Hillcrest High School

PHYSICAL SCIENCE P2

NOVEMBER 2023

Grade 11

MARKS: 100
TIME: 3 Hours

EXAMINER: Mrs J. Knox-Whitehead
MODERATOR: Ms N. Badenhorst

Instructions

1. Answer ALL the questions.
2. This question paper consists of TWO sections:
3. SECTION A (10)
   SECTION B (90)

   Answer SECTIONS A and B in the ANSWER BOOK.
4. Non-programmable calculators may be used.
5. Appropriate mathematical instruments may be used.
6. Number the answers correctly according to the numbering system used in this question paper.
7. Data sheets and a periodic table are attached for your use.
8. Give brief motivations, discussions, et cetera where required.
9. Numbers must be rounded off to **two decimal** places.

SECTION A

QUESTION 1: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Write only the letter (A – D) next to the question number (1.1 – 1.5) in the ANSWER BOOK.

1.1 For which ONE of the following bonds is the difference in electronegativity the GREATEST?

A C—O

B C—H

C C—Br

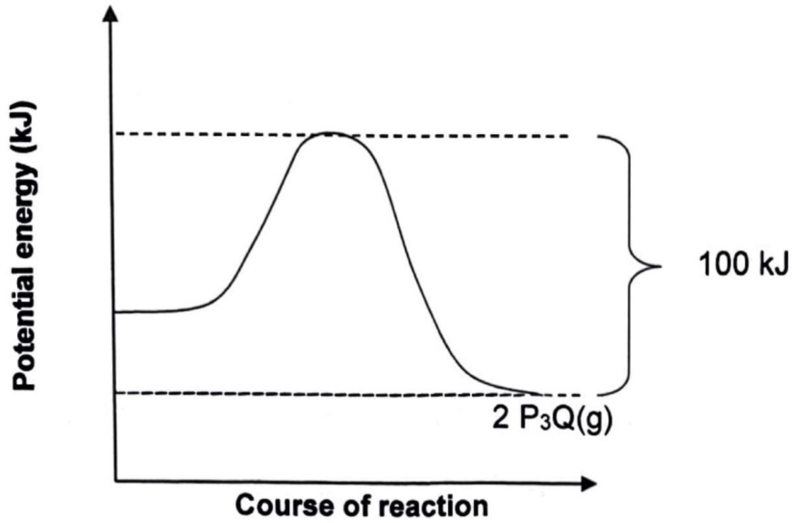
D H—Br (2)

1.2 Which ONE of the following combinations is correct if the number of bonding electron pairs between two identical atoms is increased?

	Bond length	**Bond Energy**
A	Increases	Increases
B	Decreases	Decreases
C	Decreases	Increases
D	Increases	decreases

1.3 The graph below shows the change in potential energy for the hypothetical reaction:

$$3\,P_2\,(g) + Q_2\,(g) \rightarrow 2\,P_3Q\,(g) \qquad \Delta H = -40\ kJ$$



Which ONE of the following could represent the activation energy for the forward reaction when a catalyst is added to the reaction?

A 50 kJ

B 60 kJ

C 90 kJ

D 120 kJ

1.4 Which of the following substances is NOT amphoteric?

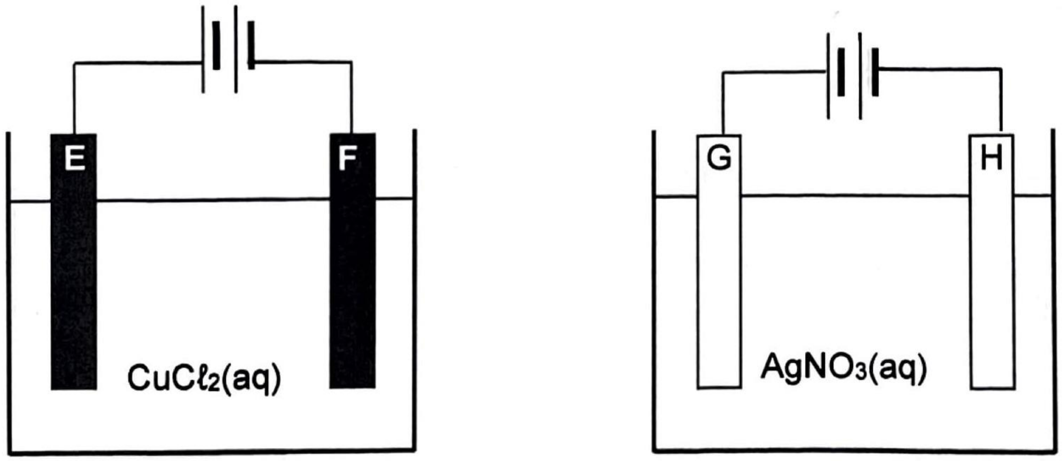
A H_2O

B HSO_4^-

C H_3O^+

D $H_2PO_4^-$

1.5 The simplified diagrams below represent two electrochemical cells using electrolytes of equal concentrations and identical batteries.



The electrode that shows the LARGEST increase in mass per unit time is:

A **E**

B **F**

C **G**

D **H**

[2 x 5 = 10]

SECTION B

Question 2

Ozone (O_3) reacts with nitrogen monoxide (NO) to produce NO_2 gas. The NO gas forms largely as a result of emissions from exhausts of motor vehicles and certain jet planes. The NO_2 gas causes the brown smog which is seen over most urban areas. This gas is harmful as it causes breathing problems.

The following chemical equation shows the reaction between ozone and nitrogen monoxide:

$$O_3(g) + NO(g) \rightarrow O_2(g) + NO_2(g)$$

In one such reaction, 0,74 g of O_3 reacts with 0,67 g of NO.

2.1 Identify the limiting reagent in the reaction, showing workings to justify your answer. (Round all answers off to THREE decimal places for this question.) (7)

2.2 Calculate the volume of NO_2 produced from this reaction occurring at STP. (4)

[11]

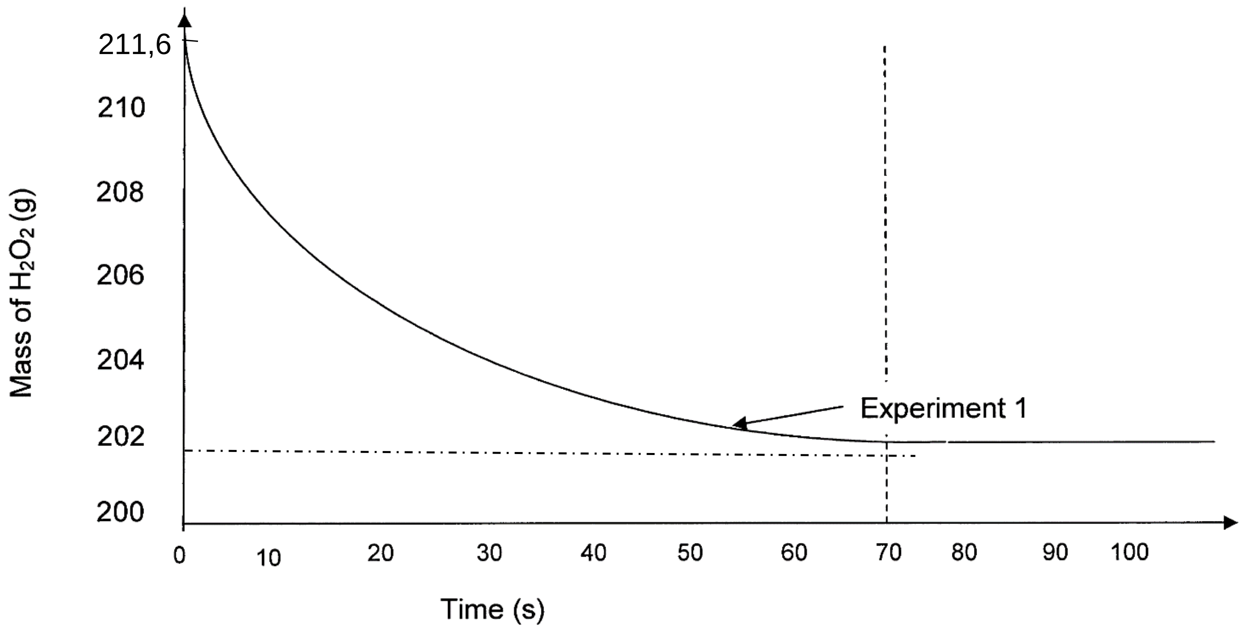
Question 3

The decomposition of hydrogen peroxide can be accelerated by the catalyst manganese dioxide. The peroxide rapidly decomposes to oxygen and water.

$$2\,H_2O_2(aq) \xrightarrow{MnO_2(s)} O_2(g) + 2\,H_2O(l)$$

3.1 Refer to the activation energy to explain the function of the MnO_2. (2)

3.2 A graph is drawn for the mass of the peroxide solution against time for the decomposition.



3.2.1 What does the HORIZONTAL section of the graph after 70 s indicate? (1)

3.2.2 Why does the mass of the solution decrease with time? (1)

3.2.3 During which ONE of the following time intervals was the rate of reaction the highest? Choose from 5 – 15 seconds, 15-25 seconds or 25-35 seconds. (1)

3.2.4 Give a reason for your answer to QUESTION 3.2.3. (1)

3.2.5 Calculate the average rate of reaction for this experiment. (3)

3.3 The experiment is now repeated using the same mass of H_2O_2 but the peroxide solution was HEATED prior to adding the manganese dioxide.

3.3.1 Define the term *reaction rate*. (2)

3.3.2 Use the Collision Theory to explain how the above change will affect the rate of the reaction for this experiment. (3)

[14]

Question 4

4.1 Define the term *acid* according to the Arrhenius theory. (2)

4.2 Consider the following acid-base reactions:

X: $HF + H_2O \leftrightarrows H_3O^+ + F^-$

Y: $HNO_3 + NH_3 \leftrightarrows NH_4^+ + NO_3^-$

4.2.1 From reactions **X** and **Y** identify the reaction that illustrates the Arrhenius theory. (1)

4.2.2 Rewrite reaction **Y** and identify the conjugate acid-base pairs for this reaction. (2)

4.3 Sodium hydroxide pellets of mass **X** g are added to sufficient distilled water to prepare a solution of volume 25 cm^3 in a flask.

12 cm^3 of sulphuric acid, H_2SO_4, of concentration 0,10 $mol.dm^{-3}$ is added to the flask containing the sodium hydroxide and the acid and base react according to the equation shown below.

The total volume of the mixture formed is 37 cm^3 and the pH after mixing the acid and base together is 12,56.

$$2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + H_2O(\ell)$$

4.3.1 Define the term *strong base*. (2)

4.3.2 How does the concentration of the hydroxide ions (OH^-) compare to the concentration of the hydronium ions (H_3O^+) in the final mixture? Choose from LARGER THAN, SMALLER THAN or EQUAL TO. (1)

4.3.3 Calculate the number of moles of H_2SO_4 that were added to the flask.
(Write all answers in scientific notation and round all answers to 3 decimal places.) (3)

4.3.4 Calculate the value of **X**.
(Write all answers in scientific notation and round all answers to 3 decimal places.) (7)

[18]

Question 5

Consider the following molecules and answer the questions below:

CO_2 HCl H_2O $BeCl_2$ N_2 NH_3 CO

5.1 Draw the Lewis structure for NH_3. (2)

5.2 Which molecule shown in the list above would be able to form a *dative covalent bond*? (1)

5.3 Indicate whether the following MOLECULES are polar or non-polar.

5.3.1 HCl (1)
5.3.2 N_2 (1)
5.3.3 CO_2 (1)

5.4 Explain your answer to QUESTION 5.3.3 in terms of electronegativity and molecular shape. (3)

[9]

Question 6

Air bags are installed in modern cars to protect the driver and passengers in case of a collision. The compound, sodium azide, found in an airbag is activated by an electrical signal. The equation for the reaction is represented below:

$$2\,NaN_3(s) \rightarrow 2\,Na(s) + 3\,N_2(g)$$

6.1 Name the law that is described by the equation $P_1V_1 = P_2V_2$. (1)

6.2 When an airbag was activated and inflated fully, the pressure inside the airbag was 98 kPa and the volume it expanded to was 140 dm^3. If the same airbag was only able to inflate to 80% of this volume due to a restriction caused by the collision, what would the pressure be inside the airbag? (3)

6.3 If 170 g of N_2 gas is required to be produced in the airbag on inflation and the yield of the activation reaction is known to be 95%, calculate the mass of $NaN_3(s)$ that needs to be placed into the airbag initially. (5)

[9]

Question 7

The rusting of iron is an example of a redox reaction. The following balanced equation represents the rusting of iron:

$$4\,Fe + 3\,O_2 \rightarrow 2\,Fe_2O_3$$

7.1 Give the oxidation number for the iron in the PRODUCT. (1)

7.2 Identify the reducing agent in this reaction. (1)

7.3 Write down the oxidation half-reaction. (2)

[4]

Question 8

The equation below represents a reaction that takes places under standard conditions in an electrochemical cell.

$$Fe^{2+}(aq) + X^{+}(aq) \rightarrow Fe^{3+}(aq) + X(s)$$

X is an unknown metal. The initial emf of this cell is + 0,03 V. The cell uses one platinum electrode.

8.1 Write down the energy conversion that takes place in this electrochemical cell. (1)

8.2 State TWO standard conditions under which this cell operates. (2)

8.3 Write down the:

8.3.1 cell notation for this cell. (3)

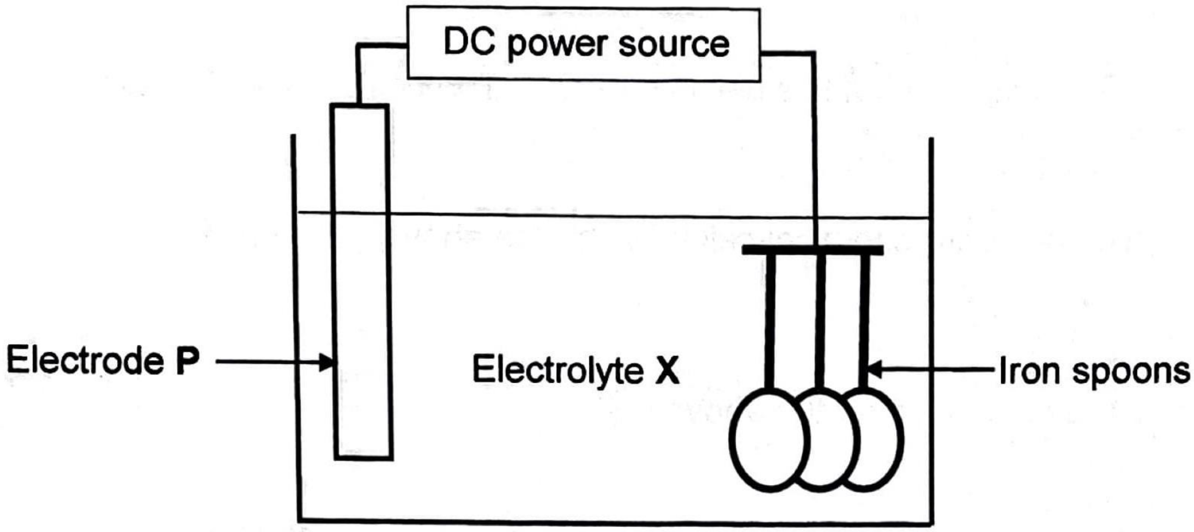
8.3.2 half-reaction that takes place at the cathode in the above electrochemical cell. (2)

8.4 Identify metal **X**, with the aid of a calculation. (4)

[12]

Question 9

The simplified diagram below shows an electrolytic cell used to electroplate iron spoons with copper.



9.1 Define the term *electrolyte*. (2)

9.2 Suggest a suitable electrolyte for the above reaction. (1)

9.3 Identify the anode in this cell. Choose between electrode **P** and the iron spoons. (1)

9.4 Write down the equation for the half reaction that results in the plating of the spoon. (2)

9.5 If the number of electrons transferred during this reaction was 8,5 x 10^{22} electrons, what mass gain would be expected onto the iron spoons? (5)

9.6 The copper used in this electrolytic cell is NOT PURE. It contains a small percentage of zinc. It is observed that the iron spoons are not coated with zinc. Explain this observation in terms of the relative oxidising strengths of the substances. (2)

[13]

Total 100

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

Increasing oxidising ability/*Toenemende oksiderende vermoë* (↑)

Increasing reducing ability/*Toenemende reduserende vermoë* (↓)

Half-reactions/*Halfreaksies*			E^{θ} (V)
$F_2(g) + 2e^-$	⇌	$2F^-$	+ 2,87
$Co^{3+} + e^-$	⇌	Co^{2+}	+ 1,81
$H_2O_2 + 2H^+ + 2e^-$	⇌	$2H_2O$	+1,77
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	+ 1,51
$C\ell_2(g) + 2e^-$	⇌	$2C\ell^-$	+ 1,36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇌	$2Cr^{3+} + 7H_2O$	+ 1,33
$O_2(g) + 4H^+ + 4e^-$	⇌	$2H_2O$	+ 1,23
$MnO_2 + 4H^+ + 2e^-$	⇌	$Mn^{2+} + 2H_2O$	+ 1,23
$Pt^{2+} + 2e^-$	⇌	Pt	+ 1,20
$Br_2(\ell) + 2e^-$	⇌	$2Br^-$	+ 1,07
$NO_3^- + 4H^+ + 3e^-$	⇌	$NO(g) + 2H_2O$	+ 0,96
$Hg^{2+} + 2e^-$	⇌	$Hg(\ell)$	+ 0,85
$Ag^+ + e^-$	⇌	Ag	+ 0,80
$NO_3^- + 2H^+ + e^-$	⇌	$NO_2(g) + H_2O$	+ 0,80
$Fe^{3+} + e^-$	⇌	Fe^{2+}	+ 0,77
$O_2(g) + 2H^+ + 2e^-$	⇌	H_2O_2	+ 0,68
$I_2 + 2e^-$	⇌	$2I^-$	+ 0,54
$Cu^+ + e^-$	⇌	Cu	+ 0,52
$SO_2 + 4H^+ + 4e^-$	⇌	$S + 2H_2O$	+ 0,45
$2H_2O + O_2 + 4e^-$	⇌	$4OH^-$	+ 0,40
$Cu^{2+} + 2e^-$	⇌	Cu	+ 0,34
$SO_4^{2-} + 4H^+ + 2e^-$	⇌	$SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + e^-$	⇌	Cu^+	+ 0,16
$Sn^{4+} + 2e^-$	⇌	Sn^{2+}	+ 0,15
$S + 2H^+ + 2e^-$	⇌	$H_2S(g)$	+ 0,14
$2H^+ + 2e^-$	⇌	**$H_2(g)$**	**0,00**
$Fe^{3+} + 3e^-$	⇌	Fe	− 0,06
$Pb^{2+} + 2e^-$	⇌	Pb	− 0,13
$Sn^{2+} + 2e^-$	⇌	Sn	− 0,14
$Ni^{2+} + 2e^-$	⇌	Ni	− 0,27
$Co^{2+} + 2e^-$	⇌	Co	− 0,28
$Cd^{2+} + 2e^-$	⇌	Cd	− 0,40
$Cr^{3+} + e^-$	⇌	Cr^{2+}	− 0,41
$Fe^{2+} + 2e^-$	⇌	Fe	− 0,44
$Cr^{3+} + 3e^-$	⇌	Cr	− 0,74
$Zn^{2+} + 2e^-$	⇌	Zn	− 0,76
$2H_2O + 2e^-$	⇌	$H_2(g) + 2OH^-$	− 0,83
$Cr^{2+} + 2e^-$	⇌	Cr	− 0,91
$Mn^{2+} + 2e^-$	⇌	Mn	− 1,18
$A\ell^{3+} + 3e^-$	⇌	$A\ell$	− 1,66
$Mg^{2+} + 2e^-$	⇌	Mg	− 2,36
$Na^+ + e^-$	⇌	Na	− 2,71
$Ca^{2+} + 2e^-$	⇌	Ca	− 2,87
$Sr^{2+} + 2e^-$	⇌	Sr	− 2,89
$Ba^{2+} + 2e^-$	⇌	Ba	− 2,90
$Cs^+ + e^-$	⇌	Cs	- 2,92
$K^+ + e^-$	⇌	K	− 2,93
$Li^+ + e^-$	⇌	Li	− 3,05

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

Increasing oxidising ability/*Toenemende oksiderende vermoë* (↓)

Increasing reducing ability/*Toenemende reduserende vermoë* (↑)

Half-reactions/*Halfreaksies*			E^θ (V)
$Li^+ + e^-$	⇌	Li	− 3,05
$K^+ + e^-$	⇌	K	− 2,93
$Cs^+ + e^-$	⇌	Cs	− 2,92
$Ba^{2+} + 2e^-$	⇌	Ba	− 2,90
$Sr^{2+} + 2e^-$	⇌	Sr	− 2,89
$Ca^{2+} + 2e^-$	⇌	Ca	− 2,87
$Na^+ + e^-$	⇌	Na	− 2,71
$Mg^{2+} + 2e^-$	⇌	Mg	− 2,36
$A\ell^{3+} + 3e^-$	⇌	$A\ell$	− 1,66
$Mn^{2+} + 2e^-$	⇌	Mn	− 1,18
$Cr^{2+} + 2e^-$	⇌	Cr	− 0,91
$2H_2O + 2e^-$	⇌	$H_2(g) + 2OH^-$	− 0,83
$Zn^{2+} + 2e^-$	⇌	Zn	− 0,76
$Cr^{3+} + 3e^-$	⇌	Cr	− 0,74
$Fe^{2+} + 2e^-$	⇌	Fe	− 0,44
$Cr^{3+} + e^-$	⇌	Cr^{2+}	− 0,41
$Cd^{2+} + 2e^-$	⇌	Cd	− 0,40
$Co^{2+} + 2e^-$	⇌	Co	− 0,28
$Ni^{2+} + 2e^-$	⇌	Ni	− 0,27
$Sn^{2+} + 2e^-$	⇌	Sn	− 0,14
$Pb^{2+} + 2e^-$	⇌	Pb	− 0,13
$Fe^{3+} + 3e^-$	⇌	Fe	− 0,06
$2H^+ + 2e^-$	**⇌**	**$H_2(g)$**	**0,00**
$S + 2H^+ + 2e^-$	⇌	$H_2S(g)$	+ 0,14
$Sn^{4+} + 2e^-$	⇌	Sn^{2+}	+ 0,15
$Cu^{2+} + e^-$	⇌	Cu^+	+ 0,16
$SO_4^{2-} + 4H^+ + 2e^-$	⇌	$SO_2(g) + 2H_2O$	+ 0,17
$Cu^{2+} + 2e^-$	⇌	Cu	+ 0,34
$2H_2O + O_2 + 4e^-$	⇌	$4OH^-$	+ 0,40
$SO_2 + 4H^+ + 4e^-$	⇌	$S + 2H_2O$	+ 0,45
$Cu^+ + e^-$	⇌	Cu	+ 0,52
$I_2 + 2e^-$	⇌	$2I^-$	+ 0,54
$O_2(g) + 2H^+ + 2e^-$	⇌	H_2O_2	+ 0,68
$Fe^{3+} + e^-$	⇌	Fe^{2+}	+ 0,77
$NO_3^- + 2H^+ + e^-$	⇌	$NO_2(g) + H_2O$	+ 0,80
$Ag^+ + e^-$	⇌	Ag	+ 0,80
$Hg^{2+} + 2e^-$	⇌	$Hg(\ell)$	+ 0,85
$NO_3^- + 4H^+ + 3e^-$	⇌	$NO(g) + 2H_2O$	+ 0,96
$Br_2(\ell) + 2e^-$	⇌	$2Br^-$	+ 1,07
$Pt^{2+} + 2e^-$	⇌	Pt	+ 1,20
$MnO_2 + 4H^+ + 2e^-$	⇌	$Mn^{2+} + 2H_2O$	+ 1,23
$O_2(g) + 4H^+ + 4e^-$	⇌	$2H_2O$	+ 1,23
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇌	$2Cr^{3+} + 7H_2O$	+ 1,33
$C\ell_2(g) + 2e^-$	⇌	$2C\ell^-$	+ 1,36
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	+ 1,51
$H_2O_2 + 2H^+ + 2e^-$	⇌	$2H_2O$	+1,77
$Co^{3+} + e^-$	⇌	Co^{2+}	+ 1,81
$F_2(g) + 2e^-$	⇌	$2F^-$	+ 2,87

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

TABLE 2: FORMULAE/*TABEL 2: FORMULES*

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$
$c = \frac{n}{V}$ or/*of* $c = \frac{m}{MV}$	$n = \frac{V}{V_m}$
$\frac{c_aV_a}{c_bV_b} = \frac{n_a}{n_b}$	$pH = -\log[H_3O^+]$
$K_w = [H_3O^+][OH^-] = 1 \times 10^{-14}$ at/*by* 298 K	
$E^\theta_{cell} = E^\theta_{cathode} - E^\theta_{anode}$ / $E^\theta_{sel} = E^\theta_{katode} - E^\theta_{anode}$ or/*of* $E^\theta_{cell} = E^\theta_{reduction} - E^\theta_{oxidation}$ / $E^\theta_{sel} = E^\theta_{reduksie} - E^\theta_{oksidasie}$ or/*of* $E^\theta_{cell} = E^\theta_{oxidising\ agent} - E^\theta_{reducing\ agent}$ / $E^\theta_{sel} = E^\theta_{oksideermiddel} - E^\theta_{reduseermiddel}$	

$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$	$pV = nRT$

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

KEY/*SLEUTEL*

Electronegativity / *Elektronegatiwiteit*	Atomic number / *Atoomgetal*	Symbol / *Simbool*	Approximate relative atomic mass / *Benaderde relatiewe atoommassa*
1,9	29	Cu	63,5

1 (I)	2 (II)	3	4	5	6	7	8	9	10	11	12	13 (III)	14 (IV)	15 (V)	16 (VI)	17 (VII)	18 (VIII)
1 2,1 H 1																	2 He 4
3 1,0 Li 7	4 1,5 Be 9											5 2,0 B 11	6 2,5 C 12	7 3,0 N 14	8 3,5 O 16	9 4,0 F 19	10 Ne 20
11 0,9 Na 23	12 1,2 Mg 24											13 1,5 Aℓ 27	14 1,8 Si 28	15 2,1 P 31	16 2,5 S 32	17 3,0 Cℓ 35,5	18 Ar 40
19 0,8 K 39	20 1,0 Ca 40	21 1,3 Sc 45	22 1,5 Ti 48	23 1,6 V 51	24 1,6 Cr 52	25 1,5 Mn 55	26 1,8 Fe 56	27 1,8 Co 59	28 1,8 Ni 59	29 1,9 Cu 63,5	30 1,6 Zn 65	31 1,6 Ga 70	32 1,8 Ge 73	33 2,0 As 75	34 2,4 Se 79	35 2,8 Br 80	36 Kr 84
37 0,8 Rb 86	38 1,0 Sr 88	39 1,2 Y 89	40 1,4 Zr 91	41 Nb 92	42 1,8 Mo 96	43 1,9 Tc	44 2,2 Ru 101	45 2,2 Rh 103	46 2,2 Pd 106	47 1,9 Ag 108	48 1,7 Cd 112	49 1,7 In 115	50 1,8 Sn 119	51 1,9 Sb 122	52 2,1 Te 128	53 2,5 I 127	54 Xe 131
55 0,7 Cs 133	56 0,9 Ba 137	57 La 139	72 1,6 Hf 179	73 Ta 181	74 W 184	75 Re 186	76 Os 190	77 Ir 192	78 Pt 195	79 Au 197	80 Hg 201	81 1,8 Tℓ 204	82 1,8 Pb 207	83 1,9 Bi 209	84 2,0 Po	85 2,5 At	86 Rn
87 0,7 Fr	88 0,9 Ra 226	89 Ac															
				58 Ce 140	59 Pr 141	60 Nd 144	61 Pm	62 Sm 150	63 Eu 152	64 Gd 157	65 Tb 159	66 Dy 163	67 Ho 165	68 Er 167	69 Tm 169	70 Yb 173	71 Lu 175
				90 Th 232	91 Pa	92 U 238	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr