡⠇⠕⠗⠔⠑⠒⠀⠸⠩⠀⠠⠉⠇⠸⠒⠻⠠⠉⠇⠀⠸⠱⠲

Section 2
Chemical Bonds

BRIEF CONTENTS

2.1 Depiction of Chemical Bonds

Chemical bond signs may be transcribed as braille symbols or drawn as tactile graphics according to the following guidelines.

2.1.1 **Braille Symbols.** Braille symbols may be used for "straight line" single, double, or triple bonds (horizontal or vertical) and for arrow bonds but only if no other type of bond appears in the structure.

2.1.2 **Tactile Graphics.** When a chemical structure contains bonds other than those stated above, all of the bonds should be drawn as a tactile graphic, including the "straight line" single, double, or triple bonds and any arrow bonds. Methods are not to be mixed within the same diagram. See Section 10, Molecular Diagrams.

2.1.3 **Exception.** If methods for timely production of tactile graphics are not available, all of the bonds may be transcribed as braille symbols. See Appendix B, Braille Symbols Used in Molecular Diagrams.

2.2 Horizontal Bond Symbols

The components of a horizontal bond are assembled in the following order:

a. Opening horizontal bond indicator (dots 456)

b. Bond symbol

c. Closing horizontal bond indicator (dots 12456)

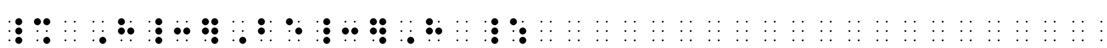
Bond indicators are unspaced from the material to which they apply. The bond symbol may be extended in order to accommodate surrounding material in a spatial diagram. See Section 2.2.5.

2.2.1 **Horizontal Single, Double, and Triple Bonds.** When braille symbols are used to depict "straight line" single, double, or triple horizontal bonds, the following symbols are provided.

⠸⠒⠻	Single horizontal bond (including bond indicators)	—
⠸⠶⠻	Double horizontal bond (including bond indicators)	=
⠸⠿⠻	Triple horizontal bond (including bond indicators)	≡

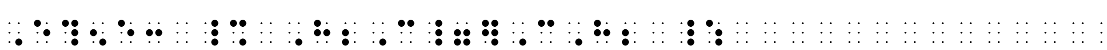
Example 2-1: Single Horizontal Bond

H — Be — H



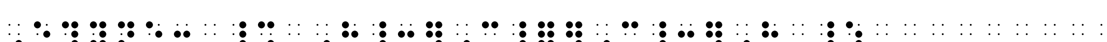
Example 2-2: Double Horizontal Bond

Ethene: $H_2C = CH_2$



Example 2-3: Triple Horizontal Bond

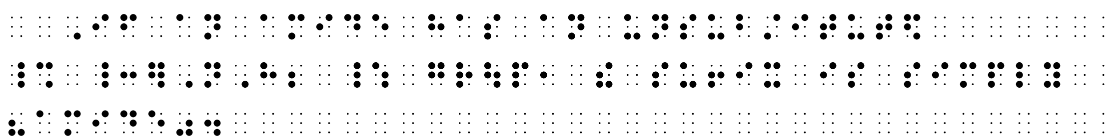
Ethyne: $H - C \equiv C - H$



a. **Similar Signs.** Horizontal bonds are similar in appearance to other signs. Examine the context in order to transcribe the proper symbol. Examples: a single bond vs. a dash, a double bond vs. an equals sign, a triple bond vs. a congruency sign, a wavy bond vs. an extended tilde, a dotted bond vs. an ellipsis.

Example 2-4: Single Horizontal Bond or Dash?

If an amide has an unsubstituted —NH_2 group, the suffix is simply "amide".

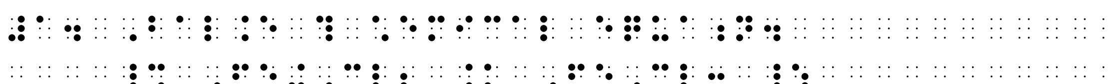


Observe: The print sign that looks like a dash is actually a single bond.

Example 2-5: Double Horizontal Bond or Equals Sign?

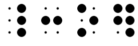
1. Balance this chemical equation.

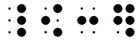
$$Fe + Cl_2 = FeCl_3$$



Observe: The text gives clues that this is an equals sign, not a double bond.

2.2.2 **Horizontal Arrow Bonds.** Arrows may be used to indicate coordinate covalent bonds. Context of surrounding material will help identify the purpose of the arrow.

 Right-pointing arrow bond (including bond indicators) $\rightarrow$

 Left-pointing arrow bond (including bond indicators) $\leftarrow$

Caution: Horizontal arrow bonds are not the same as reaction arrows, which are signs of comparison. Learn to distinguish between arrow bonds and reaction arrows. Bonds occur between two different element SYMBOLS and/or molecular fragments, whereas reaction arrows occur between two different molecules, compounds, or chemical groups. Compare:

a. Arrow bond between elements C and Cl.

$$\mathrm{C} \rightarrow \mathrm{Cl}$$

⠸⠩⠀⠠⠉⠸⠒⠕⠻⠠⠉⠇⠀⠸⠱

b. Arrow bond between molecular fragment CH_2 and element Cl.

$$\mathrm{CH_2} \leftarrow \mathrm{Cl}$$

⠸⠩⠀⠠⠉⠠⠓⠆⠸⠪⠒⠻⠠⠉⠇⠀⠸⠱

c. Reaction arrow between molecule Cl_2 and compound NaCl.

$$2\mathrm{Na} + \mathrm{Cl_2} \rightarrow 2\mathrm{NaCl}$$

⠸⠩⠀⠼⠆⠠⠝⠁⠬⠠⠉⠇⠆⠀⠫⠕⠀⠼⠆⠠⠝⠁⠠⠉⠇⠀⠸⠱

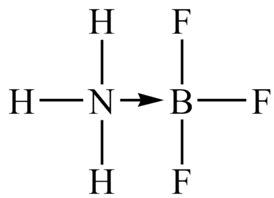
d. Reaction arrow between chemical groups X and R.

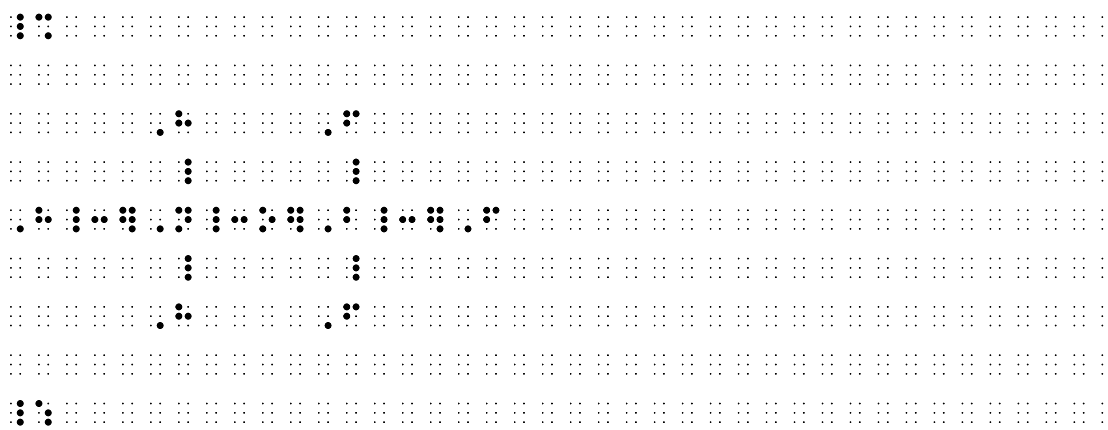
$$\mathrm{RNH_2} + \mathrm{RX} \rightarrow \mathrm{R_2NH_2^{+}X^{-}}$$

⠸⠩⠀⠠⠗⠠⠝⠠⠓⠆⠬⠠⠗⠠⠭⠀⠫⠕⠀⠠⠗⠆⠠⠝⠠⠓⠆⠐⠘⠬⠐⠠⠭⠘⠤⠀⠸⠱

See Section 3.2.2 for a discussion of dipole arrows. In print, the shaft of the dipole arrow is superposed with a vertical line which represents a plus sign.

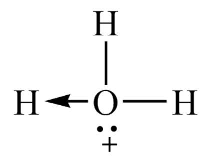
Example 2-6: Right-Pointing Arrow Bond





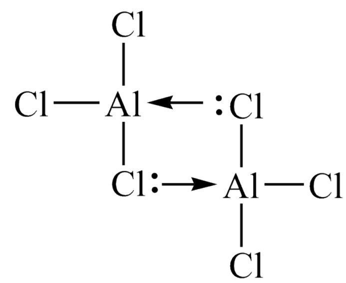
Observe: An arrow bond is between elements N and B.

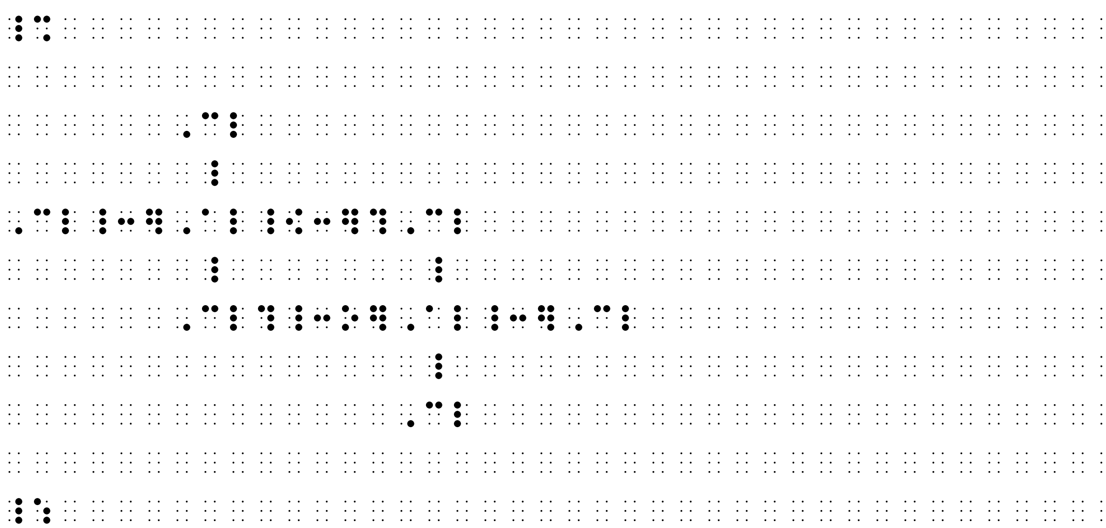
Example 2-7: Left-Pointing Arrow Bond



Observe: An arrow bond is between elements H and O. See Section 4.3 regarding the depiction of the detached plus sign.

Example 2-8: Horizontal Arrow Bonds in a Spatial Structure

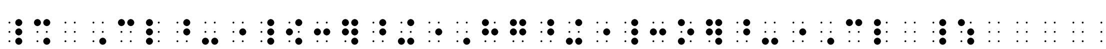




Observe: An arrow bond is between elements Al and Cl.

Example 2-9: Horizontal Arrow Bonds in a Linear Structure

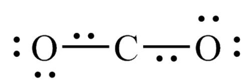
$Cl^{-} \leftarrow {}^{+}Hg^{+} \rightarrow {}^{-}Cl$

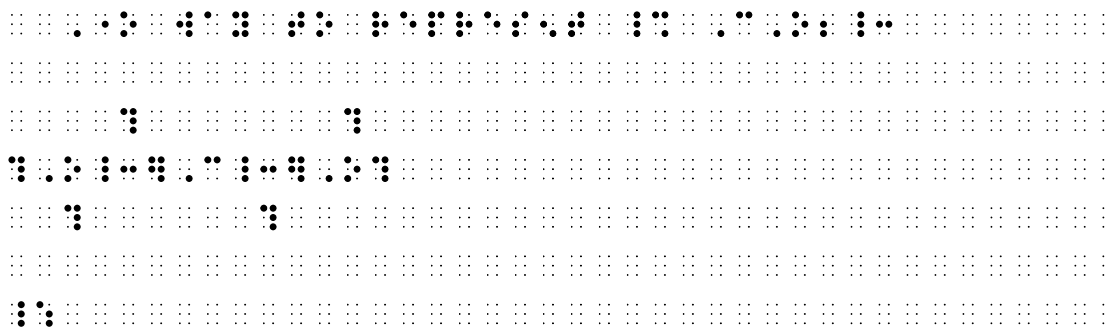


Observe: Arrow bonds are between Cl and Hg ions.

2.2.3 **Modified Bonds.** Simple modifications may be represented with braille symbols. More complicated modifications may be rendered best as a tactile graphic. See Section 10, Molecular Diagrams. For dipole arrows associated with a bond, see Section 3.2.2, Dipole Arrows. See also, Section 8.3, Labeled Bonds.

Example 2-10: Lewis Dot Pairs Above and Below a Bond

One way to represent CO_2: 

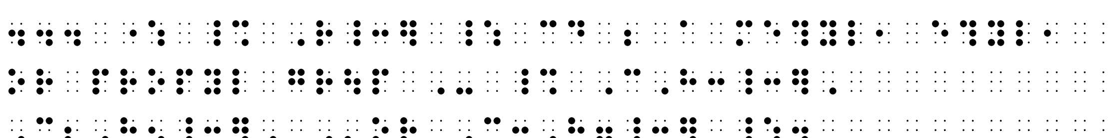


Note: Lewis dot pairs are discussed in Section 2.5.1.

2.2.4 **Punctuation of Bond Indicators.** If punctuation occurs within technical content, the indicators are punctuated in mathematical mode.

Example 2-11: Horizontal Bonds Followed by Punctuation

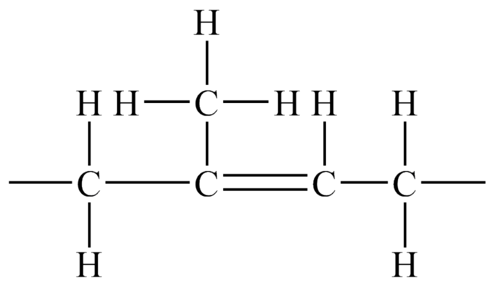
… where R— could be a methyl, ethyl, or propyl group – CH_3—, C_2H_5—, or C_3H_7—.

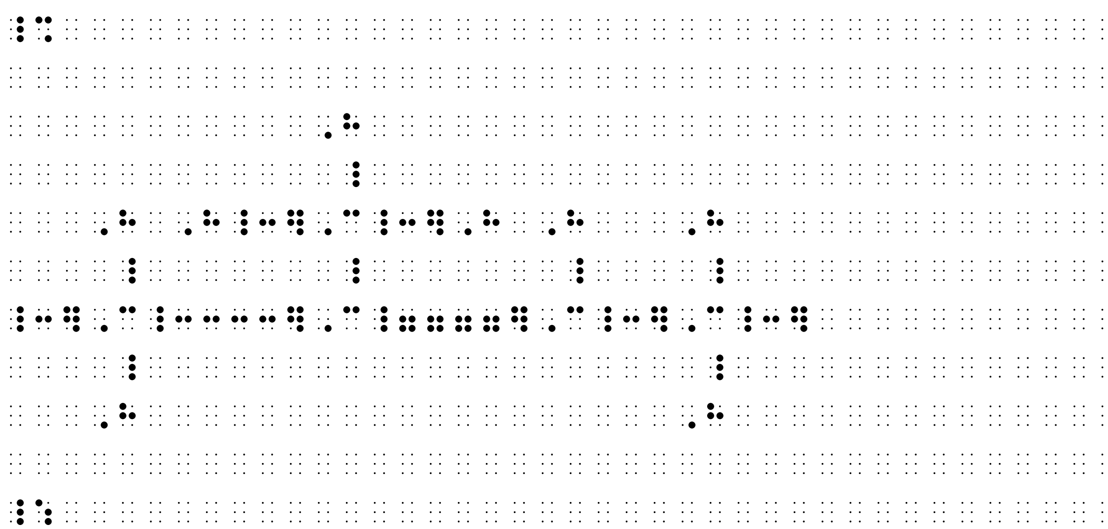


Observe: Inside the code switches, the Nemeth comma is used; outside the code switches, the UEB period and dash are used.

2.2.5 **Extending the Horizontal Bond Symbol.** The bond symbol or the shaft of the arrow bond symbol may be extended to accommodate surrounding material. The meaning does not change when the bond symbol is extended.

Example 2-12: Extended Horizontal Bonds

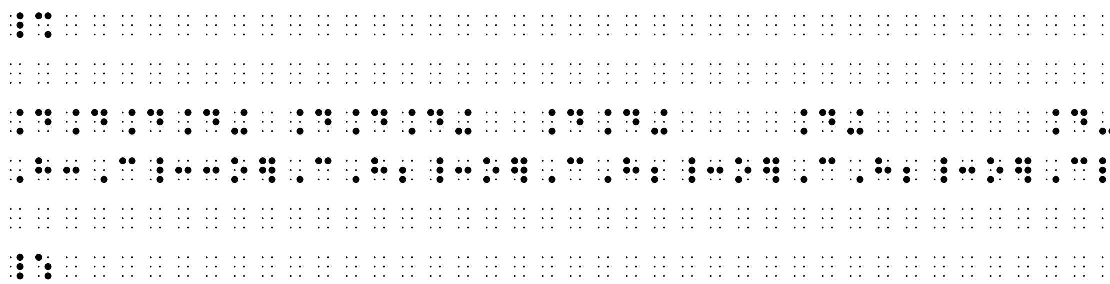




Observe: The horizontal bonds on the fifth line of the diagram are extended to accommodate the spacing requirements of the hydrogen SYMBOLS on the third line.

Example 2-13: Extended Arrow Bond

$$\overset{\delta\delta\delta\delta+}{H_3C} \longrightarrow \overset{\delta\delta\delta+}{CH_2} \longrightarrow \overset{\delta\delta+}{CH_2} \longrightarrow \overset{\delta+}{CH_2} \longrightarrow \overset{\delta-}{Cl}$$



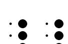
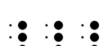
Observe: The first arrow bond shaft is extended in order to accommodate the necessary space between the first and second label on the line above.

2.2.6 **Other Horizontal Bonds.** It is preferable to use tactile graphics for all other horizontal bonds, such as bold, broken, dotted, jagged, and wavy bonds. See Section 10, Molecular Diagrams.

2.3 Vertical Bond Symbols

Structures containing vertical bonds are spatial arrangements and require a blank line preceding and following the diagram, whether embedded or displayed. At least one space must precede and follow a vertical bond symbol.

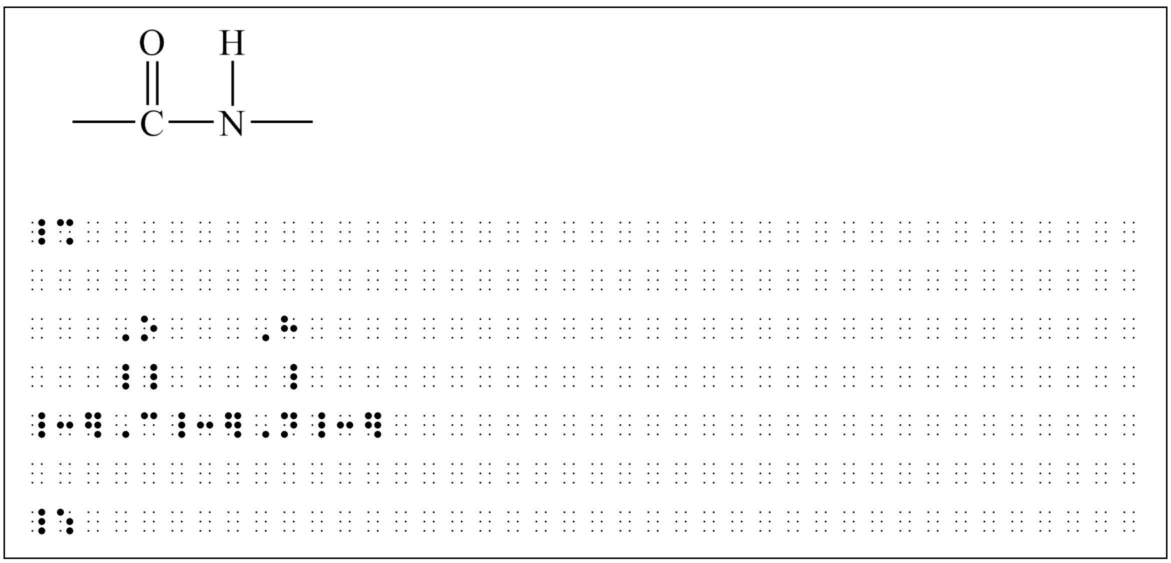
2.3.1 **Vertical Single, Double, and Triple Bonds.** When braille symbols are used to depict "straight line" single, double, or triple vertical bonds, the following symbols are provided.

	Single vertical bond	|
	Double vertical bond	||
	Triple vertical bond	|||

The bond symbol may be extended in order to accommodate surrounding material in a spatial diagram. See Section 2.3.3.

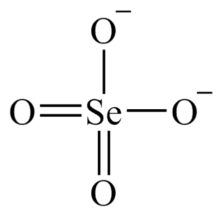
a. **Alignment.** A single vertical bond is aligned with the first letter of the SYMBOL to which it applies. When a double vertical bond applies to a single-letter SYMBOL, the first cell of the bond should be aligned with the capitalization indicator. When a double vertical bond applies to a two-letter SYMBOL, the first cell of the bond should be aligned with the first letter of the SYMBOL. The first cell of a triple vertical bond should be aligned with the element's capitalization indicator, whether it is a one- or two-letter SYMBOL.

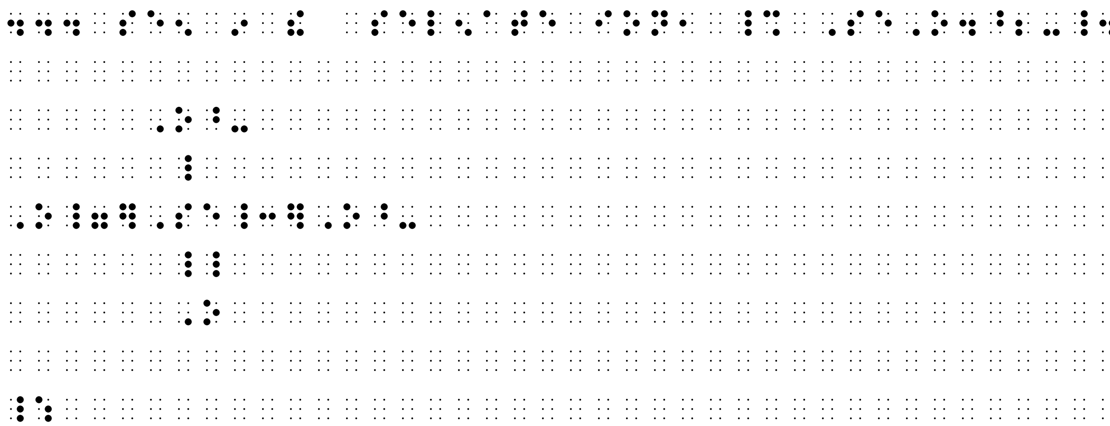
Example 2-14: Vertical Bonds and One-Letter SYMBOLS



Example 2-15: Vertical Bonds and Two-Letter SYMBOLS

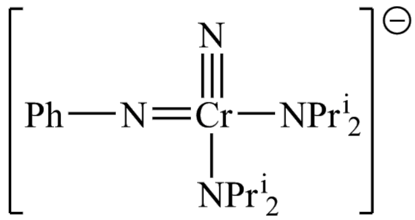
… seen in the selenate ion, SeO_4^{2-}.

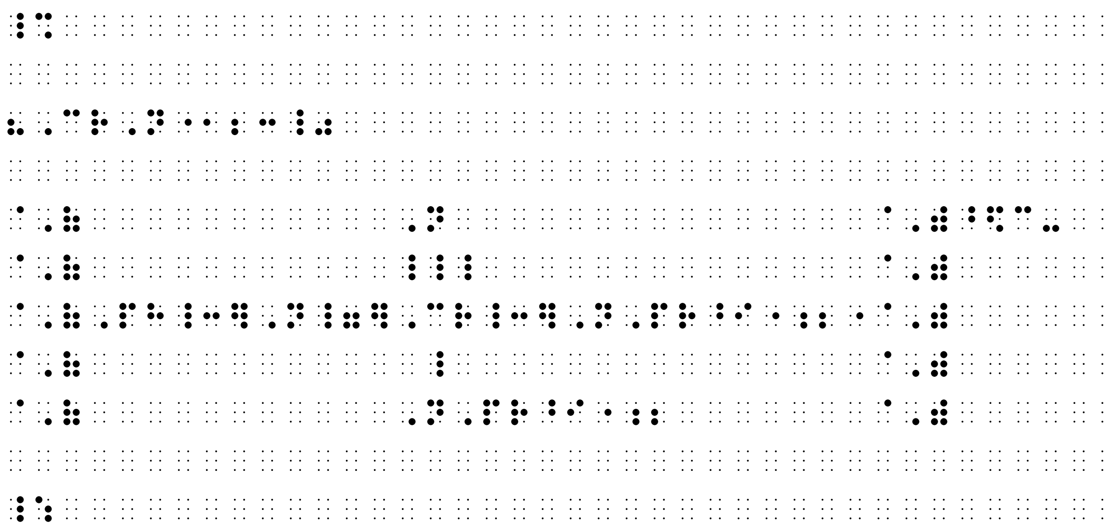




Example 2-16: Triple Vertical Bond

"CrN123"

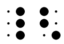
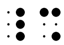




Note: See Section 4.3 regarding the depiction of the minus sign within a circle. Section 8 discusses label placement.

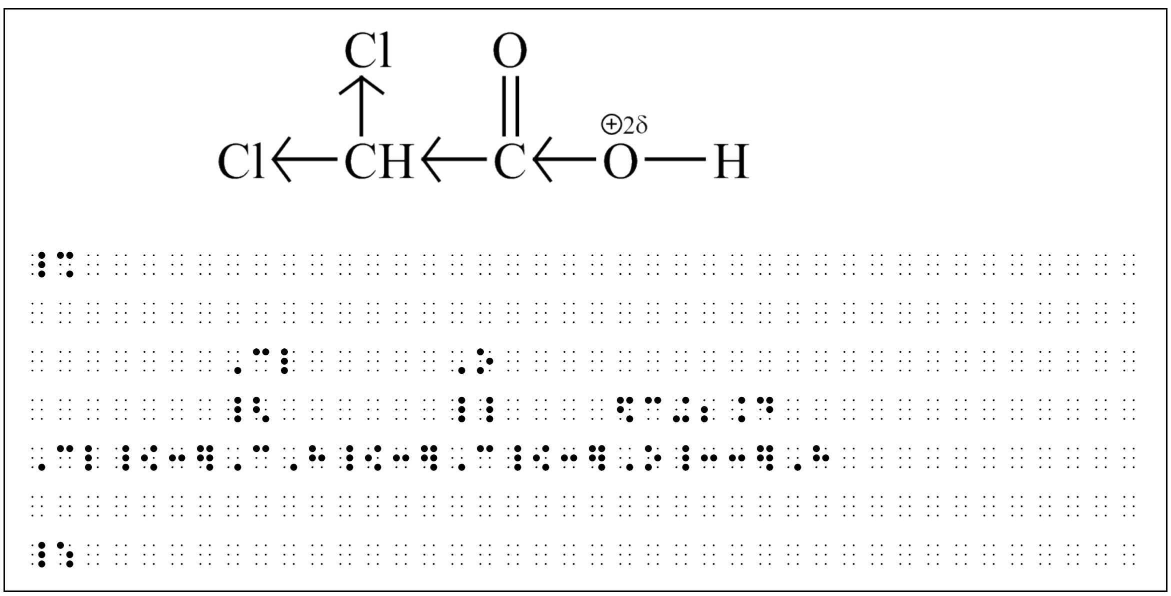
b. **Similar Signs.** Vertical bonds are similar in appearance to other signs. Examine the context in order to transcribe the proper symbol. For example, partition lines have the same appearance in print as vertical single and double bonds. See Section 4.4.1, Partition Lines in Voltaic Cell Notation.

2.3.2 **Vertical Arrow Bonds.** Arrows may be used to indicate coordinate covalent bonds. Context of surrounding material will help identify the purpose of the arrow, nor will the down-pointing arrow bond be misread as a switch indicator.

	Arrow bond, up-pointing	↑
	Arrow bond, down-pointing	↓

Do not mistake vertical arrow bonds with vaporization and precipitation arrows. See Section 3.2.4, Vaporization and Precipitation Arrows. See Section 3.2.2 for a discussion of dipole arrows. Orbital notation uses up-pointing and down-pointing arrows. See Section 3.2.3, Valence Arrows.

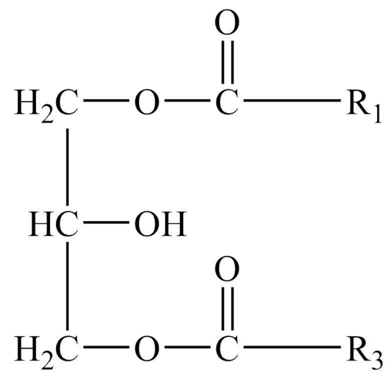
Example 2-17: Vertical Arrow Bond



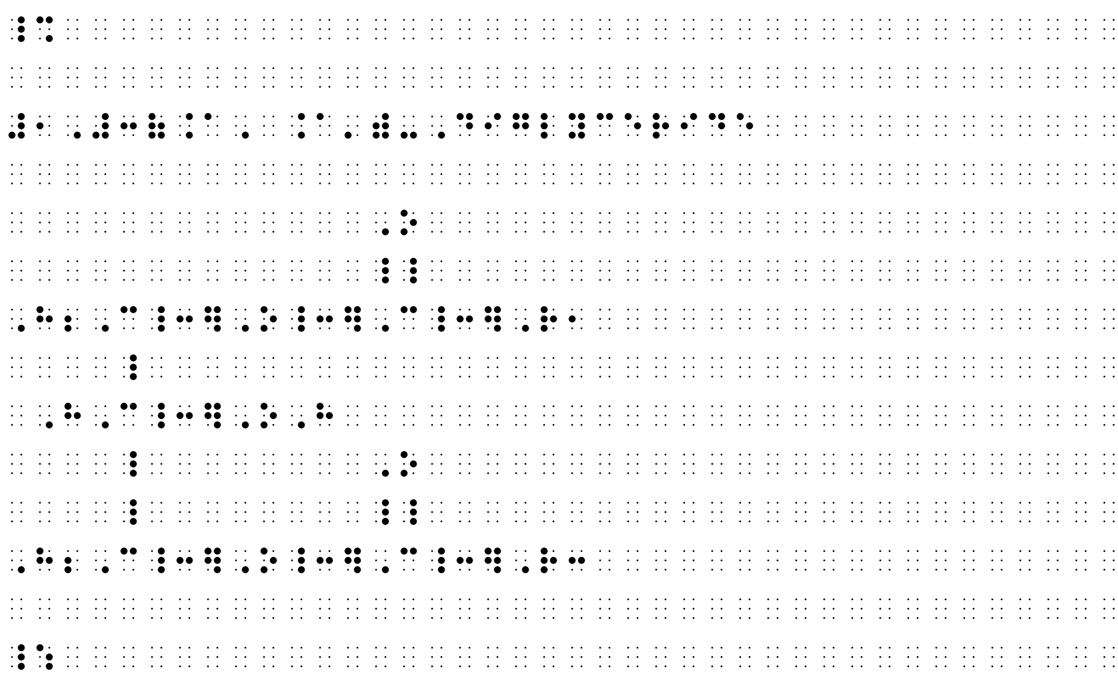
Note: See Section 4.3 regarding the depiction of the plus sign within a circle.

2.3.3 **Extending the Vertical Bond Symbol.** The bond symbol may be extended to accommodate surrounding material. The meaning does not change when the bond symbol is extended. If a vertical arrow bond must be extended, it is best rendered as a tactile graphic. See Section 10, Molecular Diagrams.

Example 2-18: Extended Vertical Bond



1,3 (α,α') - Diglyceride



2.3.4 **Other Vertical Bonds.** It is preferable to use tactile graphics for all other vertical bonds, such as bold, broken, dotted, jagged, and wavy bonds. See Section 10, Molecular Diagrams.

2.4 Oblique Bonds, Wedge Bonds, and Ring Structures

It is preferable to use tactile graphics for oblique bonds, wedge bonds, and ring structures. See Section 10, Molecular Diagrams.

2.5 Lewis Structures (Electron Dot Structures)

A Lewis structure uses special symbols to show valence electron positions around an atom within a molecule. More than one print form may be used: a solid dot, hollow dot, bold dot, colored dot, or a small x. Henceforth, "electron dot" will refer to any of these signs or symbols.

2.5.1 **Electron Dot Symbols—Singles and Pairs.** Electron dots are transcribed as braille symbols, never drawn.

⠡	Single, regular electron dot	•	
⠌	Single, hollow* electron dot	∘	
⠭	Small x electron dot	×	
⠹	Pair of regular electron dots	••	:
⠼	Pair of hollow* electron dots	○○	○ ○
⠪	Pair of small x electron dots	x x	x x

____

** "hollow" denotes a hollow, bold, or colored electron dot*

A particular text may show an electron dot as a small black dot or as a larger black dot. The "bold" designation is in relation to the type of dot used for the "regular" dot. See 2.5.3 for details regarding colored electron dots.

Electron dots are printed above, below, to the left, or to the right of an element SYMBOL. They may also be printed on the diagonal (upper left, upper right, lower left, lower right).

a. **Horizontally Positioned Electron Dots.** The braille electron symbol is unspaced from the element SYMBOL to which it applies. Follow established spacing rules when other symbols or indicators precede or follow electron symbols.

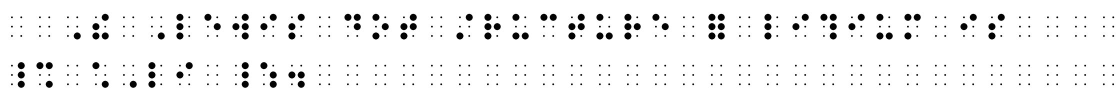
In print, the electron dot may be slightly raised or slightly lowered from the midline. In braille, this displacement is ignored. This is not the same as diagonally situated electron dots. (See Section 2.5.1.d.)

In print, an electron dot may be positioned as a superscript when it lies outside of a bracket, or when it is in conjunction with an element SYMBOL that has a subscript. The superscript position of the electron dot in print is not indicated in the transcription.

When only left or right electron dots are shown and no other vertical components are present, the structure is not considered to be spatial.

Example 2-19: Single Regular Electron Dot

The Lewis dot structure for lithium is • Li.

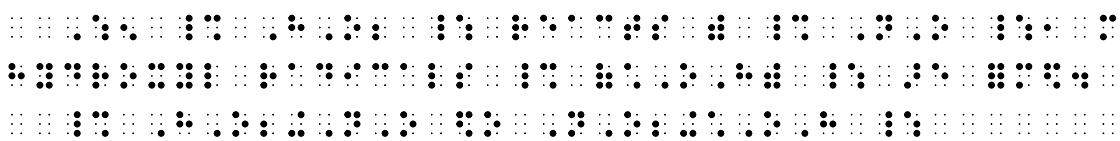


Observe: The electron dot symbol is unspaced from the element SYMBOL, even though it is spaced in print.

Example 2-20: Single Regular Electron Dot in a Formula

When HO_2 reacts with NO, more hydroxyl radicals (•OH) are formed.

$$HO_2 + NO \rightarrow NO_2 + \bullet OH$$



Observe: The electron dot is unspaced from the preceding plus sign, following the spacing rules for operation symbols.

Example 2-21: Electron Dot Printed Above Midline

$$R^{\bullet} + {}^{\bullet}CH_3 \rightarrow RCH_3$$

Observe: The electron dots are not centered on the SYMBOL in print. These electron dots are not superscripts, nor are they diagonally situated, and are transcribed in the normal fashion. See Section 2.5.1.d for a discussion of diagonal layout.

Example 2-22: Electron Dot Printed in Superscript Position

$$[CH_3]^{\bullet}$$

Observe: The superscript position of the electron dot is not indicated in the transcription.

Example 2-23: Electron Dot Printed in Superscript Position

$$CH_3^{\bullet} \text{ or } CH_3{}^{\bullet}$$

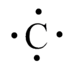
Observe: The superscript position is not indicated in the transcription.

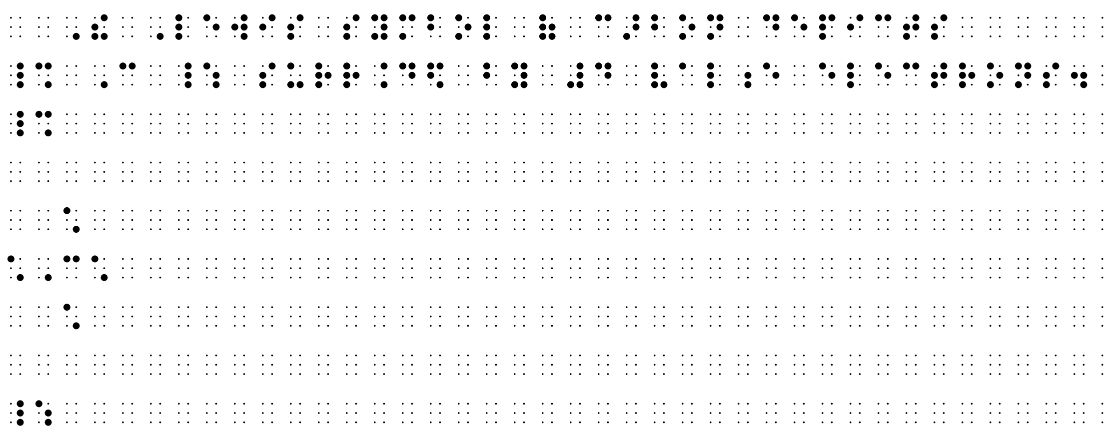
b. **Vertically Positioned Electron Dots.** When upper or lower electron dots are present, the structure is spatial and must be preceded and followed by a blank line, whether embedded or displayed. Align the electron dot symbol with the first letter of the element SYMBOL.

A single dot which appears above or below the SYMBOL may not be centered in print, but in braille this displacement is ignored. This is not the same as diagonally situated electron dots. (See Section 2.5.1.d.)

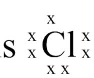
Example 2-24: Electron Dots with a One-Letter SYMBOL

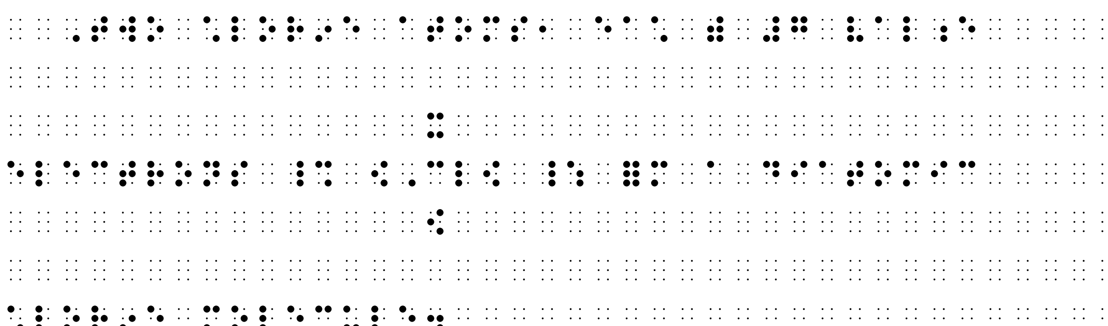
The Lewis symbol of carbon depicts C surrounded by 4 valence electrons.





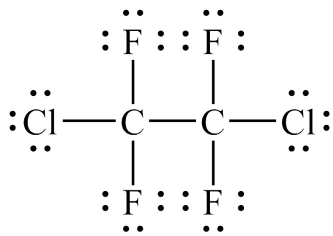
Example 2-25: Electron Dots with a Two-Letter SYMBOL

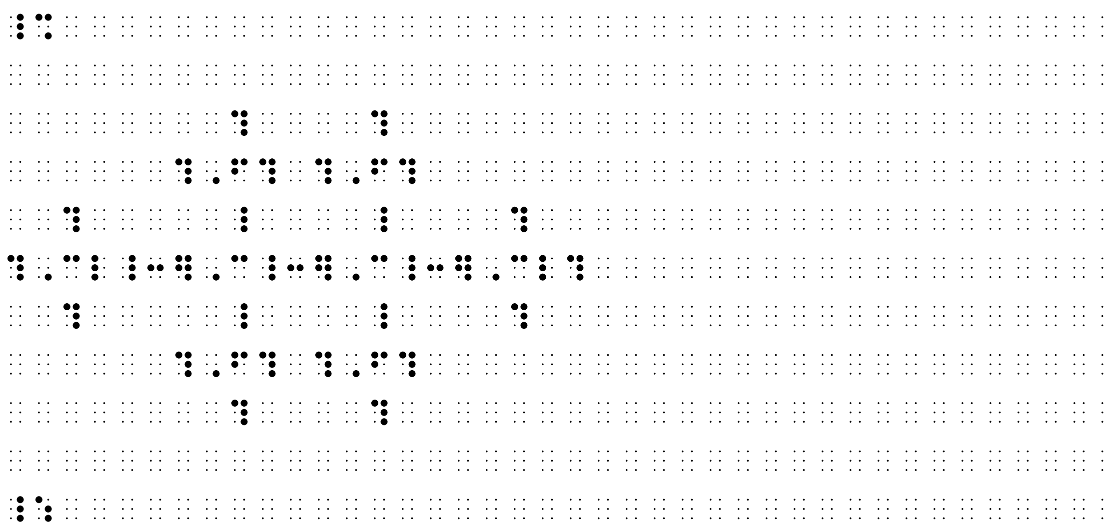
Two chlorine atoms, each with 7 valence electrons  form a diatomic chlorine molecule.



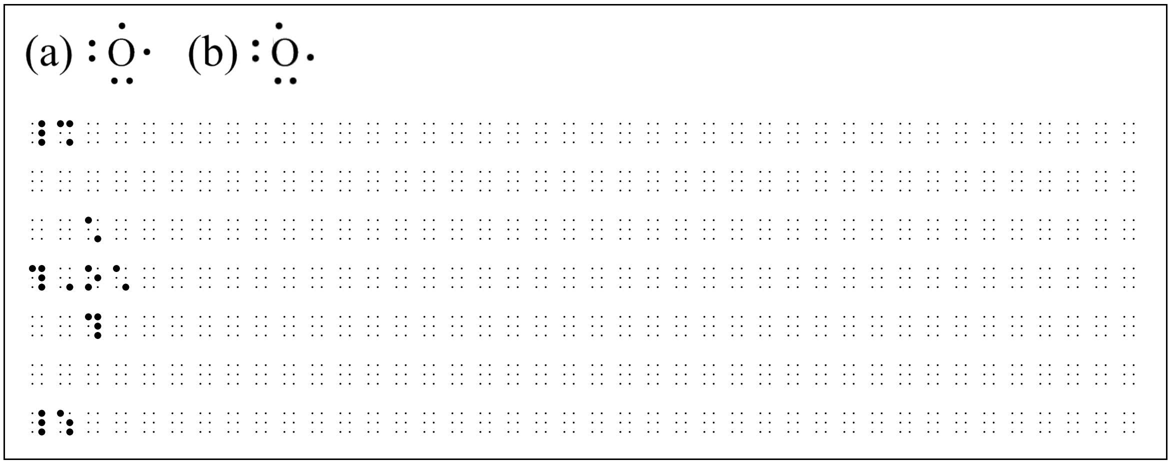
Observe: These electron dots are small x's, single and pairs. This arrangement is embedded within narrative.

Example 2-26: Electron Pair with Two-Letter SYMBOL





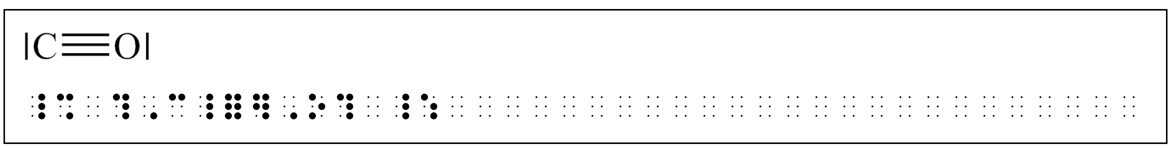
Example 2-27: Centered and Uncentered Electron Dot



Observe: In print image (a), the single dots (upper and right) are centered on the SYMBOL. In print image (b), the single dots (upper and right) are not centered on the SYMBOL. The transcription is identical for both print forms.

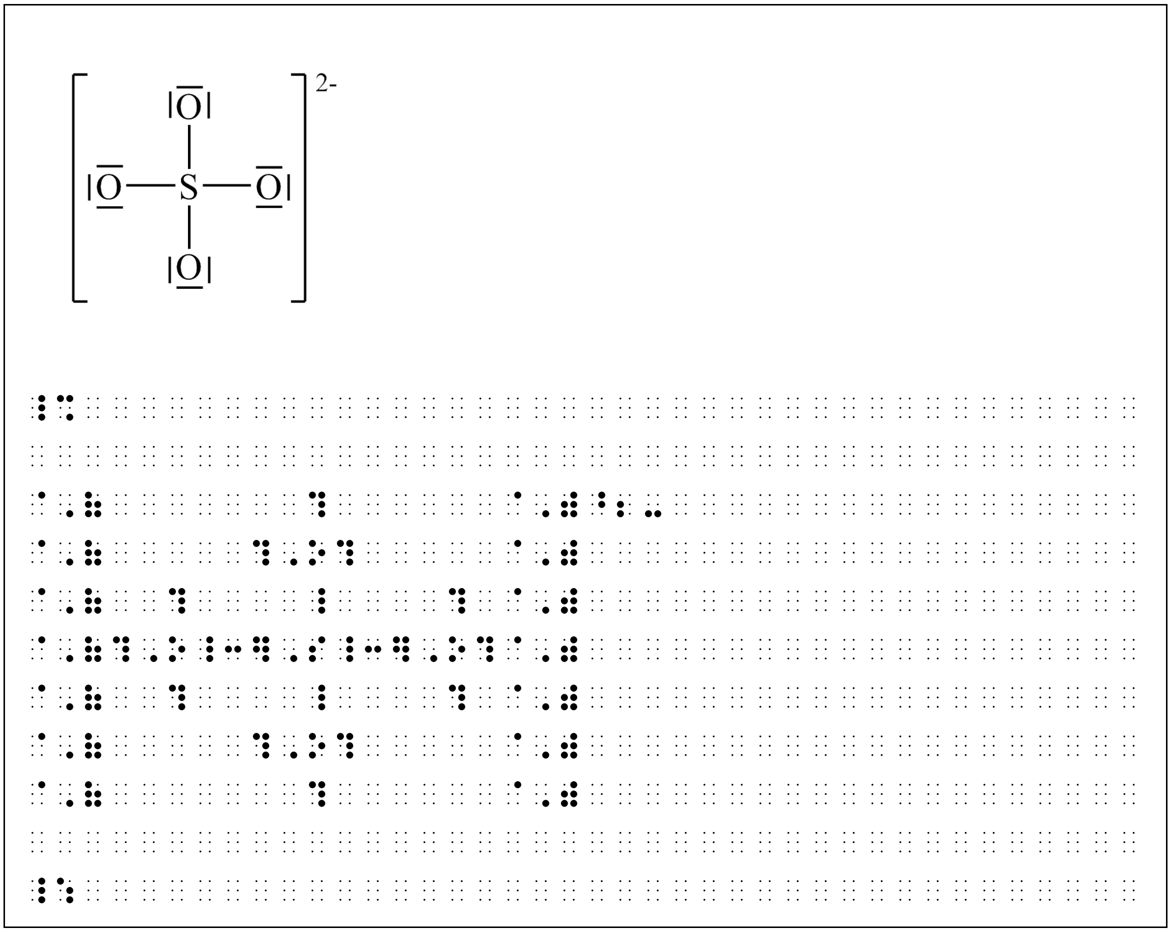
c. **Electron Pairs Printed as a Straight Line.** Older publications may show nonbonding electron pairs as a horizontal or vertical line instead of as a pair of dots or x's. If encountered, use one of the symbols for an electron pair from the list in Section 2.5.1.

Example 2-28: Electron Pairs Printed as Straight Lines



Observe: The symbol for a pair of regular dots is used to represent this outdated print sign.

Example 2-29: Electron Pairs Printed as Straight Lines

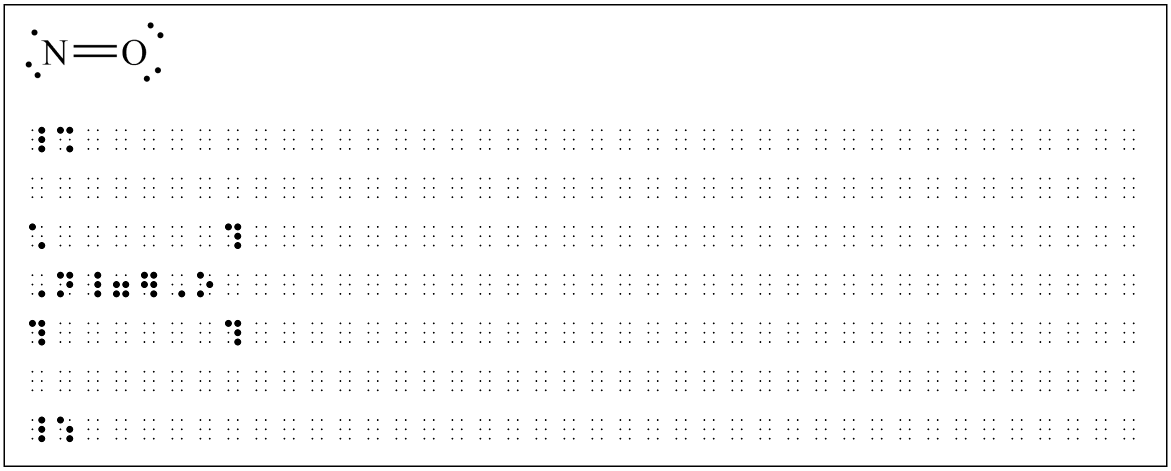


Observe: The symbol for a pair of regular dots is used to represent this outdated print sign.

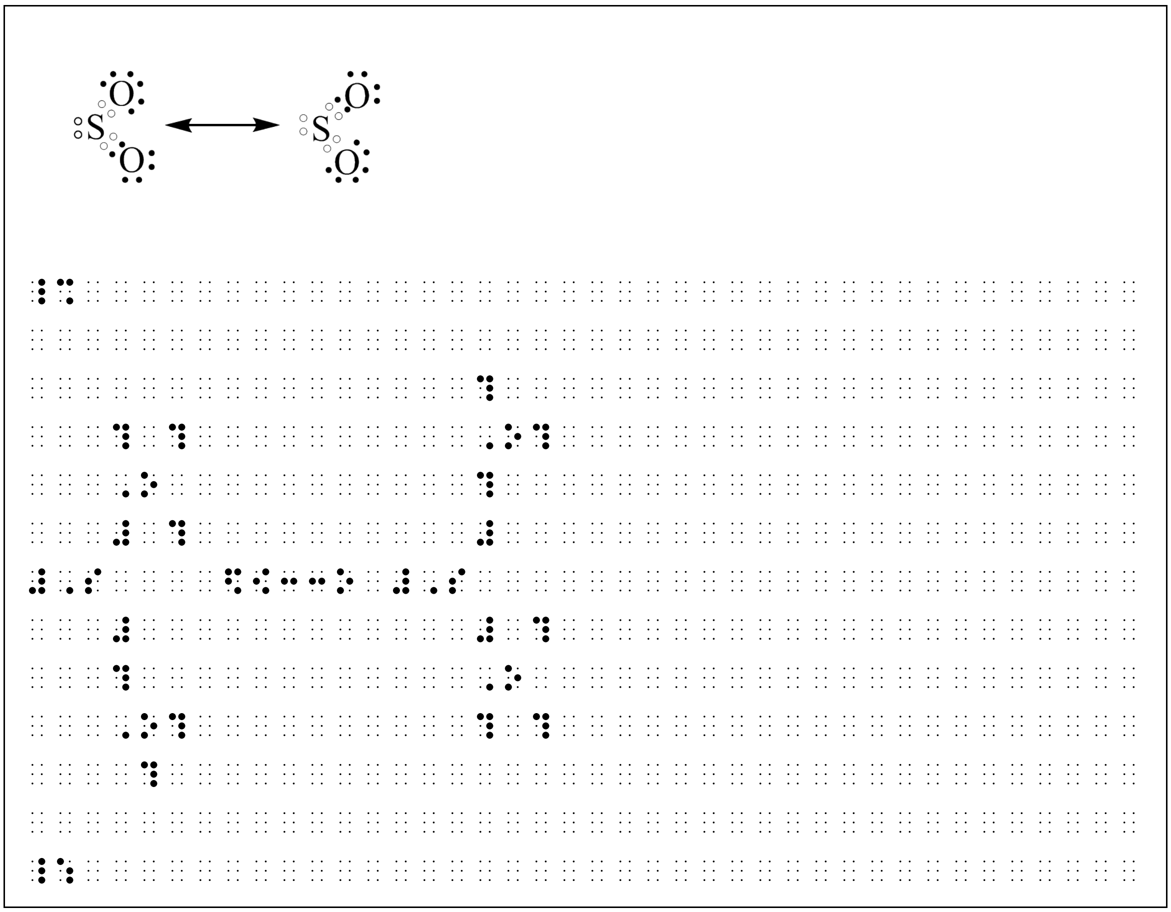
d. **Diagonally Situated Electron Dots.** When dots appear on the diagonal to the element SYMBOL in print, place the symbol on the line immediately above or below in the first cell to the left or right of the SYMBOL, as appropriate. This will be directly over or under the capitalization indicator for a diagonally left dot symbol.

If there are two sets of dots on the diagonal in print, the preferred layout is to place one directly under the other. However, they may be placed diagonally to each other when it is necessary to avoid confusion with other notation in the diagram.

Example 2-30: Diagonally Situated Electron Dots



Example 2-31: Two Sets of Diagonally Situated Dot Pairs



Observe: On the third line of the diagram, the regular dot pair associated with O is transcribed directly above the hollow dot pair associated with S. On the sixth line of the diagram, the hollow dot pair associated with S is *transcribed directly above the regular dot pair associated with O.*

2.5.2 **Dissimilar Electron Pairs.** To illustrate electron transfer, dot pairs may show two different dot styles. Dissimilar Lewis dot pairs are transcribed as two cells. Pairs which are printed horizontally are transcribed in left-to-right order, as printed. Pairs which are printed vertically are transcribed side by side on one braille line according to the guidelines in Section 2.5.2.a, below.

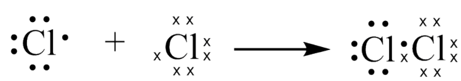
		Horiz.	Vert.
⠡⠌	Dissimilar electron dot pair: regular/hollow*	●○	$\overset{\bullet}{\circ}$ or $\overset{\circ}{\bullet}$
⠡⠭	Dissimilar electron dot pair: regular/x	●x	$\overset{\bullet}{x}$ or $\overset{x}{\bullet}$
⠌⠡	Dissimilar electron dot pair: hollow*/regular	○●	$\overset{\circ}{\bullet}$ or $\overset{\bullet}{\circ}$
⠌⠭	Dissimilar electron dot pair: hollow*/x	○x	$\overset{\circ}{x}$ or $\overset{x}{\circ}$
⠭⠡	Dissimilar electron dot pair: x/regular	x●	$\overset{x}{\bullet}$ or $\overset{\bullet}{x}$
⠭⠌	Dissimilar electron dot pair: x/hollow*	x○	$\overset{x}{\circ}$ or $\overset{\circ}{x}$

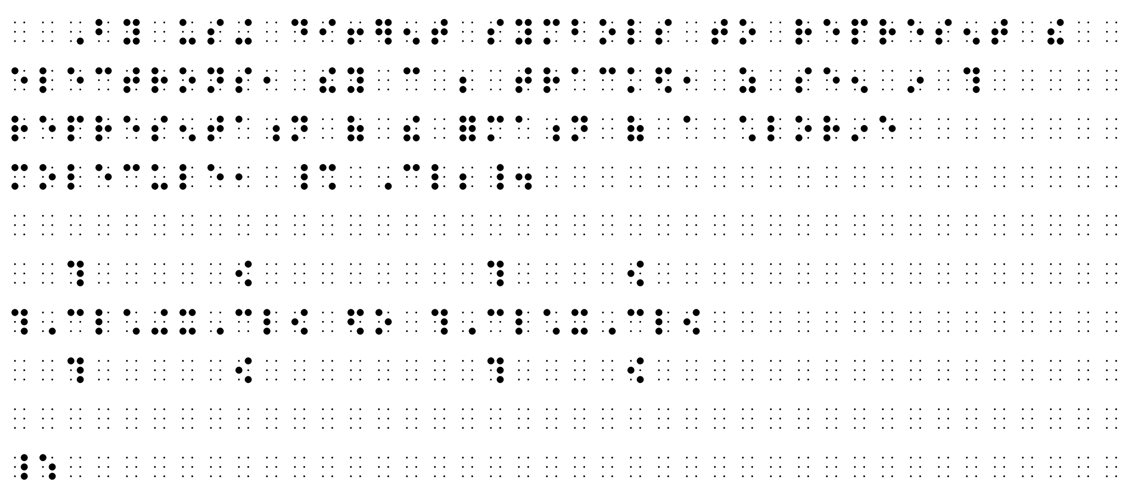
** "hollow" denotes a hollow, bold, or colored electron dot*

a. **Order of Presentation of Vertical Dissimilar Pairs.** Although vertical dissimilar pairs may be transcribed left to right in either order without changing the chemical implication, it is more meaningful to transcribe the dot positions in the following manner. The left-hand dot should match the predominant dot style used in the atom to its left; the right-hand dot should match the predominant dot style used in the atom to its right. When a dissimilar pair is printed on the diagonal, the same consideration is applied. See Example 2-35.

Example 2-32: Dissimilar Vertical Dot Pair in Product

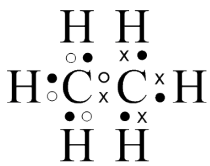
By using different symbols to represent the electrons, they can be tracked, as seen in this representation of the formation of a chlorine molecule, Cl_2.

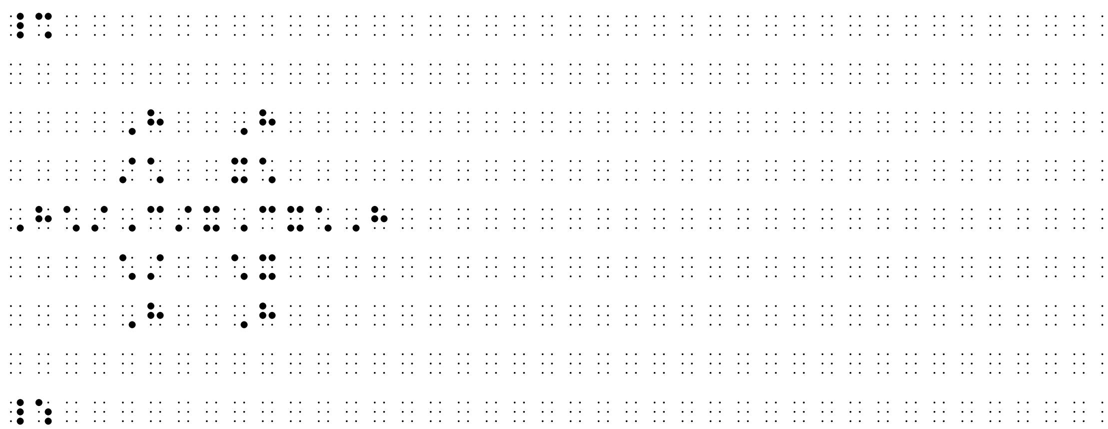




Observe: The Cl atom on the left is predominantly regular electron dots; the Cl atom on the right is predominantly "x" electron dots.

Example 2-33: Dissimilar Dot Pairs—Horizontal and Vertical





Observe: The horizontal pairs are transcribed as printed. Notice in the vertical pairs, the first C is predominantly surrounded by hollow dots; the second C is predominantly surrounded by x's. Note the vertical alignment of a pair of dissimilar electron dots above or below a single-letter SYMBOL.

2.5.3 **Colored Electron Dots.** When color is used in print, mention the color in a transcriber's note.

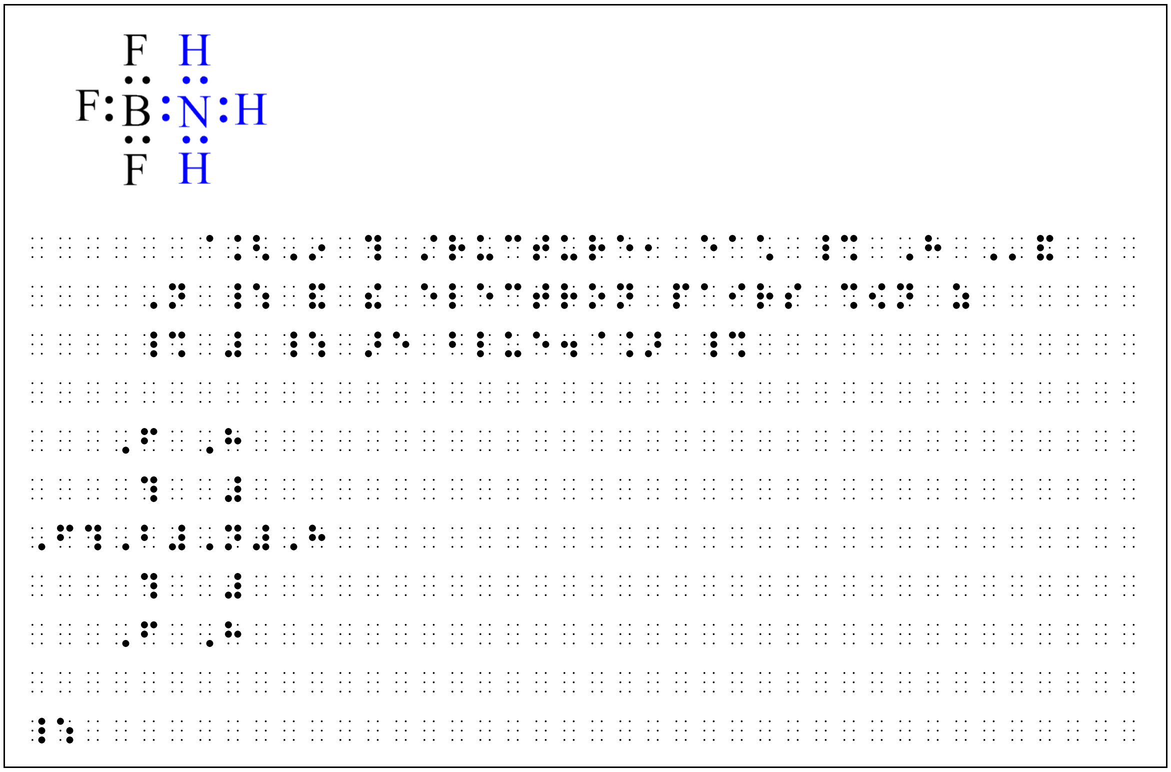
Sample transcriber's note:

In this structure, each H and N and the electron pairs shown as ⠼ are blue.

Sample transcriber's note:

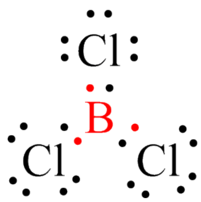
In this structure, B and the electron dot shown as ⠌ are red.

Example 2-34: Dots and Letters in Colored Print

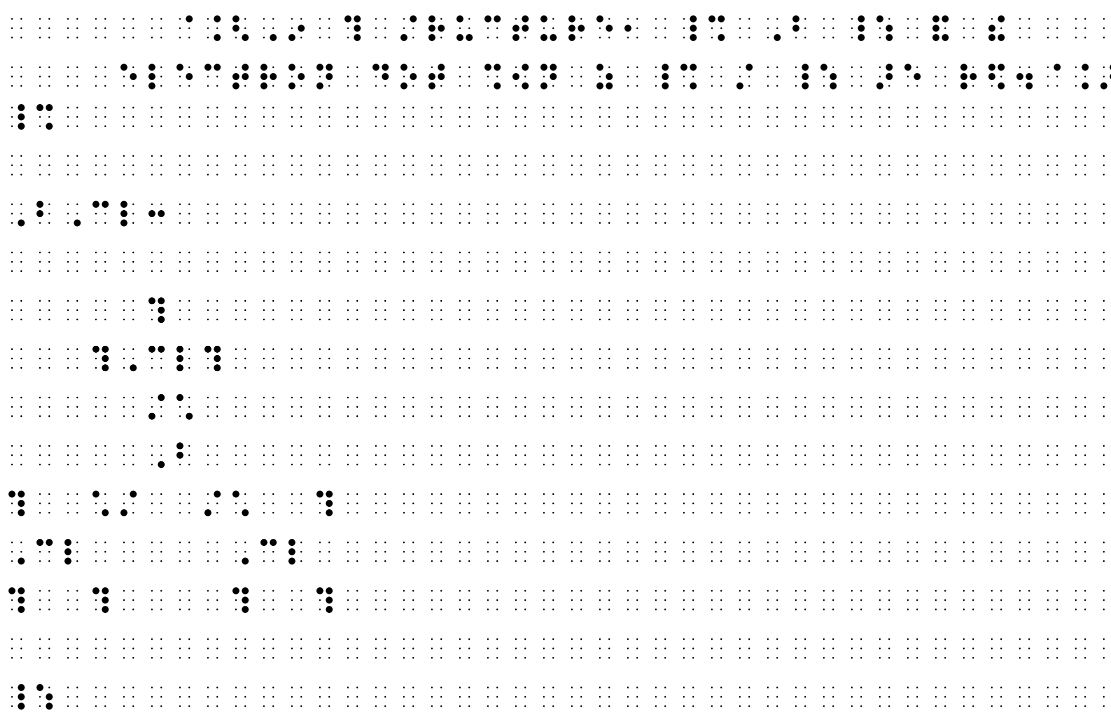


Observe: In the print copy, the N, the four H's, and eight of the electron dots are in blue ink.

Example 2-35: Dissimilar Dot Pairs Situated Diagonally



BCl_3



Observe: In the print copy, the B and three of the electron dots are in red ink.

Observe: The hollow dot (representing the red dots in print) is situated closest to B in the transcription. Note the arrangement of the various electron dots above, below, and oblique to the element SYMBOLS. Section 8 discusses label placement.

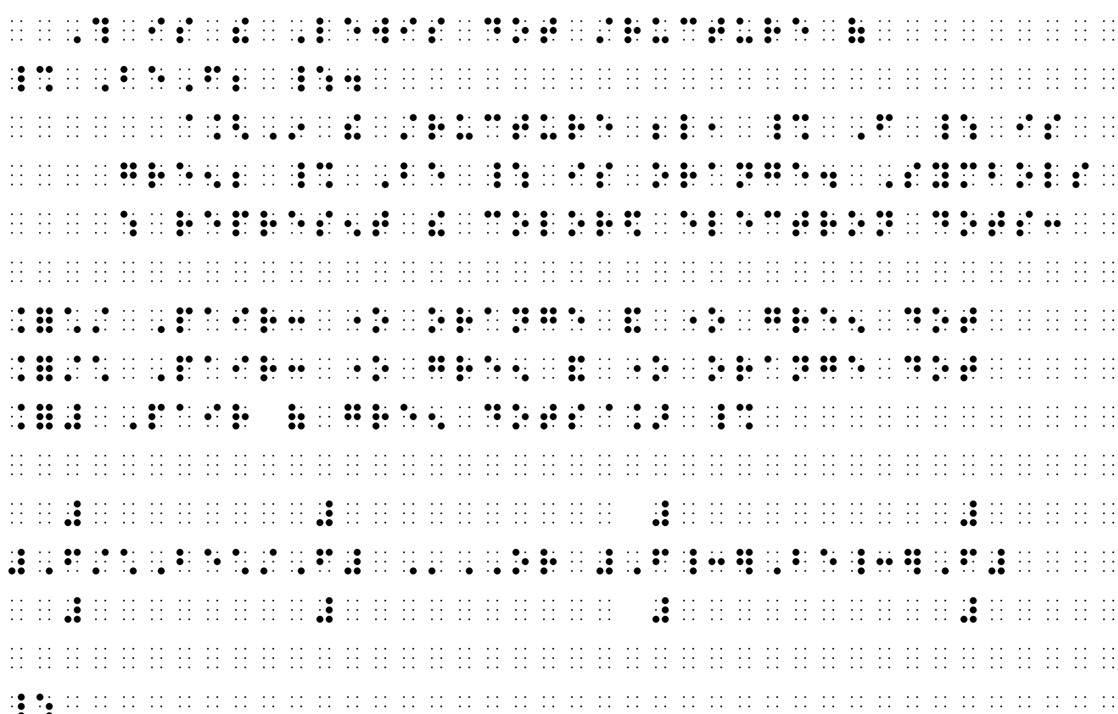
When two different colored dots are used in print, choose one of the other dot configurations to represent the second color. Write a transcriber's note, explaining the meaning of the symbol chosen. If the technique is used throughout the text, include the description of the print dot (its color) in your definition of the dot on the Special Symbols page. Use similar techniques if colored/bold, colored/hollow, or bold/hollow constructions are encountered. Sample transcriber's note:

In the structure below, F is green; Be is orange.
Symbols which represent the colored electron dots:

Pair: one orange and one green dot
Pair: one green and one orange dot
Pair of green dots

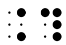
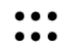
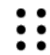
Example 2-36: Dissimilar Electron Pairs in Color

This is the Lewis dot structure of BeF_2.



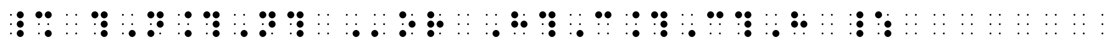
Observe: In the print copy, the F's and the surrounding six or seven electron dots are in green ink. The Be's and one dot on either side are in orange ink.

2.5.4 **Electron Dot Symbols—Triplets.** To make three pairs of electron dots, insert dots 46 before a pair shown in the previous lists of paired dots. See Sections 2.5.1 and 2.5.2. The most common triplet is three pairs of regular electron dots.

 Three pairs of regular electron dots  or  (triplet)

Example 2-37: Triplets Printed Vertically and Horizontally

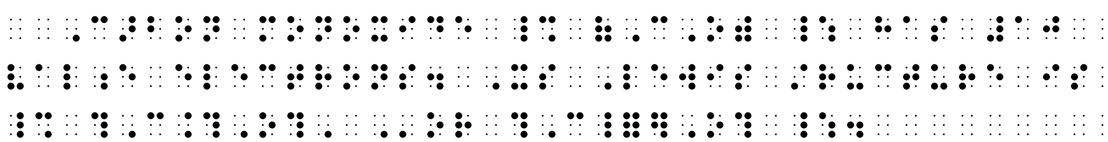
:N:::N: or H:C⁝C:H



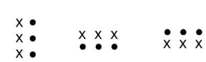
Observe: The same symbol is transcribed for either orientation of the printed triplet.

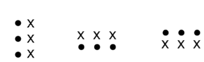
Example 2-38: Lewis Structure with Pairs and a Triplet

Carbon monoxide (CO) has 10 valence electrons. Its Lewis structure is :C:::O:, or :C≡O:.



a. **Triplets of Dissimilar Pairs.** To show a triplet with three dissimilar pairs, precede the appropriate pair symbol with dots 46.

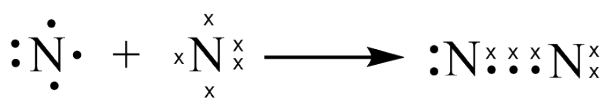
 Electron dot triplet: three x/regular pairs 

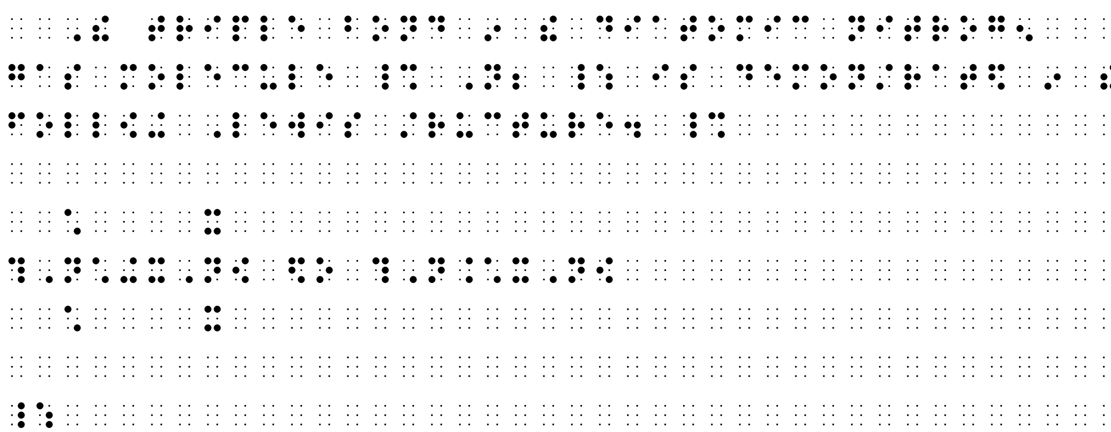
 Electron dot triplet: three regular/x pairs 

When transcribing triplets made of three side-by-side dissimilar vertical pairs, it is more meaningful to arrange the dot positions so that the left-hand dot matches the predominant dot style used in the atom to its left and the right-hand dot matches the predominant dot style used in the atom to its right.

Example 2-39: Triplet of Dissimilar Dots in Product

The triple bond in the diatomic nitrogen gas molecule N_2 is demonstrated in the following Lewis structure.





Observe: The N atom on the left is predominantly surrounded by regular electron dots; the N atom on the right is predominantly surrounded by "x" electron dots. The dissimilar triplet symbol reflects this.

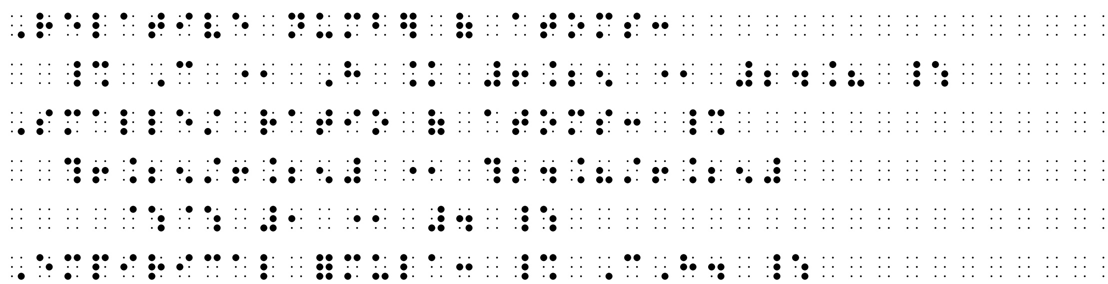
2.5.5 **Similar Signs.** A midline dot or pair of dots may not be representing electrons. Context will determine the meaning of the dots. See Section 4.2 regarding the chemical period, which is a single midline dot. A pair of dots may be a colon or may denote proportion (ratio).

Example 2-40: Dots Meaning Ratio, Not Electron Dots

Relative number of atoms: $\mathrm{C} : \mathrm{H} = 6.25 : 24.8$

Smallest ratio of atoms: $\dfrac{6.25}{6.25} : \dfrac{24.8}{6.25} \approx 1 : 4$

Empirical formula: CH_4



Section 3
Chemical Arrows

BRIEF CONTENTS

Chemistry Code symbols are to be listed on the Special Symbols page as directed in Section 1.2.2. Include all of the chemical arrows used in a volume, even if the arrow symbol is identical to the one used in the Nemeth Code. Identify each arrow with its chemical name.

3.1 Reaction Arrows

Reaction arrows are signs of comparison as defined by the Nemeth Code and follow the spacing and linage rules for comparison signs.

Caution: Reaction arrows are not the same as horizontal arrow bonds. Learn to distinguish between the two. See Section 2.2.2, Horizontal Arrow Bonds.

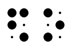
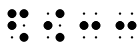
3.1.1 **Depiction of Reaction Arrows.** Chemical reaction arrows may be transcribed as braille symbols or drawn as tactile graphics according to the following guidelines.

a. **Braille Symbols.** Braille symbols may be used for the reaction arrows shown in this section when these are the only reaction arrows in that chemical expression.

b. **Tactile Graphics.** Do not mix methods within one expression. When a chemical expression contains other components that must be drawn, the reaction arrows should also be drawn. See Section 10, Molecular Diagrams.

c. **Exception.** If methods for timely production of tactile graphics are not available, reaction arrows may be transcribed as braille symbols. See Appendix B, Braille Symbols Used in Molecular Diagrams.

3.1.2 **Yields Arrow.** A chemical equation consists of the chemical formulas of the reactants (on the left) and the products (on the right). The reaction is indicated by a one-way arrow, usually pointing to the right, often read aloud as “yields”. The contracted form of the right-pointing arrow from the Nemeth Code is used. An arrow pointing in the opposite direction signifies a reverse reaction.

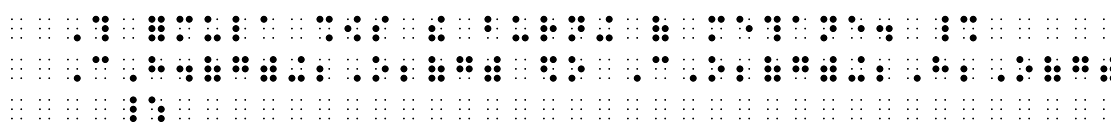
	Yields arrow	$\rightarrow$
	Yields arrow with extended shaft (length varies)	
	Reverse reaction arrow	$\leftarrow$

See Section 3.1.5, Snaking, for vertical and left-pointing yields arrows.

Example 3-1: Yields Arrow

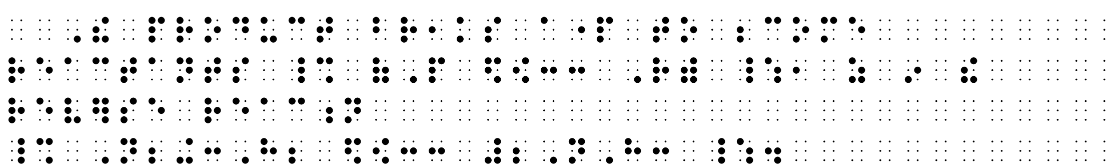
This formula shows the burning of methane.

$$CH_4(g)+2O_2(g) \rightarrow CO_2(g)+2H_2O(g)$$



Example 3-2: Reverse Reaction Arrow

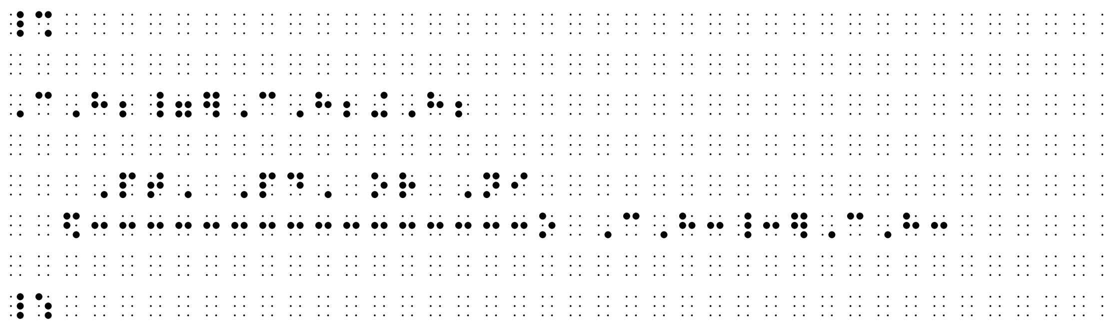
The product breaks apart to become reactants (P ← R), as in the reverse reaction $N_2+3H_2 \leftarrow 2NH_3$.



a. **Modified Yields Arrow.** Spatial presentation of modified arrows is preferred over the horizontal method of the Nemeth Code. The length of the arrow shaft is adjusted to the length of the modifier. Extending the length of the arrow shaft does not affect meaning. A word in the modifier is part of the technical label and is transcribed in Nemeth, without contractions.

Example 3-3: Modified Yields Arrow

$$CH_2{=}CH_2 \ + \ H_2 \xrightarrow{\text{Pt, Pd, or Ni}} CH_3{-}CH_3$$



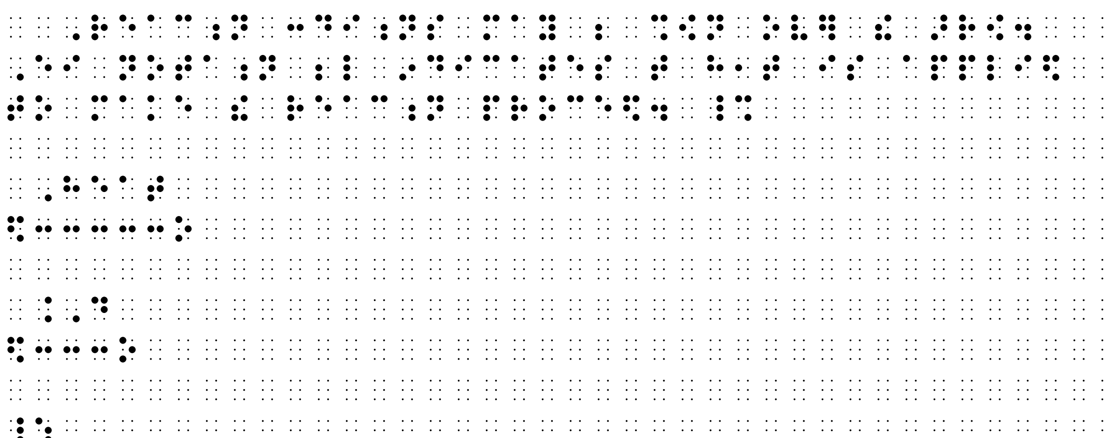
Observe: A blank line precedes and follows the construction even though the arrow is modified above and not below.

Example 3-4: Modified Yields Arrows

Reaction conditions may be shown over the arrow. Either notation below indicates that heat is applied to make the reaction proceed.

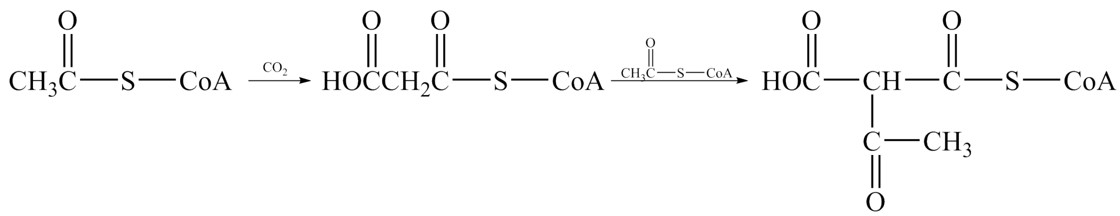
$$\xrightarrow{\text{Heat}}$$

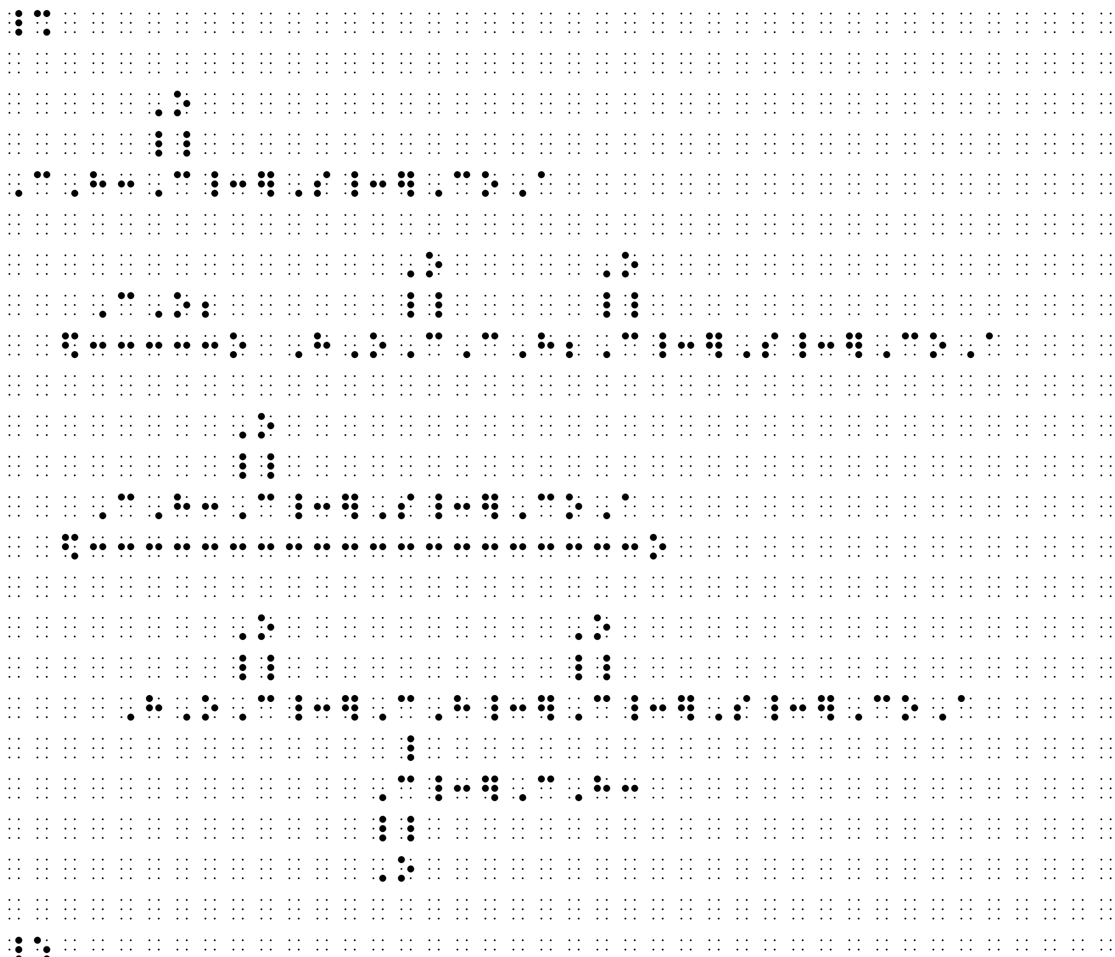
$$\xrightarrow{\Delta}$$



Example 3-5: Modified Yields Arrows

(See <u>Example 3-19</u> for a transcription of the second part of this reaction.)



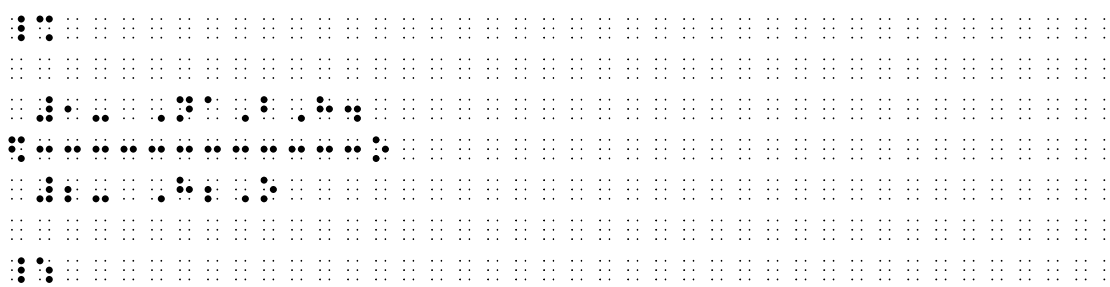


b. **Placement.** If the modifier of a yields arrow is divided so that part of the modifier appears above and part below the arrow, it is a printer's method of saving space. In braille, the modifier may be completed above the shaft or divided as in print. The decision is based upon the ease of reading.

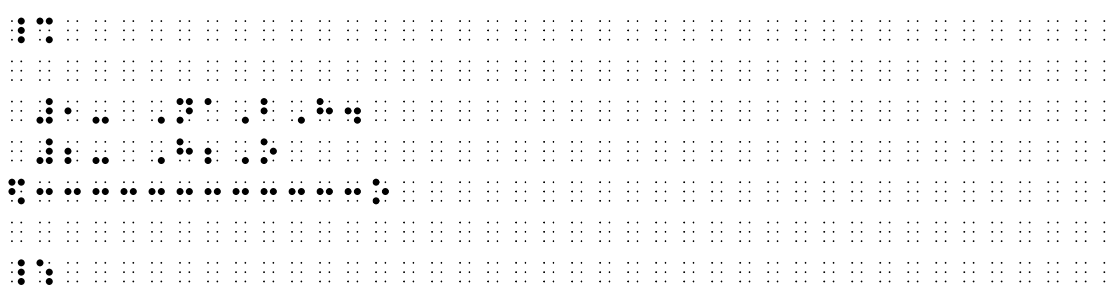
If the modifier is all above the arrow in print, follow the print layout—that is, do not divide the modifier if it is not divided in print.

Example 3-6: Arrow Modified Above and Below

$$\xrightarrow[\text{2-}\quad H_2O]{\text{1-}\quad NaBH_4}$$



Alternate transcription:



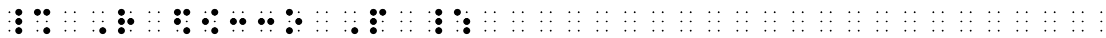
Observe: The first transcription follows print placement of modifiers above and below the arrow shaft. The alternate transcription places both modifiers above the shaft. Because the modifiers are numbered, they begin in the same cell rather than being centered to the shaft.

3.1.3 **Resonance Arrow.** Use the double-headed arrow of the Nemeth Code to represent the resonance arrow.

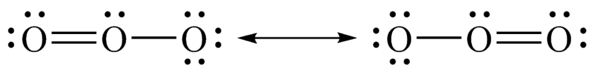
 Resonance arrow $\longleftrightarrow$

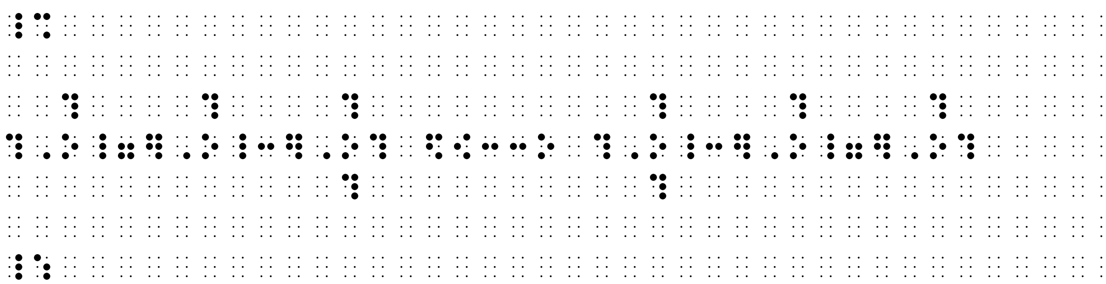
Example 3-7: Resonance Arrow

R $\longleftrightarrow$ P



Example 3-8: Resonance Arrow





3.1.4 **Reversible Reaction Arrow.** The reversible reaction arrow consists of two arrows pointing in opposite directions, printed one above the other. In print, the arrowheads may be a full barb or a half barb ("harpoon"). The top arrow may be right-pointing, or vice versa. The arrow shafts may be the same length, or one may be longer than the other.

In the Chemistry Code, the symbol for the reversible reaction arrow differs from the rules of the Nemeth Code. When reversible reaction arrow shafts are the same length, each shaft consists of only one braille cell. The signs are transcribed linearly, with the top arrow shown first. Full barbs are transcribed regardless of the print form.

⠫⠒⠕⠫⠪⠒ Reversible reaction arrow (top arrow right-pointing) ⇌ or ⇄

⠫⠪⠒⠫⠒⠕ Reversible reaction arrow (top arrow left-pointing) ⇋ or ⇆

The rules are different when these arrows are drawn as a tactile graphic. See Section 10, Molecular Diagrams.

See Section 3.1.5, Snaking, for vertical reversible reaction arrows.

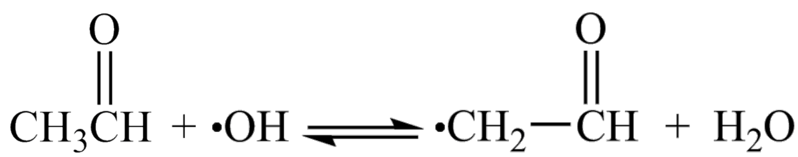
Example 3-9: Reversible Reaction Arrow in a Linear Formula

$H_2(g)+I_2(g) \rightleftharpoons 2HI(g)$

⠸⠩⠀⠠⠓⠆⠷⠛⠾⠬⠠⠊⠆⠷⠛⠾⠀⠫⠒⠕⠫⠪⠒⠀⠼⠆⠠⠓⠠⠊⠷⠛⠾⠀⠸⠱

Observe: In the print copy, the arrowheads are harpoons.

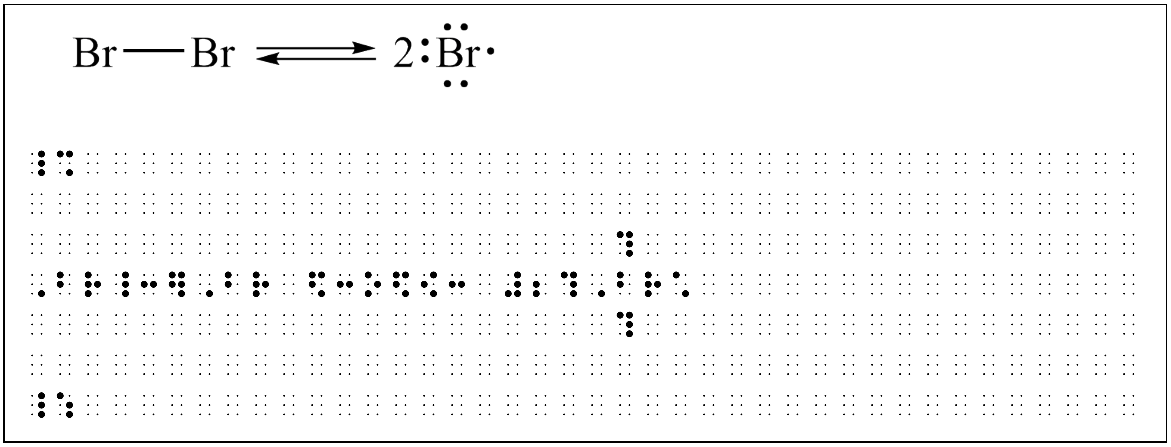
Example 3-10: Reversible Reaction Arrow in a Spatial Formula



```
⠸⠩

⠀⠀⠀⠀⠀⠀⠀⠠⠕
⠀⠀⠀⠀⠀⠀⠀⠸⠸
⠠⠉⠠⠓⠒⠠⠉⠠⠓⠬⠡⠠⠕⠠⠓

⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠠⠕
⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠀⠸⠸
⠀⠀⠫⠒⠕⠫⠪⠒⠀⠡⠠⠉⠠⠓⠆⠸⠒⠻⠠⠉⠠⠓⠬⠠⠓⠆⠠⠕

⠸⠱
```

Observe: In the print copy, the arrowheads are harpoons.

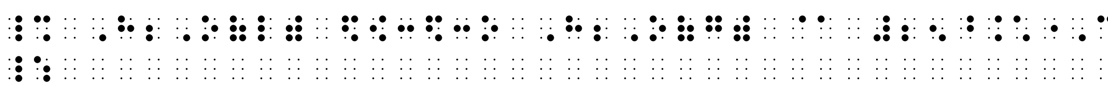
Example 3-11: Reversible Reaction Arrow in a Spatial Formula



Observe: In the print copy, the arrowheads have full barbs.

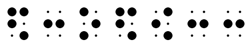
Example 3-12: Reversible Reaction Arrow

$H_2O(l) \rightleftharpoons H_2O(g)$ @ 25°C

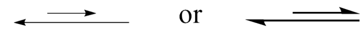


Observe: The top harpoon is pointing to the left and the bottom harpoon is pointing to the right.

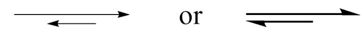
a. **Unequal Reversible Reaction Arrows.** Reversible reaction arrows with unequal shaft lengths are referred to in the Chemistry Code as unequal reversible reaction arrows. The relative length of the arrow shaft has chemical significance. The longer shaft is represented by the two-cell shaft symbol; the shorter shaft by the one-cell shaft symbol. The top arrow is transcribed first, and full barbs are used regardless of the print form.



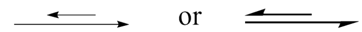
Unequal reversible reaction arrow (left-favored, right-pointing on top)



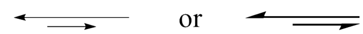
Unequal reversible reaction arrow (right-favored, right-pointing on top)



Unequal reversible reaction arrow (right-favored, left-pointing on top)

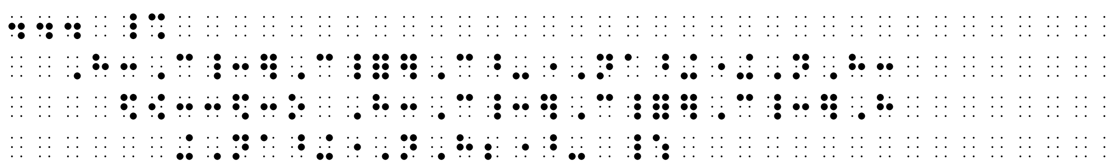


Unequal reversible reaction arrow (left-favored, left-pointing on top)



Example 3-13: Unequal Reversible Reaction Arrow

$H_3C{-}C{\equiv}C^{-}Na^{+} \ + \ NH_3 \leftrightarrows H_3C{-}C{\equiv}C{-}H \ + \ Na^{+}NH_2^{-}$

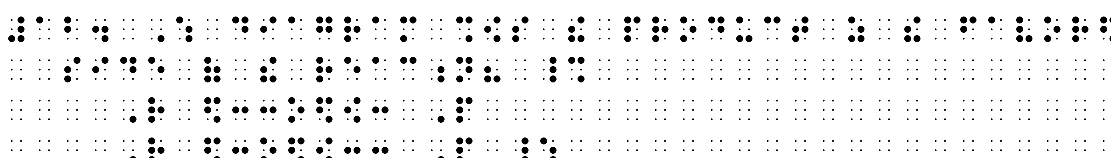


Example 3-14: Unequal Reversible Reaction Arrow

12. Which diagram shows the product as the favored side of the reaction?

$R \rightleftharpoons P$

$R \leftrightharpoons P$



Observe: In the print copy, the arrowheads are harpoons.

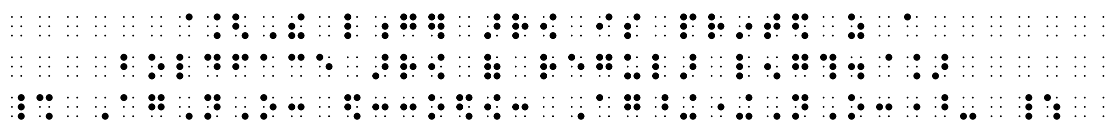
Older texts may show one of the arrows in bold type. If encountered, disregard typeface and use the longer shaft for the bold arrow. Explain the change in a transcriber's note.

Sample transcriber's note:

The longer arrow is printed as a boldface arrow of regular length.

Example 3-15: Bold Reversible Reaction Arrow

$AgNO_3 \rightleftharpoons Ag^+ + NO_3^-$



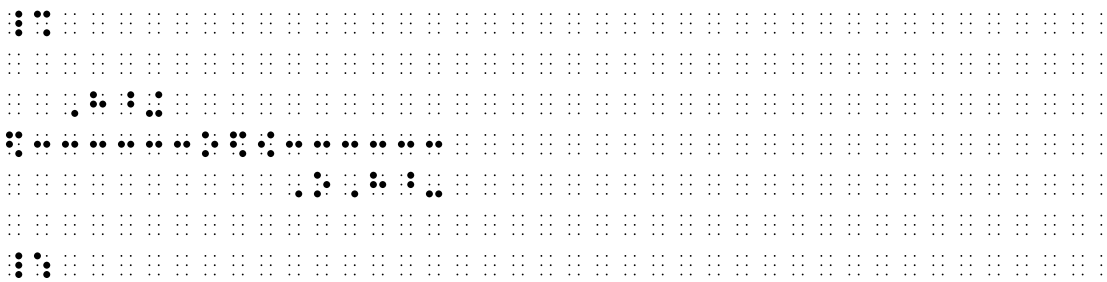
b. **Modified Reversible Reaction Arrow.** Placement of the modifiers must conform to the print notation—above or below the appropriate arrow shaft.

Shafts of Equal Length: If the two arrows are of equal length in print, the shafts of both arrows must also be of equal length in braille. The length is determined by the number of cells it takes to accommodate the longest modifier. Center the shorter modifier above or below the appropriate shaft.

Shafts of Unequal Length: If the two arrow shafts are of unequal length in print, they should be obviously unequal in braille.

Example 3-16: Modified Reversible Reaction Arrow

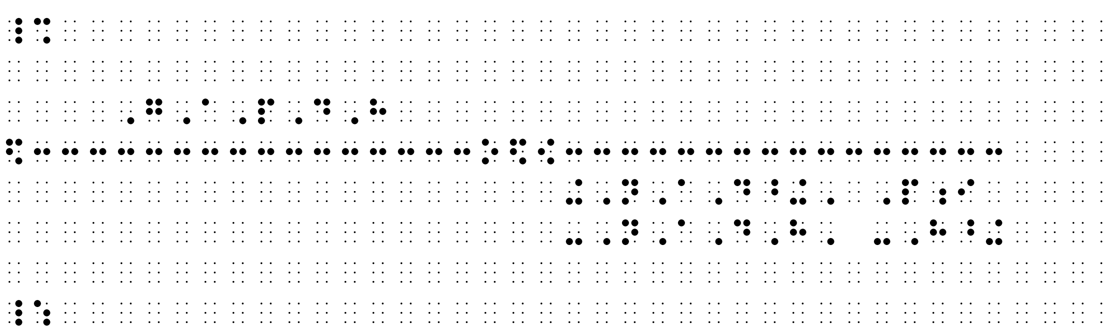
$$\underset{OH^{-}}{\overset{H^{+}}{\rightleftharpoons}}$$



Observe: Each arrow shaft is 6 cells long.

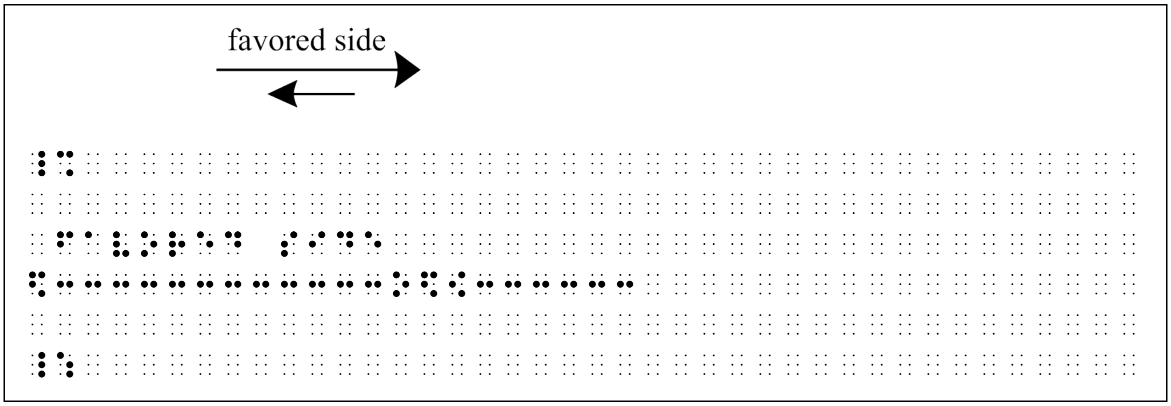
Example 3-17: Modified Reversible Reaction Arrow

$$\underset{\substack{+\,NAD^{+},\ P_{i} \\ -\,NADH,\ -\,H^{+}}}{\overset{GAPDH}{\rightleftharpoons}}$$



Observe: Each arrow shaft is 16 cells long. See Section 7.2.2 regarding capitalization of abbreviations in Nemeth context.

Example 3-18: Modified Unequal Reversible Reaction Arrow



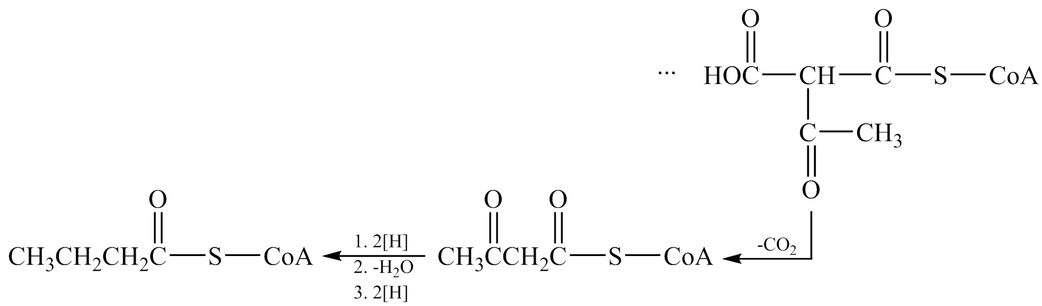
Observe: The short shaft is obviously shorter than the long shaft.

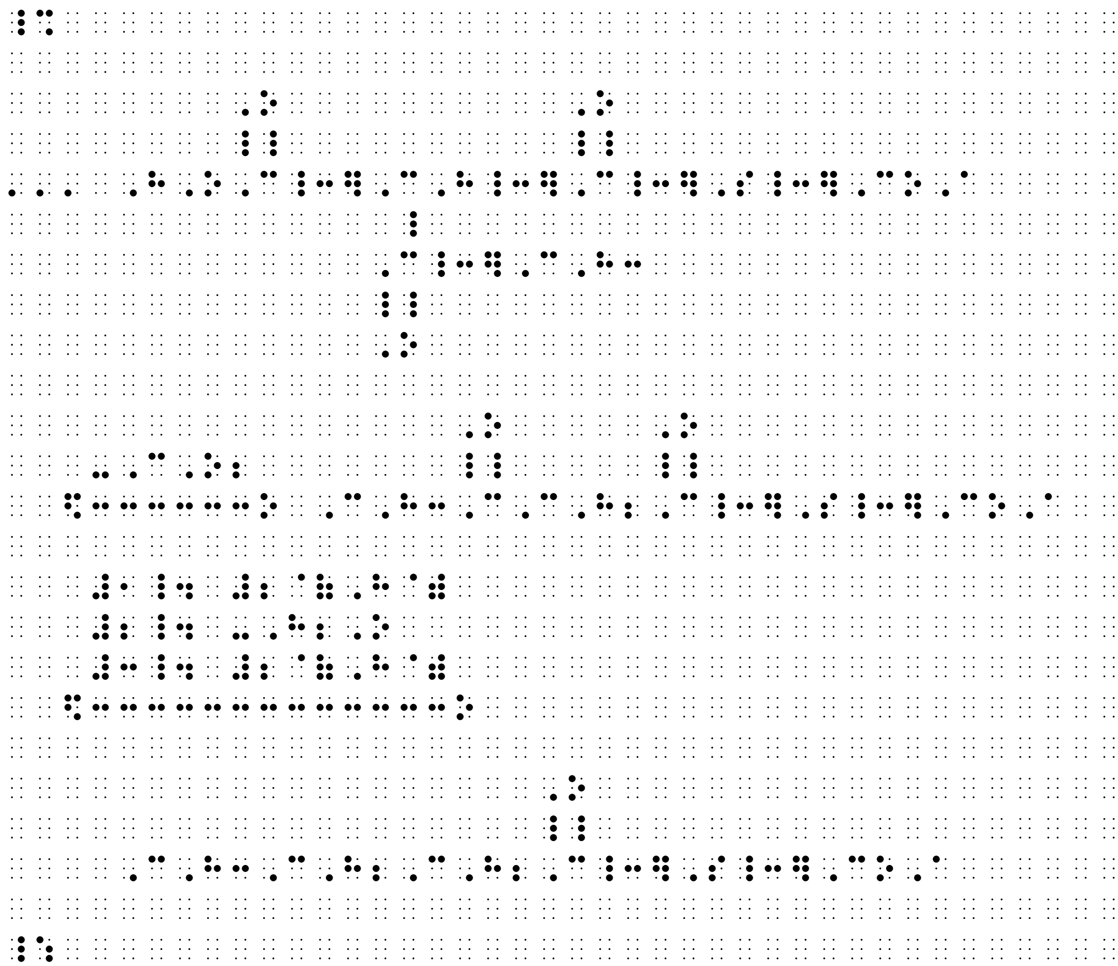
3.1.5 **Snaking.** Normally, chemical equations are arranged in print from left to right and from top to bottom. When there is not room on a print line to complete a long reaction, the symbols might be printed in a snaking pattern down the page. Reaction arrows may be printed vertically (down) or backwards (left) as the reader follows the snaking progression. Reaction arrows show the progression between entire constructs, not from the particular element which precedes or follows the arrow in the snaking configuration.

If the sequence of chemical signs can be determined without a doubt, the transcriber may rearrange the structure in left-to-right fashion following the runover directives of the Chemistry Code. The direction of the reaction from one component ("entire construct") to another must be preserved.

If the progression of chemical signs is not clear, reconstruct the print arrangement using tactile graphics to represent the reaction arrows and the bonds. See Section 10, Molecular Diagrams.

Example 3-19: Snaking





Observe: The braille transcription arranges all of the yields arrows from left to right in the normal reading direction. The yields arrows are placed between the three molecular structures ("entire constructs"). See [3.1.2.a](#) regarding transcription of the modified arrows. The print copy shows the yields arrows wrapping in a loop, left to right, down, and then from right to left. See [Example 3-5](#) for a transcription of the first part of this reaction.

3.1.6 **Other Types of Arrow Shafts.** Other types of chemical arrows tend to be within structures that render best as a tactile graphic (see Section 10, Molecular Diagrams). However, if braille symbols are being used to depict other arrows, use the arrow shafts of the Nemeth Code.

a. **Negated Arrow.** An arrow with a centered line, hash, double hash, or cross shows that a reaction cannot take place or did not work. The text may refer to it as a "broken" arrow. A negation symbol is inserted before the arrow in all cases. The uncontracted form of the right-pointing arrow is used when a yields arrow is modified with a negation symbol.

⠌⠫⠒⠒⠕	Negated yields arrow	$\not\longrightarrow$
⠌⠫⠪⠒⠒⠕	Negated resonance arrow	$\not\longleftrightarrow$

Do not mistake a negated arrow for a dipole arrow. See Section 3.2.2.

Example 3-20: Negated Yields Arrow

R $\not\longrightarrow$ P or R $\not\longrightarrow$ P

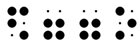
⠸⠩ ⠠⠗ ⠌⠫⠒⠒⠕ ⠠⠏ ⠸⠱

Example 3-21: Negated Resonance Arrow

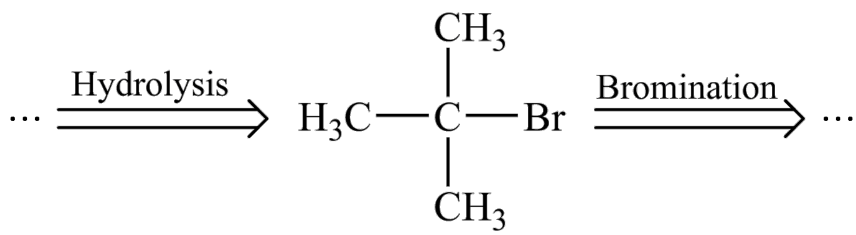
Parity Violation: A $\overset{\hat{P}}{\not\longleftrightarrow}$ B

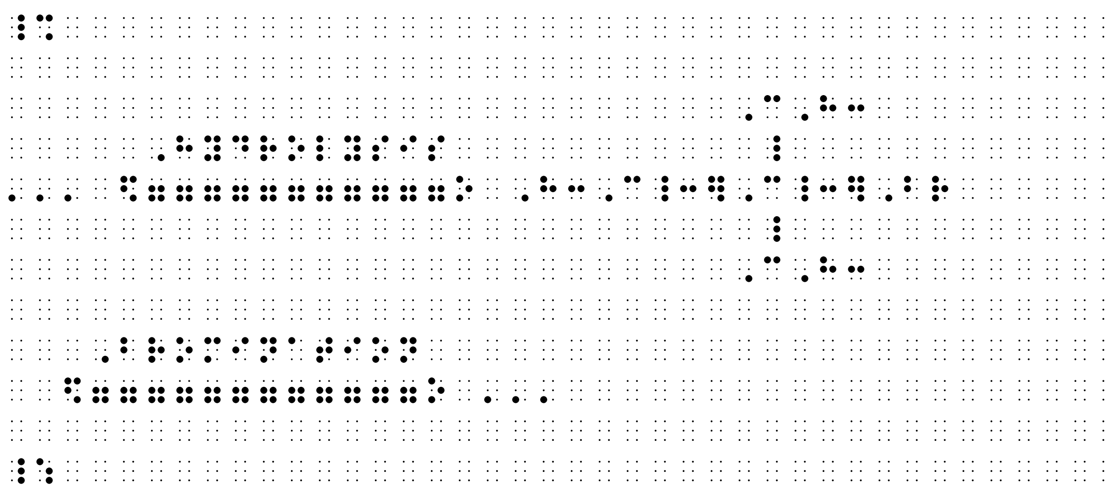
⠐⠠⠏⠣⠸⠣⠻
⠠⠏⠜⠰⠽ ⠠⠧⠊⠕⠇⠁⠰⠝⠒ ⠸⠩ ⠠⠁ ⠌⠫⠪⠒⠒⠒⠒⠒⠒⠒⠕ ⠠⠃ ⠸⠱

b. **Double-Shafted Arrow.** This arrow is used in the topic of retrosynthesis and is also used to show an implied intermediate reaction.

 Right-pointing arrow with double shaft $\Rightarrow$ or ⇨

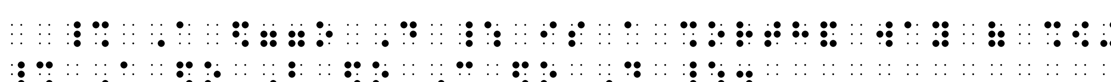
Example 3-22: Labeled Retrosynthetic Arrows





Example 3-23: Double-Shafted Arrow

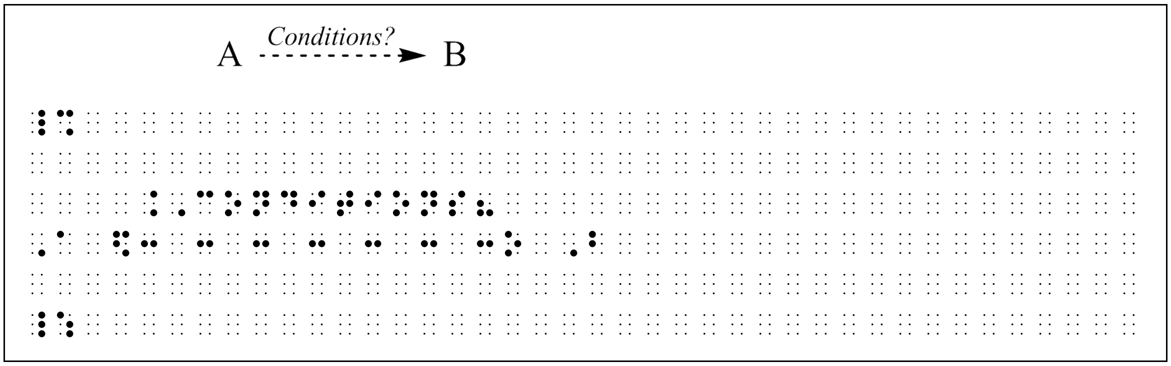
$A \Rightarrow D$ is a shorthand way of showing $A \rightarrow B \rightarrow C \rightarrow D$.



c. **Dashed Arrow.** Follow Nemeth Code rules for constructing a dashed arrow.

 Right-pointing dashed arrow - - - -▶

Example 3-24: Dashed Arrow



d. **Curved Arrow.** A curved arrow has special chemical meaning. It is best drawn as a tactile graphic. See Section 10, Molecular Diagrams.

3.2 Other Chemical Arrows

3.2.1 **Arrow Bonds.** See Sections 2.2.2, Horizontal Arrow Bonds, and 2.3.2, Vertical Arrow Bonds.

3.2.2 **Dipole Arrows.** In print, the shaft of the dipole arrow is superposed with a vertical line which represents a plus sign. Dipole arrows often appear in conjunction with a bond. When a horizontal dipole arrow appears in a simple structure, the braille symbol may be used. The length of the arrow shaft may be extended without affecting meaning.

Vertical and oblique dipole arrows as well as dipole arrows in more complex structures are best drawn as a tactile graphic. See Section 10, Molecular Diagrams.

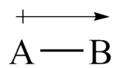
 Right-pointing dipole arrow +⟶ or +⟶

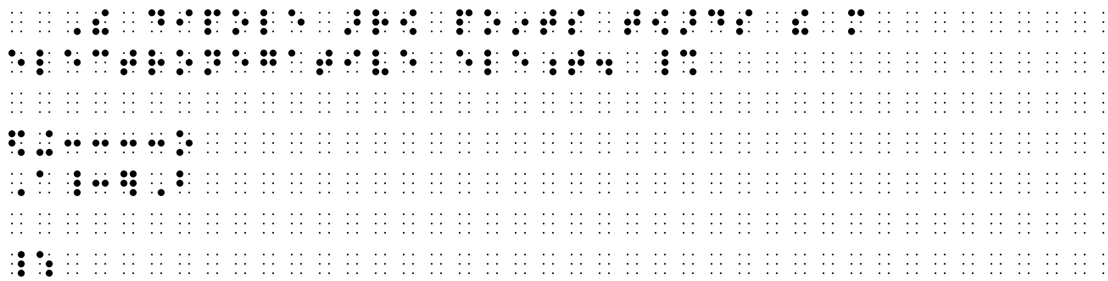
 Left-pointing dipole arrow ⟵+ or ⟵+

In print, the plus sign that is part of a dipole arrow may be touching the arrow shaft, appearing to be a vertical line. Do not mistake a dipole arrow for a negated arrow. See Section 3.1.6.a.

Example 3-25: Dipole Arrow Above Symbols

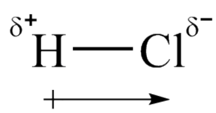
The dipole arrow points towards the more electronegative element.

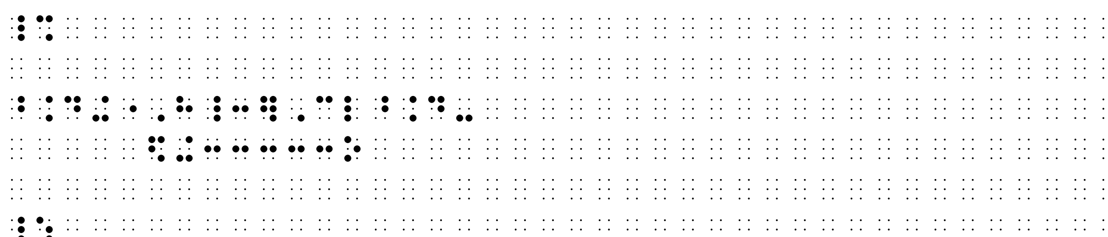




Observe: The plus symbol is directly above the letter A, as printed. The arrowhead is directly above the letter B, as printed.

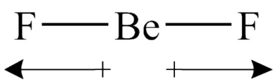
Example 3-26: Dipole Arrow Below SYMBOLS



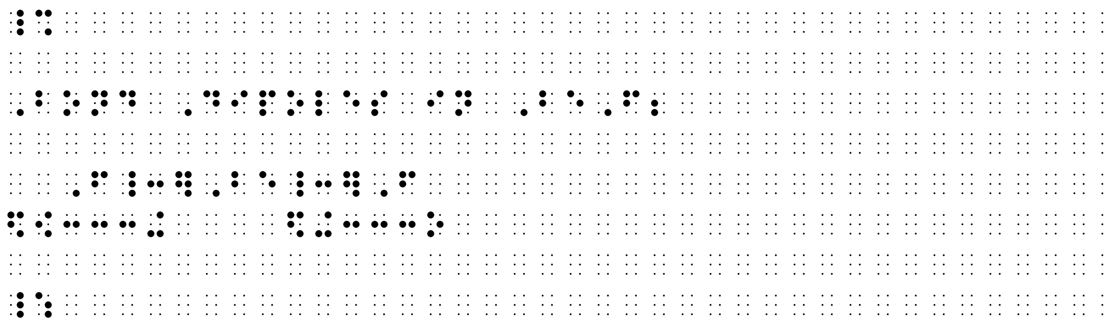


Observe: The plus symbol is directly below the H atom, as printed. The arrowhead is directly below the Cl atom, as printed. In print, the plus and minus charge associated with each delta is in the supersuperscript position. This placement is disregarded in the braille transcription, as explained in Section 5.1.a, Partial Charge.

Example 3-27: Left- and Right-Pointing Dipole Arrows



Bond Dipoles in BeF_2



Observe: Each arrowhead extends beyond each F atom, as printed. Each plus symbol is below the single bond, as printed.

3.2.3 **Valence Arrows.** In orbital notation, arrows or harpoons pointing up and down represent electrons. Indicate valence arrows in orbital diagrams with the following symbols.

	Up-pointing valence arrow	↑ or ↿
	Down-pointing valence arrow	↓ or ⇃

These symbols are unique to the Chemistry Code, used only in the context of valence arrows depicted in orbital diagrams.

Example 3-28: Up- and Down-Pointing Valence Arrows

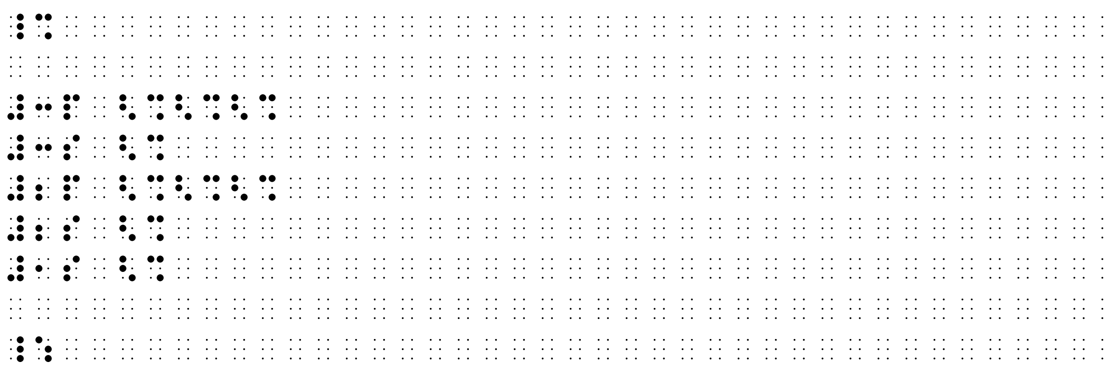
3p ↑↓↑↓↑↓

3s ↑↓

2p ↑↓↑↓↑↓

2s ↑↓

1s ↑↓



Observe: There is no space between these valence arrows.

a. **Paired Groupings.** Electron configuration diagrams often show electron pairing by underlining or boxes. Show the paired grouping by inserting one space between pairs.

When only the up arrow appears, the general omission symbol of the Nemeth Code (dots 123456) is used to show the absence of the down-pointing valence arrow within the pair.

Place element SYMBOLS or orbital level notation as column headings, leaving two spaces between columns.

Explain the layout in a transcriber's note.

Sample transcriber's notes:

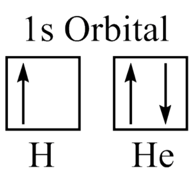
In print, orbital diagrams show paired valence arrows enclosed in a square frame. In braille, the pairs are separated by one space.

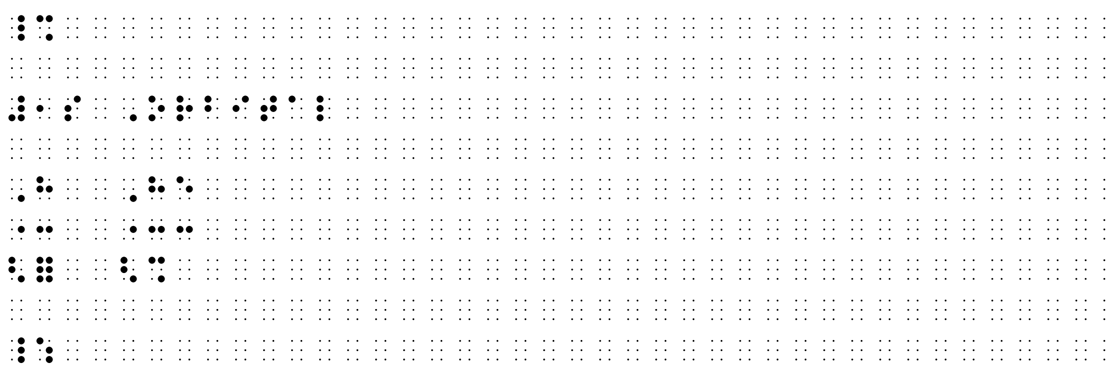
When no down-pointing valence arrow is printed in a pair, the general omission symbol of the Nemeth Code is used (dots 123456).

Element symbols printed below the boxes are transcribed as column headings above the valence arrows.

Electron shell designations printed below the boxes are transcribed as column headings above the valence arrows.

Example 3-29: Valence Arrows (Paired Groupings)

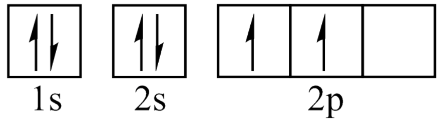


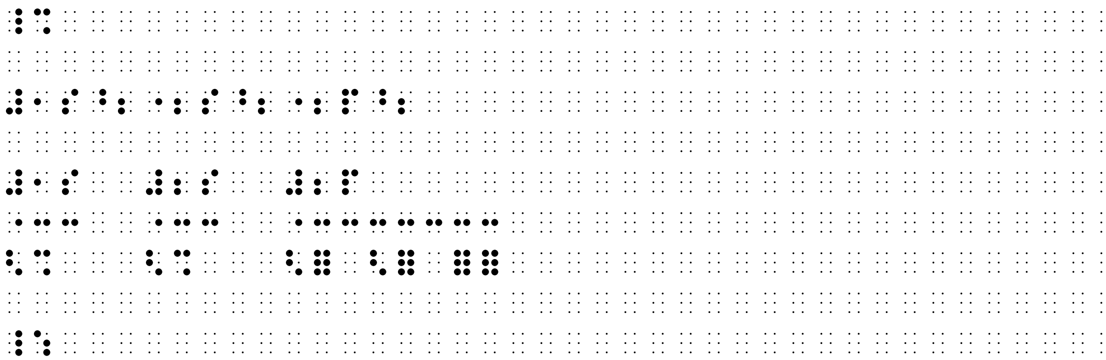


Observe: In the print copy, the valence arrows are grouped inside square frames.

Example 3-30: Valence Arrows (Paired Groupings)

$1s^2 2s^2 2p^2$

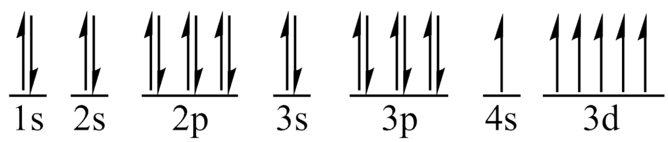


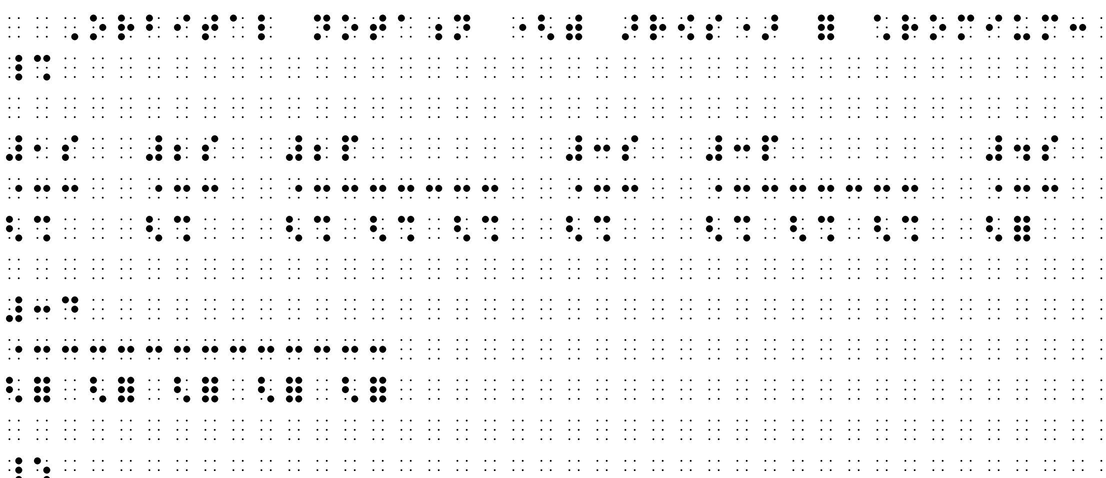


Observe: In the print copy, the valence arrows are shown as harpoons grouped inside square frames.

Example 3-31: Valence Arrows

Orbital notation (with arrows) for chromium:



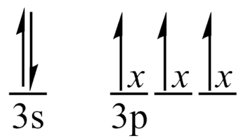


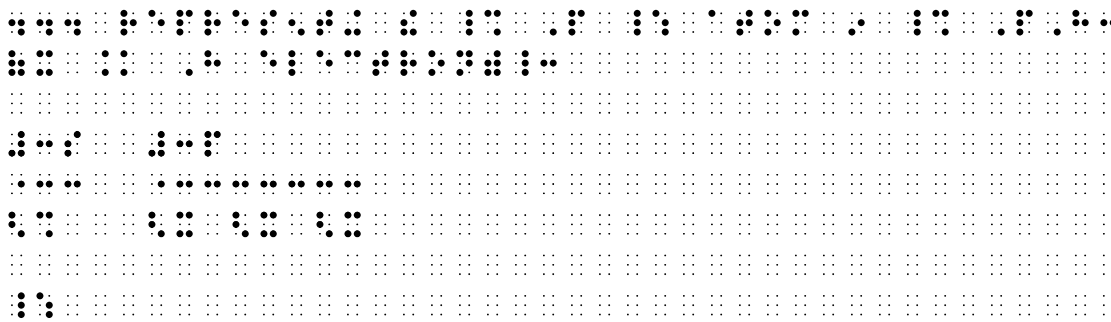
Observe: In the print copy, the valence arrows are shown as harpoons. Shells are grouped by underlining.

An electron dot may appear in an orbital diagram. Use the appropriate Lewis dot symbol. See Section 2.5, Lewis Structures.

Example 3-32: Orbital Diagram with "x" Electron Dot

… representing the P atom in PH_3 (x = H electron):

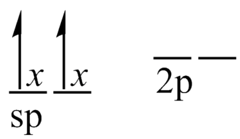


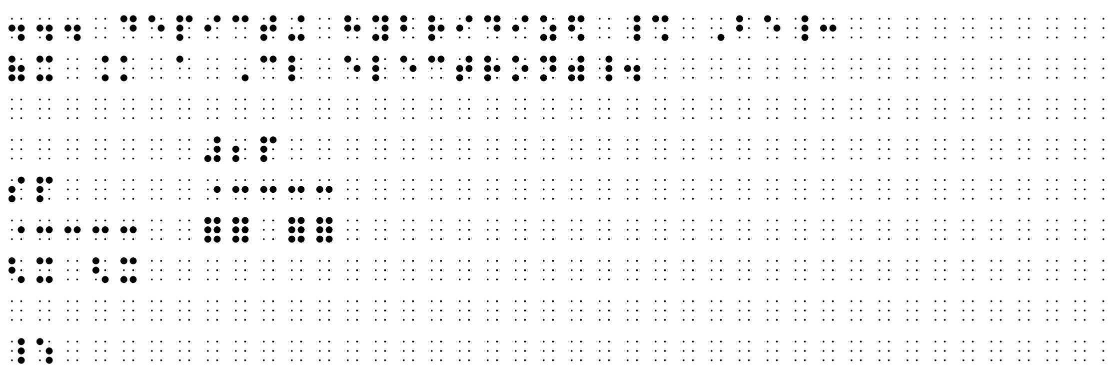


b. **Orbital Diagrams with Spatial Characteristics.** When orbital diagrams are printed side by side and one diagram is raised, its location in relation to the other diagram has meaning. The relationship is preserved in the braille transcription.

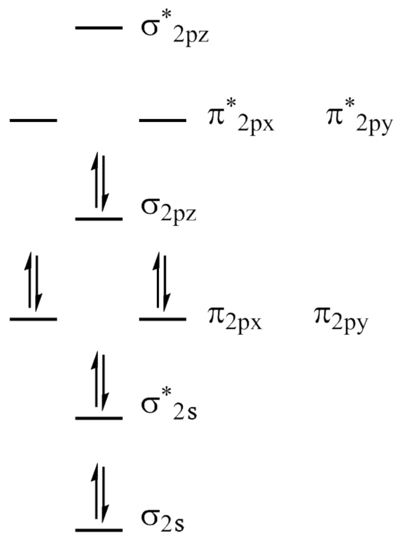
Example 3-33: Spatial Features in an Orbital Diagram

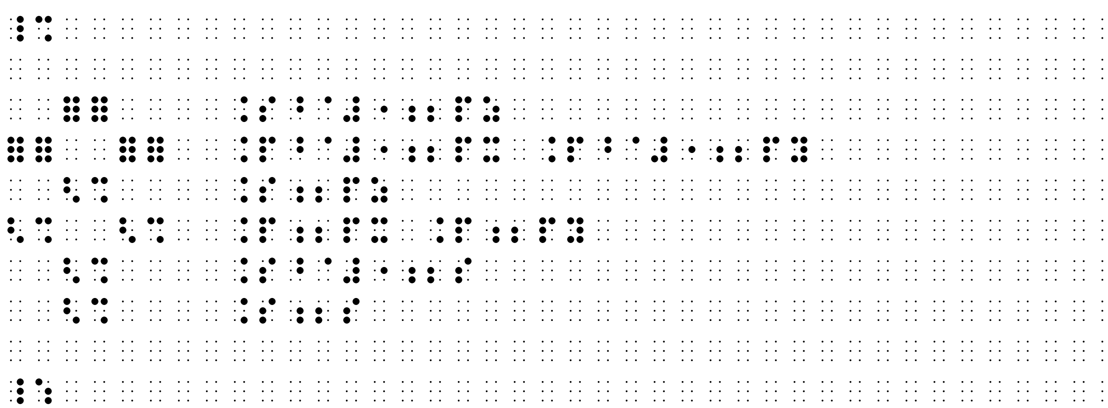
… depicting hybridized Be: (x = a Cl electron).





Example 3-34: Spatial Features in an Orbital Diagram

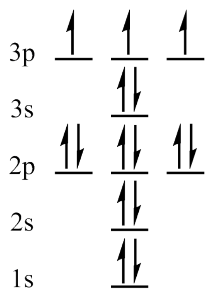


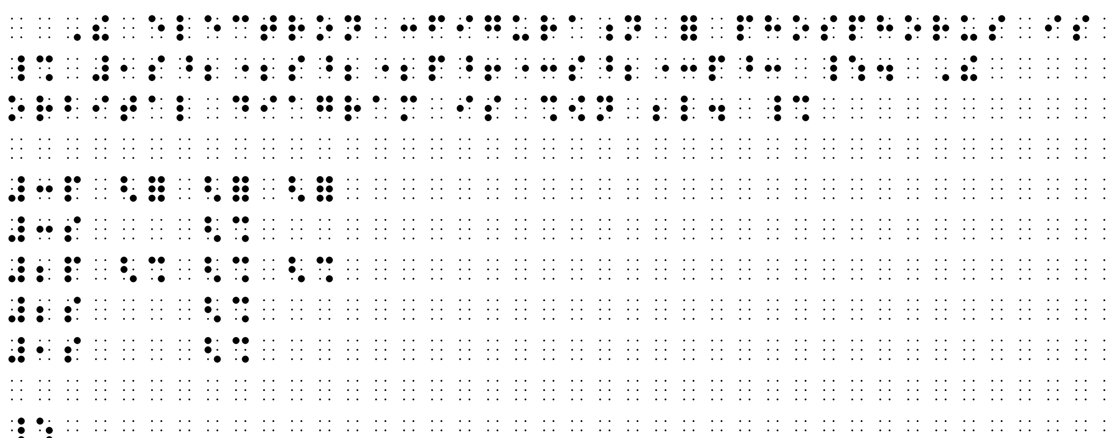


Orbital diagrams printed in tabular form follow the same format in braille, leaving only one space between columns. Blank fields in the columns and rows are left blank in the transcription.

Example 3-35: Valence Arrows in Tabular Form

The electron configuration for phosphorus is $1s^2 2s^2 2p^6 3s^2 3p^3$. The orbital diagram is shown below.





Observe: In the print copy, the valence arrows are shown as harpoons grouped by underlining.

3.2.4 **Vaporization and Precipitation Arrows.** Depicting states of matter with up-pointing and down-pointing arrows may be found in older publications. If encountered, the following symbols are used.

⠫⠣ Vaporization arrow (upward-pointing) $\uparrow$

⠫⠩ Precipitation arrow (downward-pointing) $\downarrow$

The arrow is unspaced from the element SYMBOL to which it applies and is placed on the same braille line as the SYMBOL or compound to which it applies. If the arrow is interior to the expression, a space follows the arrow.

Example 3-36: Vaporization Arrow

$$2Al + 2NaOH + 2H_2O \rightarrow Na_2Al_2O_4 + 3H_2\uparrow$$

⠲⠲⠲⠀⠸⠩

⠀⠀⠼⠆⠠⠁⠇⠬⠆⠠⠝⠁⠠⠕⠠⠓⠬⠆⠠⠓⠆⠠⠕

⠀⠀⠀⠀⠫⠕⠀⠠⠝⠁⠆⠠⠁⠇⠆⠠⠕⠲⠬⠒⠠⠓⠆⠫⠣⠀⠸⠱

Example 3-37: Precipitation Arrow

$$Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3\downarrow + 2H_2O$$

⠲⠲⠲⠀⠸⠩

⠀⠀⠠⠉⠁⠷⠠⠓⠠⠉⠠⠕⠒⠾⠰⠆⠐⠬⠠⠉⠁⠷⠠⠕⠠⠓⠾⠰⠆

⠀⠀⠀⠀⠫⠕⠀⠼⠆⠠⠉⠁⠠⠉⠠⠕⠒⠫⠩⠀⠬⠆⠠⠓⠆⠠⠕⠀⠸⠱

Observe: A space follows the arrow because it is interior to the expression.

3.2.5 **Lead Lines with Arrowheads.** Lead lines are drawn as a tactile graphic. See Section 10, Molecular Diagrams.

Section 4
Miscellaneous Chemical Symbols

BRIEF CONTENTS

For rules regarding the abbreviated forms of SI units, see Section 7.4, Standard International Units of Measure.

4.1 Symbols for the Chemical Elements (SYMBOLS)

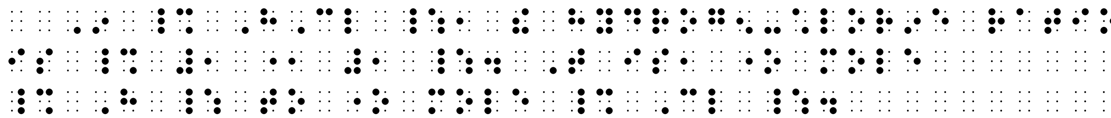
4.1.1 **Definition.** The standard nomenclature for the letter or letters representing the name of a chemical element is "chemical symbol." In the Chemistry Code, the word SYMBOL (all upper case) is used to denote the chemical elements. SYMBOLS are technical material—they are not abbreviations. See Appendix A for a list of the chemical elements.

4.1.2 **Transcription Details.** Switch to Nemeth Code when SYMBOLS appear within narrative. The English-letter indicator is not used for SYMBOLS. When SYMBOLS appear in a series, as in a molecule or compound, each SYMBOL is unspaced and capitalized individually. When punctuation occurs inside the code switches, SYMBOLS are punctuated in mathematical mode.

See also Section 7.2.3, pH and pOH.

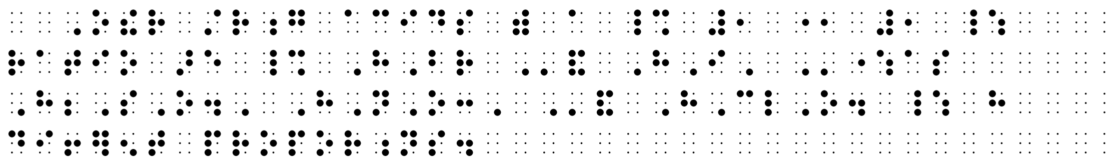
Example 4-1: SYMBOLS Within Narrative Text

In HCl, the hydrogen-chlorine ratio is 1:1. That is, one mole H to one mole Cl.



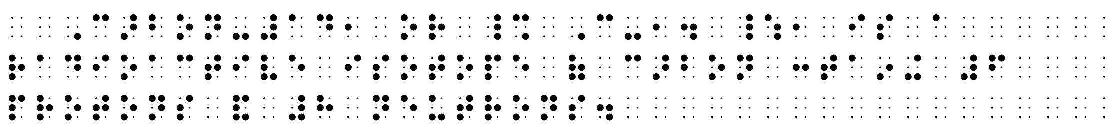
Example 4-2: Punctuation of SYMBOLS

Other strong acids with a 1:1 ratio are HBr and HI, whereas H_2SO_4, HNO_3, and $HClO_4$ have different proportions.



Example 4-3: Hyphen Notation with SYMBOLS

Carbon-14, or C-14, is a radioactive isotope of carbon containing 6 protons and 8 neutrons.



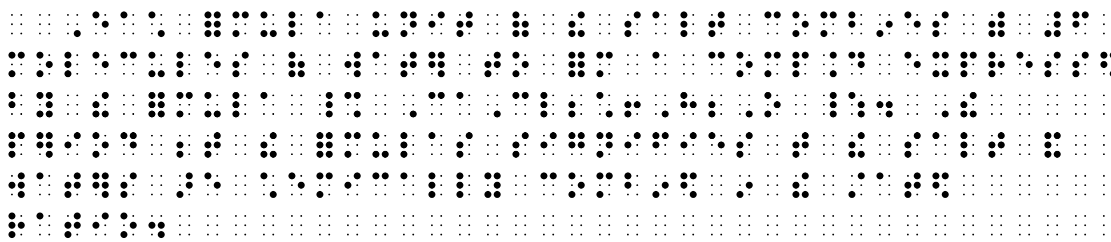
4.2 Chemical Period

 Chemical period ·

This midline dot, sometimes referred to as a chemical period, is a notational device separating two components of a chemical expression. It is often encountered under the topic of hydration. The nature of the dot will be clear from context, so it will not be mistaken for an electron dot. No space is left before or after the chemical period. Nemeth Code rules for operation signs apply to this symbol.

Example 4-4: Chemical Period in a Hydration Formula

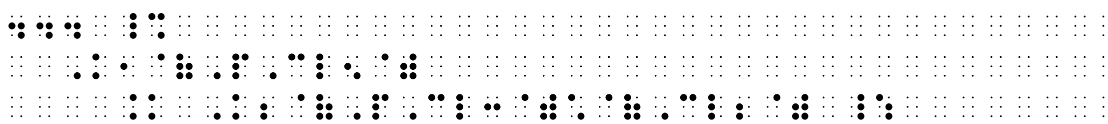
Each formula unit of the salt combines with 6 molecules of water to form a compound expressed by the formula $CaCl_2 \bullet 6H_2O$. The period between the formulas signifies that the salt and waters are chemically combined in the stated ratio.



The midline dot may also represent a multiplication dot. The rules are the same.

Example 4-5: Multiplication Dot in an Equilibrium Computation

$K_1[PCl_5] = K_2[PCl_3] \bullet [Cl_2]$



4.3 Detached Plus or Detached Minus

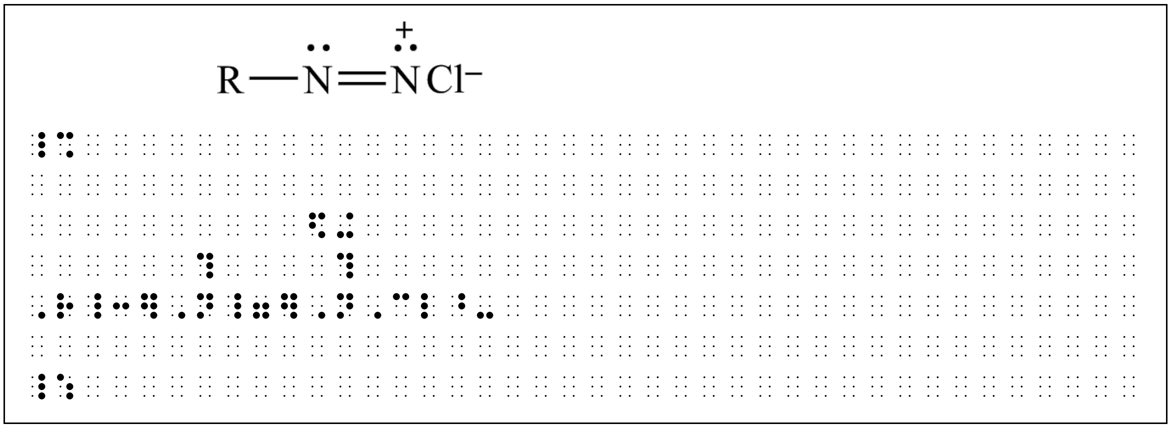
A plus or a minus sign may label certain parts of a chemical structure. The plus or minus sign may or may not be enclosed in a circle shape. *Note:* The sign depicts a positive or negative charge which applies to the item it labels.

The following symbols are to be used only in the context of a spatial diagram when the plus or minus sign stands alone.

	Plus sign within a circle	$\oplus$
	Minus sign within a circle	$\ominus$
	Detached plus sign	+
	Detached minus sign	–

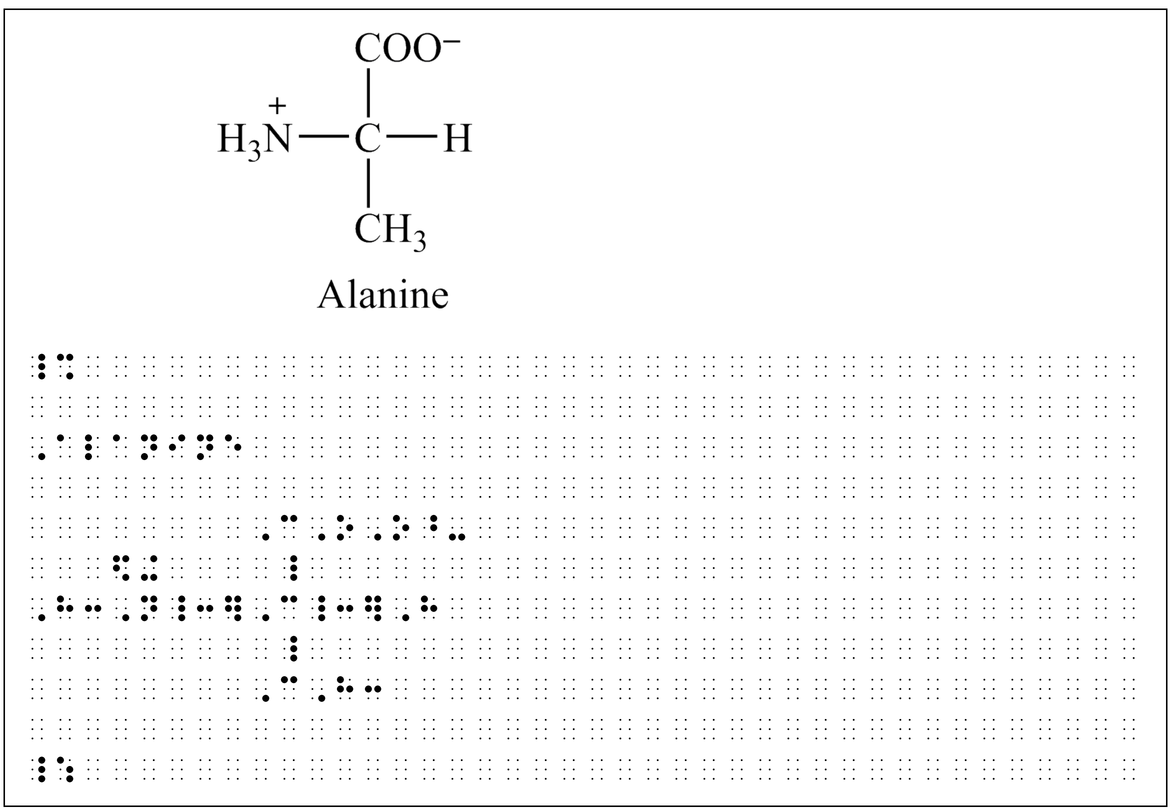
Detached charge symbols may be moved in order to accommodate surrounding material in a spatial diagram, as long as the symbol is close to the atom to which it applies. See Section 8.2, Labeled Atoms. See also Sample 10-16 in Section 10.

Example 4-6: Plus Sign Printed Above Electron Dots



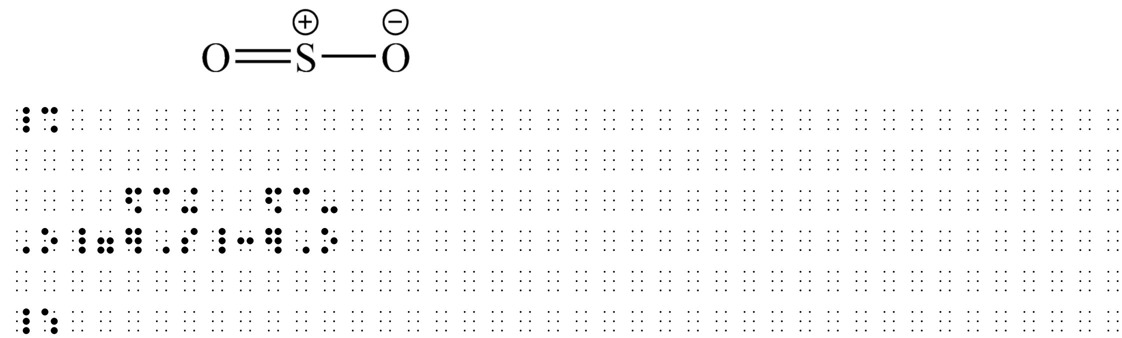
Observe: The minus sign is a superscript.

Example 4-7: Plus Sign Printed Above SYMBOL N



Observe: The minus sign is a superscript.

Example 4-8: Encircled Signs Printed Above SYMBOLS

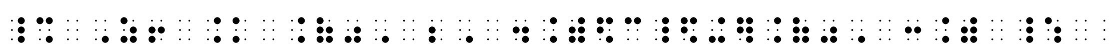


4.3.1 **Similar Signs.** Similar signs may be encountered in other types of chemical notation. The plus and minus symbols listed above are to be used only as labels within a spatial diagram, not in the situations described below.

a. **Encircled Plus Sign or Encircled Minus Sign in a Mathematical Equation.** These signs have mathematical meaning when encountered within a linear mathematical expression. Follow the full construct of "shapes with interior modification" of the Nemeth Code.

Example 4-9: Direct Sum in a Math Equation

$Z_6 = \{0, 2, 4\} \oplus \{0, 3\}$



Observe: The six-cell operation symbol of the Nemeth Code is used for the "circle with interior plus" in this math equation.

b. **Circle with Inscribed Horizontal Bar.** A circle with an inscribed horizontal bar may be encountered as a superscript in electrochemical notation and in the study of thermodynamics. It is similar in appearance to the encircled minus sign but is an entirely different symbol. See Section 5.1.2.a, Circle with Inscribed Horizontal Bar.

c. **Greek Letter Theta.** θ Use the Nemeth Code symbol for Greek letters.

d. **Electron Pairs.** See Section 2.5.1.c, Electron Pairs Printed as Straight Lines.

4.4 Straight Lines

4.4.1 **Partition Lines in Voltaic Cell Notation.** A partition line is a single or double vertical line used in voltaic cell notation to separate phase boundaries, junctions, and bridges. The nature of the lines will be clear from context, so they will not be mistaken for signs of grouping or for bonds. *Note:* This topic may also be called electrochemical, electrolytic, or galvanic cell notation.

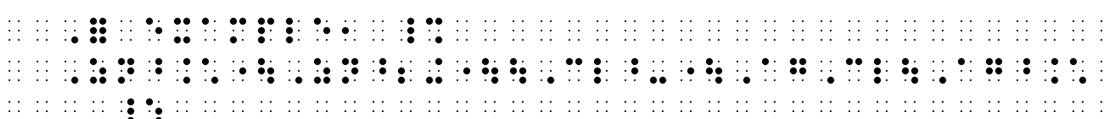
⠳	Single partition line	$\vert$
⠳⠳	Double partition line	$\Vert$

No space is left before or after a partition line. If the expression requires a runover, the first division should be made after a double partition line ("junction"). If further division is needed, divide after a single partition line.

Example 4-10: Single and Double Partition Lines

For example,

$$Zn^{\circ}\,|\,Zn^{2+}\,\|\,Cl^{-}\,|\,AgCl\,|\,Ag^{\circ}$$

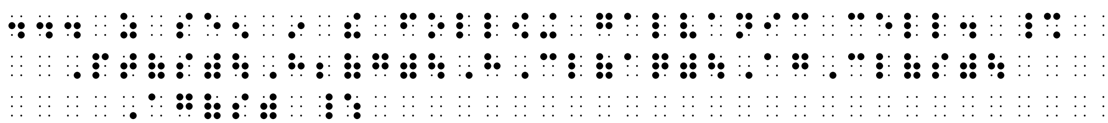


Observe: The partition lines are unspaced from related symbols.

Example 4-11: Galvanic Cell Diagram Requiring a Runover

… as seen in the following galvanic cell.

$$\mathrm{Pt}(s)\,|\,\mathrm{H_2}(g)\,|\,\mathrm{HCl}(aq)\,|\,\mathrm{AgCl}(s)\,|\,\mathrm{Ag}(s)$$

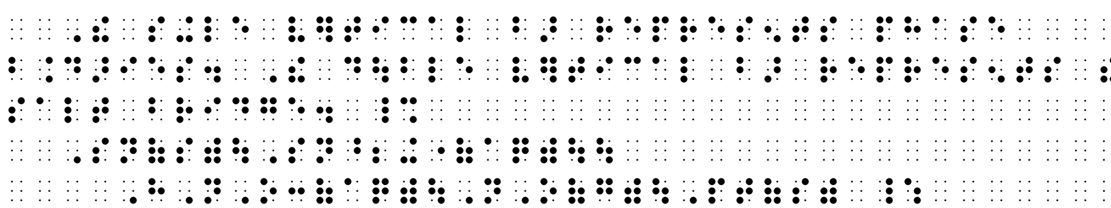


Observe: Division is made after a partition line.

Example 4-12: Voltaic Cell Diagram Requiring a Runover

The single vertical bar represents phase boundaries. The double vertical bar represents the salt bridge.

$$\mathrm{Sn}_{(s)}\,|\,\mathrm{Sn}^{2+}_{(aq)}\,||\,\mathrm{HNO}_{3(aq)}\,|\,\mathrm{NO}_{(g)}\,|\,\mathrm{Pt}_{(s)}$$



Observe: Division is made after the double partition line. See Section 6.1.2, Letters Representing Physical States, regarding physical states printed as subscripts.

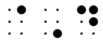
4.4.2 **Similar Signs.** Straight lines may be encountered in other types of chemical notation.

a. **Factor Label or Fraction Computation.** In factor label computation, several fractions are separated with a vertical line. See Section 9.6, Factor Label or Fraction Computation.

b. **Nonbonding Electron Pairs.** See Section 2.5.1, Electron Dot Symbols—Singles and Pairs, for vertical and horizontal lines used to represent nonbonding electron pairs.

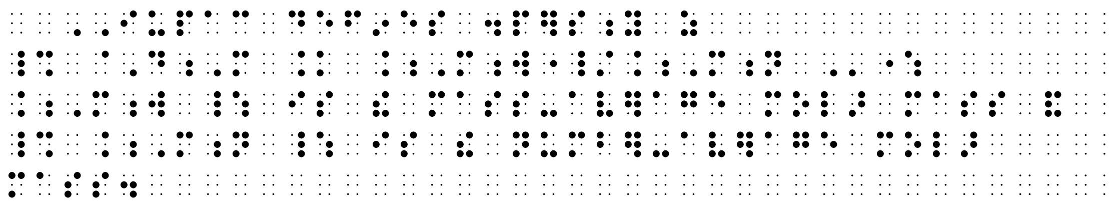
4.5 Crossed Capital Letter D

Dispersity is represented by the crossed D symbol. A switch to Nemeth Code is required.

 Crossed capital letter D Đ

Example 4-13: Crossed Letter D

IUPAC defines dispersity as $Đ_{\mathrm{M}} = M_{\mathrm{w}}/M_{\mathrm{n}}$ where M_{w} is the mass-average molar mass and M_{n} is the number-average molar mass.



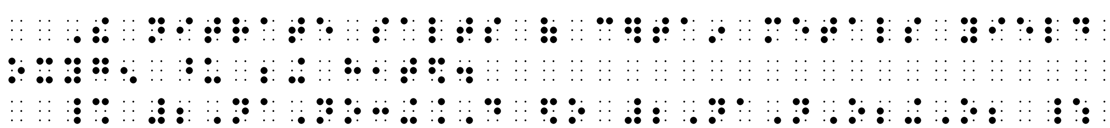
4.6 Symbol for Heat

A triangle shape meaning "heat" is transcribed as a Greek capital delta, even if it is referred to as a triangle in the text.

Example 4-14: Greek Capital Delta in a Chemical Equation

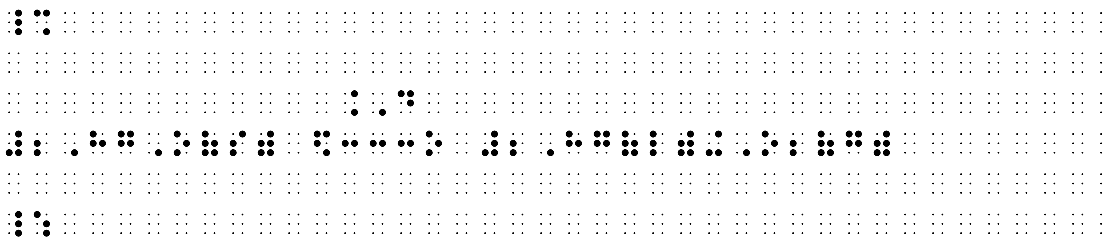
The nitrate salts of certain metals yield oxygen upon being heated.

$$2NaNO_3 + \Delta \rightarrow 2NaNO_2 + O_2$$



Example 4-15: Greek Capital Delta Labeling a Yields Arrow

$$2\mathrm{HgO}(s) \xrightarrow{\Delta} 2\mathrm{Hg}(l) + \mathrm{O}_2(g)$$



Section 5
Superscripts and Subscripts

BRIEF CONTENTS

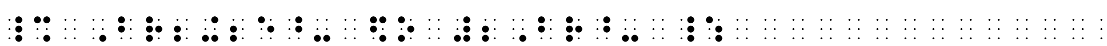
The transcription of superscripts and subscripts in chemical notation follows the rules of the Nemeth Code except in the situations presented in this section.

5.1 Superscripts in Chemical Notation

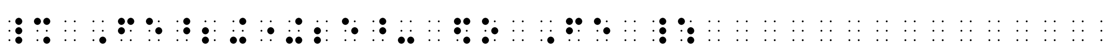
5.1.1 **Electron Charge.** An electron charge may be printed as a plus or minus sign in the superscript position. A numeral or a variable may be associated with the charge.

Example 5-1: Positive and Negative Electron Charges

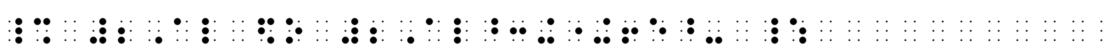
$Br_2 + 2e^- \rightarrow 2Br^-$

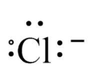


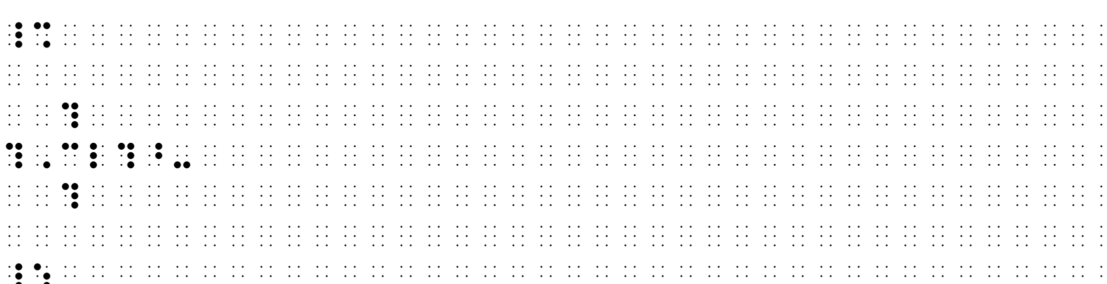
$Fe^{2+} + 2e^- \rightarrow Fe$



$2Al \rightarrow 2Al^{3+} + 6e^-$



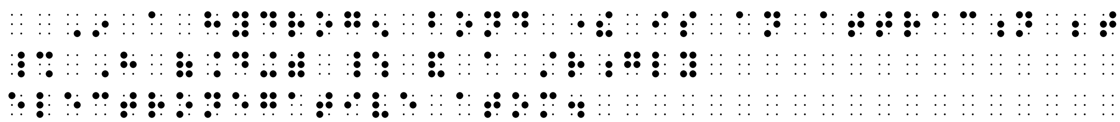




a. **Partial Charge.** The lowercase Greek delta associated with a plus or minus sign indicates a partial charge. If the print copy places a single plus or a single minus sign in the superscript position, this placement is disregarded in the braille transcription. There is no need to explain the change in a transcriber's note.

Example 5-2: Partial Charge in the Superscript Position

In a hydrogen bond there is an attraction between H (δ^+) and a strongly electronegative atom.

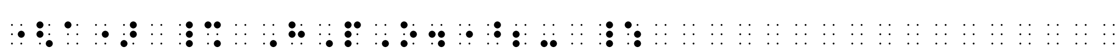


Observe: The plus charge is printed in the superscript position.

b. **Multiple Charges.** Depicting electron charges with multiple positive charges (plus signs) or multiple negative charges (minus signs) rather than with a numeral may be found in older publications. If encountered, the appropriate numeral is transcribed, followed by the charge symbol. A transcriber's note explaining the change from print is not necessary.

Examples 5-3 (a-d): Electron Charge Printed as Multiple Signs

(a) HPO_4^{--}



Observe: In print, the superscript consists of two side-by-side minus signs. See *Section 5.3* *for a discussion of nonsimultaneous superscripts/subscripts.*

(b) ${}^{4}_{2}He^{++}$

⠐⠣⠰⠃⠐⠜⠀⠸⠩⠀⠰⠆⠘⠲⠐⠠⠓⠑⠘⠆⠬⠀⠸⠱

Observe: In print, the right superscript consists of two side-by-side plus signs. See Section 5.3.3 for a discussion of left superscripts/subscripts.

(c) $(SO_4)^{=}$

⠐⠣⠰⠉⠐⠜⠀⠸⠩⠀⠷⠠⠎⠠⠕⠲⠾⠘⠆⠤⠀⠸⠱

Observe: In print, the superscript consists of two minus signs, one above the other.

(d) PO_4^{---} *or* $PO_4^{\equiv}$

⠐⠣⠰⠙⠐⠜⠀⠸⠩⠀⠠⠏⠠⠕⠲⠐⠘⠒⠤⠀⠸⠱

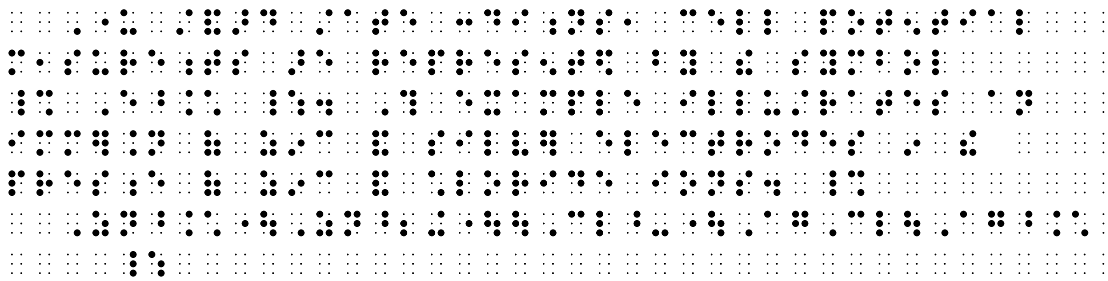
Observe: The print copy shows two different notation styles for this electron charge: as three side-by-side minus signs and as three stacked minus signs. See Section 5.3 for a discussion of nonsimultaneous superscripts/subscripts.

5.1.2 **Circle or Hollow Dot.** In the study of electrochemistry and thermodynamics, a hollow dot in the superscript position represents standard state conditions.

Example 5-4: Raised Circle Representing Standard State

Under standard state conditions, cell potential measurements are represented by the symbol E^{o}. This example illustrates an immersion of zinc and silver electrodes in the presence of zinc and chloride ions.

$$Zn^{\circ}\,|\,Zn^{2+}\,||\,Cl^{-}\,|\,AgCl\,|\,Ag^{\circ}$$



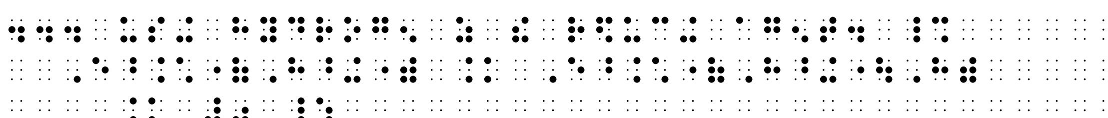
Note: See Section 4.4.1, Partition Lines in Voltaic Cell Notation, for a discussion of the vertical lines.

a. **Circle with Inscribed Horizontal Bar.** ϴ The raised circle representing standard state conditions may be printed as a circle with an inscribed horizontal bar. The bar is disregarded in the braille transcription. A raised hollow dot is transcribed. Do not mistake this sign for the Greek letter theta or for the "encircled minus sign". See Section 4.3, Detached Plus or Detached Minus.

Example 5-5: Raised Circle with Inscribed Horizontal Bar

… using hydrogen as the reducing agent.

$$E^{\ominus}\,(H^{+}) = E^{\ominus}\,(H^{+}|H) = 0$$



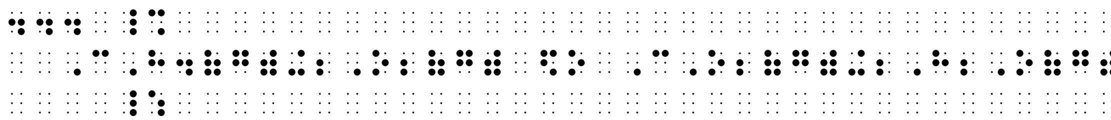
Note: See Section 4.4.1, Partition Lines in Voltaic Cell Notation, for a discussion of the vertical line between the hydrogens.

5.2 Subscripts in Chemical Notation

5.2.1 **Physical State Printed in Subscript Position.** If print shows the physical state in the subscript position, such placement is disregarded in braille. See also Section 5.3.2.

Example 5-6: States of Matter Printed in the Subscript Position

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$



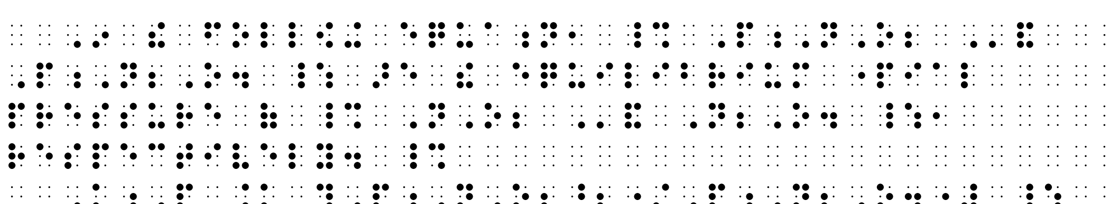
Observe: The subscript position of the physical state (g) is disregarded and is transcribed on the baseline of writing.

5.2.2 **Molecule in the Subscript Position.** When a molecule composed of a SYMBOL with an accompanying subscript is itself printed in the subscript position, the subsubscript indicator is not used.

Example 5-7: Molecule in the Subscript Position

In the following equation, P_{NO_2} and $P_{N_2O_4}$ are the equilibrium partial pressure of NO_2 and N_2O_4, respectively.

$$K_P = \frac{P^2_{NO_2}}{P_{N_2O_4}}$$



Observe: Italics are disregarded for the letters K and P. See Section 6.1, Italics: When to Disregard.

5.3 Simultaneous and Nonsimultaneous Superscripts and Subscripts

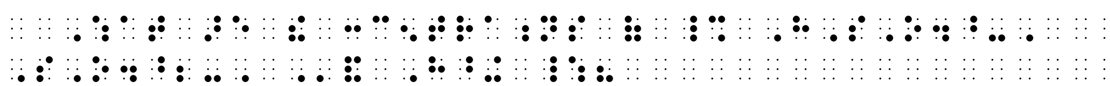
Vertical positioning of superscripts and subscripts has special significance in chemistry. Care must be taken to represent print accurately.

When superscripts and subscripts are printed directly above/below one another, they are transcribed according to Nemeth Code rules for simultaneous superscripts and subscripts except as noted in Sections 5.3.1 and 5.3.2. Nonsimultaneous superscripts and subscripts are transcribed in left-to-right order according to the rules of the Nemeth Code.

For an electron dot printed in the superscript position, see Section 2.5.1.a regarding the raised electron dot.

Example 5-8: Simultaneous Superscripts and Subscripts

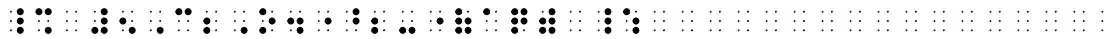
What are the concentrations of HSO_4^-, SO_4^{2-}, and H^+?



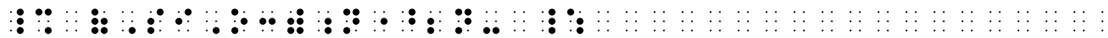
Observe: The subscript (4) is transcribed before each related superscript. The fact that there is no multipurpose indicator informs the reader that they are simultaneous.

Example 5-9: Nonsimultaneous Superscripts

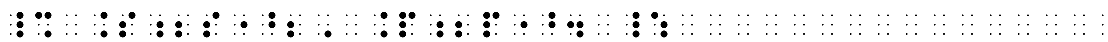
$5C_2O_4{}^{2-}(aq)$



$(SiO_3)_n{}^{2n-}$



$\sigma_{2s}{}^2$, $\pi_{2p}{}^4$

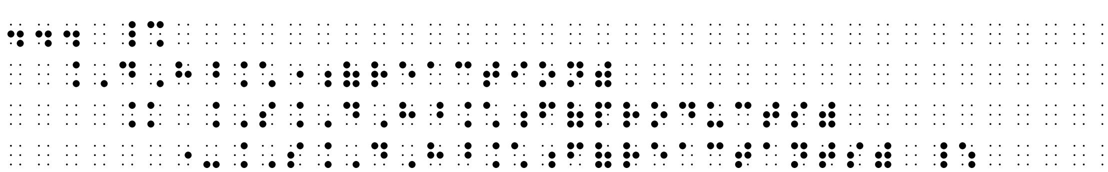


Observe: The subscript is transcribed before the superscript in left-to-right order as printed. The multipurpose indicator informs the reader that they are nonsimultaneous.

5.3.1 **Hollow Dot and Star or Asterisk in Superscript Position.** When the superscript is a hollow dot or a star (or asterisk), the symbol is an integral part of the letter to which it is superscripted and so is transcribed first. The examples below illustrate the raised hollow dot representing standard conditions in "Delta H naught", and the raised star in orbital notation representing "sigma star" and "pi star". The star may be printed as an asterisk or as a star shape. In either case, the asterisk symbol of the Nemeth Code is transcribed.

Example 5-10: Superscript Hollow Dot in Simultaneous Layout

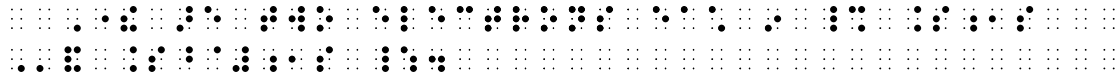
$$\Delta H^{\circ}_{(reaction)} = \Sigma\Delta H^{\circ}_{f(products)} - \Sigma\Delta H^{\circ}_{f(reactants)}$$



Observe: On the right side of the equation, each superscript hollow dot is transcribed first even though it is printed directly above a subscript. The hollow dot is an integral part of the symbol ΔH.

Example 5-11: Superscript Star in Simultaneous Layout

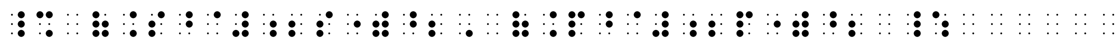
There are two electrons each in σ_{1s} and $\sigma_{1s}^{\star}$.



Observe: The superscript black star shape is transcribed as an asterisk and is transcribed first, even though it is printed directly above the subscript. The star is an integral part of the letter σ (sigma).

Example 5-12: Superscript Asterisk in Simultaneous Layout

$(\sigma_{2s}^{*})^{2}, \left(\pi_{2p}^{*}\right)^{2}$

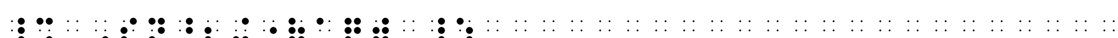


Observe: Each superscript star (asterisk) is transcribed first even though it is printed directly above a subscript. The star is an integral part of the letters σ (sigma) and π (pi).

5.3.2 **Physical State Printed as a Simultaneous Subscript.** As stated in Section 5.2.1, a physical state is transcribed on the baseline of writing even if it is printed as a subscript. A physical state printed as a simultaneous subscript is transcribed at the baseline level following the superscript.

Example 5-13: State of Matter Printed as a Subscript

$\mathrm{Sn}_{(aq)}^{2+}$

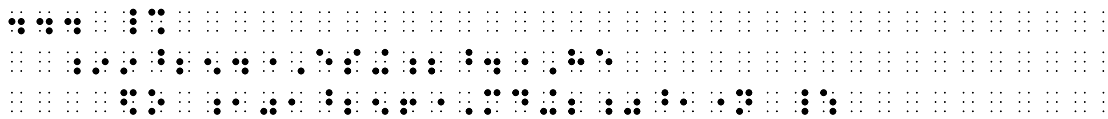


Observe: The subscript position of the physical state (aq) is disregarded and is transcribed on the baseline of writing following the superscript.

5.3.3 **Mass Number and Atomic Number.** When mass number and atomic number are printed as a simultaneous left superscript and subscript, follow the rules of the Nemeth Code and transcribe the subscript first.

Example 5-14: Left Superscripts and Subscripts

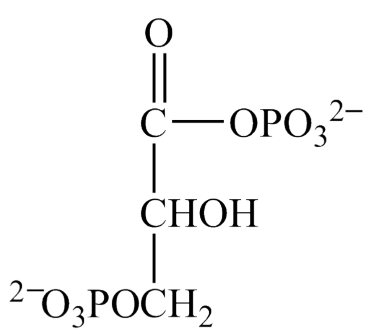
$${}^{254}_{99}\mathrm{Es} + {}^{4}_{2}\mathrm{He} \rightarrow {}^{256}_{101}\mathrm{Md} + 2{}^{1}_{0}n$$

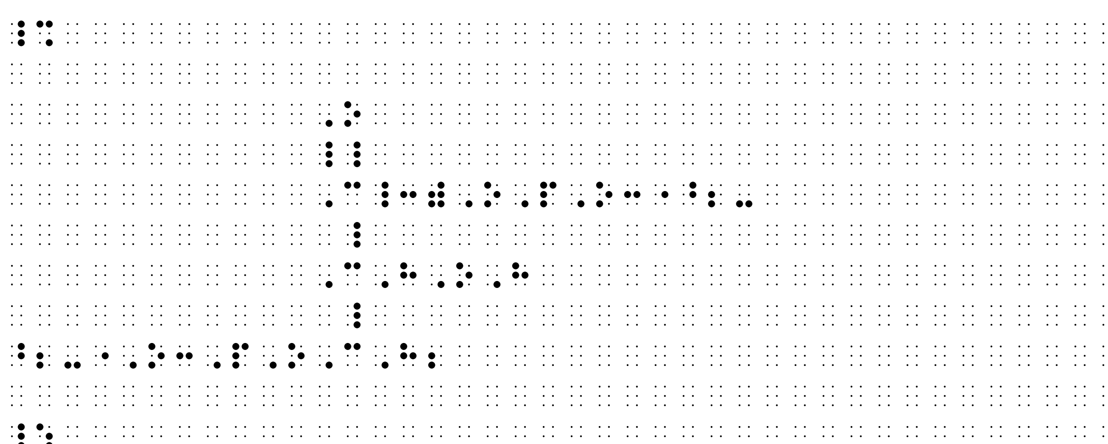


5.4 Superscripts and Subscripts in Spatial Structures

In spatial structures, the rules of the Nemeth Code are followed for the transcription of superscripts and subscripts. If an electron charge is printed directly above an element SYMBOL, see Section 4.3, Detached Plus or Detached Minus.

Example 5-15: Electron Charges in a Spatial Arrangement



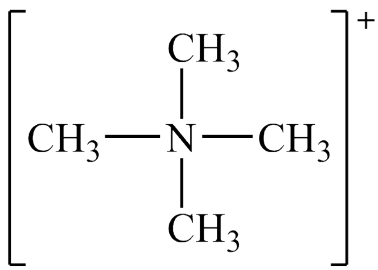


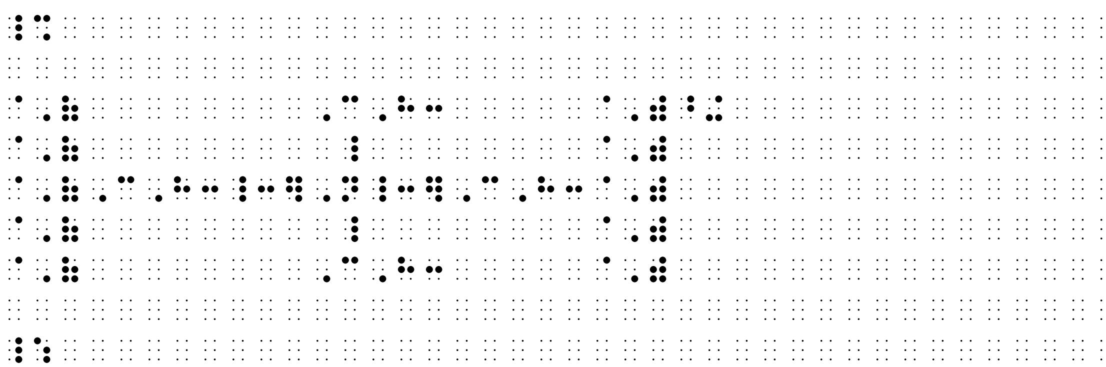
5.4.1 **Superscripts and Subscripts Next to an Enlarged Grouping Symbol.**

A superscript or subscript which applies to an entire spatial structure is transcribed outside and next to the topmost line of the enlarged grouping symbol.

For an electron dot printed in the superscript position following a closing bracket, see Section 2.5.1.a and Example 2-22.

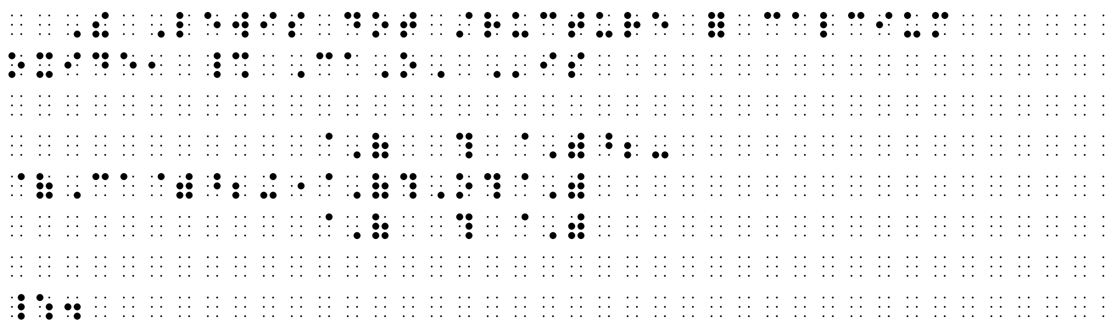
Example 5-16: Superscript Applies to Entire Structure





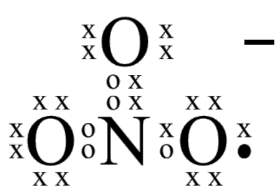
Example 5-17: Superscript Next to a Right Bracket

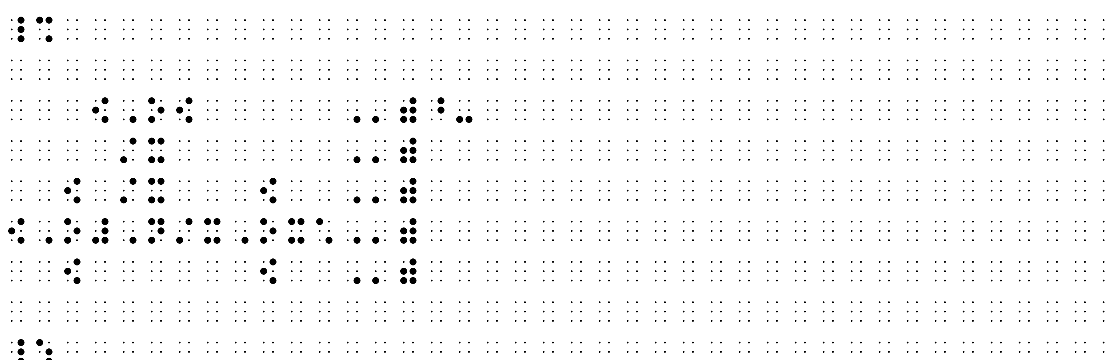
The Lewis dot structure for calcium oxide, CaO, is $[\mathrm{Ca}]^{2+}\ [:\ddot{\underset{\cdot\cdot}{\mathrm{O}}}:]^{2-}$.



5.4.2 **Transcriber-Inserted Grouping Symbols.** When a superscript or a subscript applies to a spatially arranged structure and no grouping sign is printed, the transcriber-inserted grouping symbol of the Nemeth Code is used. The superscript or subscript is transcribed on the top line of the diagram, unspaced from the grouping symbol.

Example 5-18: Superscript Applies to Entire Lewis Structure

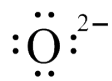


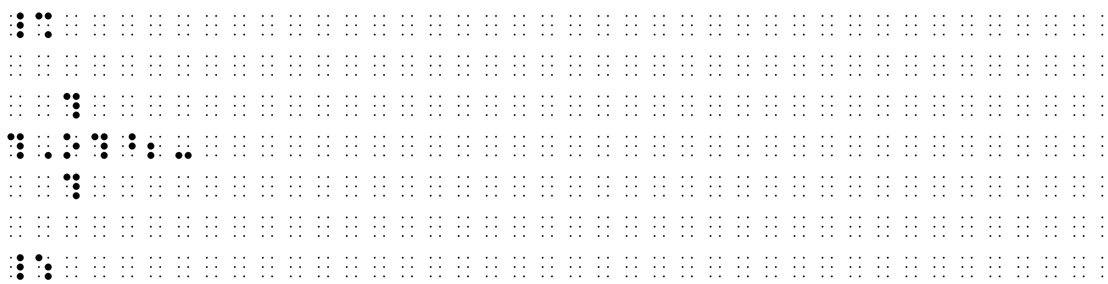


Observe: The electron charge (minus symbol) is printed to the right of the entire structure. Grouping symbols are added by the transcriber and the charge is transcribed as a superscript outside of the right grouping symbol..

a. **Clarification: Charge Applied to a Lewis Diagram.** When the charge applies to only one atom and a grouping symbol does not appear in print, grouping symbols are not added by the transcriber. The charge is transcribed as a superscript next to the rightmost Lewis dot symbol.

Example 5-19: Superscript Applies to a Dot Pair





Section 6
Typeform of English Letters in Chemical Expressions

BRIEF CONTENTS

For typeform in chemical nomenclature, see Section 7, Chemical and Scientific Nomenclature.

To enhance readability, examples in this section may be enlarged.

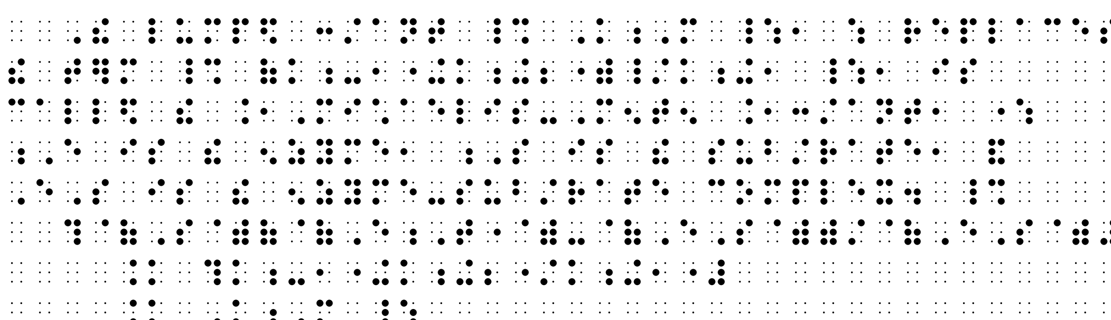
6.1 Italics: When to Disregard

6.1.1 **Constants and Variables.** Constants and variables are printed in italics throughout a publication. Such use of italics is disregarded in the braille transcription. If distinction must be made between identical letters, see Section 6.2.1.

Example 6-1: Constants and Variables Printed in Italics

The lumped constant K_M, which replaces the term $(k_{-1} + k_{+2})/k_{+1}$, is called the *Michaelis-Menten constant,* where E is the enzyme, S is the substrate, and ES is the enzyme-substrate complex.

$$\frac{[\mathrm{S}]([\mathrm{E}_T]-[\mathrm{ES}])}{[\mathrm{ES}]} = \frac{k_{-1}+k_{+2}}{k_{+1}} = K_M$$

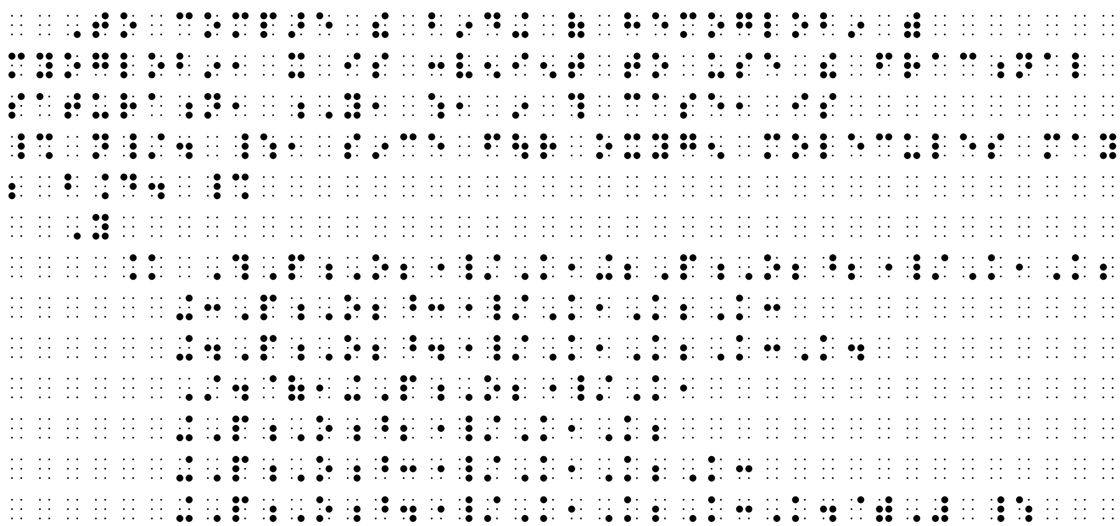


Observe: Italics are disregarded for letters K, M, k, and T. In the narrative, "ES" is individually capitalized according *to the UEB recommendation of rendering consistency within a transcription.*

Example 6-2: Constants and Variables Printed in Italics

To compare the binding of hemoglobin with myoglobin, it is convenient to use the fractional saturation, *Y*, which, in this case, is *n*/4, since four oxygen molecules may be bound.

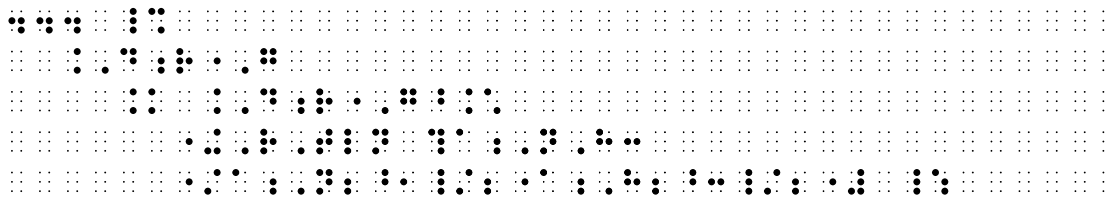
$$Y = \frac{P_{O_2}/K_1 + 2P_{O_2}^2/K_1K_2 + 3P_{O_2}^3/K_1K_2K_3 + 4P_{O_2}^4/K_1K_2K_3K_4}{4\left[1 + P_{O_2}/K_1 + P_{O_2}^2/K_1K_2 + P_{O_2}^3/K_1K_2K_3 + P_{O_2}^4/K_1K_2K_3K_4\right]}$$



Observe: Italics are disregarded for letters Y, n, P, and K. See Section 5.2.2, Molecule in the Subscript Position, for the absence of the subsubscript indicators with O_2 in the subscript position.

Example 6-3: Constants and Variables Printed in Italics

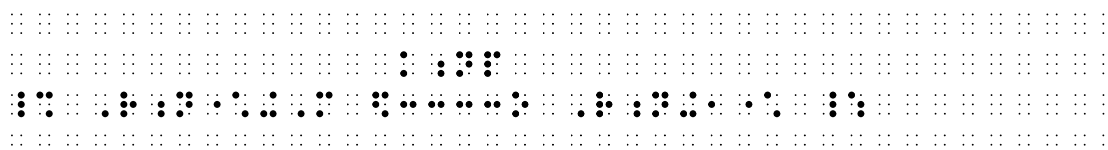
$$\Delta_{\mathrm{r}}G = \Delta_{\mathrm{r}}G^{\circ} + RT\,\ln\frac{a_{\mathrm{NH_3}}}{a_{\mathrm{N_2}}^{1/2}\,a_{\mathrm{H_2}}^{3/2}}$$



Observe: Italics are disregarded for letters G, R, T, and a. See Section 5.2.2, Molecule in the Subscript Position, for the absence of the subsubscript indicators.

Example 6-4: Constants and Variables Printed in Italics

$$\mathrm{R}_{n}\bullet + \mathrm{M} \xrightarrow{k_{np}} \mathrm{R}_{n+1}\bullet$$



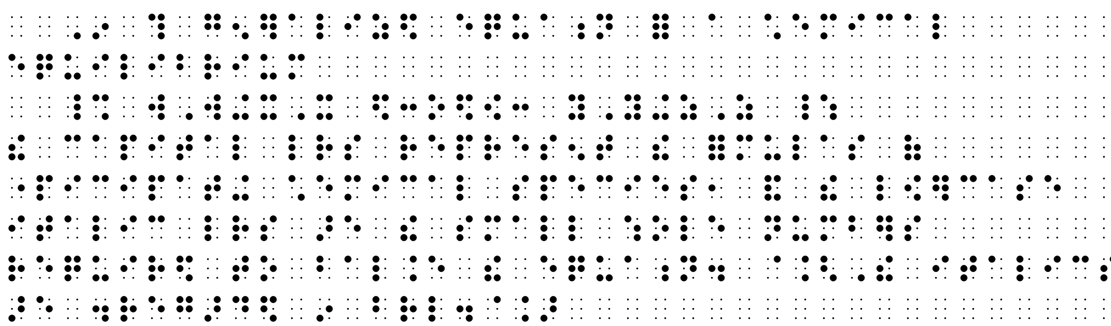
Observe: Italics are disregarded for letters n, k, and p.

Example 6-5: Variables Printed in Italics

In this generalized equation for a chemical equilibrium

$$w\mathrm{W} + x\mathrm{X} \rightleftarrows y\mathrm{Y} + z\mathrm{Z}$$

the capital letters represent the formulas of participating chemical species, and the lowercase italic letters are the small whole numbers required to balance the equation.



Observe: Because the narrative mentions italicized variables, an embedded transcriber's note tells the reader that the italics are disregarded in braille.

6.1.2 **Physical States.** Letters representing the physical state of chemical compounds are not considered to be abbreviations in the Chemistry Code. The physical state is usually enclosed between parentheses and is often printed in italics. The italic typeform is disregarded in the braille transcription. When enclosed in parentheses, the physical state is unspaced from the compound even if a space appears in print.

The letter "ell" may be printed in script type to distinguish it from the capital letter I or the numeral 1. The script typeform is ignored in braille as it has no chemical meaning.

(*s*) solid

(*l*) or (ℓ) liquid

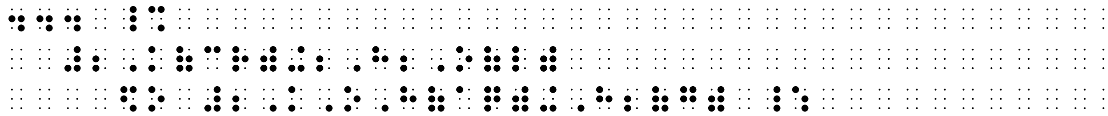
(*g*) gas

(*aq*) aqueous

(*c*) or (*cr*) crystalline

Example 6-6: Letter "ell" Printed in Script Type

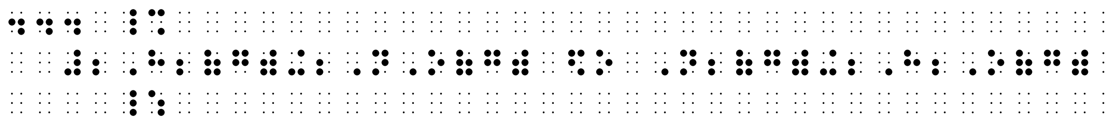
$$2\mathrm{K}(cr) + 2\mathrm{H}_2\mathrm{O}(\ell) \rightarrow 2\mathrm{KOH}(aq) + \mathrm{H}_2(g)$$



Observe: Script typeface is disregarded for the letter l. Italics are disregarded for the physical states cr, l, aq, and g.

Example 6-7: Physical State is Spaced in Print

$$2\mathrm{H}_2\ (g) + 2\mathrm{NO}\ (g) \rightarrow \mathrm{N}_2\ (g) + 2\mathrm{H}_2\mathrm{O}\ (g)$$



Observe: Spacing does not match print. Italics are disregarded for the physical state (g).

If print does not show the physical state in parentheses, the letter is spaced from the compound and the English-letter indicator is used according to the rules of the Nemeth Code.

Example 6-8: Physical State is Not Printed in Parentheses

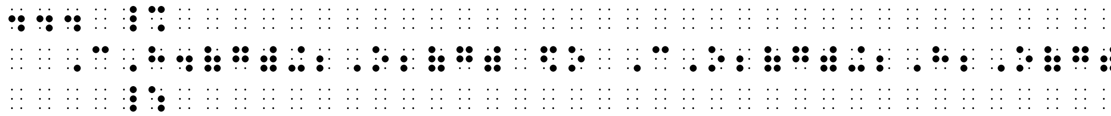
$$\mathrm{H}_2\mathrm{O\ l} \rightarrow \mathrm{H}_2\mathrm{O\ s}$$

Observe: The letters are printed in regular type.

If the physical state is printed in the subscript position, such placement is disregarded in braille. A physical state printed as a simultaneous subscript is transcribed at the baseline level *following* the superscript.

Example 6-9: Physical State Printed in the Subscript Position

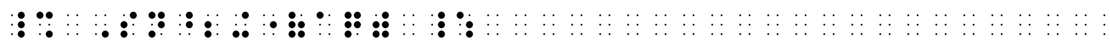
$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$



Observe: The subscript position of the physical state (g) is disregarded and is transcribed on the baseline of writing. The italic typeform is disregarded.

Example 6-10: (*aq*) Printed as a Simultaneous Subscript

$$Sn^{2+}_{(aq)}$$

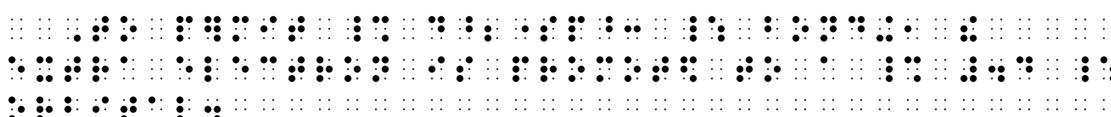


Observe: The subscript position of the physical state (aq) is disregarded and is transcribed on the baseline of writing following the superscript. The italic typeform is disregarded.

6.1.3 **Letters in Electron Configurations.** Lowercase letters s, p, d, and f representing subshells are often printed in italics. The typeform is disregarded in braille. Follow print spacing.

Example 6-11: Electron Configuration Notation

To permit d^2sp^3 bonding, the extra electron is promoted to a $4d$ orbital.



Observe: Typeform is disregarded for letters d, s, and p. Switching to Nemeth Code is required for the number-letter combination "4d".

Example 6-12: Electron Configuration Notation

Magnesium (Mg): $1s^2 2s^2 2p^6 3s^2$

⠀⠀⠠⠍⠁⠛⠝⠑⠎⠊⠥⠍⠀⠸⠩⠀⠷⠠⠍⠛⠾⠸⠒
⠼⠂⠎⠘⠆⠐⠆⠎⠘⠆⠐⠆⠏⠘⠖⠐⠒⠎⠘⠆⠀⠸⠱

Observe: Typeform is disregarded for letters s and p.

6.2 Italics: When to Retain

When an English letter is printed in italics and it is not a letter discussed in Section 6.1, the transcriber can assume that the letter has chemical significance. Typeform is retained. Within UEB narrative context, switching to Nemeth Code is not necessary unless another character in the symbols-sequence requires Nemeth Code.

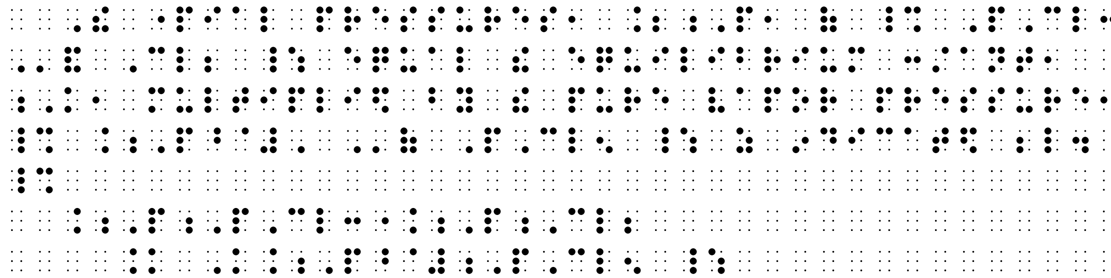
See Section 7, Chemical and Scientific Nomenclature, for examples of italicized letters in chemical abbreviations and chemical names.

6.2.1 **Distinction Between Identical Letters.** If the same letter appears in the same alphabet and in the same case but is of a different typeform, the distinction has meaning and so is preserved. This also applies to the letter when it appears in a discussion of the expression.

Example 6-13: Capital Letter P Printed in Two Typeforms

The partial pressures, *P*, of PCl_3 and Cl_2 equal the equilibrium constant, *K*, multiplied by the pure vapor pressure, *P**, of PCl_5 as indicated below.

$$P_{\mathrm{PCl_3}}P_{\mathrm{Cl_2}} = KP^{*}_{\mathrm{PCl_5}}$$



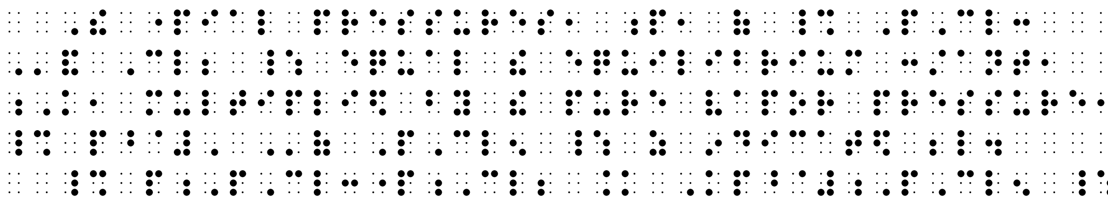
Observe: Since uppercase letter P is shown with two different typeforms (italics and regular), the difference is preserved. See Section 5.2.2, Molecule in the Subscript Position, for the absence of the subsubscript indicators.
Notes: Constants K and P are printed in italics. The asterisk is not a reference mark—it is an integral part of the chemical symbol for pure vapor pressure.

Compare Example 6–13 with the next example, where the pressure symbol is printed in lowercase. Because the italicized letter p is a different case from the regular letter P, the italic typeform is disregarded.

Example 6-14: Letter Printed in Two Typeforms, Two Cases

The partial pressures, *p*, of PCl_3 and Cl_2 equal the equilibrium constant, *K*, multiplied by the pure vapor pressure, *p**, of PCl_5 as indicated below.

$$p_{\mathrm{PCl}_3}\, p_{\mathrm{Cl}_2} = Kp^{*}_{\mathrm{PCl}_5}$$



Observe: Italic typeface for variable p is disregarded. The letter is differentiated by case. See Section 5.2.2, Molecule in the Subscript Position, for the absence of the subsubscript indicators.
Notes: Constants K and p are printed in italics. The asterisk is not a reference mark—it is an integral part of the chemical symbol for pure vapor pressure.

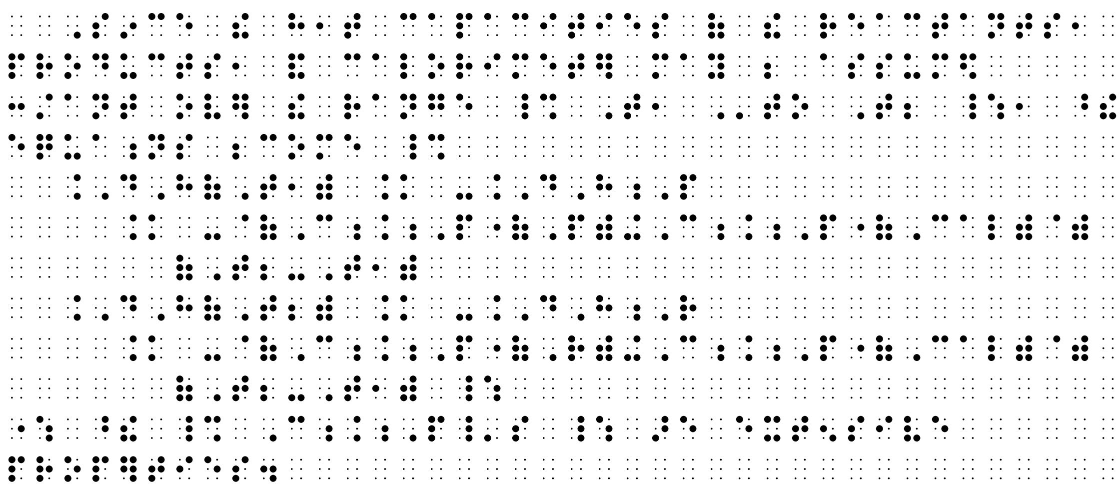
a. **Abbreviation Exception.** If a letter in regular type is an abbreviation or part of an abbreviation, and the same letter is printed in italics elsewhere in the expression, typeform may be disregarded.

Example 6-15: Capital Letters Printed in Two Typeforms

Since the heat capacities of the reactants, products, and calorimeter may be assumed constant over the range T_1 to T_2, these equations become

$$\Delta H(T_1) = -\Delta H_{\mathrm{P}} = -\left[C_P(\mathrm{P}) + C_P(\mathrm{Cal})\right]\left(T_2 - T_1\right)$$
$$\Delta H(T_2) = -\Delta H_{\mathrm{R}} = -\left[C_P(\mathrm{R}) + C_P(\mathrm{Cal})\right]\left(T_2 - T_1\right)$$

where these C_P's are extensive properties.



Observe: Although uppercase C is shown with two different typeforms, no distinction need be made because one is part of the abbreviation "Cal". Italic typeform is preserved for uppercase P (subscript to C) because it is shown with two different typeforms.

6.2.2 Letters Representing Concentration of a Solution.

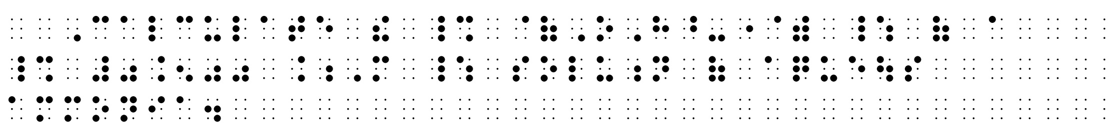
A letter representing concentration of a solution has chemical meaning. It is often associated with a value, but it is not considered to be an abbreviation.

Typeform is significant and is retained. If the letter is printed in normal type, follow the rules of the Nemeth Code regarding use of the English-letter indicator with "single letters" when it appears in Nemeth context. Space the letter from its associated value, regardless of print spacing.

M	Molarity	(the number of moles of a solute in 1 L of solution)
m	molality	(the number of moles of a solute in 1 kg of solvent)
N	Normality	(the equivalent mass of solute per liter of solution)
F	Formality	(the number of moles per liter of solution)

Example 6-16: Molarity *M*

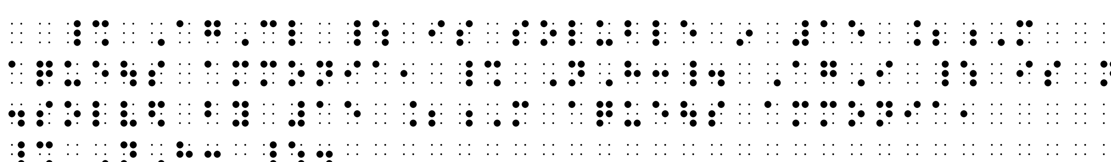
Calculate the $[OH^-]$ of a 0.500*M* solution of aqueous ammonia.



Observe: Italic typeform is preserved for the letter M meaning molarity. A switch to Nemeth Code is required for the associated decimal number. M is unspaced in print.

Example 6-17: Molarity *M*

AgCl is soluble in 15 *M* aqueous ammonia, NH_3. AgI is not dissolved by 15 *M* aqueous ammonia, NH_3.



Observe: Italic typeform is preserved for the letter M meaning molarity.

Example 6-18: Molality *m*

The molality (*m*) of a solution is the moles of solute divided by the kilograms of solvent. A solution that contains 1.0 mol of NaCl dissolved in 1.0 kg of water is a "one-molal" or 1*m* solution of sodium chloride.

⠀⠀⠠⠮ ⠍⠕⠇⠁⠇⠰⠽ ⠐⠣⠨⠆⠰⠍⠐⠜ ⠷ ⠁ ⠎⠕⠇⠥⠰⠝ ⠊⠎ ⠮
⠍⠕⠇⠑⠎ ⠷ ⠎⠕⠇⠥⠞⠑ ⠙⠊⠧⠊⠙⠫ ⠃⠽ ⠮ ⠅⠊⠇⠕⠛⠗⠁⠍⠎ ⠷
⠎⠕⠇⠧⠢⠞⠲ ⠠⠁ ⠎⠕⠇⠥⠰⠝ ⠞ ⠒⠞⠁⠔⠎ ⠸⠩ ⠼⠂⠨⠴ ⠍⠕⠇
⠠⠄ ⠷ ⠠⠝⠁⠠⠉⠇ ⠸⠱ ⠲⠎⠕⠇⠧⠫ ⠔ ⠸⠩ ⠼⠂⠨⠴ ⠅⠛ ⠸⠱ ⠷
⠺⠁⠞⠻ ⠊⠎ ⠁ ⠦⠐⠕⠤⠍⠕⠇⠁⠇⠴ ⠕⠗ ⠼⠁ ⠨⠆⠰⠍ ⠎⠕⠇⠥⠰⠝ ⠷
⠎⠕⠙⠊⠥⠍ ⠡⠇⠕⠗⠊⠙⠑⠲

Observe: Italic typeform is preserved for the letter m meaning molality. m is unspaced in print.

Example 6-19: Normality *N*

… 30.0 mL of a 4.00*N* solution.

⠲⠲⠲ ⠸⠩ ⠼⠒⠴⠨⠴ ⠍⠠⠇ ⠸⠱ ⠷ ⠁ ⠸⠩ ⠼⠲⠨⠴⠴ ⠨⠰⠠⠝ ⠸⠱
⠎⠕⠇⠥⠰⠝⠲

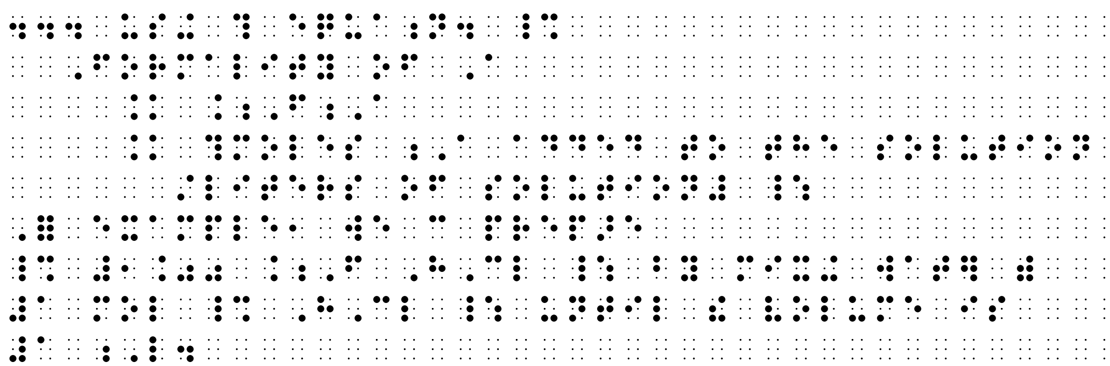
Observe: Italic typeform is preserved for the letter N meaning normality. A switch to Nemeth Code is required for the associated decimal number. N is unspaced in print.

Example 6-20: Formality *F*

… using this equation.

$$\text{Formality of A} = F_{\text{A}} = \frac{\text{moles A added to the solution}}{\text{liters of solution}}$$

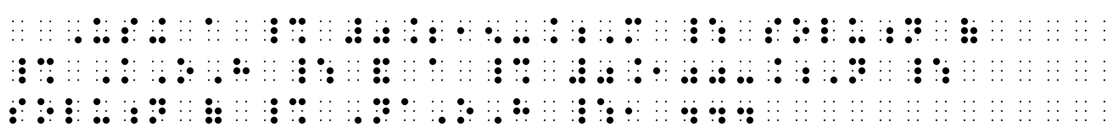
For example, we can prepare 1.00 *F* HCl by mixing water with 1 mol HCl until the volume is 1 L.



Observe: Italic typeform is preserved for the letter F meaning formality. "1 mol" is not divided between lines in braille. Chemical group A and abbreviated SI unit L are printed in regular type.

Example 6-21: Molarity *M* and Normality *N*

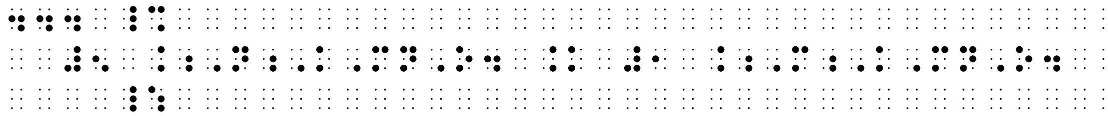
Using a 0.215-*M* solution of KOH and a 0.100-*N* solution of NaOH, …



Observe: Italic typeform is preserved for the letter M meaning molarity and the letter N meaning normality.

Example 6-22: Normality *N* and Molarity *M*

$$5\,N_{\mathrm{KMnO_4}} = 1M_{\mathrm{KMnO_4}}$$



Observe: Italic typeform is preserved for the letter N meaning normality and the letter M meaning molarity. See Section 5.2.2, Molecule in the Subscript Position, for the absence of the subsubscript indicators.

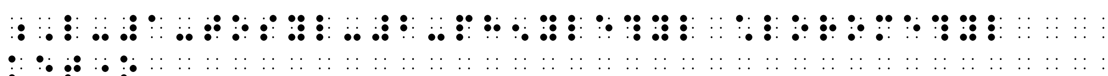
6.3 Other Typeforms

6.3.1 **Script (Cursive) Type.** The letter "ell" is often printed in cursive to distinguish it from the capital letter I or the numeral 1. The typeform used in this manner is disregarded in braille. See Section 6.1.2, Letters Representing Physical States. When cursive type has mathematical meaning, the script typeform indicator of the Nemeth Code is used.

6.3.2 **Small Capitals.** If this typeform is encountered in chemical notation for D (*dexter*) and L (*laevus*), use a regular capital letter indicator.

Example 6-23: Small Capital L in Chemical Name

L-1-tosyl-2-phenylethyl chloromethyl ketone



Observe: The chemical name is transcribed in UEB.

Example 6-24: Small Capital D in Chemical Name

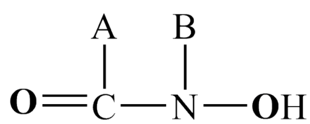
N-acetyl-D-glucosamine

Observe: The chemical name is transcribed in UEB. Italics are retained for the letter N. See Section 7, Chemical and Scientific Nomenclature, for a discussion of italicized letters in chemical names.

6.3.3 **Bold Type.** Boldface may be applied to an element SYMBOL if the typeform has significance. An English-letter indicator is required when typeform is applied to a letter.

Example 6-25: Bold Oxygen SYMBOLS in Structure

The oxygen atoms that will bind to metal ions are **bold**.



Observe: Bold typeface is retained for the element O, as described in the text.

Section 7
Chemical and Scientific Nomenclature

BRIEF CONTENTS

7.1 Names of Chemical Compounds

Names of chemical compounds may contain uppercase and lowercase English letters, non-English letters, numerals, punctuation, and other symbols. Single letters and combinations of letters used as "shorthand" names of chemical matter are common, as are abbreviations and acronyms. Typeform of English letters is significant. See Section 6.3, Other Typeforms, for exceptions regarding cursive and small capitals.

7.1.1 Code Switching Considerations

a. Names of chemical compounds containing unmodified numerals or English letters in regular or italic type may be transcribed in UEB. This includes names which contain Roman numerals in parentheses. Follow UEB rules for capitalization, spacing, and punctuation.

Example 7-1: Italicized Letter n

n-butyramide

⠨⠆⠰⠝⠤⠃⠥⠞⠽⠗⠁⠍⠊⠙⠑

Example 7-2: Italicized Prefix *trans*

trans-2-chlorobut-2-ene

⠨⠂⠞⠗⠁⠝⠎⠨⠄⠤⠼⠃⠤⠡⠇⠕⠗⠕⠃⠥⠞⠤⠼⠃⠤⠢⠑

Example 7-3: Italicized Prefix *cis* and Roman Numeral

cis-diamminedichloroplatinum(II)

Example 7-4: *trp* and *E. Coli* Printed in Italics

The *trp* operon is found in *E. coli* bacteria.

Example 7-5: Locant Printed in Italics

Opuntiol is 6-(hydroxymethyl)-4-methoxy-2*H*-pyran-2-one

Observe: Word division preferences are observed. See [Section 7.1.4](#).

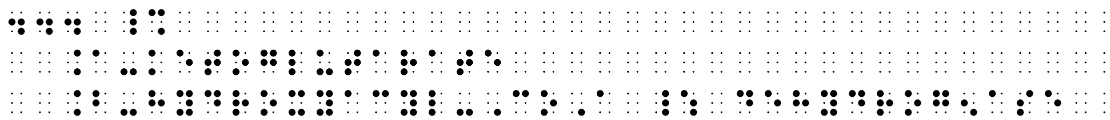
b. Switch to Nemeth Code for names of chemical compounds which contain the following: non-English letters, typeform other than italics, numbers or letters separated by punctuation with no space following the punctuation mark (see [Section 7.1.3](#)), or any other mathematical sign which requires Nemeth Code. Nemeth Code continues through the hyphenated portion of the chemical name.

Example 7-6: Locant Printed in Italics

The sequence (5')GATC(3') to N^{6}-methyladenosine is …

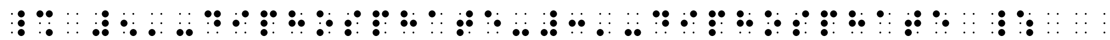
Example 7-7: Greek Letter in a Hyphenated Chemical Name

α-ketoglutarate
β-hydroxyacyl-CoA dehydrogenase



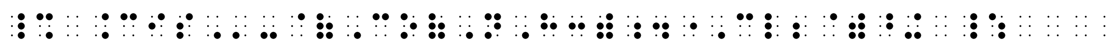
Example 7-8: Prime Sign in a Hyphenated Chemical Name

5'-diphosphate-3'-diphosphate



Example 7-9: Chemical Formula with Italicized Prefix *cis*

cis-$[Co(NH_3)_4Cl_2]^+$

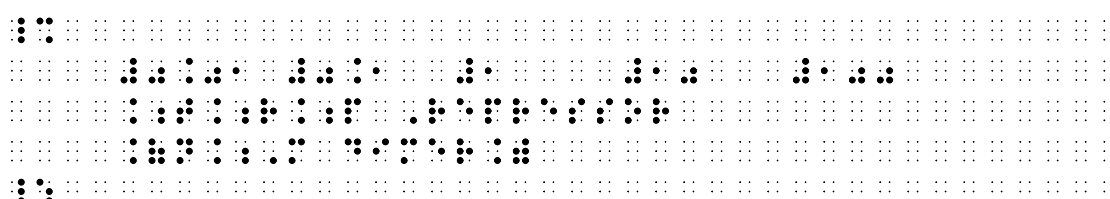


Example 7-10: Horizontal Axis Label of a Graph in Nemeth Code

[GRAPH OMITTED]

0.01   0.1   1   10   100

trp Repressor {n*M* dimer}



Observe: The chemical letters trp are individually italicized in Nemeth Code.

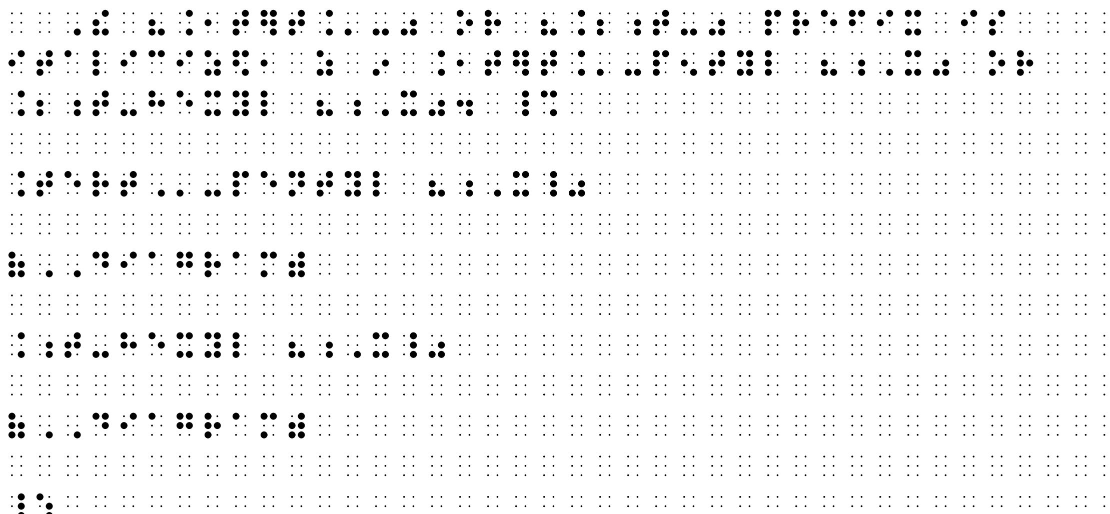
c. It is not necessary for codes to "match" when names of chemical compounds or chemical prefixes in regular or italic type appear in proximity to each other.

Example 7-11: Italicized Prefixes in UEB and in Nemeth Code

The "*tert*-" or "*t*-" prefix is italicized, as in *tert*-pentyl "X" or *t*-hexyl "X".

(DIAGRAM) (DIAGRAM)

tert-pentyl "X" *t*-hexyl "X"



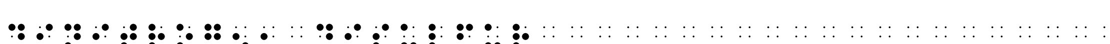
Observe: Within narrative, it is not necessary to switch to Nemeth Code for these prefixes. Assuming the diagrams require Chemistry Code, the labels are transcribed in Nemeth and are placed above each diagram. (See Section 8, Labels.)

7.1.2 **Contractions.** In UEB context, care is taken not to contract letters which overlap compound words, chemical prefixes, chemical suffixes, substituents, or functional groups.

The following examples demonstrate the use of contractions in chemical words when transcribed in UEB within narrative.

Example 7-12: Chemical Prefix "di"

dinitrogen, disulfur



Observe: To maintain the identity of "di" do not contract "in" or "dis".

Example 7-13: Chemical Prefix "tri"

trinitrotoluene

⠞⠗⠊⠝⠊⠞⠗⠕⠞⠕⠇⠥⠢⠑

Observe: To maintain the identity of "tri" do not contract "in".

Example 7-14: Chemical Prefix "hydro"

hydrofluoric

⠓⠽⠙⠗⠕⠋⠇⠥⠕⠗⠊⠉

Observe: To maintain the identity of "hydro" do not contract "of".

Example 7-15: Chemical Suffix "diol"

trichloroethanediol

⠞⠗⠊⠡⠇⠕⠗⠕⠑⠹⠁⠝⠑⠙⠊⠕⠇

Observe: To maintain the identity of "diol" do not contract "ed".

Example 7-16: Chemical Suffix "ate"

oleate

⠕⠇⠑⠁⠞⠑

Observe: To maintain the identity of "ate" do not contract "ea".

Example 7-17: Chemical Suffix "ene"

ethene

⠑⠹⠢⠑

Observe: To maintain the identity of "ene" do not contract "the".

Example 7-18: Chemical Suffix "ene" and Prefix "di"

ethylenediamine

⠑⠹⠽⠇⠢⠑⠙⠊⠁⠍⠔⠑

Observe: To maintain the identity of the suffix "ene" and of the prefix "di" in the compound word, do not contract "ed".

Example 7-19: Chemical Suffix "ase"

The body produces protease in the pancreas.

⠀⠀⠠⠮⠀⠃⠕⠙⠽⠀⠏⠗⠕⠙⠥⠉⠑⠎⠀⠏⠗⠕⠞⠑⠁⠎⠑⠀⠔⠀⠮⠀⠏⠁⠝⠉⠗⠂⠎⠲

Observe: To maintain the identity of "ase" do not contract "ea".

Example 7-20: Functional Group "chloro"

chlorofluorocarbon

⠡⠇⠕⠗⠕⠋⠇⠥⠕⠗⠕⠉⠜⠃⠕⠝

Observe: To maintain the identity of "chloro" do not contract "of".

7.1.3 **Unspaced Punctuation.** Names of chemical compounds may contain numbers, letters, or SYMBOLS separated by a comma, period, colon, or semicolon with no space following the punctuation. Such constructions must be transcribed in Nemeth Code. Follow print spacing, using a numeric indicator or a letter indicator before each number, letter, or SYMBOL. A baseline indicator is required before the punctuation if it is preceded by a superscript or a subscript.

Exception: A decimal point is used for the period, even if it is referred to as a period in print. A numeric indicator is not needed for a numeral following a decimal point.

Example 7-21: Unspaced Comma Between Numbers

2,4-dinitrobenzoic acid

Example 7-22: Unspaced Comma Between Letters

Dibenz[a,j]anthracene is an organic compound with the chemical formula $C_{22}H_{14}$.

Observe: The entire name is unspaced, including after the comma between letters. Italic typeform is retained for letters a and j.

Example 7-23: Unspaced Comma Following a Superscript

N^5,N^{10}-methylene-FH_4

Observe: There is no space following the comma. Italic typeform is retained for the letter N.

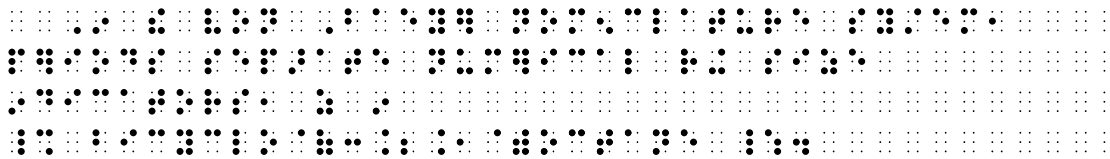
Example 7-24: Unspaced Comma Following a SYMBOL

MOX fuel may consist of a single phase solid solution (U,Pu)O_2.

Observe: An English-letter indicator precedes the element SYMBOL Pu because there is no space between it and the preceding comma.

Example 7-25: Unspaced Periods

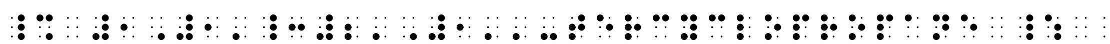
In the von Baeyer nomenclature system, periods separate numerical ring size indicators, as in bicyclo[3.2.1]octane.



Observe: A decimal point is used to represent the period.

Example 7-26: Unspaced Colon and Commas

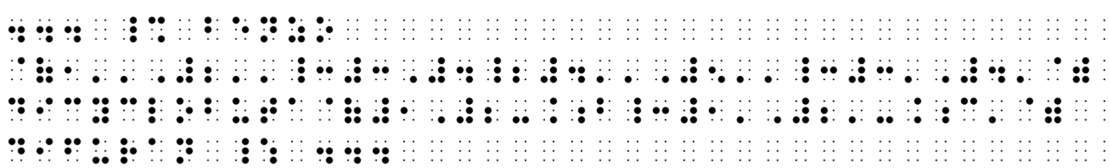
1,1':2',1"-tercyclopropane



Observe: ' and " are primes, not quotation marks.

Example 7-27: Unspaced Punctuation

… benzo[1",2":3,4;4",5":3',4']dicyclobuta[1,2-*b*:1',2'-*c*']difuran …

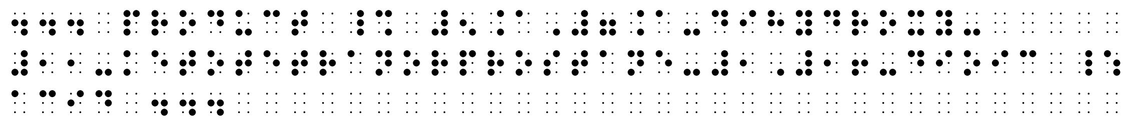


Observe: " and ' are primes, not quotation marks.
Hyphens are <u>not</u> inserted at division sites.

7.1.4 **Word Division.** If the name of a chemical compound will fit on one braille line, do not divide it regardless of the amount of space remaining on the previous line. If a name will not fit on one braille line, the division site must be chosen carefully. If possible, divide between substituents or functional groups. Attempt to place numbers or letters within the compound on the same line as the following substituent. Otherwise, it is permissible to divide after any hyphen. These guidelines apply whether in Nemeth or UEB context.

Example 7-28: Word Division

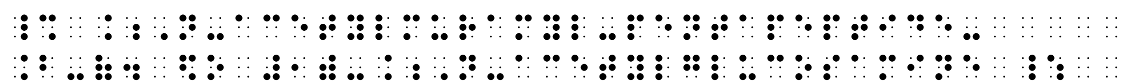
… product 5α,7α-dihydroxy-11-ketotetranorprostane-1,16-dioic acid …



Observe: The numeral 11 and the hyphen are placed on the same line as the following word even though the numeral would fit on the previous line.

Example 7-29: Word Division

N-acetylmuramyl-pentapeptide-β-(4→1)- *N*-acetylglucosamine



Observe: The beta and the hyphen are placed on the same line as the following expression even though the letter would fit on the previous line.

7.2 Chemical Abbreviations and Acronyms

Chemical abbreviations and acronyms may be transcribed in UEB within narrative; however, the presence of a chemical element SYMBOL, Greek letter, mathematical symbol, or typeform other than italics requires a switch to Nemeth Code.

Note: See Section 6, Typeform of English Letters in Chemical Expressions, for letters representing constants, variables, physical states, electron configurations, and concentration of solutions. These letters as well as letters representing element SYMBOLS (Section 4.1) are not considered to be abbreviations in the Chemistry Code.

7.2.1 **Abbreviations and Acronyms in UEB Context.** Follow UEB rules regarding capitalization and use of contractions with abbreviations and acronyms. Within narrative, italicized chemical abbreviations use the typeform indicators of UEB.

Example 7-30: Acronym within Narrative

RNase 7 is a member of the RNase A superfamily.

Observe: This acronym is transcribed in UEB within narrative. Because Nemeth Code format is applied even in UEB narrative, "RNase A" is not divided between braille lines.

Example 7-31: Acronym within Narrative

In industry, EDTA is used to sequester metal ions in aqueous solution.

Observe: This acronym is transcribed in UEB within narrative. The capitalized word indicator of UEB is used for the four-letter acronym. Because these letters are pronounced separately, no contractions are used.

7.2.2 **Abbreviations and Acronyms in Nemeth Context.** Inside the code switch indicators, chemical abbreviations and acronyms follow these rules.

a. Letters are capitalized individually.

b. Typeform is applied to letters individually.

c. Punctuation is in the mathematical mode.

d. Spacing follows print.

Example 7-32: An Acronym in a Formula

$$2[\mathrm{Fe(EDTA)}]^{-} + \mathrm{H_2S} \rightarrow 2[\mathrm{Fe(EDTA)}]^{2-} + \mathrm{S} + 2\mathrm{H}^{+}$$

Observe: The letters of the acronym are individually capitalized in Nemeth Code.

Example 7-33: An Acronym with a Subscript

tRNA_{His}

Observe: The presence of a subscript requires a switch to Nemeth Code.

Example 7-34: An Acronym with a Superscript and in Narrative

When tryptophan concentrations are high, concentrations of charged tryptophan tRNA $(\text{Trp-tRNA}^{\text{Trp}})$ are also high.

Observe: tRNA appears in both UEB and Nemeth context. Capitalization rules follow the code in use.

Example 7-35: An Acronym in an Equation and in Narrative

Unknown DNA conc. can be calculated: DNA conc. = 20 µg/mL.

Observe: DNA appears in both UEB and Nemeth context. Capitalization rules follow the code in use.

Example 7-36: Protein Sequence with a Subscript

Ser-Tyr-Ser-Met-Glu-His-Phe-Arg-Trp-Gly-Lys-Pro-Val-Gly-Lys-Lys-Arg-Arg-Pro-Val_{20}

Observe: The presence of a subscript at the end of the series requires Nemeth Code for the entire string of amino acids.

7.2.3 **pH and pOH.** These chemical properties may be transcribed in either UEB or Nemeth. In Nemeth context, punctuate pH and pOH in mathematical mode.

Example 7-37: pH and pOH within Narrative

To find the pOH, simply subtract the pH from 14.

Example 7-38: pH within Narrative and in an Equation

The pH of the solution is determined as follows: pH = –log 0.0429 = 1.37.

7.2.4 **Genetic Code Sequences.** Letters representing genetic code may be transcribed in UEB or in Nemeth Code. Spaces between the letters are disregarded in the transcription. In UEB, the letters may be capitalized as one word. Contractions are not allowed. In Nemeth, the letters are individually capitalized. At the transcriber's discretion, especially for long strings, the letters may be transcribed in lowercase. A transcriber's note is required to inform the reader of the case change.

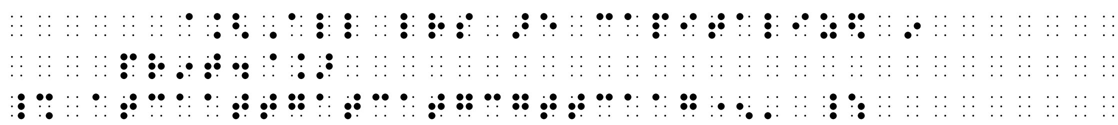
Example 7-39: Codon Expressed in Single-Letter Genetic Code

Tryptophan is encoded by the codon UGG.

Observe: Within narrative, the codon is transcribed in UEB. The capitalized word indicator is used for the letter sequence.

Example 7-40: DNA Sequence with a Prime Sign

A T C A A T T G A T C A T G C G T T C A A G 5'



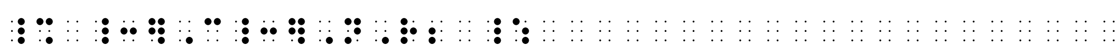
Observe: The presence of a prime sign requires a switch to Nemeth Code. A transcriber's note explains the case change. The letters are not spaced even though spaces appear in print.

7.3 Letters Representing Functional Groups

Depictions of organic compounds may include a letter or letters signifying a "functional group" as a shorthand method of representing a larger molecular structure. If printed in italics, typeform of the letter is retained. A switch to Nemeth Code is necessary only when technical symbols are associated with the letter or if typeform is other than regular or italic.

Example 7-41: Functional Group within a Structural Formula

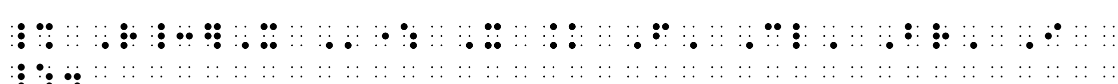
$—C—NR_2$



Note: R represents a functional "radical" group.

Example 7-42: Functional Groups within a Chemical Structure

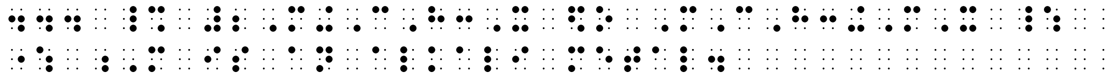
$R—X$ where $X = F, Cl, Br, I.$



Note: R and X represent functional groups.

Example 7-43: Functional Group in a Formula and in Narrative

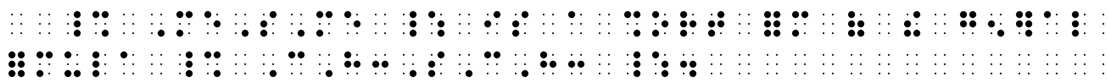
… $2M + CH_3X \rightarrow MCH_3 + MX$ where M is an alkali metal.



Observe: In the narrative, the functional group letter M is transcribed in UEB.

Example 7-44: Functional Group within a General Formula

MeSMe is a short form of the general formula CH_3SCH_3.



Observe: Presence of the chemical SYMBOL S requires Nemeth Code.

7.4 Standard International Units of Measurement

7.4.1 **Definition.** To standardize measurements in science and technology, the International System of Units (SI system) was formed to denote different measurements and quantities in the scientific community. This system assures consistency in communicating size, mass, shape, temperature, time, amount, energy, power, and speed among all areas of science around the world.

The SI system is based on the metric system. SI base units have *abbreviated forms*—for example, m for meter (a unit of length), *derived forms*—for example, m^3 for cubic meter (a unit of volume), and *compound forms*—for example, m/s for meters per second (a unit of speed).

The five SI base units commonly used by chemists are the meter, the kilogram, the Kelvin, the second, and the mole—m, kg, K, s, and mol.

7.4.2 **Code Switching.** Within narrative, an SI unit may be transcribed in UEB following the spacing, punctuation, and contraction rules of that code. A switch to Nemeth Code is required, however, when the SI unit is associated with a mathematical item that requires Nemeth Code. For example, a numeral with a decimal point, a letter from a non-English alphabet, a superscript indicator, or an operation sign within a compound unit.

Note: SI units are printed in regular type. In the example below, m meaning "meter" will not be mistaken for *m* meaning "molality" which is printed in italics. See Section 6.2.2, Letters Representing Concentration of a Solution.

Example 7-45: SI Unit in UEB

165 m

⠼⠁⠋⠑⠀⠰⠍

Observe: Within narrative, this example may be transcribed in UEB—the numeral is unmodified, and the SI unit is an English letter.

Example 7-46: Numeral Contains a Decimal Point

16.5 kg

⠸⠩⠀⠼⠂⠖⠨⠢⠀⠅⠛⠀⠸⠱

Observe: A switch to Nemeth Code is required because the number contains a decimal point. The related SI unit is included inside the switch.

Example 7-47: SI Derived Unit Includes a Superscript

47 cm^3

⠸⠩⠀⠼⠲⠶⠀⠉⠍⠘⠒⠀⠸⠱

Observe: A switch to Nemeth Code is required because the SI unit has a superscript. The related numeral is included inside the switch.

Example 7-48: SI Derived Unit Includes a Greek Letter

5 µg

⠸⠩⠀⠼⠢⠀⠨⠍⠛⠀⠸⠱

Observe: A switch to Nemeth Code is required because of the Greek letter. The related numeral is included inside the switch.

Example 7-49: SI Compound Unit

kg/mol

⠸⠩⠀⠅⠛⠸⠌⠍⠕⠇⠀⠸⠱

Observe: The presence of the slash meaning "per" requires a switch to Nemeth Code.

7.4.3 **Scientific Transcription Considerations.** Unlike abbreviations for units of measure in the imperial system such as oz., ft., and qt., the scientific community regards the abbreviated forms of SI units as symbols, not as abbreviations. For that reason, the Chemistry Code considers SI units to be symbols, not abbreviations.

The following rules apply to the transcription of abbreviated forms of SI units.

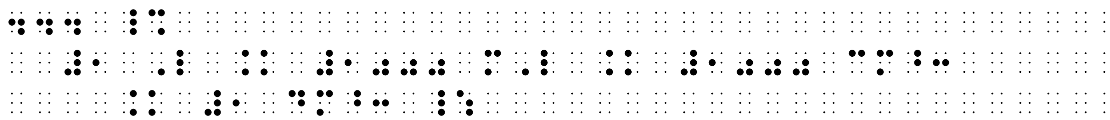
a. **Spacing.** An SI unit follows print spacing except in the following instances.

- When an SI unit has no associated value, it follows the spacing rules for variables according to the Nemeth Code.
- A compound SI unit is treated as one unit and is unspaced from its components.

Definition of Compound Unit. A compound unit is formed by multiplying or dividing two or more SI units. The overall symbol consists of the symbols for the separate units joined by a multiplication dot or a slash. See Example 7-51.

Example 7-50: SI Units in Mathematical Context

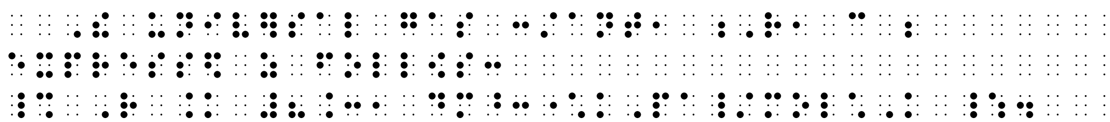
$1\ \mathrm{L} = 1000\ \mathrm{mL} = 1000\ \mathrm{cm}^3 = 1\ \mathrm{dm}^3$



Note: See Section 7.4.3.c regarding the transcription of the SI unit "L".

Example 7-51: Compound SI Unit

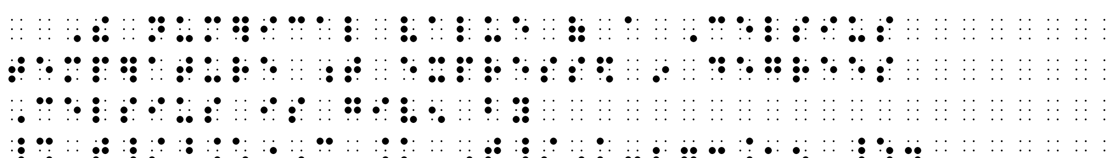
The universal gas constant, R, can be expressed as follows:
$R = 8.31\ \mathrm{dm}^3 \cdot \mathrm{kPa/mol} \cdot \mathrm{K}$.



Observe: Within the compound unit, the spacing before and after the multiplication dot is disregarded. The italic typeform is disregarded for the constant, R.

Example 7-52: SI Unit as a Variable

The numerical value of a Celsius temperature t expressed in degrees Celsius is given by $t\,/\,{}^\circ\mathrm{C} = T\,/\,\mathrm{K} - 273.15$.

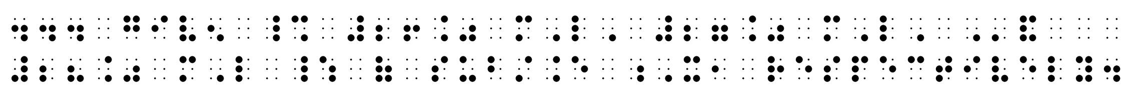


Observe: SI units °C and K have no associated value. As variables, they are unspaced from operation signs.

b. **Punctuation.** SI units do not have a related period. Abbreviated forms of SI units are punctuated mathematically when the punctuation occurs within the switches.

Example 7-53: SI Unit Punctuated Mathematically

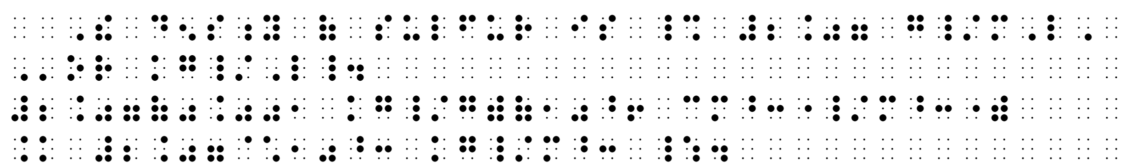
… given 26.0 mL, 27.0 mL, and 28.0 mL of substance X, respectively.



Observe: The mathematical comma (dot 6) is used following each SI unit.

Example 7-54: SI Units Punctuated Mathematically

The density of sulfur is 2.07 g/mL, or kg/L. $2.07(0.001\,\text{kg/g})(10^6\,\text{cm}^3/\text{m}^3)$
$= 2.07\times10^3\ \text{kg/m}^3$.

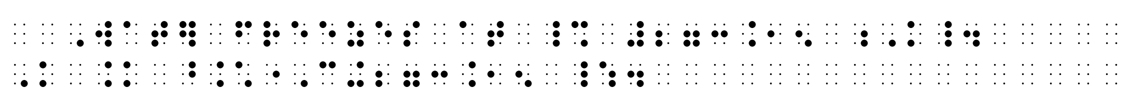


Observe: In Nemeth context, the period following SI unit L is preceded by a punctuation indicator and the mathematical comma (dot 6) is used following SI unit mL.

c. **The English-Letter Indicator.** In Nemeth context, the English-letter indicator ("ELI") is used only when the unit meets the Nemeth Code criteria for a "single letter" as defined in NC Rule 6.3.1.

Example 7-55: Single-Letter SI Unit

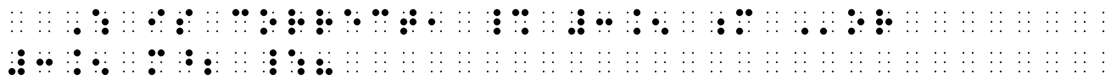
Water freezes at 273.15 K. K = °C + 273.15.



Observe: Only the first SI unit K follows the Nemeth definition of a "single letter" and so requires an ELI.

Example 7-56: Single-Letter SI Unit

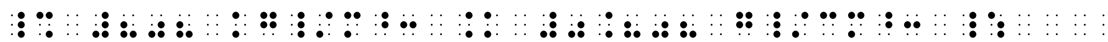
Which is correct, 3.5 m or $3.5\ \mathrm{m}^2$?



Observe: Only the first SI unit m requires an ELI.

Example 7-57: Compound SI Unit Including a Single-Letter Unit

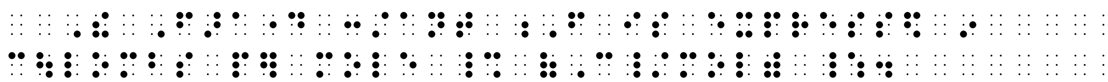
$808\ \mathrm{kg/m}^3 = 0.808\ \mathrm{g/cm}^3$



Observe: Neither single-letter SI unit requires an ELI.

Example 7-58: Compound SI Unit Including a Single-Letter Unit

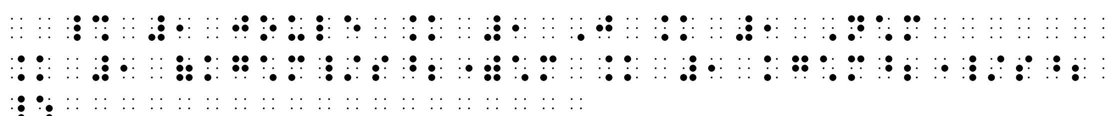
The Faraday constant F is expressed in coulombs per mole (C/mol).



Observe: SI unit C does not require an ELI.

Example 7-59: Compound SI Unit Including Single-Letter Units

$1\ \text{joule} = 1\ \mathrm{J} = 1\ \mathrm{N}\cdot\mathrm{m} = 1\,(\mathrm{kg}\cdot\mathrm{m/s}^2)\cdot\mathrm{m} = 1\ \mathrm{kg}\cdot\mathrm{m}^2/\mathrm{s}^2$

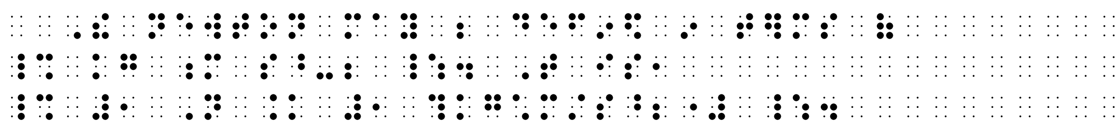


Observe: The single-letter SI unit J does not require an ELI, even though it is preceded and followed by a space, because it is followed by a sign of comparison. The other SI units (N, m, s) are unspaced or carry a superscript and so do not need an ELI.

d. **Compound Units Printed with a Space or within a Fraction.** Compound units may be printed with a space in place of a multiplication sign, or as a fraction instead of a slash. Follow established rules for nonuse of the English-letter indicator with SI units.

Example 7-60: Compound SI Unit with Spaces and as a Fraction

The newton may be defined in terms of $\mathrm{kg\ m\ s}^{-2}$. That is, $1\ \mathrm{N} = 1\,\frac{\mathrm{kg}\cdot\mathrm{m}}{\mathrm{s}^2}$.



Observe: Only the first single-letter SI unit m requires an ELI because it is preceded and followed by a space. N is followed by a sign of comparison.

Section 8
Labels

BRIEF CONTENTS

For modified chemical arrows, see Section 3, Chemical Arrows. For labels that appear in conjunction with vertices on ring structures, see Section 10.5.2, Labeled Atoms and Vertices. For remarks, conditions, or explanations printed beside a formula or structure, see Section 9.5, Remarks or Conditions.

8.1 Labeled Chemical Expressions

8.1.1 **Layout.** The label to a chemical expression may be printed in the margin, to the right, to the left, above, or below the material being labeled. In braille, it is best to provide the label first, preceded by a blank line. This arrangement should be noted on the Transcriber's Notes page.

Sample transcriber's note as it may appear on a Transcriber's Notes page:

Labels may be printed above, below, or beside a chemical expression or diagram. In braille, labels are usually transcribed above the expression or diagram.

A label may apply to the complete expression or to a portion of it. Align the label with the first cell of the expression, or the first cell of the labeled portion of the expression.

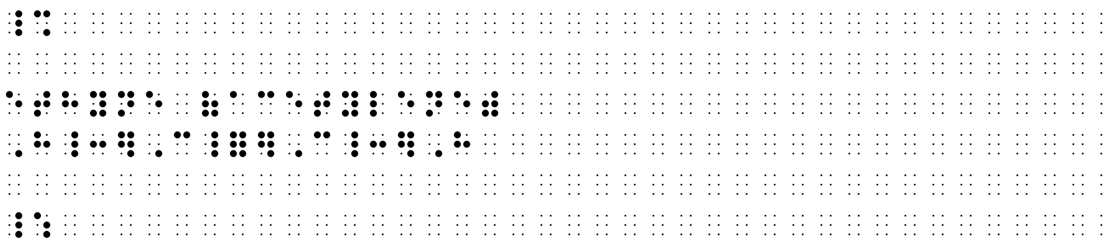
A labeled expression observes the format guidelines for a spatial arrangement. See Section 9.4, Spatial Structures. The expression begins in cell 1, even if displayed to narrative. A blank line precedes and follows the entire construction.

It is preferable to include the label inside the code switches.

Example 8-1: Label Printed Above a Displayed Linear Structure

ethyne (acetylene)

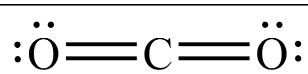
H — C ≡ C — H



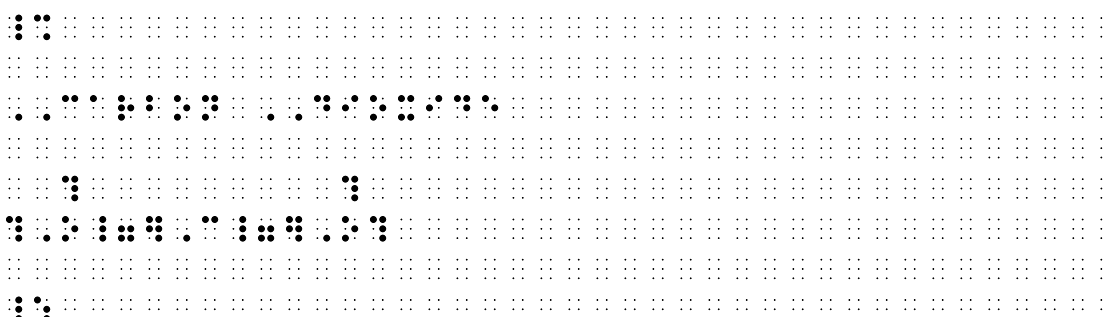
Observe: A blank line precedes the label. The left margin is cell 1. The label is aligned with the first cell of the diagram. A blank line follows the entire construction.

For a labeled spatial structure, a blank line is inserted between the label and the diagram.

Example 8-2: Label Printed Below a Displayed Spatial Structure



CARBON DIOXIDE



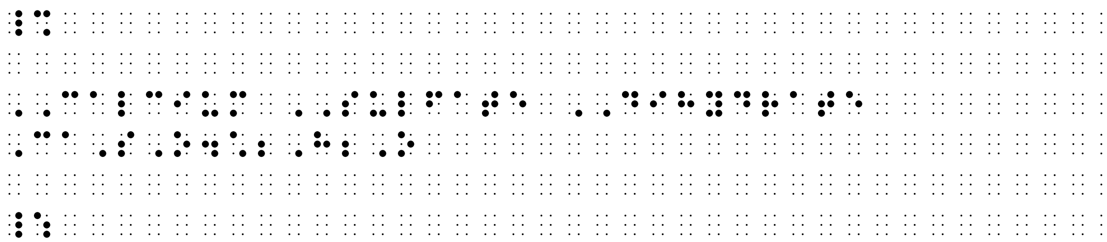
Observe: The label precedes the diagram in braille. A blank line precedes the label. A blank line precedes and follows the spatial diagram. The left margin is cell 1.

If the label is made up of three or more fully capitalized words, each word must be capitalized individually using the double capitalization indicator of the Nemeth Code.

Example 8-3: Three-Word Label Printed in Small Capital Letters

CALCIUM SULFATE DIHYDRATE

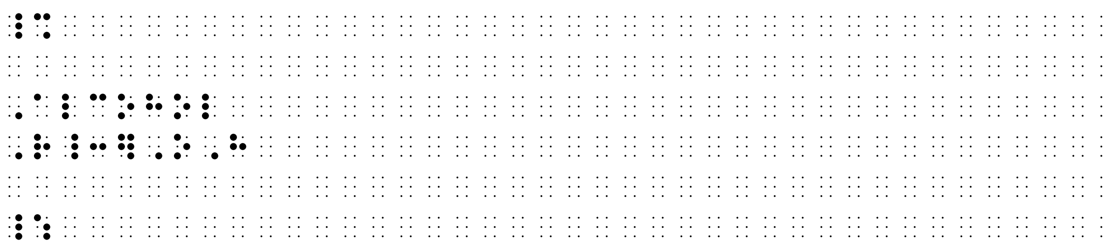
$CaSO_4 \cdot 2H_2O$



Observe: Small capitals typeform is disregarded.

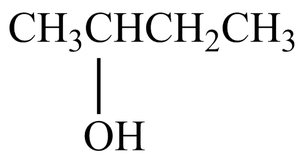
Example 8-4: Label is Printed in the Left Margin

Alcohol $\quad$ R—OH

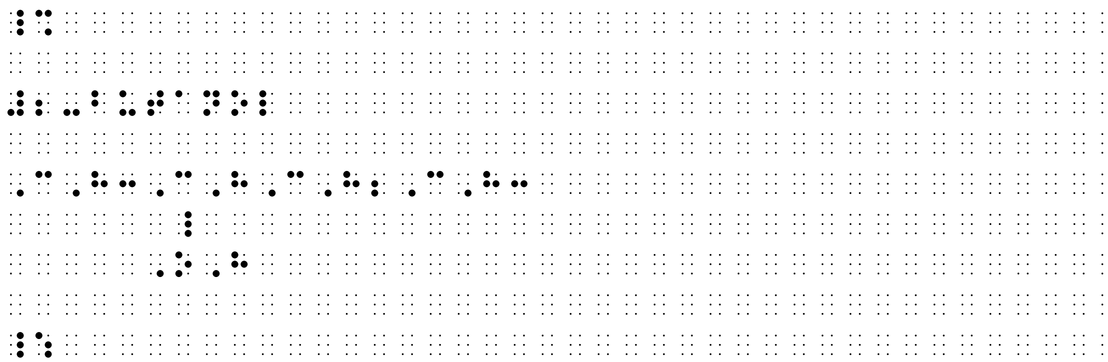


Observe: In braille, the label precedes the chemical expression.

Example 8-5: Label is Printed to the Right



2-butanol



Observe: In braille, the label precedes the diagram.

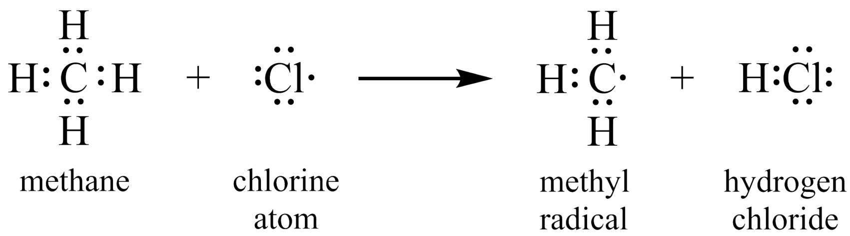
8.1.2 **Extracting the Labels.** If placing the label above the material disrupts the arrangement, alternate methods are used. Any other placement of the label should be clarified in a transcriber's note.

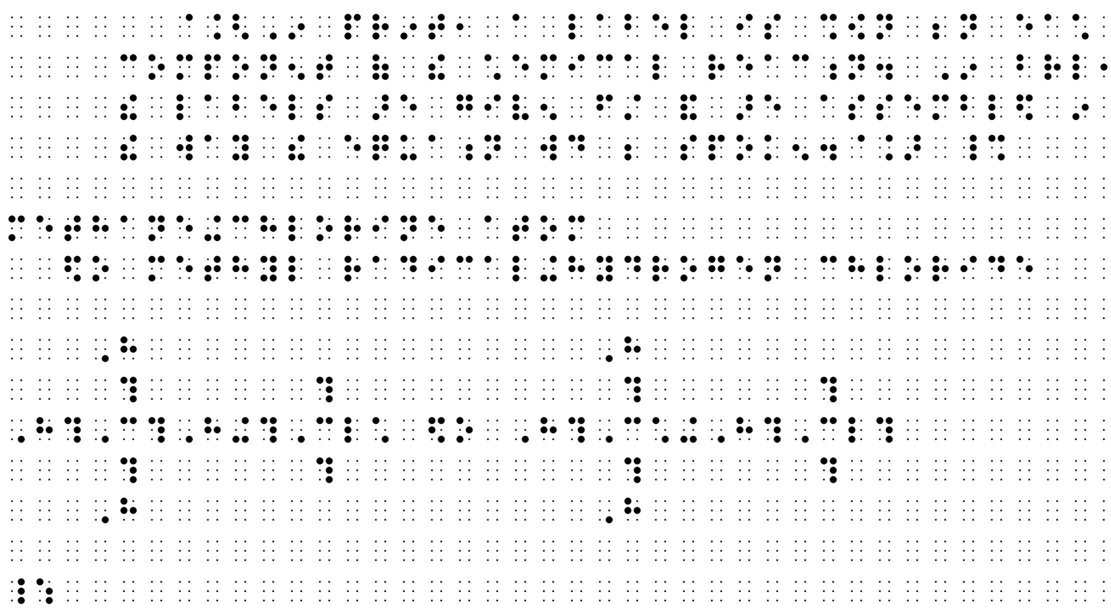
It may be possible to arrange the labels in the form of an equation.

Sample transcriber's note:

In print, a label is shown beneath each component of the chemical reaction. In braille, the labels are given first and are assembled in the way the equation would be spoken.

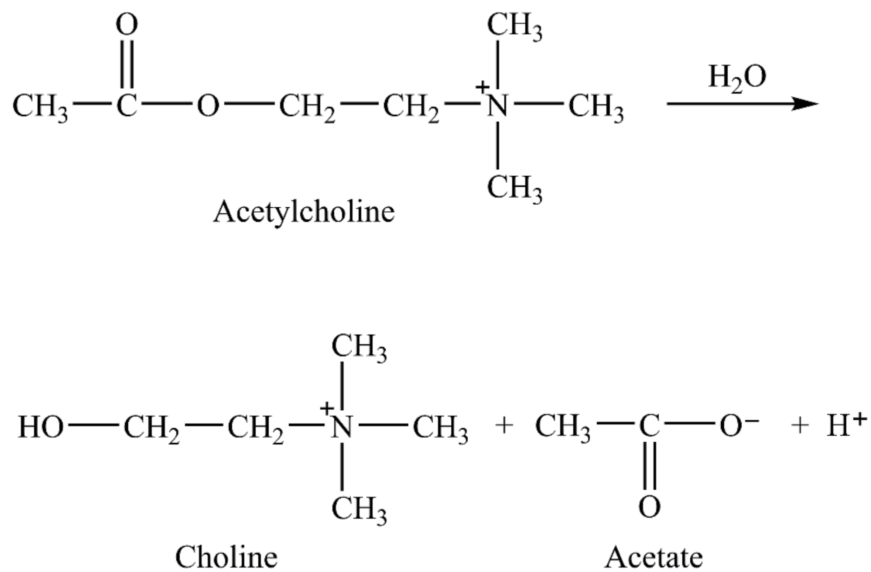
Example 8-6: Labels Printed Below Each of Four Molecules

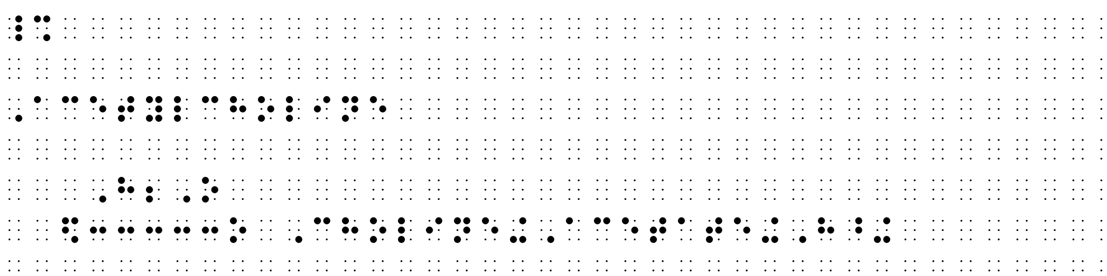




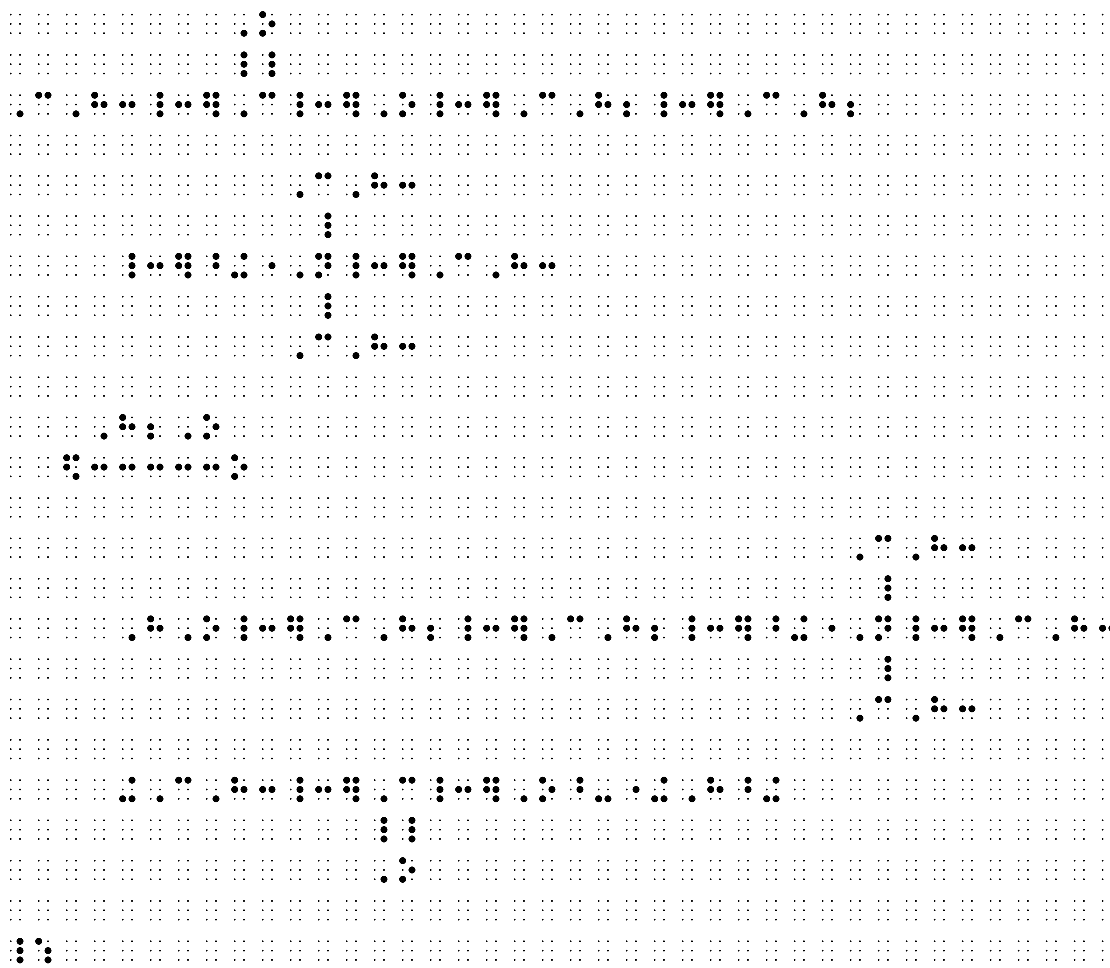
Observe: The labels are transcribed first, in the form of an equation. A blank line precedes the labels. The equation starts in cell 1, in the same manner as the related molecular diagram.

Example 8-7: Labeled Hydrolysis Reaction





//// NEW BRAILLE PAGE ////



Observe: The labels are transcribed first, within the equation form. Because the modified arrow makes the equation a spatial arrangement, the margin is cell 1.

When a label applies only to some molecules or to a portion of a molecule, see Section 10.4.4, Lead Lines.

8.2 Labeled Atoms

Labels, often called markers or numbered atoms, may appear in conjunction with atom SYMBOLS or with a vertex in a ring structure. The marker may consist of numbers, letters, Greek letters, asterisks, or other symbols.

8.2.1 **Labeled Atoms in Linear Structures.** In a linear structure, markers usually occur directly over or under the SYMBOL to which they apply. Ideal placement of the marker in braille is on the line directly above the SYMBOL. A change from print location should be stated in a transcriber's note.

Sample transcriber's note:

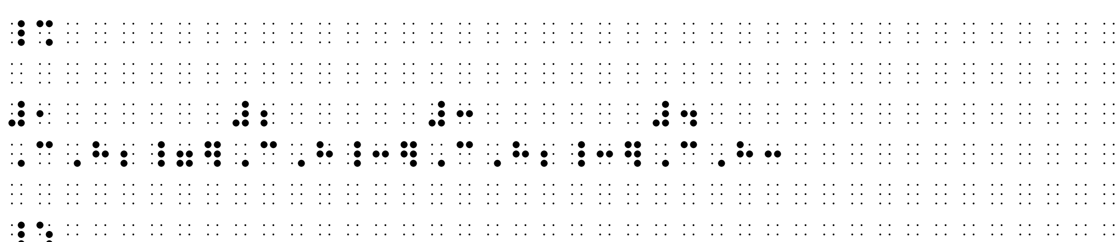
Marker labels are transcribed above the associated atom.

Preferred alignment over a single-letter SYMBOL is for the numeric indicator of the marker to be directly above the capital indicator. Above a two-letter SYMBOL, a two-cell marker is aligned above the letters, and a three-cell marker begins above the capital indicator.

The two-line arrangement is a spatial structure and so is preceded and followed by a blank line.

Example 8-8: Labeled Carbon Atoms

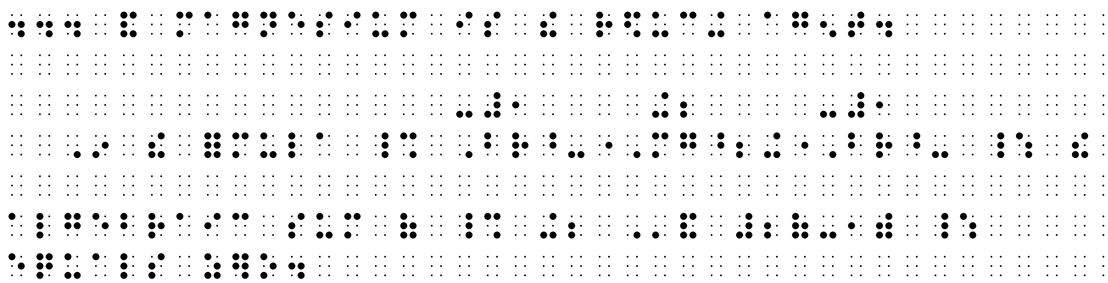
$$\overset{1}{CH_2}=\overset{2}{CH}-\overset{3}{CH_2}-\overset{4}{CH_3}$$



Example 8-9: Embedded Formula with Labels Above SYMBOLS

… and magnesium is the reducing agent.

In the formula $\overset{-1}{Br^-}\,\overset{+2}{Mg^{2+}}\,\overset{-1}{Br^-}$ the algebraic sum of +2 and 2 (–1) equals zero.

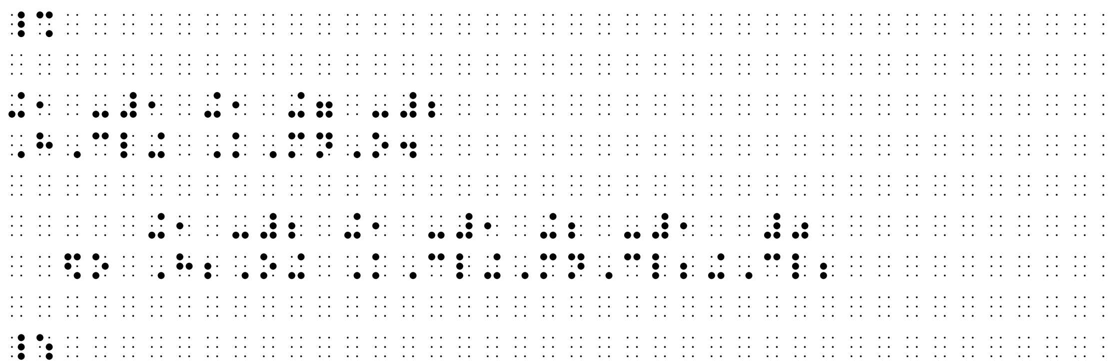


Observe: A blank line precedes and follows the lines which have a vertical component. The opening Nemeth Code indicator on the main line affects the markers on the line above.

a. **Spacing Considerations with Numeral Labels.** Individual labels which contain numerals must be separated by at least one blank cell when they appear on the same braille line. Spacing adjustments may be necessary in the formula in order to maintain alignment. Avoid spacing of atoms within a molecule. A transcriber's note is not required.

Example 8-10: Oxidation Numbers Printed Above SYMBOLS

$$\overset{+1}{H}\overset{-1}{Cl} + \overset{+1}{K}\overset{+7}{Mn}\overset{-2}{O_4} \longrightarrow \overset{+1}{H_2}\overset{-2}{O} + \overset{+1}{K}\overset{-1}{Cl} + \overset{+2}{Mn}\overset{-1}{Cl_2} + \overset{0}{Cl_2}$$



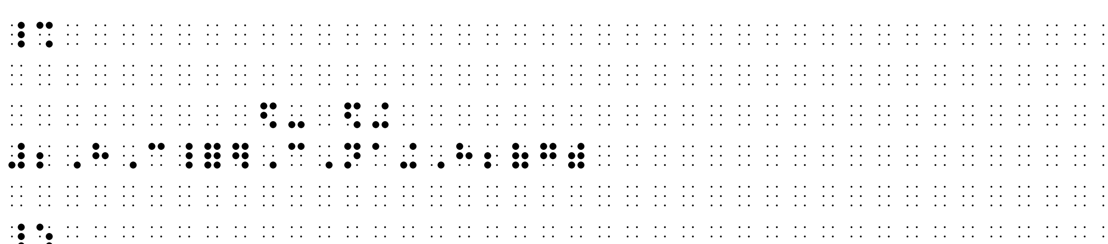
Observe: Spacing adjustments are made in the formula in order to accommodate spacing of oxidation numbers. Some labels are moved left or right one cell in order to heed spacing requirements.

b. **Spacing Considerations with Charge Symbols.** Individual charge symbols (a plus or a minus without a numeral) and partial charge symbols ($\delta-$ or $\delta+$) may be transcribed side by side without an intervening space. When alignment issues arise with partial charge symbols, one cell of the symbol may be directly above a bond indicator without obscuring interpretation of the formula.

See Section 4.3 regarding the depiction of the detached plus sign and the detached minus sign.

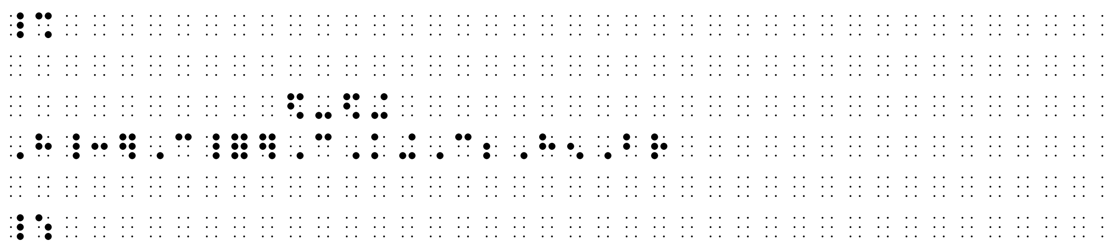
Example 8-11: Charges Above SYMBOLS

$$2\,HC\equiv\overset{-}{C}\overset{+}{Na}+H_2(g)$$



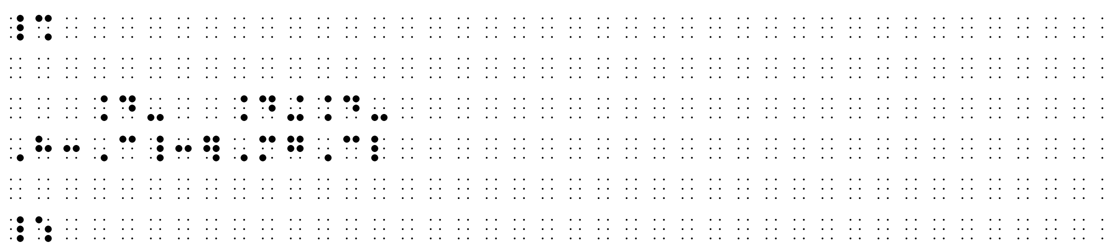
Example 8-12: Charges Above Single-Letter SYMBOLS

$$\mathrm{H{-}C{\equiv}\overset{-}{C}\overset{+}{K}+C_2H_5Br}$$



Example 8-13: Partial Charge Above Two-Letter SYMBOLS

$$\mathrm{H_3\overset{\delta^-}{C}{-}\overset{\delta^+}{Mg}\overset{\delta^-}{Cl}}$$

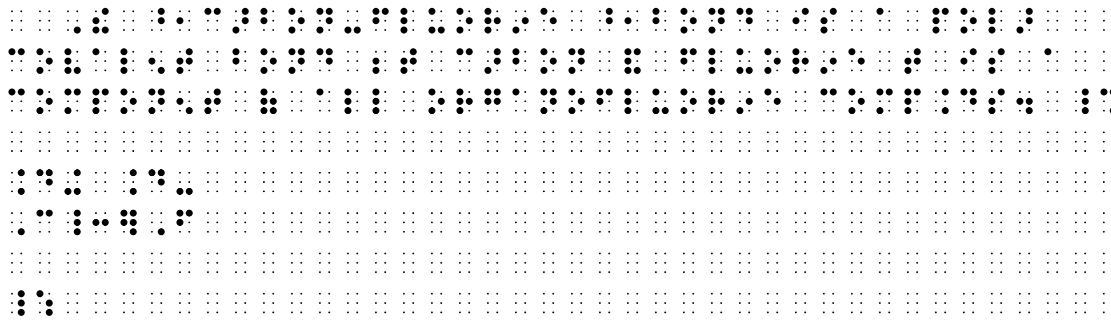


Observe: The superscript position of the plus or minus sign associated with each delta is disregarded. See Section 5.1.1.a, Partial Charge.

Example 8-14: Partial Charge Above Single-Letter SYMBOLS

The **carbon–fluorine bond** is a polar covalent bond between carbon and fluorine that is a component of all organofluorine compounds.

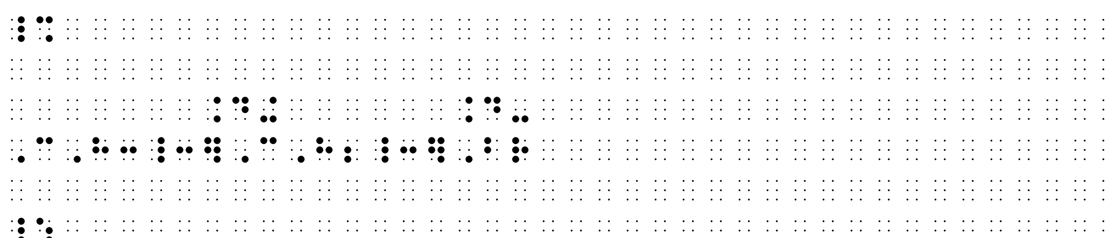
$$\overset{\delta^+}{\mathrm{C}} - \overset{\delta^-}{\mathrm{F}}$$



Observe: One cell of each partial charge is aligned above a bond indicator. The superscript position of the plus or minus sign associated with each delta is disregarded. See Section 5.1.1.a, Partial Charge.

Example 8-15: Partial Charge Above Single-Letter SYMBOL

$$\mathrm{CH_3} - \overset{\delta^+}{\mathrm{C}}\mathrm{H_2} - \overset{\delta^-}{\mathrm{Br}}$$



Observe: The first cell of the partial charge above the single-letter SYMBOL C is aligned above the closing bond indicator to keep it from lying above a character in the adjacent SYMBOL, H. The superscript position of the plus or minus sign associated with each delta is disregarded. See Section 5.1.1.a, Partial Charge.

8.2.2 **Labeled Atoms in a Spatial Diagram.** In a spatial structure, placement of markers in the print copy will vary in order to accommodate other parts of the structure. In the braille transcription, consistent placement of the markers immediately above its SYMBOL is preferred but is not always possible. When a vertical bond is present with a labeled SYMBOL, place the marker to the left of the bond. No space comes between the marker and the bond symbol.

When the arrangement differs from the print copy, it should be mentioned in a transcriber's note.

Sample transcriber's note:

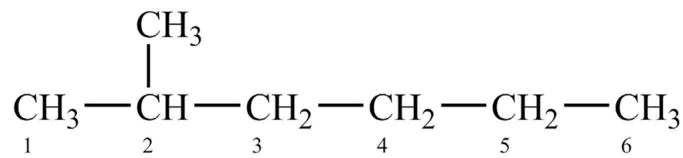
The numeric markers are transcribed above or above and to the left of the labeled element symbol.

See Section 10.5.2, Labeled Atoms and Vertices, for placement in a spatial diagram with oblique bonds or unlabeled vertices.

Markers may appear as if they were superscripts or subscripts. The transcriber can determine from context the meaning of the number. Normally, the following are superscripts or subscripts, not labels:

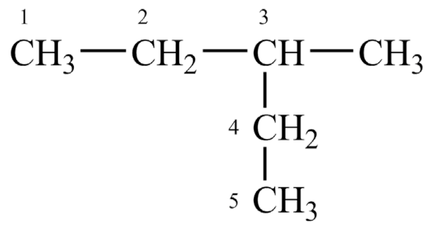
Right superscript: electron charge (as in Li^+) or isotope number (as in U^{238})
Right subscript: number of atoms (as in O_2)
Left superscript: electron charge in a structural diagram (as in $—{}^+N—$)
Left superscript/subscript: mass number and atomic number (as in ${}^{14}_{7}N$)

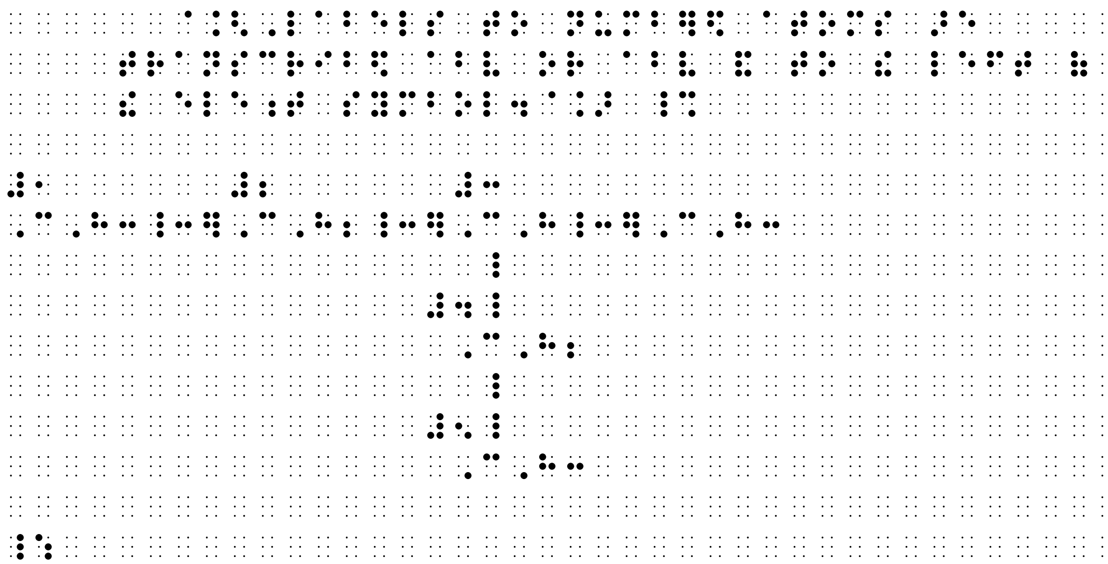
Example 8-16: Numeric Markers Printed Below SYMBOLS



Observe: Markers are transcribed in the preferred position, above the element SYMBOL. The vertical bond prevents marker "2" from aligning directly above SYMBOL C. It is placed to the left of the vertical bond.

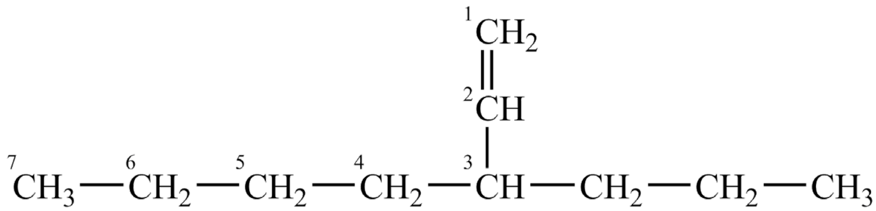
Example 8-17: Some Markers Printed to the Left of SYMBOLS



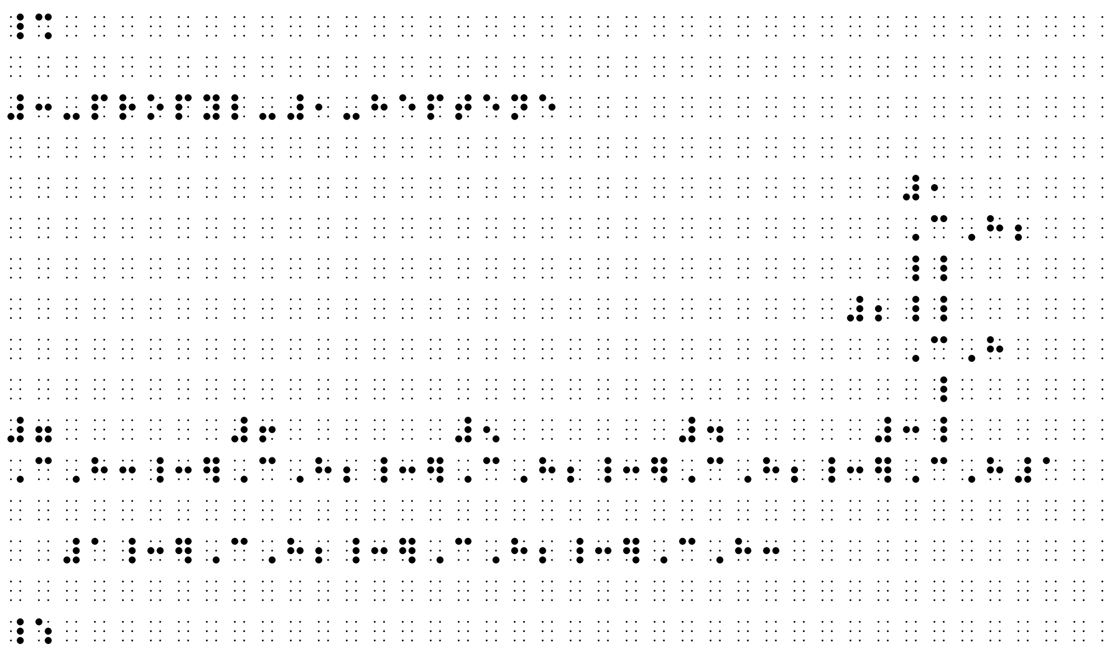


Observe: Markers are transcribed on the line above SYMBOLS, not to the left.

Example 8-18: Numbers Printed Above and Left of SYMBOLS

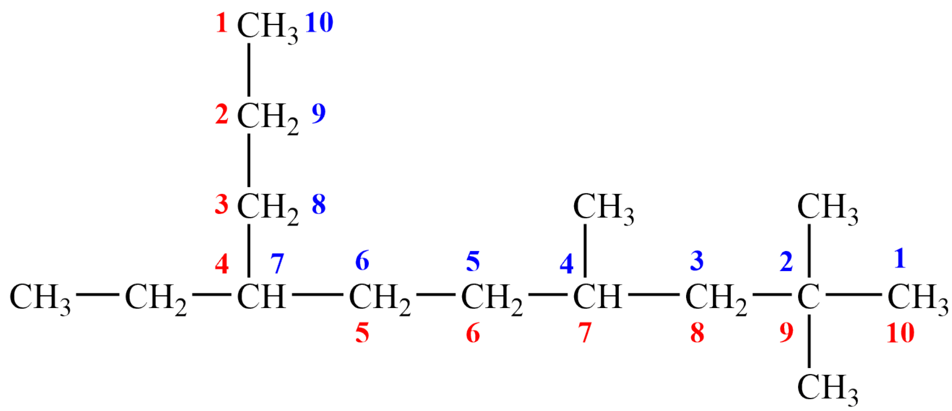


3-propyl-1-heptene



Observe: The numbers are not left superscripts. They are marker labels and are placed on the line above the appropriate SYMBOL. See Section 9.4.6, Runover Locator, regarding the use of the upper-number runover locator in this example.

Example 8-19: Two Markers Apply to the Same SYMBOL



7-ethyl-2,2,4-trimethyldecane

Note: In print, the left and lower numbers are red; the right and upper numbers are blue.

To clearly display the two different colored markers, this molecule is transcribed in two parts. Three transcriber's notes explain:

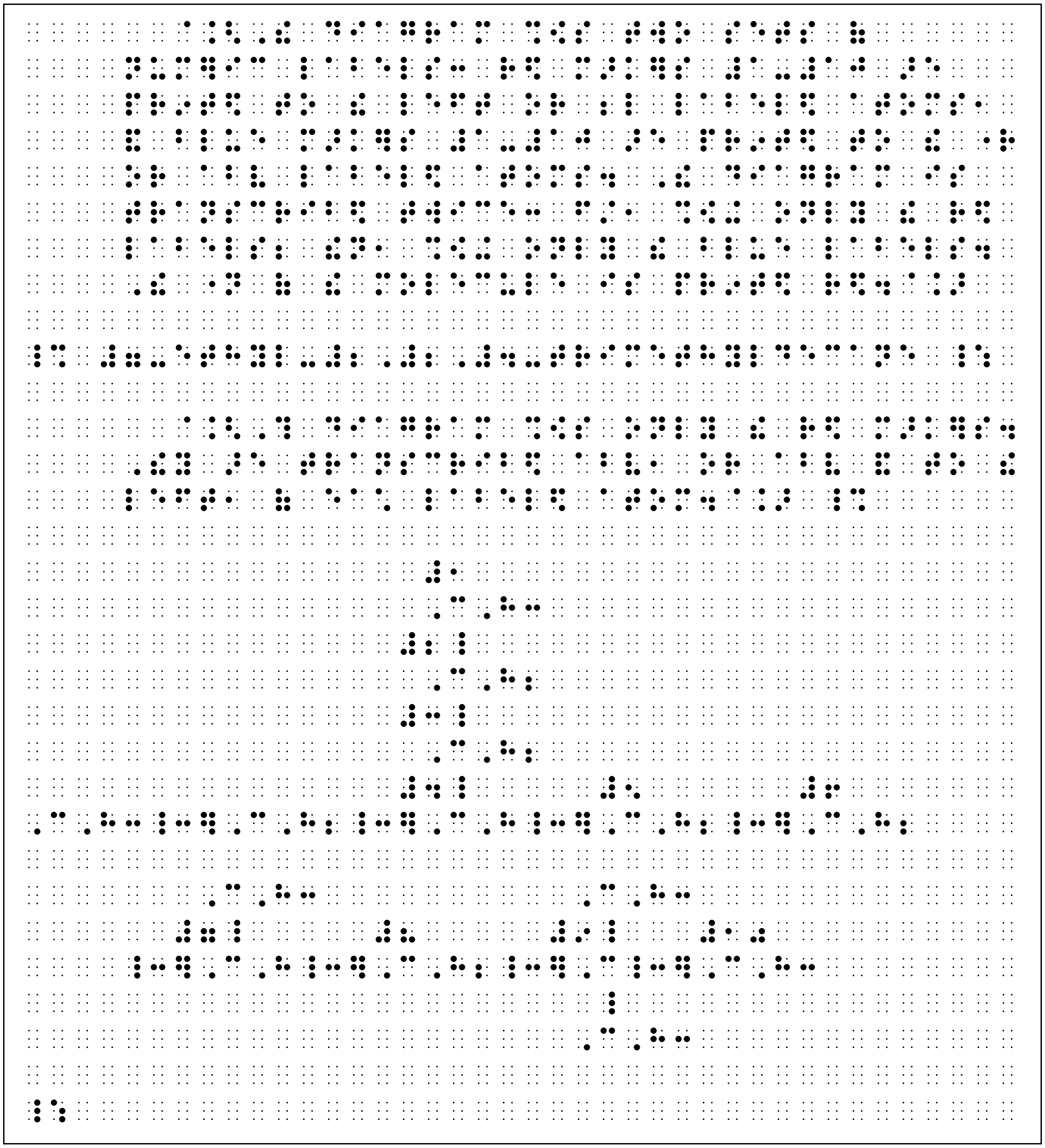
The diagram shows two sets of numeric labels: red markers 1-10 are printed to the left or below labeled atoms, and blue markers 1-10 are printed to the right or above labeled atoms. The diagram is transcribed twice: first, showing only the red labels; then, showing only the blue labels.

The next transcriber's note is placed before the first transcription.

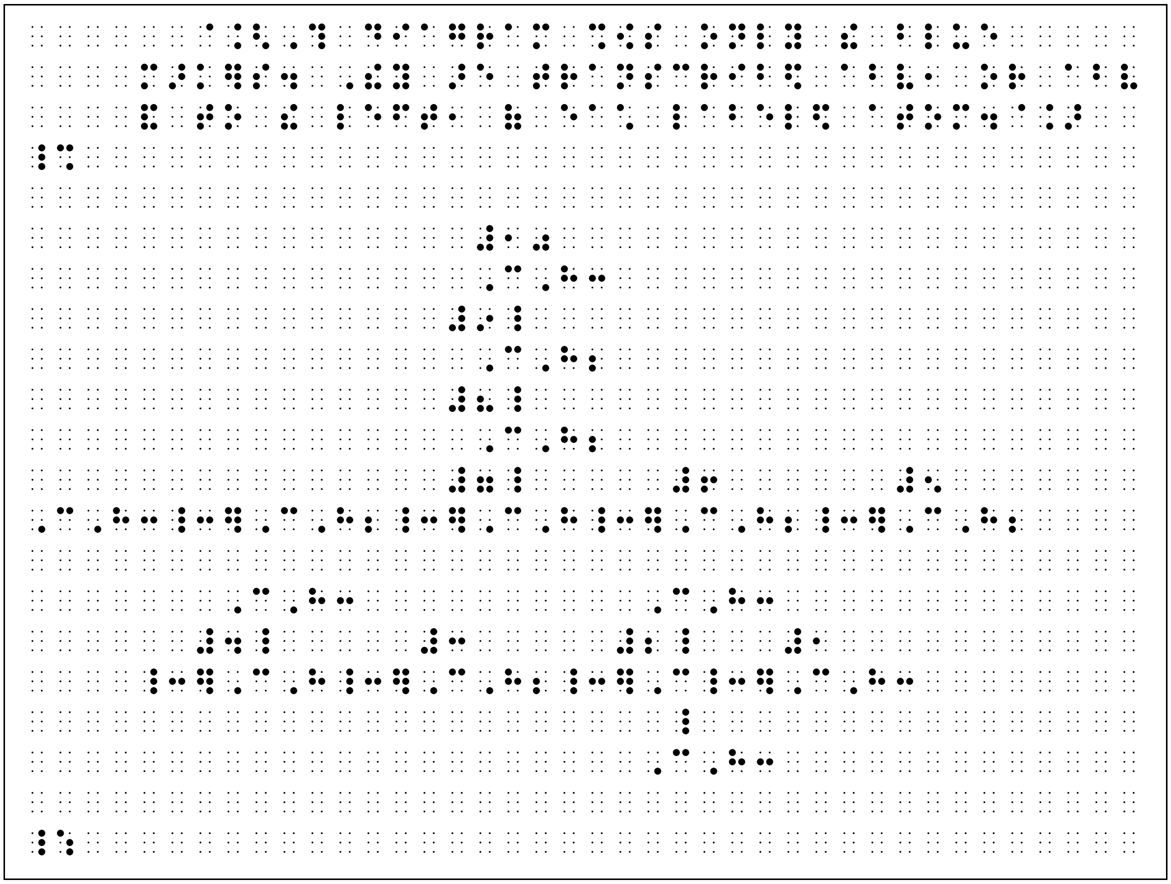
This diagram shows only the red markers. They are transcribed above, or above and to the left, of each labeled atom.

The next transcriber's note is placed before the second transcription.

This diagram shows only the blue markers. They are transcribed above, or above and to the left, of each labeled atom.



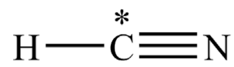
Observe: The runover line begins with a bond symbol. When the runover begins with a symbol other than a comparison symbol, it begins four cells to the right of the beginning of the structure. *See Section 9.4.3.a.*



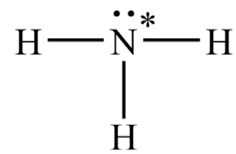
Observe: The runover line begins with a bond symbol. When the runover begins with a symbol other than a comparison symbol, it begins four cells to the right of the beginning of the structure. See Section 9.4.3.a.

Example 8-20: Asterisk Printed Above and Oblique to SYMBOLS

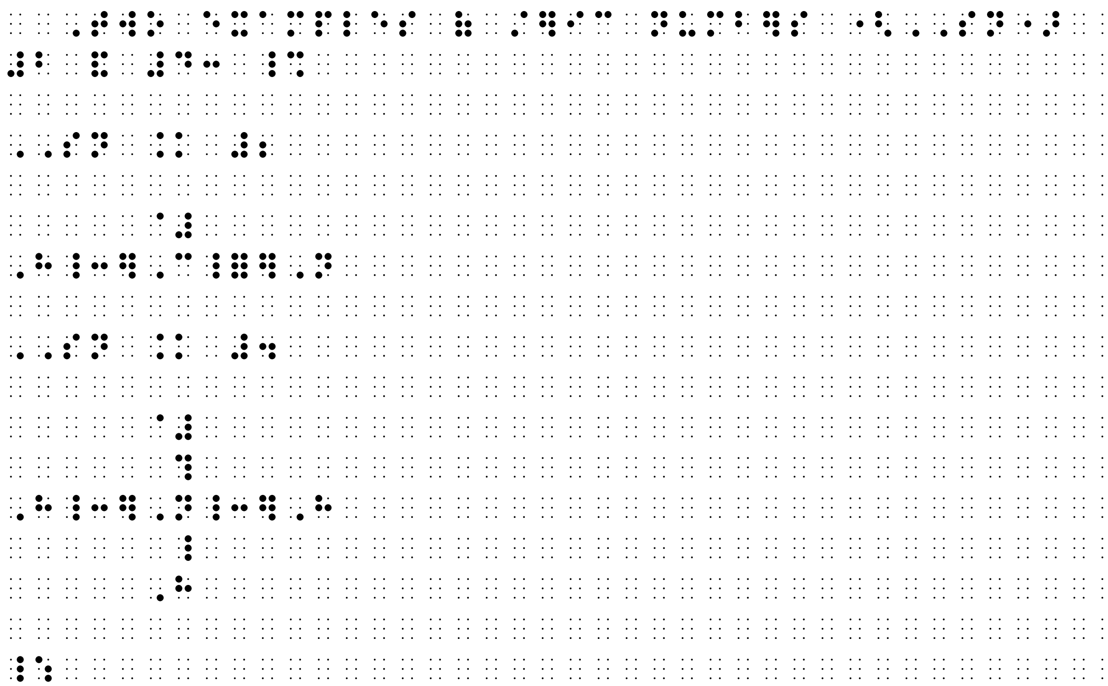
Two examples of steric numbers (SN) 2 and 4:



SN = 2



SN = 4

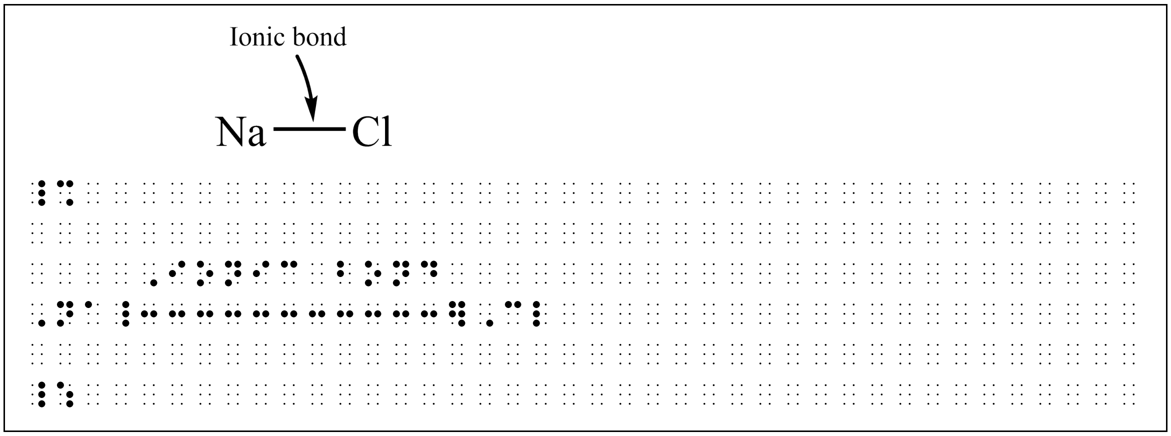


Observe: Although the second asterisk is printed in a position that appears to be a superscript to N, it is transcribed in the same position as the asterisk label above C – that is, on the line above the atom. In this case, the asterisk is placed on the line above the electron dot pair associated with the N atom.

8.3 Labeled Bonds

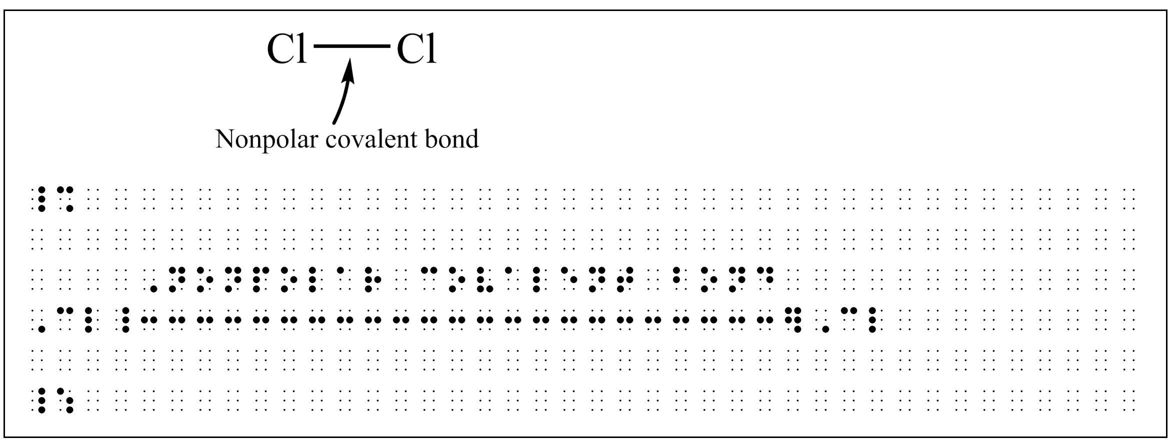
The length of a bond may be extended in order to accommodate a label. The length has no bearing on the meaning. In braille, the label is placed on the previous line. An alternative method is to draw a lead line. See Section 10.4.4, Lead Lines. See also, Section 2.2.3, Modified Bonds.

Example 8-21: Print Uses a Pointing Arrow to Label a Bond



Observe: The pointing arrow is not transcribed. The length of the bond is extended to the width of the label.

Example 8-22: Print Uses a Pointing Arrow to Label a Bond



Observe: The label is transcribed above the bond even though it is printed below the bond. The pointing arrow is not transcribed. The length of the bond is extended to the width of the label.

Section 9
Format

BRIEF CONTENTS

9.1 Fundamentals

Format refers to the layout on the braille page–blank lines, margins, division of wide expressions and diagrams, and placement of identifiers and commentary. When the rules of the Chemistry Code are being observed in a transcription, several formatting rules differ from the rules of the Nemeth Code. These rules apply only to the chemical expressions and constructions. Nemeth Code formatting rules are applied to nonchemical expressions.

9.1.1 **Linage.** Do not divide a chemical expression if it can be contained on one line within the current margins. When it does not fit on one braille line, runover sites are selected carefully to minimize the number of runovers and to keep related material intact. Observe the following guidelines.

- Fractions, parenthetical expressions, and chemical formulas should be completed on one braille line if possible.
- Avoid running over within material between bonds.
- Avoid running over within superscripts, subscripts, or within modifications.

9.1.2 **Chemical Expressions Requiring Runovers.** When a chemical expression will not fit on one braille line, runover sites should be chosen carefully. The guidelines given in Rule 26.2 of the Nemeth Code are adapted below for choosing division sites in a chemical expression. Follow the list below, starting with step a. See Section 9.3.1 for further rules which apply to a linked expression.

a. Before a symbol of comparison on the baseline of writing.

b. Before a symbol of operation on the baseline of writing.

c. Before any of the following symbols or indicators:

- an opening fraction indicator
- a chemical bond
- a fraction line if the fraction must be divided
- a baseline indicator which precedes an item listed above
- a change-of-level indicator
- within a superscript or subscript before one of the symbols listed above

d. After a termination indicator.

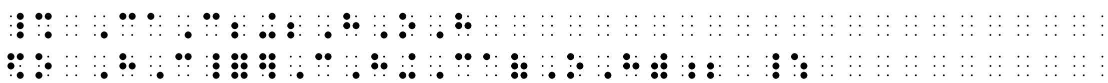
e. Between items which are enclosed within grouping symbols if the grouping will not fit on one line.

9.2 Runovers of Embedded Expressions

Runovers of embedded expressions begin in the appropriate runover cell of the current paragraph.

Example 9-1: New Line Begins at Comparison Symbol

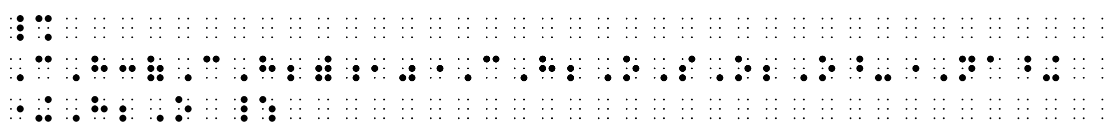
$$CaC_2 + 2HOH \rightarrow HC{\equiv}CH + Ca(OH)_2$$



Observe: The entire chemical expression will not fit on one line, even with the switch indicators removed. Division is made before the yields arrow (comparison symbol).

Example 9-2: New Line Begins at Operation Symbol

$$CH_3(CH_2)_{10}CH_2OSO_2O^-Na^+ + H_2O$$



Observe: The runover begins before the baseline indicator at an operation symbol on the baseline. Because the first part of the expression will fit on one line, the opening Nemeth Code indicator is placed on the preceding line.

9.3 Runovers of Displayed Expressions

The runover rules as they apply to displayed chemical expressions differ from the rules stated in the Nemeth Code.

9.3.1 **Displayed Expressions Containing Links.** If a displayed chemical expression is too long to fit on one line and contains one or more links (as defined in the Nemeth Code), observe the following format.

a. Indent two cells to the right of the anchor margin when the runover begins with a comparison symbol.

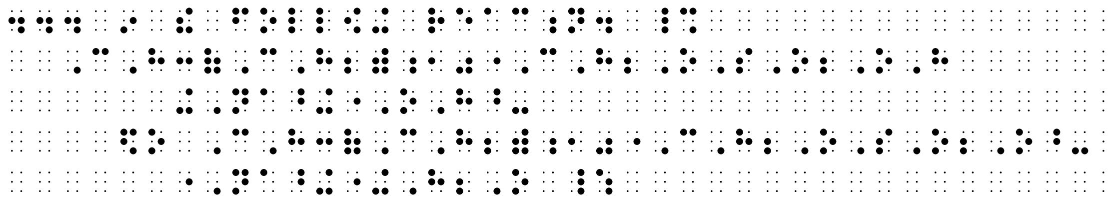
b. Indent four cells to the right of the anchor margin when the runover begins with a symbol other than a comparison symbol.

c. A division is made before each link. This format is applied regardless of the layout shown in print.

Example 9-3: Displayed Chemical Equation with a Link

… in the following reaction.

$$CH_3(CH_2)_{10}CH_2OSO_2OH + Na^+OH^-$$
$$\rightarrow CH_3(CH_2)_{10}CH_2OSO_2O^-Na^+ + H_2O$$



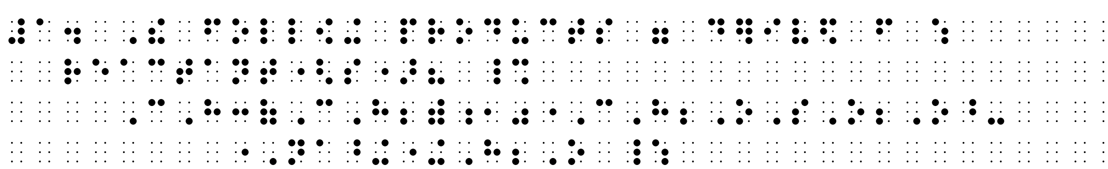
Observe: Division before the yields arrow (comparison symbol) clearly distinguishes the reactant (left side of the reaction) from the product (right side of the reaction). In the reactant, the runover line begins before a symbol of operation (plus sign). In the product, the runover line begins with the baseline indicator before the SYMBOL Na. It is not necessary to divide again before the symbol of operation (plus sign).

9.3.2 **Displayed Expressions Containing No Links.** When the runover begins with a symbol other than a comparison symbol, indent four cells to the right of the anchor margin.

Example 9-4: New Line Begins at Element SYMBOL

1. The following products were derived from which reactant(s)?

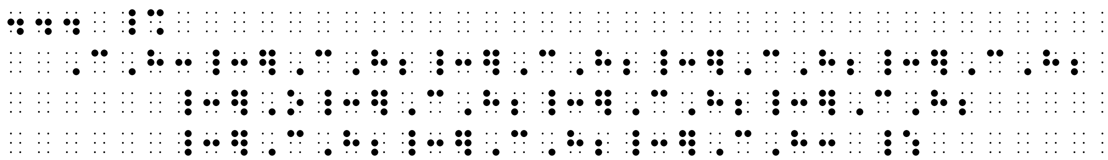
$$CH_3(CH_2)_{10}CH_2OSO_2O^-Na^+ + H_2O$$



Observe: Division is made before the baseline indicator before the SYMBOL Na. It is not necessary to divide again before the symbol of operation (plus sign).

Example 9-5: Long Chain

$$CH_3—CH_2—CH_2—CH_2—CH_2—O—CH_2—CH_2—CH_2—$$
$$CH_2—CH_2—CH_3$$



Observe: Division is made before bond symbols, as needed.

9.4 Spatial Structures

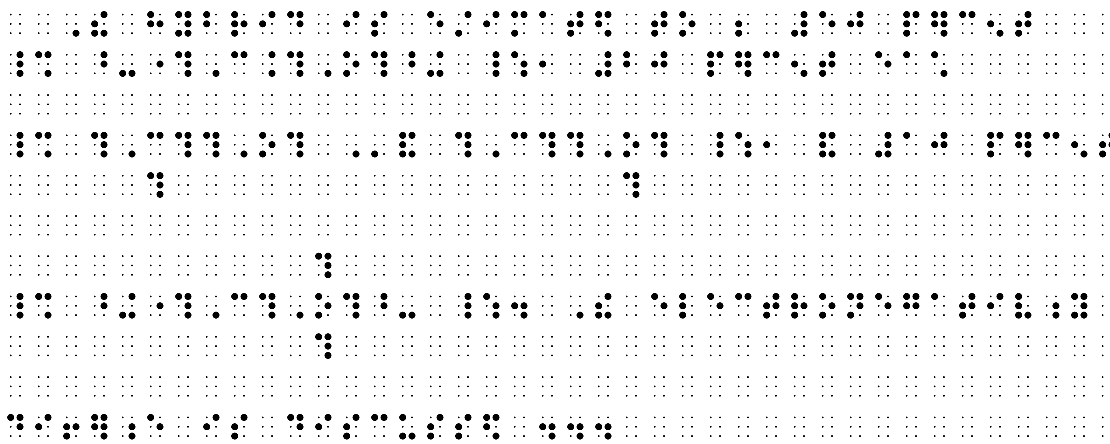
Structures occupying more than one print line and having a vertical relationship are spatial arrangements. Spatial material is preceded and followed by a blank line, whether embedded or displayed.

9.4.1 **Alignment.** Every attempt is made to align the components of a spatial chemical diagram as they align in the print copy. Note that there tends to be a main line of element SYMBOLS, around which Lewis dot symbols may lie, or off of which branching may occur. When enlarged grouping signs are included in the diagram, see Section 9.4.4.

9.4.2 **Embedded Spatial Material.** When spatial material is embedded in narrative text, the portion of text which occurs on the same braille line as the spatial material is aligned with the main line of the chemical expression.

Example 9-6: Embedded Lewis Structures

The hybrid is estimated to be 50 percent $^{-}$:C:::O:$^{+}$, 20 percent each :C::O: and :C::O:, and 10 percent $^{+}$:C:Ö:$^{-}$. The electronegativity difference is discussed …



Observe: The first embedded expression is linear; no blank lines are needed. The second and third embedded expressions are spatial; a blank line is inserted both above and below each of them.

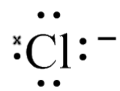
9.4.3 **Displayed Spatial Material.** When displayed chemical material contains a vertical component, the leftmost symbol is placed in cell 1 regardless of the layout of the preceding text. This rule applies to spatially arranged molecular diagrams, Lewis diagrams with dot symbols on the line above or below the element SYMBOL, labeled diagrams, modified arrows, and modified or labeled bonds. The entire structure must be preceded and followed by a blank line in order to set it apart from the surrounding narrative. Code switch indicators are placed outside of the blank lines. *Exception:* In the case of a large diagram, if space on the page does not permit the inclusion of a blank line, a code switch indicator may replace the blank line. This exception should be used sparingly.

Example 9-7: Displayed Expressions: One Linear, One Spatial

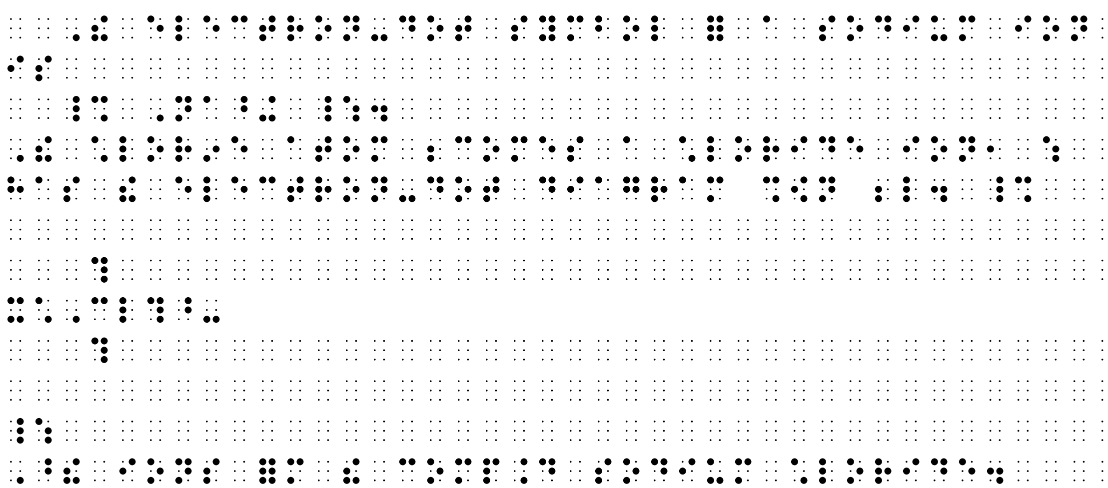
The electron-dot symbol for a sodium ion is

$$Na^{+}.$$

The chlorine atom becomes a chloride ion, which has the electron-dot diagram shown below.



These ions form the compound sodium chloride.



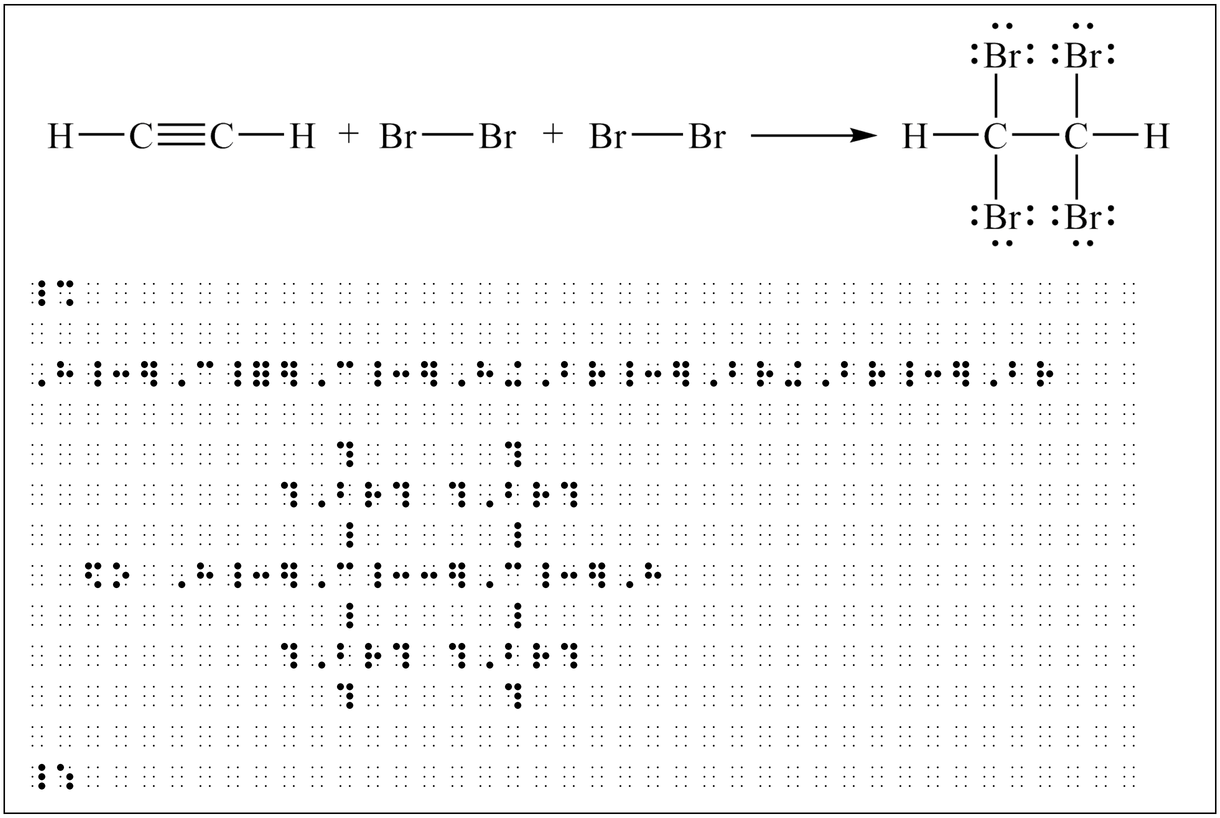
Observe: The first displayed item Na⁺ is not spatial therefore no blank lines are inserted, and it is placed in cell 3 according to format rules of the Nemeth Code. The Nemeth Code terminator is placed in cell 1 on a line by itself following the blank line after the spatial problem. See Section 2.5.2 regarding transcription of the dissimilar electron pair.

a. **Runovers to Spatial Material.** When a spatial diagram is too wide to fit on the braille page, the following rules apply. Start the runover line with a chemical arrow (or other comparison sign) or with an operation sign or a bond symbol, indented two or four cells from the left margin according to the rules for runovers of displayed expressions in the Chemistry Code. See Section 9.3.1 or Section 9.3.2. In any case, avoid dividing material between bonds or within ring structures. Leave one blank line above the highest symbol in the runover portion of the diagram.

   If a diagram requires more than one page, all runovers may begin in cell 1 if this allows the material to be presented on fewer pages. See Example 9-14, Fat Molecule.

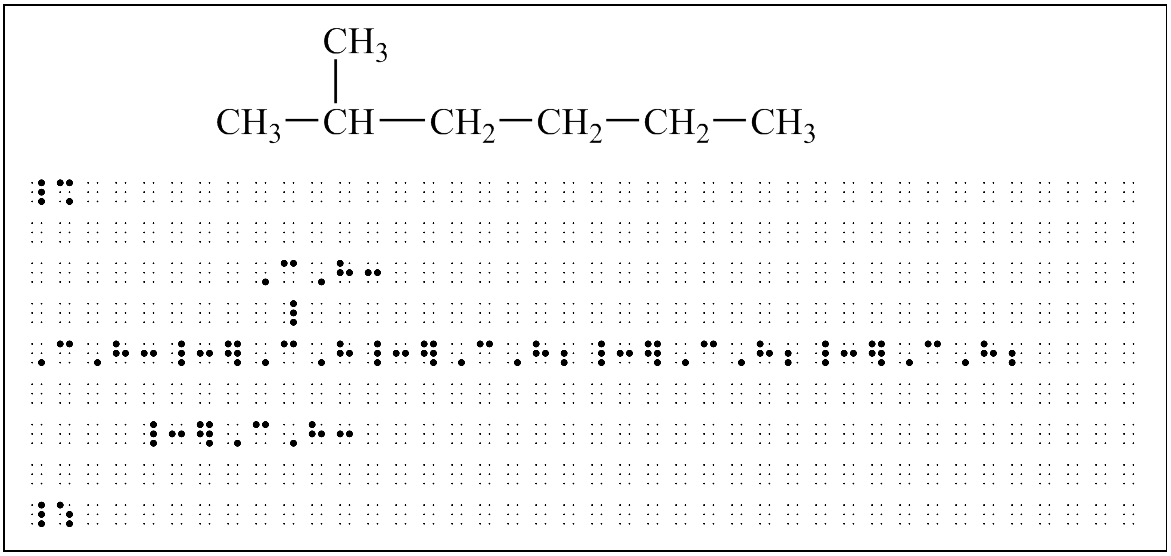
   The division site will be obvious if the line breaks at the rightmost symbol on the line and if the runover line begins at its left margin (cell 3 or cell 5). If this is not the case, a runover locator is used. See Section 9.4.6.

Example 9-8: Runover Begins with Yields Arrow (cell 3)



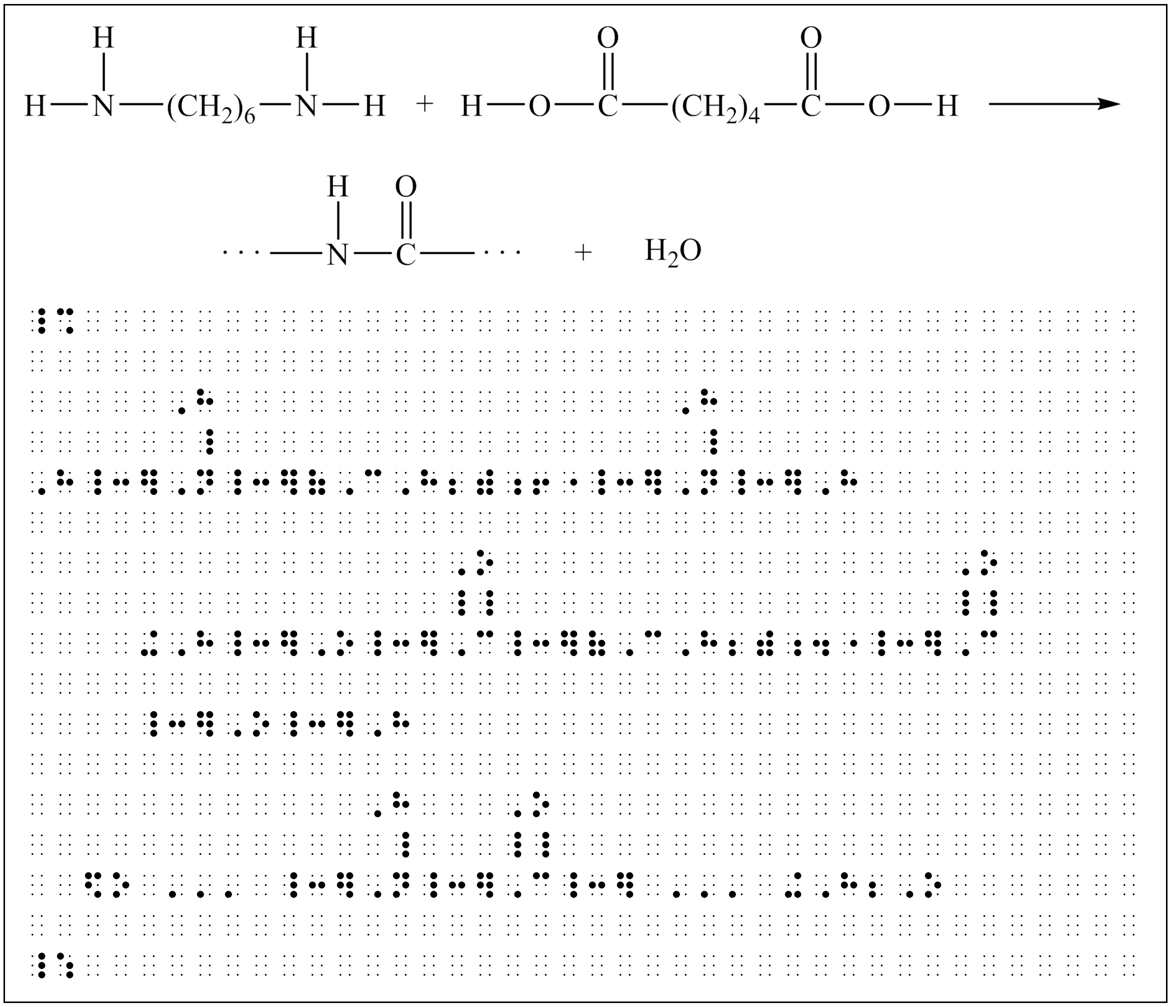
Observe: Even though the first line of this chemical equation is linear, a blank line precedes it because it is part of the overall spatial diagram. The horizontal bond between the carbon atoms is lengthened in order to maintain one blank cell between the electron pairs associated with the neighboring bromine atoms.

Example 9-9: Runover Begins with Bond Symbol (cell 5)



Observe: Even though the last line of this chemical equation is linear, a blank line follows it because it is part of the overall spatial diagram.

Example 9-10: Wide Diagram Requiring Several Runovers



Observe: The molecular diagram begins in cell 1; the yields arrow is in cell 3; the plus sign and the horizontal bond are in cell 5. (The ellipses in this example represent omissions.)

9.4.4 **Alignment with Enlarged Signs of Grouping.** Chemical symbols which lie outside of enlarged signs of grouping are aligned as they relate to the main line of the chemical structure. See Example 5-17 and Sample 10-3. Mathematical symbols which lie outside of the grouping signs are aligned with the topmost grouping symbol, according to the rules of the Nemeth Code. See Examples 2-6, 2-17, 2-30, 5-16, 5-18, 9-18, and Samples 10-3, 10-15, 10-25, and 10-26.

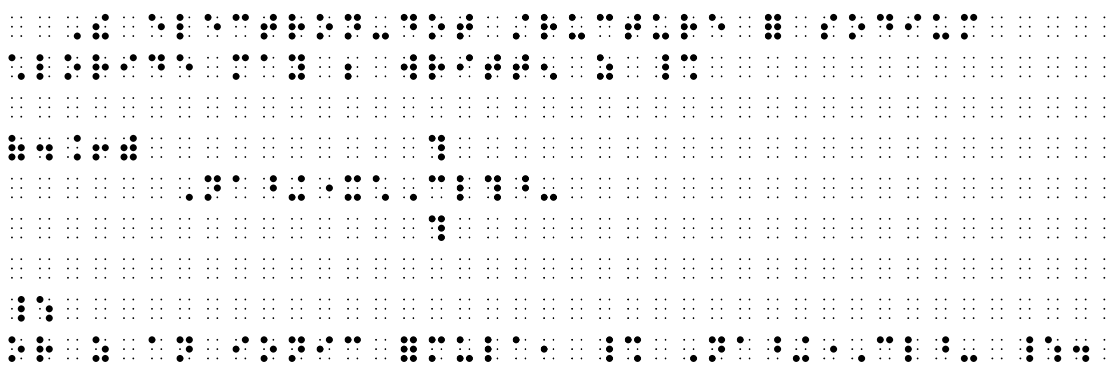
9.4.5 **Spatial Structures with Identifiers.** When a spatial chemical structure is identified by a number or letter, as in an example or in a set of exercises, the identifier is placed on the same line as the top line of the braille diagram. One column of blank cells is left between the identifier and the left-most symbol of the overall diagram.

Example 9-11: Displayed Lewis Structure with an Identifier

The electron-dot structure for sodium chloride may be written as

$$Na^{+}\ \overset{\times}{\vdots}\overset{\cdot\cdot}{\underset{\cdot\cdot}{Cl}}\colon^{-} \qquad (4.6)$$

or as an ionic formula, $Na^{+}Cl^{-}$.

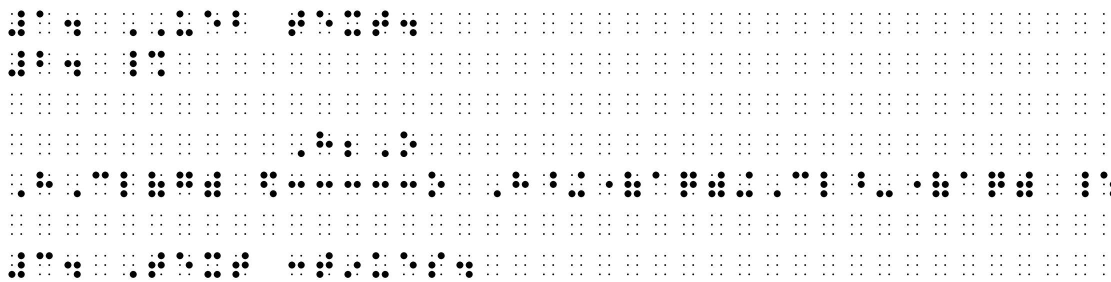


Observe: Nemeth Code rules are followed regarding placement at the left when identifiers are printed at the right. The identifier begins in cell 1 according to standard layout for displayed spatial arrangements. See Section 2.5.2 regarding transcription of the dissimilar electron pair.

If a chemical expression will not fit on the line with its identifier, but will fit on the next line without runovers, place the identifier on a separate line. The required blank line follows the identifier.

Example 9-12: Hydration Reaction

1. UEB text.
2. $\mathrm{HCl}(g) \xrightarrow{\mathrm{H_2O}} \mathrm{H}^+(aq) + \mathrm{Cl}^-(aq)$
3. Text continues.

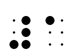


Observe: A spatial arrangement begins in cell 1, even in itemized format.

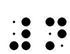
9.4.6 **Runover Locator.** A runover locator is used within a wide spatial diagram when the division site is not obvious. The division site is not clear if it is not the rightmost symbol on the line, and the runover site is not clear if it does not begin at the left margin (cell 3 or cell 5).

A runover locator may also be used when a diagram is divided between braille pages or between facing pages. The runover locator is a cue to the reader that the diagram continues.

List the symbol on the Special Symbols page as follows.

 Runover locator

When more than one runover number is needed, list the symbol on the Special Symbols page as follows.

 Runover locator (where n represents an upper number assigned by the transcriber)

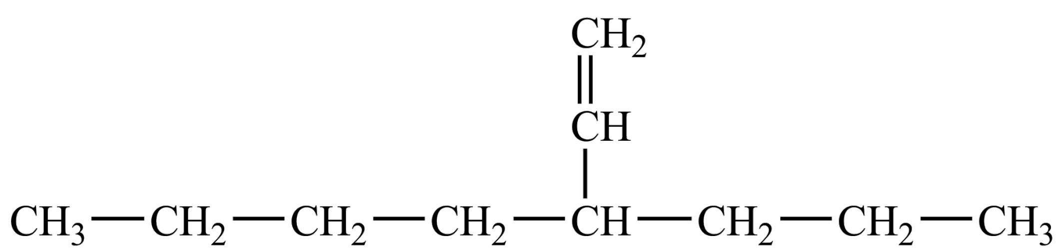
The runover locator and its associated number is inserted after the last symbol at the division site. An identical locator is then inserted before the first symbol of the continued runover line. The runover locator is unspaced from the material to which it applies. More than one runover locator may be needed in the same diagram.

A transcriber's note will inform the reader of the use of this symbol.

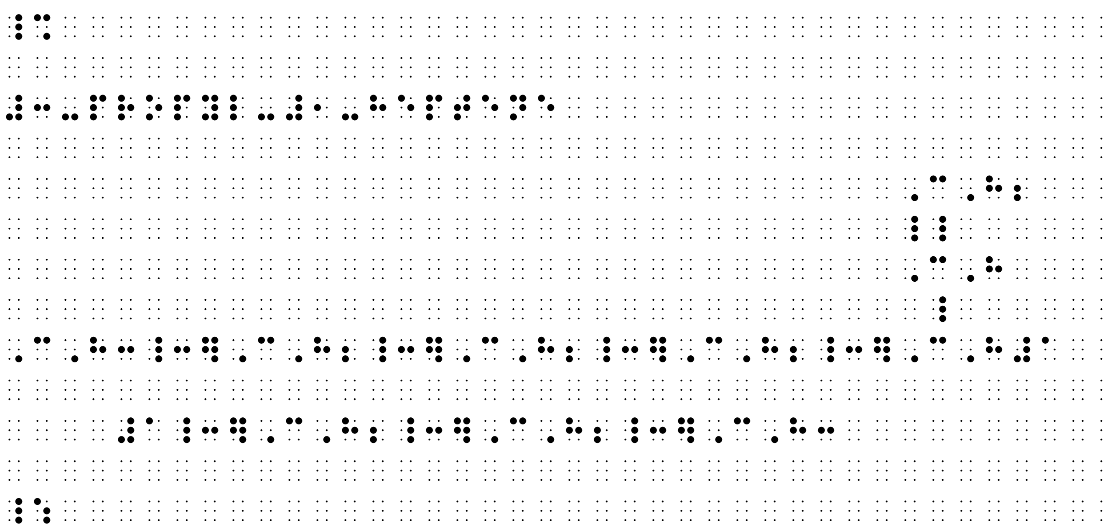
Sample transcriber's note:

Runover locators (upper-cell numbers) are used in the diagram below. Follow identical numbers to continue the line.

Example 9-13: Runover Labeled in a Chain



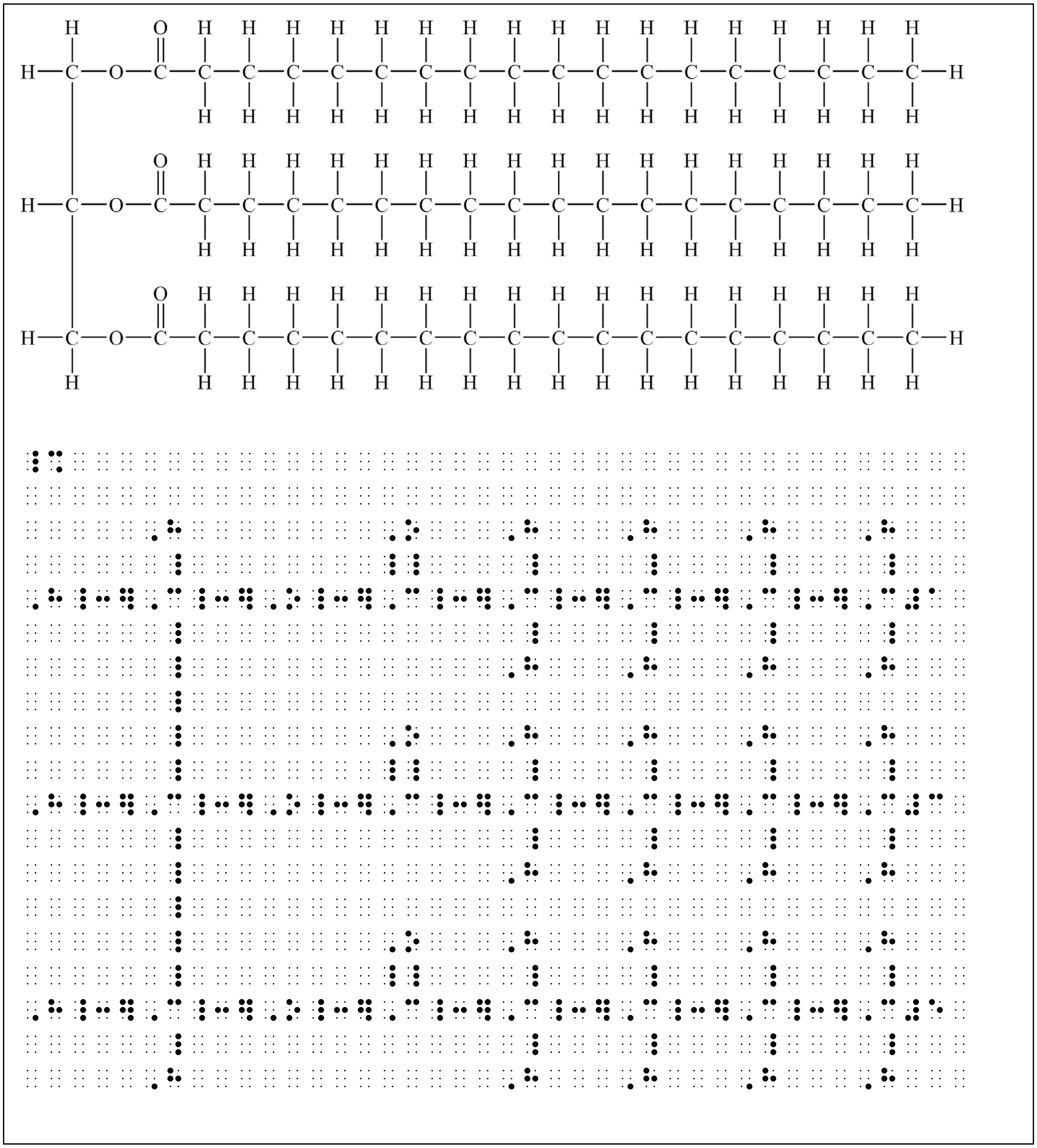
3-propyl-1-heptene



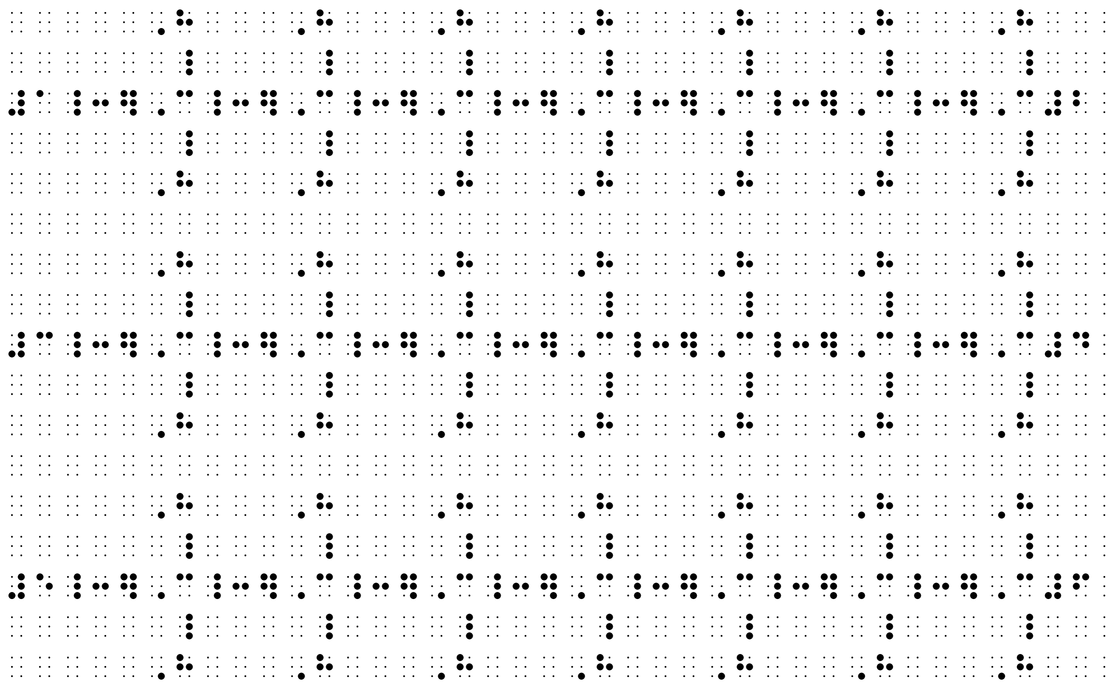
Observe: The division site is not the rightmost braille symbol in the line. The runover locator makes it clear that the line has been divided. Division is made before a bond symbol. The matching runover locator begins the runover line.

a. **Branched Structures.** In a branched structure where individual branches in the diagram require runovers, number the locators of each branch in sequence. The first division site in the overall diagram is labeled #1, the second #2, etc.

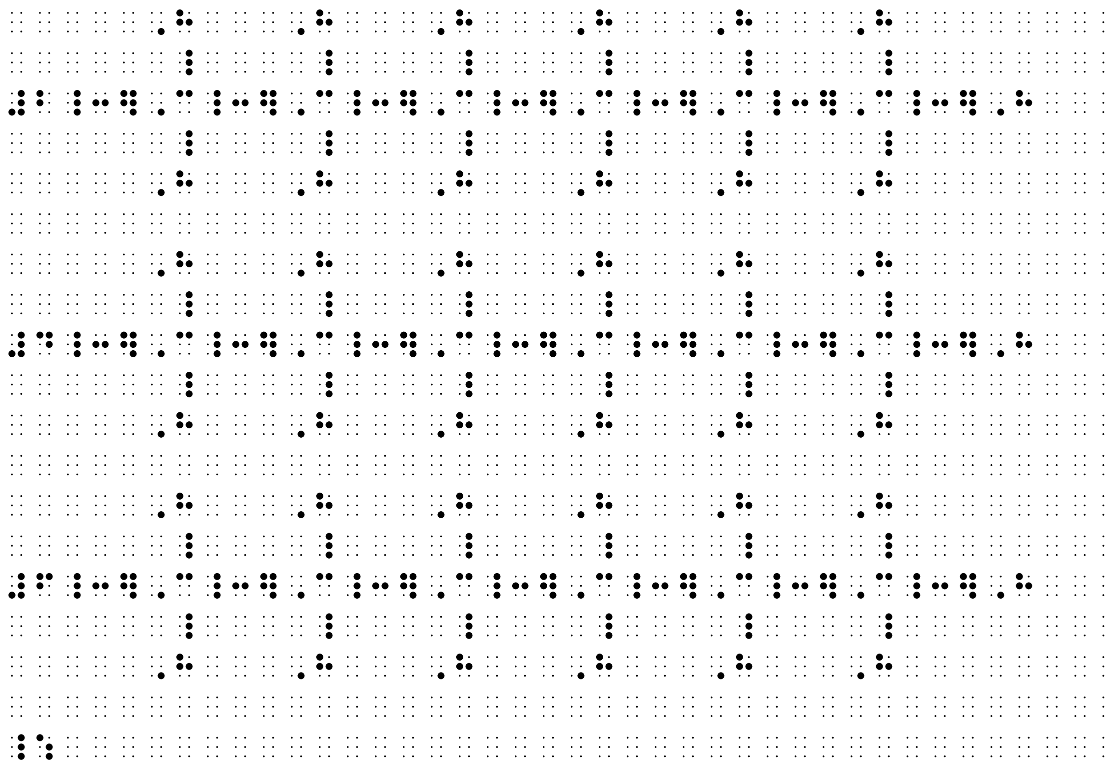
Example 9-14: Fat Molecule



//// NEW BRAILLE PAGE ////



//// NEW BRAILLE PAGE ////



Observe: This large molecule requires three braille pages with three sequentially numbered runover sites on each page. The runover to the first branch is numbered "1" and its runover is numbered "2". To avoid an additional page, all runover lines are positioned in cell 1.

9.5 Remarks or Conditions

When remarks or conditions appear with a chemical formula or chemical structure, start them on a new line regardless of their location in the print copy. Explain the change in print layout in a transcriber's note. (Sample transcriber's notes are given in the sections, below.)

9.5.1 **Condition Applied to a Linear Chemical Expression.**

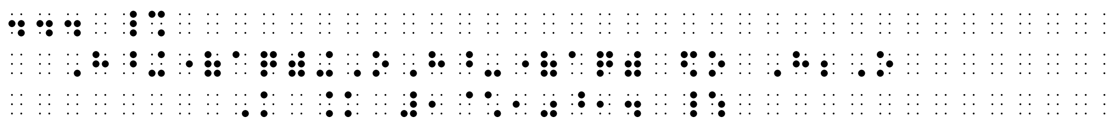
Place the remark on the next line. Block the remark six cells to the right of the start of the expression.

Sample transcriber's note:

Remarks printed to the right of chemical expressions are transcribed on a new line following the completion of the expression. Remarks are blocked six cells to the right of the start of the expression.

Example 9-15: Condition Applied to a Displayed Reaction

$$\mathrm{H}^{+}(aq) + \mathrm{OH}^{-}(aq) \rightarrow \mathrm{H_2O} \qquad \mathrm{K} = 1 \times 10^{14}$$

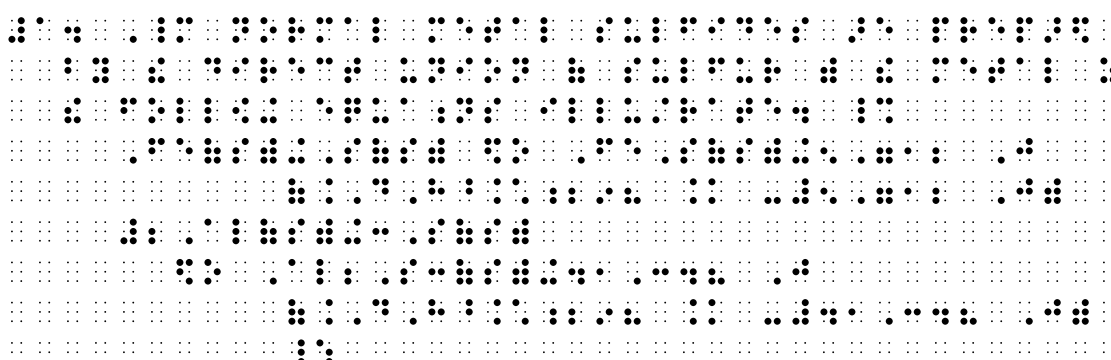


Example 9-16: Conditions with Runovers

1. Many normal metal sulfides are prepared by the direct union of sulfur with the metal as the following equations illustrate.

$$\mathrm{Fe}(s) + \mathrm{S}(s) \rightarrow \mathrm{FeS}(s) + 5{,}712\ \mathrm{J} \qquad (\Delta H^{\circ}_{298} = -5{,}712\ \mathrm{J})$$

$$2\mathrm{Al}(s) + 3\mathrm{S}(s) \rightarrow \mathrm{Al_2S_3}(s) + 41{,}348\ \mathrm{J} \qquad (\Delta H^{\circ}_{298} = -41{,}348\ \mathrm{J})$$



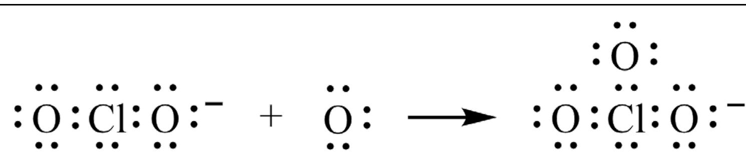
Observe: Typeform of physical states and constant H are disregarded in braille. The degree symbol is an integral part of the symbol ΔH° and is transcribed before the subscript. See Section 5.3.1, Hollow Dot and Star or Asterisk in Superscript Position.

9.5.2 **Remark Applied to a Spatial Chemical Expression.** Insert a blank line when the remark follows a spatial arrangement. Block the remark in cell 7. To make it clear that the remark belongs to the diagram, Nemeth Code does not terminate until the completion of the remark. Placing the termination symbol in cell 1 further clarifies the completion of the spatial expression.

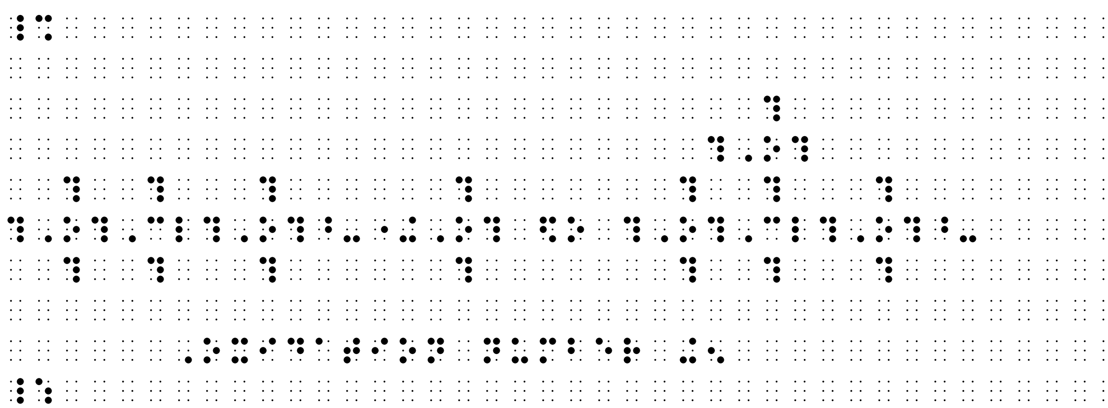
Sample transcriber's note:

Remarks printed to the right of chemical structures are transcribed on a new line following the completion of the diagram. Remarks are blocked in cell 7.

Example 9-17: Remark Applied to a Spatial Structure

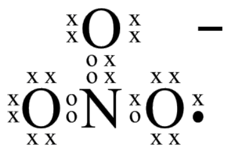


Oxidation number +5

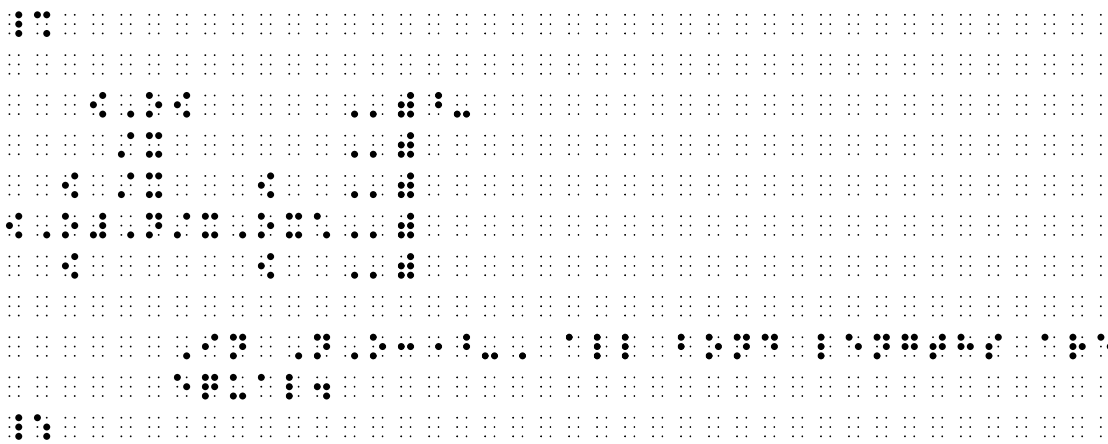


Observe: A blank line need not follow the remark unless it contains a spatial component.

Example 9-18: Comment Applied to a Spatial Structure



In NO_3^-, all bond lengths are equal.



Observe: The enlarged grouping symbol does not appear in print. See Section 5.4.2, Transcriber-Inserted Grouping Symbols.

9.6 Factor Label or Fraction Computation

⠸ Vertical line (Nemeth Code symbol) |

Note: Include the symbol on the Special Symbols page only if the vertical single bond (dots 456) also appears in the volume.

This computation method may be encountered under the topic of dimensional analysis. In factor label computation, several fractions are separated with a vertical line instead of using separate fraction indicators. Transcription rules are as follows.

a. These fractions are transcribed spatially.

b. Only two fraction indicators are transcribed. The first fraction line begins with the opening fraction indicator and the final fraction line ends with the closing fraction indicator.

c. The vertical line of the Nemeth Code is used for the dividing line between each fraction. The vertical line extends through the horizontal fraction line.

d. When a runover is necessary, a break is made after one of the vertical lines. The first cell of the continued horizontal fraction line must have a blank cell above and below it.

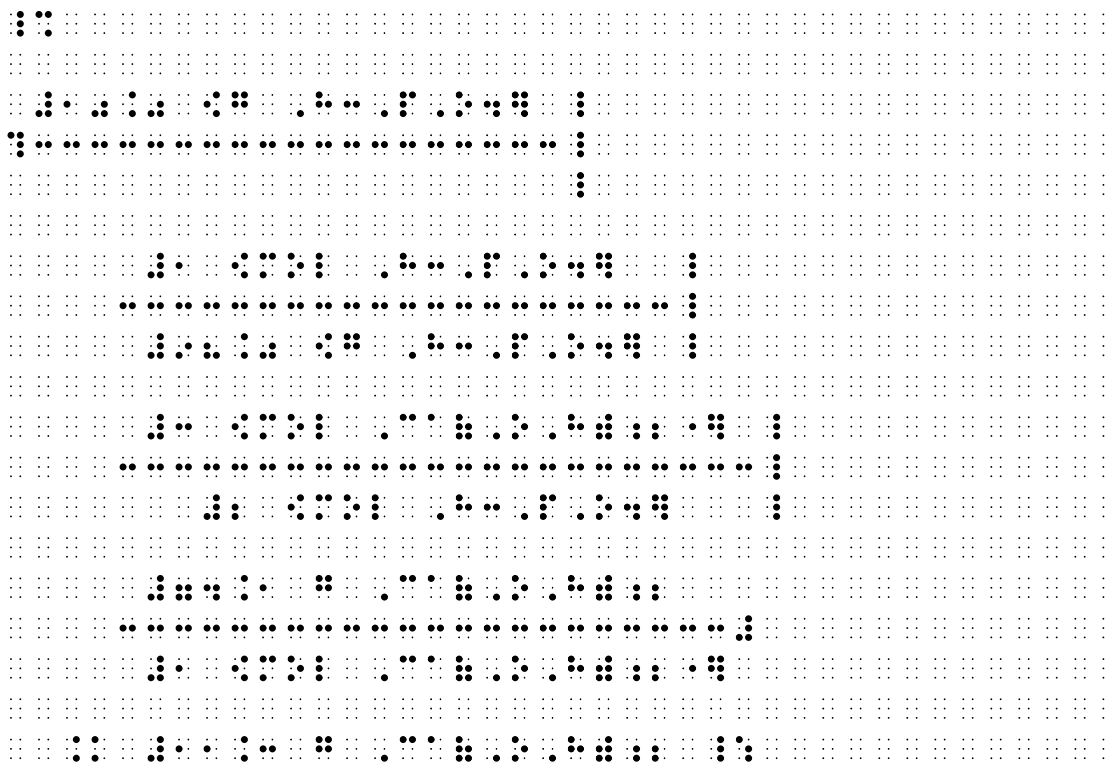
e. The fraction line extends one cell beyond the longest entry above or below it, except where the fraction line touches the opening or closing fraction indicator. Shorter entries are centered above and below the corresponding fraction line.

f. Blank fields are blank in braille. A general omission symbol is not used to represent a blank field.

Example 9-19: Factor Label Computation

$$\frac{10.0\ \cancel{\text{g H}_3\text{PO}_4}}{} \left| \frac{1\ \cancel{\text{mol H}_3\text{PO}_4}}{98.0\ \cancel{\text{g H}_3\text{PO}_4}} \right| \frac{3\ \cancel{\text{mol Ca(OH)}_2}}{2\ \cancel{\text{mol H}_3\text{PO}_4}} \left| \frac{74.1\,\text{g Ca(OH)}_2}{1\ \cancel{\text{mol Ca(OH)}_2}} \right.$$

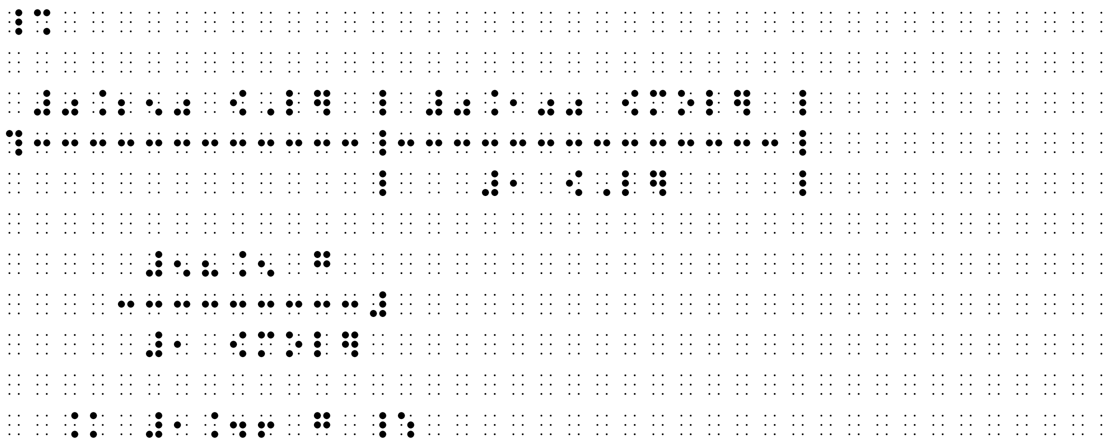
$$= 11.3\,\text{g Ca(OH)}_2$$



Note: Cancellation is discussed in Section 9.7.

Example 9-20: Factor Label Computation

$$\frac{0.250\,\cancel{L}}{} \;\Bigg|\; \frac{0.100\,\cancel{\text{mol}}}{1\,\cancel{L}} \;\Bigg|\; \frac{58.5\,\text{g}}{1\,\cancel{\text{mol}}} = 1.46\,\text{g}$$



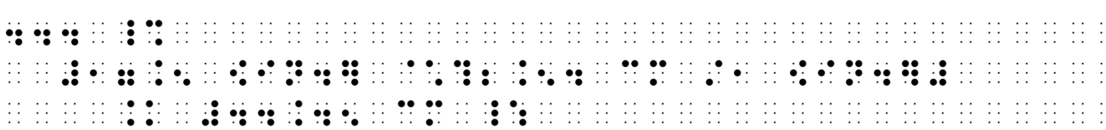
Note: Cancellation is discussed in Section 9.7.

9.7 Cancellation

Fractions containing cancellation of like items are common in chemistry. Such fractions are transcribed linearly when the cancelled items do not have replacement symbols. When replacement symbols are present, the fraction is arranged spatially. See Rule 12 of the Nemeth Code.

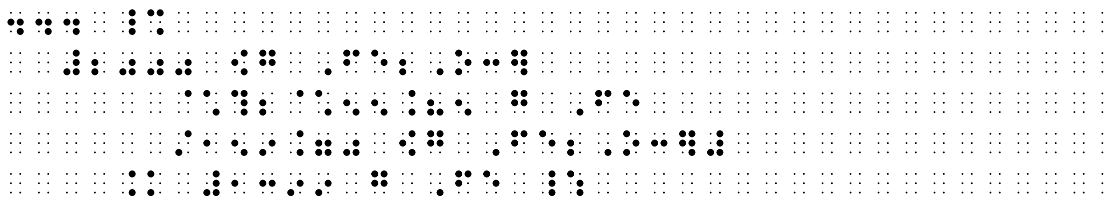
Example 9-21: Cancellation with No Replacement Symbols

$$17.5\,\cancel{\text{in}}. \times \frac{2.54\,\text{cm}}{1\,\cancel{\text{in}}.} = 44.45\,\text{cm}$$



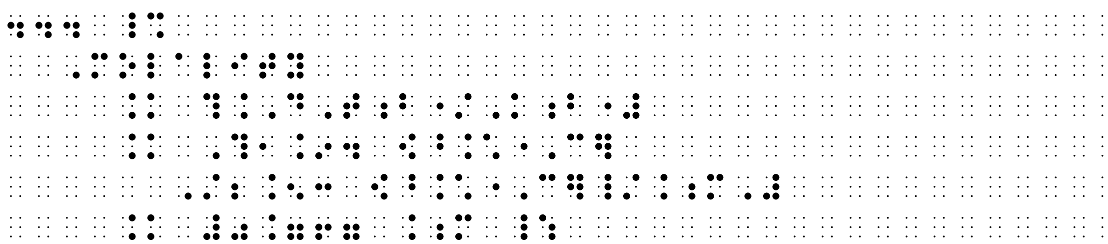
Example 9-22: Cancellation with No Replacement Symbols

$$2000\ \cancel{\text{g Fe}_2\text{O}_3} \times \frac{2\times 55.85 \text{ g Fe}}{159.70\ \cancel{\text{g Fe}_2\text{O}_3}} = 1399 \text{ g Fe}$$



Example 9-23: Cancellation with No Replacement Symbols

$$\text{Molality} = \frac{\Delta T_b}{K_b} = \frac{1.94\,\cancel{°\text{C}}}{2.53\,\cancel{°\text{C}}/m} = 0.767m$$



Observe: Typeform is retained for m (molality) but not for variable T and constant K. See Section 6, Typeform of English Letters in Chemical Expressions.

Section 10
Molecular Diagrams

BRIEF CONTENTS

The rules outlined in this section are illustrated in the Samples section. The samples are also available in braille using raised line tactile graphics.

10.1 Definition of a Molecular Structure

In chemistry, a molecular structure is a representation of a 3-dimensional configuration portrayed on a 2-dimensional page. Print publishers use a variety of shapes, lines, and dots to depict the 3-dimensional nature of a molecule.

Most molecular structures are spatial arrangements as defined by the Nemeth Code – that is, a structure which occupies more than one line and has a vertical relationship. Whether embedded or displayed, spatial material is both preceded and followed by a blank line. Exceptions may apply to a full-page diagram.

10.2 Principles Regarding the Use of Tactile Diagrams

Many chemical structures cannot be represented clearly with braille symbols alone, particularly when bonds are oblique or when chemical arrows are vertical or oblique. The preferred method is to provide a tactile graphic, representing certain parts of the molecular structure with braille symbols and other parts with raised lines. Using a combination of braille symbols and raised line drawings can improve comprehension of a diagram by allowing the element SYMBOLS to stand out from the bonds and chemical arrows. The final result gives an accurate portrayal of the print copy, facilitating collaboration with colleagues.

10.2.1 **Transcriber's Note Required.** When bonds and chemical arrows are depicted as raised line drawings in the diagrams as well as with braille symbols within the narrative, the reader must be informed, either on the Transcriber's Notes page or in a transcriber's note at the location, as appropriate. Sample transcriber's note on a Transcriber's Notes page:

> Chemical bonds and arrows are depicted either as braille symbols or as raised line drawings. Braille symbols used for bonds and chemical arrows are listed on the Special Symbols page. Tactile graphics used for bonds and chemical arrows replicate the lines and textures used in print, with the exception of certain arrowhead styles, described below. Tactile graphics which use different lines or textures than are used in the print image are explained immediately prior to the diagram.

See Section 10.4.3 regarding arrowhead styles to be used in the tactile graphic.

10.2.2 **Code Switching.** A switch to Nemeth Code is required when the diagram contains math or chemistry symbols. The opening Nemeth Code indicator is placed according to Nemeth Code rules, at the end of the preceding text or in cell 1, followed by the blank line required before the diagram. A blank line also follows the diagram, and the Nemeth Code terminator, if needed, is in cell 1 on the next line. Follow the directives in *Guidelines and Standards for Tactile Graphics* for placement of the code switch indicators with full-page diagrams.

A switch to Nemeth Code is not necessary if the structure does not contain math or chemistry braille symbols.

10.3 Considerations Regarding the Use of Braille Symbols

10.3.1 **Some Braille Symbols Are Required.** Within a chemical diagram produced as a tactile graphic, element SYMBOLS and electron dots in Lewis structures are transcribed as braille symbols. Labels and mathematical symbols, including the chemical period, are also transcribed as braille symbols. See Section 4.1, Symbols for the Chemical Elements, Section 4.2, Chemical Period, Section 2.5, Lewis Structures, and Section 8, Labels.

10.3.2 **Some Braille Symbols Are Optional.** Within a chemical diagram, the method used to depict bonds, arrows, and enlarged grouping signs is determined individually for each diagram. Some molecular structures may be depicted using only braille symbols, as illustrated in Sections 1-9 of this code book. A tactile drawing may not be necessary in the following situations.

a. **Chemical Bonds.** As long as no other chemical part of the diagram is depicted as a raised line drawing, a molecular structure containing only straight vertical or horizontal bonds may be transcribed entirely with braille symbols. This includes horizontal arrow bonds. See Section 2, Chemical Bonds. Alternatively, a simple structure may be prepared as a raised line drawing following the guidelines presented in Section 10.4.1. Methods may not be mixed within the same diagram—if one bond is drawn, all bonds in that diagram must be drawn.

b. **Chemical Arrows.** As long as no other chemical part of the structure is depicted as a raised line drawing, a molecular structure containing only horizontal chemical arrows may be transcribed entirely with braille symbols. See Section 3, Chemical Arrows. Alternatively, a simple structure may be prepared as a raised line drawing following the guidelines presented in Section 10.4.3. Methods may not be mixed within the same diagram—if one chemical arrow is drawn, all chemical arrows in that diagram must be drawn.

c. **Enlarged Grouping Signs.** Enlarged grouping signs may be transcribed as braille symbols when there are no other graphics in the structure. (See Examples 2-16 and 2-29 in Section 2, Chemical Bonds, and Examples 5-16 and 5-17 in Section 5, Superscripts and Subscripts.) However, note that the grouping sign must be drawn if it passes through a bond. See Section 10.4.7.a.

d. **Feasibility.** If methods for timely production of tactile graphics are not available, chemical bonds, chemical arrows, and ring structures may be transcribed as braille symbols. See Appendix B.

10.4 Guidelines for Depicting Molecular Structures as Tactile Diagrams

Refer to *Guidelines and Standards for Tactile Graphics* for instructions regarding production techniques including line styles and spacing.

10.4.1 **Drawing Chemical Bonds.** Care must be taken to reproduce the print layout as closely as possible. In particular, bonds must clearly lead to the correct element SYMBOL and bond angles should be duplicated as closely as possible in the drawing. A dotted bond should use a minimum of four dots. A bond may be lengthened in order to accommodate surrounding material. If production methods do not allow for a clear representation of oblique bonds, see Section 10.4.9.

See the following Samples:

10-1: Single and Double Bonds

10-2: Oblique Arrow Bonds

10-3: Dashed (Broken) Bonds

10-4: Dotted Bond

10-5: Wedge Bonds – Solid and Barred

10-6: Wedge Bonds – Solid and Barred

10-7: Jagged Bond and Wedge Bonds

10-8: Wavy Bond

10.4.2 **Drawing Ring Structures.** The unique geometric shape of ring structures can be effectively reproduced as a tactile graphic. In a labeled ring structure, place the labels outside the ring regardless of the placement in print. See Section 10.5.2 for details regarding label placement in ring structures with numbered atoms.

See Samples 10-9 (a)-(e): Ring Structures

10.4.3 **Drawing Chemical Arrows.** Chemical arrows are printed with either solid or open arrowheads. There is no difference in meaning. Because the solid triangle shape also represents a wedge bond, it is recommended that the open arrowhead be used for chemical arrows in the tactile graphic even when solid arrowheads are shown in print. A transcriber's note informs the reader of the change. Sample transcriber's note:

> Chemical arrows are drawn with an open arrowhead. In print, a solid arrowhead is used.

See *Guidelines and Standards for Tactile Graphics* for specifications regarding the shape and spacing of the "open" arrowhead. See Section 10.4.5 for rules regarding non-chemical arrowhead styles.

a. **Reversible Reaction Arrow.** The reversible reaction arrow consists of two arrows pointing in opposite directions, printed one above the other for horizontal arrows or side by side for vertical arrows. In print, the arrowheads may be a full barb or a half barb ("harpoon"). The arrow shafts may be the same length, or one may be longer than the other.

In a reversible reaction arrow, there is no difference in chemical meaning between a full barb and a half barb. When a reversible reaction arrow is drawn as a tactile graphic, use harpoons for the arrowheads regardless of the print form. This allows for a cleaner graphic. Changing a full barb to a half barb applies only to reversible reaction arrows. (Rules regarding the arrowhead are different when these arrows are depicted as a braille symbol. See Section 3.1.4, Reversible Reaction Arrow.)

A transcriber's note informs the reader of the change when arrowhead styles differ from the print. Sample transcriber's note:

> Reversible reaction arrowheads are drawn as half barbs (harpoons).

Orientation (vertical pointing or horizontal pointing) and relative length of arrow shafts should be duplicated in the drawing.

Older texts may show one of the arrows in bold type. If encountered, disregard typeface and use a longer shaft for the bold arrow. Explain the change in a transcriber's note.

Sample transcriber's note:

> The longer arrow is printed as a boldface arrow of regular length.

See the following Samples:

- 10-10: Reversible Reaction Arrow
- 10-11: Vertical Reversible Reaction Arrow
- 10-12: Unequal Reversible Reaction Arrow
- 10-13: Reversible Reaction Arrow
- 10-14: Bold Reversible Reaction Arrows

b. **Curved Arrow.** A curved chemical arrow depicts the flow of electrons. The curved line of the arrow shaft should be duplicated. The number of barbs has chemical significance and must be reproduced as printed, using the "open" arrowhead or barb in the tactile graphic.

   See the following Samples:

   10-15: Curved Arrows

   10-16: Curved Arrows

   10-17: Single-Barbed "Pushing" Arrows

   If production methods do not allow for a smooth curved line, See Section 10.4.9.

c. **Dipole Arrow.** Dipole arrows often appear in conjunction with a bond. Vertical and oblique dipole arrows as well as dipole arrows in more complex structures are best drawn as a tactile graphic, including the "plus" sign comprising the tail of the arrow shaft.

   The length of the dipole arrow is significant. Care must be taken to show the beginning and end of the dipole arrow in relation to the bond it is modifying.

   Because of the unique structure of this arrow, it is recommended that a graphic key be included for the dipole arrow. See the following samples:

   10-18: Dipole Arrows

   10-34: Partial Charge Labels; Dipole Arrow

   If production methods do not allow for a clear representation of oblique arrows, see Section 10.4.9 and Section B.3.2.b in Appendix B regarding the oblique dipole arrows represented with braille symbols.

   See Section 3.2.2, Dipole Arrows, regarding the use of the braille symbol for a horizontal dipole arrow appearing in a simple structure.

d. **Snaking.** Snaking is a print style, discussed in Section 3.1.5, Snaking. If there is doubt regarding the progression of chemical symbols, reconstruct the print arrangement using tactile graphics to represent the reaction arrows and the bonds.

10.4.4 **Lead Lines.** A lead line connects a label to the labeled component. Lead lines are drawn as a tactile graphic, even when all other portions of the diagram use braille symbols.

Current guidelines for tactile graphics state that a lead line should be straight, with no arrowhead. One end of the lead line should touch the component it identifies, and the other end should be at least 3 mm from the beginning or end of the braille label. The length of the lead line should be between 2 cm and 3.75 cm.

The label should be placed a minimum of 3 mm to a maximum of 6 mm from any other component. If this layout cannot be achieved, the label must be placed far enough away to allow a 2 cm lead line.

In a diagram with other tactile lines, the line style for the lead line must be the least significant line in the graphic. The line may be solid or textured, as needed, to distinguish it from the lines with chemical significance.

If a line or an arrow in print leads to an area rather than to a specific component, or if a component is labeled and no lead line is present in print, follow print layout as closely as possible in order not to give false information.

See the following samples:

10-19: Labels with Lead Lines

10-20: Labels With and Without a Lead Line

Note: If there is chemical significance to the direction indicated by the arrowhead, it is a chemical arrow, not a lead line. See Section 10.4.3 and Section 10.4.5.

See Section 8, Labels, for instructions regarding labeled chemical expressions, labeled atoms, and labeled bonds.

10.4.5 **Directional Arrows and Mechanistic Arrows.** Directional arrows and mechanistic arrows must be drawn as a tactile graphic, duplicating the arrowhead style used in print.

See the following Samples:

10-21: Orbital Diagram

10-22: Mechanistic Arrows

10.4.6 **Separators.** Separators may be encountered under the topic of bond enthalpy or endothermic reactions where a broken (dashed), dotted, or jagged line may occur between areas of a molecular structure in order to illustrate the breaking of a bond. These lines must be drawn as a tactile graphic, even if the other components of the structure are depicted as braille symbols.

See Sample 10-23: Broken Bond Separator

10.4.7 **Drawing Enlarged Grouping Signs.** Enlarged grouping signs should be drawn when there are other graphics in the structure. The line style used for the enlarged parentheses, brackets, or braces should be tactually less significant than the line style used within the chemical structure itself.

See the following Samples:

10-3: Dashed (Broken) Bonds

10-15: Curved Arrows

10-24: Ring Structures Within Enlarged Brackets

10-25: Enlarged Parentheses

a. **Overlapping Lines.** When an enlarged grouping sign passes through a bond, it must be drawn as a tactile graphic, using a textured line style. Keep the grouping line intact by creating a break (blank space) in the bond line where the grouping line crosses it.

See the following Samples:

10-26: Enlarged Bracket Passing Through Oblique Bonds

10-27: Monomer Unit Enclosed in Enlarged Parentheses

10-28: Enlarged Bracket Passing Through a Horizontal Bond

10.4.8 **Models.** 3-dimensional images portraying atoms as colored spheres (such as ball-and-stick models and space-filling models) can be produced as a graphic, using textures for the colors. No more than five different area textures should be used. See further instructions in *Guidelines and Standards for Tactile Graphics.*

10.4.9 **Depiction of Oblique and Curved Lines.** It is important to use a production method that allows for a clear representation of oblique and curved lines. If an agency's tactile graphics production methods do not allow for clear representation of oblique bonds, oblique arrows, or curved arrow shafts, a combination of techniques may be devised. Curved arrow shafts may be squared off, following the recommendations in *Guidelines and Standards for Tactile Graphics.* Symbols for oblique bonds from Appendix B may be used. Depiction of oblique and curved lines should be consistent throughout a transcription.

10.5 Layout and Spacing

The diagram is preceded and followed by a blank line but may begin or end on line 1 or line 25, respectively. The leftmost cell of a diagram is placed in cell 1. The tactile graphic should follow the layout shown in print, with the following exceptions. Rules apply to placement of labels (Section 8), numbered atoms (Section 8), and modifications printed at an angle (see Section 10.5.3).

When page width restricts the layout, follow directives regarding runovers found in Section 9 and throughout this code book. It is crucial to avoid runovers within a ring structure. When a diagram requires more than one page, a transcriber's note may be inserted to alert the reader that the diagram occupies more than one page.

10.5.1 **Widely Spaced Structures.** When a diagram includes an operation sign or a comparison sign that is widely spaced from a branched structure, vertical spacing must observe the following details.

a. **Signs of Operation.** The operation sign (usually a plus sign) is placed so that it is not in the same column as any symbol in any branch. In the case of an oblique bond with a loose end, i.e., with no atom attached to the bond, a clear blank column must be left between the operation sign and the beginning or end of the diagonal bond.

   See the following Samples:

   10-10: Reversible Reaction Arrow

   10-29: Operation Sign Unspaced from Branch

   10-30: Operation Sign Spaced from Oblique Bond

b. **Signs of Comparison.** A clear blank column must be left between a comparison sign (usually a chemical arrow or an equals sign) and any symbol in any branch.

   See Sample 10-31: Spacing of Plus Sign and Yields Arrow from Branch

10.5.2 **Labeled Atoms and Vertices.** As discussed in Section 8.2.2, Labeled Atoms in a Spatial Diagram, preferred label placement in braille is directly above the element SYMBOL.

See Sample 10-32: Positive Sign Labeling an Atom

Label placement may need to be adjusted, however, in order not to interfere with the bond lines.

a. If a bond line intervenes, place the label above and to the left. If that is not possible, place the label below and to the left. A label should never be placed on the same line as the SYMBOL.

See Sample 10-33: Numbered Carbon Atoms

b. When the label is situated at the bottom of a vertex, the label may be placed directly below the SYMBOL.

See Sample 10-34: Partial Charge Labels; Dipole Arrow

c. In a ring structure with SYMBOLS, the label must be placed outside of the ring structure, preferably on the line above the SYMBOL.

See Sample 10-35: Ring Structures with Numbered Atoms

d. In a ring structure with no SYMBOLS, the label may be positioned as printed provided that the label is placed outside of the ring structure.

See Sample 10-36: Ring Structure with Numbered Vertices

10.5.3 **Modifications Printed at an Angle.** Braille symbols must be transcribed horizontally. If labels are printed on the diagonal, the associated bond or chemical arrow may be able to be drawn horizontally in order to apply the labels. Another option is to key a label that appears with an oblique bond or arrow. Or, by enlarging the drawing, a short label may fit beside the associated component. The label must be sufficiently spaced from other symbols in the diagram.

See Sample 10-37: Labels Printed at an Angle

10.6 Samples

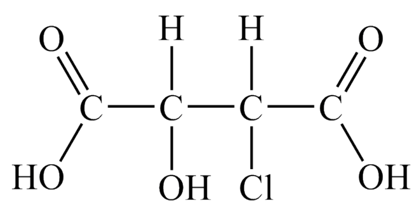
The line diagrams and simulated braille illustrations in this section are resized to fit the print page and consequently are not depicted in the actual size of a tactile graphic. The samples are also available in braille, produced on a standard 11-inch by 11.5-inch page using raised line graphics which follow the size and spacing recommendations according to *Guidelines and Standards for Tactile Graphics*.

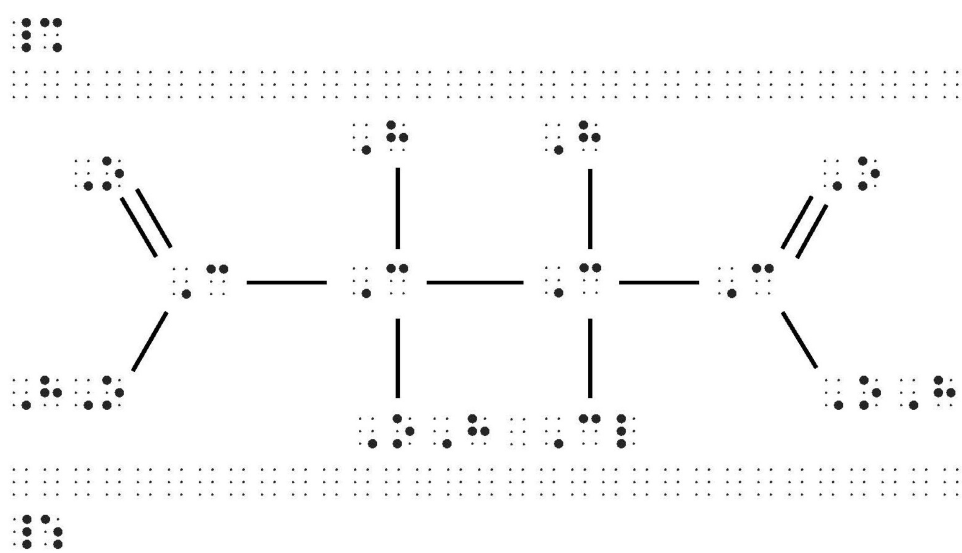
Note: In the simulated braille illustrations a blank line is indicated by a series of shadow dots across the line. Please disregard the fact that the shadow dots may not align with the braille symbols used in the diagram.

BLANK PAGE

Sample 10-1
Single and Double Bonds

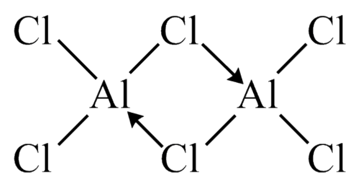
This drawing illustrates the depiction of single and double bonds as tactile lines. The angles of the oblique bonds match those in print. At least one space comes between OH and Cl because they are on separate branches.



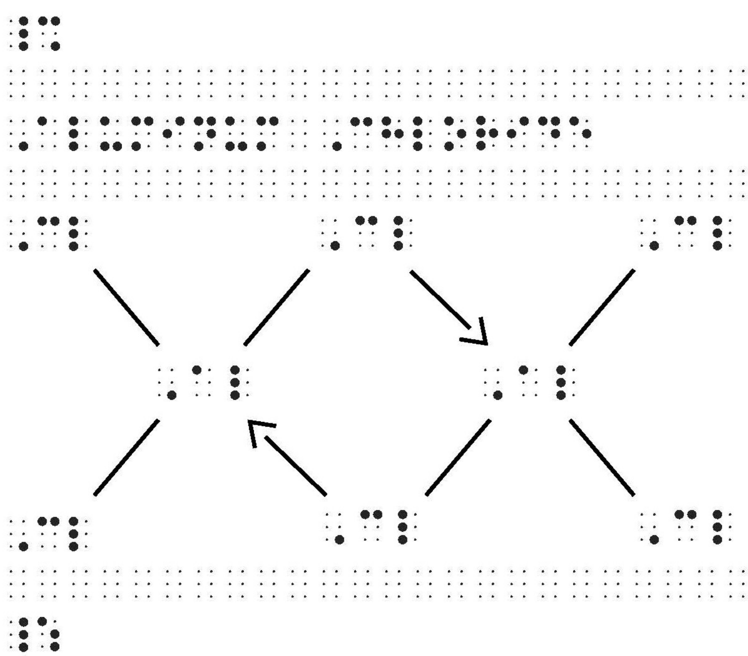


Sample 10-2
Oblique Arrow Bonds

This drawing illustrates placement of the diagram label above the drawing, the open arrowhead style used in the tactile graphic, and replication of the bond angles.

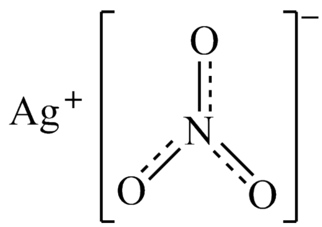


Aluminum Chloride

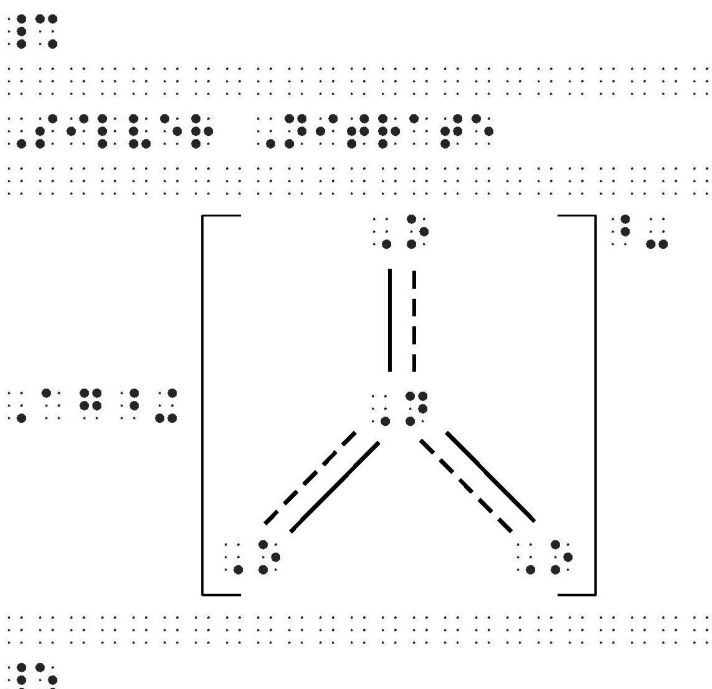


Sample 10-3
Dashed (Broken) Bonds

This drawing illustrates dashed bonds, and also the use of a tactually distinct line style for the enlarged bracket. The chemical notation to the left of the enlarged bracket is aligned with the main line of the spatial diagram, in this case, with element SYMBOL N. The diagram label is transcribed above the diagram.

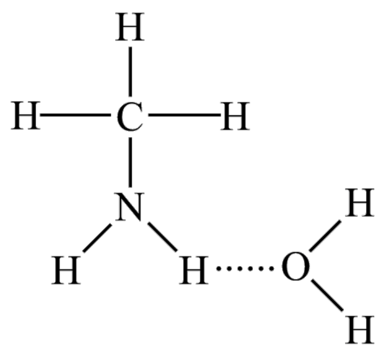


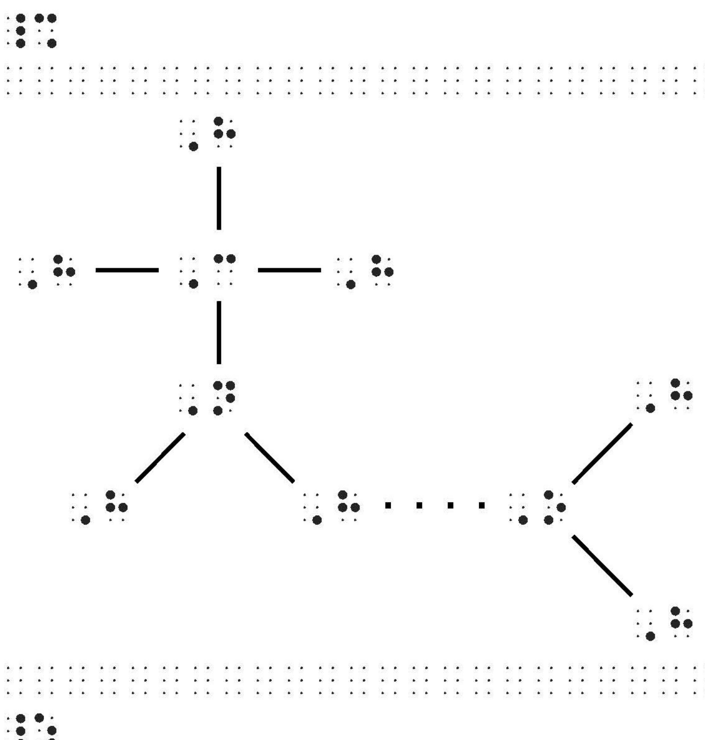
Silver Nitrate



Sample 10-4
Dotted Bond

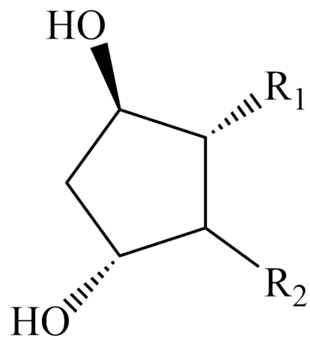
This drawing illustrates that a minimum of four dots is used for a dotted bond. It also shows that the angle of each oblique bond is the same as the angle shown in print.



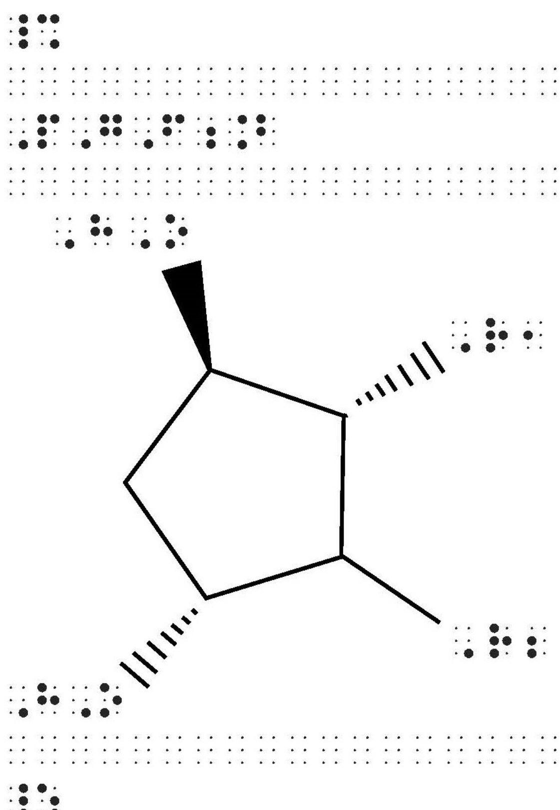


Sample 10-5
Wedge Bonds – Solid and Barred

This drawing illustrates two styles of wedge bonds. The diagram label is transcribed above the diagram.

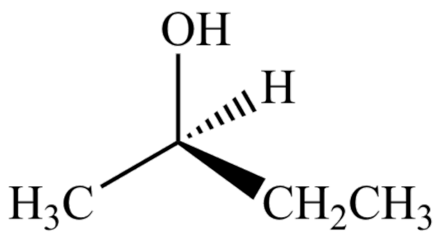


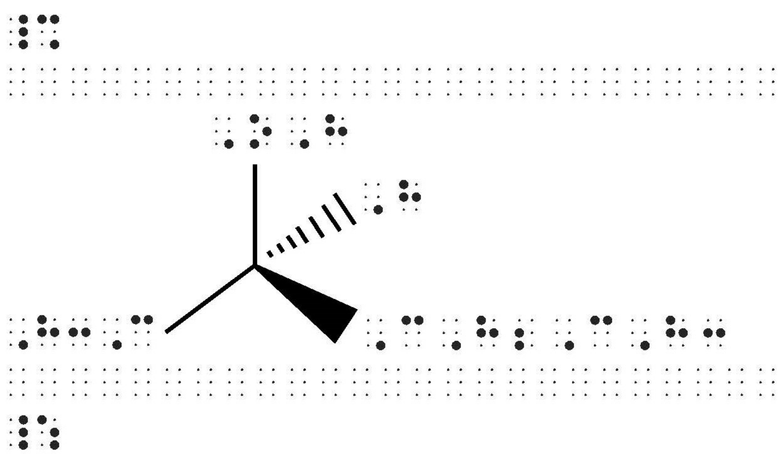
PGF$_\beta$



Sample 10-6
Wedge Bonds – Solid and Barred

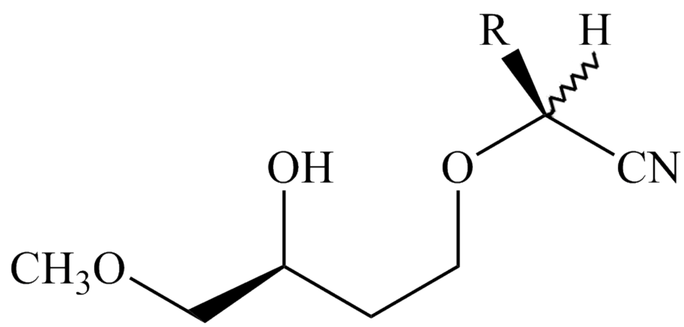
This drawing illustrates three bond styles and angles.

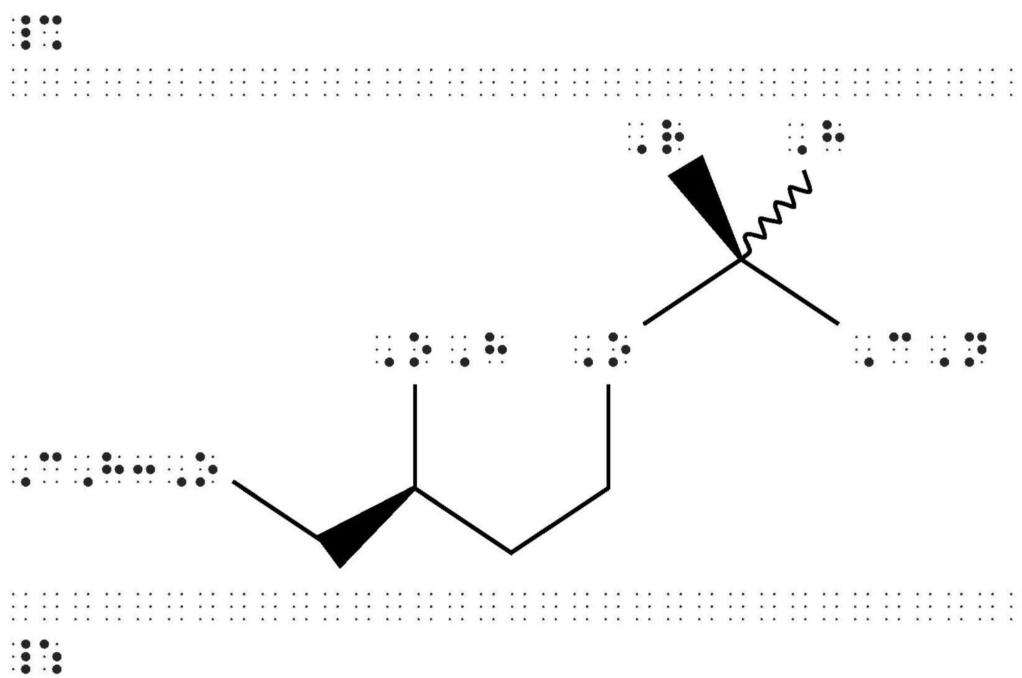




Sample 10-7
Jagged Bond and Wedge Bonds

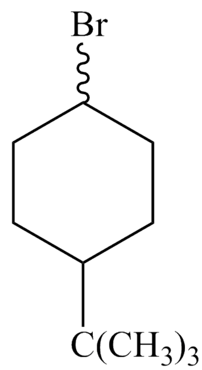
This drawing illustrates a jagged bond as well as other bond styles and angles.

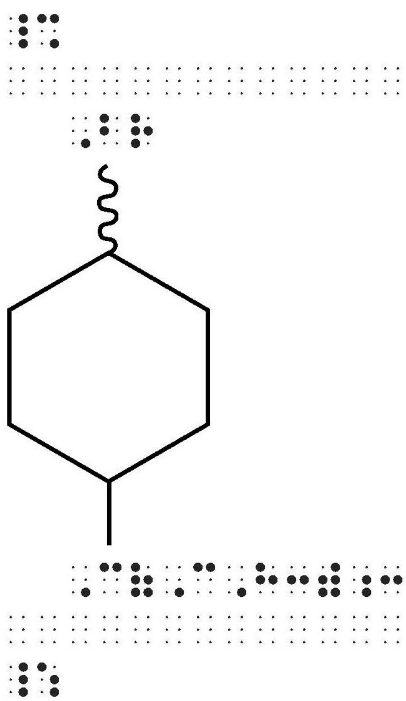




Sample 10-8
Wavy Bond

This drawing illustrates a wavy bond and a ring structure.

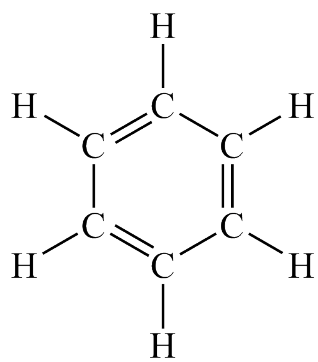


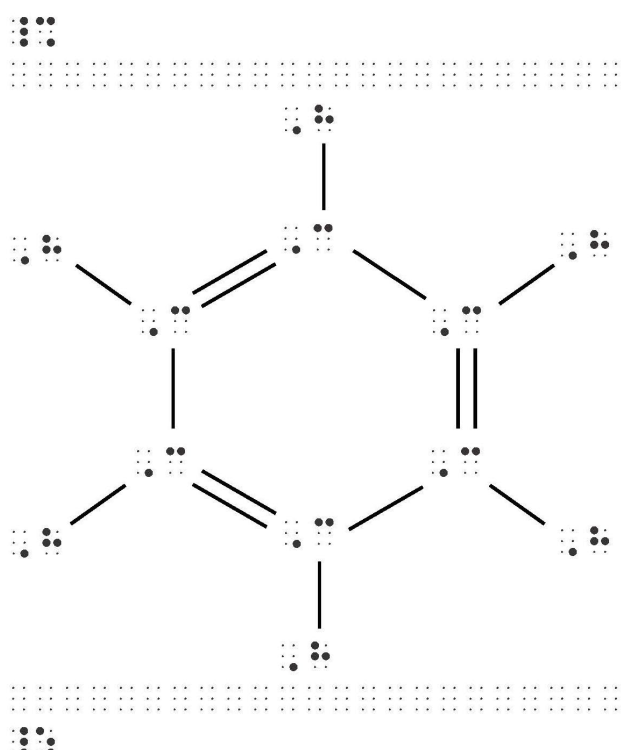


Sample 10-9
Ring Structures

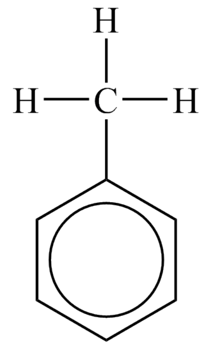
Sample 10-9 (a)
Oblique Bonds in a Ring Structure

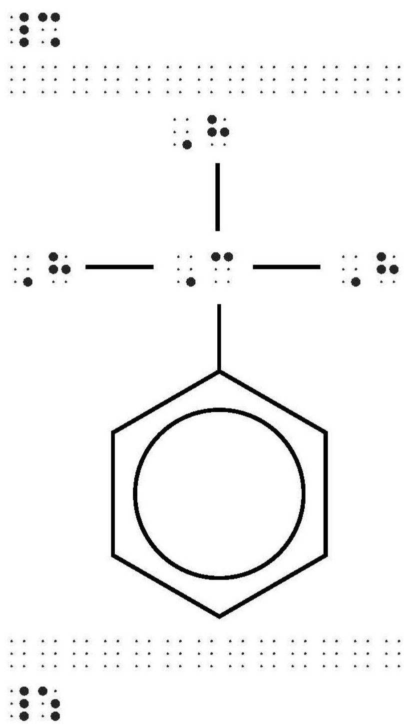
This drawing illustrates a ring structure with C SYMBOLS at each vertex, as well as single and double bonds.





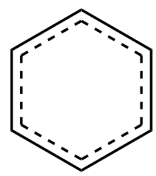
Sample 10-9 (b)
Ring Structure with Interior Circle

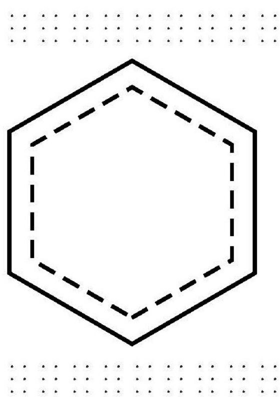




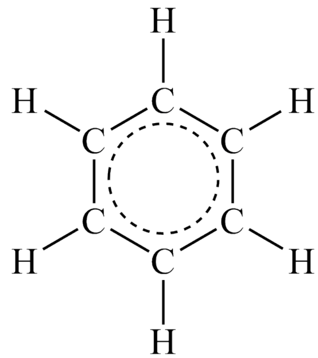
Sample 10-9 (c)
Ring Structure with Interior Hexagon (Dashed)

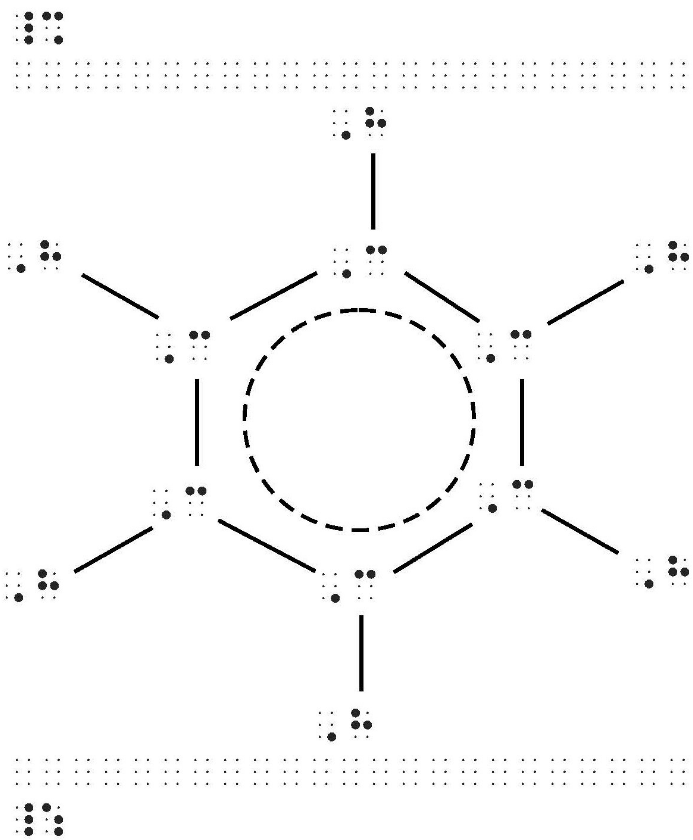
This drawing illustrates that code switch indicators are not necessary when a diagram does not contain Nemeth or chemistry braille symbols.





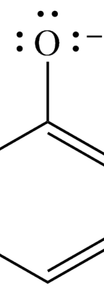
Sample 10-9 (d)
Ring Structure with Interior Circle (Dashed)

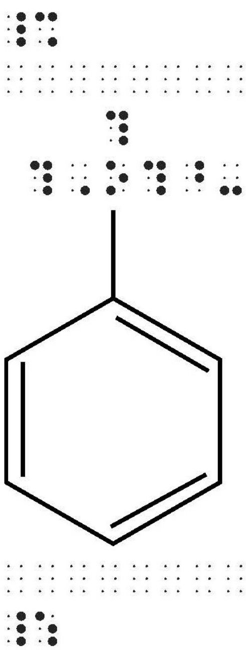




Sample 10-9 (e)
Ring Structure with Single and Double Bonds

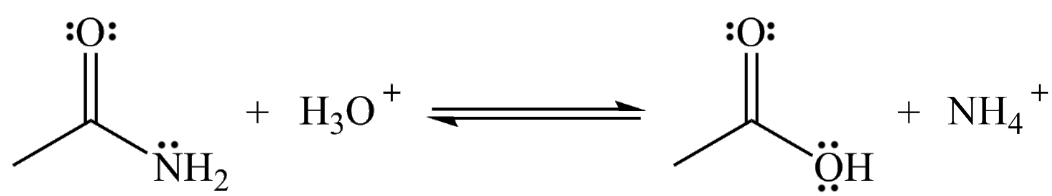
This drawing illustrates that braille symbols are used to represent electron dots. Note that the superscript applies to the element O, not to the entire structure.

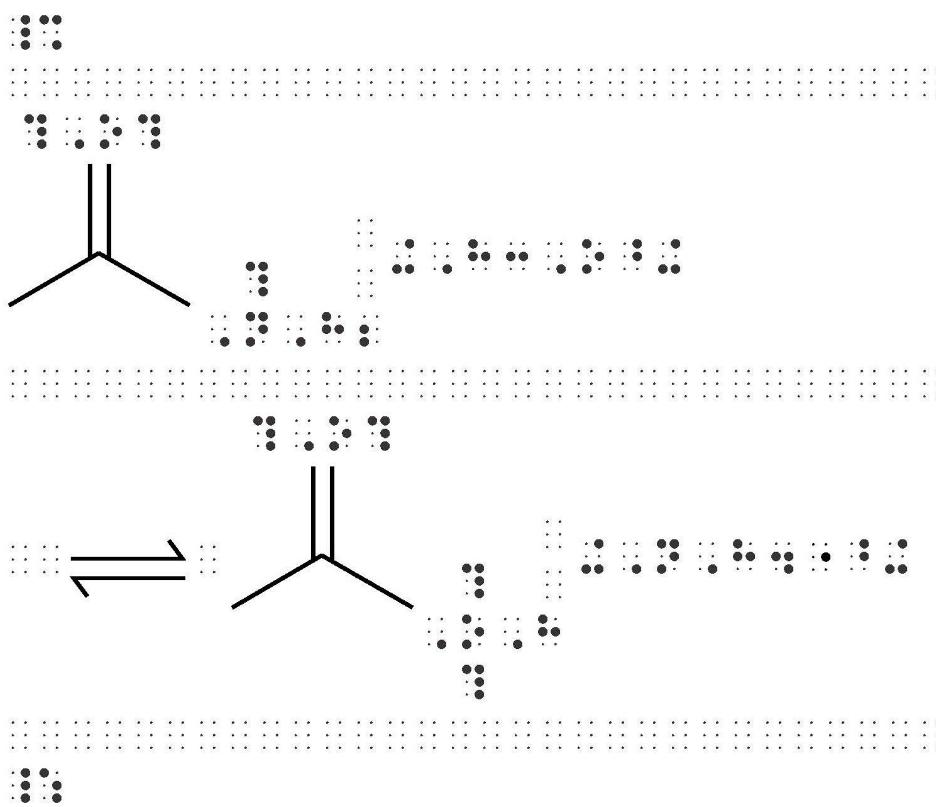




Sample 10-10
Reversible Reaction Arrow

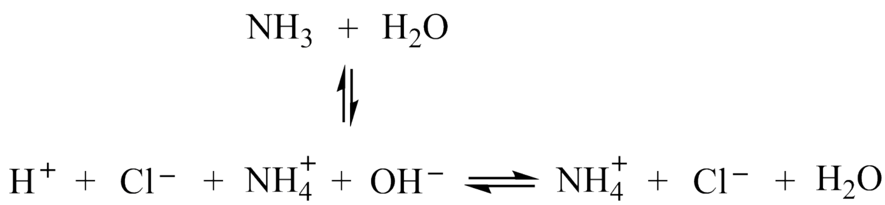
This drawing illustrates the spacing of the plus signs related to molecular formulae in a spatial diagram. It also shows the open arrowhead style used for the reversible reaction arrow, replication of bond angles, and that braille symbols represent the electron dots.

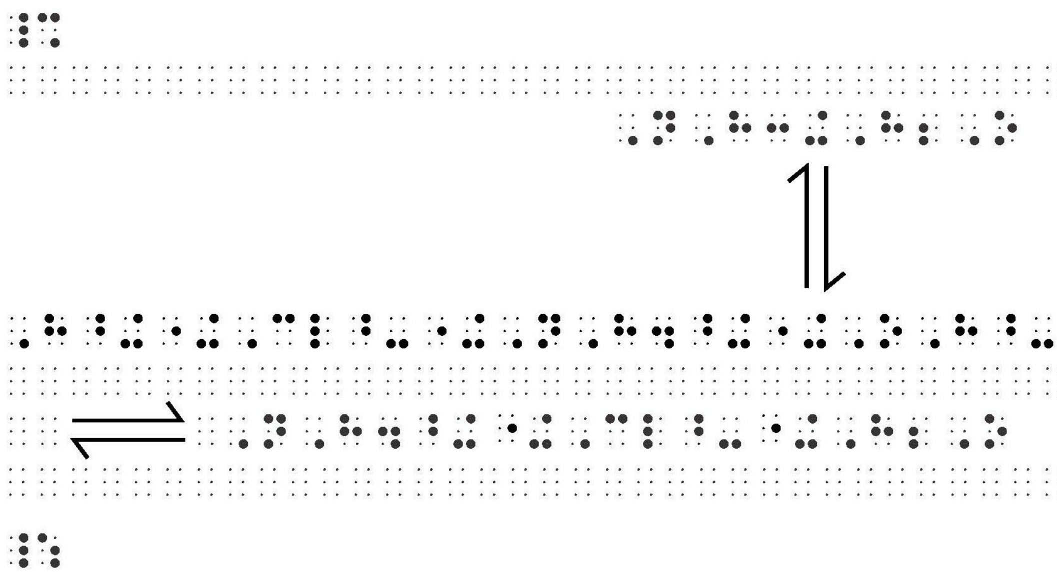




Sample 10-11
Vertical Reversible Reaction Arrow

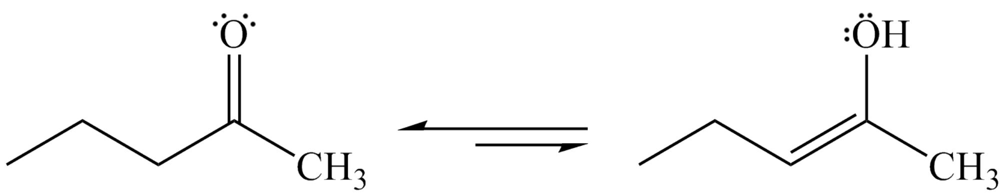
This drawing illustrates the open arrowhead style used for the reversible reaction arrows.

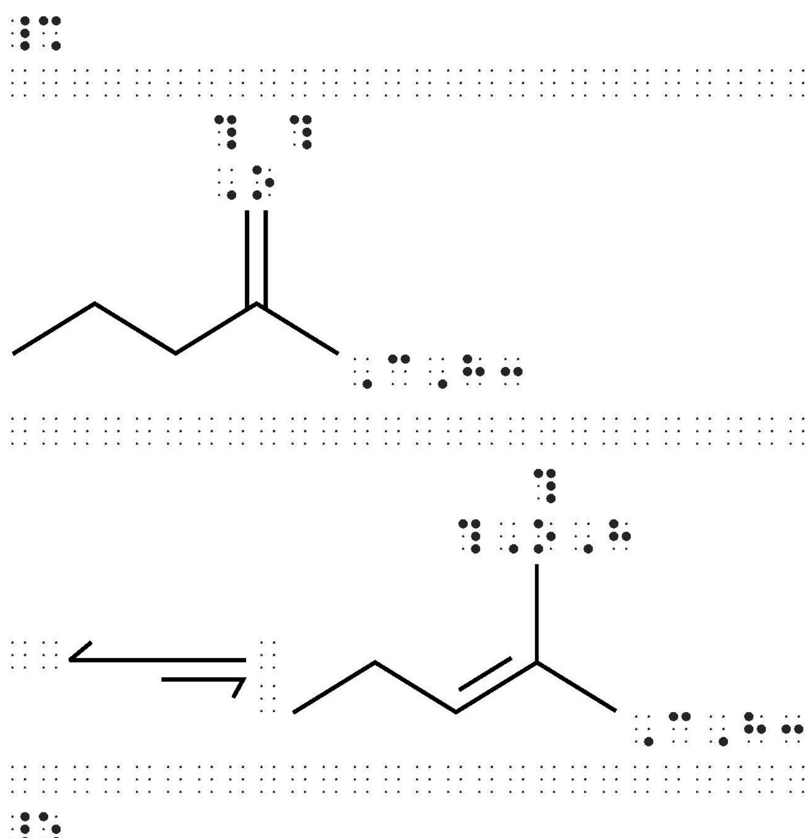




Sample 10-12
Unequal Reversible Reaction Arrow

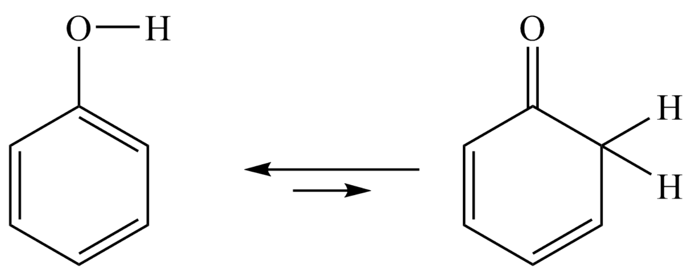
This drawing illustrates the open arrowhead style used for the reversible reaction arrow, replication of bond angles, and spacing before and after the comparison sign (arrow) as it relates to a branched structure. Braille symbols represent the electron dots.

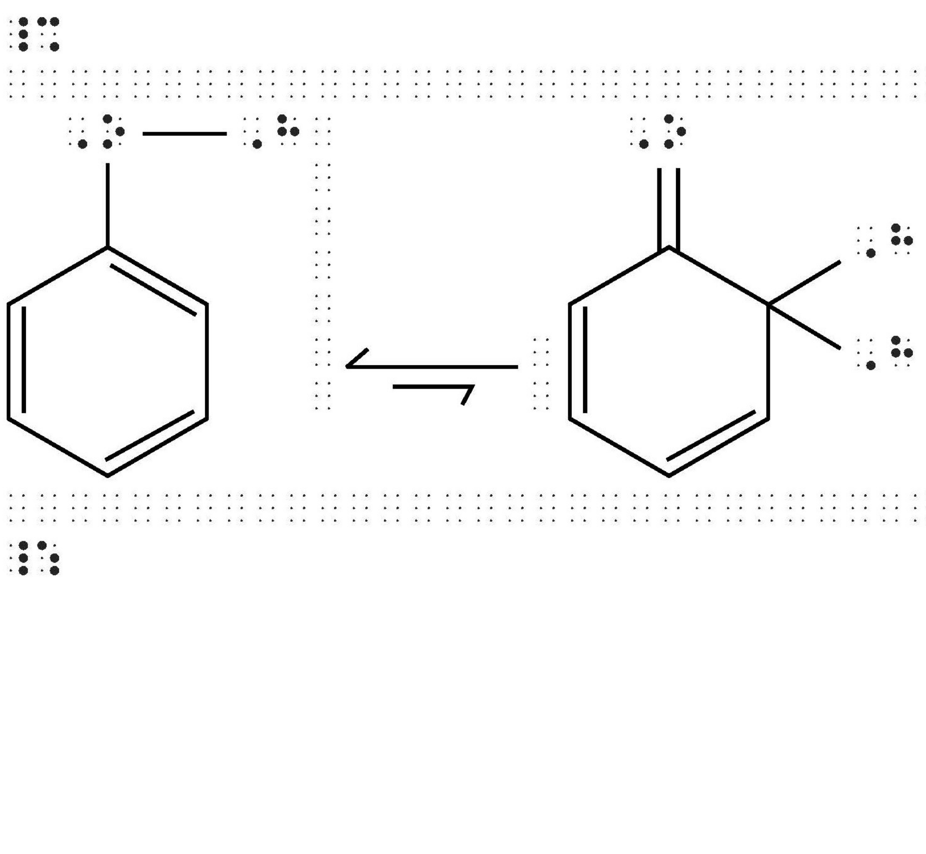




Sample 10-13
Reversible Reaction Arrow

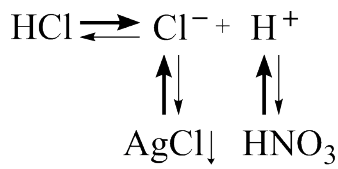
This drawing illustrates the open arrowhead half-barb ("harpoon") style used for the reversible reaction arrow, even though they are printed as solid full arrowheads.

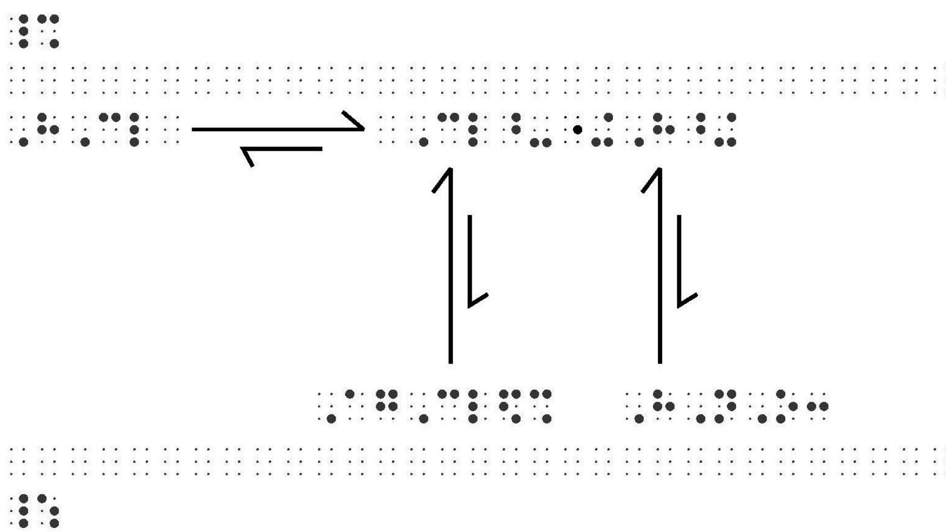




Sample 10-14
Bold Reversible Reaction Arrows

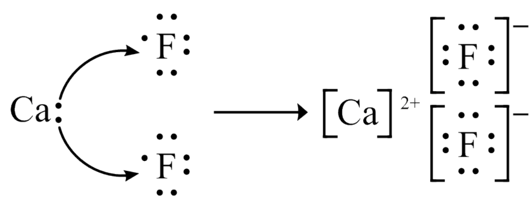
This drawing illustrates updating the bold reversible reaction arrows to the open-barb arrow with a longer shaft. A transcriber's note is required to explain the difference. (See 10.4.3.a.) Note that the braille symbol is used for the precipitation arrow (the down-pointing arrow next to Cl).

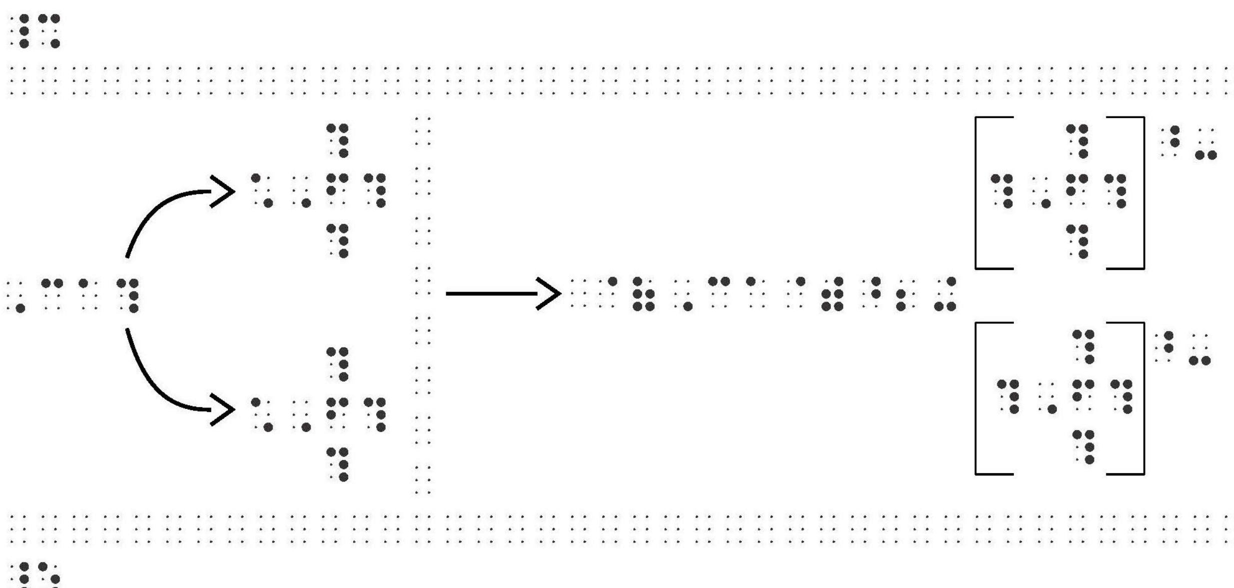




Sample 10-15
Curved Arrows

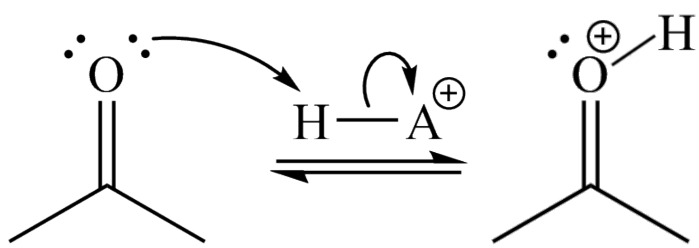
This drawing illustrates duplication of the curved arrow shaft, enlarged brackets being drawn as a tactile graphic, and the use of an open arrowhead even though the arrowheads are solid in the print diagram. Braille symbols represent the electron dots. Note that a baseline indicator is not needed when a tactile graphic follows a superscript.

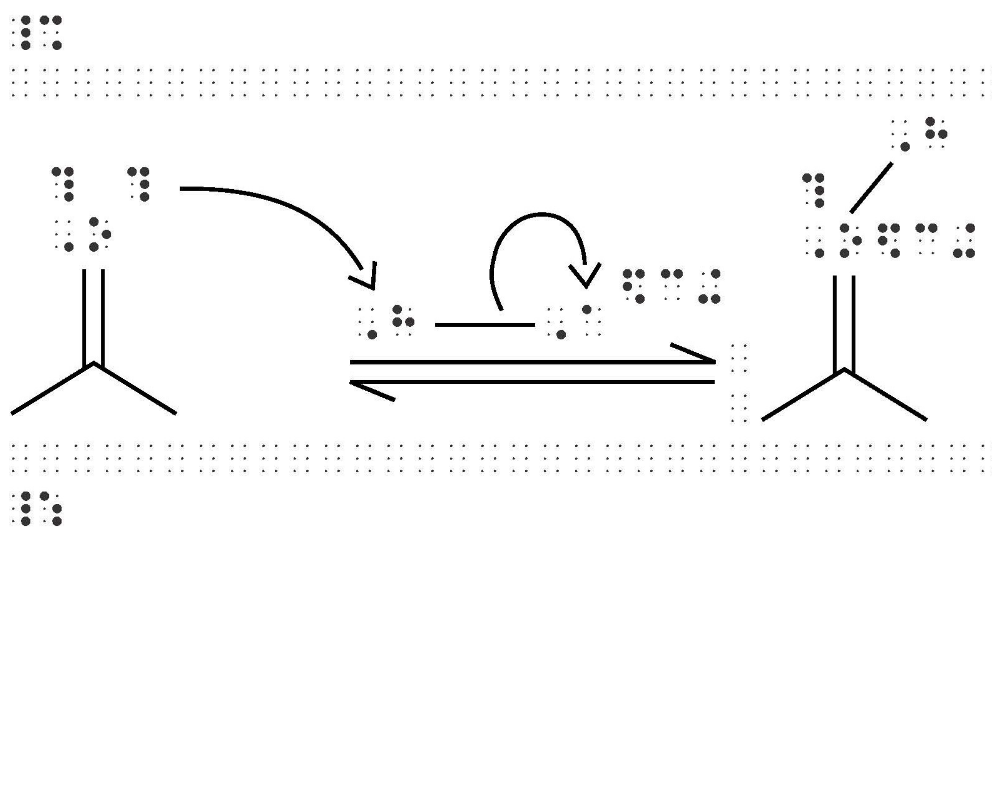




Sample 10-16
Curved Arrows

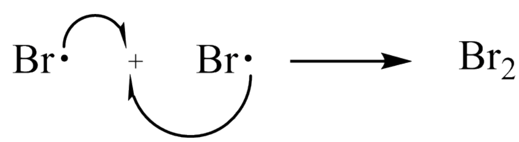
This drawing illustrates duplication of the curved arrow shaft and the use of an open arrowhead in the tactile graphic. The location of the second encircled plus label has been moved to the right of O in order to accommodate the placement of the bond. (See Section 4.3 regarding the encircled plus sign used as a label in a spatial structure.) Braille symbols represent the electron dots.

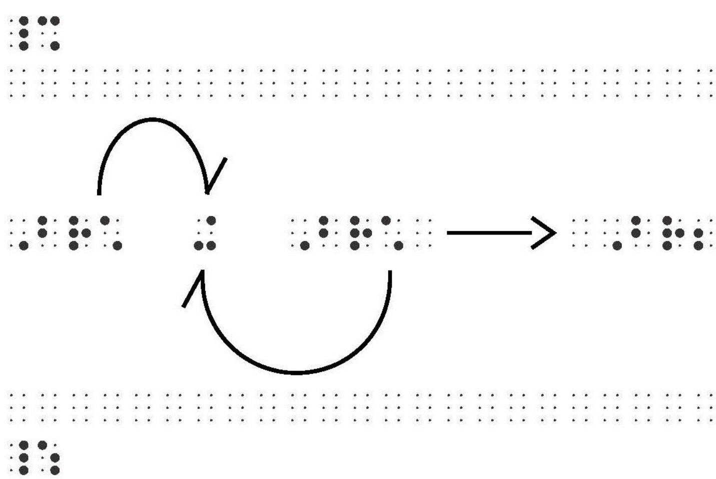




Sample 10-17
Single-Barbed "Pushing" Arrows

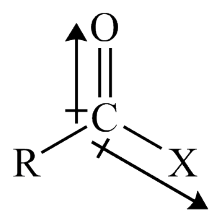
This drawing illustrates the duplication of the curved arrow shaft as well as the half-barb on the curved arrowhead, which has chemical significance and must be reproduced as printed. The plus sign is spaced in order to accommodate the size of the pushing arrows. Braille symbols represent the electron dots.

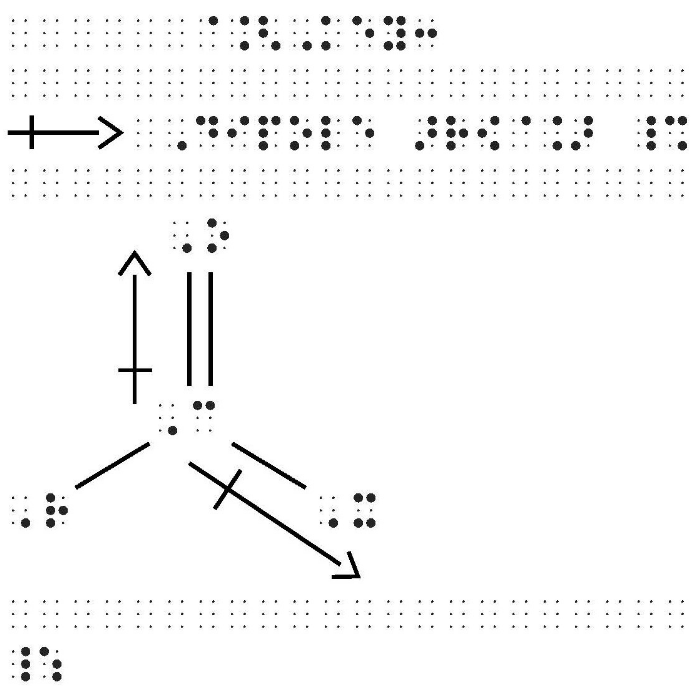




Sample 10-18
Dipole Arrows

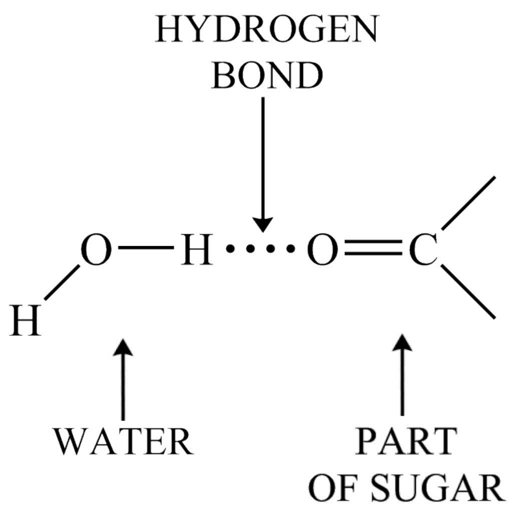
This drawing illustrates inclusion of the unique shaft of the dipole arrow in a key and that the relative length of each shaft must replicate print. The arrowhead of each dipole arrow extends the same amount of space as shown in print: beyond X, but not beyond O. An open arrowhead is used in the tactile graphic.

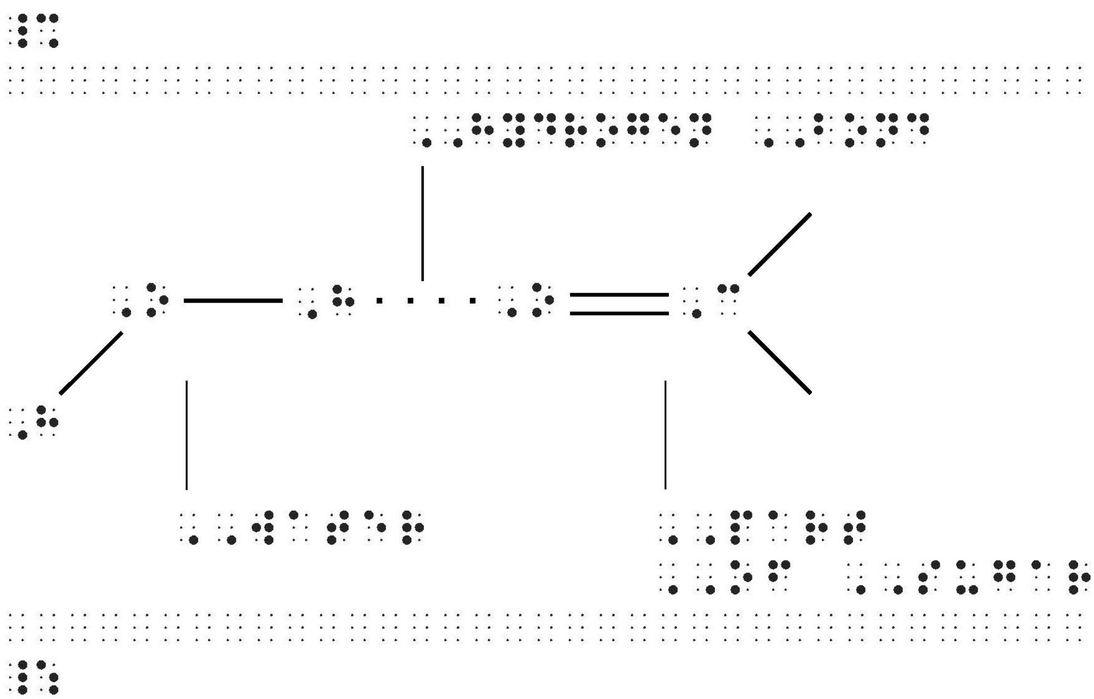




Sample 10-19
Labels with Lead Lines

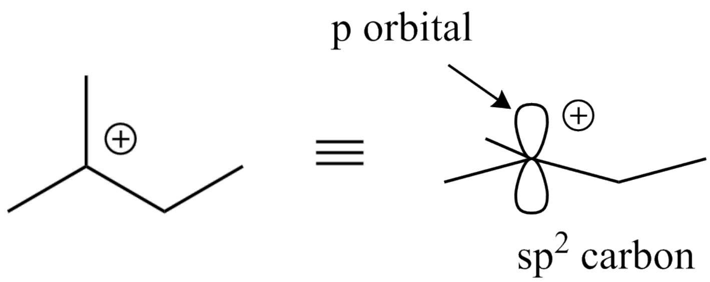
This drawing illustrates a lead line pointing to a labeled component (HYDROGEN BOND) and two lead lines pointing to nonspecific areas of a diagram.

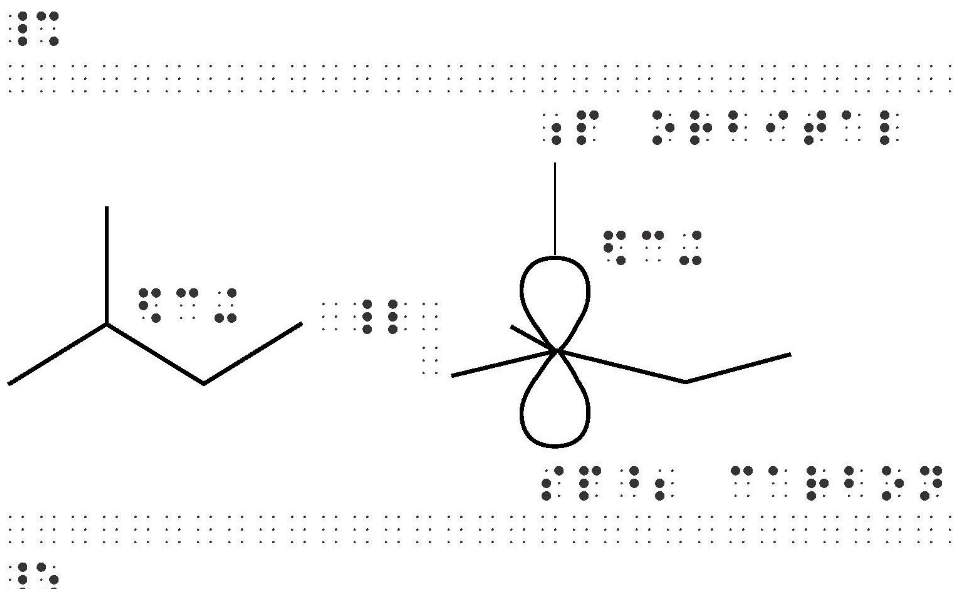




Sample 10-20
Labels With and Without a Lead Line

This drawing illustrates a lead line pointing to a labeled component (p orbital) and a label without a lead line printed below the diagram. (See Section 4.3 regarding the encircled plus sign used as a label in a spatial structure.) Note that the three parallel lines in the image is a sign of comparison, not a triple bond.

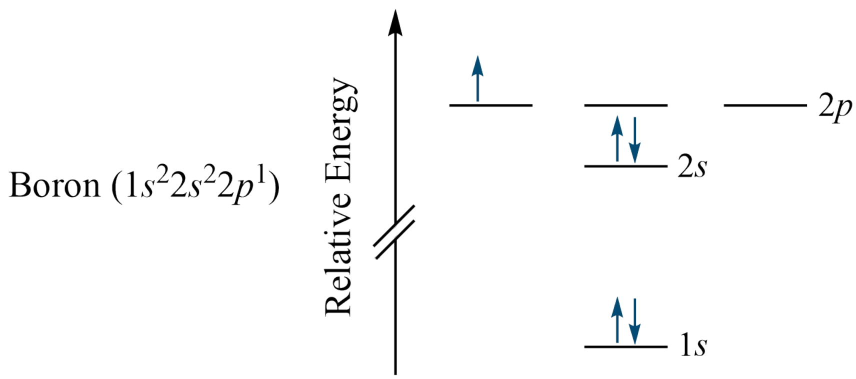


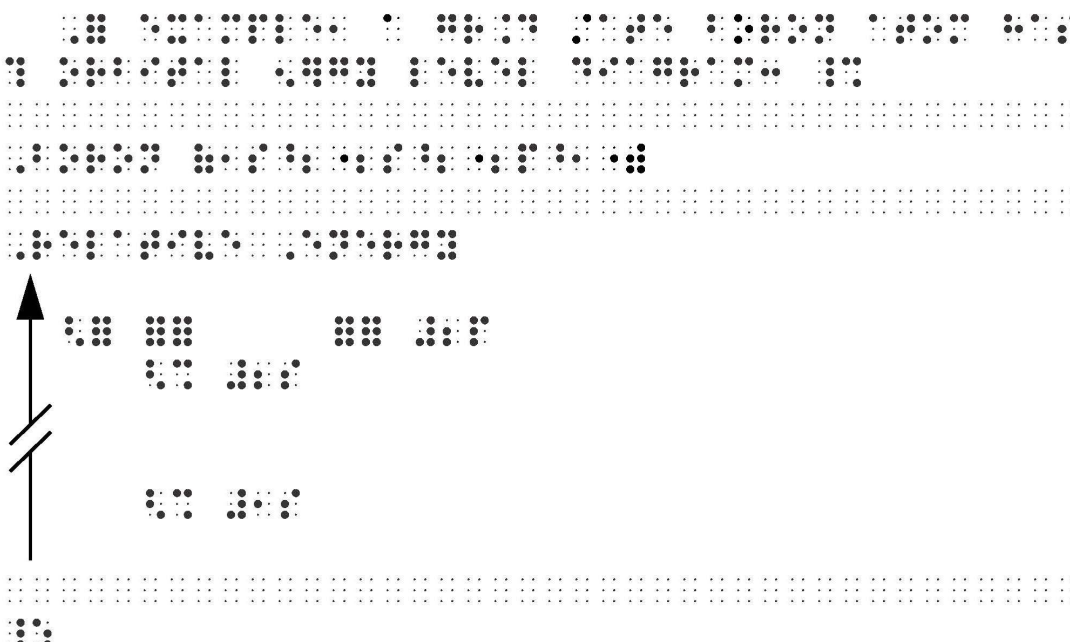


Sample 10-21
Orbital Diagram

This drawing illustrates the depiction of the vertical arrow as a tactile graphic and that the arrowhead style follows print for nonchemical arrows. The valence arrows in the orbital diagram are transcribed as braille symbols. (See Section 3.2.3.)

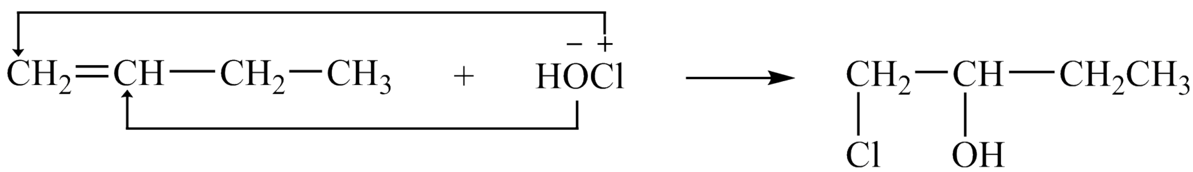
For example, a ground state boron atom has this orbital energy level diagram:

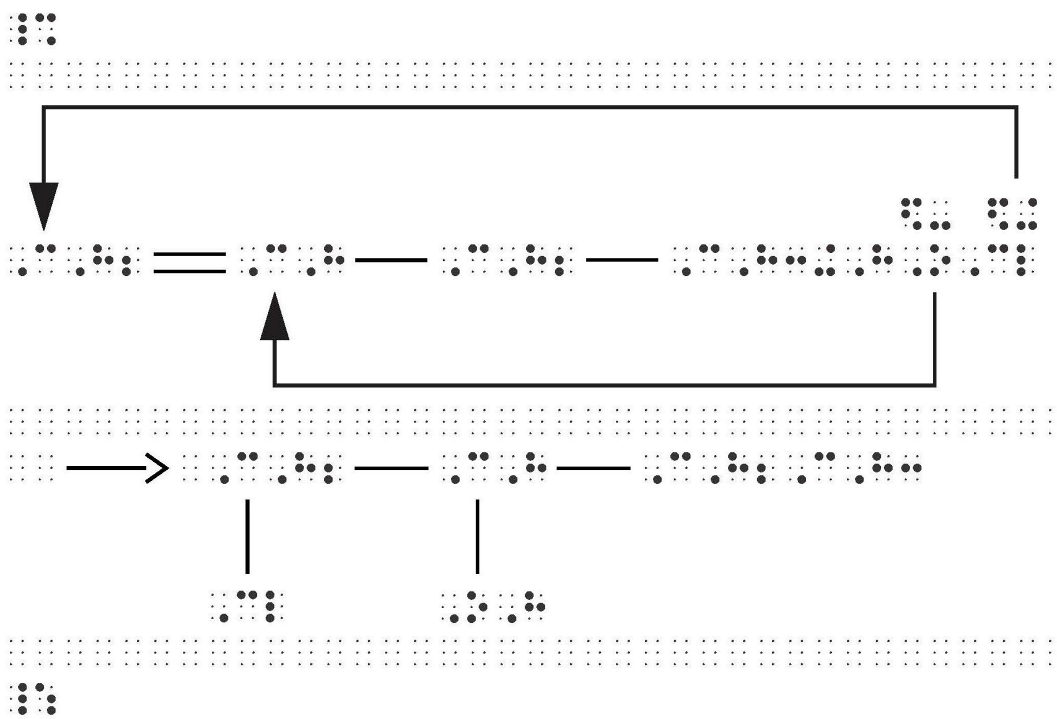




Sample 10-22
Mechanistic Arrows

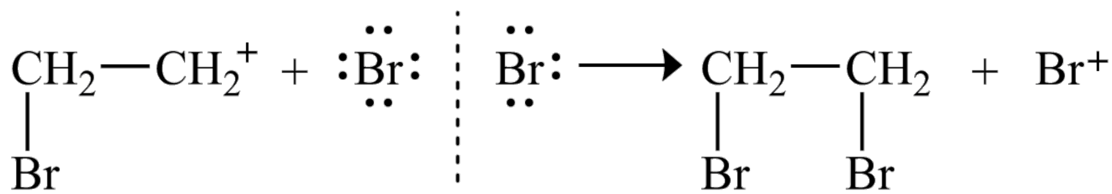
This drawing illustrates that mechanistic arrows must be drawn as a tactile graphic, duplicating the shape and the arrowhead style used in print.

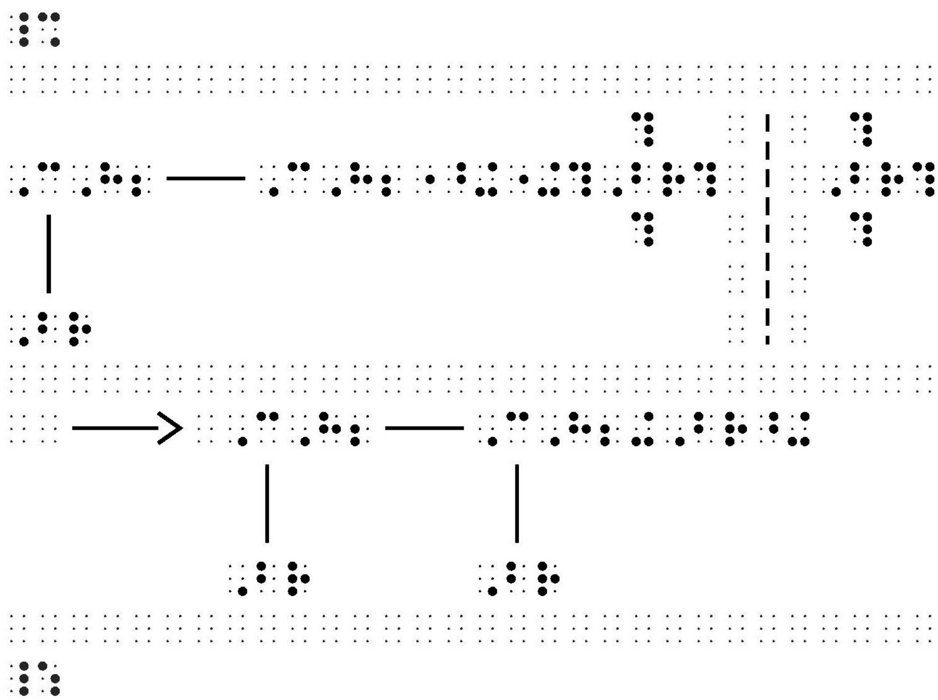




Sample 10-23
Broken Bond Separator

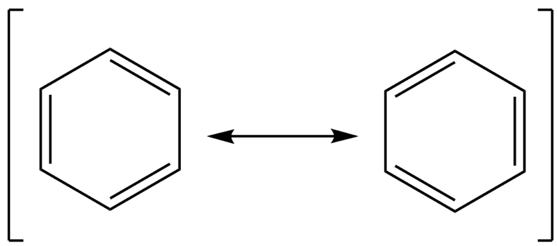
This drawing illustrates a broken bond separator, which is printed as a vertical broken line.

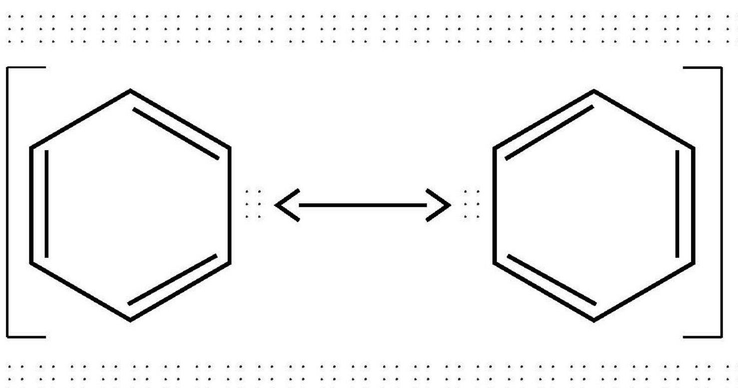




Sample 10-24
Ring Structures Within Enlarged Brackets

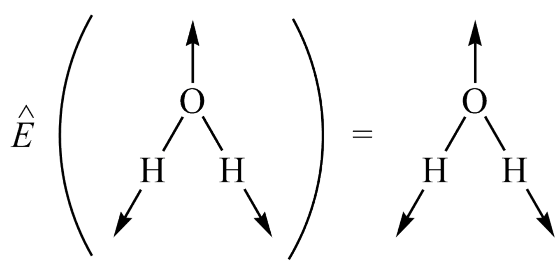
This drawing illustrates enlarged brackets being drawn as a tactile graphic when appearing within a tactile diagram. An open arrowhead style is used for the resonance arrow. Note that code switch indicators are not necessary when a diagram does not contain Nemeth or chemistry braille symbols.

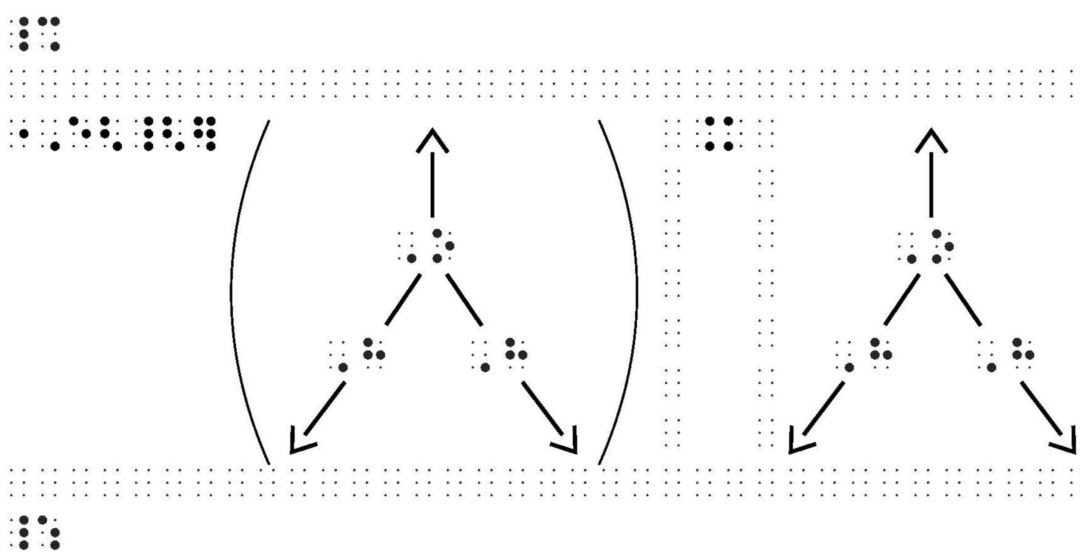




Sample 10-25
Enlarged Parentheses

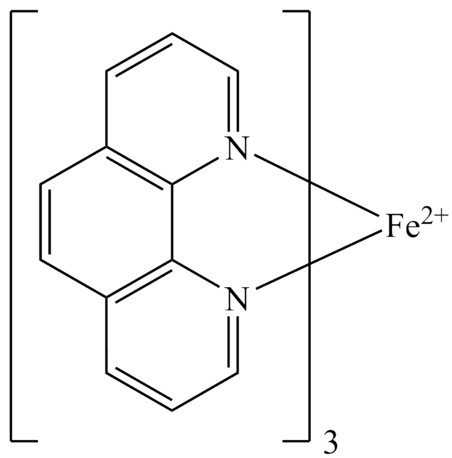
This drawing illustrates enlarged parentheses being drawn as a tactile graphic when appearing within a tactile diagram. An open arrowhead style is used for the chemical arrows. The mathematical symbols lying outside of the grouping signs are aligned with the top line of the grouping symbol.

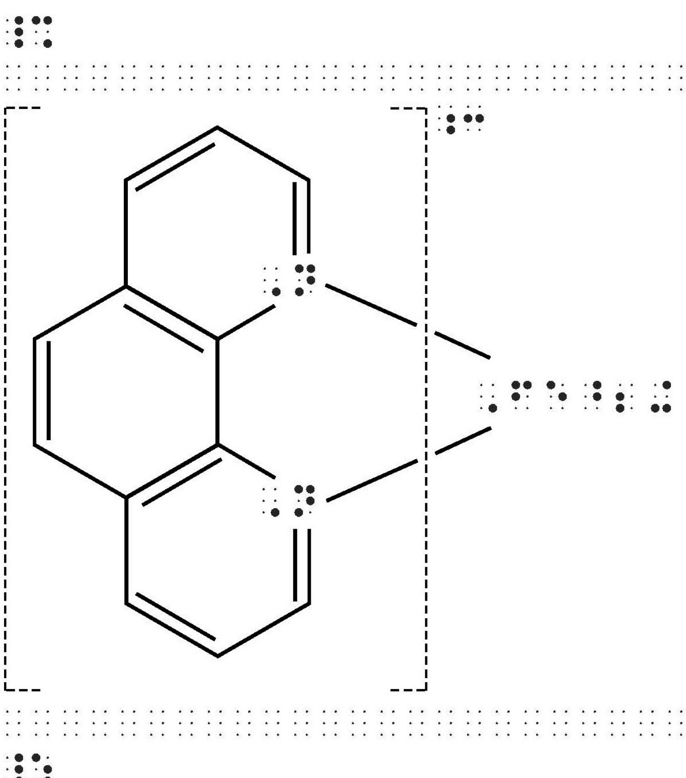




Sample 10-26
Enlarged Bracket Passing Through Oblique Bonds

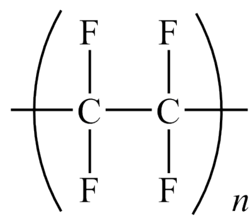
This drawing illustrates a bracket which extends through (overlaps) a bond. A textured line is used in the tactile graphic for distinction. A gap is created in the bond line where the bracket crosses it. Note that the subscript 3 applies to the material enclosed in brackets and is transcribed to align with the top line of the arrangement.

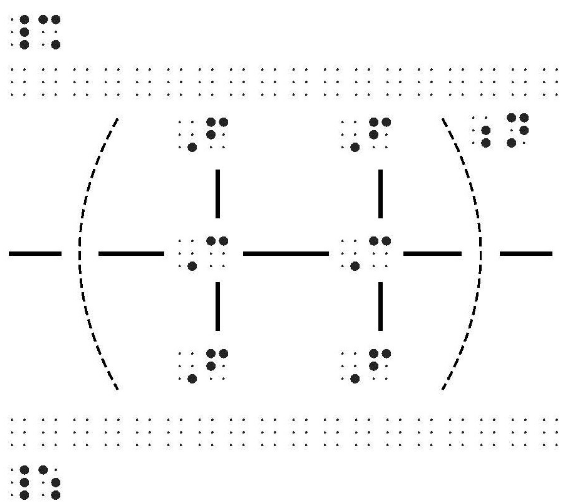




Sample 10-27
Monomer Unit Enclosed in Large Parentheses

This drawing illustrates parentheses which extend through (overlap) a bond. A textured line is used in the tactile graphic for distinction. A gap is created in each bond line where the parenthesis crosses. Note that the subscript n is transcribed to align with the top line of the arrangement.

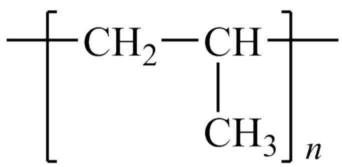


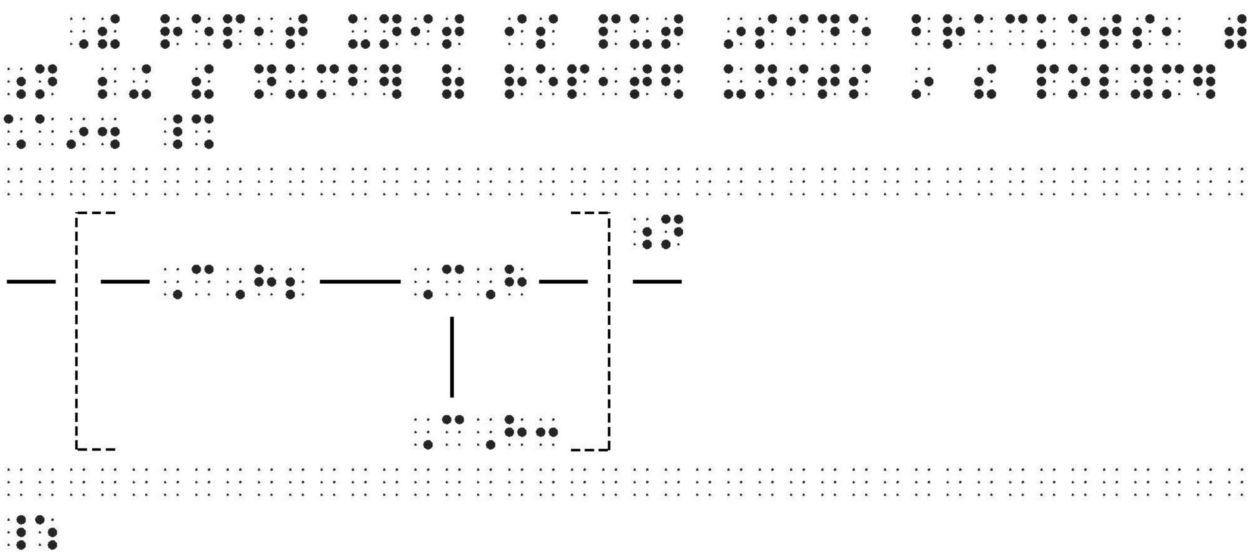


Sample 10-28
Enlarged Bracket Passing Through a Horizontal Bond

This drawing illustrates brackets which extend through (overlap) a bond. A textured line is used in the tactile graphic for distinction. A gap is created in each bond line where the bracket crosses. Note that the subscript n is transcribed to align with the top line of the arrangement.

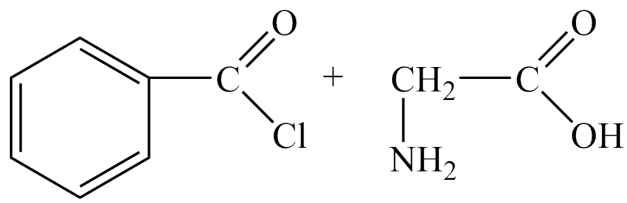
The repeat unit is put inside brackets, with n being the number of repeated units in the polymer chain.

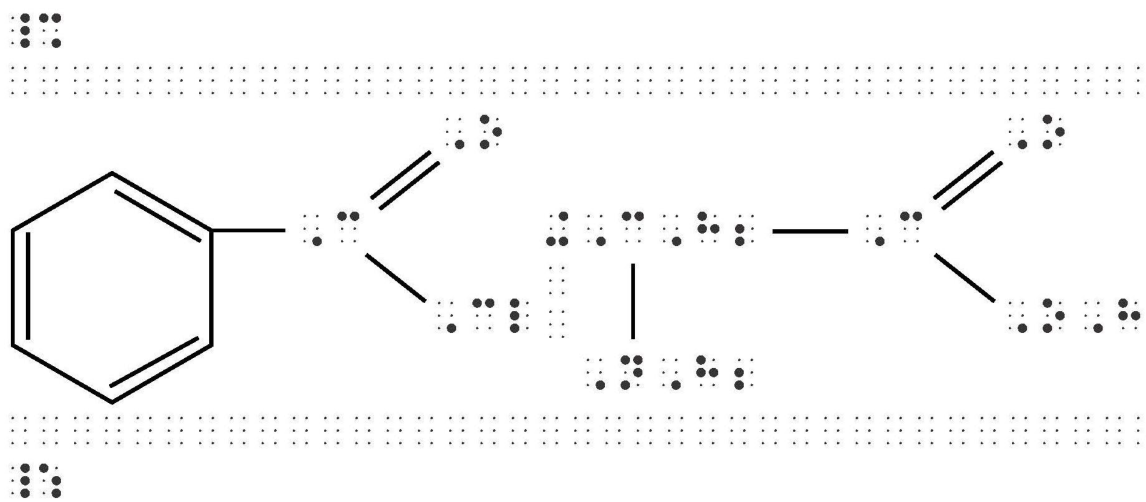




Sample 10-29
Operation Sign Unspaced from Branch

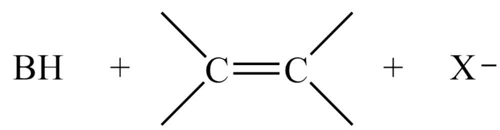
This drawing illustrates the spacing of an operation sign in a branched structure when element SYMBOLS are attached to each branch.

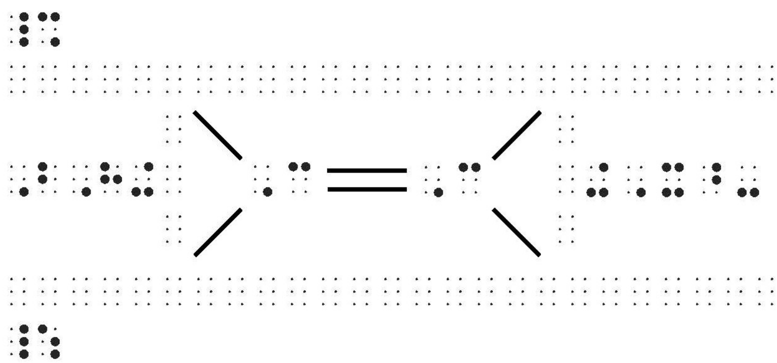




Sample 10-30
Operation Sign Spaced from Oblique Bond

This drawing illustrates the spacing of an operation sign in a branched structure when there is no element SYMBOL at the end of the branch.

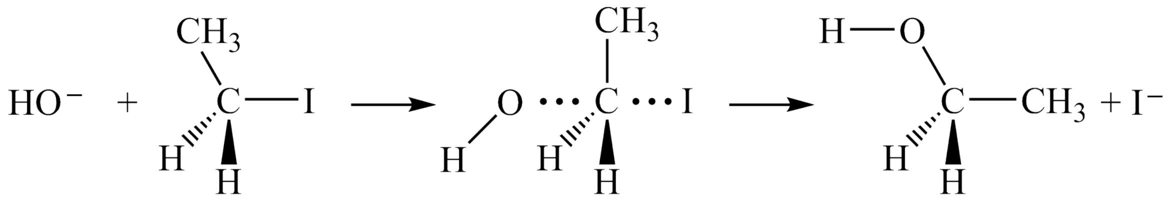


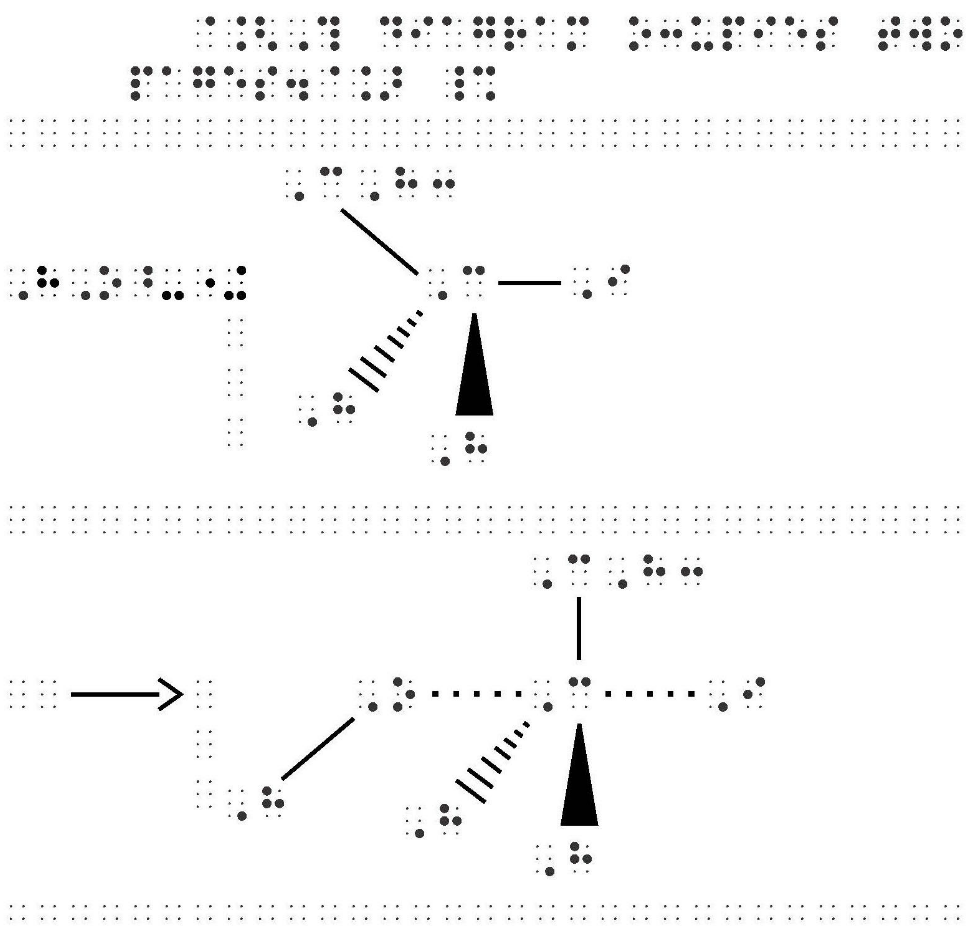


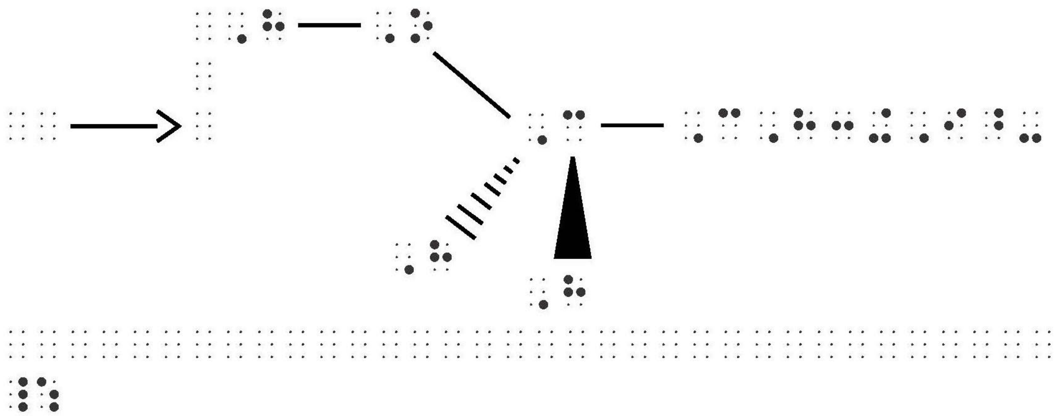
Sample 10-31

Spacing of Plus Sign and Yields Arrow from Branch

This drawing illustrates the spacing of operation signs and comparison signs in a branched structure. See *Section 10.5.1**.*

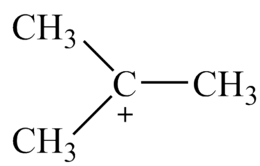


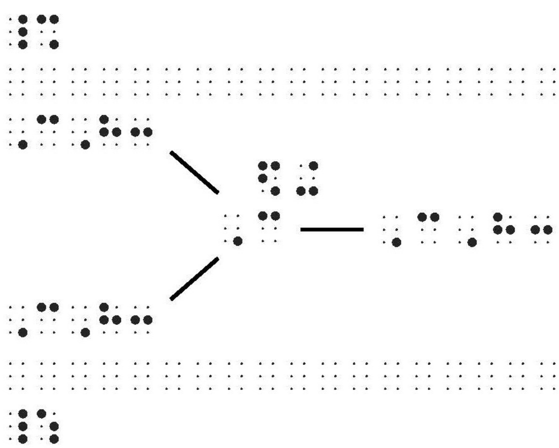




Sample 10-32
Positive Sign Labeling an Atom

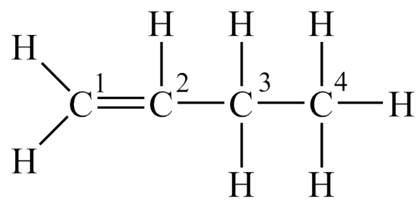
This drawing illustrates the change in placement of a label from its print placement below an atom. The plus sign is transcribed above the element SYMBOL. The symbol for the detached plus sign is transcribed. The oblique bonds are arranged as printed, leading to the "3" of CH_3.



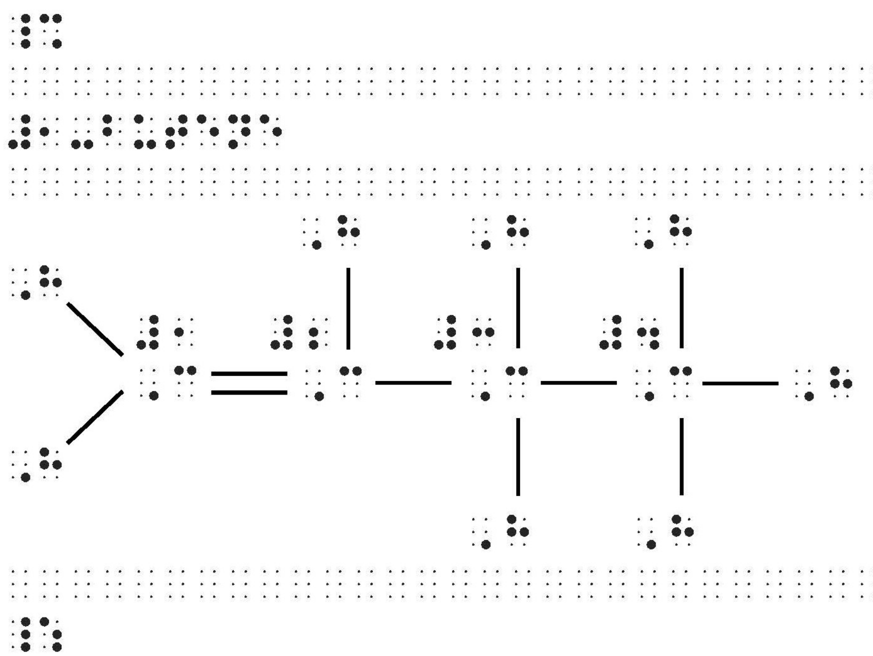


Sample 10-33
Numbered Carbon Atoms

This drawing illustrates placement of number labels, which differs from print placement. (Also note that the diagram label is transcribed above the diagram.)

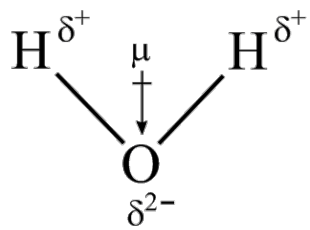


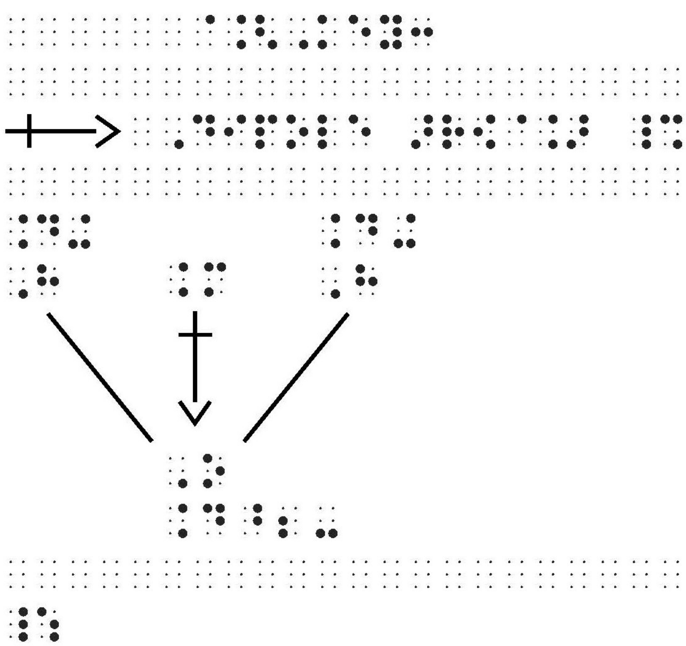
1-butene



Sample 10-34
Partial Charge Labels; Dipole Arrow

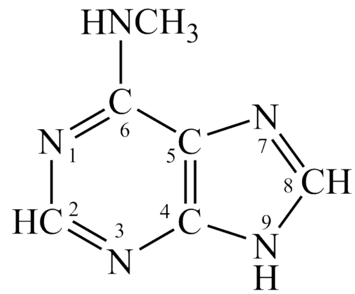
This drawing illustrates showing the unique shaft of the dipole arrow in a key and that an open arrowhead is used in the tactile graphic. It also shows placement of labels above the H atoms (the delta charges are labels, not superscripts) and that the superscript position of the "plus" charge in partial charge notation is disregarded.



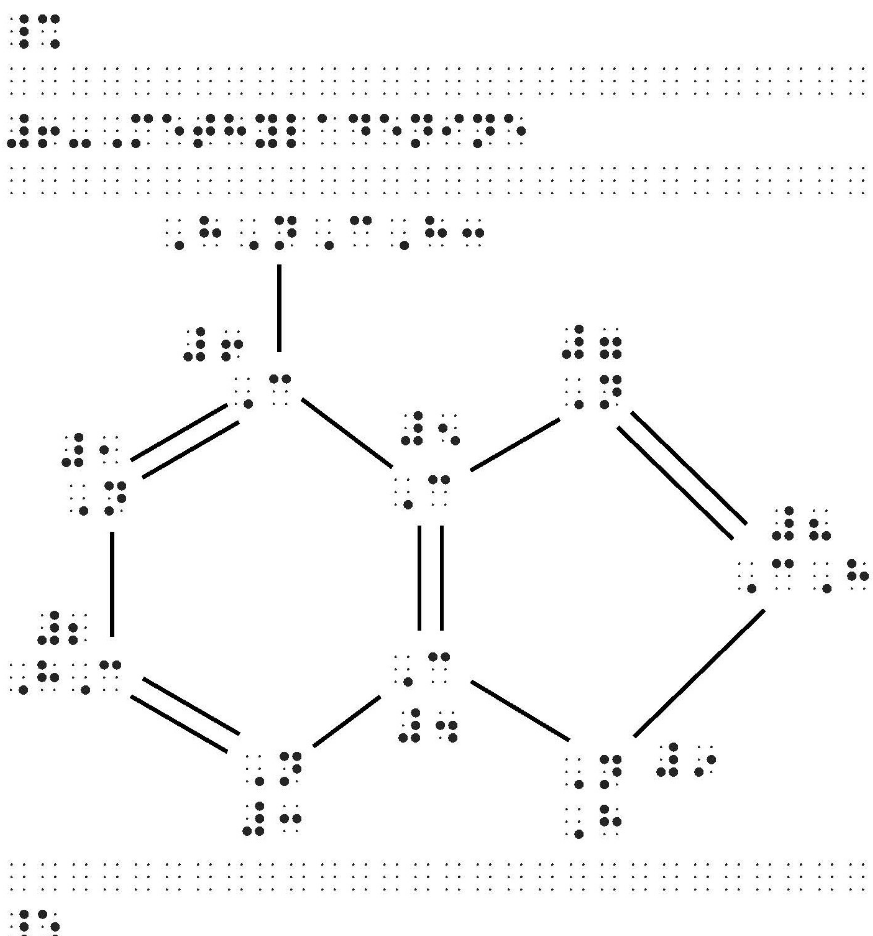


Sample 10-35
Ring Structures with Numbered Atoms

This drawing illustrates placement of number labels in a ring structure. (Also note that the diagram label is transcribed above the diagram.)

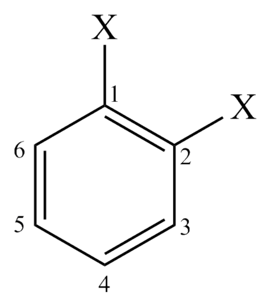


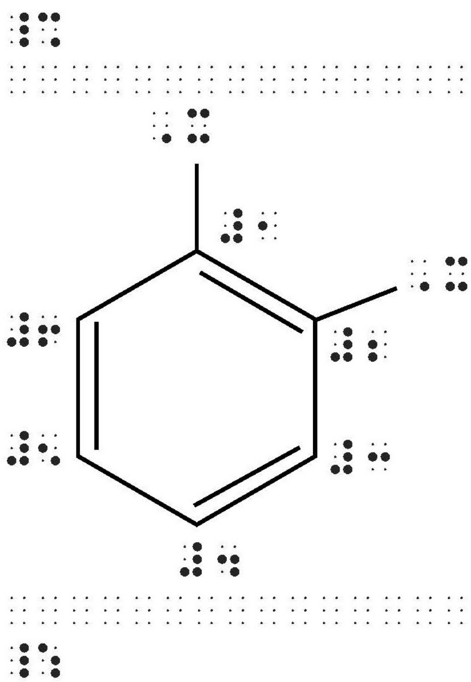
6-Methyladenine



Sample 10-36
Ring Structure with Numbered Vertices

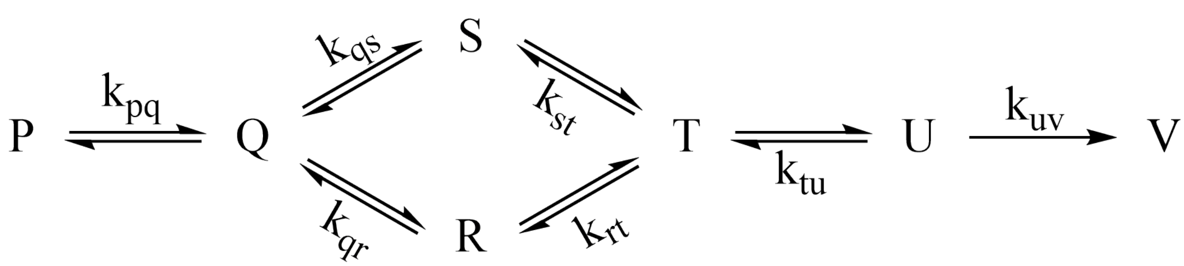
This drawing illustrates placement of number labels in a ring structure with unlabeled vertices.

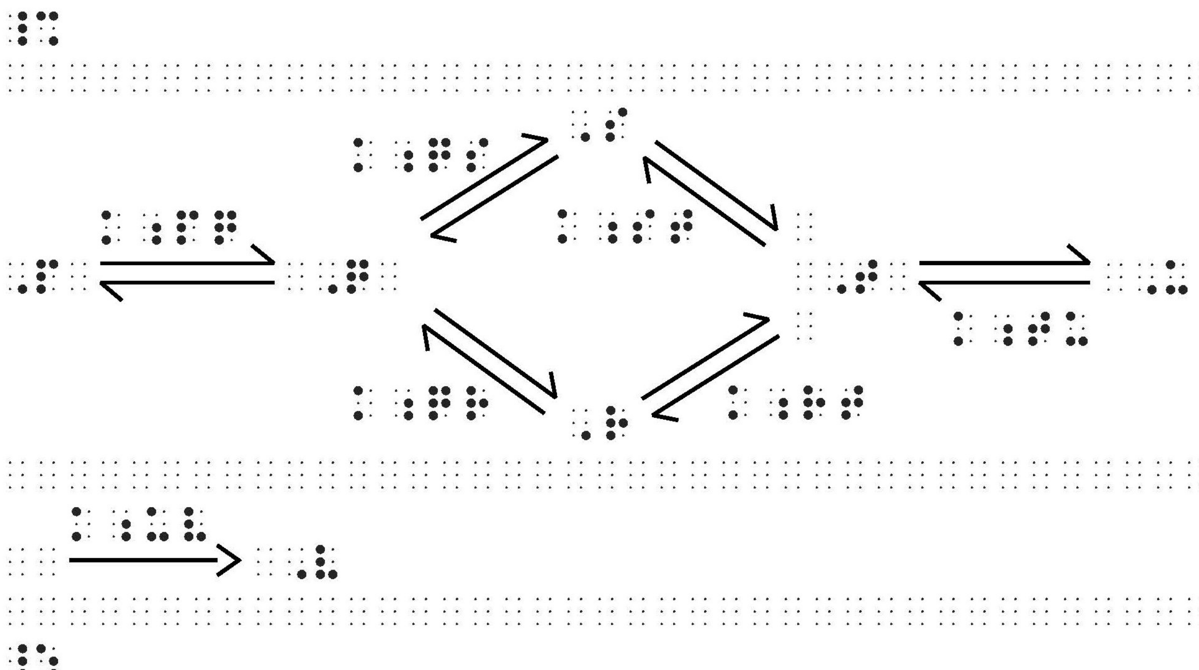




Sample 10-37
Labels Printed at an Angle

This drawing illustrates that labels printed at an angle are transcribed horizontally, situated as printed above or below the arrows.





Appendix A
List of Chemical Elements

This list of chemical elements from the Periodic Table of the Elements and their SYMBOLS is provided for your convenience. Both the old and the new International Union of Pure and Applied Chemistry (IUPAC) names for the synthetic Uu elements are included. This list is arranged alphabetically by SYMBOL.

Ac	Actinium
Ag	Silver
Al	Aluminum
Am	Americium
Ar	Argon
As	Arsenic
At	Astatine
Au	Gold
B	Boron
Ba	Barium
Be	Beryllium
Bh	Bohrium
Bi	Bismuth
Bk	Berkelium
Br	Bromine
C	Carbon
Ca	Calcium
Cd	Cadmium
Ce	Cerium
Cf	Californium
Cl	Chlorine
Cm	Curium
Cn	Copernicium
Co	Cobalt
Cr	Chromium
Cs	Cesium
Cu	Copper
Db	Dubnium
Ds	Darmstadtium
Dy	Dysprosium
Er	Erbium
Es	Einsteinium
Eu	Europium
F	Fluorine
Fe	Iron
Fl	Flerovium
Fm	Fermium
Fr	Francium
Ga	Gallium
Gd	Gadolinium
Ge	Germanium
H	Hydrogen
He	Helium
Hf	Hafnium
Hg	Mercury
Ho	Holmium
Hs	Hassium
I	Iodine
In	Indium
Ir	Iridium

K	Potassium
Kr	Krypton
La	Lanthanum
Li	Lithium
Lr	Lawrencium
Lu	Lutetium
Lv	Livermorium
Mc	Moscovium
Md	Mendelevium
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Mt	Meitnerium
N	Nitrogen
Na	Sodium
Nb	Niobium
Nd	Neodymium
Ne	Neon
Nh	Nihonium
Ni	Nickel
No	Nobelium
Np	Neptunium
Ns	Neilsborium
O	Oxygen
Og	Oganesson
Os	Osmium
P	Phosphorus
Pa	Protactinium
Pb	Lead
Pd	Palladium
Pm	Promethium
Po	Polonium
Pr	Praseodymium
Pt	Platinum
Pu	Plutonium
Ra	Radium
Rb	Rubidium
Re	Rhenium
Rf	Rutherfordium
Rg	Roentgenium
Rh	Rhodium
Rn	Radon
Ru	Ruthenium
S	Sulfur
Sb	Antimony
Sc	Scandium
Se	Selenium
Sg	Seaborgium
Si	Silicon
Sm	Samarium
Sn	Tin
Sr	Strontium
Ta	Tantalum
Tb	Terbium
Tc	Technetium
Te	Tellurium
Th	Thorium
Ti	Titanium
Tl	Thallium
Tm	Thulium
Ts	Tennessine
U	Uranium
Uuh	Ununhexium
Uuo	Ununoctium
Uup	Ununpentium
Uuq	Ununquadium

Uus	Ununseptium	Y	Yttrium
Uut	Ununtrium	Yb	Ytterbium
V	Vanadium	Zn	Zinc
W	Tungsten	Zr	Zirconium
Xe	Xenon		

Appendix B
Braille Symbols Used in Molecular Diagrams

BRIEF CONTENTS

The preferred method for transcribing molecular diagrams with oblique lines, vertical chemical arrows, or textured bonds is by using a combination of braille symbols and tactile graphics. See Section 10, Molecular Diagrams. However, if an agency determines that the production of tactile graphics is not feasible, the braille symbols listed in this appendix may be used instead.

Braille symbols used to depict the bonds, ring structures, and chemical arrows in a molecular diagrams must be listed on the Special Symbols page. Section 1.2.2 gives instructions for creating a Special Symbols page in a chemistry transcription. It may be helpful to consult Appendix C, Index of Braille Symbols for Chemical Notation, which lists the symbols in braille order.

In this appendix, Appendix B, symbols are listed by category and are grouped by similarity or in alphabetical order, not necessarily in braille order. The images shown in the right column are the print symbols, not a tactile rendition of the symbol.

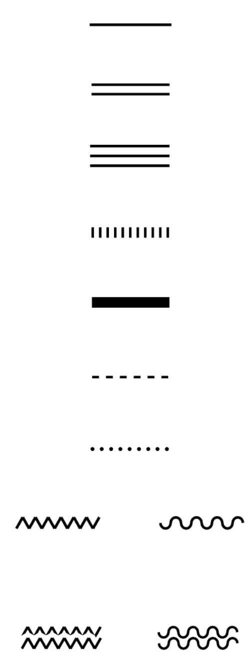
For those familiar with the original *Braille Code for Chemical Notation*, you will note that some of the symbols in this Appendix B are different than those listed in the 1997 edition.

B.1 Bonds

See Section 2, Chemical Bonds, for rules regarding construction, spacing, and layout of chemical bonds.

B.1.1 **Horizontal Bonds.** A horizontal bond begins with an opening bond indicator (dots 456) and ends with a closing bond indicator (dots 12456). Symbols in the following list include the opening and closing indicators.

⠸⠒⠻	Single horizontal bond
⠸⠶⠻	Double horizontal bond
⠸⠿⠻	Triple horizontal bond
⠸⠳⠻	Barred horizontal bond
⠸⠛⠻	Bold horizontal bond
⠸⠆⠻	Broken horizontal bond
⠸⠂⠻	Dotted horizontal bond
⠸⠔⠻	Jagged or wavy horizontal bond
⠸⠔⠢⠻	Jagged or wavy horizontal double bond



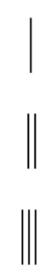
See the following Samples.

Sample B-1: Single and Double Bonds

Sample B-4: Dotted Bond

B.1.2 **Vertical Bonds**

⠸	Single vertical bond
⠸ ⠸	Double vertical bond
⠸ ⠸ ⠸	Triple vertical bond



⠸⠭	Barred vertical bond	
⠸⠛	Bold vertical bond	
⠸⠆	Broken vertical bond	
⠸⠂	Dotted vertical bond	
⠸⠔	Jagged or wavy vertical bond	
⠸⠔⠢	Jagged or wavy vertical double bond	 

See the following Samples.

Sample B-1: Single and Double Bonds

Sample B-3: Dashed (Broken) Bonds

Sample B-8: Wavy Bond

B.1.3 **Oblique Bonds.** An oblique bond begins with an opening bond indicator (dots 456). Symbols in the following list include the opening indicator.

⠸⠡	Oblique bond, upper left to lower right	
⠸⠡⠡	Oblique double bond, upper left to lower right	
⠸⠌	Oblique bond, lower left to upper right	
⠸⠌⠌	Oblique double bond, lower left to upper right	
⠸⠭⠡	Barred oblique bond, upper left to lower right	

⠸⠭⠌	Barred oblique bond, lower left to upper right	
⠸⠆⠡	Broken oblique bond, upper left to lower right	
⠸⠆⠌	Broken oblique bond, lower left to upper right	
⠸⠂⠡	Dotted oblique bond, upper left to lower right	
⠸⠂⠌	Dotted oblique bond, lower left to upper right	
⠸⠔⠡	Jagged or wavy oblique bond, upper left to lower right	
⠸⠔⠌	Jagged or wavy oblique bond, lower left to upper right	

See the following Samples.

Sample B-1: Single and Double Bonds

Sample B-3: Dashed (Broken) Bonds

Sample B-7: Jagged Bond and Wedge Bonds

a. **Labeled Atoms and Vertices.** See Section 8, Labels, for details regarding placement of labels next to bonds.

See the following Samples.

Sample B-32: Positive Sign Labeling an Atom

Sample B-33: Numbered Carbon Atoms

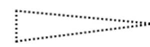
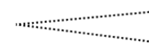
Sample B-34: Partial Charge Labels; Vertical Dipole Arrow

Sample B-35: Ring Structures with Numbered Atoms

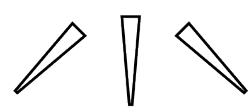
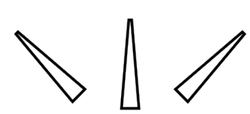
Sample B-36: Ring Structure with Numbered Vertices

B.1.4 **Wedges**

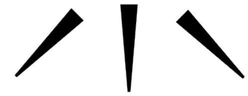
a. **Horizontal Wedges.** A horizontal bond begins with an opening bond indicator (dots 456) and ends with a closing bond indicator (dots 12456). Symbols in the following list include the opening and closing indicators.

⠸⠕⠻	Right-pointing wedge, normal outline	
⠸⠪⠻	Left-pointing wedge, normal outline	
⠸⠗⠻	Right-pointing wedge, filled in	
⠸⠺⠻	Left-pointing wedge, filled in	
⠸⠂⠕⠻	Right-pointing wedge, dotted outline	
⠸⠂⠪⠻	Left-pointing wedge, dotted outline	
⠸⠆⠕⠻	Right-pointing wedge, dashed outline	
⠸⠆⠪⠻	Left-pointing wedge, dashed outline	
⠸⠳⠕⠻	Right-pointing wedge, barred	
⠸⠳⠪⠻	Left-pointing wedge, barred	

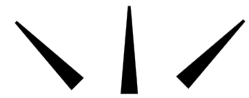
b. **Vertical or Oblique Wedges.** An oblique wedge pointing down and to the left or down and to the right uses the same symbol as its corresponding down-pointing wedge. An oblique wedge pointing up and to the left or up and to the right uses the same symbol as its corresponding up-pointing wedge.

⠸⠍	Down-pointing wedge (vertical or oblique), normal outline	
⠸⠥	Up-pointing wedge (vertical or oblique), normal outline	

⠸⠏ Down-pointing wedge (vertical or oblique), filled in



⠸⠧ Up-pointing wedge (vertical or oblique), filled in



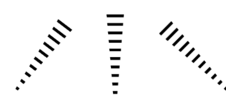
⠸⠂⠍ Down-pointing wedge (vertical or oblique), dotted outline

⠸⠂⠥ Up-pointing wedge (vertical or oblique), dotted outline

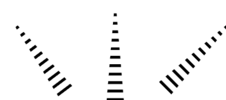
⠸⠆⠍ Down-pointing wedge (vertical or oblique), dashed outline

⠸⠆⠥ Up-pointing wedge (vertical or oblique), dashed outline

⠸⠭⠍ Down-pointing wedge (vertical or oblique), barred



⠸⠭⠥ Up-pointing wedge (vertical or oblique), barred



See the following Samples.

Sample B-5: Wedge Bonds – Solid and Barred

Sample B-6: Wedge Bonds – Solid and Barred

Sample B-7: Jagged Bond and Wedge Bonds

Sample B-31: Spacing of Plus Sign and Yields Arrow from Branch; Several Kinds of Bonds

B.1.5 **Arrow Bonds.** Refer to Section 2.2.2, Horizontal Arrow Bonds, to differentiate between arrow bonds and other chemical arrows.

⠸⠪⠒⠻	Left-pointing arrow bond (including horizontal bond indicators)	←
⠸⠒⠕⠻	Right-pointing arrow bond (including horizontal bond indicators)	→
⠸⠣	Vertical arrow bond, up-pointing	↑
⠸⠩	Vertical arrow bond, down-pointing	↓
⠸⠡⠣	Oblique arrow bond, lower right to upper left	↖
⠸⠌⠣	Oblique arrow bond, lower left to upper right	↗
⠸⠡⠩	Oblique arrow bond, upper left to lower right	↘
⠸⠌⠩	Oblique arrow bond, upper right to lower left	↙

See the following Samples.

Sample B-2: Oblique Arrow Bonds

Sample B-25: Vertical and Oblique Arrow Bonds

B.2 Ring Structures

When a ring structure is not drawn as a tactile graphic, an unlabeled vertex must be shown with the following symbol.

⠪⠕	Unlabeled vertex

Alignment with bond symbols may be adjusted to accommodate surrounding components. When a single vertical bond appears above or below an unlabeled vertex, the bond should normally be aligned with the outer cell of the two-cell symbol. However, it may be aligned with the inner cell of the two cell symbol in order to avoid confusion with other notation.

See the following Samples.

Sample B-5: Wedge Bonds – Solid and Barred

Sample B-8: Wavy Bond

Sample B-9: Ring Structures

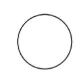
Sample B-13: Reversible Reaction Arrow; Unlabeled Vertices

Sample B-24: Bracketed Ring Structures with Resonance Arrow

Sample B-29: Operation Sign Unspaced from Branch; Unlabeled Vertices

Sample B-36: Ring Structure with Numbered Vertices

a. **Benzene Rings.** Special symbols exist for depictions of a benzene ring when a circle or hexagon is printed inside of the ring structure.

⠫⠉ Interior circle 

⠫⠃⠉ Interior circle with broken outline 

⠫⠃⠖ Interior hexagon with broken outline 

See the following Samples.

Sample B-9 (b): Ring Structure with Interior Circle

Sample B-9 (c): Ring Structure with Interior Hexagon (Dashed)

Sample B-9 (d): Ring Structure with Interior Circle (Dashed)

B.2.1 **Numbered Vertices.** Follow rules regarding numbered atoms when unlabeled vertices are numbered. See Section 10.5.2, Labeled Atoms and Vertices.

See the following Samples.

Sample B-35: Ring Structures with Numbered Atoms

Sample B-36: Ring Structure with Numbered Vertices

B.3 Chemical Arrows

When chemical reaction arrows are transcribed as braille symbols, use the symbols listed in this section. The barbed arrowhead symbol is used for either normal or half-barbed arrowheads (harpoons). Arrows which are not listed may employ the arrow symbols of the Nemeth Code but should be listed on the Special Symbols page. See Section 1.2.2, Special Symbols Page.

B.3.1 **Horizontal Chemical Arrows.** See Section 3.1, Reaction Arrows. If bold arrows are used to depict the favored side of a reversible reaction, see Section B.3.2.a.

See Sample B-24: Bracketed Ring Structures with Resonance Arrow.

Reaction arrows printed at an angle are transcribed horizontally.

See Sample B-37: Modified Arrows Printed at an Angle.

a. **Dipole Arrows.** See Section 3.2.2 for a discussion of horizontal dipole arrows.

B.3.2 **Vertical Chemical Arrows.** See Section 3.1.5 regarding changing the orientation of vertical reaction arrows in snaking arrangements. The following symbols represent vertical arrows if the orientation is not changed.

⠫⠣	Up-pointing chemical arrow	↑
⠫⠩	Down-pointing chemical arrow	↓
⠫⠣⠐⠩	Up-pointing arrow followed by down-pointing arrow	⇅ ⇅
⠫⠩⠐⠣	Down-pointing arrow followed by up-pointing arrow	⇵ ⇵

See Sample B-11: Vertical Reversible Reaction Arrow.

a. **Bold Arrows.** Bold arrows employ the boldface indicator of the Nemeth Code. A horizontal chemical arrow uses a single-cell arrow shaft.

⠫⠸⠣	Bold up-pointing arrow	**↑ ↑**
⠫⠸⠩	Bold down-pointing arrow	**↓ ↓**
⠫⠸⠪⠒	Bold left-pointing arrow	**← ←**
⠫⠸⠒⠕	Bold right-pointing arrow	**→ →**

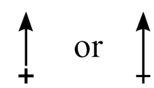
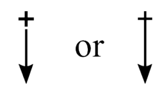
Older publications may depict the favored arrow of an unequal reversible reaction in boldface.

⠫⠣⠐⠸⠩	Regular up-pointing arrow followed by bold down-pointing arrow	⇅ ⇅
⠫⠸⠣⠐⠩	Bold up-pointing arrow followed by regular down-pointing arrow	⇅ ⇅
⠫⠒⠕⠫⠸⠪⠒	Regular right-pointing arrow over bold left-pointing arrow	⇄ ⇄
⠫⠸⠒⠕⠫⠪⠒	Bold right-pointing arrow over regular left-pointing arrow	⇄ ⇄

If the favored arrow of the vertical unequal reversible reaction arrows is printed with a longer shaft length instead of in boldface, select the appropriate symbol from the list above, using the boldface symbol for the longer-shafted arrow. Explain the substitution in a transcriber's note. If horizontal unequal reversible reaction arrows occur in the same diagram, select the appropriate symbol from the list above, using the boldface symbol for the longer-shafted arrow.

See Sample B-14: Vertical Reversible Reaction Arrows (Bold).

b. **Vertical or Oblique Dipole Arrows.**

⠫⠬⠣	Up-pointing dipole arrow (vertical or oblique)	
⠫⠬⠩	Down-pointing dipole arrow (vertical or oblique)	

If other symbols interfere with placement of the dipole arrow, the arrow can be placed on either side of the bond it is referring to without affecting meaning.

Because the length of a vertical or oblique dipole arrow cannot be shown when the arrow is depicted as a braille symbol, a transcriber's note must explain the location of the arrowhead when it extends beyond a symbol or SYMBOL. Sample transcriber's note:

The downward-pointing dipole arrowhead extends beyond X.

See the following Samples.

Sample B-18: Dipole Arrows

Sample B-34: Partial Charge Labels; Vertical Dipole Arrow

c. **Other Vertical Arrows.** See Section 3.2.4, Vaporization and Precipitation Arrows. See Section 3.2.3, Valence Arrows, for up- and down-pointing arrows used in orbital notation.

B.4 Items That Must Be Drawn

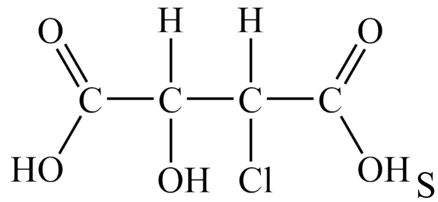
The following items must be drawn as a tactile graphic. See Section 10, Molecular Diagrams, for details.

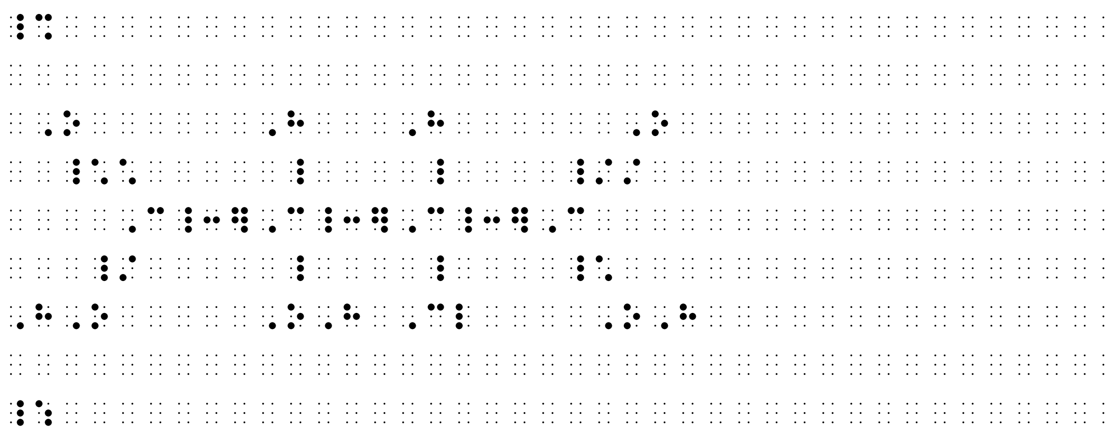
- A mechanistic arrow
- An arrow with a curved shaft
- A lead line
- A horizontal brace or bracket
- A grouping sign which extends through a bond
- A dashed, dotted, or jagged line between areas of a molecular structure illustrating the breaking of a bond
- A complex diagram where readability is a concern

B.5 Samples

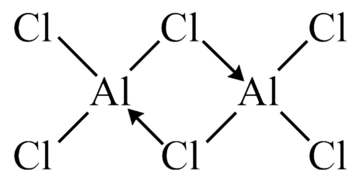
The samples in this appendix illustrate methods for transcribing many of the samples from Section 10, using braille symbols in place of tactile graphics. For ease of comparison, the numbering system is the same as that in Section 10, although titles may differ slightly in order to reflect the focus of the sample. Cross references are given for samples that require tactile representation.

Sample B-1
Single and Double Bonds

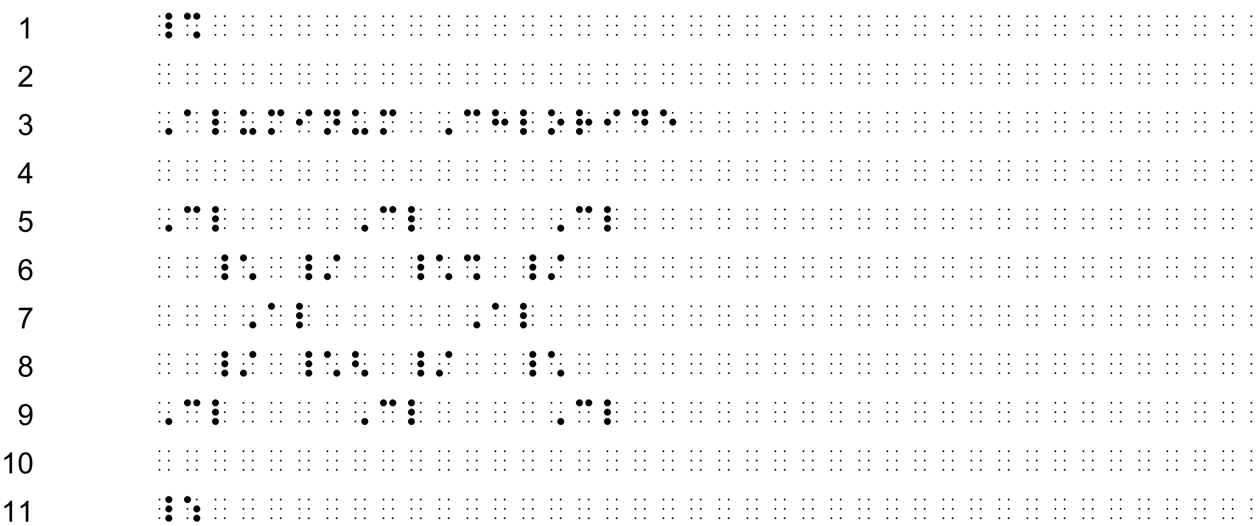




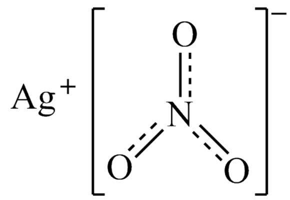
Sample B-2
Oblique Arrow Bonds



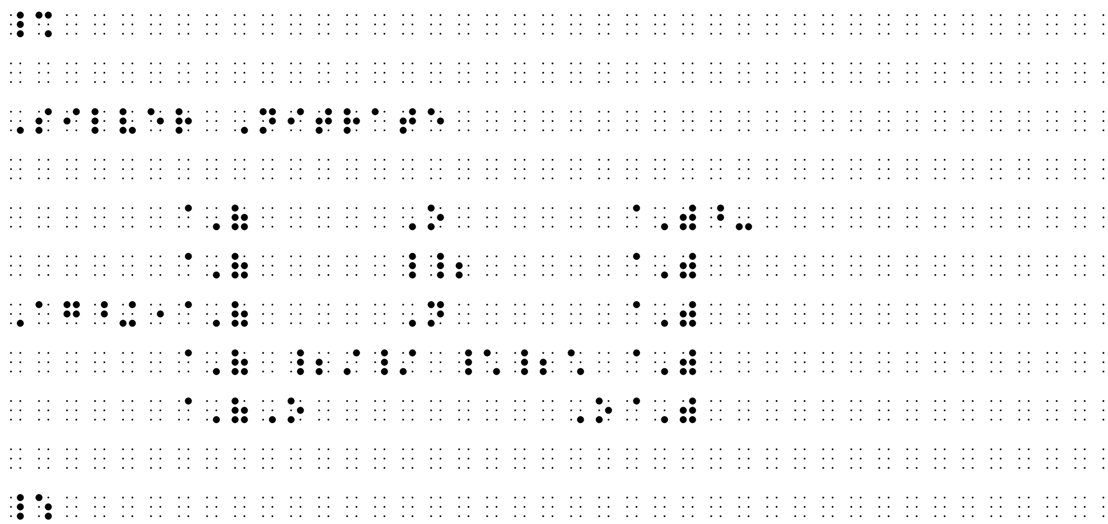
Aluminum Chloride



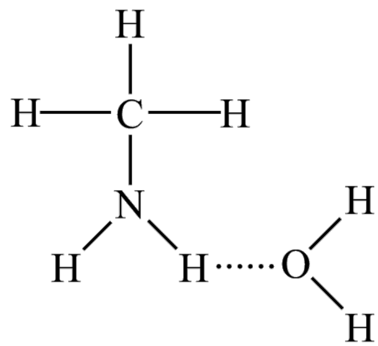
Sample B-3
Dashed (Broken) Bonds



Silver Nitrate



Sample B-4
Dotted Bond



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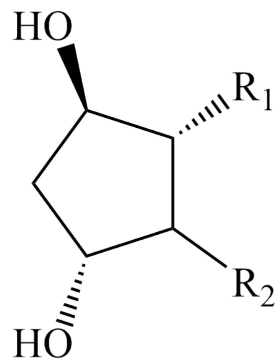
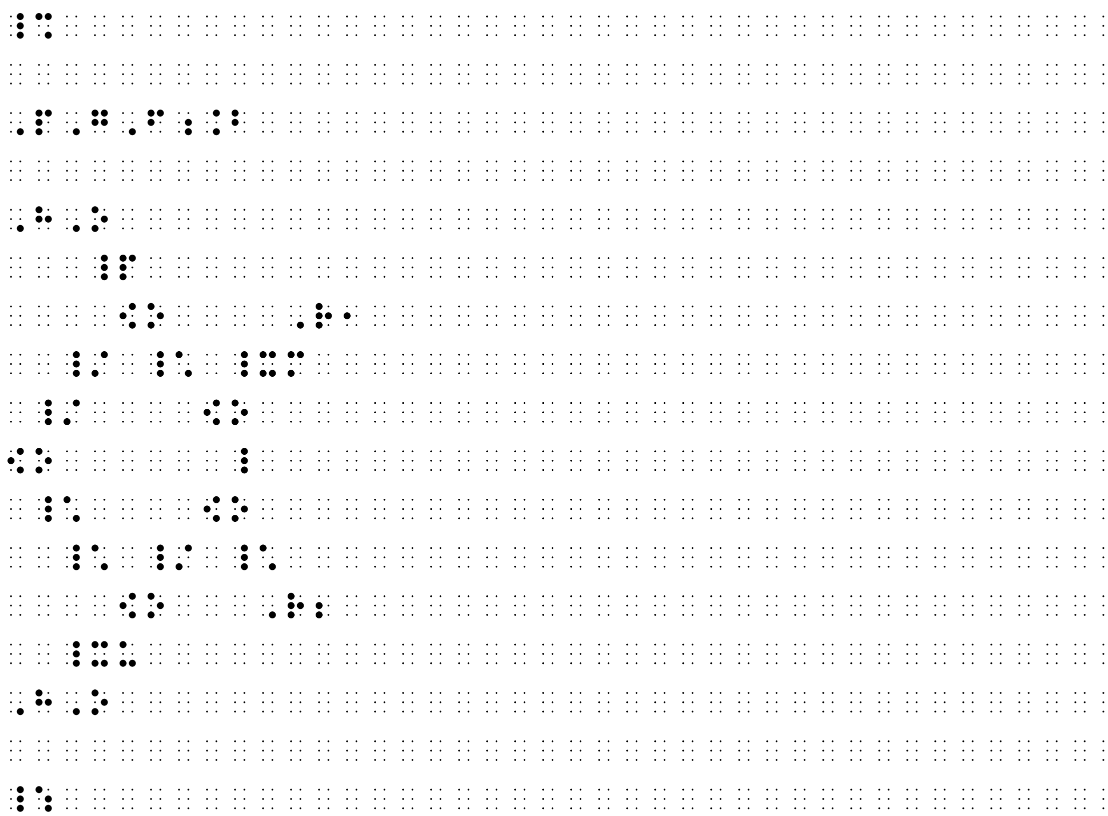
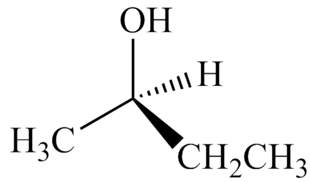
Sample B-5
Wedge Bonds – Solid and Barred

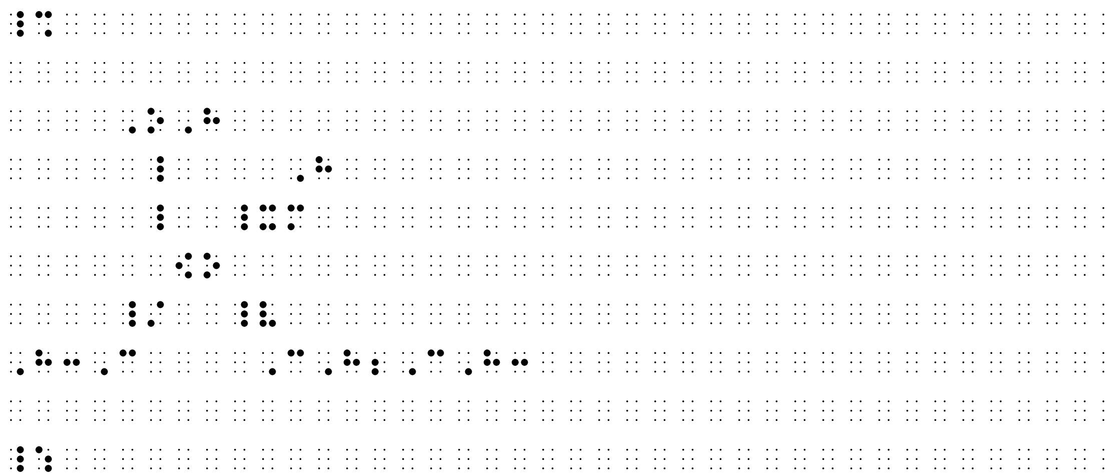


PGF$_\beta$

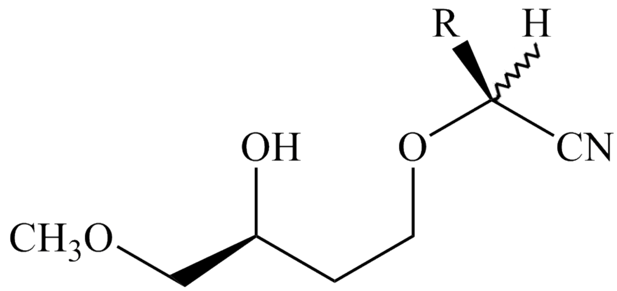


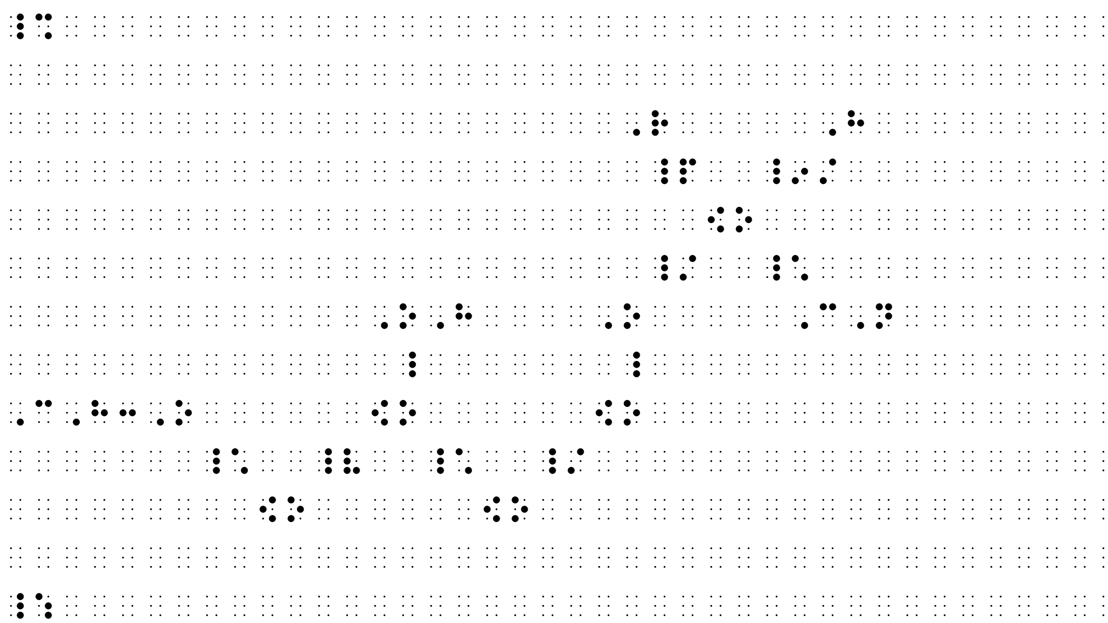
Sample B-6
Wedge Bonds – Solid and Barred



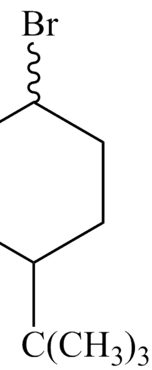


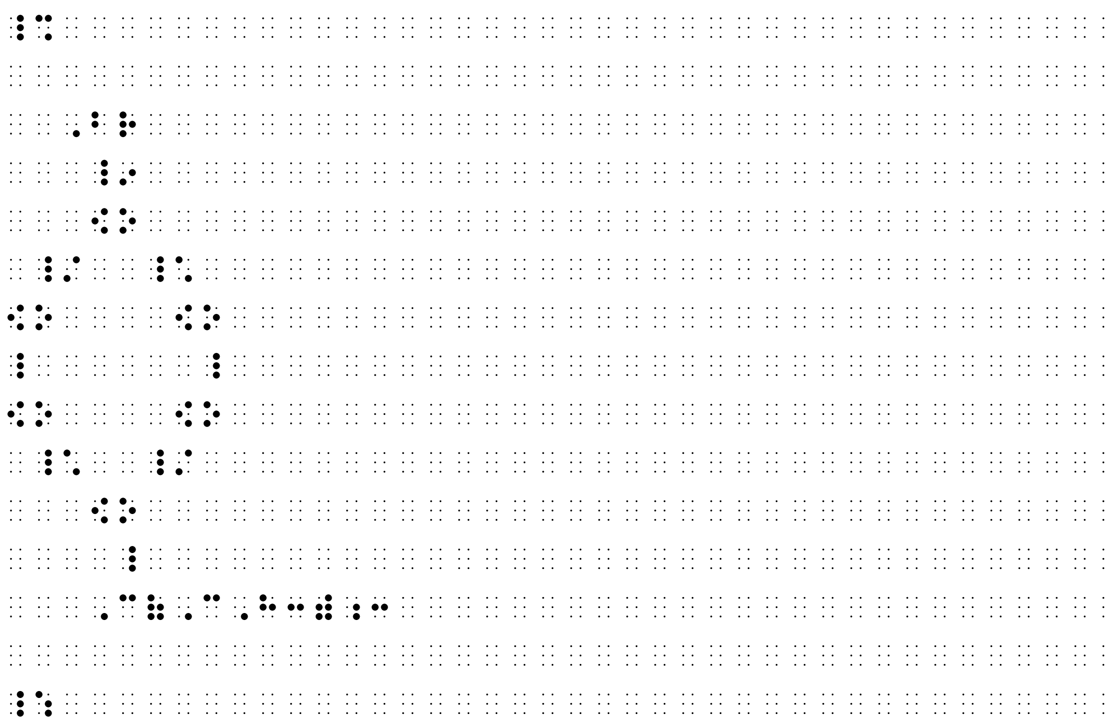
Sample B-7
Jagged Bond and Wedge Bonds





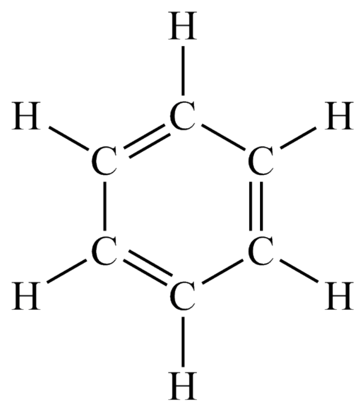
Sample B-8
Wavy Bond

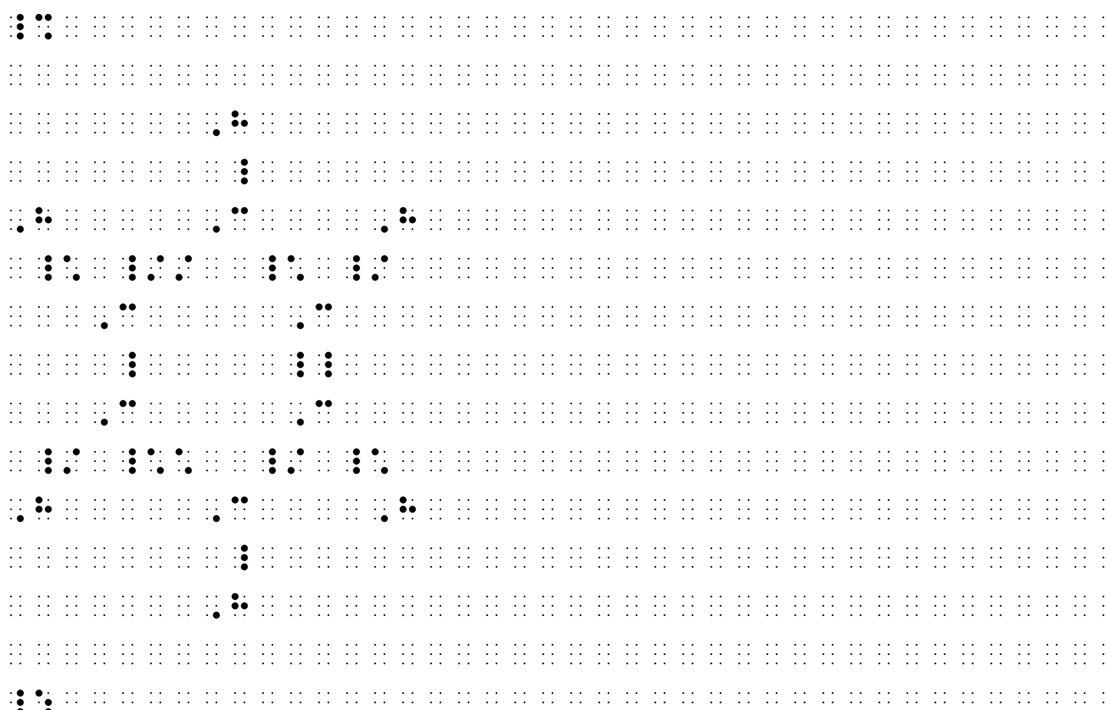




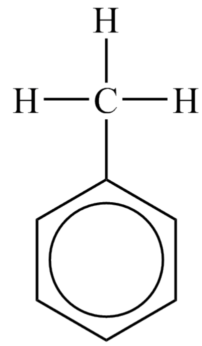
Sample B-9
Ring Structures

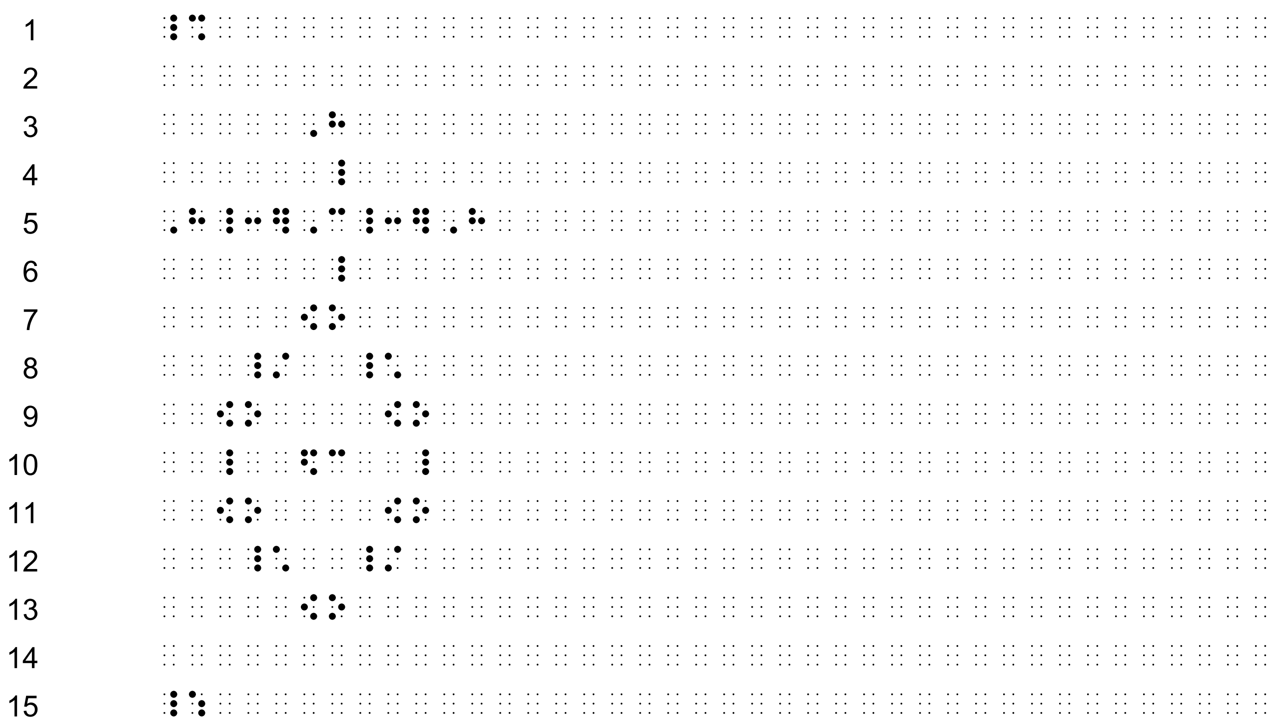
Sample B-9 (a)
Oblique Bonds in a Ring Structure



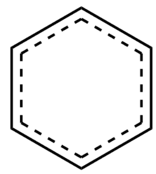


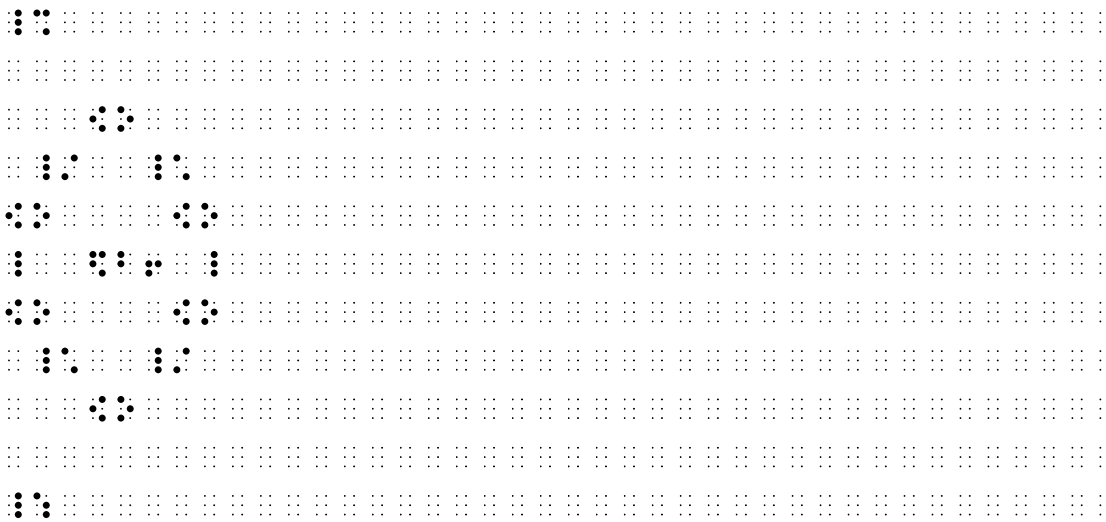
Sample B-9 (b)
Ring Structure with Interior Circle





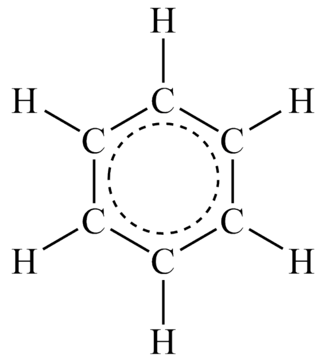
Sample B-9 (c)
Ring Structure with Interior Hexagon (Dashed)

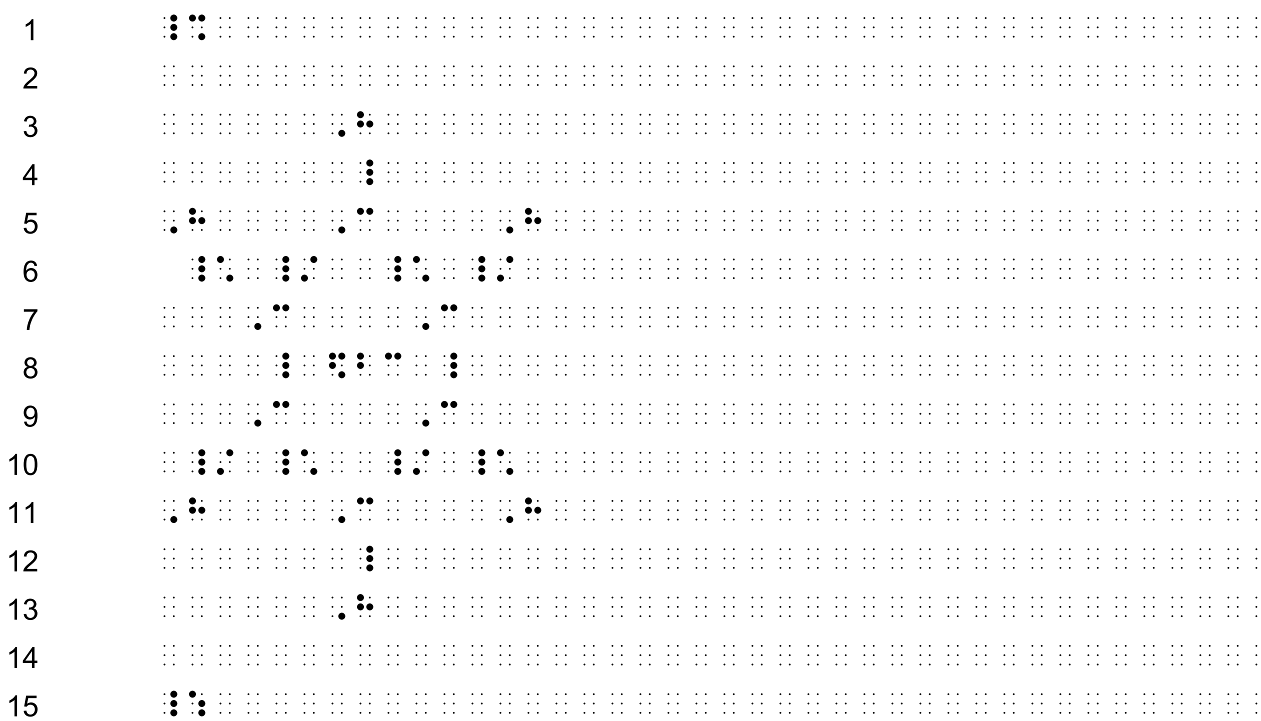




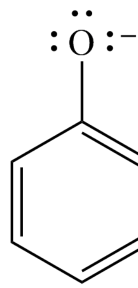
Sample B-9 (d)

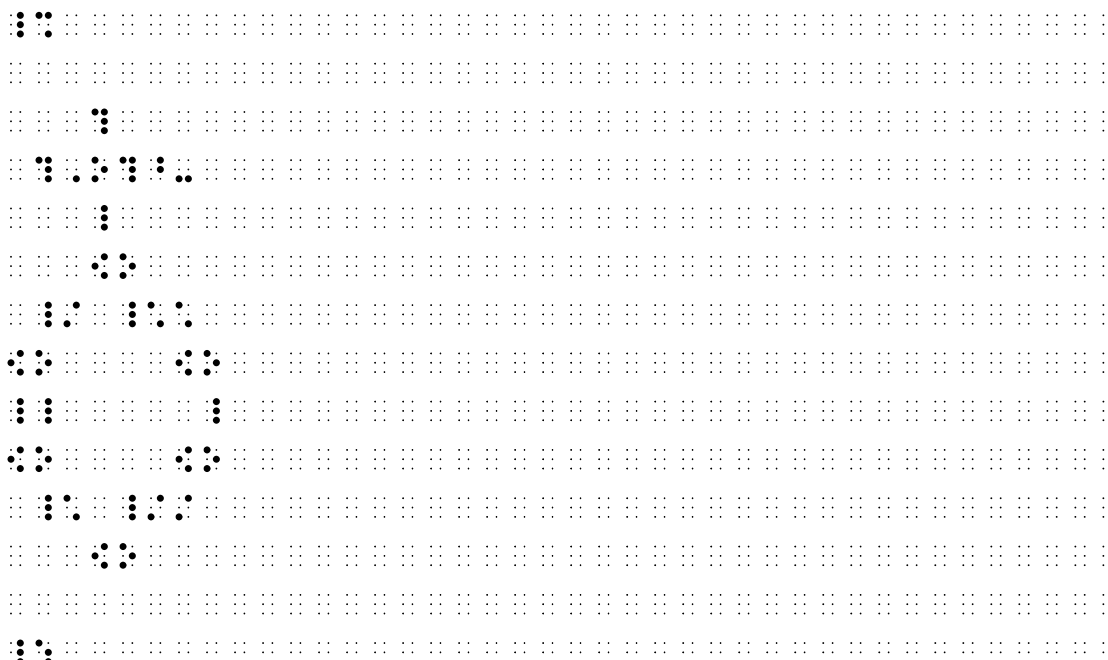
Ring Structure with Interior Circle (Dashed)





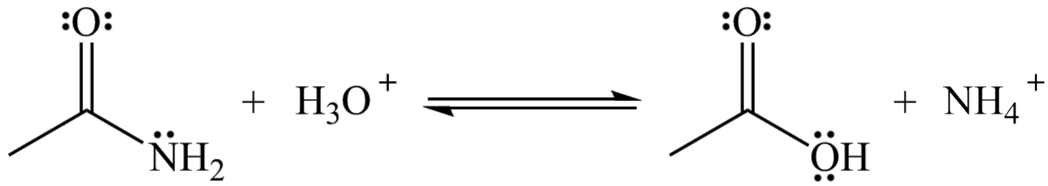
Sample B-9 (e)
Ring Structure with Single and Double Bonds

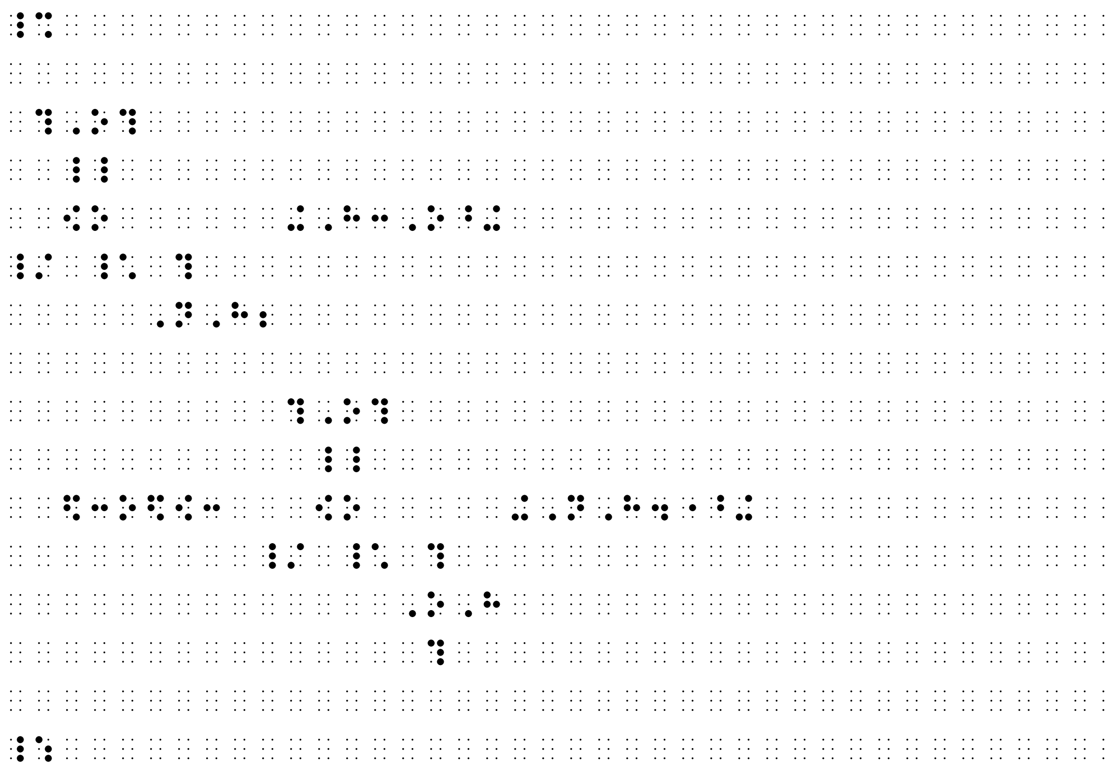




Observe: The superscript applies to the element O, not to the entire structure.

Sample B-10
Reversible Reaction Arrow
and Unlabeled Vertices





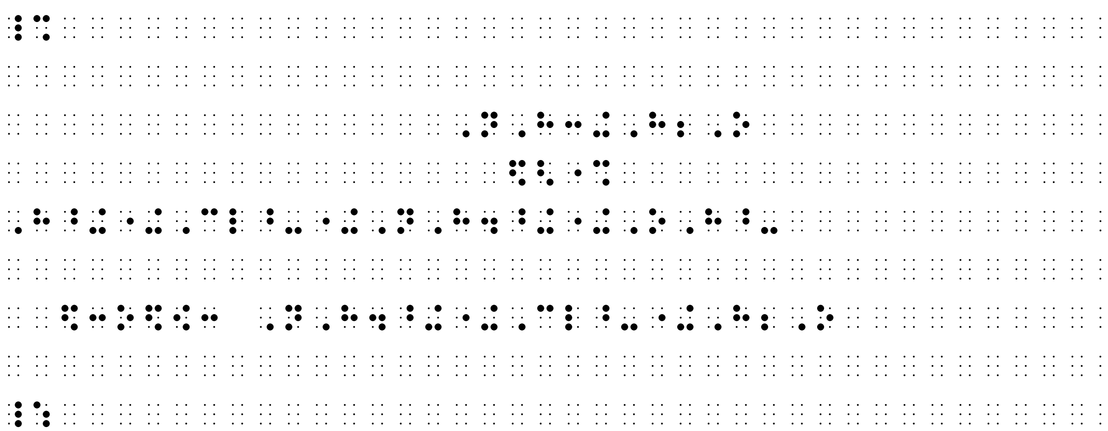
Observe: Full barbs are transcribed for the reversible reaction arrow, regardless of print form. (In print, the arrowheads are harpoons.)

Sample B-11
Vertical Reversible Reaction Arrow

$$NH_3 + H_2O$$

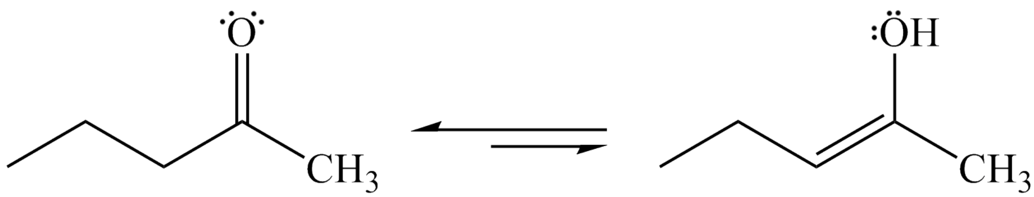
$$\upharpoonleft\downharpoonright$$

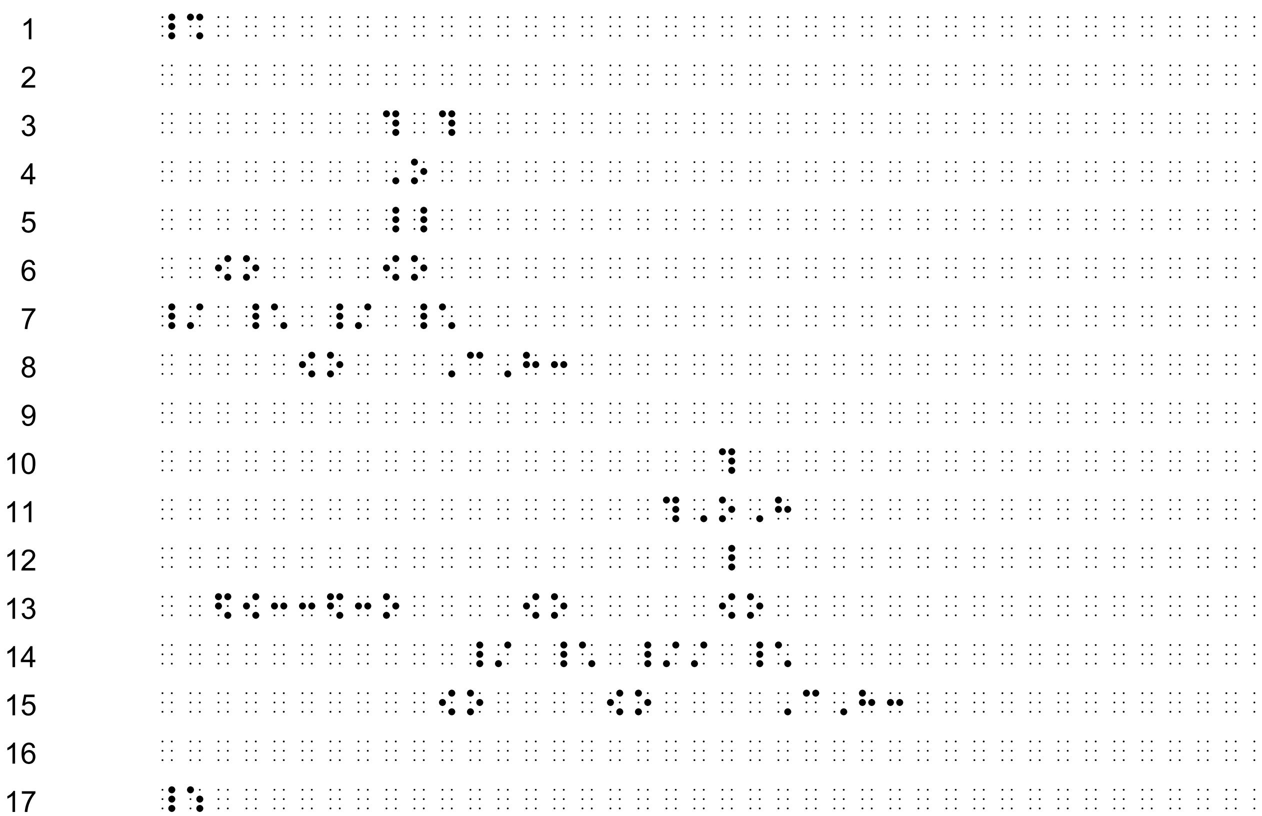
$$H^+ + Cl^- + NH_4^+ + OH^- \rightleftharpoons NH_4^+ + Cl^- + H_2O$$



Observe: Full barbs are transcribed for the reversible reaction arrow, regardless of print form. (In print, the arrowheads are harpoons.)

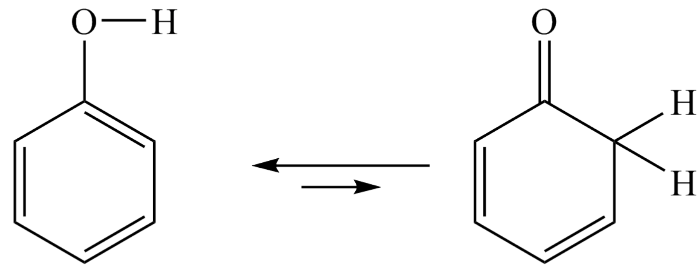
Sample B-12
Unequal Reversible Reaction Arrow;
Unlabeled Vertices

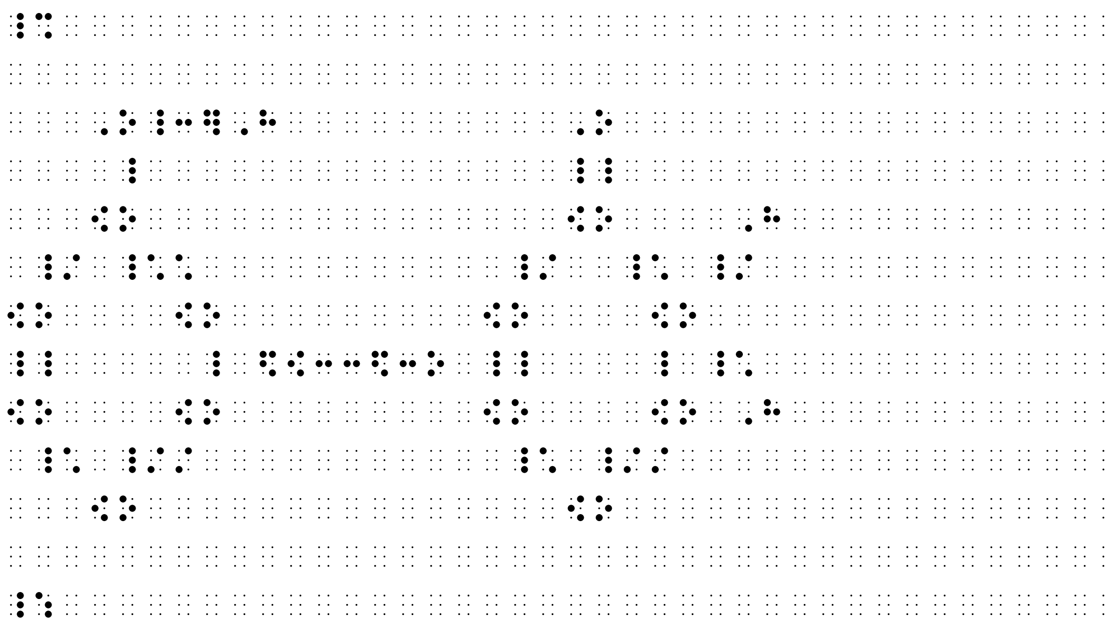




Observe: Full barbs are transcribed for the reversible reaction arrow, regardless of print form. (In print, the arrowheads are harpoons.)

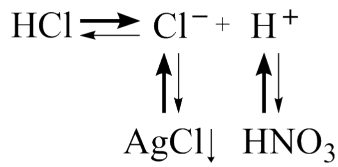
Sample B-13
Reversible Reaction Arrow;
Unlabeled Vertices

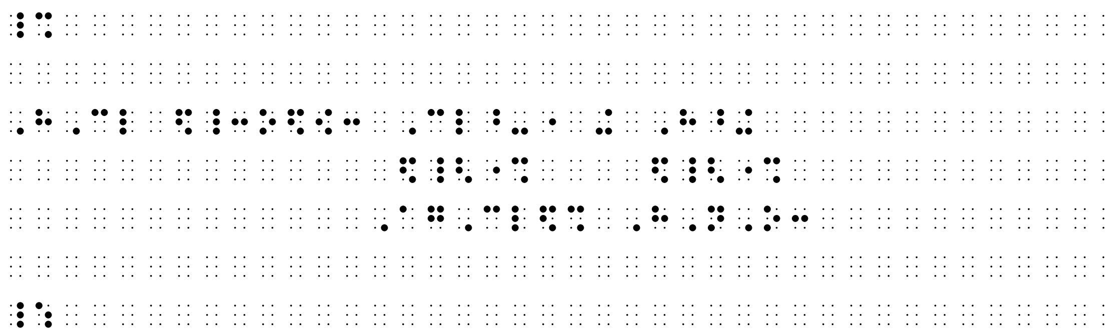




Observe: The single vertical bond in the left ring is aligned above/below the outer cell of the unlabeled vertices. The single vertical bond in the right ring is aligned above/below the inner cell of the unlabeled vertices in order to accommodate the space between it and the oblique bond to its right.

Sample B-14
Vertical Reversible Reaction Arrows (Bold)





The next three samples are not reproduced in this appendix because they contain components that must be drawn.

Sample 10-15: Curved Arrows

Sample 10-15 contains curved arrows which must be rendered as a tactile graphic. Because those chemical arrows must be drawn, the other components should also be drawn. See Sample 10-15 in Section 10, Molecular Diagrams for a visual representation. See Sample 10-15 in the Section 10 supplement for the tactile rendition.

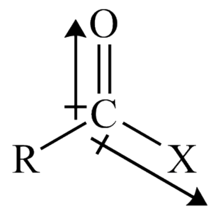
Sample 10-16: Curved Arrows

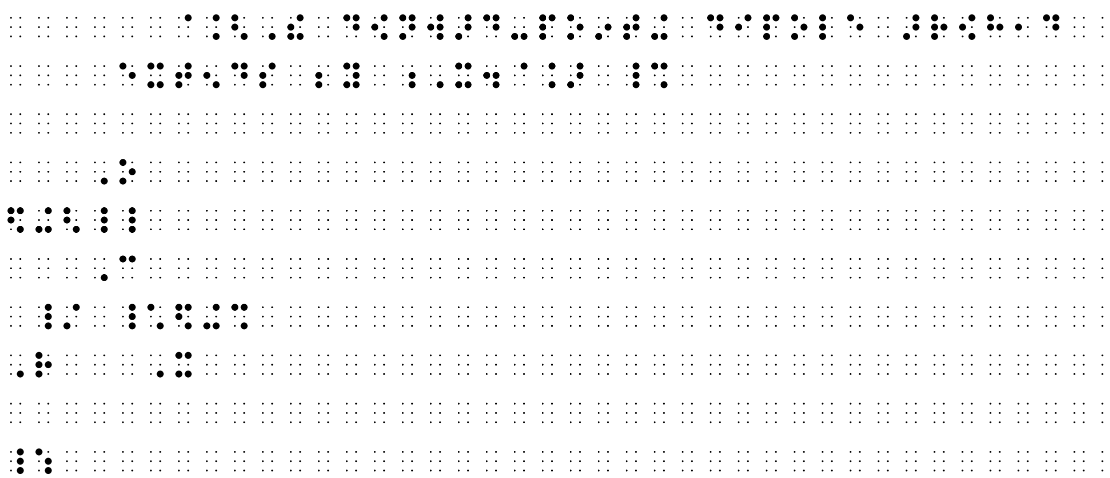
Sample 10-16 contains curved arrows which must be rendered as a tactile graphic. Because those chemical arrows must be drawn, the other components should also be drawn. See Sample 10-16 in Section 10, Molecular Diagrams for a visual representation. See Sample 10-16 in the Section 10 supplement for the tactile rendition.

Sample 10-17: Single-Barbed "Pushing" Arrows

Sample 10-17 contains curved arrows which must be rendered as a tactile graphic. Because those chemical arrows must be drawn, the other components should also be drawn. See Sample 10-17 in Section 10, Molecular Diagrams for a visual representation. See Sample 10-17 in the Section 10 supplement for the tactile rendition.

Sample B-18
Dipole Arrows





Observe: To keep the bond between C and X transcribed as usual, the dipole arrow is placed to the right of the bond even though it is printed to the left. A transcriber's note explains the location of the arrowheads. "The downward-pointing dipole arrowhead extends beyond X."

The next five samples are not reproduced in this appendix because they contain components that must be drawn.

Sample 10-19: Labels

Sample 10-19 contains lead lines which must be rendered as a tactile graphic. See the Section 10 supplement where Sample B-19 is produced showing a combination of raised line graphics and braille symbols.

Sample 10-20: Labels With and Without a Lead Line

Sample 10-20 contains orbital shapes which must be rendered as a tactile graphic. Because that chemical structure must be drawn, the branched structures should also be drawn. See Sample 10-20 in Section 10, Molecular Diagrams for a visual representation. See Sample 10-20 in the Section 10 supplement for the tactile rendition.

Sample 10-21: Orbital Diagram

Sample 10-21 contains a vertical arrow which must be rendered as a tactile graphic. See Sample 10-21 in Section 10, Molecular Diagrams for a visual representation. See Sample 10-21 in the Section 10 supplement for the tactile rendition.

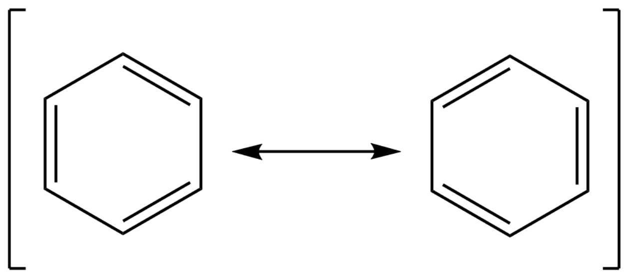
Sample 10-22: Mechanistic Arrows

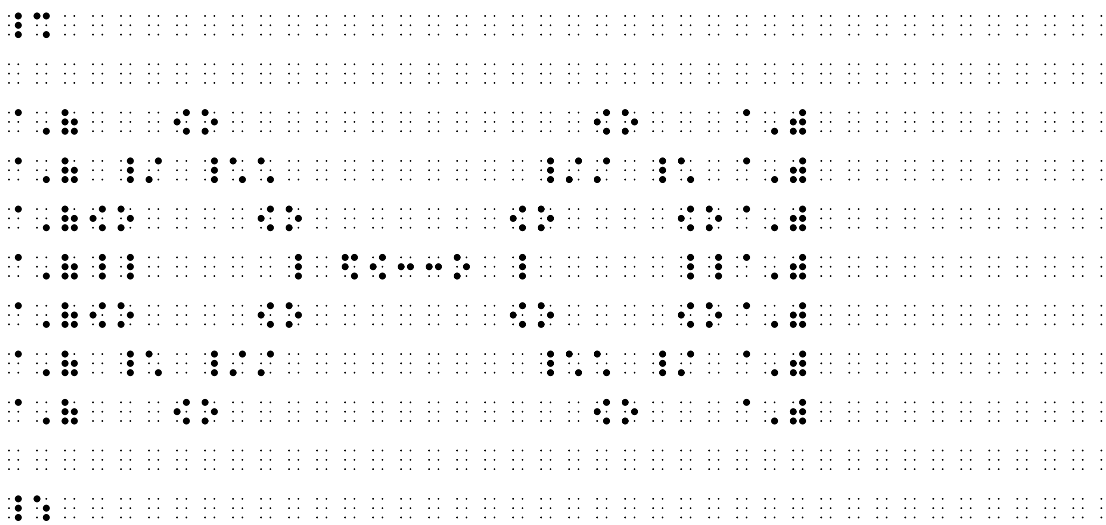
Sample 10-22 contains mechanistic arrows which must be rendered as a tactile graphic. See the Section 10 supplement where Sample B-22 is produced showing a combination of raised line graphics and braille symbols.

Sample 10-23: Broken Bond Separator

Sample 10-23 contains a broken bond separator which must be rendered as a tactile graphic. See the Section 10 supplement where Sample B-23 is produced showing a combination of raised line graphics and braille symbols.

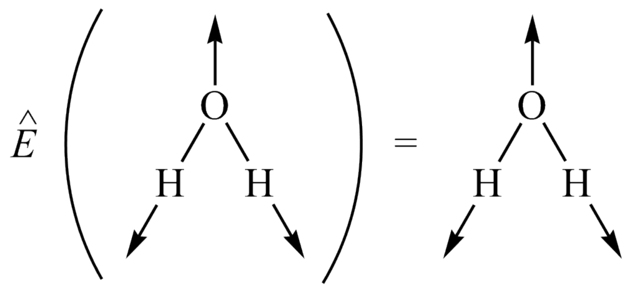
Sample B-24
Bracketed Ring Structures with Resonance Arrow

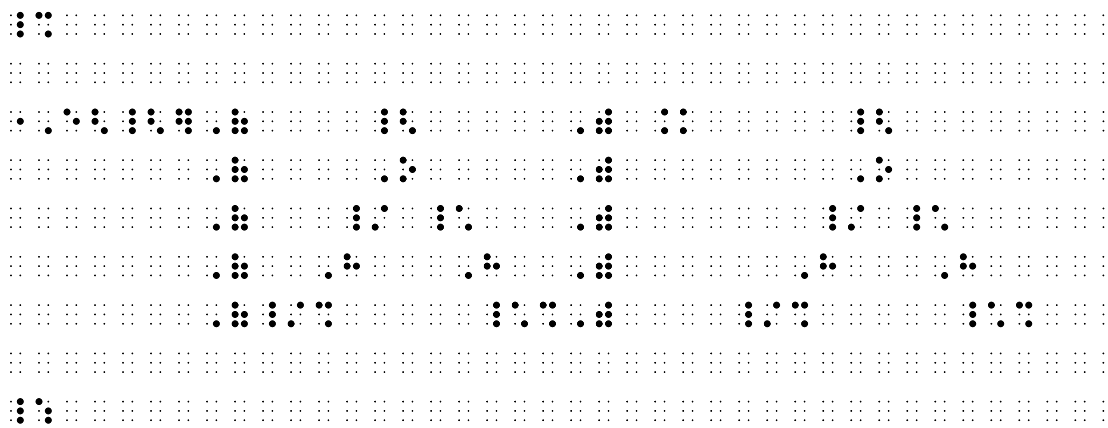




Observe: Each single vertical bond is aligned above/below the outer cell of the unlabeled vertices.

Sample B-25
Vertical and Oblique Arrow Bonds





The next three samples are not reproduced in this appendix because they contain components that must be drawn.

Sample 10-26: Enlarged Bracket Passing Through Oblique Bonds

Sample 10-26 contains an enlarged bracket overlapping a bond, which must be rendered as a tactile graphic. See Sample 10-26 in Section 10, Molecular Diagrams for a visual representation. See Sample 10-26 in the Section 10 supplement for the tactile rendition.

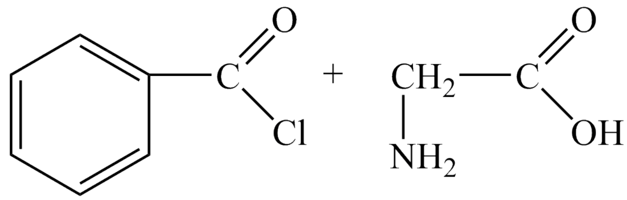
Sample 10-27: Monomer Enclosed in Large Parentheses

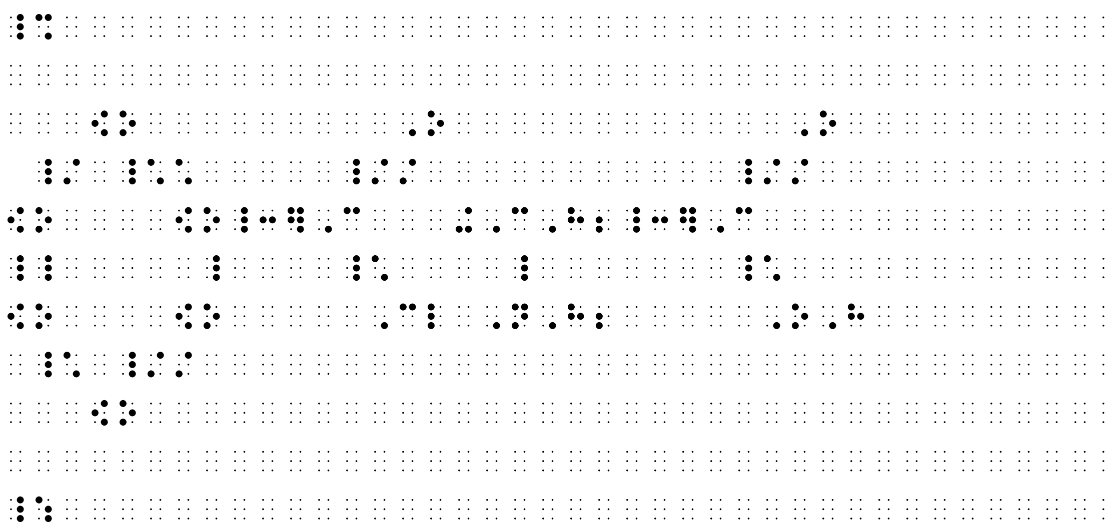
Sample 10-27 contains enlarged parentheses overlapping a bond, which must be rendered as a tactile graphic. See the Section 10 supplement where Sample B-27 is produced showing a combination of raised line graphics and braille symbols.

Sample 10-28: Enlarged Bracket Passing Through a Horizontal Bond

Sample 10-28 contains enlarged brackets overlapping a bond, which must be rendered as a tactile graphic. See the Section 10 supplement where Sample B-28 is produced showing a combination of raised line graphics and braille symbols.

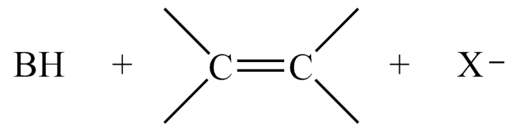
Sample B-29
Operation Sign Unspaced from Branch; Unlabeled Vertices

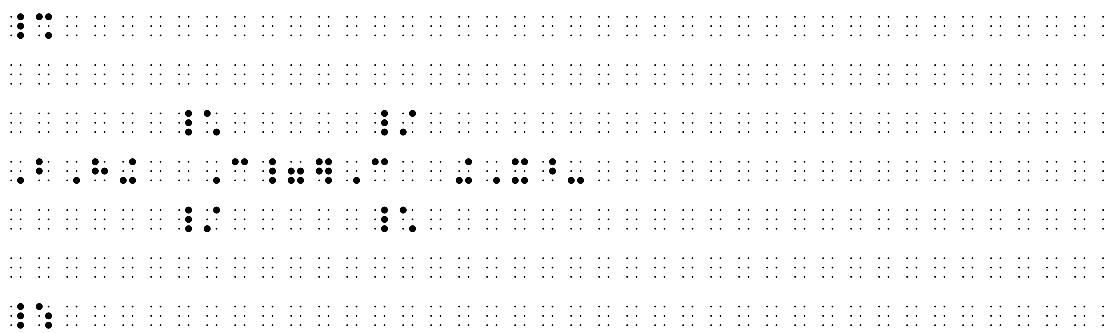




Observe: The single vertical bond in the ring is aligned above/below the outer cell of the unlabeled vertices. The plus sign in the linear portion is aligned in the next cell to the right of the element SYMBOLS in the spatial portion. See Section 10.5.1, Widely Spaced Structures.

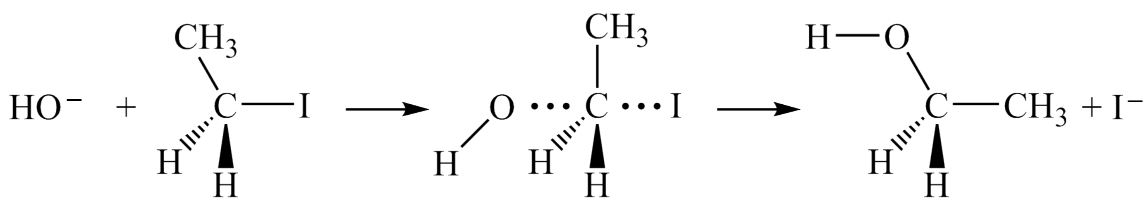
Sample B-30
Operation Sign Spaced from Oblique Bond

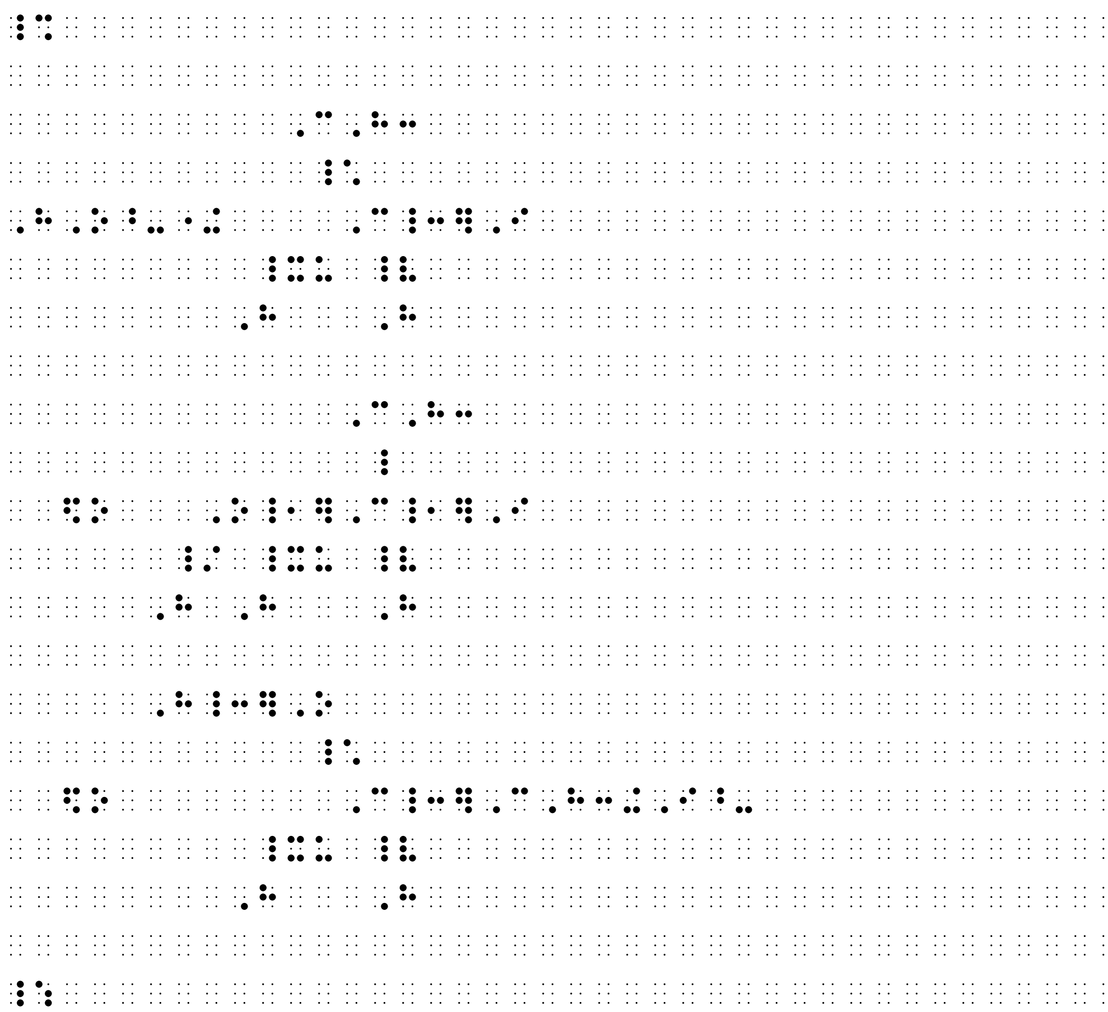




Observe: A clear (blank) column is left between each plus sign in the linear portion and the diagonal bond in the spatial portion. See Section 10.5.1, Widely Spaced Structures.

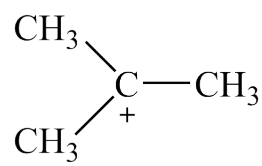
Sample B-31
Spacing of Plus Sign and Yields Arrow from Branch;
Several Kinds of Bonds

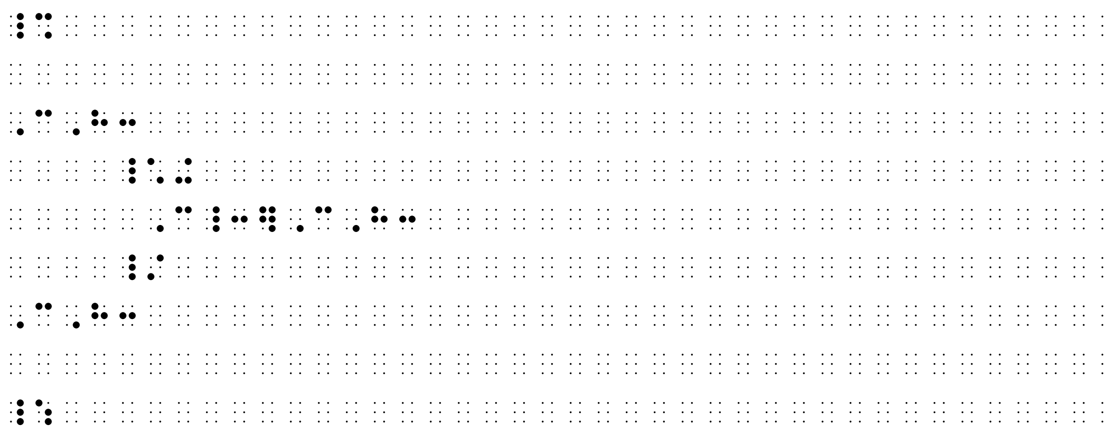




Note: See Section 10.5.1, Widely Spaced Structures.

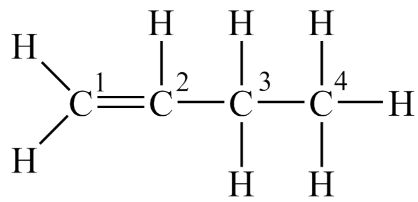
Sample B-32
Positive Sign Labeling an Atom



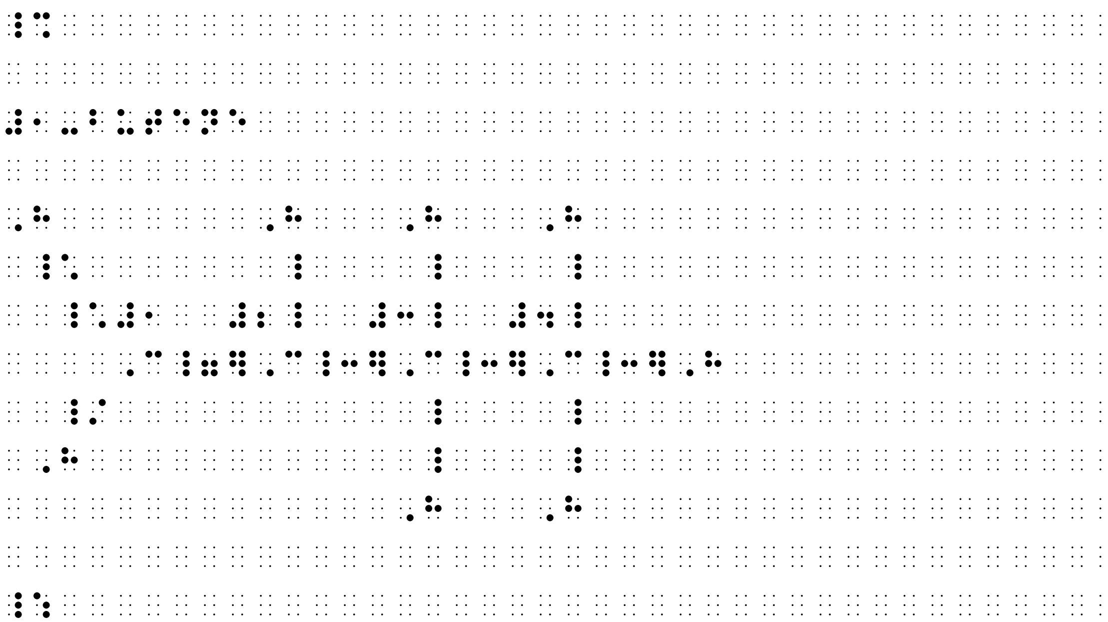


Observe: The label (plus symbol) is transcribed above the SYMBOL (it is printed below the C). See Section 8, Labels.

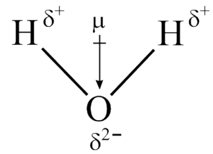
Sample B-33
Numbered Carbon Atoms

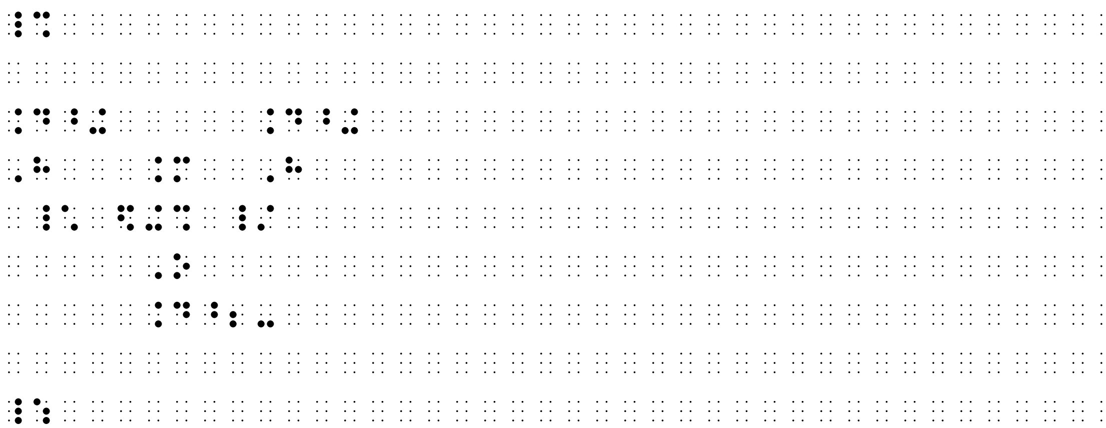


1-butene



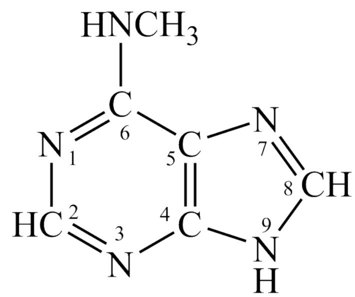
Sample B-34
Partial Charge Labels;
Vertical Dipole Arrow



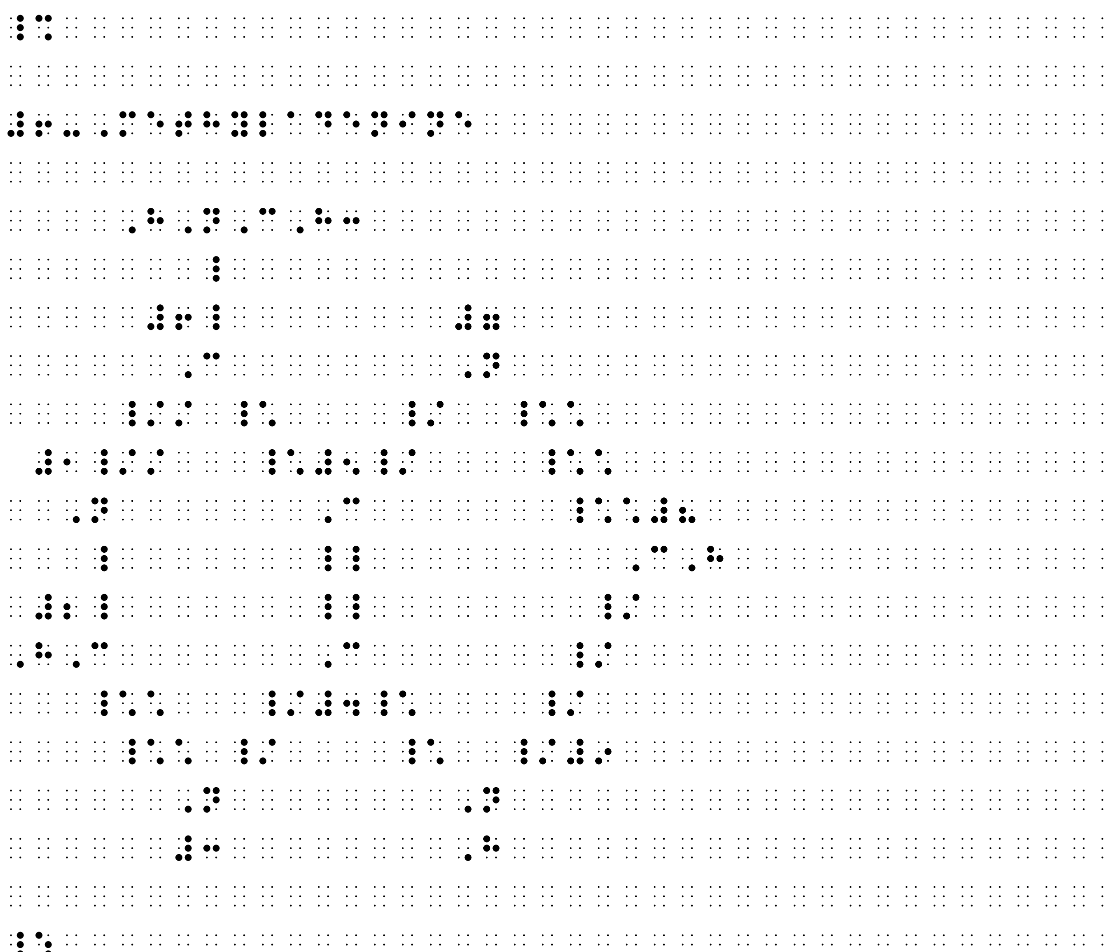


Observe: Although the partial charge labels associated with H are printed in the superscript position, it is clear from the narrative (omitted) that they are labels.

Sample B-35
Ring Structures with Numbered Atoms

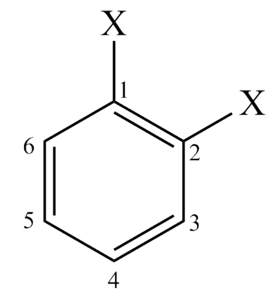


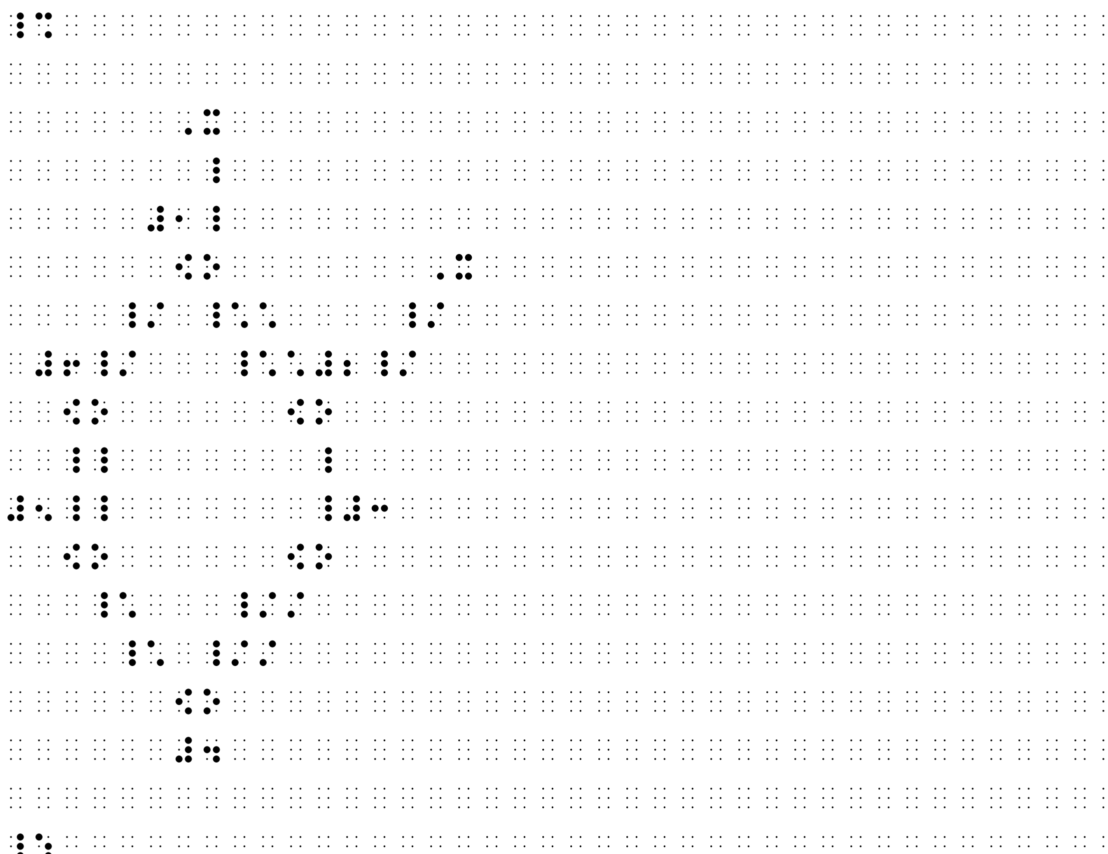
6-Methyladenine



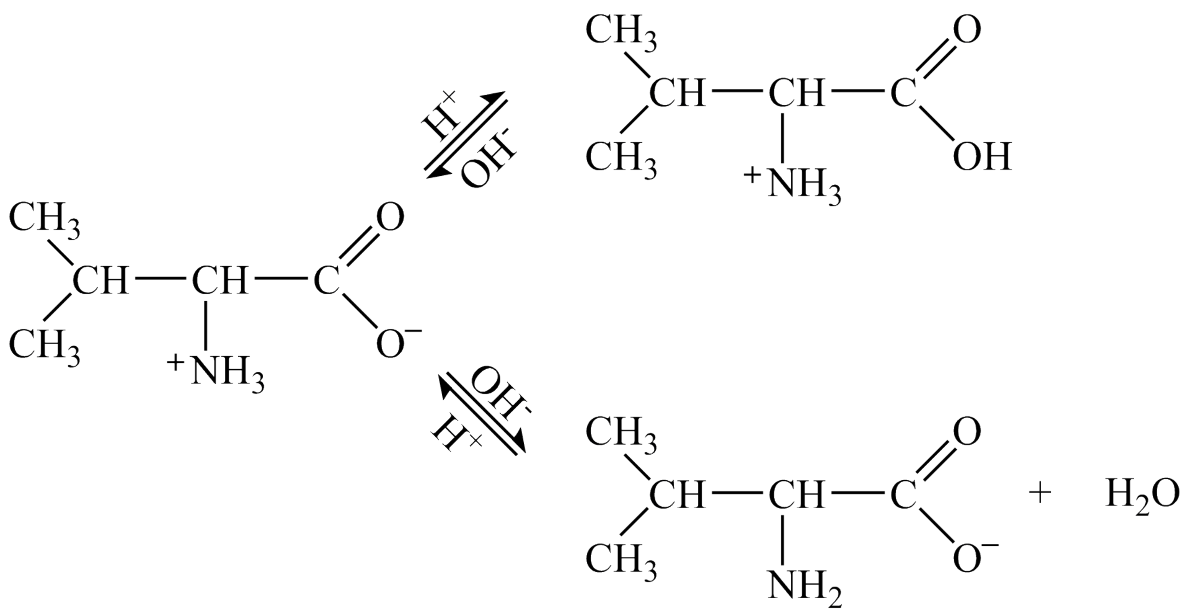
Observe: The labels are printed on the inside of the rings.

Sample B-36
Ring Structure with Numbered Vertices

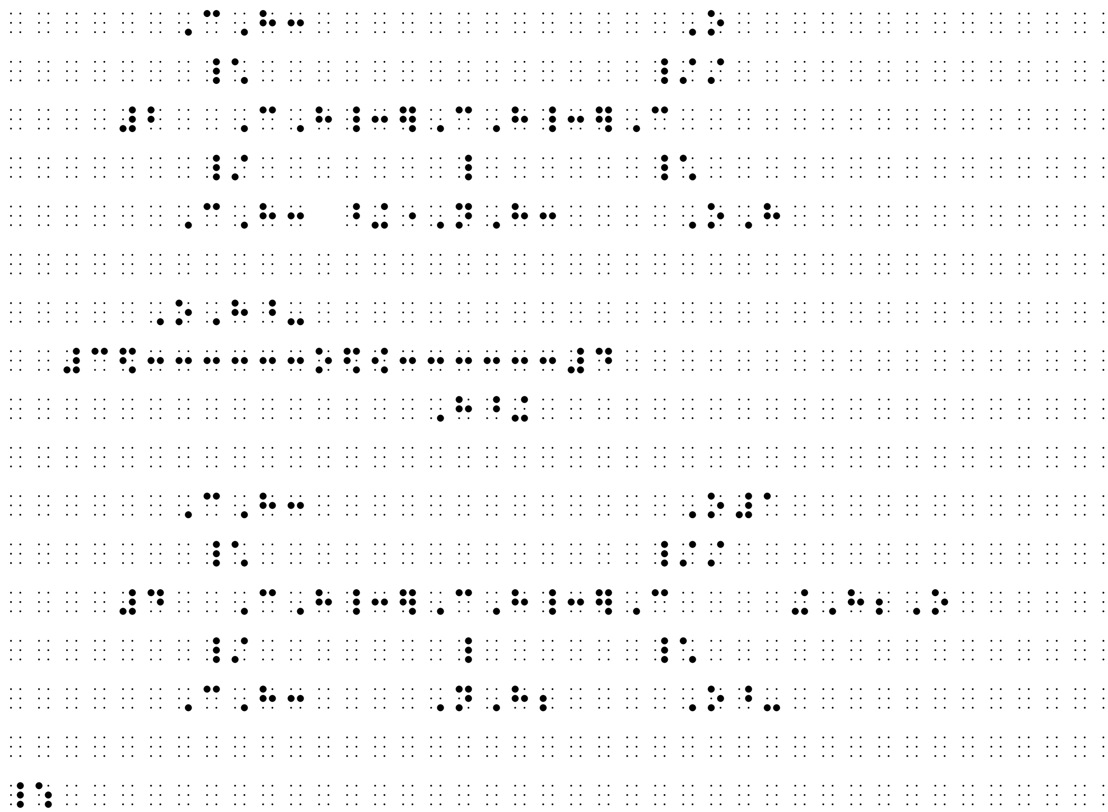




Sample B-37
Modified Arrows Printed at an Angle



(Continues on next page.)



Observe: Full barbs are transcribed for the reversible reaction arrow. (In print, the arrowheads are harpoons.) See Section 9.4.6 for rules regarding the use of runover locators.

Appendix C
Index of Braille Symbols for Chemical Notation

Symbols are listed in braille order in accordance with the UEB "braille order" table. Symbols which appear only in Appendix B are listed separately, starting on page C-8.

	⠡⠌	Dissimilar electron dot pair: regular/hollow, bold, or colored	●○ ● ○ or ○ ●	2-24
32	⠣ (126)			
	⠣	Up-pointing valence arrow	↑ or ↿	3-18
33	⠩ (146)			
	⠩	Down-pointing valence arrow	↓ or ⇂	3-18
34	⠹ (1456)			
	⠹	Pair of regular electron dots	●● :	2-16
36	⠫ (1246)			
	⠫⠉⠬	Plus sign within a circle	⊕	4-3
	⠫⠉⠤	Minus sign within a circle	⊖	4-3
	⠫⠕	Yields arrow	→	3-2
	⠫⠣	Vaporization arrow (upward-pointing)	↑	3-26
	⠫⠩	Precipitation arrow (downward-pointing)	↓	3-26

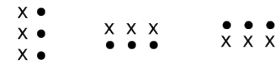
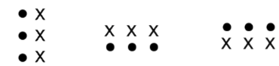
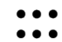
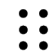
⠫⠪⠒⠫⠒⠕	Reversible reaction arrow (top arrow left-pointing)	$\leftrightarrows$ or $\leftrightharpoons$	3-7
⠫⠪⠒⠫⠒⠒⠕	Unequal reversible reaction arrow (right-favored, left-pointing on top)	$\overset{\leftarrow}{\longrightarrow}$ or $\overset{\leftharpoonup}{\longrightharpoondown}$	3-9
⠫⠪⠒⠒	Reverse reaction arrow	$\leftarrow$	3-2
⠫⠪⠒⠒⠕	Resonance arrow	$\leftrightarrow$	3-6
⠫⠪⠒⠒⠫⠒⠕	Unequal reversible reaction arrow (left-favored, left-pointing on top)	$\underset{\rightarrow}{\longleftarrow}$ or $\underset{\rightharpoondown}{\longleftharpoonup}$	3-9
⠫⠪⠒⠬	Left-pointing dipole arrow	$\leftarrow\!+$ or $\leftarrow\!+$	3-16
⠫⠒ ⠒⠕	Right-pointing dashed arrow	$\dashrightarrow$	3-16
⠫⠒⠕⠫⠪⠒	Reversible reaction arrow (top arrow right-pointing)	$\rightleftarrows$ or $\rightleftharpoons$	3-7
⠫⠒⠕⠫⠪⠒⠒	Unequal reversible reaction arrow (left-favored, right-pointing on top)	$\overset{\rightarrow}{\longleftarrow}$ or $\overset{\rightharpoonup}{\longleftharpoondown}$	3-9
⠫⠒⠒⠕⠫⠪⠒	Unequal reversible reaction arrow (right-favored, right-pointing on top)	$\underset{\leftarrow}{\longrightarrow}$ or $\underset{\leftharpoondown}{\longrightharpoonup}$	3-9

	⠫⠒⠒⠒⠕		Yields arrow with extended shaft (length varies)	$\longrightarrow$	3-2
	⠫⠶⠶⠕		Right-pointing arrow with double shaft	$\Longrightarrow$ or ⇨	3-15
	⠫⠬		Detached plus sign	+	4-3
	⠫⠬⠒⠕		Right-pointing dipole arrow	+⟶ or +⟶	3-16
	⠫⠤		Detached minus sign	–	4-3
38	⠳	(1256)			
	⠳		Single partition line	|	4-6
	⠳⠳		Double partition line	||	4-6
39	⠪	(246)			
	⠪		Pair of small x electron dots	x x $\substack{x\\x}$	2-16
51	⠌	(34)			
	⠌		Single hollow, bold, or colored electron dot	∘	2-16

	⠌⠭	Dissimilar electron dot pair: hollow, bold, or colored/x	○ x	$\overset{\circ}{\times}$ or $\overset{\times}{\circ}$	2-24
	⠌⠡	Dissimilar electron dot pair: hollow, bold, or colored/regular	○ ●	$\overset{\circ}{\bullet}$ or $\overset{\bullet}{\circ}$	2-24
	⠌⠫⠪⠒⠒⠕	Negated resonance arrow	$\nleftrightarrow$		3-14
	⠌⠫⠒⠒⠕	Negated yields arrow	$\nrightarrow$		3-14
53	⠼ (3456)				
	⠼	Pair of hollow, bold, or colored electron dots	○ ○	$\overset{\circ}{\circ}$	2-16
	⠼⠝	Runover locator (where n represents an upper number assigned by the transcriber)			9-13
57	⠈ (4)				
	⠈⠠⠙	Crossed capital letter D	Đ		4-8
59	⠸ (456)				
	⠸	Single vertical bond	|		2-10

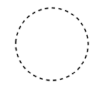
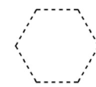
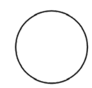
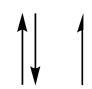
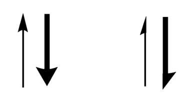
⠸⠣	Arrow bond, up-pointing	↑	2-14
⠸⠩	Arrow bond, down-pointing	↓	2-14
⠸⠿⠻	Triple horizontal bond (including bond indicators)	≡	2-2
⠸⠪⠒⠻	Left-pointing arrow bond (including bond indicators)	←	2-3
⠸⠒⠕⠻	Right-pointing arrow bond (including bond indicators)	→	2-3
⠸⠒⠻	Single horizontal bond (including bond indicators)	—	2-2
⠸⠶⠻	Double horizontal bond (including bond indicators)	═	2-2
⠸⠸	Double vertical bond	||	2-10
⠸⠸⠸	Triple vertical bond	|||	2-10

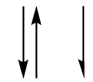
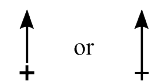
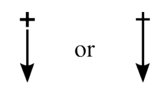
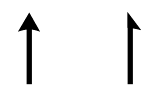
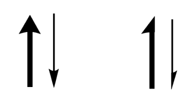
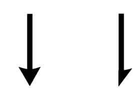
61 ⠨ (46)

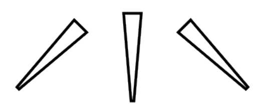
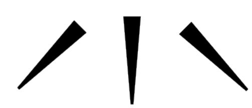
⠨⠭⠡	Electron dot triplet: three x/regular pairs		2-30
⠨⠡⠭	Electron dot triplet: three regular/x pairs		2-30
⠨⠹	Three pairs of regular electron dots (triplet)	 or 	2-30

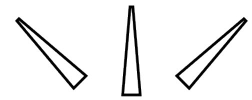
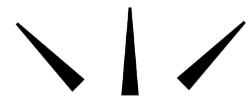
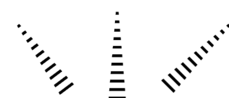
Symbols which appear only in Appendix B

If an agency determines that the production of tactile graphics for the depiction of molecular structures is not feasible, the following symbols may be transcribed. Include the symbols used in a particular volume on the Special Symbols page, inserted among the other chemistry symbols from pages C-1 through C-7, in braille order.

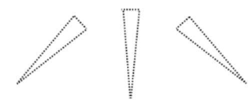
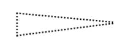
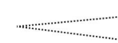
				Page
36	⠫ (1246)			
	⠫⠃⠉	Interior circle with broken outline		B-8
	⠫⠃⠖	Interior hexagon with broken outline		B-8
	⠫⠉	Interior circle		B-8
	⠫⠣	Up-pointing chemical arrow	↑	B-10
	⠫⠣⠐⠩	Up-pointing arrow followed by down-pointing arrow		B-10
	⠫⠣⠐⠸⠩	Regular up-pointing arrow followed by bold down-pointing arrow		B-10

⠫⠩	Down-pointing chemical arrow	↓	B-10
⠫⠩⠐⠣	Down-pointing arrow followed by up-pointing arrow		B-10
⠫⠒⠕⠫⠸⠪⠒	Regular right-pointing arrow over bold left-pointing arrow		B-10
⠫⠬⠣	Up-pointing dipole arrow (vertical or oblique)		B-11
⠫⠬⠩	Down-pointing dipole arrow (vertical or oblique)		B-11
⠫⠸⠣	Bold up-pointing arrow		B-10
⠫⠸⠣⠐⠩	Bold up-pointing arrow followed by regular down-pointing arrow		B-10
⠫⠸⠩	Bold down-pointing arrow		B-10
⠫⠸⠪⠒	Bold left-pointing arrow		B-10

	⠫⠸⠒⠕	Bold right-pointing arrow		B-10
	⠫⠸⠒⠕⠫⠪⠒	Bold right-pointing arrow over regular left-pointing arrow		B-10
39	⠪ (246)			
	⠪⠕	Unlabeled vertex		B-7
59	⠸ (456)			
	⠸⠛	Bold vertical bond		B-3
	⠸⠛⠻	Bold horizontal bond (including bond indicators)		B-2
	⠸⠍	Down-pointing wedge (vertical or oblique), normal outline		B-5
	⠸⠕⠻	Right-pointing wedge, normal outline (including bond indicators)		B-5
	⠸⠏	Down-pointing wedge (vertical or oblique), filled in		B-6

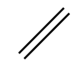
⠸⠗⠻	Right-pointing wedge, filled in (including bond indicators)		B-5
⠸⠥	Up-pointing wedge (vertical or oblique), normal outline		B-5
⠸⠧	Up-pointing wedge (vertical or oblique), filled in		B-6
⠸⠭	Barred vertical bond		B-3
⠸⠭⠍	Down-pointing wedge (vertical or oblique), barred		B-6
⠸⠭⠥	Up-pointing wedge (vertical or oblique), barred		B-6
⠸⠭⠡	Barred oblique bond, upper left to lower right		B-3

⠸⠭⠌	Barred oblique bond, lower left to upper right		B-4
⠸⠡	Oblique bond, upper left to lower right		B-3
⠸⠡⠡	Oblique double bond, upper left to lower right		B-3
⠸⠡⠣	Oblique arrow bond, lower right to upper left		B-7
⠸⠡⠩	Oblique arrow bond, upper left to lower right		B-7
⠸⠳⠑⠻	Right-pointing wedge, barred (including bond indicators)		B-5
⠸⠳⠻	Barred horizontal bond (including bond indicators)		B-2
⠸⠳⠪⠻	Left-pointing wedge, barred (including bond indicators)		B-5
⠸⠪⠻	Left-pointing wedge, normal outline (including bond indicators)		B-5

⠸⠺⠻	Left-pointing wedge, filled in (including bond indicators)		B-5
⠸⠂	Dotted vertical bond		B-3
⠸⠂⠍	Down-pointing wedge (vertical or oblique), dotted outline		B-6
⠸⠂⠕⠻	Right-pointing wedge, dotted outline (including bond indicators)		B-5
⠸⠂⠥	Up-pointing wedge (vertical or oblique), dotted outline		B-6
⠸⠂⠡	Dotted oblique bond, upper left to lower right		B-4
⠸⠂⠻	Dotted horizontal bond (including bond indicators)		B-2
⠸⠂⠪⠻	Left-pointing wedge, dotted outline (including bond indicators)		B-5

⠸⠂⠌	Dotted oblique bond, lower left to upper right		B-4
⠸⠆	Broken vertical bond		B-3
⠸⠆⠍	Down-pointing wedge (vertical or oblique), dashed outline		B-6
⠸⠆⠕⠻	Right-pointing wedge, dashed outline (including bond indicators)		B-5
⠸⠆⠥	Up-pointing wedge (vertical or oblique), dashed outline		B-6
⠸⠆⠡	Broken oblique bond, upper left to lower right		B-4
⠸⠆⠻	Broken horizontal bond (including bond indicators)		B-2
⠸⠆⠪⠻	Left-pointing wedge, dashed outline (including bond indicators)		B-5

⠸⠆⠌	Broken oblique bond, lower left to upper right		B-4
⠸⠔	Jagged or wavy vertical bond		B-3
⠸⠔⠡	Jagged or wavy oblique bond, upper left to lower right		B-4
⠸⠔⠻	Jagged or wavy horizontal bond (including bond indicators)		B-2
⠸⠔⠢	Jagged or wavy vertical double bond		B-3
⠸⠔⠢⠻	Jagged or wavy horizontal double bond (including bond indicators)		B-2
⠸⠔⠌	Jagged or wavy oblique bond, lower left to upper right		B-4
⠸⠌	Oblique bond, lower left to upper right		B-3
⠸⠌⠣	Oblique arrow bond, lower left to upper right		B-7

⠸⠌⠩	Oblique arrow bond, upper right to lower left		B-7
⠸⠌⠌	Oblique double bond, lower left to upper right		B-3