

| MARKER CODE |  |  |  |  |
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| STUDENT ENROLMENT NUMBER (SEN) |  |  |  |  |  |  |  |  |  |
|--------------------------------|--|--|--|--|--|--|--|--|--|
|                                |  |  |  |  |  |  |  |  |  |

# TONGA FORM SIX CERTIFICATE 2019 CHEMISTRY

## QUESTION AND ANSWER BOOKLET

**Time allowed:** 3 Hours

### INSTRUCTIONS:

- Write your **Student Enrolment Number (SEN)** on the top right-hand corner of this page.
- This paper consists of **SIX QUESTIONS** and is out of 70 Total scores.

| QUESTIONS    | STRANDS                                                 | TOTAL SKILL LEVEL |
|--------------|---------------------------------------------------------|-------------------|
| <b>ONE</b>   | <b>ATOMIC STRUCTURE, BONDING AND RELATED PROPERTIES</b> | <b>20</b>         |
| <b>TWO</b>   | <b>SOLIDS AND RELATED PROPERTIES</b>                    | <b>13</b>         |
| <b>THREE</b> | <b>INORGANIC CHEMISTRY</b>                              | <b>9</b>          |
| <b>FOUR</b>  | <b>REDOX CHEMISTRY</b>                                  | <b>8</b>          |
| <b>FIVE</b>  | <b>QUANTITATIVE CHEMISTRY</b>                           | <b>4</b>          |
| <b>SIX</b>   | <b>ORGANIC CHEMISTRY</b>                                | <b>16</b>         |
|              | <b>TOTAL</b>                                            | <b>70</b>         |

- Answer ALL QUESTIONS. Write your answers in the spaces provided in this booklet.
- Use a **BLUE** or **BLACK** ball point pen only for writing. Use a pencil for drawing if required.
- If you need more spaces for answers, ask the supervisor for extra paper. Write your **Student Enrolment Number (SEN)** on each additional sheet, number the questions clearly and insert them in the appropriate places in this booklet.

**NOTE:** There is a group of the **Periodic Table of the Elements** provided on page **15**. The table gives the **Symbol**, **Atomic Number** and the **Relative Atomic Mass** of the elements. The Groups (columns) are numbered I, II, III, IV etc.

**NOTE:** The symbol M is used for molar mass.  $M(\text{Na}) = \text{gmol}^{-1}$  and  $M(\text{CO}_2) = 44 \text{ gmol}^{-1}$ .

- Check that this booklet contains pages **2-15** in the correct order and that none of the pages is blank.

**YOU MUST HAND IN THIS BOOKLET TO THE SUPERVISOR BEFORE YOU LEAVE THE EXAMINATION ROOM.**

**ATTEMPT ALL QUESTIONS IN THIS EXAMINATION PAPER.**

**Write the answer to each question in the correct spaces provided.**

**QUESTION ONE: ATOMIC STRUCTURE, BONDING AND RELATED PROPERTIES**

1. An **Ion Z** has a mass number of 16 and consists of 8 *neutrons* and 10 *electrons*.

- a. Define the term **Mass number**.

\_\_\_\_\_

| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- b. Determine the number of **protons**.

\_\_\_\_\_

| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- c. Name **Ion Z** from the given data.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

**Ion Z** is an anion and also can form a covalent bond with a respective element from **Group 17.(VII)**

- d. Define the term **Anion**.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- e. Define the term **Covalent bond**.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- f. Give an example of a covalent compound that is formed between Ion Z and a member of Group 17 (VII).

| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

2. Draw the Lewis structure of **Atom Z** using a dot diagram.

| Skill level 2 |  |
|---------------|--|
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

3. Name the **TWO** (2) isotopes of Hydrogen.

- i. \_\_\_\_\_
- ii. \_\_\_\_\_

| Skill level 2 |  |
|---------------|--|
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

The diagram below shows elements in the same group.

| Group 1        | Group 7        |
|----------------|----------------|
| Li<br>Lithium  | F<br>Fluorine  |
| Na<br>Sodium   | Cl<br>Chlorine |
| K<br>Potassium | Br<br>Bromine  |
| Rb<br>Rubidium | I<br>Iodine    |
| Cs<br>Caesium  | At<br>Astatine |
| Fr<br>Francium |                |

source: <http://www.google/periodictable>

4. Explain the importance of elements in the **same group** of the periodic table.

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| Skill level 3 |  |
|---------------|--|
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

5. Explain how a methane molecule can have a **three dimensional shape**.

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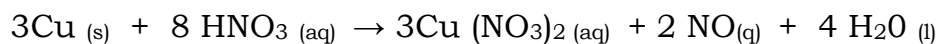
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| Skill level 3 |  |
|---------------|--|
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

6. A 150 mL sample of  $1.65 \text{ mol L}^{-1}$  aqueous nitric acid was completely reacted with 6.0 g of industrial sludge containing copper. The equation for the reaction is shown below.

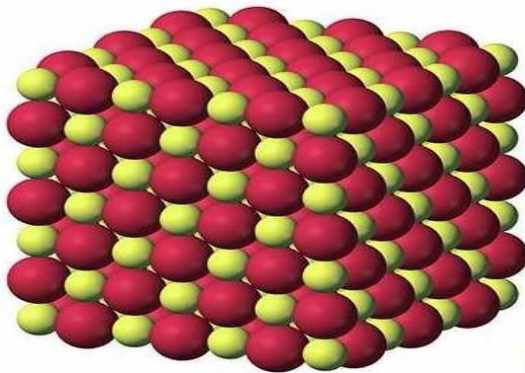


Calculate the **percentage yield of copper** in the sample. Assume that the copper would react completely with this amount of nitric acid.

| Skill level 4 |  |
|---------------|--|
| 4             |  |
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

## QUESTION TWO: SOLIDS AND RELATED PROPERTIES

1. The diagram below shows an **ionic solid structure**. Ionic solids can undergo **hydration** process.



Source: <http://www.google.com//ionicsolid>

- a. Define the term **hydration**.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- b. Determine the **bond** that is **disrupted** when ionic solids undergo hydration.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- c. State **ONE** (1) use of ionic solids in everyday life.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

2. Explain why ionic substances conduct electricity in molten form but not in solid form.

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| Skill level 3 |  |
|---------------|--|
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

3. Explain why some molecular liquids dissolve better than others in water.

|  |  |                      |  |
|--|--|----------------------|--|
|  |  | <b>Skill level 3</b> |  |
|  |  | 3                    |  |
|  |  | 2                    |  |
|  |  | 1                    |  |
|  |  | 0                    |  |
|  |  | NR                   |  |

4. Evaluate the different solids and their related properties given in the table below.

| Types of Solid     | Properties                   |
|--------------------|------------------------------|
| Discrete Molecular | Does not conduct electricity |
| Metallic           | Cannot dissolve in water     |

|  |  |                      |  |
|--|--|----------------------|--|
|  |  | <b>Skill level 4</b> |  |
|  |  | 4                    |  |
|  |  | 3                    |  |
|  |  | 2                    |  |
|  |  | 1                    |  |
|  |  | 0                    |  |
|  |  | NR                   |  |

### QUESTION THREE: INORGANIC CHEMISTRY

1.  $[\text{Cu}(\text{NH}_3)_4]^{+2}$  is a complex ion and forms a dark blue colour solution with water.

| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- a. Define the term **complex ion**.

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- b. Name the complex ion given above.

| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

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2. Write balanced equations which demonstrate the **amphoteric property** of Zinc oxide.

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| Skill level 3 |  |
|---------------|--|
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

3. Discuss tests for the presence of  $\text{Pb}^{+2}$  and  $\text{Zn}^{+2}$  in aqueous solutions by;
- applying the knowledge of solubilities and
  - describing the observations made.

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| Skill level 4 |  |
|---------------|--|
| 4             |  |
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

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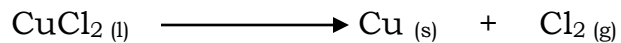


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# **QUESTION FOUR: REDOX CHEMISTRY**

1. Copper chloride in molten state undergoes **electrolysis** and respective ions will attach to the anode and the cathode.



- a. Identify the **Oxidant** (oxidizing agent) in the chemical reaction above.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- b. Define the term **Electrolysis**.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

- c. Define the term **Anode**.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

2. Determine the **oxidation state** (number) of Cl in  $\text{HClO}_4$ .

| Skill level 2 |  |
|---------------|--|
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

3. Analyse the colours of permanganate in their different oxidation states under various acidic conditions.

[illegible]

| Skill level 3 |  |
|---------------|--|
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

## QUESTION FIVE: QUANTITATIVE CHEMISTRY

1. Compounds are at times represented using formulas. Formulas used are either empirical formula or molecular formula depending on circumstances.

Define the terms:

a. **Empirical formula**

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

b. **Molecular formula**

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

2. Helium is a very light gas and is therefore used to inflate balloons.



Source: <http://www.google.heliumballon>

Calculate the number of atoms in 6.46g of Helium.

[Avogadro number =  $6 \times 10^{23}$ ]

| Skill level 2 |  |
|---------------|--|
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

**QUESTION SIX: ORGANIC CHEMISTRY**

1. Define the term
- polyhydric alcohol**
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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

2. Name a simple polyhydric alcohol.

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

3. Define the term
- Geometric isomers**
- .

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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

4. Define the term
- Stereoisomers**
- .

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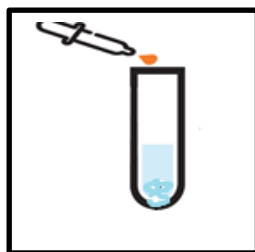
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| Skill level 1 |  |
|---------------|--|
| 1             |  |
| 0             |  |
| NR            |  |

5. Describe the observations made during the reaction of ethene and bromine water.



source: <http://www.google.ethene>

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| Skill level 2 |  |
|---------------|--|
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

6. Account for the physical properties of **cis** and **trans** isomers of ethene.

| Skill level 3 |  |
|---------------|--|
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

7. Explain the trend of rising melting points with increasing saturation of **fats**.



**Source:** <http://www.google.fats>

| Skill level 3 |  |
|---------------|--|
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

| Skill level 4 |  |
|---------------|--|
| 4             |  |
| 3             |  |
| 2             |  |
| 1             |  |
| 0             |  |
| NR            |  |

Periodic Table of the Elements

| Periodic Table of the Elements |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |
|--------------------------------|--|--|--|--|--|--|--|--|--|--|--|---------|--|--|--|--|--|
| 1                              |  |  |  |  |  |  |  |  |  |  |  | 18      |  |  |  |  |  |
| 1                              |  |  |  |  |  |  |  |  |  |  |  | 2       |  |  |  |  |  |
| H                              |  |  |  |  |  |  |  |  |  |  |  | He      |  |  |  |  |  |
| 1.01                           |  |  |  |  |  |  |  |  |  |  |  | 4.00    |  |  |  |  |  |
| 2                              |  |  |  |  |  |  |  |  |  |  |  |         |  |  |  |  |  |
| 3                              |  |  |  |  |  |  |  |  |  |  |  | 13      |  |  |  |  |  |
| Li                             |  |  |  |  |  |  |  |  |  |  |  | B       |  |  |  |  |  |
| 6.94                           |  |  |  |  |  |  |  |  |  |  |  | 10.81   |  |  |  |  |  |
| 4                              |  |  |  |  |  |  |  |  |  |  |  | 6       |  |  |  |  |  |
| Be                             |  |  |  |  |  |  |  |  |  |  |  | C       |  |  |  |  |  |
| 9.01                           |  |  |  |  |  |  |  |  |  |  |  | 12.01   |  |  |  |  |  |
| 11                             |  |  |  |  |  |  |  |  |  |  |  | 7       |  |  |  |  |  |
| Na                             |  |  |  |  |  |  |  |  |  |  |  | N       |  |  |  |  |  |
| 22.99                          |  |  |  |  |  |  |  |  |  |  |  | 14.01   |  |  |  |  |  |
| 24.31                          |  |  |  |  |  |  |  |  |  |  |  | 16.00   |  |  |  |  |  |
| 3                              |  |  |  |  |  |  |  |  |  |  |  | 9       |  |  |  |  |  |
| Mg                             |  |  |  |  |  |  |  |  |  |  |  | F       |  |  |  |  |  |
| 2.43                           |  |  |  |  |  |  |  |  |  |  |  | 19.00   |  |  |  |  |  |
| 12                             |  |  |  |  |  |  |  |  |  |  |  | 17      |  |  |  |  |  |
| Ar                             |  |  |  |  |  |  |  |  |  |  |  | 18      |  |  |  |  |  |
| 39.95                          |  |  |  |  |  |  |  |  |  |  |  | 39.95   |  |  |  |  |  |
| 4                              |  |  |  |  |  |  |  |  |  |  |  | 14      |  |  |  |  |  |
| Ti                             |  |  |  |  |  |  |  |  |  |  |  | Si      |  |  |  |  |  |
| 47.87                          |  |  |  |  |  |  |  |  |  |  |  | 28.09   |  |  |  |  |  |
| 5                              |  |  |  |  |  |  |  |  |  |  |  | 15      |  |  |  |  |  |
| V                              |  |  |  |  |  |  |  |  |  |  |  | P       |  |  |  |  |  |
| 50.94                          |  |  |  |  |  |  |  |  |  |  |  | 30.97   |  |  |  |  |  |
| 6                              |  |  |  |  |  |  |  |  |  |  |  | 16      |  |  |  |  |  |
| Cr                             |  |  |  |  |  |  |  |  |  |  |  | S       |  |  |  |  |  |
| 51.99                          |  |  |  |  |  |  |  |  |  |  |  | 32.07   |  |  |  |  |  |
| 7                              |  |  |  |  |  |  |  |  |  |  |  | 17      |  |  |  |  |  |
| Mn                             |  |  |  |  |  |  |  |  |  |  |  | Cl      |  |  |  |  |  |
| 54.94                          |  |  |  |  |  |  |  |  |  |  |  | 35.45   |  |  |  |  |  |
| 8                              |  |  |  |  |  |  |  |  |  |  |  | 18      |  |  |  |  |  |
| Fe                             |  |  |  |  |  |  |  |  |  |  |  | Kr      |  |  |  |  |  |
| 55.85                          |  |  |  |  |  |  |  |  |  |  |  | 84.80   |  |  |  |  |  |
| 9                              |  |  |  |  |  |  |  |  |  |  |  | 35      |  |  |  |  |  |
| Co                             |  |  |  |  |  |  |  |  |  |  |  | Br      |  |  |  |  |  |
| 58.93                          |  |  |  |  |  |  |  |  |  |  |  | 79.90   |  |  |  |  |  |
| 10                             |  |  |  |  |  |  |  |  |  |  |  | 36      |  |  |  |  |  |
| Ni                             |  |  |  |  |  |  |  |  |  |  |  | Xe      |  |  |  |  |  |
| 58.69                          |  |  |  |  |  |  |  |  |  |  |  | 131.25  |  |  |  |  |  |
| 11                             |  |  |  |  |  |  |  |  |  |  |  | 54      |  |  |  |  |  |
| Cu                             |  |  |  |  |  |  |  |  |  |  |  | I       |  |  |  |  |  |
| 63.55                          |  |  |  |  |  |  |  |  |  |  |  | 126.90  |  |  |  |  |  |
| 12                             |  |  |  |  |  |  |  |  |  |  |  | 86      |  |  |  |  |  |
| Zn                             |  |  |  |  |  |  |  |  |  |  |  | Rn      |  |  |  |  |  |
| 65.38                          |  |  |  |  |  |  |  |  |  |  |  | 222.02  |  |  |  |  |  |
| 31                             |  |  |  |  |  |  |  |  |  |  |  | 118     |  |  |  |  |  |
| Ga                             |  |  |  |  |  |  |  |  |  |  |  | Uuo     |  |  |  |  |  |
| 69.72                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 32                             |  |  |  |  |  |  |  |  |  |  |  | 119     |  |  |  |  |  |
| Ge                             |  |  |  |  |  |  |  |  |  |  |  | Uus     |  |  |  |  |  |
| 72.63                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 33                             |  |  |  |  |  |  |  |  |  |  |  | 120     |  |  |  |  |  |
| As                             |  |  |  |  |  |  |  |  |  |  |  | Uue     |  |  |  |  |  |
| 74.92                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 34                             |  |  |  |  |  |  |  |  |  |  |  | 121     |  |  |  |  |  |
| Se                             |  |  |  |  |  |  |  |  |  |  |  | Uub     |  |  |  |  |  |
| 78.97                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 35                             |  |  |  |  |  |  |  |  |  |  |  | 122     |  |  |  |  |  |
| Br                             |  |  |  |  |  |  |  |  |  |  |  | Uuc     |  |  |  |  |  |
| 79.90                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 36                             |  |  |  |  |  |  |  |  |  |  |  | 123     |  |  |  |  |  |
| Kr                             |  |  |  |  |  |  |  |  |  |  |  | Uud     |  |  |  |  |  |
| 84.80                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 37                             |  |  |  |  |  |  |  |  |  |  |  | 124     |  |  |  |  |  |
| Rb                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 85.47                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 38                             |  |  |  |  |  |  |  |  |  |  |  | 125     |  |  |  |  |  |
| Sr                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 87.62                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 39                             |  |  |  |  |  |  |  |  |  |  |  | 126     |  |  |  |  |  |
| Y                              |  |  |  |  |  |  |  |  |  |  |  | Uub     |  |  |  |  |  |
| 88.91                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 40                             |  |  |  |  |  |  |  |  |  |  |  | 127     |  |  |  |  |  |
| Zr                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 91.22                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 41                             |  |  |  |  |  |  |  |  |  |  |  | 128     |  |  |  |  |  |
| Nb                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 92.91                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 42                             |  |  |  |  |  |  |  |  |  |  |  | 129     |  |  |  |  |  |
| Mo                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 95.95                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 43                             |  |  |  |  |  |  |  |  |  |  |  | 130     |  |  |  |  |  |
| Tc                             |  |  |  |  |  |  |  |  |  |  |  | Uub     |  |  |  |  |  |
| 98.91                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 44                             |  |  |  |  |  |  |  |  |  |  |  | 131     |  |  |  |  |  |
| Ru                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 101.07                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 45                             |  |  |  |  |  |  |  |  |  |  |  | 132     |  |  |  |  |  |
| Rh                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 102.91                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 46                             |  |  |  |  |  |  |  |  |  |  |  | 133     |  |  |  |  |  |
| Pd                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 106.42                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 47                             |  |  |  |  |  |  |  |  |  |  |  | 134     |  |  |  |  |  |
| Ag                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 107.87                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 48                             |  |  |  |  |  |  |  |  |  |  |  | 135     |  |  |  |  |  |
| Cd                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 112.41                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 49                             |  |  |  |  |  |  |  |  |  |  |  | 136     |  |  |  |  |  |
| In                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 114.82                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 50                             |  |  |  |  |  |  |  |  |  |  |  | 137     |  |  |  |  |  |
| Sn                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 118.71                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 51                             |  |  |  |  |  |  |  |  |  |  |  | 138     |  |  |  |  |  |
| Sb                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 121.76                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 52                             |  |  |  |  |  |  |  |  |  |  |  | 139     |  |  |  |  |  |
| Te                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 127.6                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 53                             |  |  |  |  |  |  |  |  |  |  |  | 140     |  |  |  |  |  |
| I                              |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 126.90                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 54                             |  |  |  |  |  |  |  |  |  |  |  | 141     |  |  |  |  |  |
| Xe                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 131.25                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 55                             |  |  |  |  |  |  |  |  |  |  |  | 142     |  |  |  |  |  |
| Cs                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 85.47                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 56                             |  |  |  |  |  |  |  |  |  |  |  | 143     |  |  |  |  |  |
| Ba                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 137.33                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 57-71                          |  |  |  |  |  |  |  |  |  |  |  | 144     |  |  |  |  |  |
| Hf                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 178.49                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 72                             |  |  |  |  |  |  |  |  |  |  |  | 145     |  |  |  |  |  |
| Ta                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 180.95                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 73                             |  |  |  |  |  |  |  |  |  |  |  | 146     |  |  |  |  |  |
| W                              |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 183.84                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 74                             |  |  |  |  |  |  |  |  |  |  |  | 147     |  |  |  |  |  |
| Re                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 186.21                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 75                             |  |  |  |  |  |  |  |  |  |  |  | 148     |  |  |  |  |  |
| Os                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 190.23                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 76                             |  |  |  |  |  |  |  |  |  |  |  | 149     |  |  |  |  |  |
| Ir                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 192.22                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 77                             |  |  |  |  |  |  |  |  |  |  |  | 150     |  |  |  |  |  |
| Pt                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 195.09                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 78                             |  |  |  |  |  |  |  |  |  |  |  | 151     |  |  |  |  |  |
| Au                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 196.97                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 79                             |  |  |  |  |  |  |  |  |  |  |  | 152     |  |  |  |  |  |
| Hg                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 200.59                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 80                             |  |  |  |  |  |  |  |  |  |  |  | 153     |  |  |  |  |  |
| Tl                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 204.38                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 81                             |  |  |  |  |  |  |  |  |  |  |  | 154     |  |  |  |  |  |
| Pb                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 207.2                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 82                             |  |  |  |  |  |  |  |  |  |  |  | 155     |  |  |  |  |  |
| Bi                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 208.98                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 83                             |  |  |  |  |  |  |  |  |  |  |  | 156     |  |  |  |  |  |
| Po                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| [208.98]                       |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 84                             |  |  |  |  |  |  |  |  |  |  |  | 157     |  |  |  |  |  |
| At                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 209.99                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 85                             |  |  |  |  |  |  |  |  |  |  |  | 158     |  |  |  |  |  |
| Rn                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 222.02                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 86                             |  |  |  |  |  |  |  |  |  |  |  | 159     |  |  |  |  |  |
|                                |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| 87                             |  |  |  |  |  |  |  |  |  |  |  | 160     |  |  |  |  |  |
| Fr                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| 226.03                         |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 88                             |  |  |  |  |  |  |  |  |  |  |  | 161     |  |  |  |  |  |
| Ra                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| [261]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 104                            |  |  |  |  |  |  |  |  |  |  |  | 162     |  |  |  |  |  |
| Rf                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| [261]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 105                            |  |  |  |  |  |  |  |  |  |  |  | 163     |  |  |  |  |  |
| Db                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| [262]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 106                            |  |  |  |  |  |  |  |  |  |  |  | 164     |  |  |  |  |  |
| Sg                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| [266]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 107                            |  |  |  |  |  |  |  |  |  |  |  | 165     |  |  |  |  |  |
| Bh                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| [264]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 108                            |  |  |  |  |  |  |  |  |  |  |  | 166     |  |  |  |  |  |
| Hs                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| [269]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 109                            |  |  |  |  |  |  |  |  |  |  |  | 167     |  |  |  |  |  |
| Mt                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| [268]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 110                            |  |  |  |  |  |  |  |  |  |  |  | 168     |  |  |  |  |  |
| Ds                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| [269]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 111                            |  |  |  |  |  |  |  |  |  |  |  | 169     |  |  |  |  |  |
| Rg                             |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| [272]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 112                            |  |  |  |  |  |  |  |  |  |  |  | 170     |  |  |  |  |  |
| Cn                             |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| [277]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 113                            |  |  |  |  |  |  |  |  |  |  |  | 171     |  |  |  |  |  |
| Uut                            |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| unknown                        |  |  |  |  |  |  |  |  |  |  |  | Uut     |  |  |  |  |  |
| 114                            |  |  |  |  |  |  |  |  |  |  |  | 172     |  |  |  |  |  |
| Fl                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| [289]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 115                            |  |  |  |  |  |  |  |  |  |  |  | 173     |  |  |  |  |  |
| Uup                            |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| unknown                        |  |  |  |  |  |  |  |  |  |  |  | Uup     |  |  |  |  |  |
| 116                            |  |  |  |  |  |  |  |  |  |  |  | 174     |  |  |  |  |  |
| Lv                             |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| [298]                          |  |  |  |  |  |  |  |  |  |  |  | unknown |  |  |  |  |  |
| 117                            |  |  |  |  |  |  |  |  |  |  |  | 175     |  |  |  |  |  |
| Uus                            |  |  |  |  |  |  |  |  |  |  |  | Uuh     |  |  |  |  |  |
| unknown                        |  |  |  |  |  |  |  |  |  |  |  | Uus     |  |  |  |  |  |
| 118                            |  |  |  |  |  |  |  |  |  |  |  | 176     |  |  |  |  |  |
| Uuo                            |  |  |  |  |  |  |  |  |  |  |  | Uuq     |  |  |  |  |  |
| unknown                        |  |  |  |  |  |  |  |  |  |  |  | Uuo     |  |  |  |  |  |

|        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |
|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 57     | 58     | 59     | 60     | 61     | 62     | 63     | 64     | 65     | 66     | 67     | 68     | 69     | 70     | 71     |
| La     | Ce     | Pr     | Nd     | Pm     | Sm     | Eu     | Gd     | Tb     | Dy     | Ho     | Er     | Tm     | Yb     | Lu     |
| 138.91 | 140.12 | 140.91 | 144.24 | 144.91 | 150.36 | 151.96 | 157.25 | 158.93 | 162.50 | 164.93 | 167.26 | 168.93 | 173.06 | 174.97 |
| 89     | 90     | 91     | 92     | 93     | 94     | 95     | 96     | 97     | 98     | 99     | 100    | 101    | 102    | 103    |
| Ac     | Th     | Pa     | U      | Np     | Pu     | Am     | Cm     | Bk     | Cf     | Es     | Fm     | Md     | No     | Lr     |
| 227.03 | 232.04 | 231.04 | 238.03 | 237.05 | 244.06 | 243.06 | 247.07 | 247.07 | 251.08 | [254]  | 257.10 | 258.1  | 259.10 | [262]  |