1. Print your name here:
2. Print your school name and city on your STUDENT RESPONSE sheet.
3. Select, and enter on the STUDENT RESPONSE sheet, one of the following CODE numbers:

Code 1 Ontario, now studying Grade 11 Chemistry in a nonsemestered school

Code 2 Ontario, now studying Grade 11 Chemistry in a semestered school

Code 3 Ontario, Grade 11 Chemistry already completed

Code 4 Any other Ontario student
Code 5 Manitoba or Saskatchewan high school student

Code 6 Québec high school student
Code 7 not used
Code 8 Alberta or British Columbia high school student
Code 9 New Brunswick, Newfoundland, Nova Scotia, or Prince Edward Island high school student
Code 10 Northwest Territories, Nunavut, or Yukon high school student
Code 11 High school student outside Canada
Code 12 Teacher
4. Print your name (last name, first name and optional middle initial) on the STUDENT RESPONSE sheet. Also fill in the corresponding circles below your printed name.
5. Carefully detach the last page. It is the datasheet.
6. Now answer the exam questions. Questions are not in order of difficulty. Indicate your choice on the STUDENT RESPONSE sheet by marking one letter beside the question number.

- Mark only one answer for each question.
- Questions are all of the same value.
- There is a penalty ( $1 / 4$ off) for each incorrect answer, but no penalty if you do not answer.

7. Take care that you make firm, black pencil marks, just filling the oval.

Be careful that any erasures are complete-make the sheet white again.

## Carefully detach the last page. It is the Data Sheet.

1 Which atom has the most neutrons?

A ${ }_{9}^{18} \mathrm{~F}$
*B ${ }_{8}^{18} \mathrm{O}$

C $\quad{ }_{6}^{14} \mathrm{C}$

D $\quad{ }_{7}^{15} \mathrm{~N}$
E $\quad{ }_{5}^{11} B$

2 Which of the following pairs of atomic symbols and elements is incorrect?

A Fe , iron
B Mg , magnesium
C Ca , calcium
*D Br, boron
E Mn, manganese

3 Which of the following particles is not a charged particle?

A $\alpha$-particle
B $\beta$-particle
C electron
D proton
*E neutron

4 The formula of a compound is $X_{2} \mathrm{O}$. Which of the following is $X$ least likely to be?
*A barium (Ba)
B $\operatorname{sodium}(\mathrm{Na})$
C cesium (Cs)
D hydrogen $(\mathrm{H})$
E copper (Cu)

5 How many protons are there in the nucleus of ${ }_{53}^{127}$ I?

A 7
*B 53
C 74
D 127
E 180

6 Which group of elements has the greatest electron affinity?

A group 14
B group 15
C group 16
*D group 17
E group 18

7 The difference between deuterium, ${ }_{1}^{2} \mathrm{H}$, and the more common form hydrogen is that deuterium

A does not occur naturally.
B is radioactive.
C has one more atom per molecule.
D has one more proton in the nucleus.
*E has one more neutron in the nucleus.

8 Which group of atoms and ions contain the same number of electrons?

A $\mathrm{F}, \mathrm{Ne}, \mathrm{Na}$
B $\mathrm{O}^{2-}, \mathrm{S}^{2-}, \mathrm{Se}^{2-}$
C $\mathrm{Mg}, \mathrm{Al}, \mathrm{Si}$
D $\mathrm{Ca}^{2+}, \mathrm{Fe}^{3+}, \mathrm{Zn}^{2+}$
*E $\mathrm{Cl}^{-}, \mathrm{Ar}, \mathrm{K}^{+}$

9 Which of the following is an ionic solid?
A $\mathrm{N}_{2} \mathrm{O}$
B HCl
*C LiCl
D $\mathrm{CO}_{2}$
E $\mathrm{CH}_{4}$

10 What volume of $\mathrm{CO}_{2}$ is produced when you burn exactly 1.0 litre of gaseous propane $\left(\mathrm{C}_{3} \mathrm{H}_{8}\right)$ in the presence of excess oxygen in your backyard barbecue? Assume $\mathrm{H}_{2} \mathrm{O}$ and $\mathrm{CO}_{2}$ are the only combustion products and that the pressure and temperature remain constant.

A 1.0
B 1.5
C 2.0
D 2.5
*E 3.0

11 Polonium- $210\left({ }^{210} \mathrm{Po}\right)$ is radioactive, extremely toxic, and it decays according to the chemical equation below. What is the missing product in the equation?

$$
{ }^{210} \mathrm{Po} \rightarrow ?+{ }_{2}^{4} \mathrm{He}
$$

A ${ }^{214} \mathrm{Po}$
B ${ }^{212} \mathrm{~T}$

* ${ }^{206} \mathrm{~Pb}$

D ${ }^{214} \mathrm{Rn}$
E ${ }^{210} \mathrm{Po}$

12 The bubbles in boiling water are mostly
A He
*B $\mathrm{H}_{2} \mathrm{O}$
C $\mathrm{CO}_{2}$
D $\mathrm{N}_{2}$
E $\mathrm{O}_{2}$

13 An element, $X$, from group 1 of the periodic table, combines to form a stable compound with an element, Y , from group 16. The formula of that compound is most likely to be

A $X_{3} Y$
B $\mathrm{XY}_{3}$
C XY
*D $X_{2} Y$
E $X Y_{2}$

14 After a large meal the pH of your stomach drops to 1.78. What is $\left[\mathrm{H}^{+}\right]$in your stomach after the meal?
*A $1.66 \times 10^{-2} \mathrm{~mol} \mathrm{~L}^{-1}$
B $0.250 \mathrm{~mol} \mathrm{~L}^{-1}$
C $\quad 1.78 \mathrm{~mol} \mathrm{~L}^{-1}$
D $1.83 \times 10^{-3} \mathrm{~mol} \mathrm{~L}^{-1}$
E $6.03 \times 10^{-2} \mathrm{~mol} \mathrm{~L}^{-1}$

15 The chemical formula of barium perrhenate is $\mathrm{Ba}\left(\mathrm{ReO}_{4}\right)_{2}$. What is the charge on the perrhenate ion?

A +2
B +1
C 0
*D -1
E -2

16 These three compounds have been isolated: NaCl , $\mathrm{Na}_{2} \mathrm{O}$, and $\mathrm{AlCl}_{3}$. What is the formula of aluminum oxide?

A $\mathrm{Al}_{2} \mathrm{O}$
*B $\mathrm{Al}_{2} \mathrm{O}_{3}$
C $\mathrm{Al}_{3} \mathrm{O}$
D AIO
E $\mathrm{AlO}_{3}$

17 The average car in Canada uses 0.93 L of gasoline to go 100 km . If it is assumed that gasoline is pure octane $\left(\mathrm{C}_{8} \mathrm{H}_{18}\right)$, with a density of $0.70 \mathrm{~g} / \mathrm{mL}$ and a molar mass of $114.2 \mathrm{~g} / \mathrm{mol}$, then how many moles of octane are consumed by driving 100 km ?

A 0.93 mol
*B 5.7 mol
C 11 mol
D $5.7 \times 10^{-4} \mathrm{~mol}$
E $1.1 \times 10^{-3} \mathrm{~mol}$

18 How many moles of gas are present in a $15.0-\mathrm{L}$ scuba tank, if the pressure in the tank is 23.0 MPa and the temperature is 298 K ? Assume the gas behaves ideally.

A 23 mol

$$
1 \mathrm{MPa}=1 \times 10^{3} \mathrm{kPa}
$$

B 72 mol
C 44 mol
D $\quad 14.1 \mathrm{~mol}$
*E 139 mol
19 Chlorine has two abundant stable isotopes, ${ }^{35} \mathrm{Cl}$ and ${ }^{37} \mathrm{Cl}$, with atomic masses of 34.97 amu and 36.96 amu respectively. What is the percent abundance of the heavier isotope?

A 78\%
*B 24\%
C $64 \%$
D 50\%
E 36\%

20 Which of the following is not a gas at 298 K ?
A Ar
B He

* ${ }^{*} \mathrm{Br}_{2}$

D $\mathrm{H}_{2}$
E $\mathrm{O}_{2}$

21 Which of the following types of radiation has the highest energy per photon?

A radio waves
B ultraviolet radiation
C infrared radiation
*D x-rays
E purple laser light

22 The Lewis structure (i.e. electron dot) structure for the HCN molecule is given below.

$$
\mathrm{H}-\mathrm{C} \equiv \mathrm{~N}:
$$

The bond angle is nearest to
A $60^{\circ}$
B $90^{\circ}$
C $105^{\circ}$
D $120^{\circ}$
*E $180^{\circ}$

23 What volume of $0.100 \mathrm{~mol} \mathrm{~L}^{-1} \mathrm{NaOH}(a q)$ is required to neutralize 0.245 L of $0.200 \mathrm{~mol} \mathrm{~L}^{-1} \mathrm{H}_{3} \mathrm{PO}_{4}(\mathrm{aq})$ ?

A 0.490 L
B 0.500 L
*C 1.47 L
D 2.30 L
E $\quad 1.47 \mathrm{~mL}$

24 Which of the following molecules forms hydrogen bonds amongst themselves?

A dimethyl ether $\left(\mathrm{CH}_{3} \mathrm{OCH}_{3}\right)$
B methane $\left(\mathrm{CH}_{4}\right)$
C hydrogen sulfide $\left(\mathrm{H}_{2} \mathrm{~S}\right)$
*D ethanol $\left(\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}\right)$
E formaldehyde $\left(\mathrm{H}_{2} \mathrm{CO}\right)$

25 Aluminum dissolves in acidic solution according to the chemical equation below.

$$
2 \mathrm{Al}(s)+6 \mathrm{HCl}(a q) \rightarrow 2 \mathrm{AlCl}_{3}(a q)+3 \mathrm{H}_{2}(g)
$$

How many grams of aluminum ( $27 \mathrm{~g} \mathrm{~mol}^{-1}$ ) are required to produce $0.50 \mathrm{~mol} \mathrm{H}_{2}$ ?

A 20 g
*B 9.0 g
C 14 g
D 27 g
E 0.24 g

26 For which of the following reactions is the change in energy equal to the first ionization energy of oxygen?

A $\mathrm{O}^{-}(\mathrm{g})+\mathrm{e}^{-} \rightarrow \mathrm{O}^{2-}(\mathrm{g})$
B $\mathrm{O}(\mathrm{g})+2 \mathrm{e}^{-} \rightarrow \mathrm{O}^{2-}(\mathrm{g})$
${ }^{*} \mathbf{C} \mathrm{O}(g) \rightarrow \mathrm{O}^{+}(g)+\mathrm{e}^{-}$
D $\mathrm{O}(\mathrm{g})+\mathrm{e}^{-} \rightarrow \mathrm{O}^{-}(\mathrm{g})$
E $\mathrm{O}(g) \rightarrow \mathrm{O}^{2+}(g)+2 \mathrm{e}^{-}$

27 How does the pH of a solution change as HCl is added to a solution of NaOH ?
*A The pH decreases and may go below 7 .
B The pH will not change.

C The pH decreases until it reaches a value of 7 and then stops.

D The pH increases until it reaches a value of 7 and then stops.

E The pH increases and may go above 7.

28 The volume of a gas, initially at 1 atm and $20^{\circ} \mathrm{C}$, is increased from 40.0 mL to 80.0 mL . If the pressure remains constant, what is the final temperature of the gas?

A $\quad 293 \mathrm{~K}+\frac{80.0}{40.0}$
B $\quad 20^{\circ} \mathrm{C} \times \frac{80.0}{40.0}$

* $\mathbf{C} \quad 293 \mathrm{~K} \times \frac{80.0}{40.0}$

D $\quad 293 \mathrm{~K} \times \frac{40.0}{80.0}$
E $\quad 20^{\circ} \mathrm{C} \times \frac{40.0}{80.0}$

29 Which drawing shows a pipet correctly filled for delivery?


A 1
*B 2
C 3
D 4
E none of the above

30 What is the mass percentage of copper in $\mathrm{CuCl}_{2}$ ?
A 12.1\%
B 64.2\%
C 91.2\%
D 25.2\%
*E 47.3\%

31 Which one of the following solutions will be the best electrical conductor at $25^{\circ} \mathrm{C}$ ?
*A $0.10 \mathrm{~mol} \mathrm{~L}^{-1} \mathrm{Na}_{2} \mathrm{SO}_{4}(\mathrm{aq})$
B $\quad 0.10 \mathrm{~mol} \mathrm{~L}^{-1} \mathrm{NaCl}(a q)$
C $\quad 0.10 \mathrm{~mol} \mathrm{~L}^{-1} \mathrm{H}_{2} \mathrm{SO}_{4}(a q)$
D $\quad 0.10 \mathrm{~mol} \mathrm{~L}^{-1} \mathrm{HNO}_{3}(\mathrm{aq})$
E $\quad 0.10 \mathrm{~mol} \mathrm{~L}^{-1} \mathrm{CsCl}(a q)$

32 What is the coefficient of $\mathrm{O}_{2}$ when the following equation is balanced with the smallest whole-number coefficients?
$\qquad$ $\mathrm{KOH}+$ $\qquad$ $\mathrm{O}_{2} \rightarrow \ldots \mathrm{~K}_{2} \mathrm{CrO}_{4}+$ $\qquad$ $\mathrm{H}_{2} \mathrm{O}$

A 2
*B 3
C 4
D 5
E 6

33 What is the oxidation state of N in $\mathrm{HNO}_{2}$ ?
A +5
*B +3
C +1
D -1
E -3

34 If the Kelvin temperature of a sample of ideal gas doubles (e.g. from 200 K to 400 K ), then the average kinetic energy of the molecules in the sample

A increases by a factor of $\sqrt{2}$
B decreases by a factor of 2
*C increases by a factor of 2
D increases by a factor of 4
E remains the same

35 The ground state electronic configuration of a certain neutral atom is [Xe] $6 s^{2} 4 f^{14} 5 d^{10} 6 p^{4}$. To which group of the periodic table does this atom belong?

A group 1
B group 3
C group 6
D group 14

This question was NOT marked. The electron configuration was mistakenly given as:
[Xe] $6 s^{2} 5 f^{14} 6 d^{10} 6 p^{4}$
*E group 16

36 How many moles of water are there in 1.80 L of $\mathrm{H}_{2} \mathrm{O}(l)$ at 1.00 atm and 298 K ? The density of water is $1.00 \mathrm{~g} / \mathrm{mL}$ at 1.00 atm and 298 K .

A 1.00 mol
B 0.0736 mol
C 55.6 mol
*D $1.00 \times 10^{2} \mathrm{~mol}$
E 13.6 mol

37 The reaction $2 \mathrm{Al}(s)+6 \mathrm{HCl}(a q) \rightarrow 2 \mathrm{AlCl}_{3}(a q)+3 \mathrm{H}_{2}(g)$ is an example of

A a precipitation reaction
B an acid-base reaction
C a decomposition reaction
*D an oxidation-reduction reaction
E an isomerization reaction

38 If equal volumes of $0.10 \mathrm{~mol} \mathrm{~L}^{-1}$ solutions of NaOH and HCl are mixed, what is the pH of the resulting solution at 298 K ?

A 1
B 13

* 7

D 1.3
E 12.7

39 A calcium chloride solution was prepared by dissolving $11.00 \mathrm{~g} \mathrm{CaCl}_{2}$ in water to make 500 mL of solution. What is the correct way to report the concentration of this solution?
*A $0.2 \mathrm{~mol} \mathrm{~L}^{-1}$

$$
\mathrm{CaCl}_{2}, 110.98 \mathrm{~g} \mathrm{~mol}^{-1}
$$

B $0.1982 \mathrm{~mol} \mathrm{~L}^{-1}$
C $0.198 \mathrm{~mol} \mathrm{~L}^{-1}$
D $0.2000 \mathrm{~mol} \mathrm{~L}^{-1}$
E $0.20 \mathrm{~mol} \mathrm{~L}^{-1}$

The number of significant figures in the volume is ambiguous (i.e. we don't know if the zeros are significant), so we must assume the worst: that the volume is known only to 1 significant figure. Therefore, we report the concentration to 1 significant figure only. If the volume had been recorded as 0.500 L , then we could have given the concentration as $0.198 \mathrm{~mol} \mathrm{~L}^{-1}$.

40 A compound of carbon and hydrogen is found to be 85.6 \% carbon, by mass, and $14.38 \%$ hydrogen. What is the simplest formula of the compound?

A CH
*B $\mathrm{CH}_{2}$
C $\mathrm{CH}_{3}$
D $\mathrm{CH}_{4}$
E $\mathrm{C}_{3} \mathrm{H}_{4}$

## DATA SHEET <br> AVOGADRO EXAM 2007

## DETACH CAREFULLY

| $\begin{gathered} 1 \\ \text { 1A } \end{gathered}$ |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | $\begin{aligned} & 18 \\ & 8 A \end{aligned}$ |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 <br> $\mathbf{H}$ <br> 1.008 <br> 3 | $\begin{gathered} 2 \\ 2 A \\ \hline \end{gathered}$ |  |  |  |  |  |  |  |  |  |  | $\begin{aligned} & 13 \\ & 3 A \end{aligned}$ | $\begin{aligned} & 14 \\ & 4 \mathrm{~A} \\ & \hline \end{aligned}$ | $\begin{aligned} & 15 \\ & 5 \mathrm{~A} \end{aligned}$ | $\begin{aligned} & 16 \\ & 6 A \end{aligned}$ | $\begin{aligned} & 17 \\ & 7 \mathrm{~A} \end{aligned}$ |  |
| $\begin{gathered} 3 \\ \mathrm{Li} \\ 6.941 \end{gathered}$ | $\begin{gathered} 4 \\ \mathrm{Be} \\ 9.012 \end{gathered}$ |  |  |  |  |  |  |  |  |  |  | $\begin{gathered} \hline 5 \\ \mathbf{B} \\ 10.81 \end{gathered}$ | $\begin{gathered} 6 \\ \mathbf{C} \\ 12.01 \end{gathered}$ | $\begin{gathered} 7 \\ \mathbf{N} \\ 14.01 \end{gathered}$ | $\begin{gathered} 8 \\ 0 \\ 16.00 \end{gathered}$ | $\begin{gathered} 9 \\ \mathbf{F} \\ 19.00 \end{gathered}$ | $\begin{gathered} 10 \\ \mathrm{Ne} \\ 20.18 \end{gathered}$ |
| $\begin{gathered} 11 \\ \mathrm{Na} \\ 22.99 \end{gathered}$ | $\begin{gathered} 12 \\ \mathbf{M g} \\ 24.31 \end{gathered}$ | 3 $3 B$ | 4 | $\begin{gathered} 5 \\ 5 B \end{gathered}$ | $\begin{gathered} 6 \\ 6 B \end{gathered}$ | 7 | $\begin{aligned} & 8 \\ & \leftarrow \end{aligned}$ | $\begin{gathered} 9 \\ 8 B \end{gathered}$ | $\xrightarrow{10}$ | $\begin{aligned} & 11 \\ & \text { 1B } \end{aligned}$ | $\begin{aligned} & 12 \\ & 2 B \end{aligned}$ | $\begin{array}{\|c} \hline 13 \\ \text { Al } \\ 26.98 \end{array}$ | $\begin{gathered} 14 \\ \mathrm{Si} \\ 28.09 \end{gathered}$ | $\begin{gathered} 15 \\ \mathbf{P} \\ 30.97 \end{gathered}$ | $\begin{gathered} 16 \\ \mathbf{S} \\ 32.07 \end{gathered}$ | $\begin{gathered} 17 \\ \mathrm{Cl} \\ 35.45 \end{gathered}$ | $\begin{gathered} 18 \\ \mathbf{A r} \\ 39.95 \end{gathered}$ |
| $\begin{array}{\|c\|} \hline 19 \\ \mathbf{K} \\ 39.10 \\ \hline \end{array}$ | $\begin{gathered} 20 \\ \mathrm{Ca} \\ 40.08 \\ \hline \end{gathered}$ | $\begin{gathered} 21 \\ \mathrm{Sc} \\ 44.96 \\ \hline \end{gathered}$ | $\begin{gathered} 22 \\ \mathrm{Ti} \\ 47.88 \\ \hline \end{gathered}$ | $\begin{gathered} 23 \\ \mathbf{V} \\ 50.94 \end{gathered}$ | $\begin{gathered} 24 \\ \mathrm{Cr} \\ 52.00 \\ \hline \end{gathered}$ | $\begin{gathered} 25 \\ \mathrm{Mn} \\ 54.94 \\ \hline \end{gathered}$ | $\begin{gathered} 26 \\ \text { Fe } \\ 55.85 \\ \hline \end{gathered}$ | $\begin{gathered} 27 \\ \text { Co } \\ 58.93 \\ \hline \end{gathered}$ | $\begin{gathered} 28 \\ \mathrm{Ni} \\ 58.69 \\ \hline \end{gathered}$ | $\begin{gathered} 29 \\ \mathrm{Cu} \\ 63.55 \\ \hline \end{gathered}$ | $\begin{gathered} 30 \\ \mathbf{Z n} \\ 65.38 \\ \hline \end{gathered}$ | $\begin{array}{\|c} \hline 31 \\ \mathbf{G a} \\ 69.72 \\ \hline \end{array}$ | $\begin{gathered} 32 \\ \text { Ge } \\ 72.59 \\ \hline \end{gathered}$ | $\begin{gathered} 33 \\ \text { As } \\ 74.92 \\ \hline \end{gathered}$ | 34 Se 78.96 | $\begin{gathered} 35 \\ \mathrm{Br} \\ 79.90 \\ \hline \end{gathered}$ | $\begin{gathered} 36 \\ \mathbf{K r} \\ 83.80 \\ \hline \end{gathered}$ |
| $\begin{gathered} 37 \\ \mathbf{R b} \\ 85.47 \end{gathered}$ | $\begin{gathered} 38 \\ \mathrm{Sr} \\ 87.62 \end{gathered}$ | $\begin{gathered} 39 \\ \mathbf{Y} \\ 88.91 \end{gathered}$ | $\begin{gathered} 40 \\ \mathbf{Z r} \\ 91.22 \end{gathered}$ | $\begin{gathered} 41 \\ \mathrm{Nb} \\ 92.91 \end{gathered}$ | $\begin{gathered} 42 \\ \text { Mo } \\ 95.94 \end{gathered}$ | 43 <br> Tc <br> (98) | $\begin{array}{c\|} \hline 44 \\ \mathbf{R u} \\ 101.1 \\ \hline \end{array}$ | $\begin{gathered} 45 \\ \text { Rh } \\ 102.9 \end{gathered}$ | $\begin{gathered} 46 \\ \text { Pd } \\ 106.4 \\ \hline \end{gathered}$ | $\begin{gathered} 47 \\ \mathbf{A g} \\ 107.9 \end{gathered}$ | $\begin{gathered} 48 \\ \text { Cd } \\ 112.4 \\ \hline \end{gathered}$ | $\begin{array}{\|c\|} \hline 49 \\ \text { In } \\ 114.8 \end{array}$ | $\begin{gathered} 50 \\ \text { Sn } \\ 118.7 \end{gathered}$ | $\begin{gathered} 51 \\ \text { Sb } \\ 121.8 \\ \hline \end{gathered}$ | $\begin{gathered} 52 \\ \mathrm{Te} \\ 127.6 \end{gathered}$ | $\begin{gathered} 53 \\ \text { I } \\ 126.9 \end{gathered}$ | $\begin{gathered} 54 \\ \text { Xe } \\ 131.3 \end{gathered}$ |
| $\begin{array}{c\|} \hline 55 \\ \text { Cs } \\ 132.9 \\ \hline \end{array}$ | $\begin{gathered} \hline 56 \\ \text { Ba } \\ 137.3 \\ \hline \end{gathered}$ | $\begin{array}{\|c\|} \hline 57 \\ \text { La } \\ 138.9 \\ \hline \end{array}$ | $\begin{array}{\|c\|} \hline 72 \\ \mathbf{H f} \\ 178.5 \\ \hline \end{array}$ | $\begin{gathered} 73 \\ \text { Ta } \\ 180.9 \\ \hline \end{gathered}$ | $\begin{gathered} 74 \\ \text { W } \\ 183.9 \\ \hline \end{gathered}$ | $\begin{gathered} 75 \\ \text { Re } \\ 186.2 \end{gathered}$ | $\begin{gathered} \hline 76 \\ \text { Os } \\ 190.2 \\ \hline \end{gathered}$ | $\begin{gathered} 77 \\ \mathbf{I r} \\ 192.2 \\ \hline \end{gathered}$ | $\begin{gathered} \hline 78 \\ \text { Pt } \\ 195.1 \\ \hline \end{gathered}$ | $\begin{gathered} \hline 79 \\ \mathrm{Au} \\ 197.0 \\ \hline \end{gathered}$ | $\begin{gathered} 80 \\ \mathrm{Hg} \\ 200.6 \end{gathered}$ | $\begin{array}{\|c\|} \hline 81 \\ \mathrm{TI} \\ 204.4 \\ \hline \end{array}$ | $\begin{gathered} \hline 82 \\ \text { Pb } \\ 207.2 \\ \hline \end{gathered}$ | $\begin{gathered} 83 \\ \mathbf{B i} \\ 209.0 \\ \hline \end{gathered}$ | $\begin{gathered} 84 \\ \text { Po } \\ (209) \\ \hline \end{gathered}$ | $\begin{gathered} 85 \\ \text { At } \\ (210) \\ \hline \end{gathered}$ | $\begin{gathered} 86 \\ \mathbf{R n} \\ (222) \\ \hline \end{gathered}$ |
| $\begin{gathered} 87 \\ \text { Fr } \\ (223) \\ \hline \end{gathered}$ | $\begin{gathered} 88 \\ \text { Ra } \\ 226 \\ \hline \end{gathered}$ | $\begin{array}{\|c\|} \hline 89 \\ \text { Ac } \\ 227.0 \\ \hline \end{array}$ | $\begin{gathered} 104 \\ \mathbf{R f} \end{gathered}$ | 105 | 106 Sg | $\begin{aligned} & 107 \\ & \text { Bh } \end{aligned}$ | 108 Hs | $\begin{aligned} & 109 \\ & \text { Mt } \end{aligned}$ | $110$ Uun | $111$ <br> Uuu | 112 Uub | $\begin{aligned} & 113 \\ & \text { Uut } \end{aligned}$ |  |  |  |  |  |


| 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Ce | Pr | Nd | Pm | Sm | Eu | Gd | Tb | Dy | Ho | Er | Tm | Yb | u |
| 140.1 | 140.9 | 144.2 | (145) | 150.4 | 152.00 | 157.3 | 158.9 | 162.5 | 164.9 | 167.3 | 168.9 | 173.0 | 175.0 |
| 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 |
| Th | Pa | U | Np | Pu | Am | Cm | Bk | Cf | Es | Fm | Md | No | Lr |
| 232.0 | 231.0 | 238.0 | 237.0 | (244) | (243) | (247) | (247) | (251) | (252) | (257) | (258) | (259) | (260) |

## Constants:

$$
\begin{aligned}
N_{\mathrm{A}} & =6.022 \times 10^{23} \mathrm{~mol}^{-1} \\
R & =0.082058 \mathrm{~atm} \mathrm{~L} \mathrm{~K}^{-1} \mathrm{~mol}^{-1} \\
& =8.3145 \mathrm{kPa} \mathrm{~L} \mathrm{~K}^{-1} \mathrm{~mol}^{-1} \\
& =8.3145 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~mol}^{-1} \\
K_{\mathrm{w}} & =1.0 \times 10^{-14}(\text { at } 298 \mathrm{~K}) \\
F & =96485 \mathrm{C} \mathrm{~mol}^{-1}
\end{aligned}
$$

Equations:

$$
P V=n R T \quad k t_{1 / 2}=0.693
$$

## Conversion factors:

$1 \mathrm{~atm}=101.325 \mathrm{kPa}=760$ torr $=760 \mathrm{~mm} \mathrm{Hg}$
$0^{\circ} \mathrm{C}=273.15 \mathrm{~K}$

$$
\mathrm{pH}=\mathrm{pK}_{\mathrm{a}}+\log ([\text { base }] /[\text { acid }]) \quad x=\frac{-b \pm \sqrt{b^{2}-4 \mathrm{ac}}}{2 \mathrm{a}}
$$

