

MATRIC PHYSICAL SCIENCE PAPER 2 (2009)

SECTION A

QUESTION 1: ONE-WORD ITEMS

Give ONE word/term for each of the following descriptions in the questions numbered 1.1–1.5.

1.1 A group of atoms that forms the basis of a homologous series (1)

1.2 The group of atoms $\begin{array}{c} \text{O} \\ || \\ -\text{C}- \end{array}$ found in ketones, acids and amides (1)

1.3 The type of energy that is reduced by using a catalyst during a chemical reaction (1)

1.4 The type of electrochemical cell in which electrical energy is converted to chemical energy (1)

1.5 The electrode at which oxidation takes place (1)

[5]

QUESTION 2: FALSE ITEMS

The statements in questions 2.1–2.5 are FALSE. Correct the statements.

2.1 The eutrophication of fresh water is caused by algal blooms brought on by a decrease in the oxygen concentration of the water. (2)

2.2 An electrolytic cell is an electrochemical cell that converts chemical energy into electrical energy. (2)

2.3 The Ostwald, Contact and Haber processes are used in the chemical industry to produce important industrial acids. (2)

2.4 Strong reducing agents release electrons easily and improve the oxidising ability of chemical species that receive the liberated electrons. (2)

2.5 A bag of fertiliser marked 2:3:2 (28) indicates that nitrogen, phosphorus and potassium are present at a ratio of 2%:3%:2% of the total mass of fertiliser in the bag. (2)

[10]

QUESTION 3: MULTIPLE-CHOICE QUESTIONS

Four options are provided as possible answers to the following questions. Each question has only ONE correct answer. Choose the answer and write it next to the question number (3.1–3.5).

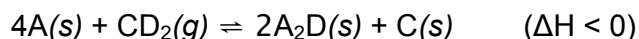
3.1 Factors that can influence chemical reaction rates are:

- A temperature, presence of catalysts, vapour pressure, catalysts
- B surface area of solids, concentration of liquid solutions, purity of solid reactants, boiling point of liquid reactants
- C surface area of solids, concentration of gaseous solutions, catalysts, proportion of successful collisions of reactants
- D concentration of reactants, concentration of gaseous solutions, gas pressure, changes in equilibrium constant. (2)

3.2 The forces that hold water molecules in a crystalline structure in ice are

- A covalent bonds
- B hydrogen bonds
- C Van der Waals forces
- D ion-dipole attractions. (2)

3.3 Consider the following statements about the chemical equilibrium below:



- I the reverse reaction is endothermic
- II the equilibrium constant depends on the concentration of CD_2
- III the concentration of C increases when the temperature is lowered
- IV when the pressure in the reaction vessel is decreased the equilibrium equation becomes $4A + CD_2 \rightleftharpoons A_2D + C$

Which statements are correct?

- A I and II
- B II and III
- C II and IV
- D III and IV (2)

3.4 Three different gases are bubbled through different ionic solutions. Use the Table of Standard Reduction Potentials to predict for which option a white precipitate will be formed.

- A SO_2 through a solution of $\text{K}_2\text{Cr}_2\text{O}_7$
- B H_2S through a solution of $\text{Zn}(\text{NO}_3)_2$
- C Cl_2 through a solution of AgNO_3
- D H_2S through a solution of FeCl_3 (2)

3.5 Consider the following statements:

- I The anode of a galvanic cell is positive.
- II Oxidation takes place at the negative electrode of an electrolytic cell.
- III Electroplating of metals occurs at the cathode.

Which statement(s) is/are correct?

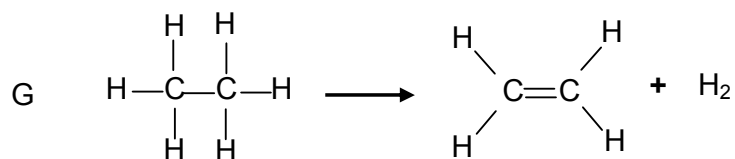
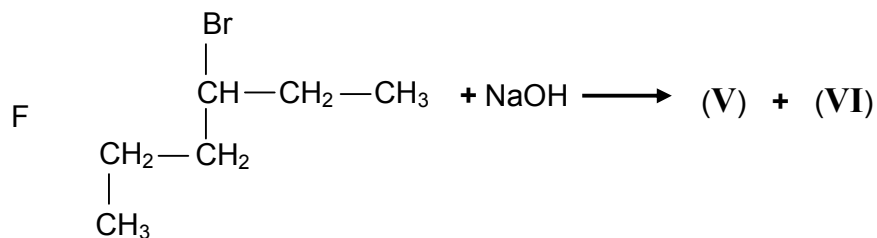
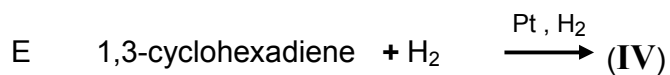
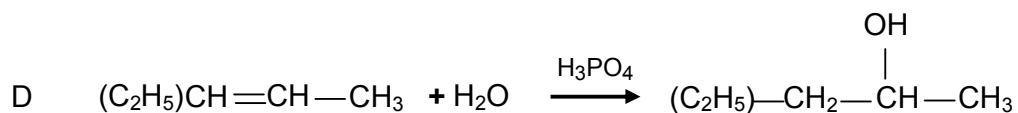
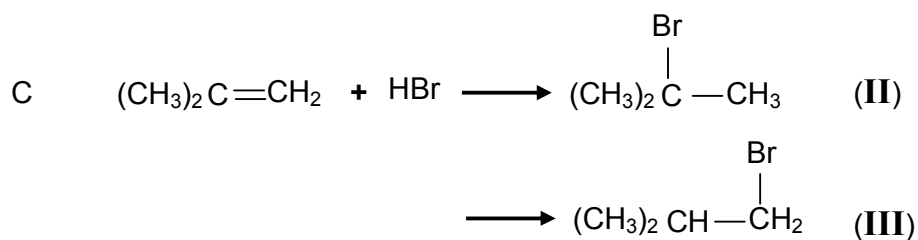
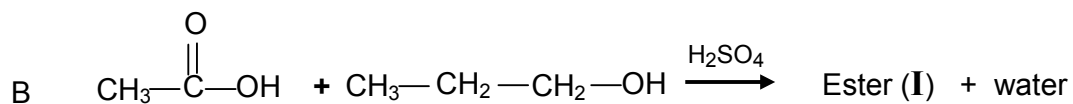
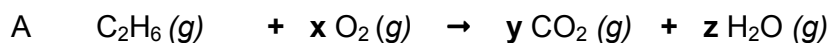
- A Only I
 - B II and III
 - C I, II and III
 - D Only III (2)
- [10]**

TOTAL FOR SECTION A: 25

SECTION B

QUESTION 4

The questions in Question 4 all refer to the following organic chemical reactions.



- 4.1 The seven reactions labelled A to G represent some basic reactions of organic compounds. Select one example for each of the following reaction types. Write down only the letter that refers to the following reactions:
- 4.1.1 substitution (2)
 - 4.1.2 condensation (2)
 - 4.1.3 oxidation (2)
 - 4.1.4 hydration (2)
- [8]
- 4.2 The process of “thermal cracking” is used in oil refineries. Long-chain hydrocarbons are broken by heating crude oils in the absence of air to produce shorter hydrocarbon molecules. Cracking also leads to the production of unsaturated hydrocarbons.
- 4.2.1 Which of reactions A to G could occur during the cracking of crude oil? Write down only the letter labelling the relevant reaction. (2)
 - 4.2.2 What method is used to separate molecules of different molecular mass and molecular properties formed during the cracking process? (1)
 - 4.2.3 In which reaction might the method of “reflux” be used? (1)
- [4]
- 4.3 During all chemical reactions the reactants and products react in fixed, whole number proportions.
- 4.3.1 Balance Reaction A and show clearly the values of **x**, **y** and **z**. (3)
 - 4.3.2 What process does Reaction A represent? (1)
 - 4.3.3 If the reaction takes place in an excess of oxygen in which exactly 24 g of methane reacts completely, what volume of carbon dioxide gas will be recovered as a product when the conditions are adjusted to S.T.P.? (4)
- [8]
- 4.4 Many chemical reactions will not take place under “normal” conditions unless a catalyst is used to promote the reaction.
- 4.4.1 Define the term catalyst. (2)
 - 4.4.2 What chemical species is active in promoting the reaction in an acid-catalysed reaction? (It could be a molecule, an atom or an ion.) (1)
 - 4.4.3 Which two of the above reactions (A–G) are acid catalysed? Write down only the letters of the relevant reactions. (2)

- 4.4.4 Which of the above reactions (A–G) uses a surface catalyst? Write down only the letter of the relevant reaction. (1) [6]
- 4.5 Hydrogenation of vegetable oils is used in the food industry to make the well-known butter substitute margarine.
- 4.5.1 Use the words *saturated*, *unsaturated*, *addition* and *double bond* in a short description of what happens to an organic molecule that is hydrogenated. (2)
- 4.5.2 Explain why liquid plant oils become low melting point solids when they are hydrogenated. (3)
- 4.5.3 Reaction E represents a hydrogenation reaction. Write the IUPAC name of the product (**IV**) if the reactant is completely hydrogenated. (3)
- 4.5.4 Can 1,5-cyclohexadiene be an isomer of 1,3-cyclohexadiene? Explain your answer. (3) [11]
- 4.6 Esters, such as the product in Reaction B, are used in the food industry as flavourings. These are not entirely artificial since esters produced by certain plants are often responsible for the plant's characteristic flavour.
- 4.6.1 Water is produced in Reaction B when H^+ and OH^- bond. Does the OH^- come from reactant alcohol or the reactant carboxylic acid? (1)
- 4.6.2 Give the IUPAC name of the carboxylic acid used in Reaction B. (1)
- 4.6.3 Give the IUPAC name of a lowest molecular mass carboxylic acid that will have a lower vapour pressure than the acid used in Reaction B. Give a reason for your answer. (2)
- 4.6.4 Give the structural molecular formula of the ester (**I**) produced in Reaction B and give its IUPAC name. (5) [9]
- 4.7 Reaction C represents an addition reaction known as hydrohalogenation.
- 4.7.1 What is the basic requirement for addition reactions to occur in organic molecules? (2)
- 4.7.2 Theoretically the product in Reaction C could be either molecule (**II**) or molecule (**III**). Explain why it is (**II**). (3)
- 4.7.3 Give the IUPAC name for molecule (**II**). (2) [7]

4.8 The terms “isotope” and “isomer” are often confused.

4.8.1 Distinguish between an *isotope* and a *structural isomer*. (3)

4.8.2 In Reaction D one of the possible products is the one shown. However, a second product, which is a structural isomer of the first, will also be formed. Draw condensed structural formulae for the two isomers and write the correct IUPAC names next to each. (4)

[7]

4.9 Name products (V) and (VI) in Reaction E and give correct IUPAC names for any organic molecules formed. (4)

[4]

[64]

QUESTION 5

[PLEASE NOTE: THE SECTION ON BOND ENERGIES IS NOT PRESCRIBED FOR GRADE 12 THIS YEAR. HOWEVER, THE QUESTION IS RETAINED IN THIS SAMPLE PAPER AS IT ILLUSTRATES THE IMPORTANT, BASIC CHEMICAL CONCEPT OF BOND ENERGIES.]

During all chemical reactions bonds are broken and formed and, depending on the relative bond energies, a net amount of energy is either taken from or released to the surroundings. Read the following account about modern rocket fuel and answer the questions that follow.



CRYOGENIC PROPELLANTS

Cryogenic propellants are liquid oxygen (LOX), which is an **oxidiser**, and liquid hydrogen (LH₂), which is a **fuel**. The word cryogenic is a derivative of the Greek *kyros*, meaning "ice cold." LOX remains in a liquid state at temperatures of -183 °C.

LH₂ remains liquid at temperatures of -253 °C. In gaseous form, oxygen and hydrogen have such low densities that extremely large tanks would be required to store them aboard a rocket. But cooling and compressing them into liquids vastly increases their density, making it possible to store them in large quantities in smaller tanks.

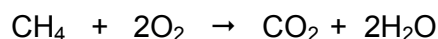
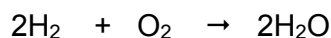
The high efficiency of the liquid hydrogen/liquid oxygen combination makes the problem of maintaining extremely low temperatures a problem worth coping with. Hydrogen gives about 40% more energy than other rocket fuels for its mass. It is very light, weighing only about 0.6 N per litre. Oxygen is much heavier, weighing about 12 N per litre. An additional advantage of LH₂ and LOX is that they burn “clean” and leave a by-product of water vapour only.

The ability to use hydrogen as a fuel means that a mission can be accomplished EITHER with smaller quantities of propellants and smaller vehicles OR with larger payloads than are possible when using the same mass of conventional propellants.

A table of bond energies for various bonds involving the elements carbon, hydrogen and oxygen is provided.

Bond	Energy	Bond	Energy
C–C	347	O=O	494
H–H	436	H–O	460
C–O	343	C=O	707
H–C	414		

- 5.1 Using the bond energies (given in $\text{kJ}\cdot\text{mol}^{-1}$) in the table, compare the energies of reaction (ΔH) for the two reactions:



(Assume that all reactants and products are in the gaseous phase.) (5)

- 5.2 Explain the difference between a fuel and an oxidiser. (2)

- 5.3 Calculate the energy output per kilogram for the two fuels in 5.1. (3)

[10]

QUESTION 6

The reaction of the industrial process for the production of ammonia gas is



Reactants and product are in the gaseous phase during the reaction. The data for the yield of ammonia gas under various temperature–pressure conditions are given in the table below.

YIELD OF NH_3 AT EQUILIBRIUM (%)							
	Pressure (atmospheres)						
Temp ($^{\circ}\text{C}$)	10	30	50	100	300	600	1000
200						5,0	
300	14,7	30,3	39,4	52,0	71,0	84,2	92,6
400	3,9	10,2	15,3	25,1	47,0	65,2	79,8
500	1,2	3,5	5,6	10,6	26,4	42,2	57,5
600	0,5	1,4	2,3	4,5	13,8	23,1	31,4
700	0,2	0,7	1,1	2,2	7,3	12,6	12,9

- 6.1 Ammonia is produced in a reaction of nitrogen and hydrogen gases during an exothermic process. The reaction equation for the process is as follows:
- $$\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$$
- 6.1.1 Explain the effect on the equilibrium of running the reaction at high temperature. (3)
- 6.1.2 Will high pressure favour the forward or reverse reaction? Explain your answer. (3)
- 6.1.3 In the industrial process to manufacture ammonia a yield of 42,2% is obtained when the reaction is run at 500 °C and 600 atm (60,8 MPa) pressure. This is less than half the yield that can be obtained at the lower temperature of 300 °C and 1000 atm (101,3 MPa) pressure. Give two reasons why the reaction is run under temperature–pressure conditions that do not give the highest possible yield. (2)
- 6.2 3 moles of nitrogen gas react with 6 moles of hydrogen gas in a reaction vessel with a volume of 2 dm³. An equilibrium is established at 300 K and an analysis shows that 3 moles of NH₃ are present at this equilibrium.
- 6.2.1 Calculate the equilibrium constant K_c at 300 K. (6)
- 6.2.2 Explain how the value of K_c will change when the temperature is raised to 500 K. (3)

[17]

QUESTION 7

Marble is composed mainly of the mineral calcite, which is pure calcium carbonate. Many ancient buildings, particularly in Greece and Italy, were built entirely of marble. With rising levels of pollution in Europe, the phenomenon of acid rain is causing great damage to old buildings. Sulphur dioxide is produced when high sulphur content coal is burnt. When the gas dissolves in atmospheric water vapour, sulphurous acid (H₂SO₃) is formed, which attacks the marble.

- 7.1 What gas is produced when sulphurous acid and calcium carbonate react? (1)
- 7.2 Write a balanced equation for the reaction. (2)
- 7.3 Ronnie and Ronelle are curious about the rate at which the acid will dissolve marble. Their science teacher provides them with a solution of sulphurous acid at a concentration of 0,001 mol dm⁻³ and a small piece of marble with a mass of 2,57 g.
- 7.3.1 State the question that the pair of learners would use to initiate their investigation. (1)

7.3.2 State a hypothesis for this investigation. (1)

7.3.3 Explain the procedure Ronnie and Ronelle would use in their investigation. The apparatus listed below is available to them. Draw a simple diagram to aid your explanation.

Thermometer
Stopwatch
Beaker
Rubber stoppers ("corks")
Rubber tubing
Measuring cylinder
Burette
Distilled water (4)

7.3.4 Name a variable besides temperature that should be controlled during the investigation. (1)

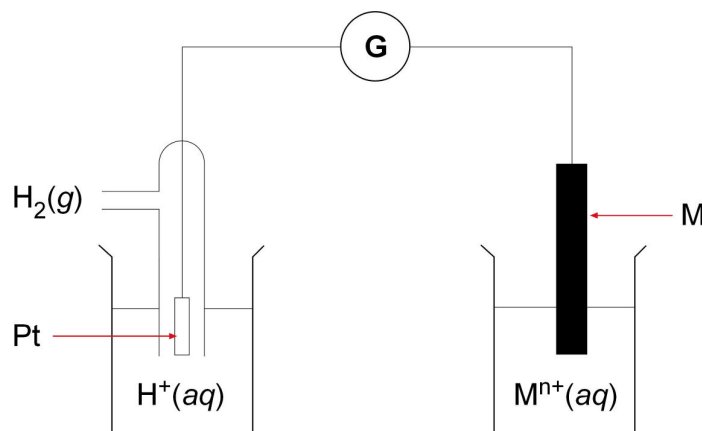
7.3.5 Once the investigation is complete, what information will the investigators have? (1)

7.3.6 What additional data will the investigators need to extrapolate their results to a real-life situation in southern Europe? (1)

[12]

QUESTION 8

The diagram below represents part of an electrochemical cell consisting of a standard hydrogen cell and a metal electrode in contact with a standard solution of its own ions.



8.1 What is the advantage of using a "centre-zeroing" galvanometer instead of a voltmeter in the circuit? (1)

8.2 What addition must be made to the apparatus before the galvanometer will show a flow of charge? (1)

- 8.3 If the galvanometer needle deflects to the left when the metal/metal ion half cell is Fe/Fe^{2+} , in which direction will it deflect for the following half cells?
- 8.3.1 Mg/Mg^{2+} (1)
- 8.3.2 Pb/Pb^{2+} (1)
- 8.4 If a new M/M^{n+} half cell is connected and the emf is 0,80 V, what metal is now being used? (1)
- 8.5 The standard hydrogen electrode is now replaced by the Fe/Fe^{2+} electrode.
- 8.5.1 Describe what will occur at the anode. (2)
- 8.5.2 Write down the equation for the whole-cell reaction. (2)
- 8.5.3 Calculate the initial emf of this electrochemical cell at standard conditions. (3)
- 8.6. If the cell is left connected, a voltmeter will show that the emf of the electrochemical cell decreases with time. Explain this observation with reference to standard conditions. (2)

[15]

QUESTION 9

The information on the table below compares three kinds of electrolytic cells used in the production of chlorine and caustic soda, both of which are very important reactants in a variety of industrial processes.

Examine the table and answer the questions as numbered.

	Membrane	Diaphragm	Mercury
Reactant	Concentrated brine (NaCl) solution	Concentrated brine (NaCl) solution	Concentrated brine (NaCl) solution
Products	Cl_2 gas H_2 gas and [9.1]	Cl_2 gas H_2 gas and [9.1]	(1) Cl_2 gas; Na metal (2) H_2 gas and [9.1] [[2] is the decomposer reaction in 9.3]
[9.2.1]	$2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$	$2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$	$2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$
[9.2.2]	$\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$	$\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$	$\text{Na}^+ + \text{e}^- \rightarrow \text{Na}$
Decomposer reaction	-	-	[9.3]
Environmental hazards	None	[9.4.1]	[9.4.2]

- 9.1 What is the correct chemical name for the caustic soda produced in the three electrolytic cells? (1)
- 9.2 Name the electrodes at which the reactions in 9.2.1 and 9.2.2 take place.(2 x 1 = 2)
- 9.3 Write down a balanced equation for the reaction that takes place in the decomposer. (2)
- 9.4 Name the environmental hazards associated with
- 9.4.1 the diaphragm cell (1)
- 9.4.2 the mercury cell. (1)
- [7]**

TOTAL FOR SECTION B: 125

GRAND TOTAL: 150

DATA FOR MATRIC PHYSICAL SCIENCE

PAPER 2 (CHEMISTRY)

TABLE 1: PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
<i>Standard pressure</i>	p^θ	$1,013 \times 10^5 \text{ Pa}$
<i>Molar gas volume at STP</i>	V_m	$22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
<i>Standard temperature</i>	T^θ	273 K

TABLE 2: FORMULAE

$n = \frac{m}{M}$	$c = \frac{n}{V}$
$c = \frac{m}{MV}$	$E_{\text{cell}}^\theta = E_{\text{cathode}}^\theta - E_{\text{anode}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{reduction}}^\theta - E_{\text{oxidation}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{oxidising agent}}^\theta - E_{\text{reducing agent}}^\theta$

TABLE 3: THE PERIODIC TABLE OF ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
(I)	(II)											(III)	(IV)	(V)	(VI)	(VII)	(VIII)
1 1,01 H												5 2,02 B	6 2,05 C	7 0,03 N	8 3,05 O	9 4,00 F	2 4 He
3 0,10 Li	4 5,05 Be											13 1,50 Al	14 1,80 Si	15 1,20 P	16 2,50 S	17 3,00 Cl	18 35,5 Ar
11 0,90 Na	12 2,00 Mg											27 1,50 Co	28 1,80 Fe	29 1,20 Ni	30 2,50 Cu	31 3,00 Zn	32 40 Ga
19 0,80 K	20 0,10 Ca	21 0,10 Sc	22 5,05 Ti	23 5,05 V	24 0,10 Cr	25 1,00 Mn	26 0,10 Fe	27 0,10 Co	28 0,10 Ni	29 0,10 Cu	30 0,10 Zn	31 0,10 Ga	32 0,10 Ge	33 0,10 As	34 0,10 Se	35 0,10 Br	36 0,10 Kr
37 0,80 Rb	38 0,10 Sr	39 0,10 Y	40 0,10 Zr	41 0,10 Nb	42 0,10 Mo	43 0,10 Tc	44 0,10 Ru	45 0,10 Rh	46 0,10 Pd	47 0,10 Ag	48 0,10 Cd	49 0,10 In	50 0,10 Sn	51 0,10 Sb	52 0,10 Te	53 0,10 I	54 0,10 Xe
55 0,70 Cs	56 0,10 Ba	57 0,10 La	72 0,10 Hf	73 0,10 Ta	74 0,10 W	75 0,10 Re	76 0,10 Os	77 0,10 Ir	78 0,10 Pt	79 0,10 Au	80 0,10 Hg	81 0,10 Tl	82 0,10 Pb	83 0,10 Bi	84 0,10 Po	85 0,10 At	86 0,10 Rn
87 0,70 Fr	88 0,10 Ra	89 0,10 Ac															

KEY

Atomic number

Electronegativity

Symbol

Approximate relative atomic mass

1 0,70 Fr	2 0,10 Ra	3 0,10 Ac	4 0,10 Ba	5 0,70 Cs	6 0,10 Pb	7 0,10 Sb	8 0,10 Te	9 0,10 I	10 0,10 Xe	11 0,10 Ag	12 0,10 Cd	13 0,10 In	14 0,10 Sn	15 0,10 Sb	16 0,10 Te	17 0,10 I	18 0,10 Xe
19 0,80 K	20 0,10 Ca	21 0,10 Sc	22 5,05 Ti	23 5,05 V	24 0,10 Cr	25 1,00 Mn	26 0,10 Fe	27 0,10 Co	28 0,10 Ni	29 0,10 Cu	30 0,10 Zn	31 0,10 Ga	32 0,10 Ge	33 0,10 As	34 0,10 Se	35 0,10 Br	36 0,10 Kr
37 0,80 Rb	38 0,10 Sr	39 0,10 Y	40 0,10 Zr	41 0,10 Nb	42 0,10 Mo	43 0,10 Tc	44 0,10 Ru	45 0,10 Rh	46 0,10 Pd	47 0,10 Ag	48 0,10 Cd	49 0,10 In	50 0,10 Sn	51 0,10 Sb	52 0,10 Te	53 0,10 I	54 0,10 Xe
55 0,70 Cs	56 0,10 Ba	57 0,10 La	72 0,10 Hf	73 0,10 Ta	74 0,10 W	75 0,10 Re	76 0,10 Os	77 0,10 Ir	78 0,10 Pt	79 0,10 Au	80 0,10 Hg	81 0,10 Tl	82 0,10 Pb	83 0,10 Bi	84 0,10 Po	85 0,10 At	86 0,10 Rn

58 140 Ce	59 141 Pr	60 144 Nd	61 141 Pm	62 150 Sm	63 152 Eu	64 157 Gd	65 159 Tb	66 163 Dy	67 165 Ho	68 167 Er	69 169 Tm	70 173 Yb	71 175 Lu
90 232 Th	91 231 Pa	92 238 U	93 238 Np	94 238 Pu	95 238 Am	96 238 Cm	97 238 Bk	98 238 Cf	99 238 Es	100 238 Fm	101 238 Md	102 238 No	103 238 Lr

TABLE 4A: STANDARD REDUCTION POTENTIALS

Half-reactions		E^0 (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
$2H^+ + 2e^- \rightleftharpoons H_2(g)$		0,00
$Fe^{3+} + 3e^- \rightleftharpoons Fe$		- 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
$Mg^{2+} + 2e^- \rightleftharpoons Mg$		- 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

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TABLE 4B: STANDARD REDUCTION POTENTIALS

Half-reactions		E^{θ} (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
$\text{Hg}^{2+} + 2\text{e}^{-} \rightleftharpoons \text{Hg}(\ell)$		+ 0,85
$\text{NO}_3^{-} + 4\text{H}^{+} + 3\text{e}^{-} \rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}$		+ 0,96
$\text{Br}_2(\ell) + 2\text{e}^{-} \rightleftharpoons 2\text{Br}^{-}$		+ 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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