Practice Questions
Placement Exam for Entry into Chemistry 120

### Periodic Table of the Elements

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>18</th>
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</thead>
<tbody>
<tr>
<td><strong>1</strong></td>
<td><strong>H</strong></td>
<td><strong>He</strong></td>
<td><strong>3</strong></td>
<td><strong>Li</strong></td>
<td><strong>Be</strong></td>
<td><strong>B</strong></td>
<td><strong>C</strong></td>
<td><strong>N</strong></td>
<td><strong>O</strong></td>
<td><strong>F</strong></td>
<td><strong>Ne</strong></td>
<td><strong>11</strong></td>
<td><strong>Na</strong></td>
<td><strong>Mg</strong></td>
<td><strong>Al</strong></td>
<td><strong>Si</strong></td>
<td><strong>P</strong></td>
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<td><strong>19</strong></td>
<td><strong>K</strong></td>
<td><strong>Ca</strong></td>
<td><strong>Sc</strong></td>
<td><strong>Ti</strong></td>
<td><strong>V</strong></td>
<td><strong>Cr</strong></td>
<td><strong>Mn</strong></td>
<td><strong>Fe</strong></td>
<td><strong>Co</strong></td>
<td><strong>Ni</strong></td>
<td><strong>Cu</strong></td>
<td><strong>Zn</strong></td>
<td><strong>Ga</strong></td>
<td><strong>Ge</strong></td>
<td><strong>As</strong></td>
<td><strong>Se</strong></td>
<td><strong>Br</strong></td>
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<tr>
<td><strong>37</strong></td>
<td><strong>Rb</strong></td>
<td><strong>Sr</strong></td>
<td><strong>Y</strong></td>
<td><strong>Zr</strong></td>
<td><strong>Nb</strong></td>
<td><strong>Mo</strong></td>
<td><strong>Tc</strong></td>
<td><strong>Ru</strong></td>
<td><strong>Rh</strong></td>
<td><strong>Pd</strong></td>
<td><strong>Ag</strong></td>
<td><strong>Cd</strong></td>
<td><strong>In</strong></td>
<td><strong>Sn</strong></td>
<td><strong>Sb</strong></td>
<td><strong>Te</strong></td>
<td><strong>I</strong></td>
</tr>
<tr>
<td><strong>55</strong></td>
<td><strong>Cs</strong></td>
<td><strong>Ba</strong></td>
<td><strong>La</strong></td>
<td><strong>Hf</strong></td>
<td><strong>Ta</strong></td>
<td><strong>W</strong></td>
<td><strong>Re</strong></td>
<td><strong>Os</strong></td>
<td><strong>Ir</strong></td>
<td><strong>Pt</strong></td>
<td><strong>Au</strong></td>
<td><strong>Hg</strong></td>
<td><strong>Tl</strong></td>
<td><strong>Pb</strong></td>
<td><strong>Bi</strong></td>
<td><strong>Po</strong></td>
<td><strong>At</strong></td>
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<tr>
<td><strong>87</strong></td>
<td><strong>Fr</strong></td>
<td><strong>Ra</strong></td>
<td><strong>Ac</strong></td>
<td><strong>Rf</strong></td>
<td><strong>Db</strong></td>
<td><strong>Sg</strong></td>
<td><strong>Bh</strong></td>
<td><strong>Hs</strong></td>
<td><strong>Mt</strong></td>
<td><strong>Ds</strong></td>
<td><strong>Rg</strong></td>
<td><strong>Cn</strong></td>
<td><strong>Nh</strong></td>
<td><strong>Fl</strong></td>
<td><strong>Mc</strong></td>
<td><strong>Lv</strong></td>
<td><strong>Ts</strong></td>
</tr>
</tbody>
</table>

*Lanthanides

~Actinides

| 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|
| **58** | **Ce** | **Pr** | **Nd** | **Pm** | **Sm** | **Eu** | **Gd** | ** Tb** | **Dy** | **Ho** | **Er** | ** Tm** | **Yb** | **Lu** | **90** | **Th** |
| **91** | **Pa** | **U** | ** Np** | **Pu** | **Am** | **Cm** | **Bk** | **Cf** | **Es** | **Fm** | **Md** | **No** | **Lr** | **232.0** | **238** | **237** | **244** | **243** | **247** | **251** | **257** | **258** | **259** | **262** |
Potentially Useful Information

Avogadro's number = 6.0221420×10^{23}

h = 6.6260688×10^{-34} \text{ Js}

c = 2.9979246×10^8 \text{ m/s}

1\text{amu} = 1.6605387×10^{-27} \text{ kg}

1\text{MeV} = 1.60217646×10^{-13} \text{ J}

1\text{Å} = 10^{-10} \text{ m}

\begin{align*}
c &= \lambda \nu \\
E &= h\nu \\
E &= mc^2 \\
\lambda &= \frac{h}{p} = \frac{h}{mv} \\
(\Delta x)(\Delta p) &\geq \frac{h}{4\pi} \\
\frac{1}{2}mv^2 &= h\nu - \phi \\
E_n &= -2.179\times10^{-18} \text{ J} \\
\Delta E &= q + w \\
w &= -p\Delta V \\
H &= E + PV \\
q &= \Delta H \\
q &= mc(\Delta T) \\
q &= C(\Delta T) \\
K_p &= K_c \left( \frac{c^o RT}{P^o} \right)^{\Delta n} \\
\Delta S_{\text{surr}} &= -\frac{\Delta H_{\text{sys}}}{T} \\
G &= H - TS \\
\Delta G &= \Delta H - T\Delta S \\
G &= G^o + RT\ln P \\
\Delta G &= \Delta G^o + RT\ln Q \\
\Delta G^o &= -RT\ln K \\
\ln K &= -\frac{\Delta H^o}{RT} + \frac{\Delta S^o}{R} \\
K &= 273.15 + ^o\text{C} \\
R &= 8.314 \text{ J mol}^{-1}\text{K}^{-1} \\
&= 0.0821 \text{ liter atm mol}^{-1}\text{K}^{-1} \\
&= 1.987 \text{ cal mol}^{-1}\text{K}^{-1} \\
1 \text{ atm} &= 760 \text{ Torr} \\
PV &= nRT \\
\text{Rate} &= k \left( \frac{[A]^y[B]^v}{[A]_0} \right) \\
\frac{1}{[A]} &= \frac{1}{[A]_0} = kt \\
\ln[A] &= -kt + \ln[A]_0 \\
[A] &= -kt + [A]_0 \\
t_{1/2} &= \frac{1}{k[A]_0} \\
t_{1/2} &= \frac{[A]_0}{2k} \\
t_{1/2} &= \frac{0.693}{k} \\
k &= A e^{\frac{-E_a}{RT}}
\end{align*}
**Question 1**

The production capacity for acrylonitrile (C$_3$H$_3$N) in the United States is over 2 billion pounds per year. Acrylonitrile, the building block for polyacrylonitrile fibers and a variety of plastics, is produced from gaseous propylene (propene), ammonia, and oxygen:

\[
2\text{C}_3\text{H}_6(g) + 2\text{NH}_3(g) + 3\text{O}_2(g) \rightarrow 2\text{C}_3\text{H}_3\text{N}(g) + 6\text{H}_2\text{O}(g)
\]

Assuming the reaction goes to completion, how many moles of acrylonitrile can be produced from a mixture of 5 moles of propylene (propene), 2 moles of ammonia, and 2 moles of oxygen?
Question 2

Succinic acid, an intermediate in the metabolism of food molecules, has a molar mass of 118.1 g. When 1.926 g of succinic acid was dissolved in water and titrated, 65.20 mL of 0.5000 M NaOH solution was required to neutralize the acid. How many acidic hydrogen atoms are there in a molecule of succinic acid?
Question 3

(a) The "stars" inside a firework produce colored flames. Stars that contain barium produce green flames, stars containing sodium produce yellow flames, and stars that contain copper produce blue flames. Why do the different elements produce different colored flames?

(b) The gas in interstellar space consists primarily of hydrogen atoms at such low densities that extremely high quantum states can be attained. In particular, transitions from the $n=110$ to $n=109$ for the hydrogen atom have been detected. Calculate the wavelength of the light emitted when an electron undergoes such a transition.
Question 4

(a) Fill in the energy level diagram (below) for the carbon atom. Use arrows to represent electrons.

(b) Which three rules did you follow in answering question (a)
Question 5

Use Lewis structures and VSEPR to predict the shapes and bond angles of the following chemical species. In addition, specify whether the molecule or ion will possess a dipole moment. Indicate the formal charges, if any, on both Lewis structures. The central atom is underlined in each case.

(i)  \( \underline{\text{CS}_2} \)

(ii)  \( \underline{\text{SeF}_4} \)
Question 6

(a) Why is enthalpy a useful state function?

(b) The bombardier beetle uses an explosive discharge as a defensive measure. The chemical reaction involved is the oxidation of hydroquinone by hydrogen peroxide to produce quinine and water:

$$C_6H_4(OH)_2(aq) + H_2O_2(aq) \rightarrow C_6H_4O_2(aq) + 2H_2O(l)$$

Calculate $\Delta H$ for this reaction from the following data.

- $C_6H_4(OH)_2 \rightarrow C_6H_4O_2 + H_2$, $\Delta H = 177.4$ kJ
- $H_2 + O_2 \rightarrow H_2O_2$, $\Delta H = -191.2$ kJ
- $H_2 + \frac{1}{2}O_2 \rightarrow H_2O(g)$, $\Delta H = -241.8$ kJ
- $H_2O(g) \rightarrow H_2O(l)$, $\Delta H = -43.8$ kJ
Question 7

(a) State Le Chatelier’s principle

(b) A mixture containing 3.9 moles of NO and 0.88 moles of CO₂ was allowed to react in a flask at a certain temperature according to the equation

\[ \text{NO(g)} + \text{CO}_2(\text{g}) \rightleftharpoons \text{NO}_2(\text{g}) + \text{CO(g)} \]

At equilibrium 0.11 mole of CO₂ was present. Calculate the equilibrium constant \( K_c \) for this reaction at this temperature.
Question 8

A student who has but a superficial knowledge of thermodynamics comes to you with the following question:

The equilibrium constant \( K_p \) for the reaction

\[
2 \text{H}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{H}_2\text{O}(\text{g})
\]

is \(5 \times 10^{41}\) at 25 °C. I learned in class that a very large equilibrium constant indicates that the reaction overwhelmingly favors the formation of product. However, despite this fact, I know that a mixture of hydrogen and oxygen gases can be kept at room temperature, 25 °C, without producing any detectable amount of water. I am confused! Please explain.
Question 9

(a) What evidence do we have that not all collisions lead to a chemical reaction.

(b) Biological reactions nearly always occur in the presence of enzymes, which are very powerful catalysts. For example, the enzyme catalase increases the rate constant for the reaction 50 million times! If the uncatalyzed reaction has an activation energy of 72 kJ/mol, what is the activation energy of the catalyzed reaction (both occur at 298K)? You can assume that A remains constant.
QUESTION 10

It has been said that every breath we take, on average, contains tens of millions of molecules exhaled by Wolfgang Amadeus Mozart (1756 – 1791). The following calculations demonstrate the validity of this statement.

(A) Calculate the total number of molecules in the atmosphere. Assume that the mass of the earth’s atmosphere is \(5.25 \times 10^{18}\) kg and the molar mass of air is 29.0 g/mole.

(B) Assuming the volume of every breath (inhale or exhale) is 500 mL, calculate the number of molecules exhaled in each breath at 37 °C, which is the body temperature.

(C) If Mozart’s lifespan was exactly 35 years, what is the number of molecules he exhaled in that period. Assume that the average person breathes 12 times per minute.

(D) Calculate the fraction of the molecules in the earth’s atmosphere that were breathed out by Mozart. How many of Mozart’s molecules do we breathe in with every inhale of air? Round off your answer to one significant figure.

(E) Calculate the partial pressure of Mozart’s exhaled air in your inhaled air

(F) List three important assumptions in these calculations.