

Key to Supplemental Questions
for
Atoms, Elements, Molecules and Compounds Lectures

1. Fill in the following table. Assume that the entries are for the neutral atom, unless otherwise indicated.

Symbol	Mass Number	Number of Neutrons	Atomic Number	Isotope's Name
^{31}P	31	16	15	phosphorous-31
$^{80}_{35}\text{Br}^-$	80	45	35	bromine-80
$^{137}_{56}\text{Ba}$	137	81	56	barium-137
^3_1H	3	2	1	tritium

The last three symbols could be written without the atomic number, as was done for ^{31}P .

2. Fill in the following table. Assume the neutral atom, unless otherwise indicated.

Symbol	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons	Name of Isotope
$^{35}_{18}\text{Ar}^+$	18	35	18	17	17	argon-35
$^{27}_{13}\text{Al}$	13	27	13	14	13	aluminum-27
D	1	2	1	1	1	deuterium

3. The atomic weight of lithium (Li) is 6.941 amu. Lithium has two isotopes, one of which is ^6Li (isotopic mass of 6.015121 amu, 7.50% natural abundance). What is the isotopic mass and natural abundance of the other isotope?

Let ^xLi represent the other isotope.

By the definition of an atomic weight.

$$\begin{aligned} \text{atomic weight} &= \left(\frac{\% \text{abundance } ^6\text{Li}}{100} \right) (\text{isotopic mass } ^6\text{Li}) \\ &+ \left(\frac{\% \text{abundance } ^x\text{Li}}{100} \right) (\text{isotopic mass } ^x\text{Li}) \end{aligned}$$

Since there are only two isotopes

$$\%abundance {}^6\text{Li} + \%abundance {}^7\text{Li} = 100.00$$

*Substituting in the known %abundance of ${}^6\text{Li}$, and solving for the %abundance of the unknown isotope gives **the %abundance of the unknown isotope as 92.50%**.*

Substituting in the known quantities into the first equation gives

$$6.941 \text{ amu} = \left(\frac{7.50}{100}\right)(6.015121 \text{ amu}) + \left(\frac{92.50}{100}\right)(\text{isotopic mass } {}^x\text{Li})$$

$$6.941 \text{ amu} = (0.451_{13} \text{ amu}) + (0.9250)(\text{isotopic mass } {}^x\text{Li})$$

$$6.489_{87} \text{ amu} = (0.9250)(\text{isotopic mass } {}^x\text{Li})$$

$$\text{isotopic mass } {}^x\text{Li} = 7.016 \text{ amu}$$

The other isotope is present in 92.50% natural abundance and has an isotopic mass of 7.016 amu. *The unknown isotope is ${}^7\text{Li}$.*

4. Fill in the table.

Formula	Name
$\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$	iron(III) nitrate nonahydrate
NaClO	sodium hypochlorite
KHCO_3	sodium hydrogencarbonate (sodium bicarbonate)
LiH_2PO_4	lithium dihydrogenphosphate
KHSO_4	potassium hydrogensulfate
N_2O_4	dinitrogen tetroxide
$(\text{NH}_4)_2\text{Cr}_2\text{O}_7$	ammonium dichromate
CBr_4	carbon tetrabromide
$\text{Ca}_3(\text{PO}_4)_2$	calcium phosphate
PCl_5	phosphorous pentachloride
HgF_2	mercury(II) fluoride
$\text{AuCl}_3 \cdot 3\text{H}_2\text{O}$	gold(III) chloride trihydrate

Cd₃(PO₄)₂	cadmium phosphate
CS₂	carbon disulfide
CaHPO₄	calcium hydrogenphosphate
Hg₂I₂	mercury(I) iodide
TiO₂	titanium(IV) oxide
SiCl₄	silicon tetrachloride
AgNO₃	silver nitrate
CuSO₄·9H₂O	copper(II) sulfate pentahydrate
MgSO₄	anhydrous magnesium sulfate
Ca(NO₃)₂	calcium nitrate
Pb(C₂H₃O₂)₂·3H₂O	lead(II) acetate trihydrate
SF₄	sulfur tetrafluoride

5a. Magnesium has three naturally occurring isotopes: ²⁴Mg (isotopic mass 23.985042 amu, natural abundance 78.99%), ²⁵Mg (isotopic mass 24.98537 amu, 10.00% natural abundance), and one other isotope. Determine the isotopic mass and natural abundance of the other isotope.

Definition of an atomic weight.

$$\text{atomic weight} = \left(\frac{\%abundance^{24}\text{Mg}}{100} \right) (\text{isotopic mass}^{24}\text{Mg}) + \left(\frac{\%abundance^{25}\text{Mg}}{100} \right) (\text{isotopic mass}^{25}\text{Mg}) + \left(\frac{\%abundance^x\text{Mg}}{100} \right) (\text{isotopic mass}^x\text{Mg})$$

The percent abundances of the three isotopes must to sum to 100.00%.

$$100.00 = \%abundance^{24}\text{Mg} + \%abundance^{25}\text{Mg} + \%abundance^x\text{Mg}$$

$$100.00 = 78.99 + 10.00 + \%abundance^x\text{Mg}$$

$$\%abundance^x\text{Mg} = 11.01$$

Substitute atomic weight from the periodic table, and the known quantities into the first equation.

$$24.305 \text{ amu} = \left(\frac{78.99}{100}\right)(23.985042 \text{ amu}) + \left(\frac{10.00}{100}\right)(24.98537 \text{ amu}) + \left(\frac{11.01}{100}\right)(\text{isotopic mass } ^x\text{Mg})$$

$$24.305 \text{ amu} = (0.7899)(23.985042 \text{ amu}) + (0.1000)(24.98537 \text{ amu}) + (0.1101)(\text{isotopic mass } ^x\text{Mg})$$

$$24.305 \text{ amu} = (18.94_{58} \text{ amu}) + (2.498_{537} \text{ amu}) + (0.1101)(\text{isotopic mass } ^x\text{Mg})$$

$$\text{isotopic mass } ^x\text{Mg} = \frac{24.305 \text{ amu} - 18.94_{58} \text{ amu} - 2.498_{537} \text{ amu}}{0.1101}$$

$$\text{isotopic mass } ^x\text{Mg} = 26.0 \text{ amu}$$

The other isotope is present in 11.01% natural abundance and has an isotopic mass of 26.0 amu.

b. Write the elemental symbol for the missing isotope in part a.

The elemental symbol of the missing isotope is ^{26}Mg .

c. A sample of magnesium is prepared that contains only ^{24}Mg . This is then reacted with fluorine to give $^{24}\text{MgF}_2$. Fluorine has only one isotope (^{19}F) with an isotopic mass of 18.9984 amu. What is the molar mass of the $^{24}\text{MgF}_2$ sample?

Element	Atomic Mass (g/mole)	Total (g/mole)
^{24}Mg	23.985042	23.985042
2 F	2 x 18.9984	37.9968
	Molar Mass	61.9818

The molar mass of the enriched $^{24}\text{MgF}_2$ is 61.9818 g/mole.

d. If you have 1.25 mole Mg, how many atoms of ^{25}Mg do you have?

$$1.25 \text{ mole Mg} \left(\frac{6.0221367 \times 10^{23} \text{ atoms Mg}}{1 \text{ mole Mg}} \right) \left(\frac{10.00 \text{ atoms } ^{25}\text{Mg}}{100.00 \text{ atoms Mg}} \right) = 7.53 \times 10^{22} \text{ atoms } ^{25}\text{Mg}$$

In 1.25 mole Mg there are 7.53×10^{22} atoms ^{25}Mg .

6a. Chlorine has only two naturally-occurring isotopes. If one has an atomic mass of 34.96885 amu and is present at 75.77% natural abundance, what is the atomic mass and natural abundance of the other isotope? You are given the atomic weight of chlorine is 35.453 amu.

Since one of the two isotopes has a 75.77% natural abundance, the other must be present at 24.23% natural abundance.

The atomic weight is then given by the following equation, where x is the atomic mass of the unknown isotope.

$$35.453 \text{ amu} = \left(\frac{75.77}{100.00}\right)(34.96885 \text{ amu}) + \left(\frac{24.23}{100.00}\right)(x)$$

$$35.453 \text{ amu} = (0.7577)(34.96885 \text{ amu}) + (0.2423)(x)$$

$$35.453 \text{ amu} = (26.49_{5898} \text{ amu}) + (0.2423)(x)$$

$$35.453 \text{ amu} - 26.49_{5898} \text{ amu} = (0.2423)(x)$$

$$8.95_{7102} \text{ amu} = (0.2423)(x)$$

$$x = 37.0 \text{ amu}$$

The other isotope of chlorine has an atomic mass of 37.0 amu and is present at 24.23% natural abundance.

b. Give the symbols for each of the two isotopes of chlorine. ^{35}Cl , ^{37}Cl

7a. Use a periodic table to fill in the following.

The group number of the halogens is **17 (or 7A)**.

The group number of the alkaline earth elements is **2 (or 2A)**.

The period number to which the lanthanide elements belong is **6**.

The elements **B, Si, As, Te (Ge, Sb)** are metalloids. *At is also acceptable, although its chemical properties are not well defined.*

Name two transition metals **many possible answers from groups 3 - 12**.

Identify two noble gases **He, Ne, Ar, Kr, Xe, Rn**

Identify two non-metals **C, N, O, P, S, Se, any halogen, or any noble gas**

b. List the “magnificent seven” elements. Explain why they are unique among the elements.

The magnificent seven are hydrogen (H₂), nitrogen (N₂), oxygen (O₂), fluorine (F₂), chlorine (Cl₂), bromine (Br₂) and iodine (I₂).

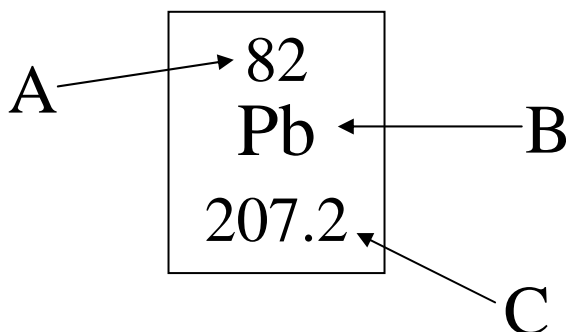
They are unique among the elements in that they exist as diatomic molecules in their elemental state (or form).

c. Explain why the “noble gases” are noble.

The noble gases do not readily form compounds.

d. Elemental phosphorous (P) exists in four different forms in the solid state. These different forms of the element are examples of **allotropes**.

e. Identify the parts of this periodic table entry.



A. **atomic number**

B. **element's symbol**

C. **atomic weight**

f. Give the definition of a compound.

A compound is a pure substance composed of two or more elements united in a fixed ratio. Because a compound is a pure substance it has definite physical and chemical properties.

g. Name the two families of compounds we have discussed in class. What properties (physical and chemical) distinguish the two?

The two families of compounds are molecular and ionic. Ionic compounds consist of cations and anions in infinite lattices, while molecular compounds are comprised of independent, neutral groupings of atoms called molecules. Molecular compounds may exist in any state of matter, while ionic compounds are most often found as solids. During a physical change (e. g. boiling, melting, etc.) the groupings of atoms in a molecular compound remain together, while in ionic compounds the interactions between the cations and anions are disturbed. The chemical (molecular) formula of a molecular compound describes the composition of the whole compound and its constituent molecules. The chemical formula of an ionic

compound only describes the simplest combination of cations and anions that give an overall neutral charge, and which is not related to the actual structure.

8a. Thallium has two isotopes, ^{203}Tl and ^{205}Tl . The atomic weight of Tl is 204.3833 amu, and the isotopic masses are 202.9723 amu and 204.9745 amu for ^{203}Tl and ^{205}Tl , respectively. What are the natural abundances of the two isotopes?

Let x = % abundance of ^{203}Tl and y = % abundance ^{205}Tl , so $x + y = 100$ and $y = 100 - x$. Then by the definition of the atomic weight

$$\text{atomic weight Tl} = \left(\frac{x}{100}\right)(\text{atomic mass } ^{203}\text{Tl}) + \left(\frac{y}{100}\right)(\text{atomic mass } ^{205}\text{Tl})$$

$$204.3833 \text{ amu} = \left(\frac{x}{100}\right)(202.9723 \text{ amu}) + \left(\frac{100-x}{100}\right)(204.9745 \text{ amu})$$

$$20438.33 \text{ amu} = (x)(202.9723 \text{ amu}) + (100-x)(204.9745 \text{ amu})$$

$$20438.33 \text{ amu} = 202.9723 x \text{ amu} + 20497.45 \text{ amu} - 204.9745 x \text{ amu}$$

$$-59.12 \text{ amu} = -2.0022 x \text{ amu}$$

$$x = 29.53\%$$

Then by difference we get $y = 70.47\%$.

The natural abundance of ^{203}Tl is 29.53% and the natural abundance of ^{205}Tl is 70.47%.

b. If a sample of Tl is enriched in ^{203}Tl , will the apparent atomic weight of the sample be greater than, less than, or the same as the atomic weight of Tl found on the periodic table? Why?

The apparent atomic weight of the sample will be a weighted average of the isotopes present. When a sample is enriched its % abundance in the sample is higher than its natural abundance, and therefore its weight in the expression for the atomic weight is higher. If a sample is enriched in ^{203}Tl , the sample's apparent atomic weight will be closer to that of ^{203}Tl , because its % abundance is higher, and its weighting will be higher. Therefore, the apparent atomic weight of the sample will be less than that shown in periodic table.