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# education

DEPARTMENT: EDUCATION  
MPUMALANGA PROVINCE

**NATIONAL  
SENIOR CERTIFICATE**

**GRADE 12**

**PHYSICAL SCIENCES: CHEMISTRY P2**

**SEPTEMBER 2020**

**MARKS: 150**

**TIME: 3 hours**

## INSTRUCTIONS AND INFORMATION

1. Write your name in the appropriate space on the ANSWER BOOK.
2. This question paper consists of TEN questions. Answer ALL the questions in the ANSWER BOOK.
3. Start EACH question on a NEW page in the ANSWER BOOK.
4. Number the answers correctly according to the numbering system used in this question paper.
5. Leave ONE line between two sub questions, for example between QUESTION 2.1 and QUESTION 2.2.
6. You may use a non-programmable calculator.
7. You may use appropriate mathematical instruments.
8. You are advised to use the attached DATA SHEETS.
9. Show ALL formulae and substitutions in ALL calculations.
10. Round off your final numerical answers to a MINIMUM of TWO decimal places.
11. Give brief motivations, discussions, et cetera where required.
12. Write neatly and legibly.

**QUESTION 1 : 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 only the letter (A – D) next to the question number (1.1 – 1.10) in the ANSWER BOOK , for example, 1.11 E.

1.1 Which ONE of the following organic compounds is an UNSATURATED HYDROCARBON?

A  $C_2H_6$

B  $C_3H_6$

C  $CH_3COOH$

D  $CH_4$

(2)

1.2 An organic compound was mistakenly named as 4,5-diethylpentan-3-ol. What is the correct IUPAC name for this compound?

A 1,2-diethylpentan-3-ol

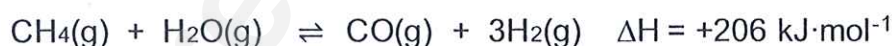
B 4-ethylheptan-5-ol

C 4-ethylheptan-3-ol

D 4-ethylhexan-5-ol

(2)

1.3 The following reaction reaches equilibrium in a closed container

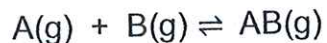


Which ONE of the following changes in temperature and pressure would lead to the greatest yield in the products?

|   | Pressure  | Temperature |
|---|-----------|-------------|
| A | Decreases | Increases   |
| B | Increases | Decreases   |
| C | Increases | Increases   |
| D | Decreases | Decreases   |

(2)

- 1.4 Consider the equation for a hypothetical reaction below.

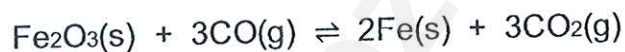


At 70°C, the heat of reaction ( $\Delta H$ ) for this reaction is  $-30 \text{ kJ}\cdot\text{mol}^{-1}$ . At a temperature of 90°C, the heat of reaction ( $\Delta H$ ), in  $\text{kJ}\cdot\text{mol}^{-1}$ , is:

- A -30
- B -10
- C +50
- D -50

(2)

- 1.5 Consider the reaction represented by the following equation:



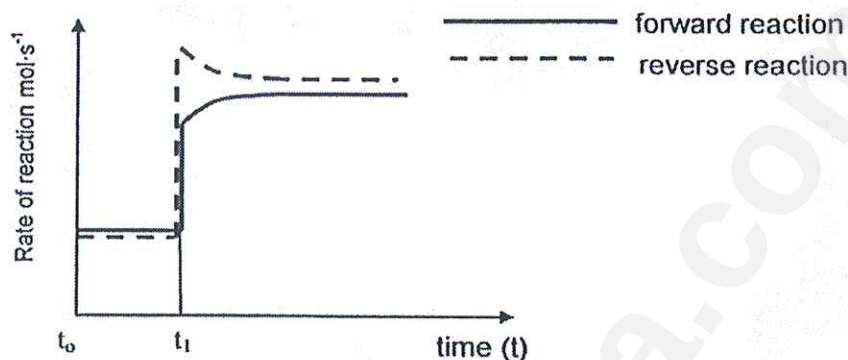
The  $K_c$  expression for this reaction is:

- A  $K_c = [\text{Fe}_2\text{O}_3][\text{CO}]^2$
- B  $K_c = \frac{[\text{Fe}]^2[\text{CO}_2]}{[\text{Fe}_2\text{O}_3][\text{CO}]^2}$
- C  $K_c = \frac{[\text{Fe}]^2[\text{CO}_2]^3}{[\text{Fe}_2\text{O}_3][\text{CO}]^3}$
- D  $K_c = \frac{[\text{CO}_2]^3}{[\text{CO}]^3}$

- 1.6 The reaction represented by the equation below reaches equilibrium in a closed container at time  $t_0$



A change is made to the equilibrium system at time  $t_1$ , as shown in the graph below.



Which ONE of the following describes the change to the equilibrium at  $t_1$  as indicated on the graph?

- A Increase the concentration of  $\text{O}_2(\text{g})$
- B Increase the temperature.
- C Increase in the pressure by decreasing the volume.
- D Increase in the concentration of  $\text{SO}_2(\text{g})$  (2)

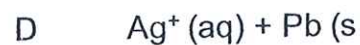
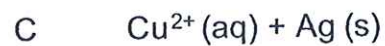
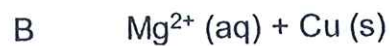
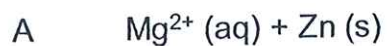
- 1.7 Which ONE of the following species CANNOT act as a Brønsted-Lowry acid and a Brønsted-Lowry base?

- A  $\text{H}_2\text{PO}_4^-$
- B  $\text{H}_2\text{O}$
- C  $\text{HSO}_4^-$
- D  $\text{CH}_3\text{COOH}$  (2)

- 1.8 The process used to deposit a metal onto a conductive object is called:

- A Electrefining
- B Electroextraction
- C Electroplating
- D Neutralisation (2)

1.9 Which ONE of the following pairs will react spontaneously?



(2)

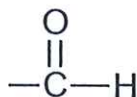
1.10 Which ONE of the following is correct for the industrial preparation of nitric acid?

|   | PROCESS | CATALYST           |
|---|---------|--------------------|
| A | Haber   | Platinum           |
| B | Ostwald | Platinum           |
| C | Contact | Iron               |
| D | Contact | Vanadium pentoxide |

(2)  
[20]

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

- 2.1 The structural formula of a functional group of a certain organic compound is given below.



- 2.1.1 Define the term *functional group*. (2)

Write down the

- 2.1.2 Name of this functional group (1)

- 2.1.3 General formula of the homologous series to which this functional group belongs. (1)

- 2.2 Consider the condensed structural formula of the organic compound below.



The above-mentioned organic compound has one functional isomer.

- 2.2.1 Define the term *functional isomer*. (2)

- 2.2.2 Draw the structural formula of the FUNCTIONAL ISOMER of this compound (2)

The same compound can be prepared in a laboratory.

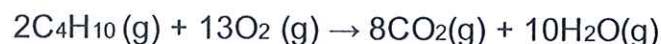
- 2.2.3 Write down the name for this type of reaction. (1)

- 2.2.4 Write down the IUPAC name of the alcohol needed to prepare this compound. (1)

- 2.2.5 Write down two reaction conditions for this reaction. (2)

- 2.2.6 How can one easily identify whether this compound is being formed (1)

- 2.3 A sample of impure butane ( $\text{C}_4\text{H}_{10}$ ) of mass 26 g burns in excess oxygen, 34 g of  $\text{CO}_2$  forms. The balanced equation for this reaction is given below:



- Calculate the percentage purity of the sample of butane. (5)  
[18]

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

Two separate experiments are conducted to determine the boiling points of organic compounds from different homologous series, under the same conditions. The results obtained are shown in the table below.

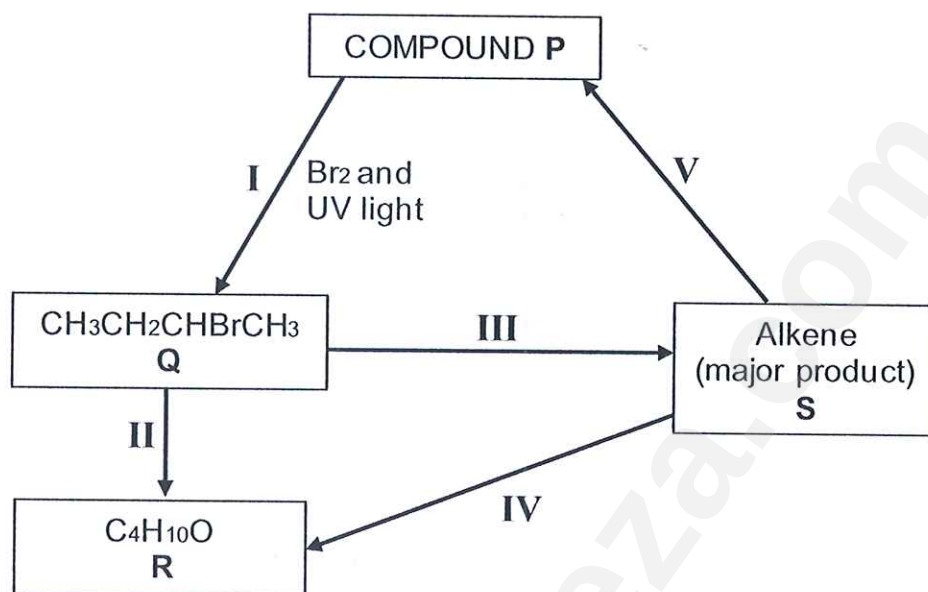
| Experiment | Organic compound |                                                                    | Boiling point (°C) |
|------------|------------------|--------------------------------------------------------------------|--------------------|
| <b>I</b>   | <b>A</b>         | 2,2-dimethylpropane                                                | 9                  |
|            | <b>B</b>         | 2-methylbutane                                                     | 27                 |
|            | <b>C</b>         | Pentane                                                            | 36                 |
| <b>II</b>  | <b>P</b>         | CH <sub>3</sub> CH <sub>2</sub> CH <sub>2</sub> CH <sub>2</sub> OH | 117,7              |
|            | <b>Q</b>         | CH <sub>3</sub> CH <sub>2</sub> COOH                               | 141,2              |

- 3.1 Define the term *homologous series*. (2)
- 3.2 Consider the boiling points of the compounds in Experiment I.
- 3.2.1 Write down the dependent variable for this investigation. (1)
- 3.2.2 Fully explain why the boiling points increases from compound A to compound C. (3)
- 3.3 Use the data in Experiment II to answer the following questions.
- 3.3.1 Formulate an investigative question for this experiment. (2)
- 3.3.2 Explain why compound Q has a higher boiling point than compound P. (4)

**[12]**

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

Consider the following series of organic reactions and answer the questions that follow.



4.1 Write down the TYPE of reaction represented by:

- 4.1.1 I (1)
- 4.1.2 II (1)
- 4.1.3 V (1)

4.2 During reaction III, compound Q reacts with a base to form compound S. Write down:

- 4.2.1 Two reaction conditions for this reaction. (2)
- 4.2.2 The IUPAC name of compound Q. (2)
- 4.2.3 The STRUCTURAL FORMULA of the major product S formed. (2)

4.3 Consider reaction IV. Write down

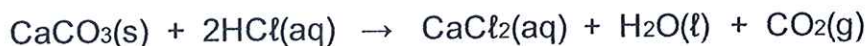
- 4.3.1 The TYPE of addition reaction that take place. (1)
- 4.3.2 The NAME or FORMULA of the catalyst that is used. (1)

4.4 Write down the FORMULA of the INORGANIC product that is formed in reaction II.

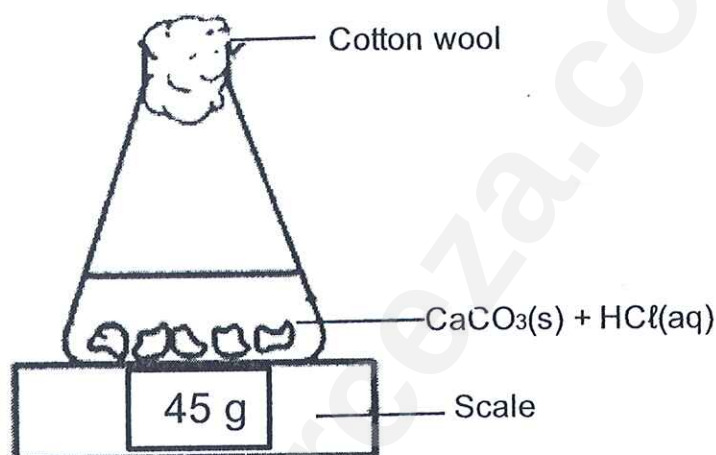
(1)  
[12]

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

A series of experiments are conducted to investigate the effect of changing temperature, concentration and surface area on the rate of reaction between hydrochloric acid and calcium carbonate. The balanced chemical equation for the reaction taking place is:



Each experiment is carried out in a conical flask, which is placed on top of a sensitive digital balance as shown in the diagram below.



The reading on the scale decreases over a period of time.

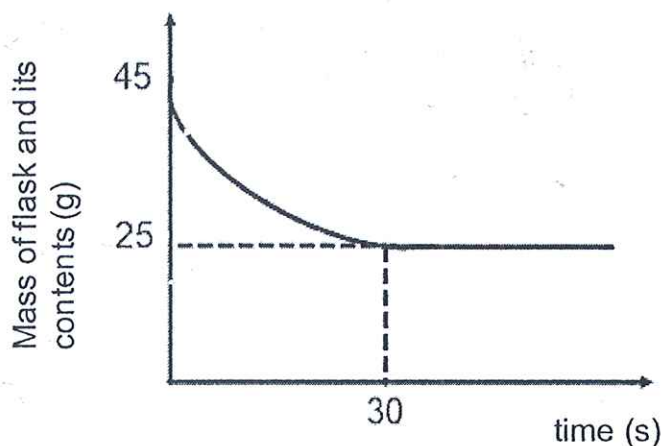
5.1 What is the reason for the decrease in the mass of the flask? (1)

5.2 Define the term *rate of reaction*. (2)

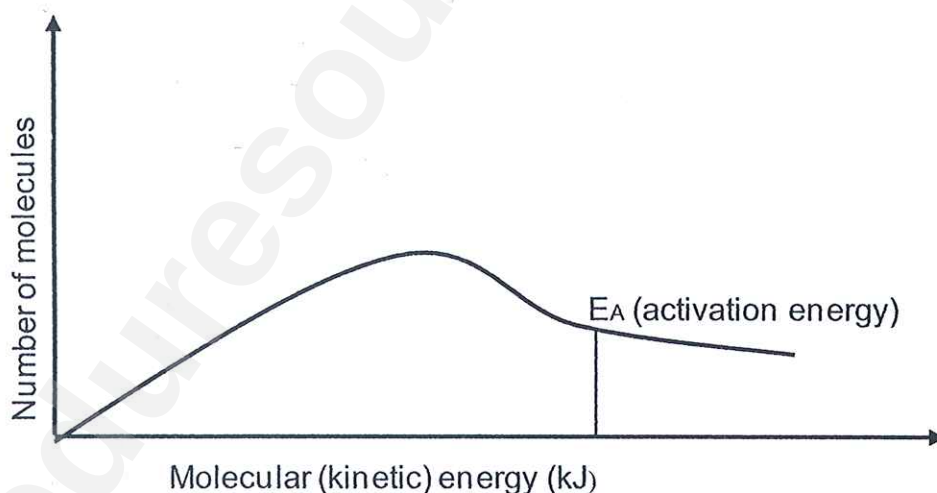
Four different experiments are carried out using the conditions indicated in the table below.

| Experiment | Temperature (°C) | Concentration of HCl (mol·dm <sup>-3</sup> ) | State of CaCO <sub>3</sub> |
|------------|------------------|----------------------------------------------|----------------------------|
| 1          | 20               | 0,1                                          | large pieces               |
| 2          | 15               | 0,1                                          | large pieces               |
| 3          | 20               | 0,1                                          | powder                     |
| 4          | 20               | 0,2                                          | large pieces               |

The results of EXPERIMENT 1 were used to sketch the graph shown below:



- 5.3 Using the graph, calculate the rate of reaction for experiment 1. (3)
- 5.4 Redraw the graph in your answerbook. On the same set of axes draw sketch graphs to represent the results of EXPERIMENT 2 and 3. CLEARLY LABEL EACH GRAPH USING 2 AND 3. (4)
- 5.5 Use the collision theory to explain the difference in rate of reactions between EXPERIMENTS 1 and 4. (4)
- 5.6 The Maxwell-Boltzmann curve below shows the distribution of molecular energies of reacting molecules in the chemical reaction of experiment 1.

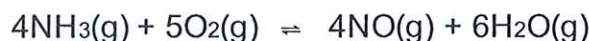


Redraw the graph in your answerbook and draw a new curve that represents experiment 2

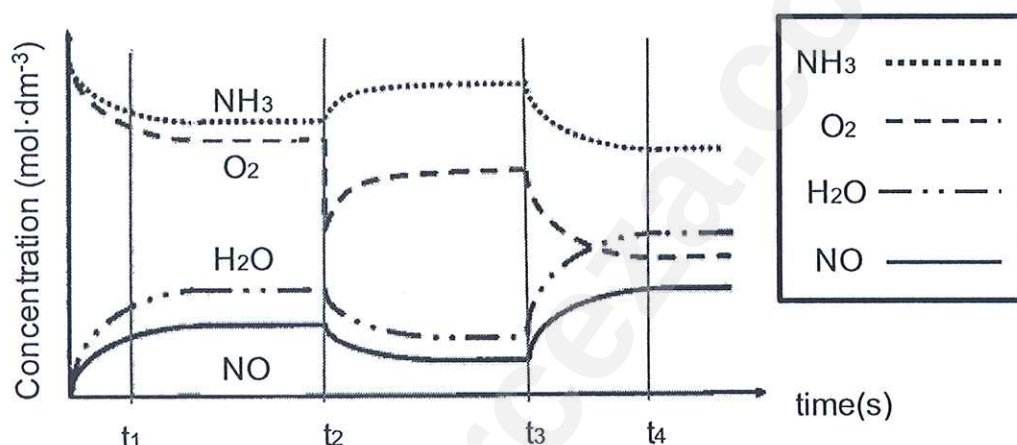
(2)  
[16]

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

- 6.1 In an experiment, ammonia gas and oxygen gas are introduced into a container at a certain temperature. The container is sealed and the reaction taking place reaches equilibrium, according to the following balanced chemical equation.



The graph below shows the change in concentration of  $\text{NH}_3(\text{g})$ ,  $\text{O}_2(\text{g})$ ,  $\text{NO}(\text{g})$  and  $\text{H}_2\text{O}(\text{g})$  with time.



- 6.1.1 If numerical values were given for concentration on the y-axis, would it be possible to calculate the equilibrium constant ( $K_c$ ) for this reaction at time  $t_1$ ? Explain the answer. (2)
- 6.1.2 Identify the change (stress) which was introduced to the reaction at time  $t_2$  and explain the subsequent changes in concentrations of all substances immediately after time  $t_2$ . (4)
- 6.1.3 At time  $t_3$  the temperature of the container is decreased. Is the forward reaction EXOTHERMIC or ENDOTHERMIC? (2)
- 6.2 Phosphorus pentachloride decomposes into phosphorous trichloride and chlorine gas. When gaseous phosphorous pentachloride is sealed in a closed container the following equilibrium is established.
- $$\text{PCl}_5(\text{g}) \rightleftharpoons \text{PCl}_3(\text{g}) + \text{Cl}_2(\text{g})$$
- 6.2.1 An unknown mass of phosphorous pentachloride is sealed in an empty  $2000 \text{ cm}^3$  container. The system is allowed to reach equilibrium at  $250^\circ\text{C}$ . When the equilibrium mixture was analysed the concentrations of  $\text{PCl}_5$  and  $\text{Cl}_2$  were  $0,7 \text{ mol}\cdot\text{dm}^{-3}$  and  $0,5 \text{ mol}\cdot\text{dm}^{-3}$  respectively. Calculate the  $K_c$  value at  $250^\circ\text{C}$ . (5)
- 6.2.2 Calculate the mass of phosphorous pentachloride that was originally placed in the container. (4)

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

7.1 Barium hydroxide ( $\text{Ba}(\text{OH})_2$ ), is defined as a strong base.

7.1.1 Define a *strong base*. (2)

7.1.2 Calculate the pH of a solution of a barium hydroxide solution,  $\text{Ba}(\text{OH})_2(\text{aq})$ , with a concentration of  $0,1 \text{ mol} \cdot \text{dm}^{-3}$ . (5)

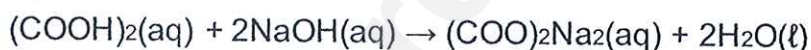
7.2 A standard solution of oxalic acid,  $(\text{COOH})_2(\text{aq})$ , with concentration  $0,2 \text{ mol} \cdot \text{dm}^{-3}$  is prepared by dissolving a certain amount of oxalic acid crystals,  $(\text{COOH})_2 \cdot 2\text{H}_2\text{O}$ , in water. The flask is then filled with distilled water up to the  $250 \text{ cm}^3$  mark.

7.2.1 Define the term *standard solution*. (2)

7.2.2 Calculate the mass of oxalic acid needed to prepare the standard solution. (4)

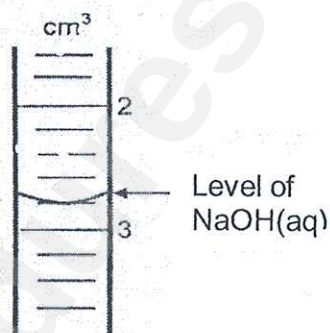
7.3 During a titration,  $25 \text{ cm}^3$  of the standard oxalic acid solution,  $(\text{COOH})_2(\text{aq})$ , prepared in QUESTION 7.2, is neutralised by a sodium hydroxide solution,  $\text{NaOH}(\text{aq})$ , from a burette.

The balanced equation for the reaction is given below.

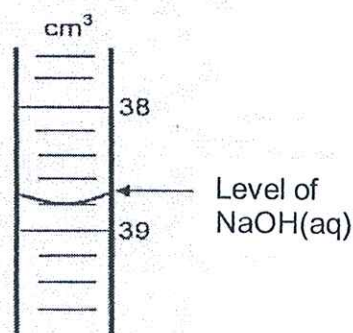


The diagrams below show the burette readings before the titration commenced and at the endpoint respectively.

Before the titration



At the endpoint



7.3.1 Define the term *endpoint*. (2)

7.3.2 What will the pH at the endpoint be? Choose from: GREATER THAN 7, EQUAL TO 7 or LESS THAN 7. (1)

7.3.3 Determine the volume of  $\text{NaOH}(\text{aq})$  that was added to the  $(\text{COOH})_2(\text{aq})$  to reach the endpoint of the titration from the diagrams above.. (1)

7.3.4 Calculate the concentration of the sodium hydroxide solution,  $\text{NaOH}(\text{aq})$ . (5)

[22]

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

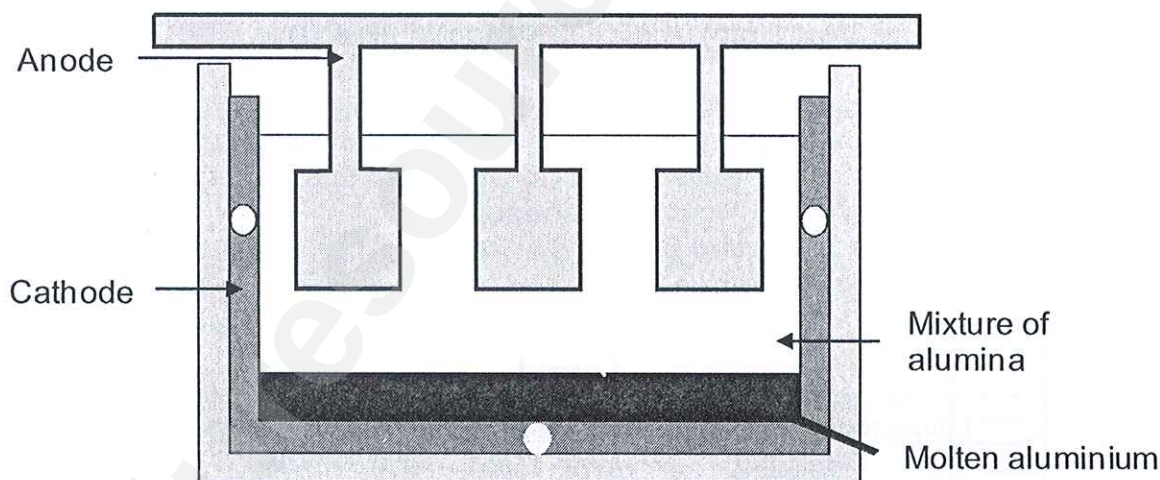
Consider the following galvanic cell at 25 °C.



- 8.1 Write down the balanced chemical equation for the net cell reaction that takes place. (3)
  - 8.2 Calculate the initial cell potential at 25 °C. (4)
  - 8.3 Write down the FORMULA of the cathode. (1)
  - 8.4 Fully explain how the salt bridge functions to maintain electrical neutrality by referring to the movement of the ions. (2)
- [10]**

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

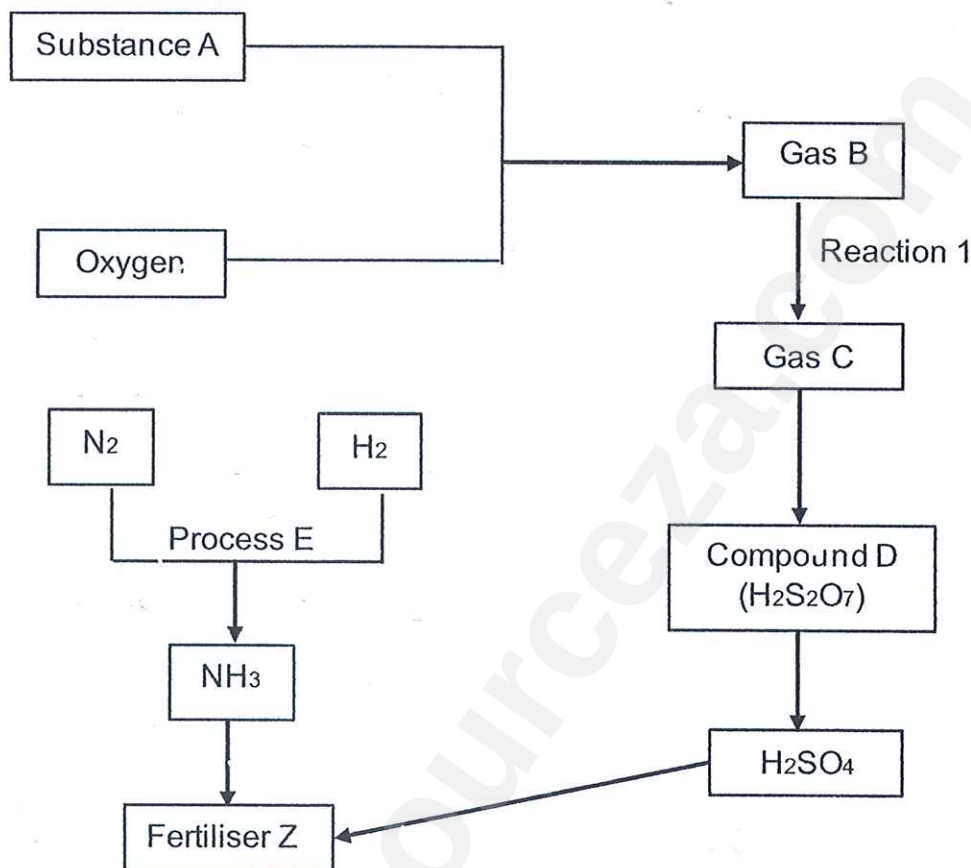
Aluminium metal is extracted from pure aluminium oxide ( $\text{Al}_2\text{O}_3$ ) in an electrolytic cell represented in the diagram below.



- 9.1 What is the NAME of the ore which contains aluminium oxide ( $\text{Al}_2\text{O}_3$ )? (1)
  - 9.2 Define the term *electrolytic cell*. (2)
  - 9.3 Write down the FORMULA of the ions present in the molten alumina ( $\text{Al}_2\text{O}_3$ ). (2)
  - 9.4 What is the advantage of adding cryolite to the alumina? (1)
  - 9.5 Write down the half reaction that takes place at the cathode. (2)
  - 9.6 Explain why the carbon anode should be replaced regularly. Make use of a chemical equation to support the answer. (3)
- [11]**

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

The fertiliser industry can be summarised as follows:



- 10.1 Write down the NAME or FORMULA for Substance A. (1)
- 10.2 Write down the NAME of the catalyst used in Reaction 1. (1)
- 10.3 Gas C is diluted with a small amount of sulphuric acid to form Compound D.
- 10.3.1 Write down the NAME for compound D. (1)
- 10.3.2 Why is gas C not added directly to water to form sulphuric acid? (2)
- 10.4 Write down a balanced equation for the formation of fertiliser Z. (3)
- 10.5 A farmer bought a 40 kg bag of fertiliser with a ratio of 3:2:1(22) for his crops. Calculate the mass of the primary nutrient required for healthy strong roots. (3)

[11]

**TOTAL: 150**

**DATA FOR PHYSICAL SCIENCES GRADE 12  
PAPER 2 (CHEMISTRY)**

**GEGEWENS VIR FISIIESE WETENSKAPPE GRAAD 12  
VRAESTEL 2 (CHEMIE)**

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

| NAME/NAAM                                          | SYMBOL/SIMBOOL | VALUE/WAARDE                              |
|----------------------------------------------------|----------------|-------------------------------------------|
| Standard pressure<br>Standaarddruk                 | $p^0$          | $1,013 \times 10^5 \text{ Pa}$            |
| Molar gas volume at STP<br>Molêre gasvolume by STD | $V_m$          | $22,4 \text{ dm}^3 \cdot \text{mol}^{-1}$ |
| Standard temperature<br>Standaardtemperatuur       | $T^0$          | $273 \text{ K}$                           |
| Avogadro's constant                                | $N_A$          | $6,023 \times 10^{23} \text{ mol}^{-1}$   |

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

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                           |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| $n = \frac{m}{M}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | $n = \frac{N}{N_A}$                       |
| $c = \frac{n}{V}$ OR/OF $c = \frac{m}{MV}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | $n = \frac{V}{V_m}$                       |
| $\frac{n_a}{n_b} = \frac{c_a V_a}{c_b V_b}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | $\text{pH} = -\log[\text{H}_3\text{O}^+]$ |
| $K_w = [\text{H}_3\text{O}^+][\text{OH}^-] = 1 \times 10^{-14} \text{ at/ by } 298 \text{ K}$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                           |
| $E_{\text{cell}}^{\theta} = E_{\text{cathode}}^{\theta} - E_{\text{anode}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{katoode}}^{\theta} - E_{\text{anode}}^{\theta}$<br>OR/OF<br>$E_{\text{cell}}^{\theta} = E_{\text{reduction}}^{\theta} - E_{\text{oxidation}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{reduksie}}^{\theta} - E_{\text{oksidasie}}^{\theta}$<br>OR/OF<br>$E_{\text{cell}}^{\theta} = E_{\text{oxidisingagent}}^{\theta} - E_{\text{reducingagent}}^{\theta} / E_{\text{sel}}^{\theta} = E_{\text{oksideermiddel}}^{\theta} - E_{\text{reduseermiddel}}^{\theta}$ |                                           |

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           |
| $2H^+ + 2e^- \rightleftharpoons H_2(g)$                           | 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           |
| $Al^{3+} + 3e^- \rightleftharpoons Al$                            | - 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

Increasing reducing ability/Toenemende reducerende vermoë

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

| Half-reactions/Halfreaksies                                                                                            | $E^{\theta}$ (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            |

Increasing oxidising ability/Toenemende oksiderende vermoë

Increasing reducing ability/Toenemende reduserende vermoë

TABLE 3: THE PERIODIC TABLE OF ELEMENTS  
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<br>H<br>1      | 3<br>Li<br>7     | 4<br>Be<br>9     | 11<br>Na<br>23   | 12<br>Mg<br>24   | 19<br>K<br>39    | 20<br>Ca<br>40   | 21<br>Sc<br>45   | 22<br>Ti<br>48   | 23<br>V<br>51    | 24<br>Cr<br>52   | 25<br>Mn<br>55   | 26<br>Fe<br>56   | 27<br>Co<br>59   | 28<br>Ni<br>59   | 29<br>Cu<br>63,5 | 30<br>Zn<br>65   | 36<br>Kr<br>84   |
| 5<br>B<br>11     | 6<br>C<br>12     | 7<br>N<br>14     | 8<br>O<br>16     | 9<br>F<br>19     | 10<br>Ne<br>20   | 13<br>Al<br>27   | 14<br>Si<br>28   | 15<br>P<br>31    | 16<br>S<br>32    | 17<br>Cl<br>35,5 | 18<br>Ar<br>40   | 31<br>Ga<br>70   | 32<br>Ge<br>73   | 33<br>As<br>75   | 34<br>Se<br>79   | 35<br>Br<br>80   | 36<br>Kr<br>84   |
| 9<br>F<br>19     | 10<br>Ne<br>20   | 11<br>Na<br>23   | 12<br>Mg<br>24   | 13<br>Al<br>27   | 14<br>Si<br>28   | 15<br>P<br>31    | 16<br>S<br>32    | 17<br>Cl<br>35,5 | 18<br>Ar<br>40   | 19<br>K<br>39    | 20<br>Ca<br>40   | 21<br>Sc<br>45   | 22<br>Ti<br>48   | 23<br>V<br>51    | 24<br>Cr<br>52   | 25<br>Mn<br>55   | 26<br>Fe<br>56   |
| 13<br>Al<br>27   | 14<br>Si<br>28   | 15<br>P<br>31    | 16<br>S<br>32    | 17<br>Cl<br>35,5 | 18<br>Ar<br>40   | 19<br>K<br>39    | 20<br>Ca<br>40   | 21<br>Sc<br>45   | 22<br>Ti<br>48   | 23<br>V<br>51    | 24<br>Cr<br>52   | 25<br>Mn<br>55   | 26<br>Fe<br>56   | 27<br>Co<br>59   | 28<br>Ni<br>59   | 29<br>Cu<br>63,5 | 30<br>Zn<br>65   |
| 17<br>Cl<br>35,5 | 18<br>Ar<br>40   | 19<br>K<br>39    | 20<br>Ca<br>40   | 21<br>Sc<br>45   | 22<br>Ti<br>48   | 23<br>V<br>51    | 24<br>Cr<br>52   | 25<br>Mn<br>55   | 26<br>Fe<br>56   | 27<br>Co<br>59   | 28<br>Ni<br>59   | 29<br>Cu<br>63,5 | 30<br>Zn<br>65   | 31<br>Ga<br>70   | 32<br>Ge<br>73   | 33<br>As<br>75   | 34<br>Se<br>79   |
| 31<br>Ga<br>70   | 32<br>Ge<br>73   | 33<br>As<br>75   | 34<br>Se<br>79   | 35<br>Br<br>80   | 36<br>Kr<br>84   | 37<br>Rb<br>86   | 38<br>Sr<br>88   | 39<br>Y<br>89    | 40<br>Zr<br>91   | 41<br>Nb<br>92   | 42<br>Mo<br>96   | 43<br>Tc<br>98   | 44<br>Ru<br>101  | 45<br>Rh<br>103  | 46<br>Pd<br>106  | 47<br>Ag<br>108  | 48<br>Cd<br>112  |
| 35<br>Br<br>80   | 36<br>Kr<br>84   | 37<br>Rb<br>86   | 38<br>Sr<br>88   | 39<br>Y<br>89    | 40<br>Zr<br>91   | 41<br>Nb<br>92   | 42<br>Mo<br>96   | 43<br>Tc<br>98   | 44<br>Ru<br>101  | 45<br>Rh<br>103  | 46<br>Pd<br>106  | 47<br>Ag<br>108  | 48<br>Cd<br>112  | 49<br>In<br>115  | 50<br>Sn<br>119  | 51<br>Sb<br>122  | 52<br>Te<br>128  |
| 53<br>I<br>127   | 54<br>Xe<br>131  | 55<br>Cs<br>133  | 56<br>Ba<br>137  | 57<br>La<br>139  | 58<br>Ce<br>140  | 59<br>Pr<br>141  | 60<br>Nd<br>144  | 61<br>Pm<br>146  | 62<br>Sm<br>150  | 63<br>Eu<br>152  | 64<br>Gd<br>157  | 65<br>Tb<br>159  | 66<br>Dy<br>163  | 67<br>Ho<br>165  | 68<br>Er<br>167  | 69<br>Tm<br>169  | 70<br>Yb<br>173  |
| 85<br>At<br>210  | 86<br>Rn<br>222  | 87<br>Fr<br>223  | 88<br>Ra<br>226  | 89<br>Ac<br>227  | 90<br>Th<br>232  | 91<br>Pa<br>231  | 92<br>U<br>238   | 93<br>Np<br>237  | 94<br>Pu<br>244  | 95<br>Am<br>243  | 96<br>Cm<br>247  | 97<br>Bk<br>247  | 98<br>Cf<br>251  | 99<br>Es<br>252  | 100<br>Fm<br>257 | 101<br>Md<br>258 | 102<br>No<br>259 |
| 127<br>I<br>127  | 128<br>Xe<br>131 | 129<br>La<br>139 | 130<br>Ce<br>140 | 131<br>Pr<br>141 | 132<br>Nd<br>144 | 133<br>Pm<br>146 | 134<br>Sm<br>150 | 135<br>Eu<br>152 | 136<br>Gd<br>157 | 137<br>Tb<br>159 | 138<br>Dy<br>163 | 139<br>Ho<br>165 | 140<br>Er<br>167 | 141<br>Tm<br>169 | 142<br>Yb<br>173 | 143<br>Lu<br>175 | 144<br>Hf<br>179 |
| 131<br>Xe<br>131 | 132<br>La<br>139 | 133<br>Ce<br>140 | 134<br>Pr<br>141 | 135<br>Nd<br>144 | 136<br>Pm<br>146 | 137<br>Sm<br>150 | 138<br>Eu<br>152 | 139<br>Gd<br>157 | 140<br>Tb<br>159 | 141<br>Dy<br>163 | 142<br>Ho<br>165 | 143<br>Er<br>167 | 144<br>Tm<br>169 | 145<br>Yb<br>173 | 146<br>Lu<br>175 | 147<br>Hf<br>179 | 148<br>Ta<br>181 |
| 135<br>At<br>210 | 136<br>Rn<br>222 | 137<br>Fr<br>223 | 138<br>Ra<br>226 | 139<br>Ac<br>227 | 140<br>Th<br>232 | 141<br>Pa<br>231 | 142<br>U<br>238  | 143<br>Np<br>237 | 144<br>Pu<br>244 | 145<br>Am<br>243 | 146<br>Cm<br>247 | 147<br>Bk<br>247 | 148<br>Cf<br>251 | 149<br>Es<br>252 | 150<br>Fm<br>257 | 151<br>Md<br>258 | 152<br>No<br>259 |
| 173<br>Yb<br>173 | 174<br>Lu<br>175 | 175<br>Hf<br>179 | 176<br>Ta<br>181 | 177<br>W<br>184  | 178<br>Re<br>186 | 179<br>Os<br>190 | 180<br>Ir<br>192 | 181<br>Pt<br>195 | 182<br>Au<br>197 | 183<br>Hg<br>201 | 184<br>Tl<br>204 | 185<br>Pb<br>207 | 186<br>Bi<br>209 | 187<br>Po<br>209 | 188<br>At<br>210 | 189<br>Rn<br>222 | 190<br>Fr<br>223 |
| 209<br>Bi<br>209 | 210<br>Po<br>209 | 211<br>At<br>210 | 212<br>Rn<br>222 | 213<br>Fr<br>223 | 214<br>Ra<br>226 | 215<br>Ac<br>227 | 216<br>Th<br>232 | 217<br>Pa<br>231 | 218<br>U<br>238  | 219<br>Np<br>237 | 220<br>Pu<br>244 | 221<br>Am<br>243 | 222<br>Cm<br>247 | 223<br>Bk<br>247 | 224<br>Cf<br>251 | 225<br>Es<br>252 | 226<br>Fm<br>257 |
| 210<br>At<br>210 | 211<br>Rn<br>222 | 212<br>Fr<br>223 | 213<br>Ra<br>226 | 214<br>Ac<br>227 | 215<br>Th<br>232 | 216<br>Pa<br>231 | 217<br>U<br>238  | 218<br>Np<br>237 | 219<br>Pu<br>244 | 220<br>Am<br>243 | 221<br>Cm<br>247 | 222<br>Bk<br>247 | 223<br>Cf<br>251 | 224<br>Es<br>252 | 225<br>Fm<br>257 | 226<br>Md<br>258 | 227<br>No<br>259 |
| 227<br>Fr<br>223 | 228<br>Ra<br>226 | 229<br>Ac<br>227 | 230<br>Th<br>232 | 231<br>Pa<br>231 | 232<br>U<br>238  | 233<br>Np<br>237 | 234<br>Pu<br>244 | 235<br>Am<br>243 | 236<br>Cm<br>247 | 237<br>Bk<br>247 | 238<br>Cf<br>251 | 239<br>Es<br>252 | 240<br>Fm<br>257 | 241<br>Md<br>258 | 242<br>No<br>259 | 243<br>Lr<br>262 | 244<br>La<br>139 |
| 259<br>No<br>259 | 260<br>Lr<br>262 | 261<br>La<br>139 | 262<br>Ce<br>140 | 263<br>Pr<br>141 | 264<br>Nd<br>144 | 265<br>Pm<br>146 | 266<br>Sm<br>150 | 267<br>Eu<br>152 | 268<br>Gd<br>157 | 269<br>Tb<br>159 | 270<br>Dy<br>163 | 271<br>Ho<br>165 | 272<br>Er<br>167 | 273<br>Tm<br>169 | 274<br>Yb<br>173 | 275<br>Lu<br>175 | 276<br>Hf<br>179 |
| 262<br>Lr<br>262 | 263<br>La<br>139 | 264<br>Ce<br>140 | 265<br>Pr<br>141 | 266<br>Nd<br>144 | 267<br>Pm<br>146 | 268<br>Sm<br>150 | 269<br>Eu<br>152 | 270<br>Gd<br>157 | 271<br>Tb<br>159 | 272<br>Dy<br>163 | 273<br>Ho<br>165 | 274<br>Er<br>167 | 275<br>Tm<br>169 | 276<br>Yb<br>173 | 277<br>Lu<br>175 | 278<br>Hf<br>179 | 279<br>Ta<br>181 |
| 275<br>Lu<br>175 | 276<br>Hf<br>179 | 277<br>Ta<br>181 | 278<br>W<br>184  | 279<br>Re<br>186 | 280<br>Os<br>190 | 281<br>Ir<br>192 | 282<br>Pt<br>195 | 283<br>Au<br>197 | 284<br>Hg<br>201 | 285<br>Tl<br>204 | 286<br>Pb<br>207 | 287<br>Bi<br>209 | 288<br>Po<br>209 | 289<br>At<br>210 | 290<br>Rn<br>222 | 291<br>Fr<br>223 | 292<br>Ra<br>226 |
| 285<br>At<br>210 | 286<br>Rn<br>222 | 287<br>Fr<br>223 | 288<br>Ra<br>226 | 289<br>Ac<br>227 | 290<br>Th<br>232 | 291<br>Pa<br>231 | 292<br>U<br>238  | 293<br>Np<br>237 | 294<br>Pu<br>244 | 295<br>Am<br>243 | 296<br>Cm<br>247 | 297<br>Bk<br>247 | 298<br>Cf<br>251 | 299<br>Es<br>252 | 300<br>Fm<br>257 | 301<br>Md<br>258 | 302<br>No<br>259 |
| 301<br>Md<br>258 | 302<br>No<br>259 | 303<br>Lr<br>262 | 304<br>La<br>139 | 305<br>Ce<br>140 | 306<br>Pr<br>141 | 307<br>Nd<br>144 | 308<br>Pm<br>146 | 309<br>Sm<br>150 | 310<br>Eu<br>152 | 311<br>Gd<br>157 | 312<br>Tb<br>159 | 313<br>Dy<br>163 | 314<br>Ho<br>165 | 315<br>Er<br>167 | 316<br>Tm<br>169 | 317<br>Yb<br>173 | 318<br>Lu<br>175 |
| 317<br>Yb<br>173 | 318<br>Lu<br>175 | 319<br>Hf<br>179 | 320<br>Ta<br>181 | 321<br>W<br>184  | 322<br>Re<br>186 | 323<br>Os<br>190 | 324<br>Ir<br>192 | 325<br>Pt<br>195 | 326<br>Au<br>197 | 327<br>Hg<br>201 | 328<br>Tl<br>204 | 329<br>Pb<br>207 | 330<br>Bi<br>209 | 331<br>Po<br>209 | 332<br>At<br>210 | 333<br>Rn<br>222 | 334<br>Fr<br>223 |
| 331<br>Po<br>209 | 332<br>At<br>210 | 333<br>Rn<br>222 | 334<br>Fr<br>223 | 335<br>Ra<br>226 | 336<br>Ac<br>227 | 337<br>Th<br>232 | 338<br>Pa<br>231 | 339<br>U<br>238  | 340<br>Np<br>237 | 341<br>Pu<br>244 | 342<br>Am<br>243 | 343<br>Cm<br>247 | 344<br>Bk<br>247 | 345<br>Cf<br>251 | 346<br>Es<br>252 | 347<br>Fm<br>257 | 348<br>Md<br>258 |
| 347<br>Md<br>258 | 348<br>No<br>259 | 349<br>Lr<br>262 | 350<br>La<br>139 | 351<br>Ce<br>140 | 352<br>Pr<br>141 | 353<br>Nd<br>144 | 354<br>Pm<br>146 | 355<br>Sm<br>150 | 356<br>Eu<br>152 | 357<br>Gd<br>157 | 358<br>Tb<br>159 | 359<br>Dy<br>163 | 360<br>Ho<br>165 | 361<br>Er<br>167 | 362<br>Tm<br>169 | 363<br>Yb<br>173 | 364<br>Lu<br>175 |
| 363<br>Yb<br>173 | 364<br>Lu<br>175 | 365<br>Hf<br>179 | 366<br>Ta<br>181 | 367<br>W<br>184  | 368<br>Re<br>186 | 369<br>Os<br>190 | 370<br>Ir<br>192 | 371<br>Pt<br>195 | 372<br>Au<br>197 | 373<br>Hg<br>201 | 374<br>Tl<br>204 | 375<br>Pb<br>207 | 376<br>Bi<br>209 | 377<br>Po<br>209 | 378<br>At<br>210 | 379<br>Rn<br>222 | 380<br>Fr<br>223 |
| 377<br>Po<br>209 | 378<br>At<br>210 | 379<br>Rn<br>222 | 380<br>Fr<br>223 | 381<br>Ra<br>226 | 382<br>Ac<br>227 | 383<br>Th<br>232 | 384<br>Pa<br>231 | 385<br>U<br>238  | 386<br>Np<br>237 | 387<br>Pu<br>244 | 388<br>Am<br>243 | 389<br>Cm<br>247 | 390<br>Bk<br>247 | 391<br>Cf<br>251 | 392<br>Es<br>252 | 393<br>Fm<br>257 | 394<br>Md<br>258 |
| 393<br>Fm<br>257 | 394<br>Md<br>258 | 395<br>No<br>259 | 396<br>Lr<br>262 | 397<br>La<br>139 | 398<br>Ce<br>140 | 399<br>Pr<br>141 | 400<br>Nd<br>144 | 401<br>Pm<br>146 | 402<br>Sm<br>150 | 403<br>Eu<br>152 | 404<br>Gd<br>157 | 405<br>Tb<br>159 | 406<br>Dy<br>163 | 407<br>Ho<br>165 | 408<br>Er<br>167 | 409<br>Tm<br>169 | 410<br>Yb<br>173 |
| 409<br>Yb<br>173 | 410<br>Lu<br>175 | 411<br>Hf<br>179 | 412<br>Ta<br>181 | 413<br>W<br>184  | 414<br>Re<br>186 | 415<br>Os<br>190 | 416<br>Ir<br>192 | 417<br>Pt<br>195 | 418<br>Au<br>197 | 419<br>Hg<br>201 | 420<br>Tl<br>204 | 421<br>Pb<br>207 | 422<br>Bi<br>209 | 423<br>Po<br>209 | 424<br>At<br>210 | 425<br>Rn<br>222 | 426<br>Fr<br>223 |
| 425<br>Rn<br>222 | 426<br>Fr<br>223 | 427<br>Ra<br>226 | 428<br>Ac<br>227 | 429<br>Th<br>232 | 430<br>Pa<br>231 | 431<br>U<br>238  | 432<br>Np<br>237 | 433<br>Pu<br>244 | 434<br>Am<br>243 | 435<br>Cm<br>247 | 436<br>Bk<br>247 | 437<br>Cf<br>251 | 438<br>Es<br>252 | 439<br>Fm<br>257 | 440<br>Md<br>258 | 441<br>No<br>259 | 442<br>Lr<br>262 |
| 441<br>No<br>259 | 442<br>Lr<br>262 | 443<br>La<br>139 | 444<br>Ce<br>140 | 445<br>Pr<br>141 | 446<br>Nd<br>144 | 447<br>Pm<br>146 | 448<br>Sm<br>150 | 449<br>Eu<br>152 | 450<br>Gd<br>157 | 451<br>Tb<br>159 | 452<br>Dy<br>163 | 453<br>Ho<br>165 | 454<br>Er<br>167 | 455<br>Tm<br>169 | 456<br>Yb<br>173 | 457<br>Lu<br>175 | 458<br>Hf<br>179 |
| 457<br>Lu<br>175 | 458<br>Hf<br>179 | 459<br>Ta<br>181 | 460<br>W<br>184  | 461<br>Re<br>186 | 462<br>Os<br>190 | 463<br>Ir<br>192 | 464<br>Pt<br>195 | 465<br>Au<br>197 | 466<br>Hg<br>201 | 467<br>Tl<br>204 | 468<br>Pb<br>207 | 469<br>Bi<br>209 | 470<br>Po<br>209 | 471<br>At<br>210 | 472<br>Rn<br>222 | 473<br>Fr<br>223 | 474<br>Ra<br>226 |
| 473<br>Fr<br>223 | 474<br>Ra<br>226 | 475<br>Ac<br>227 | 476<br>Th<br>232 | 477<br>Pa<br>231 | 478<br>U<br>238  | 479<br>Np<br>237 | 480<br>Pu<br>244 | 481<br>Am<br>243 | 482<br>Cm<br>247 | 483<br>Bk<br>247 | 484<br>Cf<br>251 | 485<br>Es<br>252 | 486<br>Fm<br>257 | 487<br>Md<br>258 | 488<br>No<br>259 | 489<br>Lr<br>262 | 490<br>La<br>139 |
| 489<br>La<br>139 | 490<br>Ce<br>140 | 491<br>Pr<br>141 | 492<br>Nd<br>144 | 493<br>Pm<br>146 | 494<br>Sm<br>150 | 495<br>Eu<br>152 | 496<br>Gd<br>157 | 497<br>Tb<br>159 | 498<br>Dy<br>163 | 499<br>Ho<br>165 | 500<br>Er<br>167 | 501<br>Tm<br>169 | 502<br>Yb<br>173 | 503<br>Lu<br>175 | 504<br>Hf<br>179 | 505<br>Ta<br>181 | 506<br>W<br>184  |
| 505<br>Ta<br>181 | 506<br>W<br>184  | 507<br>Re<br>186 | 508<br>Os<br>190 | 509<br>Ir<br>192 | 510<br>Pt<br>195 | 511<br>Au<br>197 | 512<br>Hg<br>201 | 513<br>Tl<br>204 | 514<br>Pb<br>207 | 515<br>Bi<br>209 | 516<br>Po<br>209 | 517<br>At<br>210 | 518<br>Rn<br>222 | 519<br>Fr<br>223 | 520<br>Ra<br>226 | 521<br>Ac<br>227 | 522<br>Th<br>232 |
| 519<br>Fr<br>223 | 520<br>Ra<br>226 | 521<br>Ac<br>227 | 522<br>Th<br>232 | 523<br>Pa<br>231 | 524<br>U<br>238  | 525<br>Np<br>237 | 526<br>Pu<br>244 | 527<br>Am<br>243 | 528<br>Cm<br>247 | 529<br>Bk<br>247 | 530<br>Cf<br>251 | 531<br>Es<br>252 | 532<br>Fm<br>257 | 533<br>Md<br>258 | 534<br>No<br>259 | 535<br>Lr<br>262 | 536<br>La<br>139 |
| 535<br>La<br>139 | 536<br>Ce<br>140 | 537<br>Pr<br>141 | 538<br>Nd<br>144 | 539<br>Pm<br>146 | 540<br>Sm<br>150 | 541<br>Eu<br>152 | 542<br>Gd<br>157 | 543<br>Tb<br>159 | 544<br>Dy<br>163 | 545<br>Ho<br>165 | 546<br>Er<br>167 | 547<br>Tm<br>169 | 548<br>Yb<br>173 | 549<br>Lu<br>175 | 550<br>Hf<br>179 | 551<br>Ta<br>181 | 552<br>W<br>184  |
| 551<br>Ta<br>181 | 552<br>W<br>184  | 553<br>Re<br>186 | 554<br>Os<br>190 | 555<br>Ir<br>192 | 556<br>Pt<br>195 | 557<br>Au<br>197 | 558<br>Hg<br>201 | 559<br>Tl<br>204 | 560<br>Pb<br>207 | 561<br>Bi<br>209 | 562<br>Po<br>209 | 563<br>At<br>210 | 564<br>Rn<br>222 | 565<br>Fr<br>223 | 566<br>Ra<br>226 | 567<br>Ac<br>227 | 568<br>Th<br>232 |
| 565<br>Fr<br>223 | 566<br>Ra<br>226 | 567<br>Ac<br>227 | 568<br>Th<br>232 | 569<br>Pa<br>231 | 570<br>U<br>238  | 571<br>Np<br>237 | 572<br>Pu<br>244 | 573<br>Am<br>243 | 574<br>Cm<br>247 | 575<br>Bk<br>247 | 576<br>Cf<br>251 | 577<br>Es<br>252 | 578<br>Fm<br>257 | 579<br>Md<br>258 | 580<br>No<br>259 | 581<br>Lr<br>262 | 582<br>La<br>139 |
| 581<br>La<br>139 | 582<br>Ce<br>140 | 583<br>Pr<br>141 | 584<br>Nd<br>144 | 585<br>Pm<br>146 | 586<br>Sm<br>150 | 587<br>Eu<br>152 | 588<br>Gd<br>157 | 589<br>Tb<br>159 | 590<br>Dy<br>163 | 591<br>Ho<br>165 | 592<br>Er<br>167 | 593<br>Tm<br>169 | 594<br>Yb<br>173 | 595<br>Lu<br>175 | 596<br>Hf<br>179 | 597<br>Ta<br>181 | 598<br>W<br>184  |
| 597<br>Ta<br>181 | 598<br>W<br>184  | 599<br>Re<br>186 | 600<br>Os<br>190 | 601<br>Ir<br>192 | 602<br>Pt<br>195 | 603<br>Au<br>197 | 604<br>Hg<br>201 | 605<br>Tl<br>204 | 606<br>Pb<br>207 | 607<br>Bi<br>209 | 608<br>Po<br>209 | 609<br>At<br>210 | 610<br>Rn<br>222 | 611<br>Fr<br>223 | 612<br>Ra<br>226 | 613<br>Ac<br>227 | 614<br>Th<br>232 |
| 613<br>Ac<br>227 | 614<br>Th<br>232 | 615<br>Pa<br>231 | 616<br>U<br>238  | 617<br>Np<br>237 | 618<br>Pu<br>244 | 619<br>Am<br>243 | 620<br>Cm<br>247 | 621<br>Bk<br>247 | 622<br>Cf<br>251 | 623<br>Es<br>252 | 624<br>Fm<br>257 | 625<br>Md<br>258 | 626<br>No<br>259 |                  |                  |                  |                  |