CHEMISTRY

Written examination 1

Wednesday 13 June 2007

Reading time: 11.45 am to 12.00 noon (15 minutes)
Writing time: 12.00 noon to 1.30 pm (1 hour 30 minutes)

QUESTION AND ANSWER BOOK

Structure of book

<table>
<thead>
<tr>
<th>Section</th>
<th>Number of questions</th>
<th>Number of questions to be answered</th>
<th>Number of marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td>7</td>
<td>7</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total 73</td>
</tr>
</tbody>
</table>

• Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
• Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied
• Question and answer book of 21 pages, with a detachable data sheet in the centrefold.
• Answer sheet for multiple-choice questions.

Instructions
• Detach the data sheet from the centre of this book during reading time.
• Write your student number in the space provided above on this page.
• Check that your name and student number as printed on your answer sheet for multiple-choice questions are correct, and sign your name in the space provided to verify this.
• All written responses must be in English.

At the end of the examination
• Place the answer sheet for multiple-choice questions inside the front cover of this book.

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SECTION A – Multiple-choice questions

Instructions for Section A
Answer all questions in pencil on the answer sheet provided for multiple-choice questions. Choose the response that is correct or that best answers the question. A correct answer scores 1, an incorrect answer scores 0. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Question 1
Analysis of the components of a mixture using gas-liquid chromatography normally involves measuring the
A. \( R_f \) values of components, using a gas as the mobile phase.
B. \( R_f \) values of components, using a liquid as the mobile phase.
C. retention time of components, using a gas as the mobile phase.
D. retention time of components, using a liquid as the mobile phase.

Question 2
Which one of the following analyses is best performed using atomic absorption spectroscopy?
A. measuring the amount of potassium in salt
B. determining the amount of caffeine in coffee
C. measuring the carbonate content of mineral water
D. detecting the presence of ethanoic acid in a sample of wine

Question 3
Different quantities of nitrogen oxide (NO) are listed below. Which one contains the least number of molecules?
A. \( 6 \times 10^2 \) L at 273 K and 1 atm
B. \( 6 \times 10^{23} \) molecules
C. \( 6 \times 10^2 \) g
D. 6 mol

Question 4
When 2.54 g of solid iodine reacts with excess chlorine and the unreacted chlorine is evaporated, 4.67 g of a yellow product remains. The empirical formula of the product is
A. ICl_2
B. ICl_3
C. ICl_4
D. ICl_5
Question 5
Chromatogram 1 was obtained by analysis of a sample of a mixture of two sugars, A and B, using high-performance liquid chromatography (HPLC). Chromatogram 2 was obtained by analysing another sample of the same mixture by HPLC under different conditions.

Consider the following changes which could be made to the operating conditions for HPLC.
   I  decreasing the pressure of the mobile phase
   II decreasing the temperature
   III  using a less tightly packed column

Which of the changes would be most likely to produce chromatogram 2?
A.  I only
B.  II only
C.  III only
D.  I and II only
Questions 6 and 7 refer to the following information.
Propanone (C₃H₆O) can be made from 2-propanol using a copper-zinc catalyst.

\[ C₃H₈O(g) \rightleftharpoons C₃H₆O(g) + H₂(g); \Delta H = -54 \text{ kJ mol}^{-1} \]

**Question 6**
At equilibrium at a particular temperature, 10% of the 2-propanol is converted to propanone.
In order to increase the percentage yield of propanone at equilibrium, you should
A. lower the temperature and lower the pressure.
B. lower the temperature and raise the pressure.
C. raise the temperature and lower the pressure.
D. raise the temperature and raise the pressure.

**Question 7**
When 2-propanol reacts to form an equilibrium mixture with propanone and hydrogen, which one of the following best represents how the rates of the forward and back reactions change over time?

A. [Graph A]
B. [Graph B]
C. [Graph C]
D. [Graph D]

**Question 8**
A chemical reaction has a \( \Delta H \) of \(-150 \text{ kJ mol}^{-1}\) and the activation energy for its reverse reaction is \( 350 \text{ kJ mol}^{-1}\). The activation energy, in kJ mol\(^{-1}\), of the forward reaction is
A. \(+500\)
B. \(+200\)
C. \(+150\)
D. \(-200\)
Question 9
Which one of the following is least likely to be a product of a redox reaction between sulfuric acid and zinc metal?
A. H₂  
B. H₂S  
C. SO₂  
D. SO₃  

Question 10
Cuts and wounds are often stitched using a biodegradable polymer with the formula
\[
\begin{array}{c}
O \\ \| \\ \| \\ \text{\(-\text{CH}_2\text{C} \text{O} \text{CH} \text{C} \text{O}\)}_n \\
\end{array}
\]
It is made from a condensation polymerisation reaction between lactic acid (HOCH(CH₃)COOH) and glycolic acid.
The formula of glycolic acid is
A. HOCH₂COOH  
B. HOCH₂CH₂OH  
C. HOOCCH₂COOH  
D. HOOCCH₂CH₂OH  

Question 11
Which of the following statements would apply to compounds that belong to the same homologous series?
I. they have similar physical properties  
II. they have similar chemical properties  
III. they contain the same functional group  
IV. they have the same molecular formula but different structures  
A. III only  
B. IV only  
C. II and III only  
D. I, II, III and IV
Questions 12 and 13 refer to the following information.

Ethene can be converted into other carbon-containing compounds using the reagents shown in the following flow chart.

![Flow chart showing reactions: ethene → HBr → compound X → NaOH → compound Y → CH₃CH₂COOH/H⁺ → compound Z.]

**Question 12**
Compounds X, Y and Z are, respectively
A. bromoethane, ethanol, propyl ethanoate.
B. bromoethane, ethanol, ethyl propanoate.
C. bromoethene, ethanoic acid, ethyl propanoate.
D. bromoethene, ethene hydroxide, propyl ethanoate.

**Question 13**
Reactions 1, 2 and 3 can be described as, respectively
A. addition, addition, neutralisation.
B. addition, substitution, condensation.
C. substitution, neutralisation, oxidation.
D. substitution, substitution, condensation.

**Question 14**
Hydrogen iodide is produced by the reaction between hydrogen and iodine.

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

Two experiments were conducted.
**Experiment 1:** quantities of H₂(g) and I₂(g) were placed in a sealed vessel and the reaction allowed to proceed at constant temperature.
**Experiment 2:** experiment 1 was repeated, but at a different temperature.
The graph below shows the amount of hydrogen iodide produced over the course of experiments 1 and 2.

![Graph showing amount of HI produced over time for experiments 1 and 2.]

These results show that experiment 2 was conducted at a
A. lower temperature than experiment 1 and the reaction is endothermic.
B. lower temperature than experiment 1 and the reaction is exothermic.
C. higher temperature than experiment 1 and the reaction is endothermic.
D. higher temperature than experiment 1 and the reaction is exothermic.
Questions 15 and 16 refer to the following information.

One litre of an aqueous solution of potassium hydroxide (KOH) has a pH of 12.0 at 25°C.

**Question 15**
The amount of solid KOH, in mol, that must be added to the solution to **raise** the pH to 13.0 would be
A. $10^{-13}$
B. $10^{-12}$
C. 0.09
D. 0.10

**Question 16**
The amount of pure HCl gas, in mol, that must be added to the solution to **lower** the pH from pH 12.0 to 2.0 would be
A. 10
B. 2.0
C. 0.02
D. 0.01

**Question 17**
Two bottles, I and II, have the same volume and are at the same temperature.
Bottle I contains 10 g of argon gas only.
Bottle II contains 10 g of neon gas only.
Compared to bottle I, the number of atoms and pressure in bottle II would be

<table>
<thead>
<tr>
<th>number of atoms</th>
<th>pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. equal</td>
<td>the same</td>
</tr>
<tr>
<td>B. equal</td>
<td>higher</td>
</tr>
<tr>
<td>C. approximately double</td>
<td>the same</td>
</tr>
<tr>
<td>D. approximately double</td>
<td>higher</td>
</tr>
</tbody>
</table>

**Question 18**
A sodium lamp emits yellow-coloured light. If the light from the lamp was passed through a container of sodium vapour, it is likely that the light emerging from the container would appear
A. brighter, due to electrons in atoms in the sodium vapour moving from higher to lower energy levels.
B. brighter, due to electrons in atoms in the sodium vapour moving from lower to higher energy levels.
C. duller, due to electrons in atoms in the sodium vapour moving from higher to lower energy levels.
D. duller, due to electrons in atoms in the sodium vapour moving from lower to higher energy levels.
**Question 19**

The reaction

\[ A + B \rightarrow C; \ \Delta H \text{ negative} \]

involves a two-step process

\[ A + B \rightarrow X; \ \Delta H \text{ positive} \]
\[ X \rightarrow C; \ \Delta H \text{ negative} \]

Which one of the following diagrams best represents the energy changes during the course of the reaction?

A. ![Diagram A](image)

B. ![Diagram B](image)

C. ![Diagram C](image)

D. ![Diagram D](image)

**Question 20**

The following structure represents the repeating unit of a polymer used in the manufacture of contact lenses.

Which one of the following is a correct statement about the monomers that react to form this polymer?

A. Each monomer contains a double bond between carbon atoms which allows addition polymerisation to take place.

B. Two different monomers react to form the polymer, one with carboxyl groups and the other with hydroxy groups.

C. The total mass of the monomers is greater than the mass of the polymer formed because water is eliminated in the polymerisation reaction.

D. Each monomer contains both a carboxyl and a hydroxy group which allows condensation polymerisation to take place, forming a polyester.

END OF SECTION A
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SECTION B – Short answer questions

Instructions for Section B
Answer all questions in the spaces provided.
To obtain full marks for your responses you should
• give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
• show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
• make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, H₂(g); NaCl(s)

Question 1
Carbon monoxide and hydrogen can be produced from the reaction of methane with steam according to the equation

\[
\text{CH}_4(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{CO}(g) + 3\text{H}_2(g); \quad \Delta H = +206 \text{ kJ mol}^{-1}
\]

Some methane and steam are placed in a closed container and allowed to react at a fixed temperature. The following graph shows the change in concentration of methane and carbon monoxide as the reaction progresses.

<table>
<thead>
<tr>
<th>concentration</th>
<th>time</th>
</tr>
</thead>
<tbody>
<tr>
<td>CH₄(g)</td>
<td></td>
</tr>
<tr>
<td>CO(g)</td>
<td></td>
</tr>
</tbody>
</table>

a.  i. On the graph above, draw a line to show the change in concentration of hydrogen gas as the reaction progresses. **Label this line.**

ii. On the graph above, draw a line to show how the formation of carbon monoxide would differ over time in the presence of a catalyst. **Label this line.**

1 + 1 = 2 marks
b. Great care must be taken when handling carbon monoxide as it is a highly poisonous gas. Even at low concentrations it competes very successfully with oxygen for haemoglobin, the oxygen carrier in the blood.

The reactions can be written as

\[
\text{haemoglobin} + \text{oxygen} \rightleftharpoons \text{oxyhaemoglobin}; \quad K_1
\]

\[
\text{haemoglobin} + \text{carbon monoxide} \rightleftharpoons \text{carbon monoxide–haemoglobin}; \quad K_2
\]

What does the above information indicate about the magnitude of the equilibrium constant \( K_1 \) compared with the magnitude of the equilibrium constant \( K_2 \)?

---------------------------------------------------------------

1 mark

c. The rates of chemical reactions may be explained using the collision theory model. Indicate whether the following statements about rates and the collision theory model are true or false by placing ticks in the appropriate boxes.

<table>
<thead>
<tr>
<th>Statement</th>
<th>True</th>
<th>False</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Endothermic reactions are always slower than exothermic reactions.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ii. All particles have the same kinetic energy at a fixed temperature.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iii. Reactant particles need to collide with sufficient energy to react.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv. The rate of a reaction at a constant temperature increases as the reaction proceeds.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>v. Increasing the temperature increases the fraction of collisions with energy above the activation energy.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3 marks

Total 6 marks
Question 2
Bromophenol blue is a weak acid (represented as BH) that acts as an acid-base indicator. In solution the following equilibrium is established.

\[ \text{BH(aq)} \rightleftharpoons \text{B}^-\text{(aq)} + \text{H}^+\text{(aq)}; \quad K_a = 6.3 \times 10^{-5} \text{ M} \]

At low pH bromophenol blue exists mainly as the acid, BH, which is yellow in colour, while at high pH it exists mainly as its conjugate base, B\(^-\), which is blue. An intermediate colour is observed when the concentration of the acid and the concentration of the conjugate base are similar.

a. Write an expression for \( K_a \) in terms of the concentrations of BH, B\(^-\) and H\(^+\).

b. i. When [BH] = [B\(^-\)], the mixture appears green. Calculate the pH at which [BH] = [B\(^-\)].

ii. Calculate the ratio [B\(^-\)]/[BH] when the pH of a solution of bromophenol blue is 7.

iii. What colour will the indicator solution appear at pH 7? Justify your answer.
Question 3

Some rocks were thought to consist of insoluble silica (SiO₂) and calcium carbonate (CaCO₃; molar mass 100.1 g mol⁻¹). The fraction of CaCO₃ in an 8.64 g sample of the crushed rock was determined by mixing the sample with excess hydrochloric acid. The acid reacts with CaCO₃ according to the following equation:

\[ 2\text{HCl(aq)} + \text{CaCO₃(s)} \rightarrow \text{CaCl₂(aq)} + \text{H₂O(l)} + \text{CO₂(g)} \]

The resulting solution was filtered and the SiO₂ that was collected was washed and dried. The mass of SiO₂ was found to be 1.55 g.

a. Calculate the expected percentage of CaCO₃ in the original rock sample.

b. In order to check the result from part a, excess ammonium oxalate solution was added to the filtered solution. The calcium ions present precipitate as CaC₂O₄·H₂O.

The CaC₂O₄·H₂O was collected by filtration, washed and dried. It was then heated to convert it to CaO (molar mass 56.1 g mol⁻¹) and a mass of 3.87 g was obtained.

Using this mass of CaO, calculate the percentage of CaCO₃ in the rock sample. Ensure that you express your answer to an appropriate number of significant figures.

c. Suppose that the percentage of CaCO₃ determined by the chemical analysis with ammonium oxalate was less than the result found in part a. above. Provide one possible explanation for the difference.

Total 6 marks
**Question 4**

Sulfur dioxide (SO₂) is a chemical of major industrial significance.

**a.** SO₂ gas can be produced in a reaction between concentrated sulfuric acid and nickel metal. A solution containing Ni²⁺ ions is also formed.

Write balanced equations for the

i. oxidation reaction

ii. reduction reaction

iii. overall reaction, showing the states of all reactants and products.

1 + 1 + 2 = 4 marks

**b.** SO₂ can also be produced in a chemical reaction between zinc sulfite (ZnSO₃) and hydrochloric acid according to the equation

\[ \text{ZnSO}_3(s) + 2\text{H}^+(aq) \rightarrow \text{Zn}^{2+}(aq) + \text{SO}_2(g) + \text{H}_2\text{O}(l) \]

Is this reaction also a redox reaction? Explain your answer.

1 mark

**c.** The SO₂ produced as a by-product of the extraction of lead from its ore can cause serious pollution. In order to avoid releasing the SO₂ into the atmosphere it is often collected and used to produce chemicals of industrial importance. Give the formula of such a chemical.

1 mark
d. The following pairs of statements refer to the reaction of SO$_2$(g) with O$_2$(g) in the presence of vanadium (V) oxide. Each statement contains one or more missing words. **Circle** the most appropriate words beside each statement.

i.

<table>
<thead>
<tr>
<th>Statements</th>
<th>Circle the most appropriate words</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The product of this reaction is ______________.</td>
<td>oleum, sulfuric acid, sulfur trioxide</td>
</tr>
<tr>
<td>2. At constant temperature, the chemical energy of the product is ____________ the chemical energy of the reactants.</td>
<td>equal to, more than, less than</td>
</tr>
</tbody>
</table>

ii.

<table>
<thead>
<tr>
<th>Statements</th>
<th>Circle the most appropriate words</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The equilibrium yield of product is ______________ as temperature decreases at constant pressure.</td>
<td>unchanged, increased, decreased</td>
</tr>
<tr>
<td>2. The equilibrium yield of product is ______________ as pressure increases at constant temperature.</td>
<td>unchanged, increased, decreased</td>
</tr>
</tbody>
</table>

iii.

<table>
<thead>
<tr>
<th>Statements</th>
<th>Circle the most appropriate words</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The reaction rate is ______________ as the temperature increases at constant pressure.</td>
<td>unchanged, increased, decreased</td>
</tr>
<tr>
<td>2. The activation energy of the reaction is ______________ by the presence of vanadium (V) oxide.</td>
<td>unchanged, increased, decreased</td>
</tr>
</tbody>
</table>

1 + 1 + 1 = 3 marks
Total 9 marks
Question 5
Paraffin oil contains a mixture of high molecular mass alkanes. A gaseous mixture of ethene and other low molecular mass alkanes and alkenes can be produced in the laboratory by heating paraffin oil in the presence of alumina.

a. i. What is the general name given to this process?

ii. Suggest the likely function of the alumina.

b. If one of the components of paraffin oil is C_{17}H_{36}, write a balanced equation in which this component forms ethene and only one other product.

c. A chemist collects three samples of ethene and performs the following reactions. Write balanced equations for each one.
   i. addition of bromine (Br_2)

ii. complete combustion

iii. heated with steam and a catalyst at 300°C

1 + 1 = 2 marks
1 mark
1 + 1 + 1 = 3 marks
d. A low molecular mass alkane was extracted from a gas sample obtained by this method. The following sequence of chemical reactions was then performed using this alkane.

- The alkane was allowed to react with chlorine in the presence of ultraviolet light. Two compounds, A and B, were formed, each of molar mass 78.5 g mol\(^{-1}\).
- One of these two compounds was isolated and allowed to react with potassium hydroxide solution. The product of this reaction was heated with acidified potassium dichromate solution to form C, an acidic compound.

i. Draw the structural formulas of compounds A and B in the boxes below, showing **all bonds** present in the molecules. Give the systematic name of each compound.

```
Name ___________________________ Name ___________________________
```

ii. Draw the structural formula of compound C in the box below, showing **all bonds** present in the molecule. Give the systematic name of the compound.

```
Name ___________________________
```

4 + 2 = 6 marks
Total 12 marks
Question 6

When the substance CH₃CHO (substance X) is dissolved in water it reacts to form an equilibrium mixture with CH₃CH(OH)₂ (substance Y) according to the equation

\[ X(aq) + H₂O(l) \rightleftharpoons Y(aq) \]

The concentration of X can be determined using UV-visible spectroscopy. X absorbs strongly at 290 nm. Y shows no absorption at this wavelength.

In a particular experimental arrangement at 25°C, the relationship between absorbance at 290 nm and concentration of X is given by

\[ \text{Absorbance} = 4.15 \times [X] \]

In the experiment, 0.110 mol of X is dissolved rapidly in 1.00 L of water at 25°C. The absorbance of the solution changes as some of the X is converted to Y. The table below shows the change in absorbance over time (measured in seconds).

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Absorbance</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.00</td>
<td>0.430</td>
</tr>
<tr>
<td>60.0</td>
<td>0.303</td>
</tr>
<tr>
<td>90.0</td>
<td>0.270</td>
</tr>
<tr>
<td>120</td>
<td>0.255</td>
</tr>
<tr>
<td>240</td>
<td>0.250</td>
</tr>
<tr>
<td>480</td>
<td>0.250</td>
</tr>
</tbody>
</table>

**a.** Calculate the concentration of X, in M, when the reaction reached equilibrium.

**b.** Calculate the absorbance at the instant that X was dissolved in the water, before any reaction occurred.

**c.** Calculate the percentage of the original 0.110 mol of X that has been converted into Y at equilibrium.
d. The average rate of a reaction can be determined by calculating the change in concentration of a reactant per second. Calculate the average rate, in M s\(^{-1}\), at which the concentration of X changed during the first 6.00 s of the reaction.

2 marks
Total 6 marks
Question 7

Sulfur dioxide gas is commonly used as a preservative in wine. An important source of SO₂ is solid sodium metabisulfite (Na₂S₂O₅; molar mass 190 g mol⁻¹). Na₂S₂O₅ reacts readily with acid as follows.

\[ \text{Na}_2\text{S}_2\text{O}_5(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow 2\text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l}) + 2\text{SO}_2(\text{g}) \]

a. Calculate the volume, in litres, of SO₂ produced at 1.00 atm pressure and 15.0°C when 250 g of Na₂S₂O₅ reacts with excess acid.

b. The concentration of an aqueous solution of SO₂ (solution A) is to be determined using its reaction with an aqueous solution of triiodide ions (I₃⁻). The relevant half reactions are

\[ \text{SO}_2(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow 4\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq}) + 2\text{e}^- \]
\[ \text{I}_3^- (\text{aq}) + 2\text{e}^- \rightarrow 3\text{I}^- (\text{aq}) \]

50.0 mL of a 0.0125 M solution of I₃⁻ is added to 50.0 mL of solution A, providing excess of I₃⁻. The final 100.0 mL solution is called solution B.

i. Write an overall balanced chemical equation for the reaction that occurs, identifying the substance that is the reductant.

Equation _________________________________________________________
Reductant_________________________

ii. Calculate the amount, in mol, of I₃⁻ added to solution A.
iii. The excess $I_3^-$ remaining in the solution is determined by titration with a standard solution of sodium thiosulfate ($Na_2S_2O_3$). The equation for the reaction is

$$S_2O_3^{2-}(aq) + I_3^-(aq) + H_2O(l) \rightarrow 3I^-(aq) + S_2O_4^{2-}(aq) + 2H^+(aq)$$

14.70 mL of a 0.00850 M solution of $Na_2S_2O_3$ reacts exactly with all the $I_3^-$ remaining in solution B. Calculate the original concentration of $SO_2$ in solution A.

\[2 + 1 + 3 = 6 \text{ marks}\]

\[\text{Total 9 marks}\]
Directions to students

This data sheet is provided for your reference.
Make sure that you remove this data sheet from the centrefold during reading time.
Any writing, jottings, notes or drawings you make on this data sheet will **not** be considered in the marking.
At the end of the examination, make sure that you do **not** leave the data sheet in the centrefold of the question and answer book.
You may keep this data sheet.
Physical constants

\[ F = 96,500 \text{ C mol}^{-1} \]
\[ R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1} \]
1 atm = 101 325 Pa = 760 mmHg
0°C = 273 K
Molar volume at STP = 22.4 L mol\(^{-1}\)
Avogadro constant = \(6.02 \times 10^{23}\) mol\(^{-1}\)
\(K_w = 1.00 \times 10^{-14}\) M at 25°C

Ideal gas equation

\[ pV = nRT \]

The electrochemical series

\[ E^\circ \] in volt

\[
\begin{align*}
F_2(g) + 2e^- & \rightarrow 2F^- (aq) & +2.87 \\
H_2O_2(aq) + 2H^+(aq) + 2e^- & \rightarrow 2H_2O(l) & +1.77 \\
Au^+(aq) + e^- & \rightarrow Au(s) & +1.68 \\
Cl_2(g) + 2e^- & \rightarrow 2Cl^- (aq) & +1.36 \\
O_2(g) + 4H^+(aq) + 4e^- & \rightarrow 2H_2O(l) & +1.23 \\
Br_2(l) + 2e^- & \rightarrow 2Br^- (aq) & +1.09 \\
Ag^+(aq) + e^- & \rightarrow Ag(s) & +0.80 \\
Fe^{3+}(aq) + e^- & \rightarrow Fe^{2+}(aq) & +0.77 \\
I_2(s) + 2e^- & \rightarrow 2I^- (aq) & +0.54 \\
O_2(g) + 2H_2O(l) + 4e^- & \rightarrow 4OH^-(aq) & +0.40 \\
Cu^{2+}(aq) + 2e^- & \rightarrow Cu(s) & +0.34 \\
S(s) + 2H^+(aq) + 2e^- & \rightarrow H_2S(g) & +0.14 \\
2H^+(aq) + 2e^- & \rightarrow H_2(g) & 0.00 \\
Pb^{2+}(aq) + 2e^- & \rightarrow Pb(s) & -0.13 \\
Sn^{2+}(aq) + 2e^- & \rightarrow Sn(s) & -0.14 \\
Ni^{2+}(aq) + 2e^- & \rightarrow Ni(s) & -0.23 \\
Co^{2+}(aq) + 2e^- & \rightarrow Co(s) & -0.28 \\
Fe^{2+}(aq) + 2e^- & \rightarrow Fe(s) & -0.44 \\
Zn^{2+}(aq) + 2e^- & \rightarrow Zn(s) & -0.76 \\
2H_2O(l) + 2e^- & \rightarrow H_2(g) + 2OH^- (aq) & -0.83 \\
Mn^{2+}(aq) + 2e^- & \rightarrow Mn(s) & -1.03 \\
Al^{3+}(aq) + 3e^- & \rightarrow Al(s) & -1.67 \\
Mg^{2+}(aq) + 2e^- & \rightarrow Mg(s) & -2.34 \\
Na^+(aq) + e^- & \rightarrow Na(s) & -2.71 \\
Ca^{2+}(aq) + 2e^- & \rightarrow Ca(s) & -2.87 \\
K^+(aq) + e^- & \rightarrow K(s) & -2.93 \\
Li^+(aq) + e^- & \rightarrow Li(s) & -3.02
\end{align*}
\]
## Periodic table of the elements

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