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ST JOHN'S COLLEGE

Paper 2 - CHEMISTRY

Upper V Physical Science

Examiner: G Hingle

Time: 3 hours

Moderator: P Wright

Total: 200

July 2020

Name: _____

Please circle your teacher's initials:

JCT	NS	KM^cN	GH	RM	ICT
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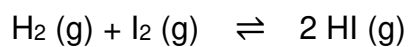
- 1) The paper consists of 14 pages of questions including this cover page. 3 pages of data sheet are provided as well as 2 pages of answer sheet for questions 1 (multiple choice) and 2.1 and graph paper for question 3.1.4.
- 2) Start a new question on a new page in the answer book.
- 3) Calculators may be used.
- 4) Round off to 2 decimal places where appropriate.

Multiple Choice – Choose the correct answer and record your answer on the answer sheet

- 1.1 Electronegativity is defined as
- A) a measure of the tendency of an atom to attract the non-bonding electron pair.
 - B) a measure of the tendency of the electron pair to be attracted to the non-metal atom.
 - C) a measure of the tendency of an atom to attract a bonding pair of electrons.
 - D) a measure of the tendency of the non-metal atom to attract the metal atom electron in the bond of molecule. (2)
- 1.2 Alkanes and alkenes exhibit
- A) only London intermolecular forces
 - B) London and dipole-dipole intermolecular forces only.
 - C) London, dipole-dipole and hydrogen bonding
 - D) Dipole-dipole and hydrogen bonding only (2)
- 1.3 Nickel powder is placed into 3 different aqueous solutions - Copper (II) chloride, Iron (II) chloride and silver (I) nitrate. The nickel powder undergoes a redox reaction in:
- A) none of the solutions
 - B) only the copper (II) chloride solution
 - C) only the copper (II) chloride and the iron(II) chloride solutions.
 - D) only the copper (II) chloride and the silver (I) nitrate solutions. (2)
- 1.4 When added to a system at equilibrium, a catalyst:
- A) has no effect on the rates of the reactions.
 - B) speeds up the forward reaction.
 - C) causes the equilibrium to favour the forward reaction.
 - D) causes the system to temporarily favour the exothermic reaction before re-establishing equilibrium. (2)

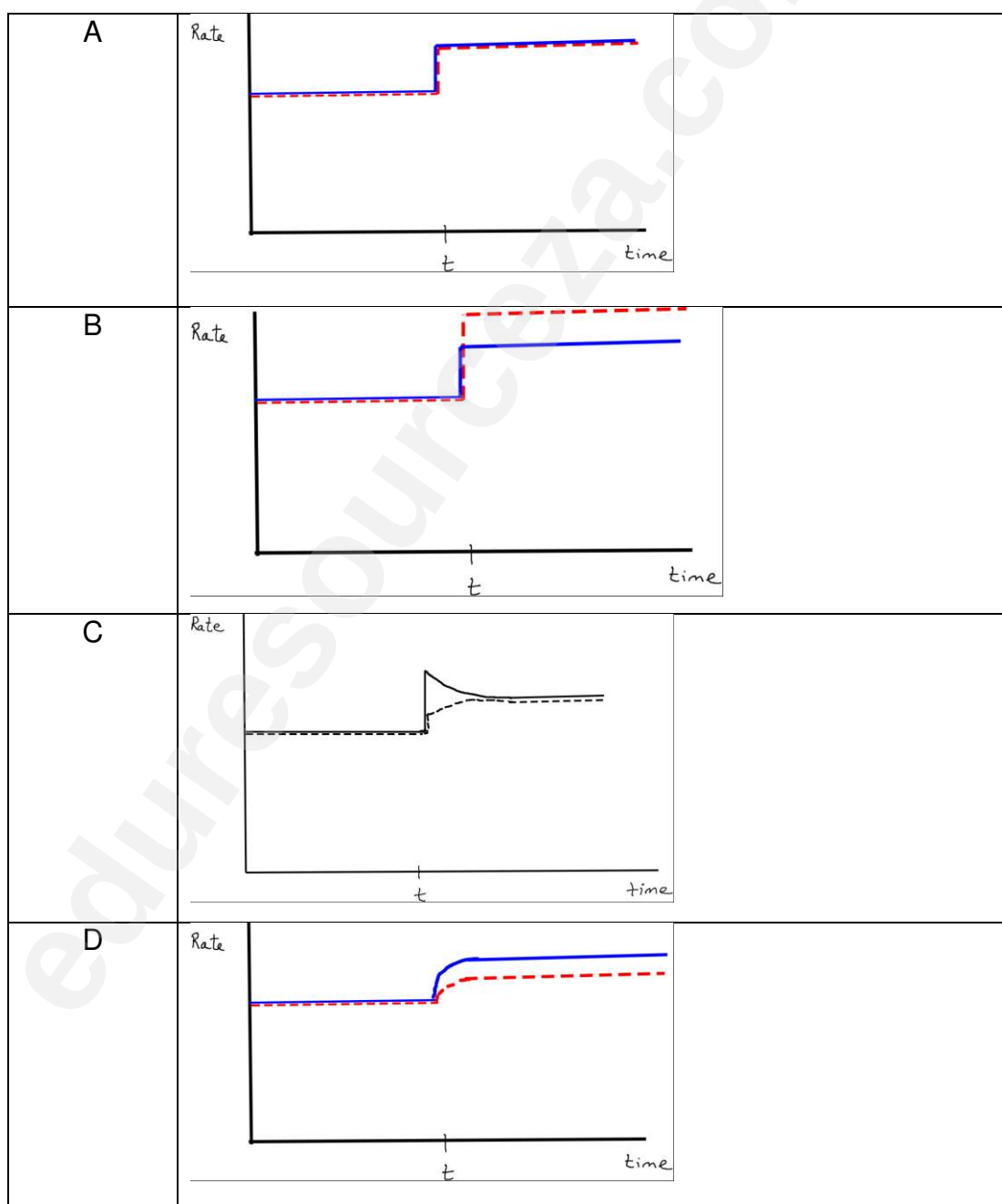
- 1.5 Increasing the temperature for a system at equilibrium
- A) speeds up the endothermic reaction and slows down the exothermic reaction.
 - B) speeds up the exothermic reaction and slows down the endothermic reaction
 - C) speeds up both the exothermic reaction and the endothermic reaction.
 - D) has no effect on the equilibrium position. (2)
- 1.6 The advantages of the membrane cell over the diaphragm cell are:
- (I) that the sodium hydroxide concentration can be adjusted.
 - (II) that the sodium hydroxide is not contaminated with unreacted NaCl.
 - (III) that the Na^+ ions do not react with the cathode.
- The correct statements are:
- A) I only
 - B) I and II only
 - C) I, II and III only
 - D) II and III only (2)
- 1.7 2-methylbutane and 2-methylpentane are molecules that illustrate the following types of isomerism when compared with each other:
- A) Chain isomerism
 - B) Positional isomerism
 - C) Functional group isomerism
 - D) They do not illustrate isomerism. (2)
- 1.8 When 15 g of $\text{Al}(\text{NO}_3)_3$ is dissolved in 1 dm³ of water, the pH of the resulting solution would be:
- A) 7
 - B) approximately 4-6
 - C) approximately 8-10
 - D) it is impossible to predict as $\text{Al}(\text{NO}_3)_3$ is insoluble in water. (2)

1.10 The following equilibrium is established in a 10 dm³ container.



The pressure of the system is changed by rapidly decreasing the container volume at time t . The solid line represents the forward reaction.

Which rate – time sketch graph best describes the system?:



(2)

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Question 2 – Bonding, Structure and Intermolecular Forces

2.1 Consider the molecules below: (Answers may have more than 1 correct answer.)

<u>Letter</u>	<u>Formula or Name</u>
A	K ₂ SO ₄
B	KI
C	SiO ₂
D	Magnesium
E	Argon
F	NH ₃
G	Water
H	BI ₃
I	SO ₂

Answer Question 2.1.1 – 2.1.7 on the Answer Sheet provided.

Answers may have more than 1 correct answer. Write all the correct answers to a question. Incorrect answers will be penalised. **Write down only the LETTER/S that correctly correspond.**

2.1.1 Exhibits hydrogen bonding between molecules

2.1.2 Conducts electricity in the molten state.

2.1.3 Ionic solid that produces a neutral solution on being dissolved in water.

2.1.4 Atoms that exhibit London forces.

2.1.5 Molecule that forms a weak acid in aqueous solution.

2.1.6 A small non-polar molecule.

2.1.7 A giant covalent molecule that exhibits a high melting point. (10)

2.2 Cl₂ molecules exhibit London forces between the molecules. Explain how these forces come about between molecules and how these molecules interact with each other. Use bullet points to organise your explanation. (4)

Please turn over to complete the question.

2.3 Consider the molecules below:

butanoic acid	$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & \\ & & & & & & \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - \text{C} - \text{O} - \text{H} \\ & & & & & & \\ & \text{H} & & \text{H} & & \text{H} & \\ & & & & & & \parallel \\ & & & & & & \text{O} \end{array} $
propyl methanoate	$ \begin{array}{ccccccc} & \text{O} & & & & \text{H} & \text{H} & \text{H} \\ & \parallel & & & & & & \\ \text{H} & - \text{C} & - \text{O} & - & \text{C} & - & \text{C} & - \text{C} - \text{H} \\ & & & & & & & \\ & & & & \text{H} & & \text{H} & \text{H} \end{array} $

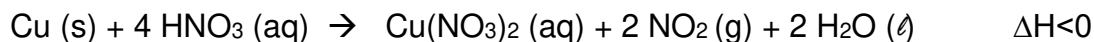
2.3.1 Predict which of these molecules will have the higher boiling point. (1)

2.3.2 Carefully explain your reasoning for your answer in 2.3.1. (4)

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Question 3 – Rates of reaction

- 3.1 The reaction of copper metal with concentrated nitric acid reacts according to the following balanced reaction:



The reaction rate is going to be investigated by the collection of NO₂ gas.

- 3.1.1 Is this a redox reaction? Explain your answer by referring to the equation. (2)
- 3.1.2 Define reaction rate. (2)
- 3.1.3 Sketch a labelled diagram that shows the method you would use to collect the gas. Name the apparatus that is being used to collect the gas. (4)
- 3.1.4 The data collected from the experiment is shown in the table below:

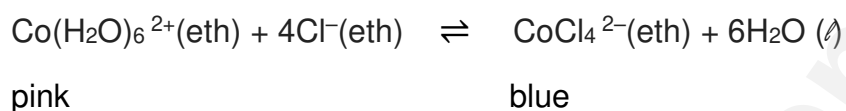
Time (s)	Total volume of NO ₂ gas collected (cm ³)
0	0
5	1
10	3
15	6
20	10
30	18
40	26
50	34
60	42
70	45
75	46

- Complete the graph on the graph paper provided on the answer sheet. (6)
- 3.1.5 Calculate the average rate of reaction for the period 0 - 15 seconds (3)
- 3.1.6 Explain why the rate is changing over the period 0 - 15 seconds. (3)
- 3.1.7 Compare the average rate of reaction for the period 0 - 15 seconds and the period 30 - 50 seconds. During which time period is the average rate faster? (2)

[22]

Question 4 – Equilibrium

The following dynamic chemical equilibrium is being investigated in the laboratory.



The cobalt salt is dissolved in ethanol, and water is added slowly until the solution goes maroon.

- 4.1 Define the term: dynamic chemical equilibrium. (2)
- 4.2 Concentrated hydrochloric acid is added to the solution.
 - 4.2.1 State Le Chatelier's principle. (2)
 - 4.2.2 Use Le Chatelier's principle to predict the colour change that would be observed on adding concentrated hydrochloric acid. (3)
- 4.3 The solution is heated and colour becomes more pink.
 - 4.3.1 Is the forward reaction exothermic or endothermic? (1)
 - 4.3.2 Explain your reasoning. (3)
- 4.4 Initially 0.300 mole of $\text{Co}(\text{H}_2\text{O})_6^{2+}$ and 1,000 mole of Cl^- is dissolved into ethanol to make 500 cm^3 of solution.
 - 4.4.1 Use the formula:
$$K_c = \frac{[\text{CoCl}_4^{2-}] \cdot [\text{H}_2\text{O}]^6}{[\text{Co}(\text{H}_2\text{O})_6^{2+}] \cdot [\text{Cl}^-]^4}$$

If there are 5×10^{-3} moles of CoCl_4^{2-} at equilibrium, then calculate the K_c value for this equilibrium. (7)
 - 4.4.2 The theoretical K_c value for this equilibrium is $8,7 \times 10^{-10}$ at 25°C . Why was the calculated K_c different from the stated K_c value? (1)
 - 4.4.3 Water is usually not placed into the K_c expression. Explain why it is correct to use water in the expression for this equilibrium. (2)

[21]

Question 5 – Acids and Bases

- 5.1 A solution of $0,2 \text{ mol} \cdot \text{dm}^{-3}$ LiOH solution needs to be prepared.
- 5.1.1 Calculate the mass of LiOH that must be dissolved to make 500 cm^3 of solution. (4)
- 5.1.2 State the approximate pH of this solution. (1)
- 5.2 The solution of LiOH could be considered a dilute solution of strong base.
- 5.2.1 Explain the underlined term: base. (2)
- 5.2.2 Explain the underlined term: strong base. (2)
- 5.2.3 Explain the underlined term: dilute solution of base. (2)
- 5.2.4 Would you expect the solution to be a good electrolyte? Explain your answer. (3)
- 5.3 A solution of sulphuric acid is titrated against the LiOH solution.
- Write down the overall balanced equation for this reaction. (3)
- 5.4 Ethanoic acid (CH_3COOH) is added to water to form an aqueous solution,
- 5.4.1 Write out the ionisation reaction for ethanoic acid - include phase symbols. (3)
- 5.4.2 Define the term: amphoteric. (2)
- 5.4.3 Identify an amphoteric substance in this reaction. (1)
- 5.4.4 Identify the conjugate acid-base pairs from the ionisation of ethanoic acid in water. (4)
- 5.4.5 Would this solution have a relatively high or low conductivity when compared with a solution of similar concentration of HCl? Explain. (2)

Please turn over to continue the question

- 5.5 Chemists are testing the purity of magnesium supplements. The magnesium supplement contains magnesium carbonate and the tablet is claimed by the manufacturer to be at least 80% pure magnesium carbonate.

The chemist places 2 tablets into a beaker. The mass of each tablet is exactly 5,0 g.

He then adds excess hydrochloric acid to the beaker and the tablets react. He adds exactly 120 cm³ of 2,00 mol·dm⁻³ HCl to the beaker.

The balanced chemical reaction is:



He then titrates any unreacted HCl with NaOH, and finds that exactly 44,10 cm³ of 1,00 mol·dm⁻³ NaOH neutralises the unreacted HCl.

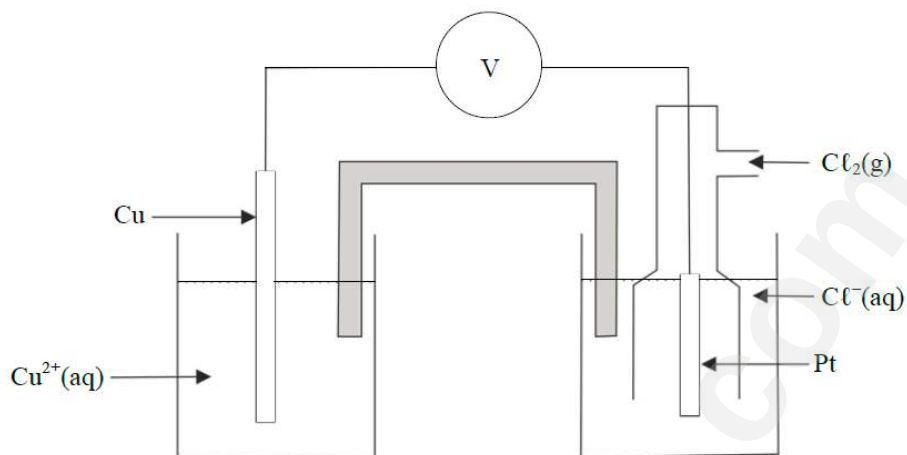


- 5.5.1 Calculate the number of moles of HCl added to the tablets. (2)
- 5.5.2 Calculate the number of moles of HCl that reacted with the tablets. (3)
- 5.5.3 Calculate the percentage purity of the magnesium supplements and comment on the manufacturer's claim. (5)

[39]

Question 6 – Redox

The following cell was set up under standard conditions.

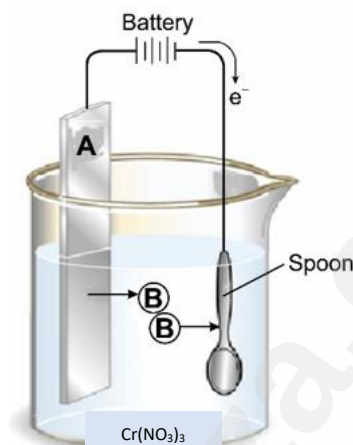


- 6.1 Define the term anode. (2)
- 6.2 Define the term reducing agent. (2)
- 6.3 State the standard conditions for this cell. (3)
- 6.4.1 Write down the oxidation half-reaction. (2)
- 6.4.2 Write down the reduction half-reaction. (2)
- 6.4.3 Write down the net ionic reaction for this cell. (2)
- 6.5 Calculate the E^0_{cell} value for this cell. (3)
- 6.6 How would the following changes affect the voltage of the cell when compared with the calculated E^0_{cell} value?
State only INCREASE, DECREASE or NO EFFECT.
- 6.6.1 Increase the concentration of Cu^{2+} ions. (2)
- 6.6.2 Decrease the pressure of Cl_2 gas. (2)
- 6.6.3 Replace the salt bridge with one that is shorter and which contains a more concentrated solution. (2)
- 6.7 What observations would be made at
- 6.7.1 the copper electrode? (1)
- 6.7.2 in the copper half-cell? (1)
- 6.8 Would it be correct to say that the cathode gains mass for this cell? Explain. (3)

[27]

Question 7 – Industrial Processes

The diagram below shows the chrome plating of an old spoon. Chrome plating gives a very shiny mirror finish and used to be used extensively on items like decorative mirrors and fittings.



The spoon is suspended in an aqueous solution of $\text{Cr}(\text{NO}_3)_3$.

- 7.1 Is the spoon the anode or the cathode? Explain (3)
- 7.2 Write down the half-reaction that takes place at the spoon. (2)
- 7.3 Identify A and B? (2)
- 7.4 Explain why A cannot be graphite? (3)
- 7.5 If the operator of the cell runs the cell with a current of 1 A for 20 minutes, calculate the mass of chromium that will deposit on the spoon. (5)
- 7.6 Explain why a metal like chromium can be electroplated in this way, but why magnesium would not be successfully plated. (3)

[18]

Question 8 – Organic Chemistry

Consider the molecules listed in the table below:

a) <pre> H H H H — C — C — C = C — C — H H H H </pre>	d) <pre> CH₃ — CH — CH₂ — CH₂ — CH₂ — CH₃ OH </pre>
b) <pre> H H H H H H Br — C — C — C — C — C — H H H H H H H — C — H H </pre>	e) ethyl propanoate
c) <pre> CH₃ — CH₂ — C — OH O </pre>	f) pentanoic acid

8.1 Define the following terms:

8.1.1 Hydrocarbon (2)

8.1.2 Functional group (2)

8.1.3 Structural Isomer (2)

8.2 Identify the functional group of molecule

8.2.1 (c)

8.2.2 (d) (4)

8.3.1 Name a positional isomer for molecule (a) and explain why the molecule you have named is a positional isomer. (3)

8.3.2 Write down the balanced reaction for the complete combustion of molecule (a). (Use a molecular formula for molecule (a) in your equation.) (4)

- 8.4 Molecule (a) reacts with HCl gas.
- 8.4.1 State the type of reaction that takes place. (1)
- 8.4.2 Name the specific type of reaction that takes place. (1)
- 8.5 Molecule (b) reacts with KOH in aqueous solution.
- 8.5.1 State the type of reaction that takes place. (1)
- 8.5.2 Name the organic product of this reaction. (3)
- 8.5.3 What product would form if ethanol were used as the solvent for KOH instead of water? (1)
- 8.5.4 What type of reaction would occur if ethanol were used as the solvent for KOH instead of water? (1)
- 8.6 Compare the molecules (d) and (e): The molecules have very similar molecular mass.
- State which of the molecules has the higher boiling point, and explain why its boiling point is higher. (4)
- 8.7 Molecule (d) is reacted with concentrated H_2SO_4 and gently warmed.
- 8.7.1 State the type of reaction that takes place. (1)
- 8.7.2 Write down the condensed structural formula of the product that is formed. (3)
- 8.7.3 What is the function of the H_2SO_4 in this reaction. (1)

[34]

2020 Physical Science Prelim Paper 2 Chemistry

ANSWER SHEET

Name _____

Teacher

Question 1 – Write down only the letter of the correct answer

1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.10

[20]

Question 2.1 – Write down the appropriate letter / letters

<u>Question Number</u>	<u>Answer</u>
2.1.1	
2.1.2	
2.1.3	
2.1.4	
2.1.5	
2.1.6	
2.1.7	

[10]

Volume of gas

Time

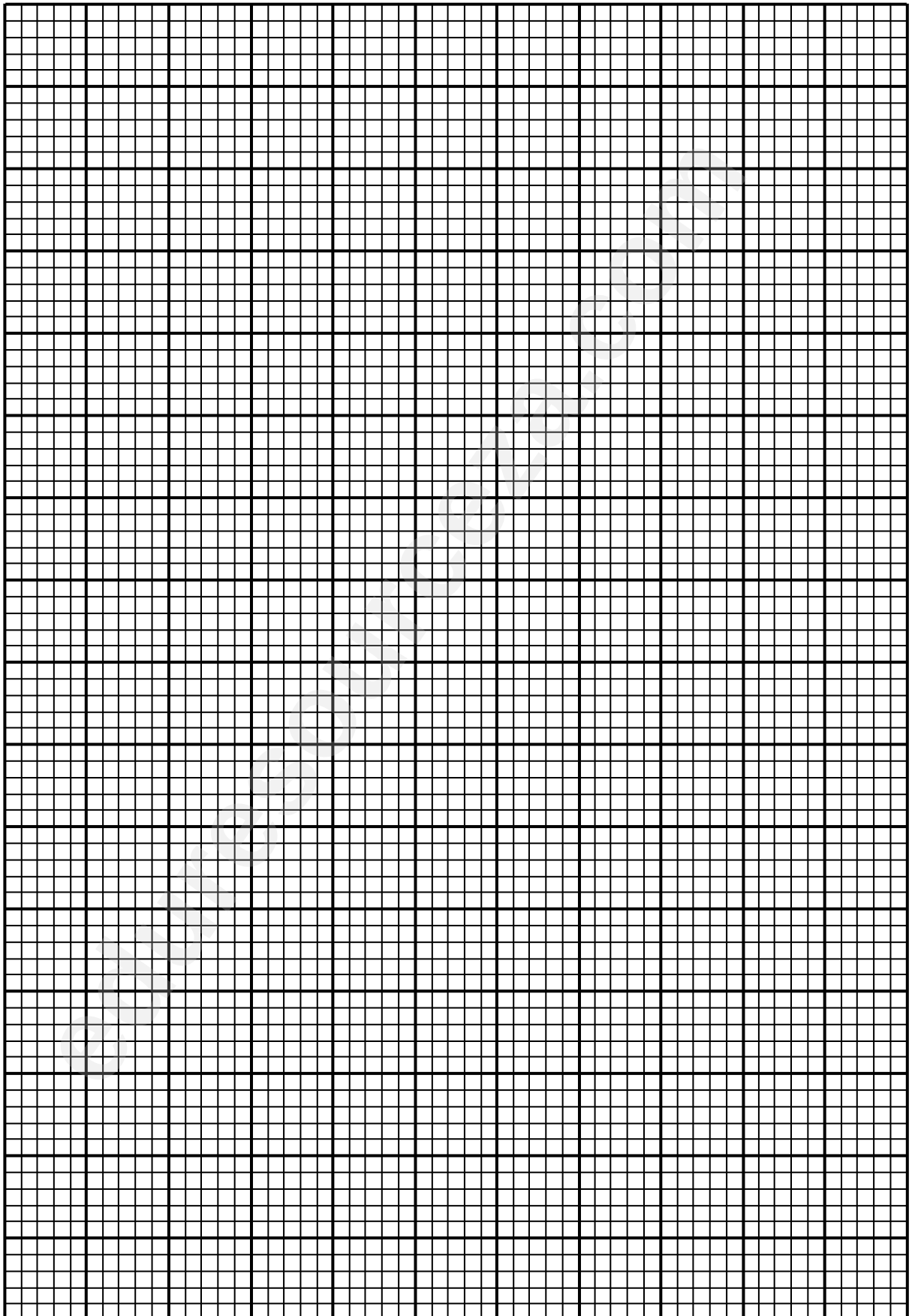


TABLE 1 PHYSICAL CONSTANTS

NAME	SYMBOL	VALUE
Magnitude of charge on electron	e	$1,6 \times 10^{-19} \text{ C}$
Mass of an electron	m_e	$9,1 \times 10^{-31} \text{ kg}$
Standard pressure	p^θ	$1,01 \times 10^5 \text{ Pa}$
Molar gas volume at STP	V_m	$22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$
Standard temperature	T^θ	273 K
Avogadro's constant	N_A	$6,02 \times 10^{23} \text{ mol}^{-1}$
Faraday's constant	F	$96\,500 \text{ C} \cdot \text{mol}^{-1}$

TABLE 2 CHEMISTRY FORMULAE

$n = \frac{m}{M}$	$n = \frac{N}{N_A}$	$n = \frac{V}{V_m}$
$c = \frac{n}{V}$ OR $c = \frac{m}{MV}$	$K_w = [H_3O^+] \cdot [OH^-] = 1 \times 10^{-14}$ at 25 °C (298 K)	
$q = It$ $q = nF$	$E_{\text{cell}}^\theta = E_{\text{cathode}}^\theta - E_{\text{anode}}^\theta$ $E_{\text{cell}}^\theta = E_{\text{oxidising agent}}^\theta - E_{\text{reducing agent}}^\theta$	

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TABLE 4 STANDARD ELECTRODE POTENTIALS

Half-reaction			E°/volt
$\text{Li}^+ + \text{e}^- \rightleftharpoons \text{Li}$			-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
$\text{Mg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mg}$			-2,37
$\text{Al}^{3+} + 3\text{e}^- \rightleftharpoons \text{Al}$			-1,66
$\text{Mn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Mn}$			-1,18
$2\text{H}_2\text{O} + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-$			-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
$\text{Cd}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cd}$			-0,40
$\text{Co}^{2+} + 2\text{e}^- \rightleftharpoons \text{Co}$			-0,28
$\text{Ni}^{2+} + 2\text{e}^- \rightleftharpoons \text{Ni}$			-0,25
$\text{Sn}^{2+} + 2\text{e}^- \rightleftharpoons \text{Sn}$			-0,14
$\text{Pb}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pb}$			-0,13
$\text{Fe}^{3+} + 3\text{e}^- \rightleftharpoons \text{Fe}$			-0,04
$2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$			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
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}$			+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
$\text{I}_2 + 2\text{e}^- \rightleftharpoons 2\text{I}^-$			+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
$\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}$			+0,79
$\text{NO}_3^- + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{NO}_2(\text{g}) + \text{H}_2\text{O}$			+0,80
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$			+0,80
$\text{NO}_3^- + 4\text{H}^+ + 3\text{e}^- \rightleftharpoons \text{NO}(\text{g}) + 2\text{H}_2\text{O}$			+0,96
$\text{Br}_2 + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$			+1,09
$\text{Pt}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pt}$			+1,20
$\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 2\text{H}_2\text{O}$			+1,21
$\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$			+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
$\text{Au}^{3+} + 3\text{e}^- \rightleftharpoons \text{Au}$			+1,42
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$			+1,51
$\text{H}_2\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons 2\text{H}_2\text{O}$			+1,77
$\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-$			+2,87

Increasing oxidising ability

Increasing reducing ability

TABLE 3 PERIODIC TABLE

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Atomic number (Z)						1	Electronegativity										
1	1 H						H											2 He
2	3 Li	4 Be					1						5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		178,5	181	184	186	190	192	195	197	200,6	204,4	207	209	-	-	-
	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu			
	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lw			