化学概説Ba 2週目と3週目

後期　月曜日4限

理学部 本多 尚

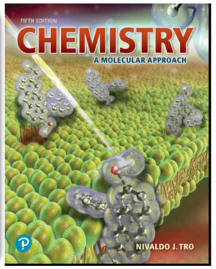
本多自己紹介

理学部 教授・共通教養長
固液中間相の研究・機能性高分子の研究・多孔性材料の研究など
担当科目：基礎化学実験・化学概説C・化学熱力学・溶液化学など
http://honda.sci.yokohama-cu.ac.jp/

教科書

Chemistry: A Molecular Approach (5th Edition)
Nivaldo J. Tro著（出版社：Pearson Education)

*この教科書は、化学全体を扱っています。また、内容のほとんどが高校化学です。授業では教科書に記されている内容をベースに大学化学の基礎を講義します。



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理系の 実験レポートの書き方

横浜市立大学学術情報センター
（化学概説B用にアレンジ）

理系の実験レポートの基本事項

☑表紙

・実験課題名
・実験実施日
・レポート提出日
・提出者
（学部名、学生番号、氏名）
・共同実験者
（学部名、学籍番号、氏名）
を書く

☑用紙

A4版のレポート用紙または
白い用紙を用いる

☑本文の構成

1　実験目的
2　実験 or 材料と方法
3　結果
4　考察
5　参考文献

実験：物理・化学系
材料と方法：生物系

☑本文の構成

各項目の注意点

1. 実験目的

実験の目的を具体的に・簡潔に書く。

あなたが「なぜ」それをやることにしたのか（理由）を記すこと

授業で行う実験の場合は、テキスト記載の実験の目的を理解し、それを自分の言葉で書くこと

☑本文の構成

各項目の注意点

2. 実験 or 材料と方法

自分の行った実験内容を書く。

あなたが行った操作を記すこと（テキスト記載の実験でも丸写ししない）

●記述すること
使用した試薬と量、器具や装置、実験方法、測定方法など

例

(1) 上皿天秤を用い、塩化アンモニウムを12.3 gはかりとった。
(2) 水200 mLのビーカーに水酸化カルシウム20 gを加えた。

実験値を正確に書く

箇条書きにするとよい

過去形で書くことが一般的

☑本文の構成

3. 結果

実験で得られた生データを示す。

事実をありのままに書くこと（ネガティブだと思う結果にも価値がある）

●実験結果を示す方法
図・表 → 通し番号、Caption は必須！

- ☑ 単位がある値には、必ず単位を明記
- ☑ 自分が行った実験結果であるため、**過去形**で書く
- ☑ 客観的な事実のみを書く

4. 考察とまとめて書くことも可能であるが、
実験事実なのか自分の考えなのか区別して書くこと！

Captionの例（図の場合）

Caption：
「その図や表が何を示しているのか」を示すもの。

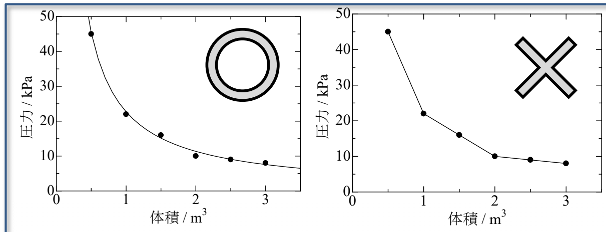


図1. 273 Kにおける気体Aの圧力と体積の関係

Captionは図の下

実験データに線を引く際は、そのデータの理論を考え、適した線を入れること。
この例の場合はボイルの法則を与えることが理論的に考えられるので、左の方が適している。

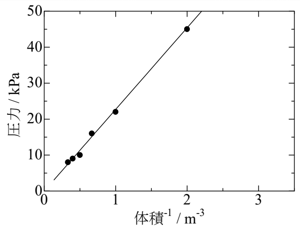


図2. 273 Kにおける気体Aの圧力と体積の逆数の関係

Captionは図の下

曲線は理論式からの「ずれ」がわかりにくいので、下図のように直線になる様にグラフを工夫できると非常に良い。

図の横軸・縦軸およびそのタイトルと単位を必ず書く

Captionの例（表の場合）

表3. 実験で得られた電流と電圧

Captionは表の上

電流 [A]	電圧 [V]
1.05	0.50
2.00	1.10
3.40	1.65

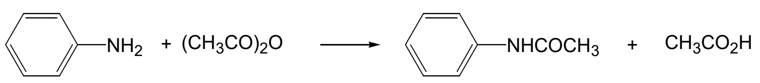
図と表それぞれで、通し番号を付けること。

表に書き込む数値には有効桁数を意識する
（例：2 Aと2.00 Aでは意味が異なる）

補足

Scheme

化学分野の実験レポートにおいて、化学反応式を示す方法。



Scheme 1. アセトアニリドの合成反応

Schemeも通し番号を付けること。

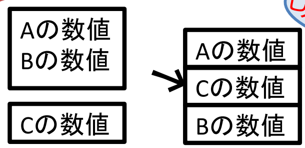
図・グラフ・画像データ…を扱うときに注意したい

不正行為、剽窃

剽窃

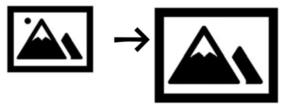
テキストや参考書の写真を撮りそのまま実験レポートに載せる

改ざん



画像を切り貼りして加工

改ざん



余計なものが写っているので除去する
都合の悪いデータを削除・修正

見栄えを良くするため…であっても、画像加工は「改ざん」になります。実験データも同じです。失敗してもテキストどおりの数値が出なくても修正したり・削除したりしないこと！

☑本文の構成

4. 考察

得られた結果について**検証**する。

教科書等に実験結果が記載されている場合も疑問を見い出し検討すること

●考察のポイント
- ☑実験結果の妥当性を関連文献を適時引用して、検討する
- ☑実験結果から何が考えられるのか、記す
- ☑実験を行って自ら疑問に思ったことを明らかにするには、次にどのような実験を行えば良いか、検討する
- ☑用いた試薬や個々の実験操作の意味を考える

「なぜ？」という疑問を持ち納得できるまで追究することが重要！

☑本文の構成

5. 参考文献

レポートに掲載した文献やデータの**出典**を示す。レポートの最後に、リストとしてまとめる。

必要な書誌情報（本や論文に関する情報）を集め、正しく示すこと

ここがポイント！

★ **実際にレポートを書くときに、著者は何人まで書くのか、などの指示をその都度確認しましょう。**

★ **図書の初版の場合、版の記載は不要です。また刷も記載不要です。**

参考文献の書式と注意点

必要な書誌情報を入れることが重要！

（1）必要な書誌情報を統一した書式で記載すること

図書の場合の例

著者名、『書名』、出版者、発行年

日本語論文の場合の例

著者名、「論文名」、『雑誌名』、巻（号）、頁数-頁数、出版年

英語論文の場合の例

Author, “Title”, Journal name, Volume(Number), page-page, Year

Webサイトの場合の例

『サイト名称』、<URL>（参照年月日）

参考文献の書式と注意点

（2）本文で引用した順に番号を付けて記すこと

本文

このプログラムでは、一宮先生のプログラムの表面層における近似を無くし、近似を用いずに正確に計算するようにした点と、試料温度を正確に反映できるようにしたところ[29]に新規性があり、詳細な強度変化を正確に再現できた[30, 31]。

例

番号を対応させる

参考文献リスト

[29] Y.Fukaya, K. Nakamura, and Y. Shigeta, “Wide range temperature dependence of RHEED rocking curve from a Si(111)-7×7 surface”, J. Vac. Sci. Technol. A18, 968-971 (2000). https://doi.org/10.1116/1.582285

[30] 重田諭吉，“高速ビームロッキング法による反射高速電子線回折強度の測定とその応用”，表面科学，第24巻，128-135 (2003). https://doi.org/10.1380/jsssj.24.128

[31] Y. Shigeta and Y. Fukaya, “Study of structure changes on the Si surfaces using reflection high-energy electron diffraction”, International Journal of Modern Physics B, Vol. 18, 289-316 (2004). https://doi.org/10.1142/S021797920402388X

重田諭吉、「反射高速電子線回析法による表面構造解析」、『横浜市立大学論叢．自然科学系列』、67（1, 2 & 3）、17-49、2019

Question　練習問題２

結果の例1：中和滴定の実験を例にして、どこが良くないのか考えてみましょう

結果

10.01 10.51 10.04 10.01

平均10.02

問題 0-1 左上のレポートの結果の部分を見て、レポートとして良くないと思う部分を書いて送りなさい

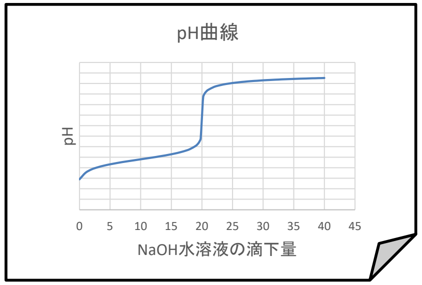
Question　練習問題２

結果の例2-1：pH曲線作成の実験を例にして、どこが良くないのか考えてみましょう

結果

滴下量	pH
0.00	2.90
1.00	3.52
2.00	3.85
3.00	4.05
4.00	4.20
5.00	4.32
6.00	4.43
7.00	4.53
8.00	4.62
9.00	4.71
10.00	4.80
11.00	4.89
12.00	4.98
13.00	5.07
14.00	5.17
15.00	5.28
16.00	5.40
17.00	5.55
18.00	5.75
19.00	6.08
19.20	6.18
19.40	6.31
19.60	6.49
19.80	6.80

20.00	8.80	
20.20	10.70	←ここで色が変わった
20.40	11.00	
20.60	11.17	
20.80	11.29	
21.00	11.39	
22.00	11.68	
23.00	11.84	
24.00	11.96	
25.00	12.05	
26.00	12.12	
27.00	12.17	
28.00	12.22	
29.00	12.26	
30.00	12.30	
31.00	12.33	
32.00	12.36	
33.00	12.39	
34.00	12.41	
35.00	12.44	
36.00	12.46	
37.00	12.47	
38.00	12.49	
39.00	12.51	
40.00	12.52	



- 縦軸の目盛りがない
- 横軸の単位がない
- 図のキャプションがない
  上にあるのはキャプションではない
- 測定した値は点で表す（測定点が結果で、その間はガイドラインにすぎない）。

- データだけのページになっている
- 「何の」滴下量なのか書いていない
- 単位がない
- 色がどのように変わったのか書いてない

Question　練習問題２

結果の例2-2：pH曲線作成の実験を例にして、どこが良くないのか考えてみましょう

結果

表1 NaOH水溶液の滴下量とpHの関係

滴下量 / mL	pH	20.00	8.80
0.00	2.90	20.20	10.70
1.00	3.52	20.40	11.00
2.00	3.85	20.60	11.17
3.00	4.05	20.80	11.29
4.00	4.20	21.00	11.39
5.00	4.32	22.00	11.68
6.00	4.43	23.00	11.84
7.00	4.53	24.00	11.96
8.00	4.62	25.00	12.05
9.00	4.71	26.00	12.12
10.00	4.80	27.00	12.17
11.00	4.89	28.00	12.22
12.00	4.98	29.00	12.26
13.00	5.07	30.00	12.30
14.00	5.17	31.00	12.33
15.00	5.28	32.00	12.36
16.00	5.40	33.00	12.39
17.00	5.55	34.00	12.41
18.00	5.75	35.00	12.44
19.00	6.08	36.00	12.46
19.20	6.18	37.00	12.47
19.40	6.31	38.00	12.49
19.60	6.49	39.00	12.51
19.80	6.80	40.00	12.52

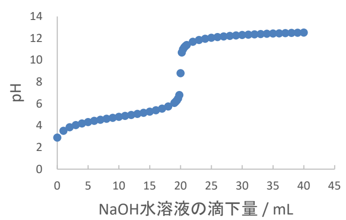


図1 NaOH水溶液の滴下量とpHの関係

・縦軸に目盛りがない（どの位置がその数値なのか分からない）

・1種類のデータだけなので、測定点を結ぶガイドラインはなくても分かる
　→ ガイドラインはあってもなくても良い
・横軸のような目盛りが縦軸にもあればこの形式でもOK
　（1ページ前の「結果の例2-1」ようにグリット線を入れなくても良い）

・色で示した値が何か書いていない
・表だけで本文がない。説明文があると良い

Question　練習問題２

考察の例1：物質AがA＋B → C の反応を示す。この反応の実験の考察の例を見て、あなたなら何を加えるか考えてみましょう（実験と結果は左。考察部分を中心に考えましょう！）

実験
(1) 上皿天秤でAを5.20 gはかりとった。
(2) メスシリンダーを用いBを10.0 mL、Aに加えた。
(3) ガラス棒を用い、室温で拡販した。
(4) 得られた沈殿を吸引ろ過した。
(5) 残渣をエタノールで洗浄した。
(6) 得られた固体を濾紙に広げ、1晩室温で乾燥した。
(7) 翌日質量を上皿天秤ではかった。

結果
　物質Aは白色の針状結晶で、物質Bは無色透明の液体であった。得られた固体は青白色の粉末であった。
　得られた固体粉末の質量は
　　　固体＋濾紙の質量　4.32 g
　　　濾紙の質量　　　　0.12 g
より、4.20 g であった。

考察
　得られた結晶が青白色である[1]ことから、目的の生成物が得られたと考えられる。
　物質Aと物質Cの分子量はそれぞれ52.0と84.0である。つまり、

物質A: $\frac{5.20}{52.0} = 0.100$ mol　　物質C： $\frac{4.20}{84.0} = 0.05$ mol

今回の反応はScheme 1に示すように1 molの物質Aから1 molの物質Cが得られる。つまり理論的には0.100 molの物質Cが得られることになる。

収率（%）$= \frac{0.050}{0.100} \times 100 = 50\%$

収率が100%にならなかったのは、ろ過でろ紙に残った試料があったためだと考えられる。

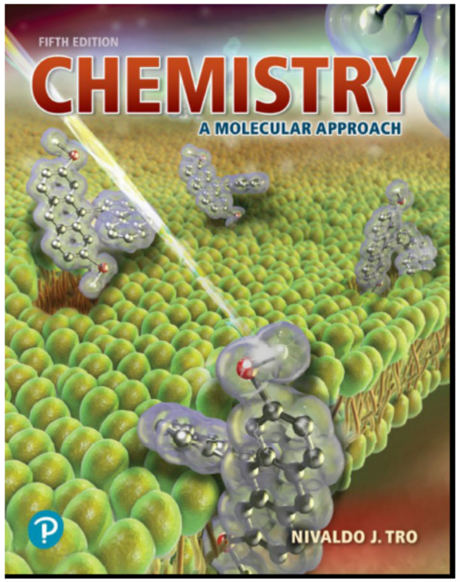
ろ紙に残った量が得られた固体粉末と同量であれば、意味のある考察です（その場合、実験をもっと丁寧にと言うことになりますが）

例えば、
・色の変化がなぜ起こったのか。物質A, B, Cの分子構造から考えることができます。
・収量は物質Bの物質量も検討する必要があります。物質Bは液体なので、文献で密度を調べる必要がありますね。
・実験でビーカーを触っています。反応により温度が上がったり下がったり感じられた場合、反応熱に関する考察もできます

実験レポートの書き方に役立つ参考書

- 「基礎実験テキスト」
  →横浜市立大学理学部　基礎実験担当者編集
- 「改訂　化学のレポートと論文の書き方」
  →小川雅彌監修代表、化学同人、1993年
  所蔵あり！ 430.7/I8N3 講義関連
- 「誰も教えてくれなかった実験ノートの書き方」
  →野島高彦、化学同人、2017年
  所蔵あり！ B407/I 講義関連、開架
- 「理科系の作文技術」
  →木下是雄、中公新書、1981年
  所蔵あり！ 407/226 開架

https://opac.yokohama-cu.ac.jp/drupal/?q=ja/guide#course%20B'



Brief Contents

Periodic Table

	1A[a] 1	2A 2	3B 3	4B 4	5B 5	6B 6	7B 7	8B 8	8B 9	8B 10	1B 11	2B 12	3A 13	4A 14	5A 15	6A 16	7A 17	8A 18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.94	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc [98]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
7	87 Fr [223.02]	88 Ra [226.03]	89 Ac [227.03]	104 Rf [261.11]	105 Db [262.11]	106 Sg [266.12]	107 Bh [264.12]	108 Hs [269.13]	109 Mt [268.14]	110 Ds [271]	111 Rg [272]	112 Cn [285]	113 Nh [284]	114 Fl [289]	115 Mc [289]	116 Lv [292]	117 Ts [294]	118 Og [294]

Main groups (1A–2A; 3A–8A) · Transition metals (3B–2B)

Metals · Metalloids · Nonmetals

Lanthanide series	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
Actinide series	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]	103 Lr [262.11]

The most incomprehensible thing about the universe is that it is comprehensible.

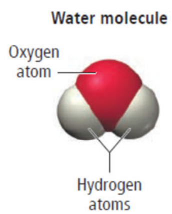
—ALBERT EINSTEIN (1879–1955)

CHAPTER 1

Matter, Measurement, and Problem Solving

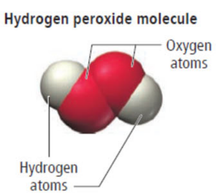
1.1 Atoms and Molecules

connection between the *properties of the stuff around us* and the *properties of atoms and molecules*. **Atoms** are submicroscopic particles that are the fundamental building blocks of ordinary matter. Free atoms are rare in nature; instead they bind together in specific geometrical arrangements to form **molecules**. A good example of a molecule is the water molecule, which I remember so well from the Disneyland ride.



A water molecule is composed of one oxygen atom bound to two hydrogen atoms in the shape shown at left. The exact properties of the water molecule—the atoms that compose it, the distances between those atoms, and the geometry of how the atoms are bound together—determine the properties of water. If the molecule were different, water would be different. For example, if water contained two oxygen atoms instead of just one, it would be a molecule like this:

H_2O_2



分子構造（Molecular Structure）
水がどうして H-O-H が折れ曲がった構造をとるのかは、量子化学の理解が必要（化学概説Cの後半）

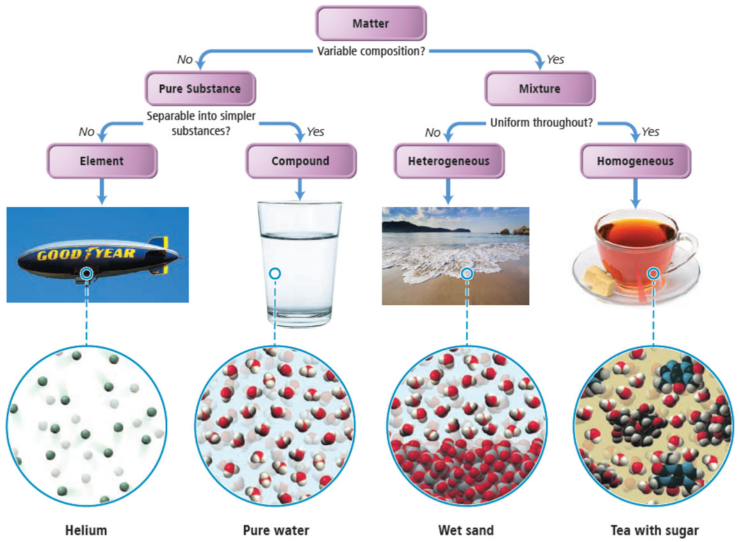
This molecule is hydrogen peroxide, which you may have encountered if you have ever bleached your hair. A hydrogen peroxide molecule is composed of *two* oxygen atoms and two hydrogen atoms. This seemingly small molecular difference results in a huge difference in the properties of water and hydrogen peroxide. Water is the familiar and stable liquid we all drink and bathe in. Hydrogen peroxide, in contrast, is an unstable liquid that, in its pure form, burns the skin on contact and is used in rocket fuel. When you pour water onto your hair, your hair simply becomes wet. However, if you put diluted hydrogen peroxide on your hair, a chemical reaction occurs that strips your hair of its color.

分子の性質
・構成元素の種類と数
・分子構造

1.2 The Scientific Approach to Knowledge

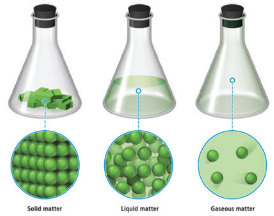
法則や理論、仮説、実証などについて書かれている。重要な内容ではあるが、ここでは触れない（法則や理論は歴史的な慣習もあるので）。

1.3 The Classification of Matter



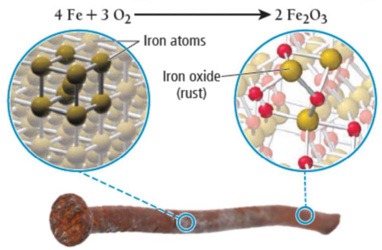
1.4 Physical and Chemical Changes and Physical and Chemical Properties

Every day we witness changes in matter: ice melts, iron rusts, gasoline burns, fruit ripens, and water evaporates. What happens to the molecules or atoms that compose these substances during such changes? The answer depends on the type of change. Changes that alter only state or appearance, but not composition, are **physical changes**. The atoms or molecules that compose a substance *do not change* their identity during a physical change. For example, when water boils, it changes its state from a liquid to a gas, but the gas remains composed of water molecules, so this is a physical change (Figure 1.6▲).

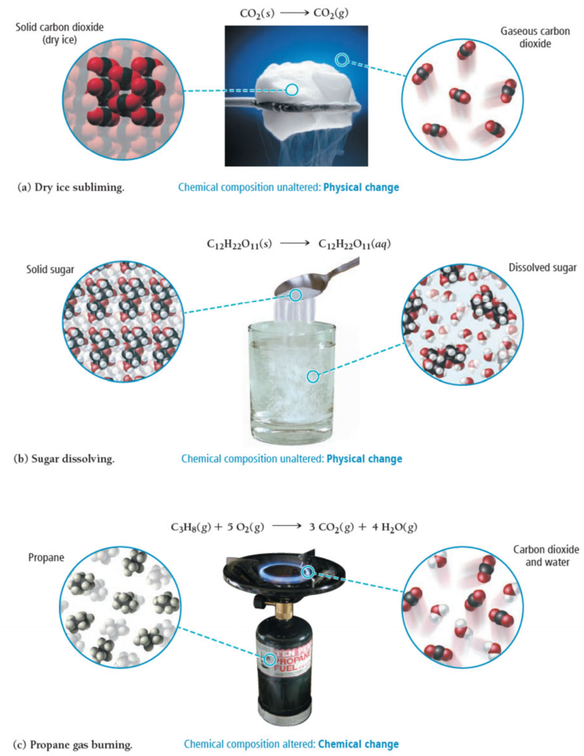


In contrast, changes that alter the composition of matter are **chemical changes**. During a chemical change, atoms rearrange, transforming the original substances into different substances. For example, the rusting of iron is a chemical change. The atoms that compose iron (iron atoms) combine with oxygen molecules from air to form iron oxide, the orange substance we call rust (Figure 1.7◀). Figure 1.8▶ illustrates other examples of physical and chemical changes.

Iron combines with oxygen to form iron oxide: **chemical change**.



▲ FIGURE 1.7 Rusting, a Chemical Change When iron rusts, the iron atoms combine with oxygen atoms to form a different chemical substance, the compound iron oxide. Rusting is a chemical change, and the tendency of iron to rust is a chemical property. A more detailed exploration of this reaction can be found in Section 20.9.



1.5 Energy: A Fundamental Part of Physical and Chemical Change

The physical and chemical changes discussed in Section 1.4 are usually accompanied by energy changes. For example, when water evaporates from your skin (a physical change), the water molecules absorb energy from your body, making you feel cooler. When you burn natural gas on the stove (a chemical change), energy is released, heating the food you are cooking. Understanding the physical and chemical changes of matter—that is, understanding chemistry—requires that you understand energy changes and energy flow.

The scientific definition of **energy** is *the capacity to do work*. **Work** is defined as the action of a force through a distance. For instance, when you push a box across the floor or pedal your bicycle across the street, you have done work.

Absorption：吸収・吸着
Desorption：脱離

Work：仕事

Force acts through distance; work is done.

問題 1-1 英文を読んで正しいものをすべて選びなさい

(1) 水が気化するとき、エネルギーを体に与える。

(2) 天然ガスの燃焼は化学変化である。また、発熱反応である。

(3) エネルギーとは、仕事をするcapacityである。

(4) ダイエット用の自転車は進まないので、ペダルをこいでも仕事にはならない。

1.6 The Units of Measurement

化学概説Cで説明したので、省略

1.7 The Reliability of a Measurement

実験データには誤差がある → 有効数字
＊基礎実験で学ぶので省略

1.8 Solving Chemical Problems

化学概説Cで扱っているので、省略

1.9 Analyzing and Interpreting Data

基礎実験で学ぶので省略（レポートの書き方などでも説明した）

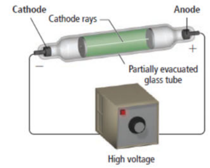
These observations have tacitly led to the conclusion which seems universally adopted, that all bodies of sensible magnitude . . . are constituted of a vast number of extremely small particles, or atoms of matter . . . .

—JOHN DALTON (1766–1844)

CHAPTER

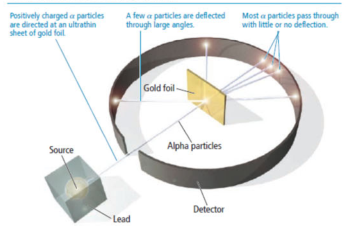
2 Atoms and Elements

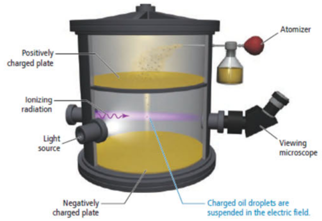
2年生の周期表の化学の内容



◀ FIGURE 2.2 Cathode Ray Tube

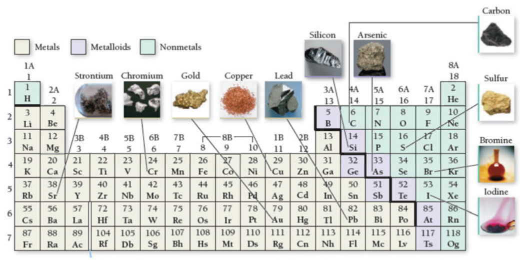
Rutherford's Gold Foil Experiment





▲ FIGURE 2.4 Millikan's Measurement of the Electron's Charge Millikan calculated the charge on oil droplets falling in an electric field. He found that it was always a whole-number multiple of -1.60×10^{-19} C, the charge of a single electron.

Major Divisions of the Periodic Table

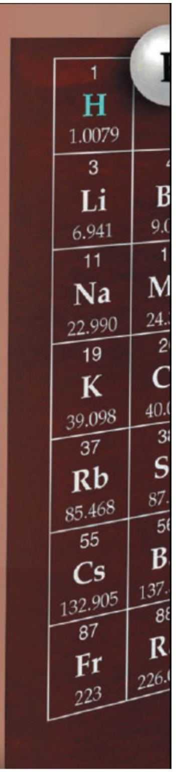


Almost all aspects of life are engineered at the molecular level, and without understanding molecules we can only have a very sketchy understanding of life itself.

—FRANCIS HARRY COMPTON CRICK (1916–2004)

CHAPTER

3 Molecules and Compounds



3.1 Hydrogen, Oxygen, and Water

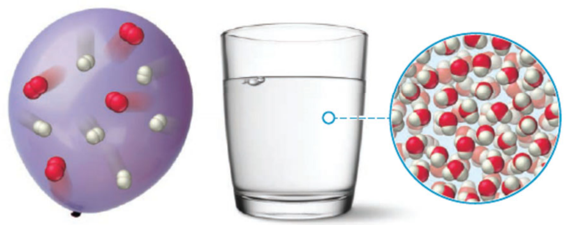
Hydrogen (H_2) is an explosive gas used as a fuel in rocket engines. Oxygen (O_2), also a gas, is a natural component of the air on Earth. Oxygen itself is not flammable but must be present for combustion (burning) to occur. Hydrogen and oxygen both have extremely low boiling points, as you can see from the table that follows.

Selected Properties	Hydrogen	Oxygen	Water
Boiling Point	−253 °C	−183 °C	100 °C
State at Room Temperature	Gas	Gas	Liquid
Flammability	Explosive	Necessary for combustion	Used to extinguish flame

Mixtures and Compounds

Hydrogen and Oxygen Mixture: This mixture can have any ratio of hydrogen to oxygen.

Water (a compound): Water molecules have a fixed ratio of atoms—2 hydrogens to 1 oxygen.

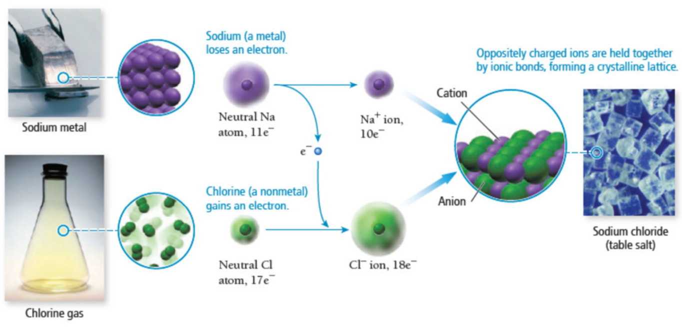


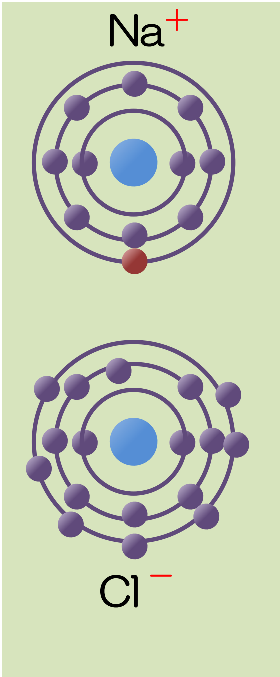
3.2 Chemical Bonds

Ionic Bonds

Recall from Chapter 2 that metals have a tendency to lose electrons and that nonmetals have a tendency to gain them. Therefore, when a metal interacts with a nonmetal, it can transfer one or more of its electrons to the nonmetal. The metal atom then becomes a *cation* (a positively charged ion), and the nonmetal atom becomes an *anion* (a negatively charged ion), as shown in Figure 3.2▼. These oppositely charged ions attract one another by electrostatic forces and form an **ionic bond**. The result is an **ionic compound**, which in the solid phase is composed of a lattice—a regular three-dimensional array—of alternating cations and anions.

The Formation of an Ionic Compound



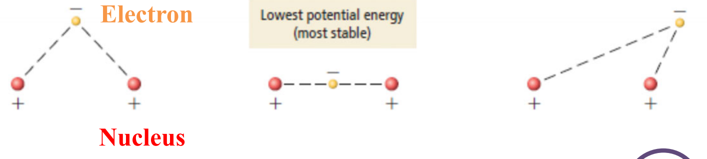


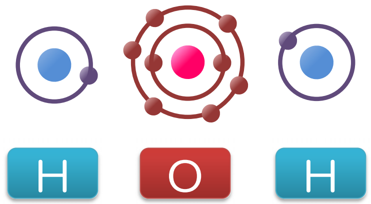
Covalent Bonds

共有結合

When a nonmetal bonds with another nonmetal, neither atom transfers its electron to the other. Instead the bonding atoms *share* some of their electrons. The shared electrons have lower potential energy than they do in the isolated atoms because they interact with the nuclei of both atoms. The bond is a **covalent bond**, and the covalently bound atoms compose a *molecule*. Each molecule is independent of the others—the molecules are themselves not covalently bound to one another. Therefore, we call covalently bonded compounds **molecular compounds**.

We can begin to understand the stability of a covalent bond by considering the most stable (or lowest potential energy) configuration of a negative charge interacting with two positive charges (which are separated by some small distance). Figure 3.3▼ shows that the lowest potential energy occurs when the negative charge lies *between* the two positive charges because in this arrangement the negative charge can interact with *both positive charges*. Similarly, shared electrons in a covalent chemical bond hold the bonding atoms together by attracting the positively charged nuclei of both bonding atoms.





詳細は、化学概説Cの後半や量子化学の講義で

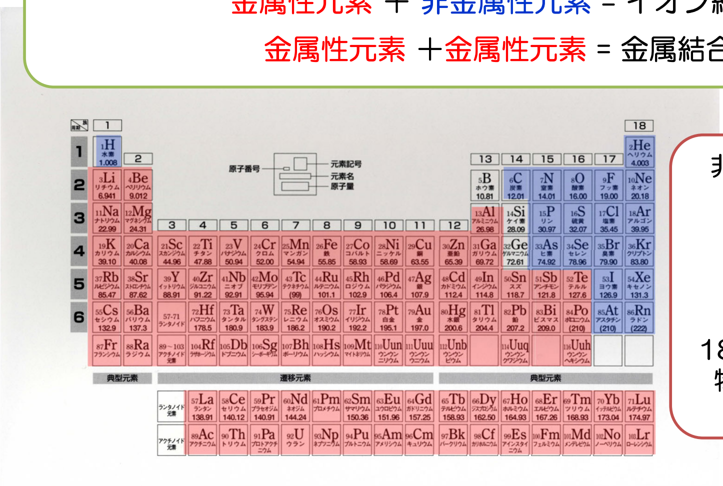
イオン結合と共有結合の見分け方

金属性元素と非金属性元素を理解できれば簡単

非金属性元素＋ 非金属性元素 =

金属性元素 ＋ 非金属性元素 = イオン結合

金属性元素 ＋金属性元素 = 金属結合



非金属性元素は少ない！
主な元素は
H, C, N, O, P, S,
F, Cl, Br, I

18族元素(希ガス)は化合物をほとんど作らない
価電子0個

3.3 Representing Compounds: Chemical Formulas and Molecular Models

Types of Chemical Formulas

We can categorize chemical formulas into three different types: empirical, molecular, and structural. An **empirical formula** gives the *relative* number of atoms of each element in a compound. A **molecular formula** gives the *actual* number of atoms of each element in a molecule of a compound. For example, the empirical formula for hydrogen peroxide is HO, but its molecular formula is H_2O_2. The molecular formula is always a whole-number multiple of the empirical formula. For some compounds, the empirical

Empirical Formula：実験式

・実測によって見いだされた諸量の間の関係式

・化合物を構成する原子の数の比が最も簡単な整数比

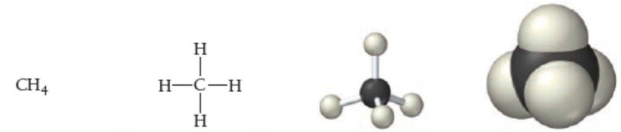
例) NaCl

CO_2やH_2Oなど分子式と同じになるものもある

Molecular Models

A *molecular model* is a more accurate and complete way to specify a compound. A **ball-and-stick molecular model** represents atoms as balls and chemical bonds as sticks; how the two connect reflects a molecule's shape. The balls are typically color-coded to specific elements. For example, carbon is customarily black, hydrogen is white, nitrogen is blue, and oxygen is red. (For a complete list of colors of elements in the molecular models used in this book, see Appendix IIA.)

In a **space-filling molecular model**, atoms fill the space between each other to more closely represent our best estimates for how a molecule might appear if scaled to visible size. Consider the following ways to represent a molecule of methane, the main component of natural gas:

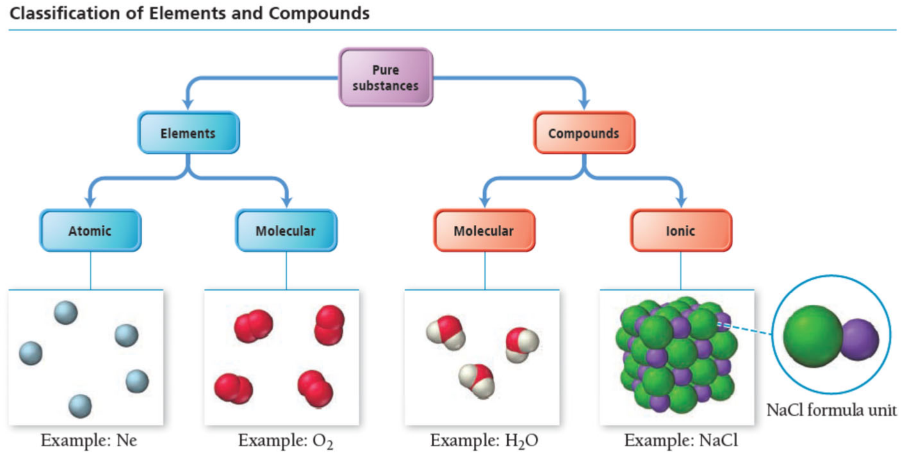


Molecular formula | Structural formula | Ball-and-stick model | Space-filling model

3.4 An Atomic-Level View of Elements and Compounds

単体：Simple Substance or Elementary Substance

Atomic elements exist in nature with single atoms as their basic units. Most elements fall into this category. For example, helium is composed of helium atoms, aluminum is composed of aluminum atoms, and iron is composed of iron atoms. **Molecular elements** do not normally exist in nature with single atoms as their basic units.



▲ **FIGURE 3.4** A Molecular View of Elements and Compounds

3.5 Ionic Compounds: Formulas and Names

INTERACTIVE WORKED EXAMPLE VIDEO 3.3

HOW TO: *Write Formulas for Ionic Compounds*	**EXAMPLE 3.3** Writing Formulas for Ionic Compounds Write the formula for the ionic compound that forms between aluminum and oxygen.	**EXAMPLE 3.4** Writing Formulas for Ionic Compounds Write the formula for the ionic compound that forms between calcium and oxygen.
1. Write the symbol for the metal cation and its charge followed by the symbol for the nonmetal anion and its charge. Determine charges from the element's group number in the periodic table (refer to Figure 2.13).	Al^{3+} O^{2-}	Ca^{2+} O^{2-}
2. Adjust the subscript on each cation and anion to balance the overall charge.	Al^{3+} O^{2-} ↓ Al_2O_3	Ca^{2+} O^{2-} ↓ CaO
3. Check that the sum of the charges of the cations equals the sum of the charges of the anions.	cations: 2(3+) = 6+ anions: 3(2−) = 6− The charges cancel.	cations: 2+ anions: 2− The charges cancel.
	FOR PRACTICE 3.3 Write the formula for the compound formed between potassium and sulfur.	**FOR PRACTICE 3.4** Write the formula for the compound formed between aluminum and nitrogen.

Naming Binary Ionic Compounds Containing a Metal That Forms Only One Type of Cation

Binary compounds contain only two different elements. The names of binary ionic compounds take the form:

name of cation (metal) | base name of anion (nonmetal) + *-ide*

For example, the name for KCl consists of the name of the cation, *potassium*, followed by the base name of the anion, *chlor*, with the ending *-ide*. Its full name is *potassium chloride*.

KCl potassium chloride

The name for CaO consists of the name of the cation, *calcium*, followed by the base name of the anion, *ox*, with the ending *-ide*. Its full name is *calcium oxide*.

CaO calcium oxide

The base names for various nonmetals and their most common charges in ionic compounds are shown in Table 3.2.

TABLE 3.2 ■ **Some Common Monoatomic Anions**

Nonmetal	Symbol for Ion	Base Name	Anion Name
Fluorine	F^-	fluor	Fluoride
Chlorine	Cl^-	chlor	Chloride
Bromine	Br^-	brom	Bromide
Iodine	I^-	iod	Iodide
Oxygen	O^{2-}	ox	Oxide
Sulfur	S^{2-}	sulf	Sulfide
Nitrogen	N^{3-}	nitr	Nitride
Phosphorus	P^{3-}	phosph	Phosphide

日本語は、逆になるので注意が必要　　塩化カリウム　酸化カルシウム

TABLE 3.3 ■ **Some Metals That Form Cations with Different Charges**

Metal	Ion	Name	Older Name*
Chromium	Cr^{2+}	Chromium(II)	Chromous
	Cr^{3+}	Chromium(III)	Chromic
Iron	Fe^{2+}	Iron(II)	Ferrous
	Fe^{3+}	Iron(III)	Ferric
Cobalt	Co^{2+}	Cobalt(II)	Cobaltous
	Co^{3+}	Cobalt(III)	Cobaltic
Copper	Cu^+	Copper(I)	Cuprous
	Cu^{2+}	Copper(II)	Cupric
Tin	Sn^{2+}	Tin(II)	Stannous
	Sn^{4+}	Tin(IV)	Stannic
Mercury	Hg_2^{2+}	Mercury(I)	Mercurous
	Hg^{2+}	Mercury(II)	Mercuric
Lead	Pb^{2+}	Lead(II)	Plumbous
	Pb^{4+}	Lead(IV)	Plumbic

*An older naming system substitutes the names found in this column for the name of the metal and its charge. Under this system, chromium(II) oxide is named chromous oxide. Additionally, the suffix *-ous* indicates the ion with the lesser charge, and *-ic* indicates the ion with the greater charge. We will *not* use the older system in this text.

TABLE 3.4 ■ **Some Common Polyatomic Ions**

Name	Formula	Name	Formula
Acetate	$C_2H_3O_2^-$	Hypochlorite	ClO^-
Carbonate	CO_3^{2-}	Chlorite	ClO_2^-
Hydrogen carbonate (or bicarbonate)	HCO_3^-	Chlorate	ClO_3^-
Hydroxide	OH^-	Perchlorate	ClO_4^-
Nitrite	NO_2^-	Permanganate	MnO_4^-
Nitrate	NO_3^-	Sulfite	SO_3^{2-}
Chromate	CrO_4^{2-}	Hydrogen sulfite (or bisulfite)	HSO_3^-
Dichromate	$Cr_2O_7^{2-}$	Sulfate	SO_4^{2-}
Phosphate	PO_4^{3-}	Hydrogen sulfate (or bisulfate)	HSO_4^-
Hydrogen phosphate	HPO_4^{2-}	Cyanide	CN^-
Dihydrogen phosphate	$H_2PO_4^-$	Peroxide	O_2^{2-}
Ammonium	NH_4^+		

name of cation (metal) | (charge of cation (metal) in Roman numerals in parentheses) | base name of anion (nonmetal) + *-ide*

問題 3-1　塩化コバルト(II)として適切なものを1つ選びなさい

(1) Cobalt(II) Chlorine　　(2) Cobalt(II) Chloride

(3) Cobaltous Dichloride　　(4) Cobalt(II) Dichloride

(5) Chlorine Cobalt (II)　　(6) Cobaltium (II) Chloride

硫酸ナトリウムを選びなさい

(1) Sodium Sulfide　　(2) Disodium Sulfide　　(3) Disodium Sulfate

(4) Sodium Sulfate　　(5) Sulfur Soda　　(6) Sulfate Sodium

Potassium Nitrateを選びなさい

(1) CsN_3　　(2) KN_3　　(3) CuN_3　　(4) $AgNO_3$

(5) $Cu(NO_3)_2$　　(6) KNO_3　　(7) KNO_2　　(8) $Cu(NO_2)_2$

(9) $AgNO_2$　　(10) $CsNO_3$　　(11) $CsNO_2$　　(12) KCN

Hydrated Ionic Compounds

The ionic compounds called **hydrates** contain a specific number of water molecules associated with each formula unit. For example, the formula for *epsom salts* is $MgSO_4 \cdot 7\,H_2O$, and its *systematic name* is magnesium sulfate heptahydrate. The seven H_2O molecules associated with the formula unit are *waters of hydration*. Waters of hydration can usually be removed by heating the compound. Figure 3.9▶ shows a sample of cobalt(II) chloride hexahydrate ($CoCl_2 \cdot 6\,H_2O$) before and after heating. The hydrate is pink and the anhydrous salt (the salt without any associated water molecules) is blue. Hydrates are named just as other ionic compounds, but they are given the additional name "*prefix*hydrate," where the *prefix* indicates the number of water molecules associated with each formula unit.

Common hydrated ionic compounds and their names are as follows:

$CaSO_4 \cdot \frac{1}{2}\,H_2O$	calcium sulfate hemihydrate
$BaCl_2 \cdot 6\,H_2O$	barium chloride hexahydrate
$CuSO_4 \cdot 5\,H_2O$	copper(II) sulfate pentahydrate

Hydrate　　Anhydrous

$CoCl_2 \cdot 6\,H_2O$　　$CoCl_2$

▲ **FIGURE 3.9 Hydrates** Heating pink cobalt(II) chloride hexahydrate removes the waters of hydration to produce blue cobalt(II) chloride.

Common hydrate prefixes
hemi = 1/2
mono = 1
di = 2
tri = 3
tetra = 4
penta = 5
hexa = 6
hepta = 7
octa = 8

結晶水：Water of Crystallization or Crystal Water

- 配位水（Coordination Water）陽イオンに直接結合している水　$MgCl_2 \cdot 6H_2O$
- 陰イオン水（Anion Water）SO_4^{2-}などに強く結合している水
- 格子水（Lattice Water）結晶格子の空間を満たす水
- 構造水（Constitution Water）OH^-として存在するが加熱でH_2Oとして抜ける　$Mg(OH)_2$
- 沸石水（Zeolite Water）格子水と同じだが、脱水で結晶構造が本質的に変わらない

3.6 Molecular Compounds: Formulas and Names

Naming Binary Acids

Binary acids are composed of hydrogen and a nonmetal. Names for binary acids have the form:

hydro + [base name of nonmetal + *-ic*] + acid

For example, HCl(*aq*) is hydro*chlor*ic acid and HBr(*aq*) is hydro*brom*ic acid.

HCl(*aq*) hydrochloric acid　　HBr(*aq*) hydrobromic acid

EXAMPLE 3.9 Naming Binary Acids

Name the acid HI(*aq*).

SOLUTION

The base name of I is *iod*, so HI(*aq*) is hydroiodic acid.

HI(*aq*)　hydroiodic acid

FOR PRACTICE 3.9 Name the acid HF(*aq*).

Naming Oxyacids

Oxyacids contain hydrogen and an oxyanion (an anion containing a nonmetal and

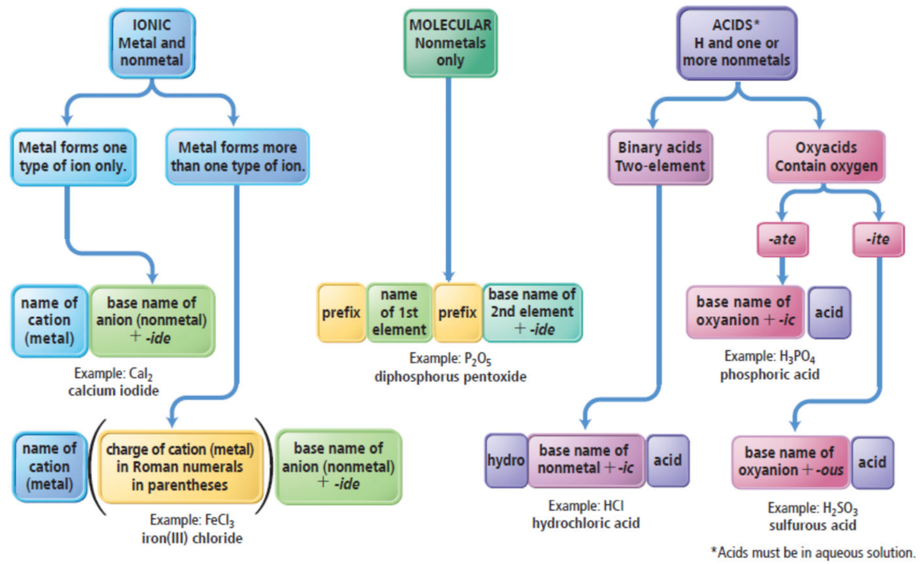
OH^-：Hydroxide

NaOH：Sodium Hydroxide

Cl^-：Chloride
SO_4^{2-}：Sulfate
NO_3^-：Nitrate
CO_3^{2-}：Carbonate
PO_4^{3-}：Phosphate

HCl：Hydrochloric Acid
H_2SO_4：Sulfuric Acid
HNO_3：Nitric Acid
H_2CO_3：Carbonic Acid
H_3PO_4：Phosphoric Acid

Inorganic Nomenclature Flowchart



命名法はまとめておいて下さい

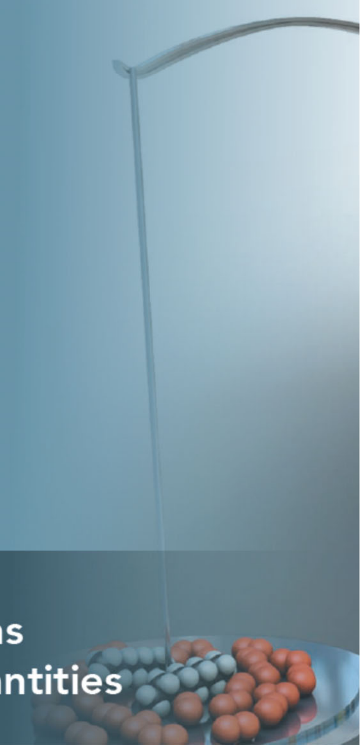
3.8 Formula Mass and the Mole Concept for Compounds

3.9 Composition of Compounds

3.10 Determining a Chemical Formula from Experimental Data

3.11 Organic Compounds

化学概説Aで習っている範囲



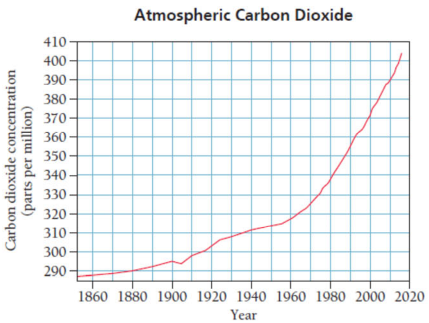
I feel sorry for people who don't know anything about chemistry. They are missing an important source of happiness.

—LINUS PAULING (1901–1994)

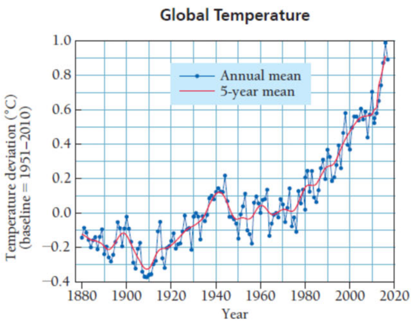
CHAPTER 4 Chemical Reactions and Chemical Quantities

4.1 Climate Change and the Combustion of Fossil Fuels

The Greenhouse Effect



▲ **FIGURE 4.2 Carbon Dioxide Concentrations in the Atmosphere** The rise in carbon dioxide levels is due largely to fossil fuel combustion.



▲ **FIGURE 4.3 Global Temperature** Average temperatures worldwide have risen by about 0.9 °C since 1880. Each point on the graph is the deviation from the 1951–2010 average temperature.

4.2 Writing and Balancing Chemical Equations

Combustion analysis (which we examined in Section 3.10) employs a **chemical reaction**, a process in which one or more substances are converted into one or more different ones. Compounds form and change through chemical reactions. For example, water is formed by the reaction of hydrogen with oxygen. A **combustion reaction** is a particular type of chemical reaction in which a substance combines with oxygen to form one or more oxygen-containing compounds. Combustion reactions also emit heat. The heat produced in a number of combustion reactions is critical to supplying our society's energy needs. For example, the heat from the combustion of gasoline expands the gaseous combustion products in a car engine's cylinders, which push the pistons and propel the car. We use the heat released by the combustion of *natural gas* to cook food and to heat our homes.

Combustion Reaction：

問題 4-1 英文を読んで燃焼反応について正しいものをすべて選びなさい

(1) 化学反応はすべて燃焼反応である

(2) 燃焼反応は物質が酸素と化合する反応をいう

(3) 燃焼反応は熱を吸収する

(4) 我々は燃焼反応を利用し、車を走らせたり料理を作ったりしている

We represent a chemical reaction with a **chemical equation**. For example, we represent the combustion of natural gas with the equation:

$$\underset{\text{reactants}}{CH_4 + O_2} \longrightarrow \underset{\text{products}}{CO_2 + H_2O}$$

The substances on the left side of the equation are the **reactants**, and the substances on the right side are the **products**. We often specify the states of each reactant or product in parentheses next to the formula as follows:

$$CH_4(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(g)$$

The (*g*) indicates that these substances are gases in the reaction. Table 4.1 summarizes the common states of reactants and products and their symbols used in chemical equations.

The equation just presented for the combustion of natural gas is not complete.

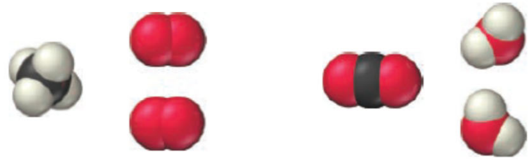
Reactant：反応物

Product：生成物

TABLE 4.1 ■ States of Reactants and Products in Chemical Equations

Abbreviation	State
(*g*)	Gas
(*l*)	Liquid
(*s*)	Solid
(*aq*)	Aqueous (water solution)

$$CH_4(g) \quad + \quad 2\,O_2(g) \longrightarrow CO_2(g) \quad + \quad 2\,H_2O(g)$$



- 反応物と生成物を化学式で書く
- 物質の状態を表すときは、化学式の後ろに（）書きする　　表4.1参照
- 反応物を左に、生成物を右に書く
- 原子の数が左右で一致するように反応の係数を書く

4.3 Reaction Stoichiometry: How Much Carbon Dioxide?

The balanced chemical equations for fossil fuel combustion reactions provide the exact relationships between the amount of fossil fuel burned and the amount of carbon dioxide emitted. In this discussion, we use octane (a component of gasoline) as a representative fossil fuel. The balanced equation for the combustion of octane is:

$$2\,C_8H_{18}(l) + 25\,O_2(g) \longrightarrow 16\,CO_2(g) + 18\,H_2O(g)$$

The balanced equation shows that 16 CO_2 molecules are produced for every 2 molecules of octane burned. We can extend this numerical relationship between molecules to the amounts in moles as follows:

The coefficients in a chemical equation specify the relative amounts in moles of each of the substances involved in the reaction.

In other words, from the equation, we know that 16 *moles* of CO_2 are produced for every 2 *moles* of octane burned. The numerical relationships between chemical amounts in a balanced chemical equation are called reaction **stoichiometry**. Stoichiometry allows us to predict the amounts of products that will form in a chemical reaction based on the amounts of reactants that react. Stoichiometry also allows us to determine the amounts of reactants necessary to form a given amount of product. These calculations are central to chemistry, allowing chemists to plan and carry out chemical reactions to obtain products in the desired quantities.

Stoichiometry
化学量論

- 質量保存の法則
- 定比例の法則
- 気体反応の法則

↓

化学組成と物理的性質の数量的な関係

C_8H_{18}		CO_2
2	:	16
22 mol	:	176 mol

問題 4-2

STOICHIOMETRY I Use the balanced equation for the combustion of octane to determine how many moles of H_2O are produced by the combustion of 22.0 moles of C_8H_{18}.

$$2\,C_8H_{18}(l) + 25\,O_2(g) \longrightarrow 16\,CO_2(g) + 18\,H_2O(g)$$

(a) 18 moles H_2O　**(b)** 22 moles H_2O
(c) 176 moles H_2O　**(d)** 198 moles H_2O

EXAMPLE 4.4 Stoichiometry

During photosynthesis, plants convert carbon dioxide and water into glucose ($C_6H_{12}O_6$) according to the reaction:

$$6\,CO_2(g) + 6\,H_2O(l) \xrightarrow{\text{sunlight}} 6\,O_2(g) + C_6H_{12}O_6(aq)$$

Suppose that a particular plant consumes 37.8 g of CO_2 in one week. Assuming that there is more than enough water present to react with all of the CO_2, what mass of glucose (in grams) can the plant synthesize from the CO_2?

SORT The problem provides the mass of carbon dioxide and asks you to find the mass of glucose that can be produced.

GIVEN: 37.8 g CO_2

FIND: g $C_6H_{12}O_6$

STRATEGIZE The conceptual plan follows the general pattern of mass A → amount A (in moles) → amount B (in moles) → mass B. From the chemical equation, deduce the relationship between moles of carbon dioxide and moles of glucose. Use the molar masses to convert between grams and moles.

CONCEPTUAL PLAN

g CO_2 → mol CO_2 → mol $C_6H_{12}O_6$ → g $C_6H_{12}O_6$

$$\frac{1\text{ mol }CO_2}{44.01\text{ g }CO_2} \qquad \frac{1\text{ mol }C_6H_{12}O_6}{6\text{ mol }CO_2} \qquad \frac{180.2\text{ g }C_6H_{12}O_6}{1\text{ mol }C_6H_{12}O_6}$$

RELATIONSHIPS USED

molar mass CO_2 = 44.01 g/mol

6 mol CO_2 : 1 mol $C_6H_{12}O_6$

molar mass $C_6H_{12}O_6$ = 180.2 g/mol

SOLVE Follow the conceptual plan to solve the problem. Begin with g CO_2 and use the conversion factors to arrive at g $C_6H_{12}O_6$.

SOLUTION

$$37.8\text{ g }\cancel{CO_2} \times \frac{1\text{ }\cancel{\text{mol }CO_2}}{44.01\text{ g }\cancel{CO_2}} \times \frac{1\text{ }\cancel{\text{mol }C_6H_{12}O_6}}{6\text{ }\cancel{\text{mol }CO_2}} \times \frac{180.2\text{ g }C_6H_{12}O_6}{1\text{ }\cancel{\text{mol }C_6H_{12}O_6}} = 25.8\text{ g }C_6H_{12}O_6$$

問題 4-3

FOR PRACTICE 4.4 Magnesium hydroxide, the active ingredient in milk of magnesia, neutralizes stomach acid, primarily HCl, according to the reaction:

$$Mg(OH)_2(s) + 2\,HCl(aq) \longrightarrow 2\,H_2O(l) + MgCl_2(aq)$$

What mass of HCl, in grams, is neutralized by a dose of milk of magnesia containing 3.26 g $Mg(OH)_2$?

H = 1, O = 16, Mg = 24, Cl=35.5
＊有効数字は無視します

magnesium hydroxide：水酸化マグネシウム
ingredient：成分
milk of magnesia：マグネシア乳
stomach acid：胃酸

選択肢　(1) 2.1 g　(2) 4.1 g　(3) 24.2 g　(4) 48.4 g

4.4 Stoichiometric Relationships: Limiting Reactant, Theoretical Yield, Percent Yield, and Reactant in Excess

Percent Yield

$$\%\text{ yield} = \frac{2\text{ pizzas}}{3\text{ pizzas}} \times 100\% = 67\%$$

Actual yield (2 pizzas) / Theoretical yield (3 pizzas)

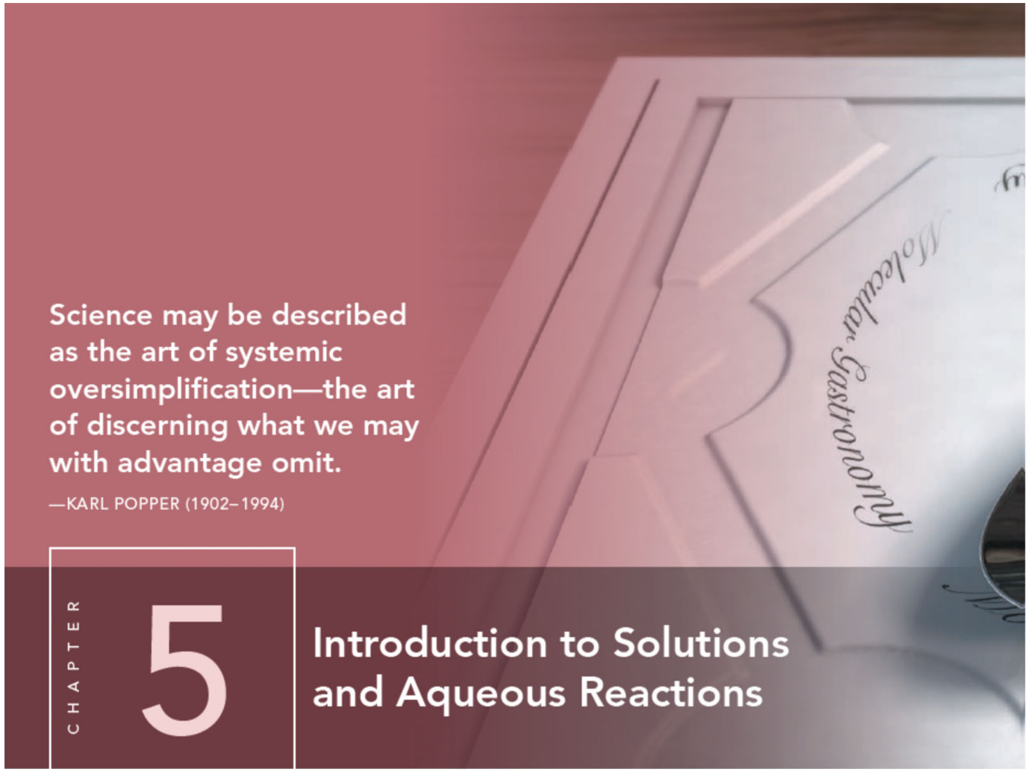
基礎化学実験B2とB6でPercent Yieldを計算する

$$2CoCl_2 + 2NH_4Cl + 10NH_3 + H_2O_2 \rightarrow 2[Co(NH_3)_6]Cl_3 + 2H_2O$$

$$\text{収率} = \frac{\text{得られた結晶の質量（グラム）}}{CoCl_2 \cdot 6H_2O\text{の質量から理論的に予想される質量（グラム）}} \times 100\,\%$$

Limiting Reactionの例） $A + 3B \rightarrow 6C$ **の反応を考える**

A を 1 mol 、B を 3 mol → C は 6 mol 生成
A を 1 mol 、B を 1 mol → C は 2 mol 生成 ← **Limiting Reaction**



5.1 Molecular Gastronomy and the Spherified Cherry

Molecular Gastronomy：分子美食学

▶ **FIGURE 5.1 The Spherified Cherry** The spherified cherry is made by precipitating an encapsulating layer around cherry juice.

In molecular gastronomy, chefs use a similar precipitation reaction—called spherification—to encapsulate liquids. Among the most popular molecular gastronomy creations is the spherified cherry (Figure 5.1▲). To make a spherified cherry, chefs take juice from real cherries and mix it with a calcium salt (such as calcium chloride), which dissolves in the cherry juice. They then carefully pour the cherry juice into a bath of sodium alginate. Sodium alginate is a sodium salt that dissolves into water, resulting in the presence of alginate ions. When the calcium ions in the cherry juice encounter the alginate ions in the bath, a precipitation reaction occurs. In this case, the precipitation reaction forms in the area immediately surrounding the cherry juice, forming an encapsulating sphere around the juice. The result is a spherical, edible "cherry" that ruptures in the mouth and releases its juice.

5.2 Solution Concentration

The reactions that occur in lakes, streams, and oceans, as well as the reactions that occur in every cell within our bodies, take place in water. Chemical reactions involving reactants dissolved in water are among the most common and important. A homogeneous mixture of two substances—such as salt and water—is a **solution**. The majority component of the mixture is the **solvent**, and the minority component is the **solute**. An **aqueous solution** is one in which water acts as the solvent. In this section, we examine how to quantify the concentration of a solution (the amount of solute relative to solvent).

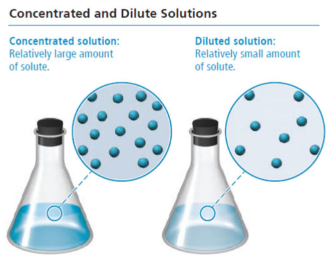
Solution：溶液
Solvent：溶媒
Solute：溶質

Solution Concentration

The amount of solute in a solution is variable. For example, we can add just a little salt to water to make a **dilute solution**, one that contains a small amount of solute relative to the solvent, or we can add a lot of salt to water to make a **concentrated solution**, one that contains a large amount of solute relative to the solvent (Figure 5.2▶). A common way to express solution concentration is **molarity (M)**, the amount of solute (in moles) divided by the volume of solution (in liters):

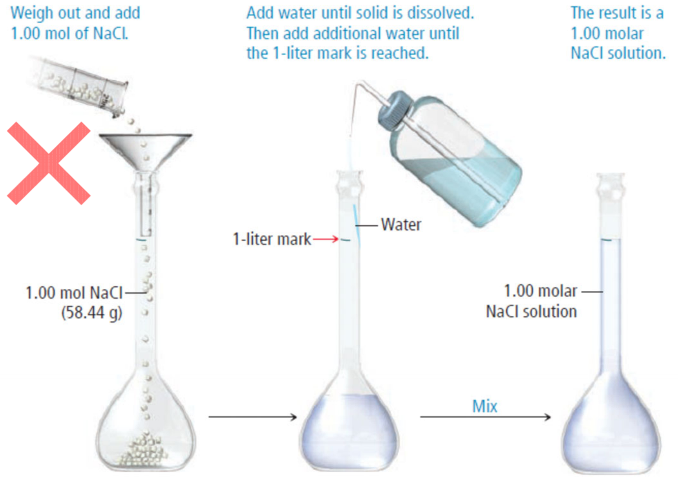
$$\text{Molarity (M)} = \frac{\text{amount of solute (in mol)}}{\text{volume of solution (in L)}}$$

$mol\ L^{-1}$ を Mで表すことがあるが、推奨しない



Dilute Solution：希薄溶液
Concentrated Solution：濃厚溶液

Preparing a Solution of Specified Concentration



Image

固体をメスフラスコに直接入れない！

Why?

基礎化学実験B3の操作で確かめよう！

問題 5-1

FOR PRACTICE 5.1 Calculate the molarity of a solution made by adding 45.4 g of $NaNO_3$ to a flask and dissolving it with water to create a total volume of 2.50 L.

H = 1, N = 14, O = 16, Na = 23

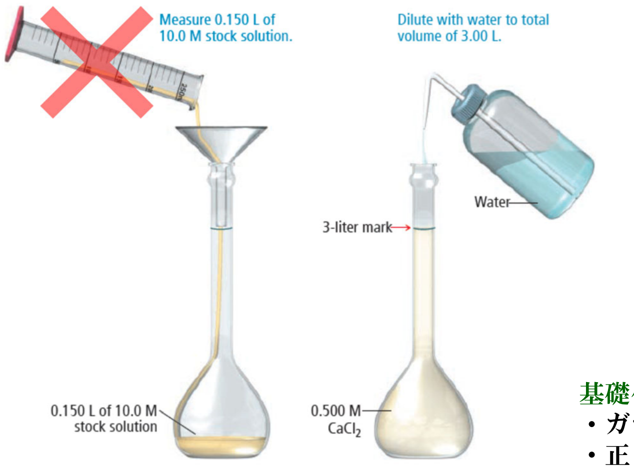
＊有効数字は無視します

選択肢　(1) 0.21 mol L^{-1}　(2) 0.42 mol L^{-1}　(3) 4.7 mol L^{-1}　(4) 18.2 mol L^{-1}

FOR PRACTICE 5.3 To what volume (in mL) should you dilute 100.0 mL of a 5.00 M $CaCl_2$ solution to obtain a 0.750 M $CaCl_2$ solution?

選択肢　(1) 125 mL　(2) 567 mL　(3) 667 mL　(4) 1.0 L

Diluting a Solution



メスシリンダーは使わない

Why?

基礎化学実験B3・B4・B5で
・ガラス器具の特性を学んで下さい
・正しい希釈方法を学んで下さい

容量器(測容器)のおよその誤差

100 mL メスフラスコ	± 0.12 mL	10 mL メスシリンダー	± 0.2 mL
250 mL メスフラスコ	± 0.15 mL	50 mL メスシリンダー	± 0.5 mL
5 mL ホールピペット	± 0.02 mL	10 mL ホールピペット	± 0.02 mL
25 mL ビュレット	± 0.03 mL	10 mL マクロピペット	± 0.1 mL

基礎実験テキスト より

5.3 Solution Stoichiometry

EXAMPLE 5.4 Solution Stoichiometry

What volume (in L) of a 0.150 M KCl solution will completely react with 0.150 L of a 0.175 M $Pb(NO_3)_2$ solution according to the following balanced chemical equation?

$$2\,KCl(aq) + Pb(NO_3)_2(aq) \longrightarrow PbCl_2(s) + 2\,KNO_3(aq)$$

SORT You are given the volume and concentration of a $Pb(NO_3)_2$ solution. You are asked to find the volume of KCl solution (of a given concentration) required to react with it.

GIVEN: 0.150 L of $Pb(NO_3)_2$ solution, 0.175 M $Pb(NO_3)_2$ solution, 0.150 M KCl solution

FIND: volume KCl solution (in L)

STRATEGIZE The conceptual plan has the form: volume A → amount A (in moles) → amount B (in moles) → volume B. Use the molar concentrations of the KCl and $Pb(NO_3)_2$ solutions as conversion factors between the number of moles of reactants in these solutions and their volumes. Use the stoichiometric coefficients from the balanced equation to convert between number of moles of $Pb(NO_3)_2$ and number of moles of KCl.

CONCEPTUAL PLAN

L $Pb(NO_3)_2$ solution → mol $Pb(NO_3)_2$ → mol KCl → L KCl solution

$\frac{0.175 \text{ mol } Pb(NO_3)_2}{1 \text{ L } Pb(NO_3)_2 \text{ solution}}$　$\frac{2 \text{ mol KCl}}{1 \text{ mol } Pb(NO_3)_2}$　$\frac{1 \text{ L KCl solution}}{0.150 \text{ mol KCl}}$

RELATIONSHIPS USED

$M\,Pb(NO_3)_2 = \frac{0.175 \text{ mol } Pb(NO_3)_2}{1 \text{ L } Pb(NO_3)_2 \text{ solution}}$

2 mol KCl : 1 mol $Pb(NO_3)_2$

$M\,KCl = \frac{0.150 \text{ mol KCl}}{1 \text{ L KCl solution}}$

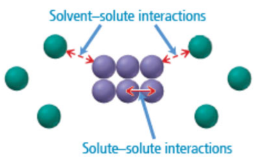
SOLVE Begin with L $Pb(NO_3)_2$ solution and follow the conceptual plan to arrive at L KCl solution.

SOLUTION

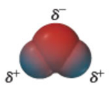
$$0.150 \text{ L } Pb(NO_3)_2 \text{ solution} \times \frac{0.175 \text{ mol } Pb(NO_3)_2}{1 \text{ L } Pb(NO_3)_2 \text{ solution}} \times \frac{2 \text{ mol KCl}}{1 \text{ mol } Pb(NO_3)_2} \times \frac{1 \text{ L KCl solution}}{0.150 \text{ mol KCl}} = 0.350 \text{ L KCl solution}$$

5.4 Types of Aqueous Solutions and Solubility

Solute and Solvent Interactions

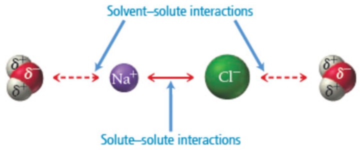


▲ **FIGURE 5.5** **Solute and Solvent Interactions**



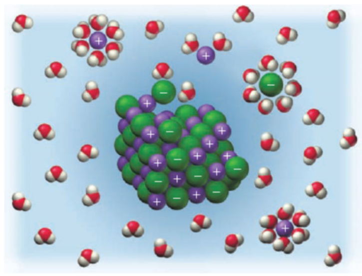
▲ **FIGURE 5.6** **Charge Distribution in Water** An uneven distribution of electrons causes the oxygen side of the water molecule to have a partial negative charge and the hydrogen side to have a partial positive charge.

Interactions in a Sodium Chloride Solution

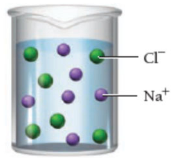


▲ **FIGURE 5.7** **Solute and Solvent Interactions in a Sodium Chloride Solution** When sodium chloride is put into water, the attraction of Na^+ and Cl^- ions to water molecules competes with the attraction between the oppositely charged ions themselves.

Dissolution of an Ionic Compound



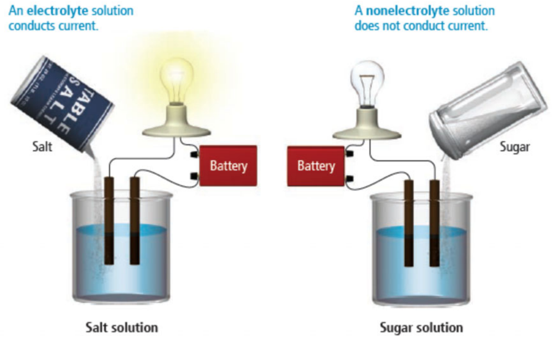
▲ **FIGURE 5.8** **Sodium Chloride Dissolving in Water** The attraction between water molecules and the ions of sodium chloride causes NaCl to dissolve in the water.



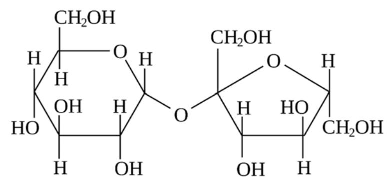
$NaCl(aq)$

Strong electrolyte

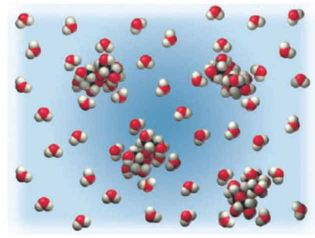
Electrolyte and Nonelectrolyte Solutions



Electrolyte **Nonelectrolyte**

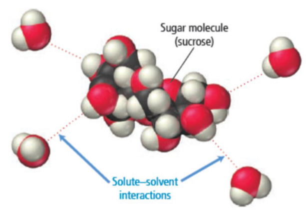


Sugar Solution



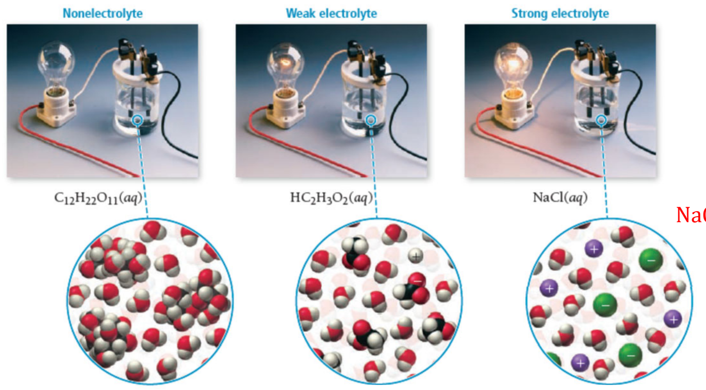
▲ **FIGURE 5.11** **A Sugar Solution** Sugar dissolves because the attractions between sugar molecules and water molecules, which both contain a distribution of electrons that results in partial positive and partial negative charges, overcome the attractions between sugar molecules to each other.

Interactions between Sugar and Water Molecules



▲ **FIGURE 5.10** **Sugar and Water Interactions** Partial charges on sugar molecules and water molecules (which we will discuss more fully in Chapter 12) result in attractions between the sugar molecules and water molecules.

Electrolytic Properties of Solutions



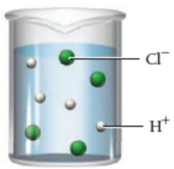
$NaCl \rightarrow Na^+(aq) + Cl^-(aq)$

$C_{12}H_{22}O_{11}$ $CH_3COOH(aq) \rightleftarrows H^+(aq) + CH_3COO^-(aq)$

Many acids are **weak acids**; they do not completely ionize in water. For example, acetic acid ($HC_2H_3O_2$), the acid in vinegar, is a weak acid. A solution of a weak acid is composed mostly of the nonionized acid—only a small percentage of the acid molecules ionize. We represent the partial ionization of a weak acid with opposing half arrows between the reactants and products:

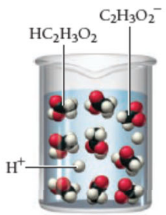
$$HC_2H_3O_2(aq) \rightleftharpoons H^+(aq) + C_2H_3O_2^-(aq)$$

Weak acids are **weak electrolytes**, and the resulting solutions—called *weak electrolyte solutions*—conduct electricity only weakly. Figure 5.12▼ summarizes the electrolytic properties of solutions.



$HCl(aq)$

Strong acid



$HC_2H_3O_2(aq)$

Weak acid

The Solubility of Ionic Compounds

As we have just discussed, when an ionic compound dissolves in water, the resulting solution contains not the intact ionic compound itself, but its component ions dissolved in water. However, not all ionic compounds dissolve in water. If we add AgCl to water, for example, it remains solid and appears as a white powder at the bottom of the water.

基礎化学実験B1の内容

TABLE 5.1 ■ **Solubility Rules for Ionic Compounds in Water**

Compounds Containing the Following Ions Are Generally Soluble	Exceptions
Li^+, Na^+, K^+, and NH_4^+	None
NO_3^- and $C_2H_3O_2^-$	None
Cl^-, Br^-, and I^-	When these ions pair with Ag^+, Hg_2^{2+}, or Pb^{2+}, the resulting compounds are insoluble.
SO_4^{2-}	When SO_4^{2-} pairs with Sr^{2+}, Ba^{2+}, Pb^{2+}, Ag^+, or Ca^{2+}, the resulting compound is insoluble.
Compounds Containing the Following Ions Are Generally Insoluble	**Exceptions**
OH^- and S^{2-}	When these ions pair with Li^+, Na^+, K^+, or NH_4^+, the resulting compounds are soluble. When S^{2-} pairs with Ca^{2+}, Sr^{2+}, or Ba^{2+}, the resulting compound is soluble. When OH^- pairs with Ca^{2+}, Sr^{2+}, or Ba^{2+}, the resulting compound is slightly soluble.
CO_3^{2-} and PO_4^{3-}	When these ions pair with Li^+, Na^+, K^+, or NH_4^+, the resulting compounds are soluble.

▲ AgCl does not dissolve in water; it remains as a white powder at the bottom of the beaker.

詳細は13章

5.5 Precipitation Reactions

Have you ever taken a bath in hard water? Hard water contains dissolved ions such as Ca^{2+} and Mg^{2+} that diminish the effectiveness of soap. These ions react with soap to form a gray soap scum that may appear as a "bathtub ring" after you drain the tub. Hard water is particularly troublesome when washing clothes. Consider how your white shirt would look covered with the soap scum from the bathtub and you can understand the problem. Consequently, most laundry detergents include substances designed to remove Ca^{2+} and Mg^{2+} from the laundry mixture. The most common substance used for this purpose is sodium carbonate, which dissolves in water to form sodium cations (Na^+) and carbonate (CO_3^{2-}) anions:

$$Na_2CO_3(aq) \longrightarrow 2\,Na^+(aq) + CO_3^{2-}(aq)$$

Sodium carbonate is soluble, but calcium carbonate and magnesium carbonate are not (see the solubility rules in Table 5.1). Consequently, the carbonate anions react with dissolved Mg^{2+} and Ca^{2+} ions in hard water to form solids that *precipitate* from (or come out of) solution:

$$Mg^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow MgCO_3(s)$$
$$Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$$

← B2の実験内容

The precipitation of these ions prevents their reaction with the soap, eliminating curd and preventing white shirts from turning gray.

Precipitation：

Hard Water：硬水

Soap Scum：石けんカス

▲ The reaction of ions in hard water with soap produces a gray soap scum that is visible after you drain the bathwater.

問題 5-2　英文を読んで正しいものをすべて選びなさい（1つということもある）

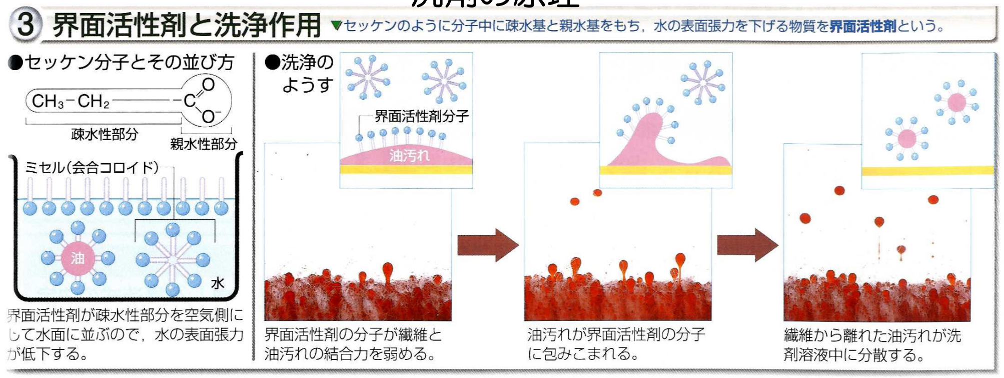
(1) 硬水にはCa^{2+}や Mg^{2+} が溶けにくい

(2) 石けんの活性は Ca^{2+} や Mg^{2+} が多い水では低くなる

(3) 硬水の場合、排水するとバスタブには灰色の石けんカスが残る

(4) 洗濯洗剤の中の炭酸ナトリウムが、Mg や Ca と反応して沈殿を生成する。
この、沈殿がシャツが洗濯しても汚れる原因になっている

洗剤の原理



ダイナミックワイド図説化学　東京書籍　(2006)

課題：水道水中には、Na^+以外にもCa^{2+}、Mg^{2+}などがある

Ca^{2+}、Mg^{2+}は、石けん分子と強く結合 → 水に不溶（石けんカス）

（硬水では、洗浄力が落ちる）

↓

Ca^{2+}、Mg^{2+}を水中から取り除く

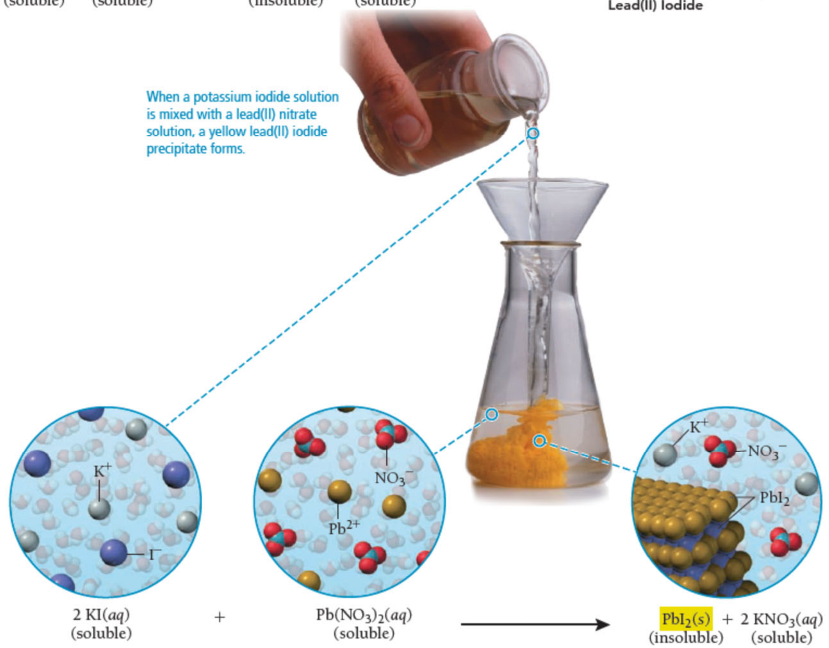
助剤（ビルダー）

黄ばみ・洗濯機の目詰まりの原因

Precipitation Reaction

$$2\ KI(aq) + Pb(NO_3)_2(aq) \longrightarrow PbI_2(s) + 2\ KNO_3(aq)$$
(soluble)　(soluble)　(insoluble)　(soluble)

◀ **FIGURE 5.13** **Precipitation of Lead(II) Iodide**



5.6 Representing Aqueous Reactions: Molecular, Ionic, and Net Ionic Equations

Consider the following equation for a precipitation reaction:

$$Pb(NO_3)_2(aq) + 2\,KCl(aq) \longrightarrow PbCl_2(s) + 2\,KNO_3(aq)$$

Molecular Equation

This equation is a **molecular equation**, an equation showing the complete neutral formulas for each compound in the reaction as if they existed as molecules. In actual solutions of soluble ionic compounds, dissolved substances are present as ions. We can write equations for reactions occurring in aqueous solution in a way that better shows the dissociated nature of dissolved ionic compounds. For example, we can rewrite the previous equation as:

$$Pb^{2+}(aq) + 2\,NO_3^-(aq) + 2\,K^+(aq) + 2\,Cl^-(aq) \longrightarrow PbCl_2(s) + 2\,K^+(aq) + 2\,NO_3^-(aq)$$

Complete Ionic Equation

Equations such as this, which list all of the ions present as either reactants or products in a chemical reaction, are **complete ionic equations**. Strong electrolytes are always represented as their component ions in ionic equations—weak electrolytes are not.

Notice that in the complete ionic equation, some of the ions in solution appear unchanged on both sides of the equation. These ions are called **spectator ions** because they do not participate in the reaction.

$$Pb^{2+}(aq) + 2\,NO_3^-(aq) + 2\,K^+(aq) + 2\,Cl^-(aq) \longrightarrow$$
$$PbCl_2(s) + 2\,K^+(aq) + 2\,NO_3^-(aq)$$

Spectator ions

To simplify the equation and to show more clearly what is happening, we can omit spectator ions:

$$Pb^{2+}(aq) + 2\,Cl^-(aq) \longrightarrow PbCl_2(s)$$

Net Ionic Equation

Equations that show only the species that actually change during the reaction are **net ionic equations**.

5.7 Acid–Base Reactions

Two other important classes of reactions that occur in aqueous solution are acid–base reactions and gas-evolution reactions. *In an* ***acid–base reaction*** (also called a **neutralization reaction**), an acid reacts with a base and the two neutralize each other, producing water (or in some cases a weak electrolyte). In a **gas-evolution reaction**, a gas forms, resulting in bubbling. In both cases, as in precipitation reactions, the reactions occur when the anion from one reactant combines with the cation of the other. Many gas-evolution reactions are also acid–base reactions.

Arrhenius Definition

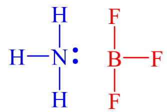
- Acid: Substance that produces H^+ ions in aqueous solution
- Base: Substance that produces OH^- ions in aqueous solution

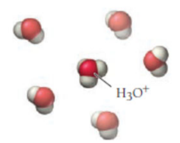
Brønsted-Lowry Definition

酸：H⁺を失う物質
塩基： H⁺を受け取る物質

Lewis Definition

酸：電子対を受ける物質
塩基：電子対を与える物質





▲ FIGURE 5.15 The Hydronium Ion Protons normally associate with water molecules in solution to form H_3O^+ ions, which in turn interact with other water molecules.

H_3O^+ ：高校では何と教わった？ Oxonium Ion？

水溶液中で水素イオンはH^+として単独に存在しない
1分子のH_2Oと結合しH_3O^+を形成
さらに、周りの水と結合し、 $[H(H_2O)_n]^+$となっている

Some acids—called **polyprotic acids**—contain more than one ionizable proton and release them sequentially. For example, sulfuric acid, H_2SO_4, is a **diprotic acid**. It is strong in its first ionizable proton, but weak in its second:

多塩基酸

$$H_2SO_4(aq) \longrightarrow H^+(aq) + HSO_4^-(aq)$$

$$HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$$

Diprotic Acid
2塩基酸
⇕
Diacidic Base
2酸塩基

▲ These household substances all contain acids.

▲ Many common household products contain bases.

Acid + Base → Salt + Water

$$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4(aq) + 2H_2O(l)$$

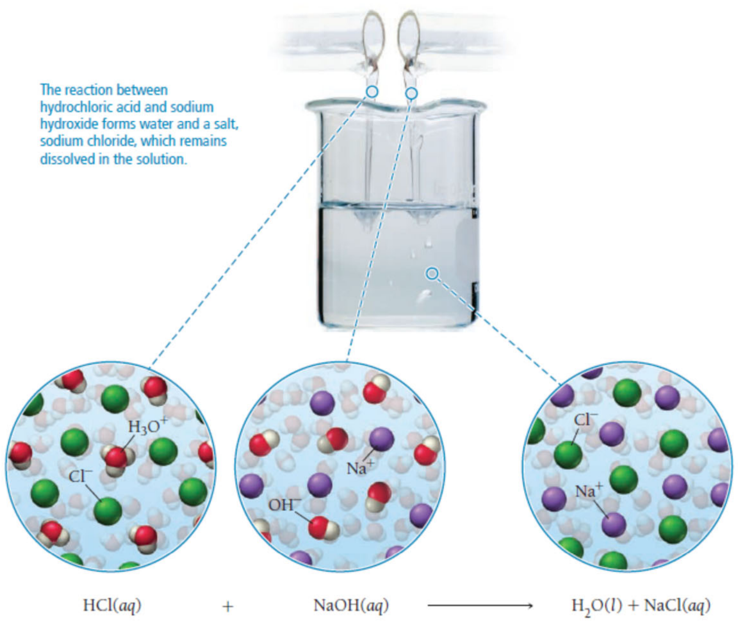
TABLE 5.2 ■ Some Common Acids and Bases

Name of Acid	Formula	Name of Base	Formula
Hydrochloric acid	HCl	Sodium hydroxide	$NaOH$
Hydrobromic acid	HBr	Lithium hydroxide	$LiOH$
Hydroiodic acid	HI	Potassium hydroxide	KOH
Nitric acid	HNO_3	Calcium hydroxide	$Ca(OH)_2$
Sulfuric acid	H_2SO_4	Barium hydroxide	$Ba(OH)_2$
Perchloric acid	$HClO_4$	Ammonia*	NH_3 (weak base)
Formic acid	$HCHO_2$ (weak acid)		
Acetic acid	$HC_2H_3O_2$ (weak acid)		
Hydrofluoric acid	HF (weak acid)		

*Ammonia does not contain OH^-, but it produces OH^- in a reaction with water that occurs only to a small extent: $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$.

Acid–Base Reaction

$$HCl(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCl(aq)$$



▲ FIGURE 5.16 Acid–Base Reaction

Acid–Base Titrations

基礎化学実験B5の内容

We can apply the principles of acid–base neutralization and stoichiometry to a common laboratory procedure called a *titration*. In a **titration**, a substance in a solution of known concentration is reacted with another substance in a solution of unknown concentration. For example, consider the following acid–base reaction:

Titration：滴定

$$HCl(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCl(aq)$$

The net ionic equation for this reaction eliminates the spectator ions:

$$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$$

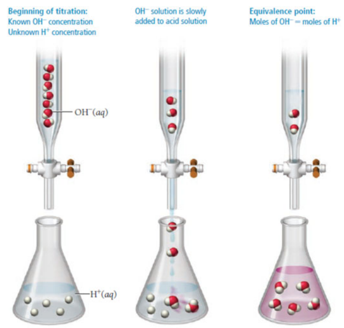
Suppose we have an HCl solution represented by the molecular diagram shown here (for purposes of clarity, we have omitted the Cl^- ions and the H_2O molecules not involved in the reaction from this representation).

In titrating this sample, we slowly add a solution of known OH^- concentration, as shown in the molecular diagrams in Figure 5.17▼. As we add the OH^-, it reacts with and neutralizes the H^+, forming water. At the **equivalence point**—the point in the titration when the number of moles of OH^- added equals the number of moles of H^+ initially in solution—the titration is complete. The equivalence point is typically signaled by an **indicator**, a dye whose color depends on the acidity or basicity of the solution (Figure 5.18▶).

Equivalent Point：当量点

Indicator：指示薬

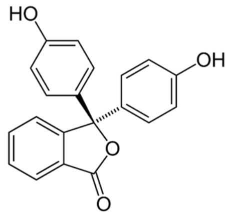
Indicator in Titration



問題 5-3

ACID–BASE TITRATION A 10.0 mL sample of 0.20 M HBr solution is titrated with 0.10 M NaOH. What volume of NaOH is required to reach the equivalence point?

(a) 10.0 mL **(b)** 20.0 mL **(c)** 40.0 mL



フェノールフタレイン
（無色の状態）

Indicator in Titration

基礎化学実験B5のレポートを書くときに調べて下さい

5.8 Gas-Evolution Reactions

基礎化学実験B1の関連内容

In a *gas-evolution reaction*, two aqueous solutions mix to form a gaseous product that bubbles out of solution. Some gas-evolution reactions form a gaseous product directly when the cation of one reactant combines with the anion of the other. For example, when sulfuric acid reacts with lithium sulfide, dihydrogen sulfide gas forms:

$$H_2SO_4(aq) + Li_2S(aq) \longrightarrow \underset{\text{gas}}{H_2S(g)} + Li_2SO_4(aq)$$

Other gas-evolution reactions often form an intermediate product that then decomposes (breaks down into simpler substances) to form a gas. For example, when aqueous hydrochloric acid is mixed with aqueous sodium bicarbonate, the following reaction occurs (Figure 5.19▶):

$$HCl(aq) + NaHCO_3(aq) \longrightarrow \underset{\text{Intermediate product}}{H_2CO_3(aq)} + NaCl(aq) \longrightarrow H_2O(l) + \underset{\text{gas}}{CO_2(g)} + NaCl(aq)$$

The intermediate product, H_2CO_3, is not stable and decomposes into H_2O and gaseous CO_2. Other important gas-evolution reactions form either H_2SO_3 or NH_4OH as intermediate products:

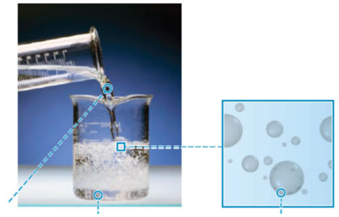
$$HCl(aq) + NaHSO_3(aq) \longrightarrow \underset{\text{Intermediate product}}{H_2SO_3(aq)} + NaCl(aq) \longrightarrow H_2O(l) + \underset{\text{gas}}{SO_2(g)} + NaCl(aq)$$

$$NH_4Cl(aq) + NaOH(aq) \longrightarrow \underset{\text{Intermediate product}}{NH_4OH(aq)} + NaCl(aq) \longrightarrow H_2O(l) + \underset{\text{gas}}{NH_3(g)} + NaCl(aq)$$

Table 5.3 lists the main types of compounds that form gases in aqueous reactions, as well as the gases formed.

▲ Gas-evolution reactions, such as the reaction of hydrochloric acid (HCl) with limestone ($CaCO_3$), typically produce CO_2; bubbling occurs as the gas is released.

強塩基＋弱酸の塩 は 強酸 を加えると弱酸が分解する



5.9 Oxidation–Reduction Reactions

酸化と還元は、酸化数で理解できる

酸化還元反応

Rules for Assigning Oxidation States	**Examples**
(These rules are hierarchical. If any two rules conflict, follow the rule that is higher on the list.)	
1. The oxidation state of an atom in a free element is 0.	Cu (0 ox state) Cl_2 (0 ox state)
2. The oxidation state of a monoatomic ion is equal to its charge.	Ca^{2+} (+2 ox state) Cl^- (−1 ox state)
3. The sum of the oxidation states of all atoms in:	
■ A neutral molecule or formula unit is 0.	H_2O 2(H ox state) + 1(O ox state) = 0
■ An ion is equal to the charge of the ion.	NO_3^- 1(N ox state) + 3(O ox state) = −1
4. In their compounds, metals have positive oxidation states.	
■ Group 1A metals *always* have an oxidation state of +1.	NaCl (+1 ox state)
■ Group 2A metals *always* have an oxidation state of +2.	CaF_2 (+2 ox state)
5. In their compounds, nonmetals are assigned oxidation states according to the table shown here. Entries at the top of the table take precedence over entries at the bottom of the table.	

酸化数が上がる

「酸化された」
「相手を還元した」
「還元剤」

⇕

酸化数が下がる

「還元された」
「相手を酸化した」
「酸化剤」

When assigning oxidation states, keep these points in mind:

- The oxidation state of any given element generally depends on what other elements are present in the compound. (The exceptions are the group 1A and 2A metals, which are *always* +1 and +2, respectively.)
- Rule 3 must always be followed. Therefore, when following the hierarchy shown in rule 5, give priority to the element(s) highest on the list and then assign the oxidation state of the element lowest on the list using rule 3.
- When assigning oxidation states to elements that are not covered by rules 4 and 5 (such as carbon), use rule 3 to deduce their oxidation state once all other oxidation states have been assigned.

Redox Reaction：
酸化還元反応

問題 5-4 正しいものをすべて選びなさい

FOR PRACTICE 5.15 Determine whether or not each reaction is a redox reaction. For each redox reaction, identify the oxidizing agent and the reducing agent.

(a) $2\,Li(s) + Cl_2(g) \longrightarrow 2\,LiCl(s)$
(b) $2\,Al(s) + 3\,Sn^{2+}(aq) \longrightarrow 2\,Al^{3+}(aq) + 3\,Sn(s)$
(c) $Pb(NO_3)_2(aq) + 2\,LiCl(aq) \longrightarrow PbCl_2(s) + 2\,LiNO_3(aq)$
(d) $C(s) + O_2(g) \longrightarrow CO_2(g)$

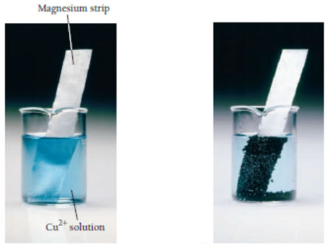
(1) 上記の(a), (b), (d) の反応が酸化還元反応である

(2) 上記の(a)は酸化還元反応ではない

(3)上記の(d)で、炭素は還元されている

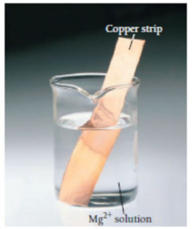
(4)上記の(d)で、炭素は還元剤である

(5)上記の(b)で、スズは酸化剤である



$$Mg(s) + Cu^{2+}(aq) \longrightarrow Mg^{2+}(aq) + Cu(s)$$

▲ **FIGURE 5.23 Cu^{2+} Oxidizes Magnesium** When we put a magnesium strip into a Cu^{2+} solution, the magnesium is oxidized to Mg^{2+} and the copper ion is reduced to Cu(s). Notice the fading of the blue color (due to Cu^{2+} ions) in solution and the appearance of solid copper on the magnesium strip.



▲ **FIGURE 5.24 Mg^{2+} Does Not Oxidize Copper** When we place solid copper in a solution containing Mg^{2+} ions, no reaction occurs.

イオン化傾向

TABLE 5.4 ■ Activity Series of Metals

$Li(s) \longrightarrow Li^{+}(aq) + e^{-}$	Most reactive
$K(s) \longrightarrow K^{+}(aq) + e^{-}$	Most easily oxidized
$Ca(s) \longrightarrow Ca^{2+}(aq) + 2e^{-}$	Strongest tendency to lose electrons
$Na(s) \longrightarrow Na^{+}(aq) + e^{-}$	
$Mg(s) \longrightarrow Mg^{2+}(aq) + 2e^{-}$	
$Al(s) \longrightarrow Al^{3+}(aq) + 3e^{-}$	
$Mn(s) \longrightarrow Mn^{2+}(aq) + 2e^{-}$	
$Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^{-}$	
$Cr(s) \longrightarrow Cr^{3+}(aq) + 3e^{-}$	
$Fe(s) \longrightarrow Fe^{2+}(aq) + 2e^{-}$	
$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^{-}$	
$Sn(s) \longrightarrow Sn^{2+}(aq) + 2e^{-}$	
$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^{-}$	
$H_2(g) \longrightarrow 2H^{+}(aq) + 2e^{-}$	Least reactive
$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^{-}$	Most difficult to oxidize
$Ag(s) \longrightarrow Ag^{+}(aq) + e^{-}$	
$Au(s) \longrightarrow Au^{3+}(aq) + 3e^{-}$	Least tendency to lose electrons