GRADE 11 EXAMINATION
NOVEMBER 2007

PHYSICAL SCIENCE: PAPER II
(CHEMISTRY FOCUS)

Time: 3 hours 150 marks

PLEASE READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of:
   - a question paper of 14 pages
   - an information sheet

2. There are two **optional questions** at the end of the paper, on page **12 and 13:**
   Question 10 can be done as another option for question 1.4.
   Question 11 can be done as another option for question 5.

3. All the other questions must be answered.

4. Write legibly.

5. Make neat diagrams where necessary.

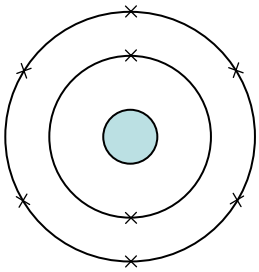
6. Show the formulas and equations you use.

7. Show all calculations.

8. All answers should have the correct units.

QUESTION 1

1.1 Using the shell model the electron configuration for an oxygen atom can be represented as follows:



Electron configuration of an O atom where x represents an electron

Give the electron configuration for carbon using the shell model. (1)

1.2 Draw separate Lewis Structures for a hydrogen, a carbon and an oxygen atom. (3)

1.3 Give Lewis Structures for:
(a) a water molecule and
(b) a carbon dioxide molecule (4)

1.4 **(If you intend answering the optional question 10 (VSEPR Theory) on page 11 you should not answer this question; 1.4)**

A water molecule is polar while a carbon dioxide molecule is non polar.
(a) What is the difference between a polar and a non polar molecule? (2)
(b) Explain why carbon dioxide, which contains polar bonds, is non polar? (2)

1.5 Water vapour and carbon dioxide are 'greenhouse gases'. What do we mean by 'greenhouse gases'? (2)

14 marks

QUESTION 2

Table: Atmospheric carbon dioxide record from Mauna Loa Hawaii (1964-2004)

Year	1964	1974	1984	1994	2004
%CO_2 by volume	0,032	0,033	0,034	0,036	0.038

[Source: Carbon Dioxide Research Group, *Scripps Institution of Oceanography*, University of California, La Jolla, California 92093-0444, U.S.A.]

2.1 Identify the independent variable in this investigation. Give a reason for your choice. (3)

2.2 Use the information in the table to draw a graph of the results. (5)

2.3 What does the slope or gradient of this graph represent? (2)

2.4 Comment on the magnitude of the slope over time. (2)

2.5 Predict the percentage of carbon dioxide that can be expected over Mauna Loa in 2030. (2)

14 marks

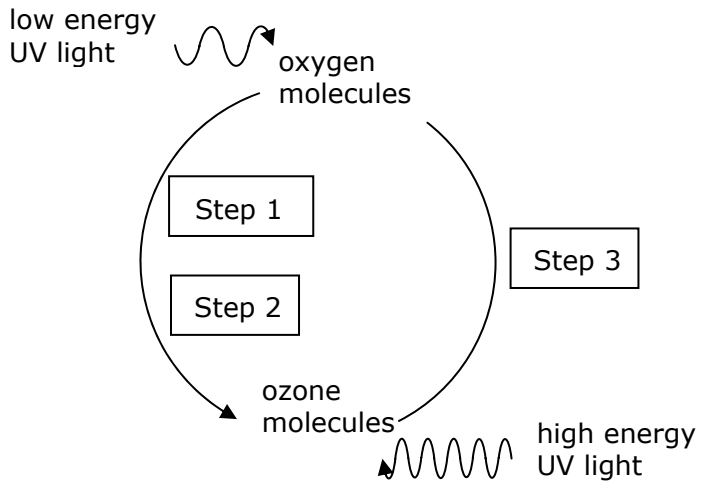
QUESTION 3

Ozone, also a greenhouse gas, is a form of oxygen found naturally in the ozone layer in the upper atmosphere.

3.1 Match the following reaction equations to steps 1, 2 and 3 to complete the diagram below showing the "ozone cycle":

	Equation
1	$2O_3 \xrightarrow{hf} 3O_2$
2	$O_2 \xrightarrow{hf} O + O$
3	$O_2 + O \rightarrow O_3$

Ozone Cycle



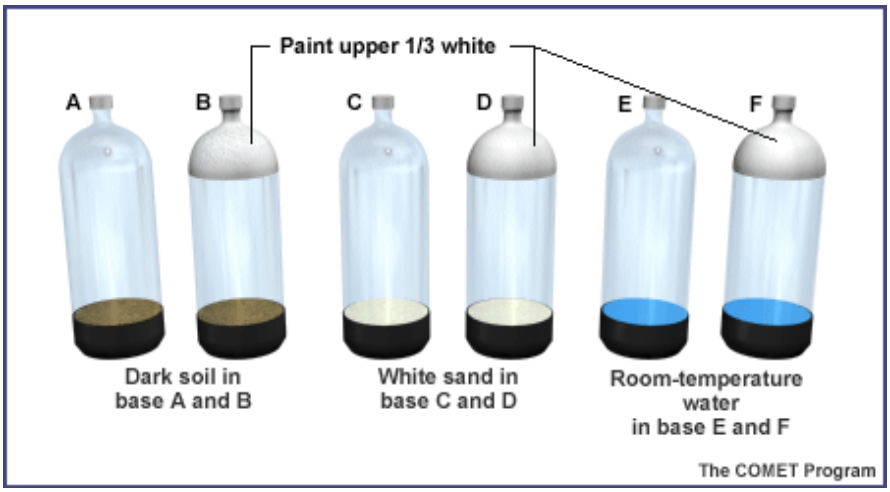
To answer, write the step, e.g. 'Step 1:', and next to it the appropriate equation selected from the list of three equations given above. (3)

3.2 By looking at the cycle, or otherwise, can you suggest what vital function ozone performs and why do you think a depletion of ozone will be so harmful to life on earth? (4)

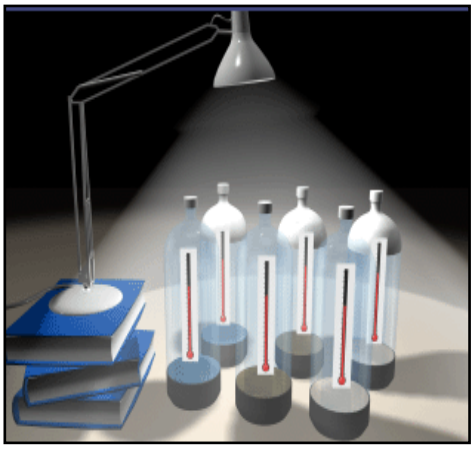
7 marks

QUESTION 4

(This question is based on material supplied by the University Corporation for Atmospheric Research (UCAR). Source: <http://www.ucar.edu/learn/1_3_2_13t.htm>.)
A teacher wishes to demonstrate the effect of certain factors related to global warming, or the 'greenhouse effect', to her learners.
She sets up six empty 2 litre plastic cold drink bottles as we show in the first sketch.



She then tapes a thermometer (using transparent tape) to the inside of each bottle (facing out). She ensures that the bulbs of the thermometers are just above the top of the bases and replaces the caps. She then places the bottles approximately 15 cm away from a lamp with the thermometer facing away from the light. She gets the learners to record the temperature on each thermometer before switching on the light. The teacher then switches on the light and the learners record the temperature on each thermometer at two minute intervals for 20 minutes.



4.1 Give two questions the teacher and her learners are investigating. (2)

4.2 For one of the investigative questions give the dependent and the independent variable as well as a variable that needs to be controlled. (3)

4.3 Here is one of the tables the learners draw up after completing their investigation.

Bottle	Temperature Increase in 20 minutes /°C
A	14
C	17
E	12

Give a conclusion the learners are able to draw from these results. (2)

4.4 Another group of learners repeat this investigation. They record the following results.

Bottle	Temperature Increase in 20 minutes /°C
A	9
C	12
E	7

Suggest a possible reason for the different results. (2)

4.5 The upper third of bottles B, D and F are all painted white as shown in the above pictures.

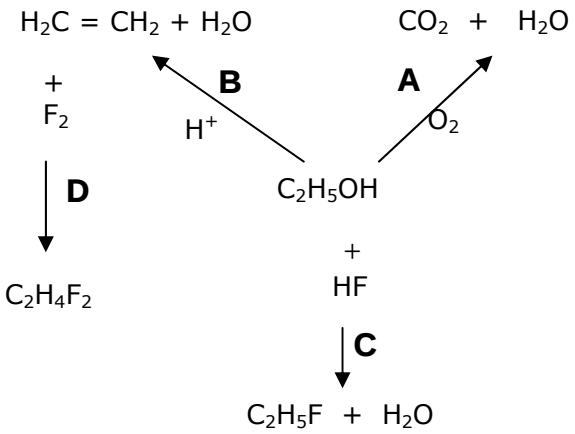
(a) What does the white paint simulate? (2)
(b) How would the temperatures in bottles B, D and F compare with those in A, C and E after 20 minutes? (See the pictures.) Explain briefly. (2)
(c) If all the bottles were allowed to cool from the same temperature how do you think the rate of cooling of bottles B, D and F would compare with that of bottles A, C and E? Explain briefly. (2)

15 marks

QUESTION 5

(If you intend answering the optional question 11 (Radioactivity) on page 11 you should not answer this question; 5)

Study the sequence of organic chemical reactions that are illustrated below



5.1 Name the type of reaction, labelled A, B, C and D, that is represented in the sequence above. (4)

5.2 C_2H_4 is **ethene** and is characterised by the presence of a double bond between the carbon atoms in its molecular structure.

(a) What is the **name** of the family of organic molecules that contain a double bond between adjacent carbon atoms? (1)

(b) What **term** is used to describe any organic molecule that has more than one bond, i.e. a double or a triple bond, between the carbon atoms in its structure? (1)

5.3 The organic reaction represented by the following equation is similar to reaction A.

$$\underline{C}H_4(g) + 2\underline{O}_2(g) \rightarrow \underline{CO}_2 + 2H_2O$$

(a) Give the oxidation number of each (underlined) element in each of the molecules represented in the equation. (4)

(b) Which substance undergoes oxidation and which reduction? (2)

12 marks

QUESTION 6

6.1 Chloroflourocarbons (CFC's) are a type of organic molecule that destroys ozone in the upper atmosphere. One example of a CFC is the compound with the formula $C_2F_3Cl_3$. It has a melting point of -35^0C and boiling point of 48^0C.

(a) In what physical state would you find this CFC at room temperature? Explain your answer. (2)

(b) What characteristic of this CFC allows its vapour to reach the upper atmosphere chemically unchanged? (2)

Once the CFC vapour reaches the upper atmosphere, the following reactions occur.

Reaction 1 $\quad CFC + UV\ light \rightarrow CFC\ fragment + Cl$

Reaction 2 $\quad Cl + O_3 \rightarrow ClO + O_2$

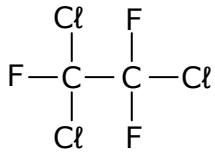
Reaction 3 $\quad ClO + O \rightarrow Cl + O_2$

(c) It has been suggested that one Cl atom destroys many ozone molecules. Suggest, by reference to Reactions 2 and 3, how this could happen. (3)

6.2 Ultraviolet light at high altitudes, with an energy equivalence of 400 $kJ{\cdot}mol^{-1}$, has the ability to decompose CFC's as mentioned in the previous question. The following data concerning bond energies is listed below.

Bond	Bond Energy /$kJ{\cdot}mol^{-1}$
C – Cℓ	330
C – C	346
C – F	450
C – H	435
Cℓ – Cℓ	397
H – Cℓ	431

and the structure of a typical CFC molecule is as follows:



(a) What is meant by the term 'bond energy'? (2)

(b) Why is a CFC molecule decomposed by UV light, with an energy equivalence of 400 $kJ{\cdot}mol^{-1}$, to form chlorine atoms rather than fluorine atoms? (2)

(c) What other bond would you expect to change in the CFC molecule? (2)

Chlorotriflouromethane ($CF_3C\ell$) is also a chlorofluorocarbon. It is manufactured from trifluoromethane (CHF_3) according to the following reaction equation:

$$\underset{\text{trifluoromethane}}{CHF_3} + C\ell_2 \rightarrow \underset{\text{chlorotriflouromethane}}{CF_3C\ell} + HC\ell$$

(d) Give the structural formula of both the CFC's, CHF_3 and CF_3Cl, showing all the bonds between the atoms. (4)

(e) What is meant by 'exothermic reaction' and 'endothermic reaction'? (4)

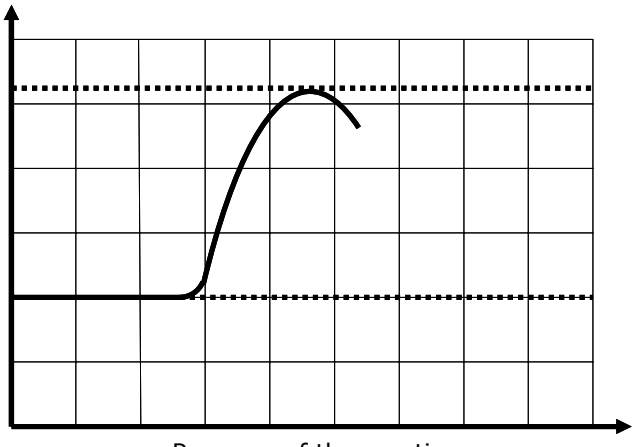
(f) State which of the following processes can be classified as exothermic and which endothermic.

(i) The breaking of a chemical bond (1)
(ii) The forming of a chemical bond (1)

(g) Use the Table of Bond Energies to answer the following:

(i) What is the total energy required to break all the bonds in a mole of trifluoromethane and a mole of chlorine? (3)
(ii) How much energy is transferred when bonds form to produce a mole of chlorotrifluoromethane and a mole of hydrogen chloride? (2)
(iii) Hence calculate the energy transferred (ΔH_r) when a mole of each of the reactants forms a mole of each of the products. Is the overall reaction endothermic or exothermic? (2)

(h) Copy and complete the graph below for this reaction. Label the vertical axis. Place the following additional labels on the graph:



Progress of the reaction

(i) the heat of reaction (or enthalpy change, ΔH)
(ii) activation energy
(iii) energy of reactants
(iv) energy of products

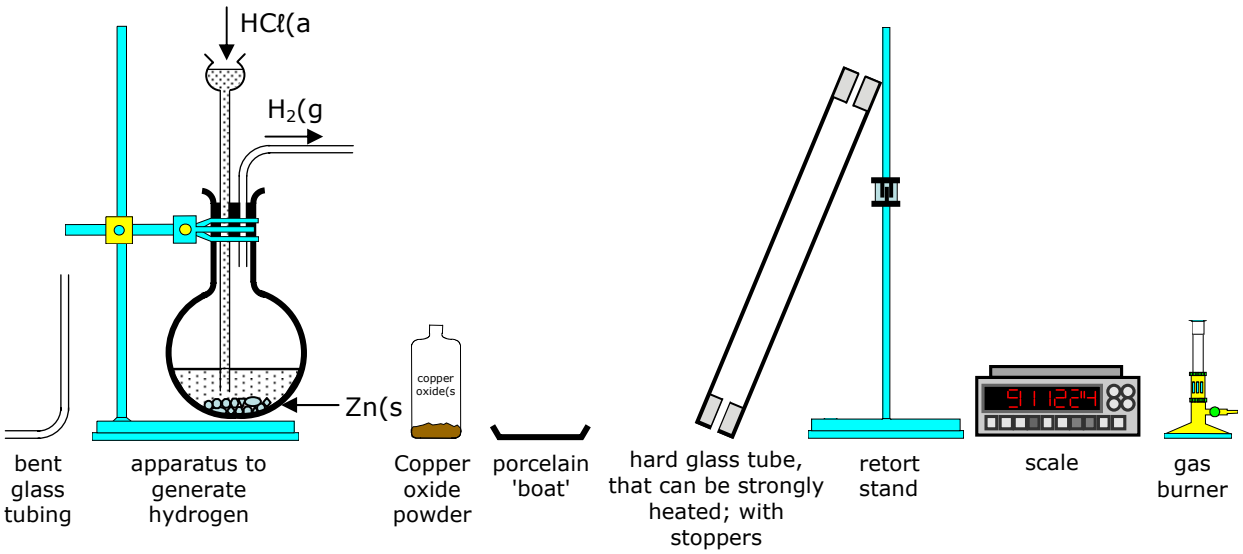
(5)

35 marks

QUESTION 7

Christine wants to determine experimentally the formula of copper oxide. She knows that if copper oxide is strongly heated in a stream of hydrogen gas it is reduced to copper metal. She has the following apparatus available.

Diagram 3



She places 2000 cm^3 of water in an aluminium container and records its temperature with a sensitive thermometer.
A crucible and ethanol are weighed, placed under the aluminium container, and the ethanol is ignited.

She has also been given the following table in which to record her results.

	Mass / g
Mass of empty porcelain boat	15,0
Mass of boat and copper oxide before heating	18,97
Mass of copper oxide before heating	
Mass of boat and copper after heating	18, 17
Mass of copper after heating	
Mass of oxygen removed	

7.1 Draw a labelled diagram of the apparatus as Christine would set it up to determine the formula of copper oxide. (4)

7.2 Describe the steps, in an appropriate sequence, that Christine needs to take to determine the formula of copper oxide. (8)

7.3 Copy and complete the table. (3)

7.4 Calculate the formula of copper oxide based on Christine's results. (3)

18 marks

QUESTION 8

Sulphur dioxide gas, amongst other gases, is released as a pollutant when coal, a fossil fuel, is burned power stations. This gas is highly soluble and will dissolve easily in atmospheric water to form sulphurous acid, a form of acid rain. The acid ionises in water according to the following equation:

$$H_2SO_3 \quad + \quad H_2O \rightarrow H_3O^+ \quad + \quad HSO_3^-$$

8.1 What type of reaction is this? Select from the list provided below and then select the chemical process that best describes this reaction.

Type of Reaction	Chemical process
Redox reaction	Transfer of ions
Acid –base reaction	Transfer of electrons
Chemical decomposition reaction	Transfer of protons
Ion exchange	Breakdown of chemical substances

(3)

8.2 What is the name of the H_3O^+ ion produced in this reaction? (1)

8.3 Identify the conjugate pairs in this reaction. (2)

8.4 One strategy for limiting the amount of acid pollution in the atmosphere is *scrubbing.* In particular, calcium oxide (CaO) is injected into the combustion chamber of a power plant, where it reacts with the sulfur dioxide produced, to yield solid calcium sulfite according to the following chemical equation:

$$SO_2 \quad + \quad CaO \quad \longrightarrow \quad CaSO_3$$

(a) Approximately 900 kg of calcium sulfite is generated each year per person who benefits from a power plant. How much sulfur dioxide (in moles) is prevented from entering the atmosphere when this much calcium sulfite is generated? (3)

(b) What volume (in litres) does this amount of gas represent at STP? (2)

11 marks

QUESTION 9

Some of the human activities in which scientific discoveries have led to technological advances are listed in the left column of the following table.

9.1 Redraw this table and match the chemical processes in column 2 with the human activities listed in column 1.

Column 1	Column 2	Column 3
Human activity	**Chemical Processes on which the human activity is based**	**List of greenhouse gases emitted**
Transport	Combustion of coal and/or oil	
Electric power generation	Reduction of ore, fractional distillation, production of refrigerants	
Manufacturing, e.g. blast furnace, refineries, …	Decomposition of organic vegetable matter	
Waste Disposal	Combustion of hydrocarbons	

(4)

9.2 In the third column, give two greenhouse gases selected from: H_2O, CH_4, CO_2, NO_2, CO, SO_2, N_2O, hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) to match the first two columns in the table. You may use any one gas more than once and you do not have to use them all.

NOTE: HFCs and PFCs are now used as propellants in aerosol containers in place of CFC's. (8)

9.3 List **three** advantages and **three** disadvantages of generating electric power. (6)

9.4 At the beginning of the Industrial Revolution coal was first used as a source energy. In the beginning coal was used to drive steam engines. Later coal was used to generate electricity. If you had been present at the beginning of the Industrial Revolution, knowing what you know now, what two pieces of advice would you have given the authorities? Give a reason for each piece of advice. (2)

9.5 Chemists that study plastics first made carbon fibre in the 1960s. In the 1990s people started using carbon fibre for sports equipment and even aircraft parts because it is very light and incredibly strong. These scientific developments have made it possible for the production of the Boeing 787 in which metal has been replaced by carbon fibre. Predict the likely impact of the introduction of this aircraft on global warming. Explain your prediction. (4)

24 marks

OPTIONAL QUESTIONS

QUESTION 10 Can be done in place of **question 1.5**.

Water can carbon dioxide are molecules which are made up of three atoms each, yet they have different shapes.

10.1 Give the shape of a …

(a) Water molecule (1)
(b) Carbon dioxide molecule (1)

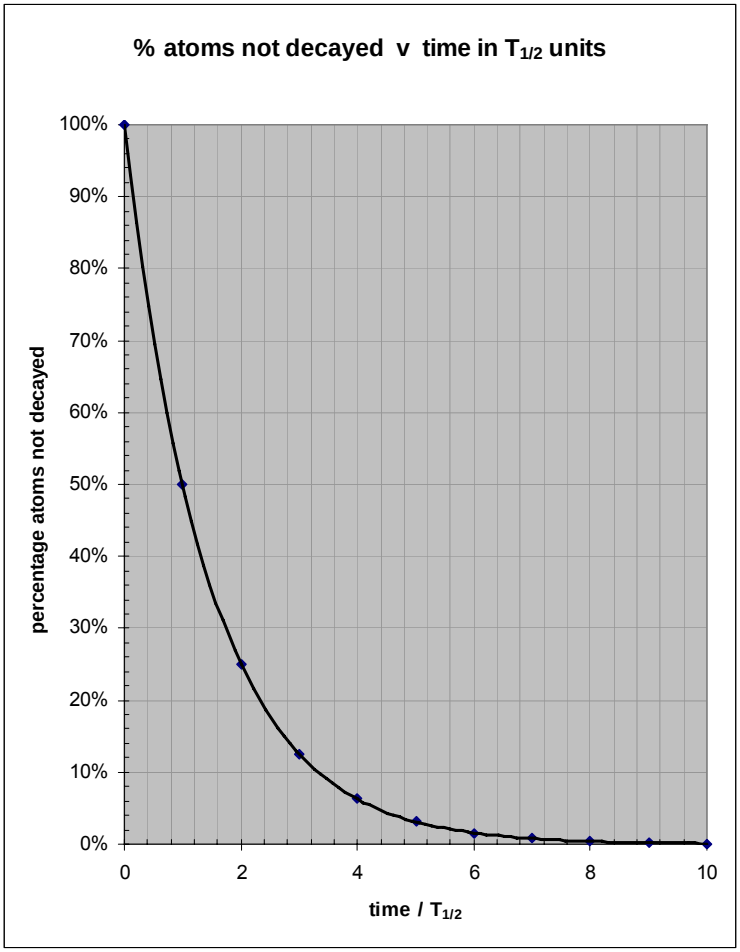
10.2 Using Valence Shell Electron Pair Repulsion (VSEPR) theory explain the shape of the water molecule. (2)

4 marks

QUESTION 11 Can be done in place of **question 5**.

11.1 ^{226}Ra has a half life of 1600 years.

(a) Explain what we mean by "a half life of 1600 years". (1)



(b) What fraction of ^{226}Ra remains in the sample after 4800 years? (2)
(c) Use the graph and the half life of ^{226}Ra to find the age of a sample of ^{226}Ra in which only 20% of the ^{226}Ra remains. (2)

11.2 The following nuclear equation represents the transformation of lead into bismuth. Rewrite the equation replacing the question marks with the correct values to complete the equation.

$$^{212}_{?}\text{Pb} \rightarrow {}^{212}_{?}\text{Bi} + ?$$ (3)

11.3 Consider the nuclear reactions represented by the following nuclear equations:

1 $$^{235}_{92}\text{U} + {}^{1}_{0}\text{n} \rightarrow {}^{139}_{57}\text{La} + {}^{95}_{42}\text{Mo} + 2\,{}^{1}_{0}\text{n} + 7\,{}^{0}_{-1}\text{e}$$

2 $$^{3}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{4}_{2}\text{He} + {}^{1}_{0}\text{n}$$

(a) Which of the above nuclear equations represents a nuclear fusion reaction? (1)

(b) Why is nuclear fusion of huge importance for life on Earth? (1)

(c) Which of one the reactions do we currently used to generate electricity? (1)

(d) Give one advantage or one disadvantage of generating electricity using the process represented by this nuclear reaction. (1)

12 marks

DATA FOR THE PHYSICAL SCIENCES PAPER 2 (GR 11 CHEMISTRY)

TABLE 1 PHYSICAL CONSTANTS

Avogadro's constant	N_A or L	6,02 x 10^{23} mol^{-1}
Molar gas constant	R	8,31 $J.K^{-1}.mol^{-1}$
Standard pressure	p^θ	1,013 x 10^5 Pa
Molar gas volume at STP	V_m	22,4 $dm^3.mol^{-1}$
Standard temperature	T^θ	273 K

TABLE 2 FORMULAE

$$\frac{p_1 V_1}{T_1} = \frac{p_2 V_2}{T_2} \qquad pV = nRT$$

$$n = \frac{m}{M} \qquad c = \frac{n}{V} \qquad c = \frac{m}{MV}$$

$$\frac{n_A}{n_B} = \frac{c_A V_A}{c_B V_B}$$

TABLE 3 PERIODIC TABLE

Key

1 2.1 **H** 1 — Atomic number (Z) / Electronegativity / Relative atomic mass

	I	II											III	IV	V	VI	VII	0
1	1 2.1 **H** 1																	2 **He** 4
2	3 1.0 **Li** 7	4 1.5 **Be** 9											5 2.0 **B** 10.8	6 2.5 **C** 12	7 3.0 **N** 14	8 3.5 **O** 16	9 4.0 **F** 19	10 **Ne** 20
3	11 0.9 **Na** 23	12 1.2 **Mg** 24.3											13 1.5 **Aℓ** 27	14 1.8 **Si** 28	15 2.1 **P** 31	16 2.5 **S** 32	17 3.0 **Cℓ** 35.5	18 **Ar** 40
4	19 0.8 **K** 39	20 1.0 **Ca** 40	21 1.3 **Sc** 45	22 1.5 **Ti** 48	23 1.6 **V** 51	24 1.6 **Cr** 52	25 1.5 **Mn** 55	26 1.8 **Fe** 56	27 1.8 **Co** 59	28 1.8 **Ni** 59	29 1.9 **Cu** 63.5	30 1.6 **Zn** 65.4	31 1.6 **Ga** 70	32 1.8 **Ge** 72.6	33 2.0 **As** 75	34 2.4 **Se** 79	35 2.8 **Br** 80	36 **Kr** 84
5	37 0.8 **Rb** 85.5	38 1.0 **Sr** 88	39 1.2 **Y** 89	40 1.4 **Zr** 91	41 1.6 **Nb** 93	42 1.8 **Mo** 96	43 1.9 **Tc** 99	44 2.2 **Ru** 101	45 2.2 **Rh** 103	46 2.2 **Pd** 106	47 1.9 **Ag** 108	48 1.7 **Cd** 112	49 1.7 **In** 115	50 1.8 **Sn** 119	51 1.9 **Sb** 121	52 2.1 **Te** 128	53 2.5 **I** 127	54 **Xe** 131
6	55 **Cs** 133	56 **Ba** 137.3		72 **Hf** 178.5	73 **Ta** 181	74 **W** 184	75 **Re** 186	76 **Os** 190	77 **Ir** 192	78 **Pt** 195	79 **Au** 197	80 **Hg** 200.6	81 **Tℓ** 204.4	82 **Pb** 207	83 **Bi** 209	84 **Po** -	85 **At** -	86 **Rn** -
7	87 **Fr**	88 **Ra**																

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**