Cambridge International AS & A Level

CHEMISTRY

Paper 1 Multiple Choice

May/June 2022

You must answer on the multiple choice answer sheet.

You will need:  Multiple choice answer sheet
                 Soft clean eraser
                 Soft pencil (type B or HB is recommended)

INSTRUCTIONS

- There are forty questions on this paper. Answer all questions.
- For each question there are four possible answers A, B, C and D. Choose the one you consider correct and record your choice in soft pencil on the multiple choice answer sheet.
- Follow the instructions on the multiple choice answer sheet.
- Write in soft pencil.
- Write your name, centre number and candidate number on the multiple choice answer sheet in the spaces provided unless this has been done for you.
- Do not use correction fluid.
- Do not write on any bar codes.
- You may use a calculator.

INFORMATION

- The total mark for this paper is 40.
- Each correct answer will score one mark.
- Any rough working should be done on this question paper.
- The Periodic Table is printed in the question paper.
- Important values, constants and standards are printed in the question paper.

This document has 16 pages.
1 Which atom has its outermost electron in an orbital of the shape shown, with principal quantum number 3?

A sodium  
B chlorine  
C calcium  
D bromine

2 Which atom has the same number of electrons as the hydroxide ion, OH⁻?

A F  
B Ne  
C Na  
D Mg

3 In separate experiments, 5.0g samples of each of four s-block metals are added to an excess of water. The gas evolved is collected and its volume measured under the same conditions of temperature and pressure for each sample.

Which metal produces the largest volume of gas?

A calcium  
B potassium  
C rubidium  
D strontium

4 A student reacts 1 mol of copper with concentrated nitric acid to produce 1 mol of copper(II) nitrate, 2 mol of water and substance X. No other product is formed.

Substance X does not contain copper or hydrogen.

What could be substance X?

A N₂  
B N₂O  
C NO  
D NO₂

5 In which structure are three atoms bonded together in a straight line?

A poly(ethene), \( \text{CH}_2\text{CH}_2 \)\( \text{CH}_2\text{CH}_2 \)\( \text{CH}_2\text{CH}_2 \)\( n \)  
B propane, \( \text{C}_3\text{H}_8 \)  
C silicon tetrachloride, \( \text{SiCl}_4 \)  
D sulfur hexafluoride, \( \text{SF}_6 \)
6 Which statement about aluminium chloride is correct?

A Aluminium chloride has a much higher melting point than magnesium chloride due to the small size of the aluminium ion.

B Anhydrous aluminium chloride reacts vigorously with water to form a solution with a pH greater than 7.

C Each $\text{Al}_2\text{Cl}_6$ molecule found in aluminium chloride vapour contains two coordinate bonds.

D The bonding between aluminium and chlorine is strongly ionic due to the large difference in electronegativity.

7 ‘Black powder’ is a mixture of potassium nitrate, carbon and sulfur. The mixture reacts as shown.

$$4\text{KNO}_3(s) + 7\text{C}(s) + \text{S}(s) \rightarrow 3\text{CO}_2(g) + 3\text{CO}(g) + 2\text{N}_2(g) + \text{K}_2\text{S}(s) + \text{K}_2\text{CO}_3(s)$$

A sealed tube containing black powder has a volume of 10.0 cm$^3$. When all of the black powder reacts, the reaction causes a pressure of $2 \times 10^6$ Pa and a temperature of 2500 K.

The volume of the $\text{K}_2\text{CO}_3$ and $\text{K}_2\text{S}$ produced can be ignored.

How many moles of $\text{KNO}_3$ are contained in the sealed tube?

A $4.81 \times 10^{-4}$  
B $9.63 \times 10^{-4}$  
C $1.93 \times 10^{-3}$  
D $9.63 \times 10^{-1}$

8 For which pair is the boiling point of the first compound higher than the boiling point of the second compound?

A $\text{CH}_3\text{CH}_2\text{OH}$ and $\text{CH}_3\text{CH}_2\text{SH}$

B $\text{CH}_3\text{CO}_2\text{CH}_3$ and $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$

C $\text{CH}_3\text{OCH}_3$ and $\text{CH}_3\text{CH}_2\text{OH}$

D $\text{CH}_3\text{CH}_2\text{CHO}$ and $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$

9 The equation for an enthalpy change is shown. The enthalpy change is $Q$.

$$2\text{C}(s) + 3\text{H}_2(g) + 3.5\text{O}_2(g) \xrightarrow{Q} 2\text{CO}_2(g) + 3\text{H}_2\text{O}(l)$$

What is the correct expression to calculate $Q$?

A $2 \times \Delta H^\circ_\text{f} [\text{CO}_2(g)] - 3 \times \Delta H^\circ_\text{f} [\text{H}_2(g)]$

B $3 \times \Delta H^\circ_\text{f} [\text{H}_2\text{O}(g)] + 2 \times \Delta H^\circ_\text{f} [\text{CO}_2(g)]$

C $2 \times \Delta H^\circ_\text{f} [\text{CO}_2(g)] - 3 \times \Delta H^\circ_\text{f} [\text{H}_2(g)]$

D $3 \times \Delta H^\circ_\text{f} [\text{H}_2\text{O}(l)] + 2 \times \Delta H^\circ_\text{f} [\text{CO}_2(g)]$
10 A reaction pathway diagram for the reaction of aqueous sodium hydroxide and dilute sulfuric acid is shown.

\[ 2 \text{NaOH} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O} \]

What is the value of the enthalpy change of neutralisation, \( \Delta H_{\text{neut}} \)?

A \( x \)  
B \( x - y \)  
C \( \frac{x}{2} \)  
D \( \frac{(x - y)}{2} \)

11 A student reacts 4 mol of ammonia with oxygen to produce an oxide of nitrogen and water only. Each nitrogen atom increases its oxidation state by 5 in the reaction.

How many moles of oxygen gas react with 4 mol of ammonia in this reaction?

A \( 4 \) mol  
B \( 5 \) mol  
C \( 7 \) mol  
D \( 10 \) mol

12 In the treatment of domestic water supplies, chlorine is added to water to kill bacteria. Some \( \text{ClO}^- \) ions are formed.

What is the change in oxidation number of chlorine when forming the \( \text{ClO}^- \) ion from aqueous chlorine?

A \( -1 \)  
B \( 0 \)  
C \( +1 \)  
D \( +2 \)
13 Ethanoic acid is mixed with ethanol.

The ethanol is contaminated with a small amount of methanol.

The following equilibria are established.

\[
\begin{align*}
\text{CH}_3\text{CO}_2\text{H}(l) + \text{CH}_3\text{CH}_2\text{OH}(l) & \rightleftharpoons \text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3(l) + \text{H}_2\text{O}(l) & K_c = K_1 \\
\text{CH}_3\text{CO}_2\text{H}(l) + \text{CH}_3\text{OH}(l) & \rightleftharpoons \text{CH}_3\text{CO}_2\text{CH}_3(l) + \text{H}_2\text{O}(l) & K_c = K_2
\end{align*}
\]

Which statement about the equilibrium mixture is correct?

A Only ethyl ethanoate will be formed because there is much more ethanol present than methanol.

B In this mixture \(\frac{[\text{CH}_3\text{CO}_2\text{CH}_2\text{CH}_3]}{[\text{CH}_3\text{CO}_2\text{CH}_3]} = \frac{K_1}{K_2}\).

C Adding water to the mixture will alter the mole ratio of the two esters.

D Adding methyl ethanoate to the mixture will increase the number of moles of ethyl ethanoate.

14 SO\textsubscript{3} is manufactured from SO\textsubscript{2} and O\textsubscript{2} in the Contact process.

The reaction is exothermic.

Which row shows the effect on the equilibrium yield obtained in the Contact process of increasing the temperature and of adding a vanadium(V) oxide catalyst?

<table>
<thead>
<tr>
<th></th>
<th>increasing the temperature</th>
<th>adding vanadium(V) oxide as catalyst</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A</strong></td>
<td>equilibrium yield decreases</td>
<td>equilibrium yield increases</td>
</tr>
<tr>
<td><strong>B</strong></td>
<td>equilibrium yield decreases</td>
<td>equilibrium yield unchanged</td>
</tr>
<tr>
<td><strong>C</strong></td>
<td>equilibrium yield increases</td>
<td>equilibrium yield unchanged</td>
</tr>
<tr>
<td><strong>D</strong></td>
<td>equilibrium yield increases</td>
<td>equilibrium yield increases</td>
</tr>
</tbody>
</table>
15 The Boltzmann distribution for a gas at a constant temperature of 50°C is shown.

![Graph showing Boltzmann distribution]

If the temperature of the gas is reduced by 10°C, the graph changes shape.

What happens to the values of \( n \) for the molecular energies X, Y and Z?

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>higher</td>
<td>lower</td>
<td>higher</td>
</tr>
<tr>
<td>B</td>
<td>higher</td>
<td>lower</td>
<td>lower</td>
</tr>
<tr>
<td>C</td>
<td>lower</td>
<td>higher</td>
<td>lower</td>
</tr>
<tr>
<td>D</td>
<td>lower</td>
<td>lower</td>
<td>lower</td>
</tr>
</tbody>
</table>

16 A 3.0 g sample of Na₂CO₃ powder is stirred into 50 cm³ of 1.0 mol dm⁻³ HCl. The volume of CO₂ produced is 600 cm³.

\[
\text{Na}_2\text{CO}_3(s) + 2\text{HCl}(aq) \rightarrow 2\text{NaCl}(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l)
\]

\[M_r: \text{Na}_2\text{CO}_3, 106.0\]

Which volume of CO₂ is produced if 1.0 g of Na₂CO₃ powder is stirred into 50 cm³ of 1.0 mol dm⁻³ HCl under the same conditions?

- A 600 cm³
- B 452 cm³
- C 226 cm³
- D 200 cm³

17 Solid sodium iodide reacts with concentrated sulfuric acid to form more than one product that contains sulfur.

What is the lowest oxidation number of sulfur in these products?

- A –2
- B 0
- C +4
- D +6
18 Which statement for the element in Period 3 and Group 13 of the Periodic Table is correct?
   A It has the highest melting point of the elements in its period.
   B It has exactly one electron in its shell with principal quantum number 3.
   C It forms an oxide that reacts with aqueous sodium hydroxide.
   D It forms a chloride that dissolves in water to give a neutral solution.

19 A student reacts 0.100 mol of each of sodium, magnesium and phosphorus atoms separately with an excess of oxygen.

Which rows are correct?

<table>
<thead>
<tr>
<th></th>
<th>oxide</th>
<th>mass of oxide formed / g</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>sodium</td>
<td>3.10</td>
</tr>
<tr>
<td>2</td>
<td>magnesium</td>
<td>4.03</td>
</tr>
<tr>
<td>3</td>
<td>phosphorus</td>
<td>7.10</td>
</tr>
</tbody>
</table>

A 1, 2 and 3  B 1 and 2 only  C 1 and 3 only  D 2 and 3 only

20 A mixture contains magnesium carbonate and barium carbonate only. A sample of the mixture is dissolved in nitric acid to produce a solution.

How could this solution be processed into a magnesium compound and a separate barium compound?

A Add HCl(aq), filter off the solid barium chloride.
B Add HCl(aq), filter off the solid magnesium chloride.
C Add H₂SO₄(aq), filter off the solid barium sulfate.
D Add H₂SO₄(aq), filter off the solid magnesium sulfate.
21 A sample of magnesium nitrate is heated in the apparatus shown.

The pH of the solution in the trough is measured.

The gas collected is tested with a glowing splint.

What are the results?

<table>
<thead>
<tr>
<th></th>
<th>pH of solution in trough</th>
<th>splint test</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8</td>
<td>relights</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>relights</td>
</tr>
<tr>
<td>C</td>
<td>8</td>
<td>extinguished</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>extinguished</td>
</tr>
</tbody>
</table>

22 The results of tests performed on a white crystalline solid, X, are given in the table.

<table>
<thead>
<tr>
<th>reagent and conditions</th>
<th>observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>X is gently heated</td>
<td>X sublimes</td>
</tr>
<tr>
<td>X is shaken with H₂O</td>
<td>a colourless solution, Y, forms</td>
</tr>
<tr>
<td>Y is warmed with NaOH(aq)</td>
<td>a gas is given off</td>
</tr>
<tr>
<td>AgNO₃(aq) is added to Y</td>
<td>a white precipitate, Z, forms</td>
</tr>
<tr>
<td>Z is shaken with NH₃(aq)</td>
<td>a colourless solution forms</td>
</tr>
</tbody>
</table>

What is the identity of X?

A aluminium bromide

B aluminium chloride

C ammonium bromide

D ammonium chloride
23 Silicon is heated in an excess of chlorine, producing compound J. An excess of water is added to the sample of J produced. Which row is correct?

<table>
<thead>
<tr>
<th>structure of J</th>
<th>Is HCl produced when water is added to J?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A  giant molecular</td>
<td>no</td>
</tr>
<tr>
<td>B  giant molecular</td>
<td>yes</td>
</tr>
<tr>
<td>C  simple molecular</td>
<td>no</td>
</tr>
<tr>
<td>D  simple molecular</td>
<td>yes</td>
</tr>
</tbody>
</table>

24 In a catalytic converter, 5.6 g of carbon monoxide react with an excess of nitrogen monoxide. What is produced in this reaction?

A  2.4 g of C and 6.0 g of NO₂
B  2.4 g of C and 9.2 g of NO₂
C  8.8 g of CO₂ and 1.4 g of N₂
D  8.8 g of CO₂ and 2.8 g of N₂

25 Which reaction mixture produces an acidic gas?

A  aqueous ammonium nitrate and solid calcium oxide
B  calcium and aqueous hydrochloric acid
C  potassium chloride and concentrated sulfuric acid
D  sodium oxide and water
26 Ethanol can be used to make propanenitrile in two steps.

\[
\text{CH}_3\text{CH}_2\text{OH} \xrightarrow{X} \text{CH}_3\text{CH}_2\text{Br} \xrightarrow{Y} \text{CH}_3\text{CH}_2\text{CN}
\]

What types of reaction are X and Y?

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>free-radical substitution</td>
<td>electrophilic substitution</td>
</tr>
<tr>
<td>B</td>
<td>free-radical substitution</td>
<td>nucleophilic substitution</td>
</tr>
<tr>
<td>C</td>
<td>nucleophilic substitution</td>
<td>nucleophilic substitution</td>
</tr>
<tr>
<td>D</td>
<td>nucleophilic substitution</td>
<td>electrophilic substitution</td>
</tr>
</tbody>
</table>

27 Which compound will react with LiA/H₄ to form two optical isomers?

- A \( \text{CH}_3\text{CH}_2\text{COCH}_3 \)
- B \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} \)
- C \( \text{CH}_3\text{CH}_2\text{COCH}_2\text{CH}_3 \)
- D \( \text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CO}_2\text{H} \)

28 How many esters have the molecular formula C₄H₈O₂?

- A 2
- B 3
- C 4
- D 5

29 Carbon monoxide, CO, nitrogen dioxide, NO₂, and sulfur dioxide, SO₂, are all atmospheric pollutants.

Which reaction occurs in the atmosphere?

- A CO is spontaneously oxidised to CO₂.
- B NO₂ is reduced to NO by SO₂.
- C NO₂ is reduced to NO by CO.
- D SO₂ is oxidised to SO₃ by CO₂.
30 Oct-1-ene, \( \text{CH}_3(\text{CH}_2)_5\text{CH} = \text{CH}_2 \), can be thermally cracked.

Which of the compounds W, X, Y and Z can be obtained by thermally cracking oct-1-ene?

<table>
<thead>
<tr>
<th></th>
<th>W</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \text{CH}_2=\text{CH}_2 )</td>
<td>( \text{CH}_3\text{CH} = \text{CH}_2 )</td>
<td>( \text{CH}_3\text{CH}_2\text{CH}_3 )</td>
<td>( \text{CH}_2=\text{CHCH} = \text{CH}_2 )</td>
</tr>
</tbody>
</table>

A  W, X, Y and Z  
B  W, X and Y only  
C  W, X and Z only  
D  W and X only

31 Structural isomerism and stereoisomerism should be taken into account when answering this question.

How many isomeric alkenes with formula \( \text{C}_5\text{H}_8 \) are present in the mixture produced when 1,4-dibromopentane is reacted with NaOH in ethanol?

A  1  
B  2  
C  3  
D  4

32 The presence of a halogen in an organic compound may be detected by warming the organic compound with aqueous silver nitrate.

Which compound would be the quickest to produce a precipitate?

A  
B  
C  
D  

33 17.6 g of pentan-1-ol is completely combusted.

Which volume of gaseous products is formed when measured at s.t.p.?

A  22.4 dm\(^3\)  
B  24.0 dm\(^3\)  
C  49.3 dm\(^3\)  
D  52.8 dm\(^3\)
34 Crotyl alcohol, CH₃CH=CHCH₂OH, is a colourless liquid which is used as a solvent.

Crotyl alcohol will react separately with Br₂, K₂Cr₂O₇/H⁺, conc. KMnO₄/H⁺ and PCl₅ under suitable conditions.

Which row is correct?

<table>
<thead>
<tr>
<th>reactant</th>
<th>conditions</th>
<th>main product</th>
</tr>
</thead>
<tbody>
<tr>
<td>A  Br₂</td>
<td>room temperature</td>
<td>CH₃CH=CHCH₂Br</td>
</tr>
<tr>
<td>B  K₂Cr₂O₇/H⁺</td>
<td>heat under reflux</td>
<td>CH₃CH=CHCHO</td>
</tr>
<tr>
<td>C  conc. KMnO₄/H⁺</td>
<td>heat under reflux</td>
<td>CH₃CH=CHCO₂H</td>
</tr>
<tr>
<td>D  PCl₅</td>
<td>room temperature</td>
<td>CH₃CH=CHCH₂Cl</td>
</tr>
</tbody>
</table>

35 The skeletal formulae of two organic compounds are shown.

![Skeletal formula of a compound with an OH group and another with a carbonyl group.]

Which reagents can be used to distinguish these two compounds?

1 alkaline I₂(aq)
2 acidified K₂Cr₂O₇
3 2,4-dinitrophenylhydrazine (2,4-DNPH reagent)

A 1, 2 and 3  B 1 and 3 only  C 2 and 3 only  D 2 only

36 A carbonyl compound, X, reacts with HCN in the presence of NaCN to make a compound with M, 85. Compound X does not react with Fehling’s reagent.

What is compound X?

A butanal  B butanone  C propanal  D propanone
37 Which compound produces butan-2-ol and ethanoic acid on hydrolysis?
   A  CH₃CO₂CH(CH₃)₂
   B  CH₃CO₂CH(CH₃)CH₂CH₃
   C  CH₃CH(CH₃)CO₂CH₂CH₃
   D  CH₃CH₂CO₂CH(CH₃)CH₂CH₃

38 Two 1g samples of Y are reacted separately and completely with sodium and with sodium carbonate. The volumes of the gases produced are collected and measured.

<table>
<thead>
<tr>
<th></th>
<th>with Na</th>
<th>with Na₂CO₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

What could Y be?
   A  CH₃CH(OH)CH₂OH
   B  CH₃CH(OH)CO₂H
   C  CH₃COCH₂OH
   D  CH₃COCO₂H

39 The diagram shows a section of an addition polymer formed from two different monomers.

One of the monomers is propene.

What is the other monomer?
   A  
   B  
   C  
   D  
A scientist chooses either infrared spectroscopy or mass spectrometry to find a particular piece of information.

In which row has the **best** choice been made?

<table>
<thead>
<tr>
<th></th>
<th>target information</th>
<th>analytic method used</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>identities of functional groups in an organic compound</td>
<td>infrared spectroscopy</td>
</tr>
<tr>
<td>B</td>
<td>identities of functional groups in an organic compound</td>
<td>mass spectrometry</td>
</tr>
<tr>
<td>C</td>
<td>values of successive ionisation energies of Na</td>
<td>infrared spectroscopy</td>
</tr>
<tr>
<td>D</td>
<td>values of successive ionisation energies of Na</td>
<td>mass spectrometry</td>
</tr>
</tbody>
</table>
### Important values, constants and standards

<table>
<thead>
<tr>
<th></th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>molar gas constant</td>
<td>$R = 8.31 \text{JK}^{-1}\text{mol}^{-1}$</td>
</tr>
<tr>
<td>Faraday constant</td>
<td>$F = 9.65 \times 10^{4} \text{Cmol}^{-1}$</td>
</tr>
<tr>
<td>Avogadro constant</td>
<td>$L = 6.02 \times 10^{23} \text{mol}^{-1}$</td>
</tr>
<tr>
<td>electronic charge</td>
<td>$e = -1.60 \times 10^{-19} \text{C}$</td>
</tr>
<tr>
<td>molar volume of gas</td>
<td>$V_m = 22.4 \text{dm}^3\text{mol}^{-1}$ at s.t.p. (101 kPa and 273 K)</td>
</tr>
<tr>
<td></td>
<td>$V_m = 24.0 \text{dm}^3\text{mol}^{-1}$ at room conditions</td>
</tr>
<tr>
<td>ionic product of water</td>
<td>$K_w = 1.00 \times 10^{-14} \text{mol}^2\text{dm}^{-6}$ (at 298 K (25°C))</td>
</tr>
<tr>
<td>specific heat capacity of water</td>
<td>$c = 4.18 \text{kJkg}^{-1}\text{K}^{-1}$ (4.18 Jg$^{-1}$K$^{-1}$)</td>
</tr>
</tbody>
</table>
# The Periodic Table of Elements

<table>
<thead>
<tr>
<th>Group</th>
<th>Period</th>
<th>Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>H, He</td>
</tr>
<tr>
<td>2</td>
<td>3-18</td>
<td>Li, Be, B, C, N, O, F, Ne, Na, Mg, Al, Si, P, S, Cl, Ar</td>
</tr>
<tr>
<td>3</td>
<td>18-32</td>
<td>K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Kr</td>
</tr>
<tr>
<td>4</td>
<td>32-46</td>
<td>Rb, Sr, Y, Zr, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe</td>
</tr>
<tr>
<td>5</td>
<td>46-50</td>
<td>Cs, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu</td>
</tr>
<tr>
<td>6</td>
<td>50-54</td>
<td>Fr, Ra, Actinoids, Lanthanoids</td>
</tr>
</tbody>
</table>

**Key**
- **Atomic Number:** The number of protons in the nucleus.
- **Atomic Symbol:** The chemical symbol for the element.
- **Name:** The name of the element.
- **Relative Atomic Mass:** The mass number of the element.

## Lanthanoids
- La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu

## Actinoids
- Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, Lr