Section A [70 marks]
Answer **all** questions.

1 The formulae of some elements are given in the following list.

Al **Cu** **Fe** **H_2** **Na** **O_2** **Zn**

(a) Choose elements from the list to answer the questions.

(i) Which element is used as a catalyst in the Haber process?

………………………………………………………………………………….. [1]

(ii) Choose **one** element which shows both metallic and non-metallic character.

………………………………………………………………………………….. [1]

(iii) Which element can be extracted from its ore by heating with carbon and is purified by electrolysis?

………………………………………………………………………………….. [1]

(iv) Which element is produced at the graphite anode during electrolysis of aqueous sodium sulfate?

………………………………………………………………………………….. [1]

(v) Which element is used for galvanizing?

………………………………………………………………………………….. [1]

(b) **(i)** Which elements in the list are transition elements?

………………………………………………………………………………….. [1]

(ii) Give three characteristic properties of transition elements.

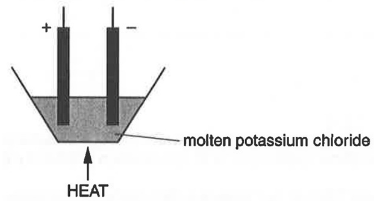
…………………………………………………………………………………..

…………………………………………………………………………………..

………………………………………………………………………………….. [2]

[Total: 8]

2 Read the information about the electrolysis of potassium chloride.

> Potassium chloride has a melting point of over 700 °C.
>
> Molten potassium chloride can be electrolysed.
>
> 
>
>
> Chlorine gas forms at the anode. We might expect potassium metal to form at the cathode, but in practice, potassium is very soluble in molten potassium chloride. A solution of potassium in molten potassium chloride forms. This problem means that electrolysis cannot be used to extract potassium from potassium chloride.

(a) The information contains an example of a compound and an example of a mixture.

(i) Identify the compound and mixture in the information.

compound ……………………………………………………………...

mixture ……………………………………………………………... [1]

(ii) Explain the difference between a compound and a mixture.

……………………………………………………………………………..

……………………………………………………………………………... [1]

(b) The electronic configuration of a potassium atom is 2,8,8,1.

Complete Table 2.1 to show the electronic configuration of a potassium **ion** and a chloride **ion**.

Table 2.1

Ion	electronic configuration
K^+	
$C\ell^-$	

[1]

(c) **(i)** Write the ionic half-equation for the reaction that happens at the anode.

…………………………………………………………………………….. [1]

(ii) Describe a simple test that would confirm the identity of the element at the anode.
Include the result of the test in your answer.

……………………………………………………………………………..

…………………………………………………………………………….. [1]

(d) Dilute aqueous potassium chloride can also be electrolysed.

Describe two differences between the products of the electrolysis of **dilute aqueous** potassium chloride and the products of the electrolysis of **molten** potassium chloride.

1 ....

....

....

2 ....

....

.... [2]

[Total: 7]

3 ^{37}Cl is an isotope of chlorine.

(a) Explain what is meant by the term *isotope*.

…………………………………………………………………………………..……..

…………………………………………………………………………………..…….. [2]

(b) An ion of ^{37}Cl contains the following particles in Table 3.1.

Table 3.1

particle	number
X	20
Y	18
Z	17

Identify particles X, Y and Z.

particle X …………………………..

particle Y …………………………..

particle Z ………………………….. [2]

(c) ^{35}Cl is another isotope of chlorine.
Complete Table 3.2 to show the numbers of each type of particle in an atom of ^{35}Cl.

Table 3.2

particle	number
X	
Y	
Z	

[2]

[Total: 6]

4 Nitrogen oxides in the upper atmosphere cause damage to the ozone layer. Aircraft engines are one source of nitrogen oxides.

(a) **(i)** Explain how nitrogen oxides are formed in the engine of an aircraft.

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………….. [2]

(ii) Give one **natural** source of nitrogen oxides in the atmosphere.

…………………………………………………………………………………….. [1]

(b) Nitrogen monoxide, NO, damages the ozone layer by reacting with ozone in a two step reaction.

$NO + O_3 \rightarrow NO_2 + O_2$ step 1

$NO_2 + O_3 \rightarrow NO + 2O_2$ step 2

(i) Use oxidation states to identify which element is oxidised in step 1.

element ………………………………………………..

change in oxidation state ……………………………………………….. [2]

(ii) One nitrogen monoxide molecule can destroy thousands of ozone molecules.
Use the equations for steps 1 and 2 to explain why.

……………………………………………………………………………………..

……………………………………………………………………………………..

…………………………………………………………………………………….. [2]

(c) Nitrogen oxides are removed from car exhaust emissions by catalytic converters.
In a converter, nitrogen monoxide reacts with carbon monoxide.

(i) Write an equation for this reaction.

…………………………………………………………………………………….. [1]

(ii) Cars fitted with catalytic converters still give out environmentally harmful gases.

Name one environmentally harmful gas that is emitted in large amounts, and describe the problem it causes.

……………………………………………………………………………………..

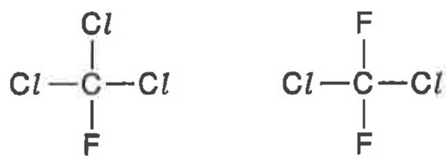
…………………………………………………………………………………….. [1]

[Total: 9]

5 Chlorofluorocarbons (CFCs) were widely used as aerosol propellants until the mid-1980s.

They are now banned in most countries because they lead to the depletion of the ozone layer.

Fig. 5.1 shows two CFCs have the trade names *Freon-11* and *Freon-12*.



Freon-11 *Freon-12*

Fig. 5.1

(a) Draw a 'dot-and-cross' diagram to show the bonding in *Freon-11*.
Show outer shell electrons only.

[2]

(b) Suggest the full structural formula for *Freon-13*.

[1]

(c) Another Freon has the formula CF_4.
Suggest the trade name of this Freon.

………..……………………………………………………………………………….. [1]

(d) Can all of these Freons be classified as CFCs?
Give a reason for your answer.

………..………………………………………………………………………………..

………..……………………………………………………………………………….. [1]

(e) *Freon-11* has a boiling point of 23.77 °C.
Explain why *Freon-11* has a low boiling point.

………..……………………………………………………………………………..

………..……………………………………………………………………………..

………..……………………………………………………………………………..

………..…………………………………………………………………………….. [2]

(f) Other than melting and boiling points, state **two** other physical properties of *Freon-11*.

………..……………………………………………………………………………..

………..…………………………………………………………………………….. [2]

[Total: 9]

6 **(a)** CFCs cause the breakdown of ozone in several steps.

The first step happens when energy from sunlight breaks a bond in a CFC to produce a chlorine atom.

For example: $CF_2C\ell_2 \rightarrow CF_2C\ell + C\ell$

Table 6.1 shows the bond energies for some bonds.

Table 6.1

bond	bond energy in kJ/mol
C – F	485
C – Cℓ	327
O – O	146
O = O	496

Use the data in Table 6.1 to explain why the ozone layer contains more chlorine atoms than fluorine atoms.

....

....

.... [2]

(b) Chlorine atoms cause the breakdown of ozone in a two-step reaction.

$$C\ell + O_3 \rightarrow C\ell O + O_2$$

$$C\ell O + O_3 \rightarrow 2O_2 + C\ell$$

Explain how the equations show that chlorine atoms act as a catalyst for the breakdown of ozone.

....

.... [1]

(c) Fig. 6.2 shows the 'dot and cross diagram' for an ozone molecule.

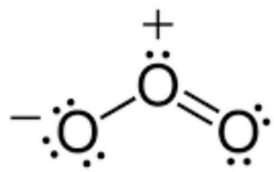


Fig. 6.2

The overall equation for the reactions in **(b)** is shown below.

$$2O_3 \rightarrow 3O_2$$

(i) Using the bond energies in Table 6.1, calculate the enthalpy change for the overall reaction. State if the reaction is exothermic or endothermic.

[3]

(ii) Hence, complete the energy profile diagram for the reaction in **(c)(i)**.

Your diagram should include:

- the reactant and product of the reaction,
- labels to show the enthalpy change of reaction and the activation energy.

[3]

[Total: 9]

7 A student carried out an experiment as shown in Fig. 7.1.

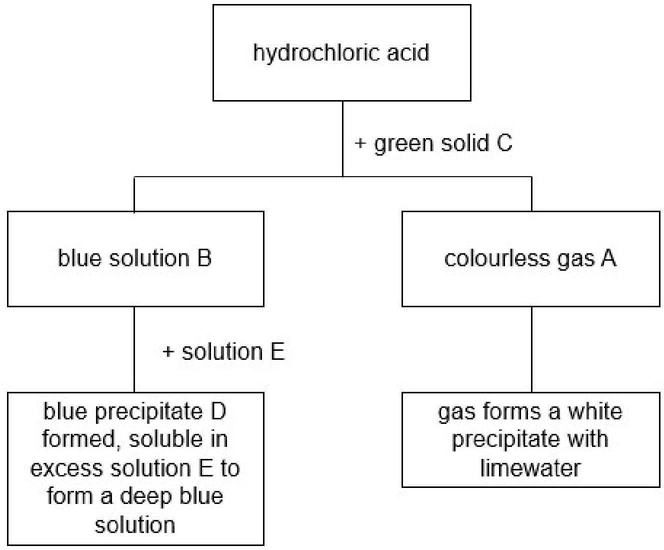


Fig. 7.1

(a) State the names for substances A to E.

A: ……………………………………..

B: ……………………………………..

C: ……………………………………..

D: ……………………………………..

E: …………………………………….. [5]

(b) Write the ionic equation, for the formation of D.

……………………………………………………………………………………………… [1]

[Total: 6]

8 **(a)** State the differences between the bonding and structures of diamond and graphite.

....

....

....

....

.... [2]

(b) When graphite is heated in air, it reacts with oxygen to produce carbon dioxide.

Table 8.1 shows some differences between the properties of graphite and carbon dioxide.

Table 8.1

	graphite	carbon dioxide
melting and boiling points	both above 3000 °C	both below 0 °C
electrical conductivity	good	does not conduct

Explain why graphite and carbon dioxide have different properties.

....

....

....

....

....

....

....

.... [4]

[Total: 6]

9 Read the information about some processing units in the petrochemical industry.

Cracking unit
There are two main types of cracking units: thermal crackers and catalytic crackers. Thermal crackers use high temperatures (600 – 900 °C) to crack long chain alkanes, producing short chain hydrocarbons which are mostly unsaturated. Catalytic crackers involve the use of a catalyst consisting of aluminium oxide and silicon dioxide in the cracking process, and produce mostly small branched alkanes from long chain alkanes.

Isomerisation unit
In an isomerisation unit, straight chain hydrocarbons are converted directly into branched hydrocarbons in the presence of a catalyst. The catalyst used is similar to that in a catalytic cracker. For example, an isomerisation unit converts butane into methylpropane as shown in Fig. 9.1.

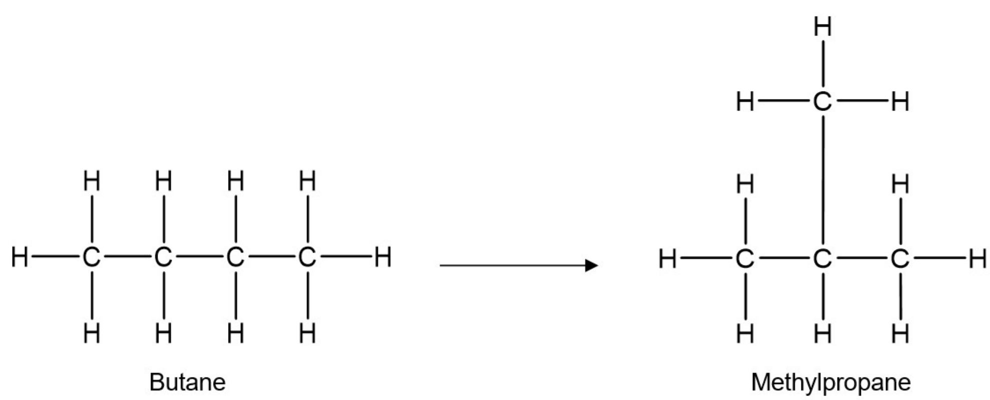


Fig. 9.1

Reforming unit

In a reforming unit, straight chain alkanes are converted into ring structures, called cycloalkanes, using a fairly high temperature (500 °C) and a platinum catalyst. Hydrogen is usually obtained as the other product. For example, a reforming unit converts butane into cyclobutane and hexane into cyclohexane as shown in Fig. 9.2 and 9.3 respectively.

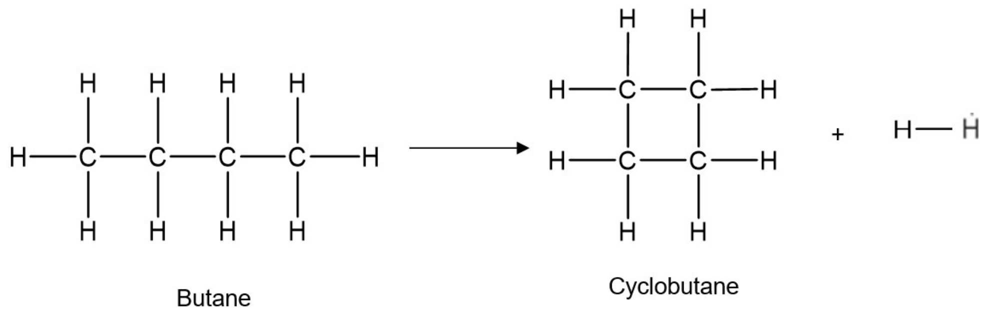


Fig. 9.2

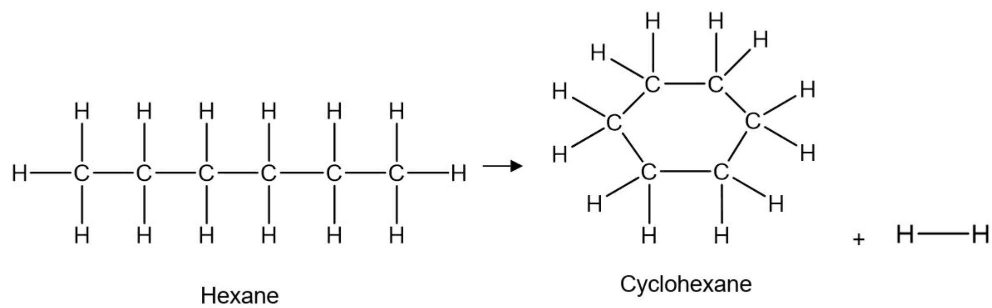


Fig. 9.3

The flow diagram in Fig. 9.4 shows how different processing units are involved in the making of some useful substances in a petrochemical plant.

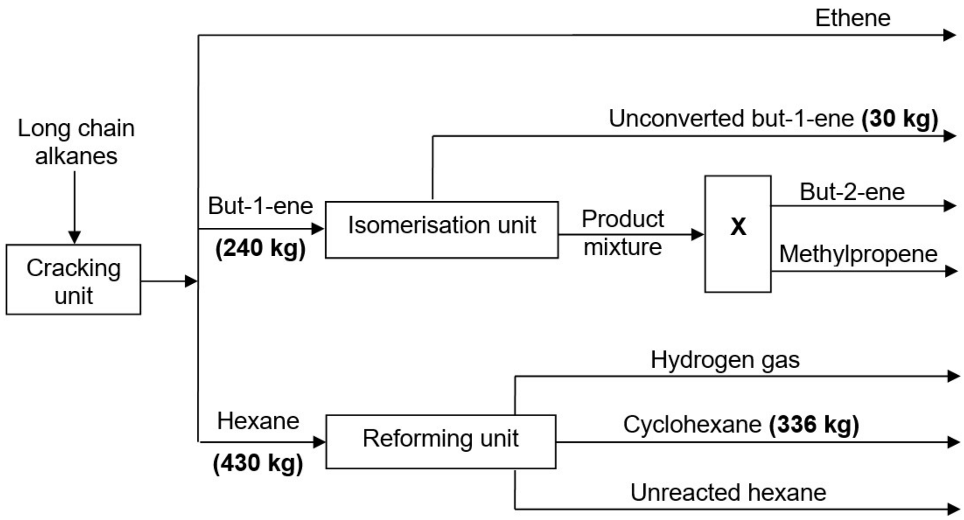
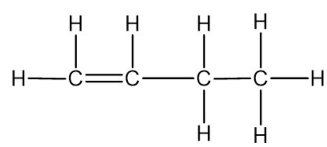
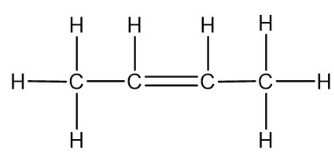
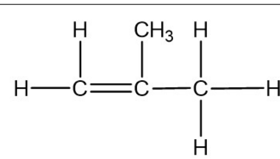


Fig. 9.4

Table 9.1 shows the structures and boiling points of some hydrocarbons.

Table 9.1

hydrocarbon	structure	boiling point / °C
but-1-ene		−6.3
but-2-ene		+3.7
methyl propene		−6.6

(a) Fig. 9.5 shows the equation of a cracking reaction.

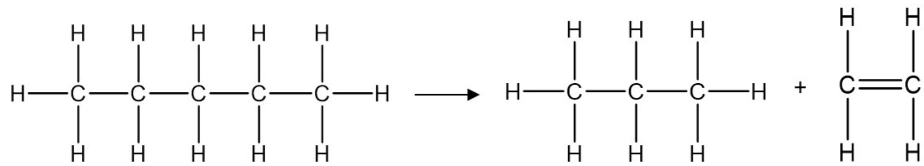


Fig. 9.5

Suggest whether this reaction is likely to take place in a thermal cracker or a catalytic cracker. Explain your answer.

....

.... [2]

(b) Two students talk about the structures of some hydrocarbons.

Student 1: Methylpropane and cyclobutane are all isomers of butane.

Student 2: Cyclobutane is an isomer of butene.

State and explain whether you agree with the two students.

....

....

....

.... [2]

(c) **(i)** Refer to the isomerisation unit in Fig. 9.4.

The mass ratio of but-2-ene to methylpropene in the product mixture is found to be 1:1. Using this information and other information from the flow diagram in Fig. 9.4, calculate the mass of but-2-ene and methylpropene produced by the isomerisation unit.

[2]

(ii) The but-2-ene and methylpropene in the product mixture from the isomerisation unit can be separated by X. With reference to relevant data from the information given, suggest what X is likely to be. Explain your answer.

………………………………………………………………………………..

………………………………………………………………………………..

………………………………………………………………………………..

……………………………………………………………………………….. [2]

(d) Refer to the reforming unit in the flow diagram in Fig. 9.4.
Show by calculation that the mass of hydrogen gas produced by the unit is 8 kg.

[2]

[Total: 10]

Section B [10 marks]
Answer **one** question from this section.

10 Ethanoic acid is manufactured by reacting methanol with carbon monoxide.

$$CH_3OH + CO \rightarrow CH_3COOH$$

(a) An industrial process uses 8 tonnes of methanol to produce 14.5 tonnes of ethanoic acid.

Calculate the percentage yield of ethanoic acid.
[1 tonne = 1 000 kg]

[3]

(b) One industrial use of ethanoic acid is to remove limescale (calcium carbonate) from steel pipes.

Write the equation for the reaction that occurs when ethanoic acid reacts with calcium carbonate.

.... [2]

(c) Hydrochloric acid is a strong acid, ethanoic acid is a weak acid.

(i) Describe a **simple** test to show which is the strong acid and which is the weak acid.

…………………………………………………………………………………..

…………………………………………………………………………………..

…………………………………………………………………………………..

………………………………………………………………………………….. [2]

(ii) Describe the differences between strong and weak acids.

…………………………………………………………………………………..

…………………………………………………………………………………..

………………………………………………………………………………….. [2]

(iii) Explain why hydrochloric acid should not be used for removing limescale from steel pipes.

…………………………………………………………………………………..

………………………………………………………………………………….. [1]

[Total: 10]

11 Nylon and *Terylene* are synthetic polymers.
Fig. 11.1 and Fig. 11.2 show the structures of nylon and *Terylene* respectively.

nylon

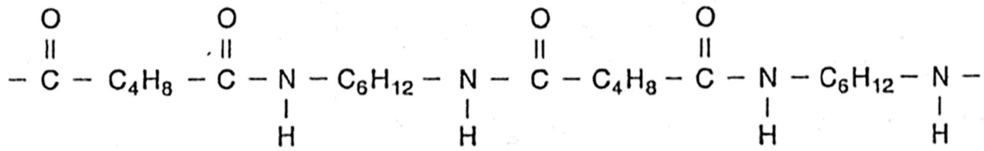


Fig. 11.1

Terylene

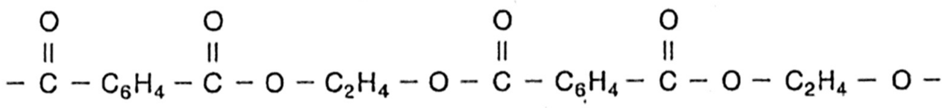


Fig. 11.2

(a) State the name and draw the structural formula of the type of linkages present in nylon and *Terylene*.

[2]

(b) Draw the structure of the monomers of nylon and *Terylene*.

[3]

(c) State the formula of the common molecule that is eliminated when both nylon and *Terylene* forms.

………………………………………………………………………………………… [1]

(d) Both nylon and *Terylene* are used to make tents for camping.
One reason that they are suitable for this purpose is that they are non-biodegradable.

Explain why being non-biodegradable is both an advantage and a disadvantage.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [2]

(e) Recycling plastics can be carried out using the chemical method.

Describe one chemical method of recycling.

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

………………………………………………………………………………………… [2]

[Total: 10]

The Periodic Table of Elements

Key

proton (atomic) number atomic symbol name relative atomic mass

Group 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

lanthanoids	57 La lanthanum 139	58 Ce cerium 140	59 Pr praseodymium 141	60 Nd neodymium 144	61 Pm promethium –	62 Sm samarium 150	63 Eu europium 152	64 Gd gadolinium 157	65 Tb terbium 159	66 Dy dysprosium 163	67 Ho holmium 165	68 Er erbium 167	69 Tm thulium 169	70 Yb ytterbium 173	71 Lu lutetium 175
actinoids	89 Ac actinium –	90 Th thorium 232	91 Pa protactinium 231	92 U uranium 238	93 Np neptunium –	94 Pu plutonium –	95 Am americium –	96 Cm curium –	97 Bk berkelium –	98 Cf californium –	99 Es einsteinium –	100 Fm fermium –	101 Md mendelevium –	102 No nobelium –	103 Lr lawrencium –

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

The Avogadro constant, $L = 6.02 \times 10^{23}\ mol^{-1}$