

Common Ions and Their Charges

A mastery of the common ions, their formulas and their charges, is essential to success in AP Chemistry. You are expected to know all of these ions on the first day of class, when I will give you a quiz on them. You will always be allowed a periodic table, which makes indentifying the ions on the left "automatic." For tips on learning these ions, see the opposite side of this page.

From the table:	
Cations	Name
H ⁺	Hydrogen
Li ⁺	Lithium
Na ⁺	Sodium
K ⁺	Potassium
Rb ⁺	Rubidium
Cs ⁺	Cesium
Be ²⁺	Beryllium
Mg ²⁺	Magnesium
Ca ²⁺	Calcium
Ba ²⁺	Barium
Sr ²⁺	Strontium
Al ³⁺	Aluminum
Anions	Name
H ⁻	Hydride
F ⁻	Fluoride
Cl ⁻	Chloride
Br ⁻	Bromide
I ⁻	Iodide
O ²⁻	Oxide
S ²⁻	Sulfide
Se ²⁻	Selenide
N ³⁻	Nitride
P ³⁻	Phosphide
As ³⁻	Arsenide
Type II Cations	Name
Fe ³⁺	Iron(III)
Fe ²⁺	Iron(II)
Cu ²⁺	Copper(II)
Cu ⁺	Copper(I)
Co ³⁺	Cobalt(III)
Co ²⁺	Cobalt(II)
Sn ⁴⁺	Tin(IV)
Sn ²⁺	Tin(II)
Pb ⁴⁺	Lead(IV)
Pb ²⁺	Lead(II)
Hg ²⁺	Mercury(II)

Ions to Memorize	
Cations	Name
Ag ⁺	Silver
Zn ²⁺	Zinc
Hg ₂ ²⁺	Mercury(I)
NH ₄ ⁺	Ammonium
Anions	Name
NO ₂ ⁻	Nitrite
NO ₃ ⁻	Nitrate
SO ₃ ²⁻	Sulfite
SO ₄ ²⁻	Sulfate
HSO ₄ ⁻	Hydrogen sulfate (bisulfate)
OH ⁻	Hydroxide
CN ⁻	Cyanide
PO ₄ ³⁻	Phosphate
HPO ₄ ²⁻	Hydrogen phosphate
H ₂ PO ₄ ⁻	Dihydrogen phosphate
NCS ⁻	Thiocyanate
CO ₃ ²⁻	Carbonate
HCO ₃ ⁻	Hydrogen carbonate (bicarbonate)
ClO ⁻	Hypochlorite
ClO ₂ ⁻	Chlorite
ClO ₃ ⁻	Chlorate
ClO ₄ ⁻	Perchlorate
BrO ⁻	Hypobromite
BrO ₂ ⁻	Bromite
BrO ₃ ⁻	Bromate
BrO ₄ ⁻	Perbromate
IO ⁻	Hypoiodite
IO ₂ ⁻	iodite
IO ₃ ⁻	iodate
IO ₄ ⁻	Periodate
C ₂ H ₃ O ₂ ⁻	Acetate
MnO ₄ ⁻	Permanganate
Cr ₂ O ₇ ²⁻	Dichromate
CrO ₄ ²⁻	Chromate
O ₂ ²⁻	Peroxide
C ₂ O ₄ ²⁻	Oxalate
NH ₂ ⁻	Amide
BO ₃ ³⁻	Borate
S ₂ O ₃ ²⁻	Thiosulfate

Tips for Learning the Ions

“From the Table”

These ions can be organized into two groups.

1. Their place on the table suggests the charge on the ion, since the neutral atom gains or loses a predictable number of electrons in order to obtain a noble gas configuration. This was a focus in first year chemistry, so if you are unsure what this means, get help BEFORE the start of the year.
 - a. All Group 1 Elements (alkali metals) lose one electron to form an ion with a 1+ charge
 - b. All Group 2 Elements (alkaline earth metals) lose two electrons to form an ion with a 2+ charge
 - c. Group 13 metals like aluminum lose three electrons to form an ion with a 3+ charge
 - d. All Group 17 Elements (halogens) gain one electron to form an ion with a 1- charge
 - e. All Group 16 nonmetals gain two electrons to form an ion with a 2- charge
 - f. All Group 15 nonmetals gain three electrons to form an ion with a 3- charge

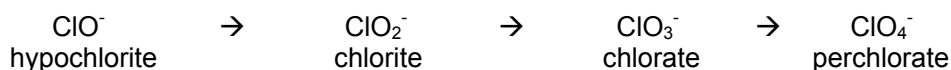
Notice that cations keep their name (sodium ion, calcium ion) while anions get an “-ide” ending (chloride ion, oxide ion).

2. Metals that can form more than one ion will have their positive charge denoted by a roman numeral in parenthesis immediately next to the name of the

Polyatomic Anions

Most of the work on memorization occurs with these ions, but there are a number of patterns that can greatly reduce the amount of memorizing that one must do.

1. “ate” anions have one more oxygen than the “ite” ion, but the same charge. If you memorize the “ate” ions, then you should be able to derive the formula for the “ite” ion and vice-versa.
 - a. sulfate is SO_4^{2-} , so sulfite has the same charge but one less oxygen (SO_3^{2-})
 - b. nitrate is NO_3^- , so nitrite has the same charge but one less oxygen (NO_2^-)
2. If you know that a sulfate ion is SO_4^{2-} then to get the formula for hydrogen sulfate ion, you add a hydrogen ion to the front of the formula. Since a hydrogen ion has a 1+ charge, the net charge on the new ion is less negative by one.
 - a. Example:
$$\begin{array}{ccccccc} \text{PO}_4^{3-} & & \rightarrow & & \text{HPO}_4^{2-} & & \rightarrow & & \text{H}_2\text{PO}_4^- \\ \text{phosphate} & & & & \text{hydrogen phosphate} & & & & \text{dihydrogen phosphate} \end{array}$$
3. Learn the hypochlorite \rightarrow chlorite \rightarrow chlorate \rightarrow perchlorate series, and you also know the series containing iodite/iodate as well as bromite/bromate.
 - a. The relationship between the “ite” and “ate” ion is predictable, as always. Learn one and you know the other.
 - b. The prefix “hypo” means “under” or “too little” (think “hypodermic”, “hypothermic” or “hypoglycemia”)
 - i. Hypochlorite is “under” chlorite, meaning it has one less oxygen
 - c. The prefix “hyper” means “above” or “too much” (think “hyperkinetic”)
 - i. the prefix “per” is derived from “hyper” so perchlorate (hyperchlorate) has one more oxygen than chlorate.
 - d. Notice how this sequence increases in oxygen while retaining the same charge:



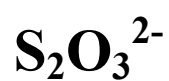
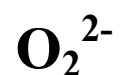
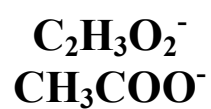
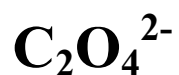
INFORMATION IN THE TABLE BELOW AND IN THE TABLES ON PAGES 3-5 MAY BE USEFUL IN ANSWERING THE QUESTIONS IN THIS SECTION OF THE EXAMINATION.

DO NOT DETACH FROM BOOK.

PERIODIC TABLE OF THE ELEMENTS

1	H 1.008											2	He 4.00																						
3	Li 6.94	4	Be 9.01											9	F 19.00	10	Ne 20.18																		
11	Na 22.99	12	Mg 24.30											17	Cl 35.45	18	Ar 39.95																		
19	K 39.10	20	Ca 40.08	21	Sc 44.96	22	Ti 47.90	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 65.39	31	Ga 69.72	32	Ge 72.59	33	As 74.92	34	Se 78.96	35	Br 79.90	36	Kr 83.80
37	Rb 85.47	38	Sr 87.62	39	Y 88.91	40	Zr 91.22	41	Nb 92.91	42	Mo 95.94	43	Tc (98)	44	Ru 101.1	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 121.75	52	Te 127.60	53	I 126.91	54	Xe 131.29
55	Cs 132.91	56	Ba 137.33	57	*La 138.91	72	Hf 178.49	73	Ta 180.95	74	W 183.85	75	Re 186.21	76	Os 190.2	77	Ir 192.2	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 (209)	85	At (210)	86	Rn (222)
87	Fr (223)	88	Ra 226.02	89	†Ac 227.03	104	Rf (261)	105	Db (262)	106	Sg (266)	107	Bh (264)	108	Hs (277)	109	Mt (268)	110	Ds (271)	111	Rg (272)														
				*Lanthanide Series																															
				†Actinide Series																															
				58	Ce 140.12	59	Pr 140.91	60	Nd 144.24	61	Pm (145)	62	Sm 150.4	63	Eu 151.97	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 173.04	71	Lu 174.97				
				90	Th 232.04	91	Pa 231.04	92	U 238.03	93	Np (237)	94	Pu (244)	95	Am (243)	96	Cm (247)	97	Bk (247)	98	Cf (251)	99	Es (252)	100	Fm (257)	101	Md (258)	102	No (259)	103	Lr (262)				

Sulfite	Sulfate	Hydrogen sulfate
Phosphate	Dihydrogen Phosphate	Hydrogen Phosphate
Nitrite	Nitrate	Ammonium
Thiocyanate	Carbonate	Hydrogen carbonate
Borate	Chromate	Dichromate
Permanganate	Oxalate	Amide
Hydroxide	Cyanide	Acetate
Peroxide	Hypochlorite	Chlorite
Chlorate	Perchlorate	Thiosulfate



Significant Figures in Measurement and Calculations

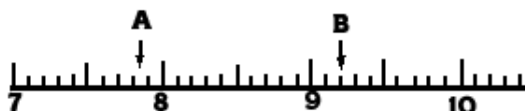
A successful chemistry student habitually labels all numbers, because the unit is important. Also of great importance is the number itself. Any number used in a calculation should contain only figures that are considered reliable; otherwise, time and effort are wasted. Figures that are considered reliable are called *significant figures*. Chemical calculations involve numbers representing actual measurements. In a measurement, significant figures in a number consist of:

Figures (digits) definitely known + One estimated figure (digit)

In class you will hear this expressed as "all of the digits known for certain plus one that is a guess."

Recording Measurements

When one reads an instrument (ruler, thermometer, graduate, buret, barometer, balance), he expresses the reading as one which is reasonably reliable. For example, in the accompanying illustration, note the reading marked A. This reading is definitely beyond the 7 cm mark and also beyond the 0.8 cm mark. We read the 7.8 with certainty. We further *estimate* that the reading is five-tenths the distance from the 7.8 mark to the 7.9 mark. So, we estimate the length as 0.05 cm more than 7.8 cm. All of these have meaning and are therefore significant. We express the reading as 7.85 cm, accurate to three significant figures. All of these figures, *7.85*, can be used in calculations. In reading B we see that 9.2 cm is definitely known. We can include one estimated digit in our reading, and we estimate the next digit to be zero. Our reading is reported as 9.20 cm. It is accurate to three significant figures.



Rules for Zeros

If a zero represents a measured quantity, it is a significant figure. If it merely locates the decimal point, it is not a significant figure.

Zero Within a Number. In reading the measurement 9.04 cm, the zero represents a measured quantity, just as 9 and 4, and is, therefore, a significant number. A zero between any of the other digits in a number is a significant figure.

Zero at the Front of a Number. In reading the measurement 0.46 cm, the zero does not represent a measured quantity, but merely locates the decimal point. It is not a significant figure. Also, in the measurement 0.07 kg, the zeros are used merely to locate the decimal point and are, therefore, not significant. Zeros at the first (left) of a number are not significant figures.

Zero at the End of a Number. In reading the measurement 11.30 cm, the zero is an estimate and represents a measured quantity. It is therefore significant. Another way to look at this: The zero is not needed as a placeholder, and yet it was included by the person recording the measurement. It must have been recorded as a part of the measurement, making it significant. Zeros to the right of the decimal point, and at the end of the number, are significant figures.

Zeros at the End of a Whole Number. Zeros at the end of a whole number may or may not be significant. If a distance is reported as 1600 feet, one assumes two sig figs. Reporting measurements in scientific notation removes all doubt, since all numbers written in scientific notation are considered significant.

1 600 feet	1.6×10^3 feet	Two significant figures
1 600 feet	1.60×10^3 feet	Three significant figures
1 600 feet	1.600×10^3 feet	Four significant figures

Sample Problem #1: Underline the significant figures in the following numbers.

- | | | | |
|---------------|----------------------------|--------------------------|--------------------------------------|
| (a) 0.0420 cm | answer = 0.04 <u>20</u> cm | (e) 2 403 ft. | answer = <u>2 403</u> ft. |
| (b) 5.320 in. | answer = <u>5.320</u> in. | (f) 80.5300 m | answer = <u>80.5300</u> m |
| (c) 10 lb. | answer = <u>10</u> lb. | (g) 200. g | answer = <u>200</u> g |
| (d) 0.020 ml | answer = 0.0 <u>20</u> ml | (h) 2.4×10^3 kg | answer = <u>2.4</u> $\times 10^3$ kg |

Rounding Off Numbers

In reporting a numerical answer, one needs to know how to "round off" a number to include the correct number of significant figures. Even in a series of operations leading to the final answer, one must "round off" numbers. The rules are well accepted rules:

1. If the figure to be dropped is less than 5, simply eliminate it.
2. If the figure to be dropped is greater than 5, eliminate it and raise the preceding figure by 1.
3. If the figure is 5, followed by nonzero digits, raise the preceding figure by 1
4. If the figure is 5, not followed by nonzero digit(s), and preceded by an odd digit, raise the preceding digit by one
5. If the figure is 5, not followed by nonzero digit(s), and the preceding significant digit is even, the preceding digit remains unchanged

Sample Problem #2: Round off the following to three significant figures.

- (a) 3.478 m answer = 3.48 m (c) 5.333 g answer = 5.33 g
(b) 4.8055 cm answer = 4.81 cm (d) 7.999 in. answer = 8.00 in.

Multiplication

In multiplying two numbers, when you wish to determine the number of significant figures you should have in your answer (the product), you should inspect the numbers multiplied and find which has the least number of significant figures. This is the number of significant figures you should have in your answer (the product). Thus the answer to 0.024×1244 would be rounded off to contain two significant figures since the factor with the lesser number of significant figures (0.024) has only *two* such figures.

Sample Problem #3: Find the area of a rectangle 2.1 cm by 3.24 cm.

Solution: Area = $2.1 \text{ cm} \times 3.24 \text{ cm} = 6.804 \text{ cm}^2$

We note that 2.1 contains two significant figures, while 3.24 contains three significant figures. Our product should contain no more than *two* significant figures. Therefore, our answer would be recorded as 6.8 cm^2

Sample Problem #4: Find the volume of a rectangular solid 10.2 cm x 8.24 cm x 1.8 cm

Solution: Volume = $10.2 \text{ cm} \times 8.24 \text{ cm} \times 1.8 \text{ cm} = 151.2864 \text{ cm}^3$

We observe that the factor having the least number of significant figures is 1.8 cm. It contains two significant figures. Therefore, the answer is rounded off to 150 cm^3 .

Division

In dividing two numbers, the answer (quotient) should contain the same number of significant figures as are contained in the number (divisor or dividend) with the least number of significant figures. Thus the answer to $528 \div 0.14$ would be rounded off to contain *two* significant figures. The answer to $0.340 \div 3242$ would be rounded off to contain three significant figures.

Sample Problem #5: Calculate $20.45 \div 2.4$

Solution: $20.45 \div 2.4 = 8.52083$

We note that the 2.4 has fewer significant figures than the 20.45. It has only *two* significant figures. Therefore, our answer should have no more than two significant figures and should be reported as 8.5.

Addition and Subtraction

In adding (or subtracting), set down the numbers, being sure to keep like decimal places under each other, and add (or subtract). Next, note which column contains the first estimated figure. This column determines the last decimal place of the answer. After the answer is obtained, it should be rounded off in this column. In other words, round to the least number of decimal places in your data.

Sample Problem #6: Add $42.56 \text{ g} + 39.460 \text{ g} + 4.1 \text{ g}$

Solution:

	42.56 g
	39.460 g
	4.1 g
Sum =	86.120 g

Since the number 4.1 only extends to the first decimal place, the answer must be rounded to the first decimal place, yielding the answer 86.1 g.

Average Readings

The average of a number of successive readings will have the same number of decimal places that are in their sum.

Sample Problem #7: A graduated cylinder was weighed three times and the recorded weighings were 12.523 g, 12.497 g, 12.515 g. Calculate the average weight.

Solution:

	12.523 g
	12.497 g
	<u>12.515 g</u>
	37.535 g

In order to find the average, the sum is divided by 3 to give an answer of 12.51167. Since each number extends to three decimal places, the final answer is rounded to three decimal places, yielding a final answer of 12.512 g. Notice that the divisor of 3 does not effect the rounding of the final answer. This is because 3 is an exact number - known to an infinite number of decimal places.

Name _____

Give the number of significant figures in each of the following:

_____ 402 m	_____ 34.20 lbs	_____ 0.03 sec
_____ 0.00420 g	_____ 3 200 liters	_____ 0.0300 ft.
_____ 5.1×10^4 kg	_____ 0.48 m	_____ 1 400.0 m
_____ 78 323.01 g	_____ 1.10 torr	_____ 760 mm Hg

Multiply each of the following, observing significant figure rules:

17 m x 324 m = _____	1.7 mm x 4 294 mm = _____
0.005 in x 8 888 in = _____	0.050 m x 102 m = _____
0.424 in x .090 in = _____	324 000 cm x 12.00 cm = _____

Divide each of the following, observing significant figure rules:

23.4 m ÷ 0.50 sec = _____	12 miles ÷ 3.20 hours = _____
0.960 g ÷ 1.51 moles = _____	1 200 m ÷ 12.12 sec = _____

Add each of the following, observing significant figure rules:

3.40 m	102.45 g	102. cm
0.022 m	2.44 g	3.14 cm
<u>0.5 m</u>	<u>1.9999 g</u>	<u>5.9 cm</u>

Subtract each of the following, observing significant figure rules:

42.306 m	14.33 g	234.1 cm
<u>1.22 m</u>	<u>3.468 g</u>	<u>62.04 cm</u>

Work each of the following problems, observing significant figure rules:

Three determinations were made of the percentage of oxygen in mercuric oxide. The results were 7.40%, 7.43%, and 7.35%. What was the average percentage?

A rectangular solid measures 13.4 cm x 11.0 cm x 2.2 cm. Calculate the volume of the solid.

If the density of mercury is 13.6 g/ml, what is the mass in grams of 3426 ml of the liquid?

A copper cylinder, 12.0 cm in radius, is 44.0 cm long. If the density of copper is 8.90 g/cm^3 , calculate the mass in grams of the cylinder. (assume $\pi = 3.14$)