1. (Isotopes) Consider the Br_2 molecule. If there are two common isotopes, ^{79}Br and ^{81}Br, how many <u>physically distinguishable</u> combinations of Br atoms are there in Br_2?

       2, **3**, 4

2. (Isotopes, natural abundance, probabilities, mass spectrometry) If the two Br isotopes, ^{79}Br and ^{81}Br, each has a natural abundance of about 50%, what is the most likely molecular weight of Br_2 molecules?
       158 amu, **160 amu**, 162 amu, all three are equally likely
       Demonstration: Students in class flip coins twice in succession and the numbers of two heads, two tails, and one head/one tail flips can be tabulated by show of hands to make a connection with probabilities of independent events being multiplicative.
       Which is the expected mass spectrum of the parent cation, Br_2^+?
       A, **B**, C, D

3. (Isotopes, natural abundance, probabilities, mass spectrometry) Another diatomic molecule is H_2:

       The two nonradioactive isotopes of hydrogen are H and D, with ~99.9 % and ~0.01 % natural abundance, respectively. Which combination is most likely to be found in nature?
       H_2, HD, D_2

At how many amu is the largest peak expected in the mass spectrum?
   2, 3, 4

4. (Extended structures, discrete molecules; Table 3.1 "Companion")
   Demonstration: $HgO(s) \rightarrow Hg(l) + 1/2\ O_2(g)$
   Is HgO an **extended structure** or discrete molecule?
   Is O_2 an extended structure or **discrete molecule**?

5. (Unit cells; Ch. 3 "Companion") Which of the parallelograms in the figure below are unit cells?
   A, B, C, **D**, **E**

After a unit cell is identified: What number of atoms belong to the unit cell?
   1, 2, other

6. (Unit cells; Ch. 3 "Companion;" empirical formula) Pictured below is an NaCl layer. Which of the squares are unit cells?
   A, **B**, C

Having identified B as a unit cell, for example, how many Na and Cl atoms belong to it?
   Na_2Cl_2, Na_4Cl_4, **Na_8Cl_8**
What is the empirical formula?

NaCl, Na$_2$Cl, NaCl$_2$

In terms of relative size, Na$^+$ and Cl$^-$ would be represented, respectively, by **small and large circles**, large and small circles

7. (Unit cells; Ch. 3 "Companion") A corner atom is part of how many unit cells? **At-Seat Demonstration**: cubes like dice can be handed out for students to examine for this question.

    1, 2, 4, **8**

8. (Coordination number; Ch. 5 "Companion") In the two-dimensional square packing shown, what is the coordination number of the central atom?

    2, **4**, 6

9. (Coordination number; Ch. 5 "Companion") **At-Seat Demonstration**: Give students 10 pennies (students can share a set of ten) and ask them to pack them at their desks to determine the largest coordination number in two dimensions.

    4, **6**, 8, 9

10. (Unit cells, layer sequences; Ch. 3 "Companion") In the figures below, how many atoms per unit cell are present?

11. (Stoichiometry, empirical formula, elemental analysis, atomic weights, magnetism) **Demonstration 10.1** "Companion": On an overhead, show that with a magnet, nickel powder is separable from the aluminum powder. Show that the pressed bar comprising Ni and Al powder is also magnetic using the overhead projector.

    The reaction goes from face-centered cubic Ni and Al to produce an alloy of Ni and Al with the following layer sequence:

    What is the empirical formula of the product?
       NiAl, $NiAl_2$, Ni_2Al, Ni_8Al
    Run the reaction and show that the product bar is less magnetic using the overhead projector.
    Will the elemental analysis be the same for the bar before and after the reaction?
       Same, Different

    Al atoms weigh about one-half of Ni atoms:

    For a complete reaction (Ni + Al ---> NiAl), roughly what mass ratio of reagents should be used?

equal masses of Ni and Al, **half the mass of Al as of Ni**, twice the mass of Al as Ni

(An analogous set of questions could be developed for the quantitative reaction of Fe and S.)

12. (Atoms, ions) How many atoms are in the formula $Al_2(SO_4)_3$?
      3, 5, **17**
   How many moles of ions are there per mole of $Al_2(SO_4)_3$?
      2, 3, **5**

20. (Ionization energy) $A(g) + energy \rightarrow e^- + A^?(g)$. What is the charge, if any, on the product A?
      +1, 0, –1

39. (Specific heat, heat capacity; Ch. 2 "Companion") Setup: In solids, heat capacity near room temperature often reflects the number of atoms in the solid. **Demonstration 2.1** "Companion": Heat equal masses of Al and Pb in boiling water. Transfer the Al to a beaker of room temperature water. Measure the temperature increase with a digital thermometer. Before repeating with Pb transferred to a separate beaker of the same volume of room temperature water, ask whether the temperature change
      will be greater with Pb, **less with Pb**, the same with Pb

42. (Elemental analysis, diffraction, solid solutions; Ch. 3 & 4 "Companion") Sample A is an equimolar physical mixture of Si and Ge. Sample B is a $Si_{0.5}Ge_{0.5}$ solid solution. Which measurements will be identical and which different for the two samples?
   elemental analysis: **same**, different
   x-ray diffraction: same, **different**
   absorption spectrum: same, **different**

43. (Vapor pressure) **Demonstration**: Drops of water and ethanol are placed on an overhead projector and the ethanol drop is seen to evaporate more rapidly. The graph below compares the vapor pressures of ethanol and water. Which curve corresponds to ethanol?
      A, B

Demonstration: Syringes are used to bring drops of H_2O and ethanol to the top of columns of Hg, as shown below. What will happen to the heights of the Hg columns?
both column heights will be the same, the column below H_2O is shorter, **the column below   EtOH is shorter**

50. (Layer sequences; Ch. 3 & 5 "Companion") How many atoms are in the following layer sequence of the diamond structure?
   4, 6, **8**, 13
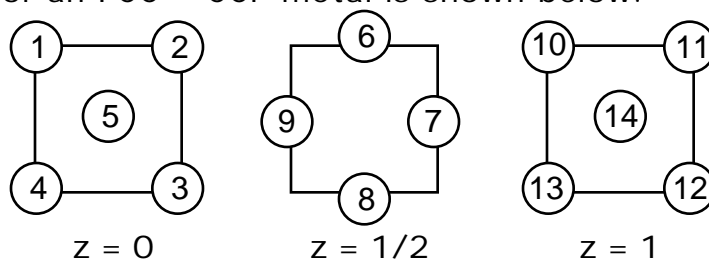   What is the coordination number?
   4, 6, 8
   What is the coordination geometry?
   tetrahedral, square, octahedral, cubic

53. (Layer sequences; Ch. 3 & 5 "Companion") What is the empirical formula of the solid represented by the following layer sequence?

LiO, LiO_2, **Li$_2$O**, Li_8O_{14}

65. (Unit cells, layer sequences, close packed spheres; Ch. 3 & 5 "Companion") A layer sequence for an FCC = CCP metal is shown below.

z = 0   z = 1/2   z = 1

A face diagonal passes through the center of atom 4 and the center(s) of which other atom(s)?
   1, **2**, **5**, 11   Also correct: **8**, **12** & **9**, **10**

A body diagonal passes through the center of atom 4 and the center(s) of which other atom(s)?
   2, 5, **11**, 14

A close-packed plane is comprised of six atoms. If atoms 2, 4, 5 are three of the six atoms, which other three atoms are need to define the plane?
   11, 13, 14; 6, 9, 13; **7**, **8**, **12**; **6**, **9**, **10**

89. (Isotopes) The radioactive isotope ^{14}C has how many neutrons?
   6, **8**, other

107. (Isotopes, elements) The identity of an element is determined by the number of which particle?   **protons**, neutrons, electrons

149. (Chemical formula) An elemental analysis shows a sample of buckyball to be 100% carbon, and its mass spectrum shows a parent peak at 720 amu. The formula would be written
   60 C, **C$_{60}$**, C

158. (Solid solutions; Ch. 3 "Companion") The following trio of metals all form the BCC structure.

Metal	Atomic Radius
V	1.31 Angstroms
Mo	1.36 Angstroms
Na	1.86 Angstroms

Which two metals are most likely to form a solid solution?
   V and Mo, V and Na, Mo and Na

Additional example: Group 14 Element Unit Cell Length
C 3.57 Angstroms
Si 5.43 Angstroms
Ge 5.66 Angstroms

Which two elements are most likely to form a solid solution?
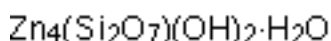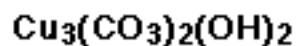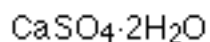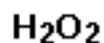C and Si, C and Ge, **Si and Ge**

175. Hydrogen can occur as H (1 amu), 2H (deuterium, 2 amu), and 3H (tritium, 3 amu) with respective natural abundances of >99.98%, <0.02%, and almost 0, respectively. Do all water molecules have equal masses?
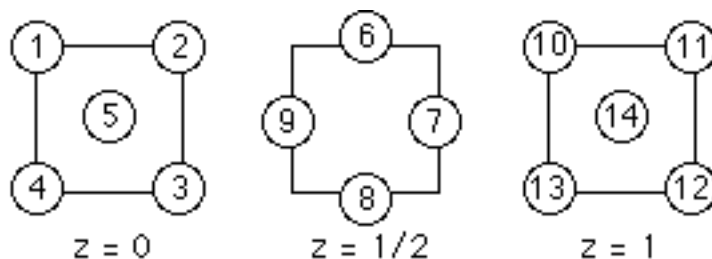
yes, **no**

Considering only these hydrogen isotopes, how many masses (integer amu) can occur?

3, **5**, 9

176. Which member of the following pairs contains more atoms in the formula?

H_2O H_2O_2

$CaSO_4 \cdot 2H_2O$ $Cu_3(CO_3)_2(OH)_2$

$Zn_4(Si_2O_7)(OH)_2 \cdot H_2O$ $Ca_5(PO_4)_3Cl$

177. Locate the tetrahedral hole inside this unit cell that is defined, in part, by atoms number 4 and 5.

z = 0   z = 1/2   z = 1

Which other numbered atoms define the tetrahedral hole?

1 and 3, **8 and 9**, 13 and 14

At what value of z is its center?

0, **1/4**, 1/2, 1

184. When the solid solution CdS0.5Se0.5 is reacted with excess strong acid, H+, the gases H2S and H2Se are released.

Which of the following plots represents the mass of each of the gases vs. mL of acid added, and which represents the volume of each of the gases vs. mL of acid added (i.e., label the y-axis)?

plot A represents the volumes of the two gases (H2S and H2Se) and plot B represents the masses of the two gases
plot A represents masses of the two gases and plot B represents volume of the two gases

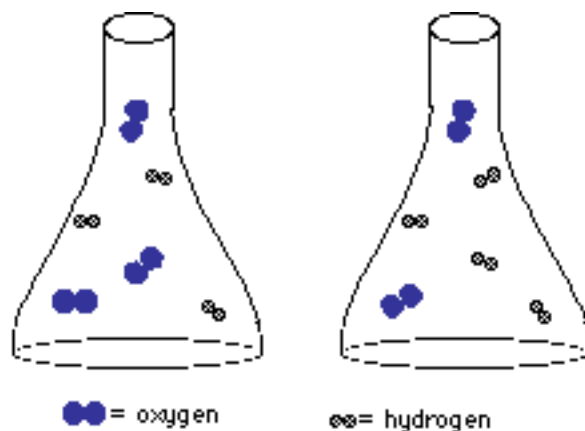Which of the two curves in plot B represents the mass of H2S?

1, **2**

In which part of either plot is the acid the limiting reagent?
    flat part
    rising part

185. Which of the flasks below will contain a mixture when all the hydrogen reacts with oxygen to give water?

●●= oxygen   ○○= hydrogen

Flask A, Flask B

189. Buckyball (C60) crystallizes with the face-centered cubic structure. The layer sequence for a face-centered cubic unit cell is shown below. Each circle represents a buckyball molecule.

How many buckyball molecules are in the unit cell?

4, 6, **8**

Potassium reacts with C60 to fill all the tetrahedral and octrahedral holes of the FCC structure formed by the C60 molecules. What is x in the formula of the solid, KxC60? [The solid is a superconductor.]

1,2,**3**,4

218. Which of the parallelograms in the figure below are unit cells?

A, B, **C**

How many total heads are included in the correct unit cell?

4, 6, **8**

(A digital camera can be used to quickly photograph students in an entire class at the beginning of a course; groups of several students can be photographed at a time, with subsequent computer cropping to produce individual pictures. The collection of class photographs can be distributed to everyone in the course with their preferred name to facilitate communication. These photographs can also be incorporated into a unit cell question, as shown above.)

237. Scanning tunneling microscopy depends upon the flow of electricity (current) between a surface and an atomically-sharp probe tip. Two plots of current vs. tip-to-surface distance are shown. Which is correct?

A, B