



# basic education

Department:  
Basic Education  
**REPUBLIC OF SOUTH AFRICA**

## NATIONAL SENIOR CERTIFICATE

GRADE 11

PHYSICAL SCIENCES: CHEMISTRY (P2)

NOVEMBER 2019

**MARKS: 150**

**TIME: 3 hours**

This question paper consists of 15 pages, 4 data sheets and 1 graph sheet.



\* I P H S C E 2 \*



**INSTRUCTIONS AND INFORMATION**

1. Write your name and class (e.g. 11A) in the appropriate spaces on the ANSWER BOOK.
2. This question paper consists of TEN questions. Answer ALL the questions in the ANSWER BOOK, except QUESTION 4.2 that must be answered on the attached GRAPH SHEET.
3. Hand in the ANSWER SHEET with the ANSWER BOOK.
4. Start EACH question on a NEW page in the ANSWER BOOK.
5. Number the answers correctly according to the numbering system used in this question paper.
6. Leave ONE line between two subquestions, e.g. between QUESTION 2.1 and QUESTION 2.2.
7. You may use a non-programmable calculator.
8. You may use appropriate mathematical instruments.
9. You are advised to use the attached DATA SHEETS.
10. Show ALL formulae and substitutions in ALL calculations.
11. Round off your FINAL numerical answers to a minimum of TWO decimal places.
12. Give brief motivations, discussions, etc. where required.
13. Write neatly and legibly.



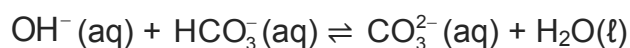
**QUESTION 1: MULTIPLE-CHOICE QUESTIONS**

Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A–D) next to the question numbers (1.1 to 1.10) in the ANSWER BOOK, e.g. 1.11 E. Each question has only ONE correct answer.

- 1.1 The number of valence electrons in a silicon atom is ...  
A 4  
B 6  
C 14  
D 28 (2)
- 1.2 In a polar covalent bond ...  
A the difference in electronegativity between two atoms is zero.  
B electrons are shared unequally between two atoms.  
C electrons are transferred from the less electronegative atom to the more electronegative atom.  
D delocalised electrons are shared between atoms. (2)
- 1.3 The type of intermolecular forces present between  $N_2$  molecules are ...  
A triple bonds.  
B dipole-dipole forces.  
C hydrogen bonds.  
D London forces. (2)
- 1.4 Which ONE of the following contains ionic bonds?  
A  $OF_2$   
B  $H_2O$   
C  $CH_3Cl$   
D  $NaCl$  (2)



- 1.5 The number of ions present in 3 moles of  $\text{MgCl}_2$  is ...
- A  $3 \times 6,02 \times 10^{23}$
- B  $6 \times 6,02 \times 10^{23}$
- C  $9 \times 6,02 \times 10^{23}$
- D  $12 \times 6,02 \times 10^{23}$  (2)
- 1.6 Two different gases of the same volume at STP will have the same ...
- A mass.
- B density.
- C molar mass.
- D number of molecules. (2)
- 1.7 4 moles of nitrogen gas is sealed in a balloon at temperature **T** and pressure **p**. The volume of the balloon changes from **V** to **2V** when the temperature is increased to **1,5T**.
- The new pressure in the balloon is ...
- A 0,75p
- B 1,33p
- C 1,5p
- D 3p (2)
- 1.8 Consider the chemical equation below:



The Lowry-Brønsted bases in the above reaction are ...

- A  $\text{HCO}_3^-(\text{aq})$  and  $\text{OH}^-(\text{aq})$
- B  $\text{H}_2\text{O}(\ell)$  and  $\text{OH}^-(\text{aq})$
- C  $\text{H}_2\text{O}(\ell)$  and  $\text{HCO}_3^-(\text{aq})$
- D  $\text{OH}^-(\text{aq})$  and  $\text{CO}_3^{2-}(\text{aq})$  (2)



1.9 A few drops of bromothymol blue indicator are added to a hydrochloric acid solution,  $\text{HCl(aq)}$ . When ammonium hydroxide,  $\text{NH}_4\text{OH(aq)}$ , is added to this solution, the colour of the indicator will change from ...

A blue to yellow.

B yellow to blue.

C yellow to red.

D blue to red.

(2)

1.10 Oxidation takes place when the ...

A reducing agent loses electrons.

B oxidising agent loses electrons.

C reducing agent gains electrons.

D oxidising agent gains electrons.

(2)

**[20]**



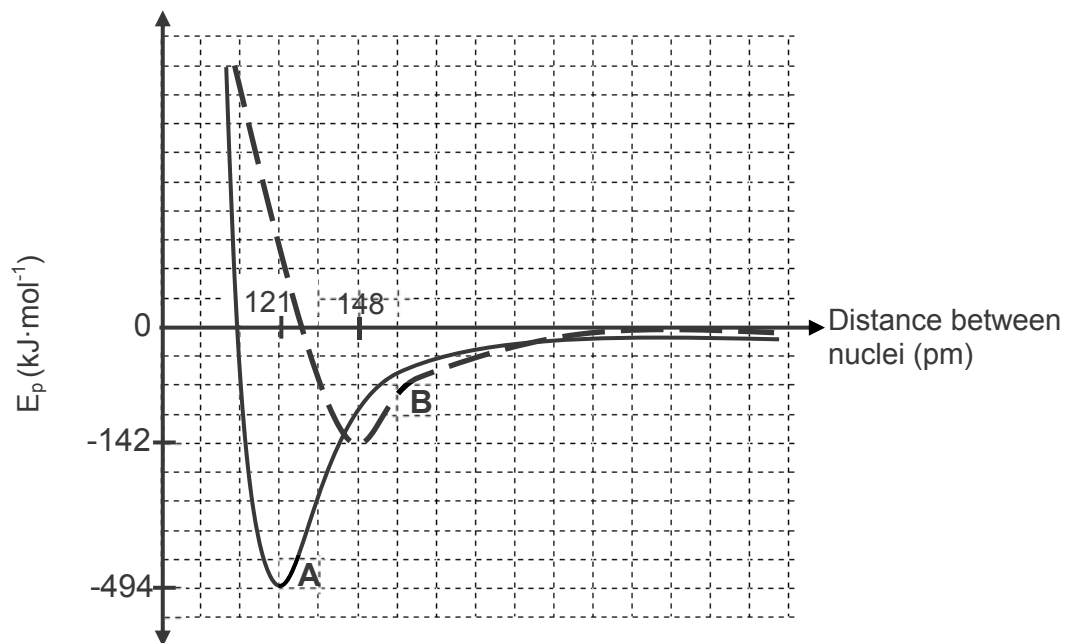
**QUESTION 2 (Start on a new page.)**

- 2.1 Ammonia  $\text{NH}_3(\text{g})$  and hypochlorous acid  $\text{HOCl}(\text{l})$  are both examples of covalent compounds.
- 2.1.1 Define the term *bonding pair*. (2)
- 2.1.2 Draw Lewis structures for the following molecules:
- (a)  $\text{NH}_3$  (2)
- (b)  $\text{HOCl}$  (2)
- 2.1.3 Write down the:
- (a) Number of bonding pairs in  $\text{NH}_3$  (1)
- (b) Number of lone pairs on the oxygen atom in  $\text{HOCl}$  (1)
- (c) Shape of an ammonia molecule (1)
- 2.1.4 Which bond, N-H or O-H, is more polar? Give a reason for the answer. (2)
- 2.1.5 Write down the type of intermolecular forces present in BOTH ammonia and hypochlorous acid. (1)
- 2.1.6 When ammonia dissolves in water, the ammonium ion ( $\text{NH}_4^+$ ) is formed.
- What type of bond forms between the ammonia molecule and the hydrogen ion? (1)



- 2.2 The graph of potential energy versus distance between the nuclei of two oxygen atoms during bond formation is shown below.

**Graph of potential energy versus distance between nuclei**



- 2.2.1 Define the term *bond energy*. (2)
- 2.2.2 Which curve, **A** or **B**, represents the formation of the double bond ( $\text{O}=\text{O}$ ) between oxygen atoms? Briefly explain the answer. (3)
- 2.2.3 Write down the bond length of the bond represented by curve **B**. (1)
- [19]**

**QUESTION 3 (Start on a new page.)**

The melting points and boiling points of four substances (**A**, **B**, **C** and **D**) are shown in the table below.

|          | SUBSTANCES      | MELTING POINT<br>(°C) | BOILING POINT<br>(°C) |
|----------|-----------------|-----------------------|-----------------------|
| <b>A</b> | HF              | - 83,11               | 19,54                 |
| <b>B</b> | HCl             | - 114,2               | - 81,7                |
| <b>C</b> | CS <sub>2</sub> | - 111                 | 46,0                  |
| <b>D</b> | CO <sub>2</sub> | - 56,6                | - 78,5                |

- 3.1 Define the term *melting point*. (2)
- 3.2 Explain the difference in melting points of HF and HCl by referring to the TYPE of intermolecular forces. (4)
- 3.3 Which ONE of the substances (**A**, **B**, **C** or **D**) above is a liquid at 25 °C? (1)
- 3.4 Explain why CS<sub>2</sub> has a higher boiling point than CO<sub>2</sub>. (3)
- 3.5 Which ONE of the substances (**A**, **B**, **C** or **D**) above has the highest vapour pressure? Give a reason for the answer by referring to the data in the table. (2)
- [12]**

**QUESTION 4 (Start on a new page.)**

The relationship between pressure and volume of an enclosed gas at 25 °C is investigated. The results obtained are shown in the table below.

| PRESSURE (kPa) | VOLUME (m <sup>3</sup> ) | $\frac{1}{V}$ (m <sup>-3</sup> ) |
|----------------|--------------------------|----------------------------------|
| 50             | 0,121                    | 8,2                              |
| 80             | 0,076                    | 13,2                             |
| 125            | 0,049                    | 20,6                             |
| 140            | 0,043                    | 23,1                             |
| 175            | 0,035                    | 28,8                             |

4.1 State *Boyle's law* in words. (2)

4.2 ANSWER THIS QUESTION ON THE ATTACHED GRAPH PAPER.

Use the data in the table above to draw a graph of pressure (p) versus the inverse of the volume ( $\frac{1}{V}$ ) on the attached graph paper. (3)

4.3 Which physical quantity can be determined from the gradient of the graph? Give a reason for the answer. (2)

4.4 It is found that, at high pressures, the shape of the graph deviates from that of the graph obtained in QUESTION 4.2. Explain this deviation. (3)

4.5 Calculate the number of moles of gas present in the sealed container at a pressure of 125 kPa. (4)  
**[14]**

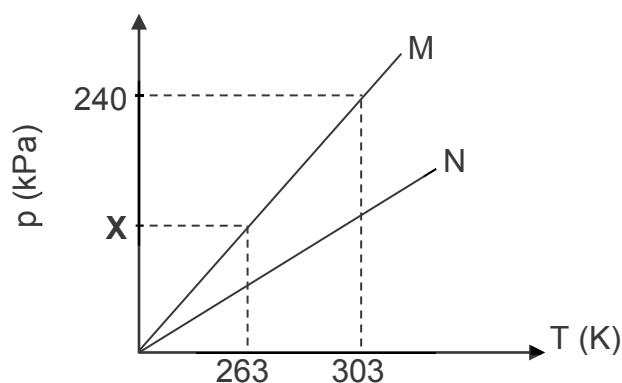
**QUESTION 5 (Start on a new page.)**

An unknown mass of gas is sealed in container **M**. The temperature is increased and the pressure inside the container is measured.

The experiment is now repeated using the same mass of the same gas in a different container, **N**.

The results obtained are represented in the sketch graph below.

**Graph of pressure versus temperature**



- 5.1 Determine the value of **X** as shown on the graph. (3)
- 5.2 How does the volume of container **N** compare to that of container **M**? Choose from GREATER THAN, SMALLER THAN or EQUAL TO. (1)
- 5.3 Explain the answer to QUESTION 5.2 with the aid of a relevant equation. (3)
- [7]**

**QUESTION 6 (Start on a new page.)**

- 6.1 Potassium permanganate,  $\text{KMnO}_4$ , burns with a bright flame when a few drops of glycerine are added to it.

The incomplete equation for the reaction is:



- 6.1.1 Define the term *molar mass*. (2)

- 6.1.2 The composition of glycerine is as follows:

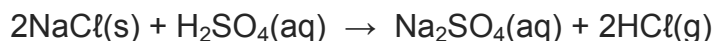
39,13% carbon; 8,7% hydrogen; 52,17% oxygen

Determine the EMPIRICAL formula of glycerine. Show ALL calculations. (6)

- 6.1.3 Write down the value of  $x$  in the equation above if the MOLECULAR formula of glycerine is  $\text{C}_3\text{H}_8\text{O}_3$ . (1)

- 6.1.4 Calculate the mass of  $\text{Mn}_2\text{O}_3$  that can be prepared if 18 g of  $\text{KMnO}_4$  reacts with excess glycerine. (4)

- 6.2 The balanced equation for the reaction of sodium chloride,  $\text{NaCl}$ , with sulphuric acid,  $\text{H}_2\text{SO}_4$ , is as follows:



During a reaction, 1,5 g of an impure sample of sodium chloride reacts with  $100 \text{ cm}^3$  sulphuric acid of concentration  $0,1 \text{ mol} \cdot \text{dm}^{-3}$  at room temperature.

- 6.2.1 Define the term *concentration*. (2)

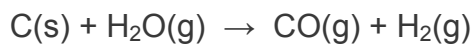
- 6.2.2 Calculate the number of moles of sulphuric acid used in the reaction above. (3)

On completion of the reaction it is found that  $460 \text{ cm}^3$  of  $\text{HCl}$  gas has formed.

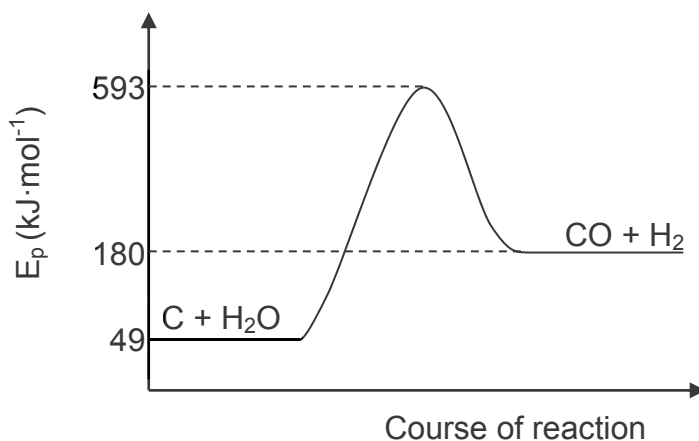
- 6.2.3 Calculate the percentage purity of the sodium chloride. Use  $24,45 \text{ dm}^3$  as the molar gas volume ( $V_m$ ) at room temperature. (6)  
**[24]**

**QUESTION 7 (Start on a new page.)**

The balanced equation for the reaction of carbon with steam is as follows:



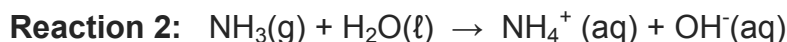
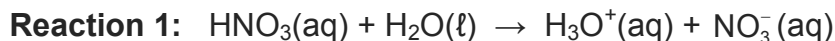
The graph below, NOT drawn to scale, represents the change in potential energy of the substances during the reaction.



- 7.1 Define the term *heat of reaction*. (2)
- 7.2 Is the reaction ENDOTHERMIC or EXOTHERMIC? Give a reason for the answer. (2)
- 7.3 Use the information on the graph and write down the value of the:
- 7.3.1 Activation energy (2)
- 7.3.2 Heat of reaction (2)
- [8]**

**QUESTION 8 (Start on a new page.)**

- 8.1 Consider the balanced equations for the reaction of water with nitric acid and ammonia below:



- 8.1.1 Define an *acid* in terms of the Lowry-Brønsted theory. (2)

- 8.1.2 Write down the FORMULA of ONE conjugate acid-base pair in **Reaction 1**. (2)

- 8.1.3 Is the solution formed in **Reaction 1** ACIDIC or BASIC (ALKALINE)? Give a reason for the answer. (2)

- 8.1.4 Define the term *ampholyte*. (2)

- 8.1.5 Write down the FORMULA of a substance that acts as an ampholyte in the reactions above. (1)

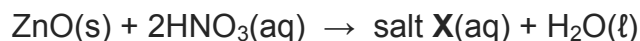
- 8.1.6 Explain the answer by referring to the role of this substance in **Reaction 1** and **Reaction 2**. (2)

100 cm<sup>3</sup> of HNO<sub>3</sub> of a concentration of 0,2 mol·dm<sup>-3</sup> is diluted to 0,16 mol·dm<sup>-3</sup>.

- 8.1.7 Calculate the volume of water that must be added to the 0,2 mol·dm<sup>-3</sup> HNO<sub>3</sub>. (4)

- 8.2 Zinc oxide, ZnO, is insoluble in water and can be harmful to the environment. Nitric acid can be used to neutralise zinc oxide.

The incomplete equation for the reaction is:



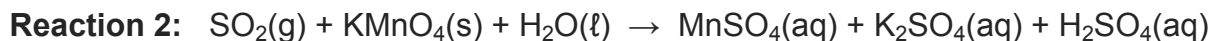
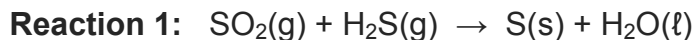
- 8.2.1 Calculate the mass of zinc oxide that can be neutralised by 80 cm<sup>3</sup> of nitric acid with a concentration of 0,16 mol·dm<sup>-3</sup>. (5)

- 8.2.2 Write the NAME and FORMULA of salt **X** that forms during this reaction. (2)  
**[22]**



**QUESTION 9 (Start on a new page.)**

The unbalanced equations for two redox reactions, in which  $\text{SO}_2$  is involved, are shown below.

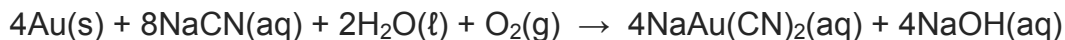


- 9.1 Explain what is meant by the term *redox reaction*. (2)
- 9.2 Write down the oxidation number of Mn in:
- 9.2.1  $\text{KMnO}_4$  (1)
- 9.2.2  $\text{MnSO}_4$  (1)
- 9.3 Is Mn in **Reaction 2** OXIDISED or REDUCED? Give a reason for the answer. (2)
- 9.4 In which reaction, **Reaction 1** or **Reaction 2**, does  $\text{SO}_2$  act as an oxidising agent? Give a reason for the answer. (2)
- 9.5 Write down the oxidation half-reaction in **Reaction 1**. (2)
- 9.6 Use the Table of Standard Reduction Potentials and write down the balanced net ionic equation for **Reaction 1**. Show the half-reactions and how you arrived at the final equation. (4)
- [14]**



**QUESTION 10 (Start on a new page.)**

The balanced chemical equation for the EXTRACTION of gold from its ore is as follows:



- 10.1 State ONE disadvantage of using cyanide ( $\text{CN}^-$ ) in the extraction of gold. (1)
- 10.2 Will the final solution of the extraction process be ACIDIC or BASIC (ALKALINE)? Give a reason for the answer. (2)
- 10.3 Determine the oxidation number of gold in  $\text{NaAu(CN)}_2$ . (1)
- 10.4 Write down the FORMULA of the reducing agent in the reaction above. (1)

Zinc powder is now used to PRECIPITATE the gold.

The balanced equation for the reaction is:



- 10.5 Does zinc undergo OXIDATION or REDUCTION during the precipitation reaction? (1)
- 10.6 Write down a half-reaction to support the answer to QUESTION 10.5. (2)
- 10.7 Calculate the percentage of gold in  $\text{NaAu(CN)}_2$ . (2)

**[10]****TOTAL: 150**



**DATA FOR PHYSICAL SCIENCES GRADE 11  
PAPER 2 (CHEMISTRY)**

**GEGEWENS VIR FISIIESE WETENSKAPPE GRAAD 11  
VRAESTEL 2 (CHEMIE)**

**TABLE 1: PHYSICAL CONSTANTS/TABEL 1: FISIIESE KONSTANTES**

| NAME/NAAM                                                 | SYMBOL/SIMBOOL | VALUE/WAARDE                                               |
|-----------------------------------------------------------|----------------|------------------------------------------------------------|
| Avogadro's constant<br><i>Avogadro-konstante</i>          | $N_A$          | $6,02 \times 10^{23} \text{ mol}^{-1}$                     |
| Molar gas constant<br><i>Molêre gaskonstante</i>          | $R$            | $8,31 \text{ J} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$ |
| Standard pressure<br><i>Standaarddruk</i>                 | $p^\theta$     | $1,013 \times 10^5 \text{ Pa}$                             |
| Molar gas volume at STP<br><i>Molêre gasvolume by STD</i> | $V_m$          | $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$                  |
| Standard temperature<br><i>Standaardtemperatuur</i>       | $T^\theta$     | $273 \text{ K}$                                            |

**TABLE 2: FORMULAE/TABEL 2: FORMULES**

|                                             |                                            |
|---------------------------------------------|--------------------------------------------|
| $\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2}$ | $pV = nRT$                                 |
| $n = \frac{m}{M}$                           | $n = \frac{N}{N_A}$                        |
| $n = \frac{V}{V_m}$                         | $c = \frac{n}{V}$ OR/OF $c = \frac{m}{MV}$ |



TABLE 3: THE PERIODIC TABLE OF ELEMENTS/TABEL 3: DIE PERIODIEKE TABEL VAN ELEMENTE

| KEY/SLEUTEL            |  |                        |  |                        |  |                          |  |                          |  |                         |  |                          |  |                          |  |                          |  | Atomic number<br>Atoomgetal |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                         |  |                          |  |                          |  |                          |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                        |  |                        |  |                        |  |
|------------------------|--|------------------------|--|------------------------|--|--------------------------|--|--------------------------|--|-------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|-----------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|-------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|--------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|--------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|--------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|---------------------------|--|--------------------------|--|---------------------------|--|------------------------|--|------------------------|--|------------------------|--|
| 1<br>(I)               |  | 2<br>(II)              |  | 3                      |  | 4                        |  | 5                        |  | 6                       |  | 7                        |  | 8                        |  | 9                        |  | 10                          |  | 11                       |  | 12                       |  | 13<br>(III)              |  | 14<br>(IV)               |  | 15<br>(V)                |  | 16<br>(VI)               |  | 17<br>(VII)              |  | 18<br>(VIII)             |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                         |  |                          |  |                          |  |                          |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                        |  |                        |  |                        |  |
| 1<br>1,01<br><b>H</b>  |  | 3<br>6,94<br><b>Li</b> |  | 4<br>9,01<br><b>Be</b> |  | 11<br>22,99<br><b>Na</b> |  | 12<br>24,31<br><b>Mg</b> |  | 19<br>39,09<br><b>K</b> |  | 20<br>40,08<br><b>Ca</b> |  | 21<br>44,96<br><b>Sc</b> |  | 22<br>47,88<br><b>Ti</b> |  | 23<br>50,94<br><b>V</b>     |  | 24<br>51,99<br><b>Cr</b> |  | 25<br>54,94<br><b>Mn</b> |  | 26<br>55,85<br><b>Fe</b> |  | 27<br>58,93<br><b>Co</b> |  | 28<br>58,69<br><b>Ni</b> |  | 29<br>63,55<br><b>Cu</b> |  | 30<br>65,38<br><b>Zn</b> |  | 31<br>69,72<br><b>Ga</b> |  | 32<br>72,64<br><b>Ge</b> |  | 33<br>74,92<br><b>As</b> |  | 34<br>78,96<br><b>Se</b> |  | 35<br>79,90<br><b>Br</b> |  | 36<br>83,80<br><b>Kr</b> |  | 37<br>85,47<br><b>Rb</b> |  | 38<br>87,62<br><b>Sr</b> |  | 39<br>88,91<br><b>Y</b> |  | 40<br>90,92<br><b>Zr</b> |  | 41<br>92,91<br><b>Nb</b> |  | 42<br>95,94<br><b>Mo</b> |  | 43<br>97,90<br><b>Tc</b> |  | 44<br>101,07<br><b>Ru</b> |  | 45<br>101,07<br><b>Rh</b> |  | 46<br>106,42<br><b>Pd</b> |  | 47<br>107,87<br><b>Ag</b> |  | 48<br>112,41<br><b>Cd</b> |  | 49<br>114,82<br><b>In</b> |  | 50<br>118,71<br><b>Sn</b> |  | 51<br>121,76<br><b>Sb</b> |  | 52<br>127,60<br><b>Te</b> |  | 53<br>126,91<br><b>I</b> |  | 54<br>131,29<br><b>Xe</b> |  | 55<br>132,91<br><b>Cs</b> |  | 56<br>137,33<br><b>Ba</b> |  | 57<br>138,91<br><b>La</b> |  | 58<br>140,12<br><b>Ce</b> |  | 59<br>140,91<br><b>Pr</b> |  | 60<br>144,24<br><b>Nd</b> |  | 61<br>144,91<br><b>Pm</b> |  | 62<br>150,36<br><b>Sm</b> |  | 63<br>151,96<br><b>Eu</b> |  | 64<br>157,25<br><b>Gd</b> |  | 65<br>158,93<br><b>Tb</b> |  | 66<br>162,50<br><b>Dy</b> |  | 67<br>164,93<br><b>Ho</b> |  | 68<br>167,26<br><b>Er</b> |  | 69<br>168,93<br><b>Tm</b> |  | 70<br>173,04<br><b>Yb</b> |  | 71<br>175,09<br><b>Lu</b> |  | 72<br>178,49<br><b>Hf</b> |  | 73<br>180,94<br><b>Ta</b> |  | 74<br>183,84<br><b>W</b> |  | 75<br>186,21<br><b>Re</b> |  | 76<br>190,23<br><b>Os</b> |  | 77<br>192,22<br><b>Ir</b> |  | 78<br>195,08<br><b>Pt</b> |  | 79<br>196,97<br><b>Au</b> |  | 80<br>200,59<br><b>Hg</b> |  | 81<br>204,38<br><b>Tl</b> |  | 82<br>207,2<br><b>Pb</b> |  | 83<br>208,98<br><b>Bi</b> |  | 84<br>209<br><b>Po</b> |  | 85<br>210<br><b>At</b> |  | 86<br>222<br><b>Rn</b> |  |
| 87<br>223<br><b>Fr</b> |  | 88<br>226<br><b>Ra</b> |  | 89<br><b>Ac</b>        |  |                          |  |                          |  |                         |  |                          |  |                          |  |                          |  |                             |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                         |  |                          |  |                          |  |                          |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                        |  |                        |  |                        |  |
| 90<br>232<br><b>Th</b> |  | 91<br>231<br><b>Pa</b> |  | 92<br>238<br><b>U</b>  |  | 93<br><b>Np</b>          |  | 94<br><b>Pu</b>          |  | 95<br><b>Am</b>         |  | 96<br><b>Cm</b>          |  | 97<br><b>Bk</b>          |  | 98<br><b>Cf</b>          |  | 99<br><b>Es</b>             |  | 100<br><b>Fm</b>         |  | 101<br><b>Md</b>         |  | 102<br><b>No</b>         |  | 103<br><b>Lr</b>         |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                          |  |                         |  |                          |  |                          |  |                          |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                           |  |                          |  |                           |  |                        |  |                        |  |                        |  |



**TABLE 4A: STANDARD REDUCTION POTENTIALS**  
**TABEL 4A: STANDAARD-REDUKSIEPOTENSIALE**

| Half-reactions/Halfreaksies                                       | $E^{\theta}$ (V) |
|-------------------------------------------------------------------|------------------|
| $F_2(g) + 2e^- \rightleftharpoons 2F^-$                           | + 2,87           |
| $Co^{3+} + e^- \rightleftharpoons Co^{2+}$                        | + 1,81           |
| $H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$                   | +1,77            |
| $MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$        | + 1,51           |
| $Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-$                         | + 1,36           |
| $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$ | + 1,33           |
| $O_2(g) + 4H^+ + 4e^- \rightleftharpoons 2H_2O$                   | + 1,23           |
| $MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O$          | + 1,23           |
| $Pt^{2+} + 2e^- \rightleftharpoons Pt$                            | + 1,20           |
| $Br_2(l) + 2e^- \rightleftharpoons 2Br^-$                         | + 1,07           |
| $NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$           | + 0,96           |
| $Hg^{2+} + 2e^- \rightleftharpoons Hg(l)$                         | + 0,85           |
| $Ag^+ + e^- \rightleftharpoons Ag$                                | + 0,80           |
| $NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2(g) + H_2O$           | + 0,80           |
| $Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$                        | + 0,77           |
| $O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$                  | + 0,68           |
| $I_2 + 2e^- \rightleftharpoons 2I^-$                              | + 0,54           |
| $Cu^+ + e^- \rightleftharpoons Cu$                                | + 0,52           |
| $SO_2 + 4H^+ + 4e^- \rightleftharpoons S + 2H_2O$                 | + 0,45           |
| $2H_2O + O_2 + 4e^- \rightleftharpoons 4OH^-$                     | + 0,40           |
| $Cu^{2+} + 2e^- \rightleftharpoons Cu$                            | + 0,34           |
| $SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2(g) + 2H_2O$      | + 0,17           |
| $Cu^{2+} + e^- \rightleftharpoons Cu^+$                           | + 0,16           |
| $Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$                       | + 0,15           |
| $S + 2H^+ + 2e^- \rightleftharpoons H_2S(g)$                      | + 0,14           |
| <b><math>2H^+ + 2e^- \rightleftharpoons H_2(g)</math></b>         | <b>0,00</b>      |
| $Fe^{3+} + 3e^- \rightleftharpoons Fe$                            | - 0,06           |
| $Pb^{2+} + 2e^- \rightleftharpoons Pb$                            | - 0,13           |
| $Sn^{2+} + 2e^- \rightleftharpoons Sn$                            | - 0,14           |
| $Ni^{2+} + 2e^- \rightleftharpoons Ni$                            | - 0,27           |
| $Co^{2+} + 2e^- \rightleftharpoons Co$                            | - 0,28           |
| $Cd^{2+} + 2e^- \rightleftharpoons Cd$                            | - 0,40           |
| $Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$                        | - 0,41           |
| $Fe^{2+} + 2e^- \rightleftharpoons Fe$                            | - 0,44           |
| $Cr^{3+} + 3e^- \rightleftharpoons Cr$                            | - 0,74           |
| $Zn^{2+} + 2e^- \rightleftharpoons Zn$                            | - 0,76           |
| $2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$                  | - 0,83           |
| $Cr^{2+} + 2e^- \rightleftharpoons Cr$                            | - 0,91           |
| $Mn^{2+} + 2e^- \rightleftharpoons Mn$                            | - 1,18           |
| $Al^{3+} + 3e^- \rightleftharpoons Al$                            | - 1,66           |
| $Mg^{2+} + 2e^- \rightleftharpoons Mg$                            | - 2,36           |
| $Na^+ + e^- \rightleftharpoons Na$                                | - 2,71           |
| $Ca^{2+} + 2e^- \rightleftharpoons Ca$                            | - 2,87           |
| $Sr^{2+} + 2e^- \rightleftharpoons Sr$                            | - 2,89           |
| $Ba^{2+} + 2e^- \rightleftharpoons Ba$                            | - 2,90           |
| $Cs^+ + e^- \rightleftharpoons Cs$                                | - 2,92           |
| $K^+ + e^- \rightleftharpoons K$                                  | - 2,93           |
| $Li^+ + e^- \rightleftharpoons Li$                                | - 3,05           |

Increasing oxidising ability/Toenemende oksiderende vermoë

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**TABLE 4B: STANDARD REDUCTION POTENTIALS**  
**TABEL 4B: STANDAARD-REDUKSIEPOTENSIALE**

| Half-reactions/ <i>Halfreaksies</i>                                                                                    | $E^{\theta}$ (V) |
|------------------------------------------------------------------------------------------------------------------------|------------------|
| $\text{Li}^{+} + \text{e}^{-} \rightleftharpoons \text{Li}$                                                            | -3,05            |
| $\text{K}^{+} + \text{e}^{-} \rightleftharpoons \text{K}$                                                              | -2,93            |
| $\text{Cs}^{+} + \text{e}^{-} \rightleftharpoons \text{Cs}$                                                            | -2,92            |
| $\text{Ba}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Ba}$                                                          | -2,90            |
| $\text{Sr}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Sr}$                                                          | -2,89            |
| $\text{Ca}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Ca}$                                                          | -2,87            |
| $\text{Na}^{+} + \text{e}^{-} \rightleftharpoons \text{Na}$                                                            | -2,71            |
| $\text{Mg}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Mg}$                                                          | -2,36            |
| $\text{Al}^{3+} + 3\text{e}^{-} \rightleftharpoons \text{Al}$                                                          | -1,66            |
| $\text{Mn}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Mn}$                                                          | -1,18            |
| $\text{Cr}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Cr}$                                                          | -0,91            |
| $2\text{H}_2\text{O} + 2\text{e}^{-} \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^{-}$                         | -0,83            |
| $\text{Zn}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Zn}$                                                          | -0,76            |
| $\text{Cr}^{3+} + 3\text{e}^{-} \rightleftharpoons \text{Cr}$                                                          | -0,74            |
| $\text{Fe}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Fe}$                                                          | -0,44            |
| $\text{Cr}^{3+} + \text{e}^{-} \rightleftharpoons \text{Cr}^{2+}$                                                      | -0,41            |
| $\text{Cd}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Cd}$                                                          | -0,40            |
| $\text{Co}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Co}$                                                          | -0,28            |
| $\text{Ni}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Ni}$                                                          | -0,27            |
| $\text{Sn}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Sn}$                                                          | -0,14            |
| $\text{Pb}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Pb}$                                                          | -0,13            |
| $\text{Fe}^{3+} + 3\text{e}^{-} \rightleftharpoons \text{Fe}$                                                          | -0,06            |
| $2\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons \text{H}_2(\text{g})$                                                | 0,00             |
| $\text{S} + 2\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons \text{H}_2\text{S}(\text{g})$                             | +0,14            |
| $\text{Sn}^{4+} + 2\text{e}^{-} \rightleftharpoons \text{Sn}^{2+}$                                                     | +0,15            |
| $\text{Cu}^{2+} + \text{e}^{-} \rightleftharpoons \text{Cu}^{+}$                                                       | +0,16            |
| $\text{SO}_4^{2-} + 4\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$      | +0,17            |
| $\text{Cu}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Cu}$                                                          | +0,34            |
| $2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^{-} \rightleftharpoons 4\text{OH}^{-}$                                   | +0,40            |
| $\text{SO}_2 + 4\text{H}^{+} + 4\text{e}^{-} \rightleftharpoons \text{S} + 2\text{H}_2\text{O}$                        | +0,45            |
| $\text{Cu}^{+} + \text{e}^{-} \rightleftharpoons \text{Cu}$                                                            | +0,52            |
| $\text{I}_2 + 2\text{e}^{-} \rightleftharpoons 2\text{I}^{-}$                                                          | +0,54            |
| $\text{O}_2(\text{g}) + 2\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons \text{H}_2\text{O}_2$                         | +0,68            |
| $\text{Fe}^{3+} + \text{e}^{-} \rightleftharpoons \text{Fe}^{2+}$                                                      | +0,77            |
| $\text{NO}_3^{-} + 2\text{H}^{+} + \text{e}^{-} \rightleftharpoons \text{NO}_2(\text{g}) + \text{H}_2\text{O}$         | +0,80            |
| $\text{Ag}^{+} + \text{e}^{-} \rightleftharpoons \text{Ag}$                                                            | +0,80            |
| $\text{Hg}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Hg}(\text{l})$                                                | +0,85            |
| $\text{NO}_3^{-} + 4\text{H}^{+} + 3\text{e}^{-} \rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}$         | +0,96            |
| $\text{Br}_2(\text{l}) + 2\text{e}^{-} \rightleftharpoons 2\text{Br}^{-}$                                              | +1,07            |
| $\text{Pt}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Pt}$                                                          | +1,20            |
| $\text{MnO}_2 + 4\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$                 | +1,23            |
| $\text{O}_2(\text{g}) + 4\text{H}^{+} + 4\text{e}^{-} \rightleftharpoons 2\text{H}_2\text{O}$                          | +1,23            |
| $\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^{+} + 6\text{e}^{-} \rightleftharpoons 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ | +1,33            |
| $\text{Cl}_2(\text{g}) + 2\text{e}^{-} \rightleftharpoons 2\text{Cl}^{-}$                                              | +1,36            |
| $\text{MnO}_4^{-} + 8\text{H}^{+} + 5\text{e}^{-} \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$             | +1,51            |
| $\text{H}_2\text{O}_2 + 2\text{H}^{+} + 2\text{e}^{-} \rightleftharpoons 2\text{H}_2\text{O}$                          | +1,77            |
| $\text{Co}^{3+} + \text{e}^{-} \rightleftharpoons \text{Co}^{2+}$                                                      | +1,81            |
| $\text{F}_2(\text{g}) + 2\text{e}^{-} \rightleftharpoons 2\text{F}^{-}$                                                | +2,87            |

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