

Properties of Matters:

(1) Atoms

-2006 I(1):

Choose the correct description of the element $^{13}_3\text{C}$.

- 1) It contains 7 electrons.
- 2) It contains 13 electrons.
- 3) It contains 7 protons.
- 4) It contains 13 protons.
- 5) It contains 7 neutrons.
- 6) It contains 13 neutrons.

-2007 I(5)

(5) Which of the following gaseous atoms 1) to 5) has the smallest first ionization potential?

- | | | |
|------------|----------|----------|
| 1) helium | 2) neon | 3) argon |
| 4) krypton | 5) xenon | |

-2010 Q1

Q1 From ①–⑤ below choose the atom that has the largest number of outermost shell electrons.

1

- ① B ② Cl ③ He ④ Na ⑤ S

-2010 Q2

Q2 An atom has 32 neutrons and its trivalent cation has 24 electrons. From ①–⑤ below choose the atom. **2**

- ① ^{53}Cr ② ^{55}Mn ③ ^{57}Fe ④ ^{59}Co ⑤ ^{66}Zn

-2012 I(1)

(1) Which of the ions or atom 1) to 4) has the smallest radius?

- 1) F^- 2) Ne 3) Na^+ 4) Mg^{2+}

-2013 I(1)

(1) Which of the atoms 1) to 4) has the smallest first ionization energy?

- 1) Li 2) Be 3) Na 4) Mg

-2015 I(1)

(1) Which of the atoms and ions 1) to 4) has a different electron configuration from those of the others?

- 1) F^- 2) Ne 3) Na^+ 4) Ar

-2016 I(1)

(1) Which of the atoms 1) to 4) has the highest first ionization energy?

- 1) F 2) Ne 3) Na 4) Ar

-2017 I(1)

(1) Which of the atoms 1) to 4) has the largest electronegativity?

1) H

2) F

3) I

4) Cs

-2018 I(1)(2)

(1) Which of the atoms 1) to 4) has the largest electron affinity?

1) N

2) O

3) F

4) Ne

(2) Which of the ions 1) to 4) has the largest ionic radius?

1) Li^+

2) Na^+

3) K^+

4) Rb^+

-2019 I(1)(2)

(1) Which nucleus of the atoms 1) to 4) has just one neutron?

1) ^1H

2) ^4He

3) ^6Li

4) ^5Be

(2) Which of the atoms 1) to 4) has the smallest atomic radius?

1) Si

2) Ge

3) Sn

4) Pb

-2020 I(1)

(1) Which of the following ions has the same electron configuration as Ne atom?

1) K^+

2) Mg^{2+}

3) Fe^{3+}

4) Cl^-

(2) Chemical Bonding

-2008 I(3)

- (3) Arrange the following substances A, B, and C in order of decreasing melting point.

A : graphite

B : naphthalene

C : sodium chloride

1) $A > B > C$

2) $A > C > B$

3) $B > A > C$

4) $B > C > A$

5) $C > A > B$

6) $C > B > A$

-2008 I(4)

- (4) Which of the following molecules and ions cannot form a coordinate bond with the Fe^{2+} ion?

1) CH_4

2) H_2O

3) NH_3

4) CN^-

5) Cl^-

6) OH^-

-2010 Q7

Q7 From ①–⑤ below choose the molecule that is linear and has the double bond.

7

① acetylene

② carbon dioxide

③ hydrogen peroxide

④ methane

⑤ propene (propylene)

-2012 I(2)

- (2) In the solid state which of the substances 1) to 4) has the highest electrical conductivity?

1) copper

2) silver iodide

3) silicon

4) graphite

-2012 I(3)

(3) Which of the substances 1) to 4) has a linear molecular shape?

- | | |
|---------------------|-------------------|
| 1) methane | 2) carbon dioxide |
| 3) nitrogen dioxide | 4) ozone |

-2013 I(3)

(3) Which of the substances 1) to 4) has a planar molecular shape?

- | | |
|----------------------|--------------|
| 1) carbon dioxide | 2) ethane |
| 3) ethylene (ethene) | 4) propylene |

-2013 I(4)

(4) Which of the substances 1) to 4) has the lowest boiling point?

- | | | | |
|-------------------------|-------------------------|--------------------------|--------------------------|
| 1) H_2O | 2) H_2S | 3) H_2Se | 4) H_2Te |
|-------------------------|-------------------------|--------------------------|--------------------------|

-2014 I(3)

(3) Which of the substances 1) to 4) contains only single bonds?

- | | |
|----------------------|--------------------|
| 1) carbon dioxide | 2) phosphoric acid |
| 3) hydrogen peroxide | 4) nitrogen |

-2015 I(3)

(3) Which of the substances 1) to 4) contains a triple bond?

- | | |
|----------------------|------------------|
| 1) hydrochloric acid | 2) sulfuric acid |
| 3) cyanic acid | 4) formic acid |

-2016 I(3)

(3) Which of the substances 1) to 4) does not contain double bonds?

- | | |
|----------------------|------------------|
| 1) acetic acid | 2) formic acid |
| 3) hydrochloric acid | 4) sulfuric acid |

-2016 I(4)

(4) Which of the substances 1) to 4) has the lowest boiling point?

- | | | | |
|-------------------------|-------------------------|--------------------------|--------------------------|
| 1) H_2O | 2) H_2S | 3) H_2Se | 4) H_2Te |
|-------------------------|-------------------------|--------------------------|--------------------------|

-2016 VI(2)

(2) Which of the descriptions 1) to 4) is correct for the structure of ethylene?

- 1) All carbon atoms and hydrogen atoms exist in the same plane.
- 2) Cis and trans isomers exist.
- 3) A carbon-carbon double bond in ethylene is shorter than a carbon-carbon triple bond in acetylene.
- 4) It has a tetrahedral molecular structure.

-2017 I(3)

(3) Which of the molecules 1) to 4) is nonpolar?

1) HCl

2) H₂O

3) CO₂

4) NH₃

-2018 I(3)(4)

(3) Which of the molecules 1) to 4) has a linear shape?

1) H₂O

2) H₂O₂

3) CO₂

4) NO₂

(4) Which of the substances 1) to 4) has the highest boiling point?

1) HF

2) HCl

3) HBr

4) HI

-2019 I(3)(4)

(3) Which of the underlined atoms in the molecules 1) to 4) has just one lone pair of electrons?

1) BF₃

2) CO₂

3) NH₃

4) HF

(4) Which of the substances 1) to 4) has the lowest boiling point?

1) He

2) N₂

3) O₂

4) Kr

-2020 I(2)

(2) Which of the following molecules has the longest bond distance?

1) H₂

2) N₂

3) F₂

4) Cl₂

-2020 I(4)

(4) Which of the aqueous solutions of the following compounds has the lowest acidity?

1) HF

2) HCl

3) HBr

4) HI

(3) Crystalline Structures

-2006 I(4)

Which is the correct combination that are molecular crystals in the solid state?

- 1) sodium chloride, carbon dioxide
- 2) carbon dioxide, diamond
- 3) diamond, naphthalene
- 4) sodium chloride, diamond
- 5) carbon dioxide, naphthalene
- 6) sodium chloride, naphthalene

-2009 I(1)

(1) In the solid state which of the following substances 1) to 5) forms a molecular crystal?

- | | | |
|---------------------|--------------------|---------------------|
| 1) sodium chloride | 2) carbon dioxide | 3) silicon dioxide |
| 4) iron | 5) diamond | |

-2010 Q12

Q12 The following statements (a)-(c) on sodium chloride (NaCl) are either true or false. From

①-⑥ below choose the correct combination of "true (T)" and "false (F)".

12

- (a) Its crystal does not conduct electricity.
- (b) Molten sodium chloride conducts electricity.
- (c) By electrolyzing its aqueous solution with a carbon electrode, chlorine (Cl_2) and hydrogen (H_2) are obtained.

	a	b	c
①	T	T	T
②	T	T	F
③	T	F	T
④	F	T	T
⑤	F	T	F
⑥	F	F	F

-2013 I(5)

(5) Which of the descriptions 1) to 4) is not correct for the properties of sodium chloride?

- 1) Sodium ions and chloride ions are bonded by electrostatic attractive forces.
- 2) Aqueous solution exhibits neutral pH.
- 3) The number of sodium ions in the closest neighbor of a chloride ion is 6.
- 4) Refractive indices differ according to the crystallographic directions in single crystal.

-2014 I(5)

(5) Which of the descriptions 1) to 4) is not correct for the properties of crystalline silicon?

- 1) A silicon atom is surrounded by its four nearest-neighbor silicon atoms.
- 2) High purity crystals are applied to solar cells.
- 3) Electrical conductivity can be tuned by doping boron or phosphorus.
- 4) Crystalline silicon is transparent to visible light.

-2014 V

IV Think of a cubic unit cell of crystal that is composed of a single kind of atom. By placing atoms at every corner of the cube, a simple cubic lattice is formed. Assume that the atoms are perfect hard spheres with a radius r and that the atoms are in close contact to minimize the volume of the cube. Write the correct answers for (a) to (d) below to two significant figures.

- (1) In the simple cubic lattice, the volume occupied by the atoms is (a) % that of the cube, and the length of the edge of the cube is (b) r .
- (2) To the simple cubic lattice described above, atoms are added to all the face-center positions of the cube. In the resulting lattice, the volume occupied by the atoms is (c) % of the cube, and the length of the edge of the cube is (d) r .

-2016 IV(2)

(2) Consider the unit cell of aluminum with an aluminum ion on every corner and every face-centered site of the cube. Using the value of ionic radius of aluminum ion $r = 0.143$ nm, the length of each edge of the unit cell can be calculated as (c) nm. Using the atomic weight value of aluminum 27.0, the density of aluminum can be calculated as (d) g cm^{-3} .

-2017 I(7)

(7) Which of the descriptions 1) to 4) is correct for ionic crystals?

- 1) The van der Waals interaction is predominant in the bonding force of ionic crystals.
- 2) Most of the ionic crystals are volatile.
- 3) When an ionic crystal is dissolved in water, the resultant aqueous solution conducts electricity.
- 4) Ionic crystals are ductile and malleable.

-2018 IV(2)

(2) The unit cell of NaCl crystal contains four Na^+ ions and four Cl^- ions. One Na^+ ion is surrounded by (c) Cl^- ions in the crystal. The ionic radii of Na^+ and Cl^- ions are 0.116 and 0.167 nm, respectively. Therefore, the edge length of the unit cell is (d) nm.

-2019 IV(2)

(2) In ionic crystals with 1:1 ratio of cations and anions, there are two representative types of crystal structure, NaCl and CsCl types. In NaCl crystals, the number of nearest-neighboring Cl^- ions surrounding one Na^+ ion is 6. On the other hand, in CsCl crystals, the number of nearest-neighboring Cl^- ions surrounding one Cs^+ ion is (c). The ionic radius of Cl^- ion is 0.167 nm, and the edge length of a cubic unit cell of CsCl is 0.412 nm. Therefore, the ionic radius of Cs^+ ion is (d) nm.

-2020 I(3)

(3) Which of the following substances is regarded as a molecular crystal at ambient temperature and pressure?

1) silicon

2) sodium chloride

3) calcium

4) iodine

-2020 II(2)

(2) A face-centered cubic structure contains (d) atoms in its unit cell. In the structure, one atom is surrounded by (e) nearest-neighboring atoms. Gold crystallizes in the face-centered cubic structure under ambient conditions. The edge length of the cubic unit cell of gold is 0.41 nm. The atomic radius of gold atom is (f) nm, and the density of crystalline gold is (g) g cm^{-3} .

(4) States of Matter

-2008 V

V What is the state of compounds (1) to (5) when these are exposed at 0°C under 1 atm? Choose from (a) to (c) and write the letter in the answer box.

- | | | |
|--------------|-----------------|------------------|
| (1) methanol | (2) acetic acid | (3) acetaldehyde |
| (4) acetone | (5) ethylene | |
| (a) gas | (b) liquid | (c) solid |

-2010 Q4

Q4 From ①-⑤ choose the best pair of methods to purify iodine (I_2) and potassium nitrate (KNO_3) .

4

	Iodine	Potassium nitrate
①	recrystallization	sublimation
②	recrystallization	distillation
③	sublimation	distillation
④	sublimation	recrystallization
⑤	distillation	recrystallization

-2014 I(1)

(1) Which of the elements 1) to 4) has no allotropes?

- | | | | |
|------|------|------|------|
| 1) C | 2) N | 3) O | 4) P |
|------|------|------|------|

-2015 I(4)

(4) Which of the substances 1) to 4) is a liquid under atmospheric pressure at 25 °C?

1) F₂

2) Cl₂

3) Br₂

4) I₂

-2015 I(7)

(7) Which of the descriptions 1) to 4) is appropriate for the phase diagram of pure substances?

1) The slope of the gas-solid boundary is negative.

2) The gas-liquid boundary extends infinitely towards higher temperatures and pressure.

3) The solid-liquid boundary of water is positive.

4) At the triple point, three phases coexist at a specified temperature and pressure.

-2016 VI(1)

(1) What is the most appropriate method for collecting ethylene, which is prepared by the reaction of ethanol and concentrated sulfuric acid? Select from 1)~4).

1) upward delivery 2) downward delivery 3) collecting gas over water 4) distillation method

-2017 I(4)

(4) Which of the simple substances 1) to 4) is liquid under atmospheric pressure at 25 °C?

1) He

2) S

3) Hg

4) Pb